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Development of a Hydroponic System using an Atmega 2560 Microcontroller with Automatic Nutrition and pH Settings for Lettuce Cultivation

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Abstract

Hydroponic system is a technique of cultivating plants without using soil as a growing medium, but using water that is given nutrients and oxygen as a growing medium. Cultivation with hydroponic techniques must be able to pay attention and control nutrients, water content, and water ph. This research aims to create a lettuce cultivation system with intelligent hydroponic techniques using the ATmega2560 microcontroller. This system uses Arduino Mega as the control center, TDS sensor to monitor nutrition, PH sensor to monitor water acidity, and ultrasonic sensor to monitor water level. The optimal growth characteristic of lettuce is that the acidity level must be at pH 5.5-6.5 with the nutrients provided at 685-950 ppm. This system can help lettuce cultivation with hydroponic techniques by monitoring and controlling nutrients, pH, and water content in cultivated plants in real time to optimize lettuce growth.
Keywords: *PH Sensor, TDS Sensor; Ultrasonic Sensor, Atmega2560*

Abstrak

Sistem hidroponik merupakan teknik budidaya tanaman tanpa menggunakan tanah sebagai media tanam, melainkan menggunakan air yang diberi nutrisi dan oksigen sebagai media tanam. Budidaya dengan teknik hidroponik harus dapat memperhatikan dan mengontrol nutrisi, kadar air, dan ph air. Penelitian ini bertujuan untuk membuat sistem budidaya selada dengan teknik hidroponik cerdas menggunakan mikrokontroler ATmega2560. Sistem ini menggunakan Arduino Mega sebagai pusat kendali, sensor TDS untuk memonitoring nutrisi, sensor PH untuk memonitoring keasaman air, dan sensor ultrasonik untuk memonitoring ketinggian air. Karakteristik pertumbuhan selada yang optimal adalah tingkat keasaman harus berada pada pH 5,5-6,5 dengan nutrisi yang diberikan sebesar 685-950 ppm. Sistem ini dapat membantu budidaya selada dengan teknik hidroponik dengan cara memonitoring dan mengontrol nutrisi, pH, dan kadar air pada tanaman yang dibudidayakan secara real time untuk mengoptimalkan pertumbuhan selada.
Kata-kata kunci: *Sensor PH, Sensor TDS, Sensor Ultrasonik, Atmega2560*

1. Introduction

The growth of the human population and the development of increasingly advanced agricultural technology have led to increasing demand for agricultural products. However, conventional agriculture that uses soil as a growing medium has limitations in terms of land and the use of resources such as water and fertilizer [1]. Therefore, hydroponic technology is an attractive alternative to meet the need for more efficient and environmentally friendly agricultural products [2]. Hydroponic systems that use water as a planting medium and nutrients can be adjusted accurately and consistently to increase resource efficiency and produce high-quality agricultural products [3]. However, regulating nutrients and pH in a hydroponic system is essential and crucial for plant growth [4]. Errors in handling nutrients and pH can cause stunted plant growth or even death [5]. Therefore, technology is needed that can help overcome this problem. In this case, a microcontroller can simplify and accelerate the adjusting of nutrients and pH in hydroponic systems [6]. The microcontroller can be programmed to automatically control the nutrients and pH of the water, thereby increasing consistency and accuracy in adjusting the nutrients and pH [7].

Several other studies were relevant to the development of hydroponic systems using microcontrollers and automatic regulation of nutrients and pH for lettuce cultivation have been carried out, including the use of Arduino Uno microcontrollers and pH and EC sensors to monitor and regulate nutrition and pH in hydroponic systems. The results showed that this system could maintain the balance of nutrients and pH in plants and increase crop productivity and quality [8]. Other research uses the Arduino Mega 2560 microcontroller and pH and EC sensors to adjust nutrition and pH in a hydroponic system automatically. The results showed that this system produced higher quality and quantity than the manual hydroponic system [9]. Other research uses a Raspberry Pi microcontroller and pH and EC sensors to regulate nutrition and pH in a hydroponic system. The system is also equipped with a web interface to monitor and control it remotely. The results showed that this system can increase the quality and quantity of hydroponic plant production [10].

This study used a hydroponic system with the DFT technique. The DFT (Deep Flow Technique) hydroponic system is a hydroponic cultivation technique that distributes nutrient water at a low rate and continues to plant roots above the water surface [11]. This technique has advantages such as saving water and fertilizer and can produce higher production in a smaller conventional planting method **[12]**. Therefore, the DFT hydroponic system is widely used in vegetable cultivation, such as lettuce, kale, and pakcoy **[13] [14] [15]**. However, even though DFT hydroponic systems have been developed and are widely used worldwide, some problems still need to be addressed. One of the biggest problems in a DFT hydroponic system is proper pH and nutrient management. Therefore, developing a more efficient and environmentally friendly DFT hydroponic system with more accurate and controlled nutrient and pH management is necessary. Previous studies show that using microcontrollers and automatic regulation of nutrients and pH in hydroponic systems have increased production efficiency, quality, and quantity in hydroponic plant cultivation. Therefore, developing a hydroponic system using the ATmega 2560 microcontroller with automatic nutrient and pH adjustments for lettuce cultivation is still an exciting topic for research. This research focuses on developing a hydroponic system using the ATmega 2560 microcontroller with automatic nutrient and pH adjustments for lettuce cultivation. This research can provide solutions for more accurate and efficient regulation of nutrients and pH in hydroponic systems and improve the quality and quantity of lettuce production. An intelligent hydroponic system for lettuce cultivation that was built using an ATmega 2560 microcontroller and three sensors, namely a pH sensor to monitor water acidity, a TDS sensor to monitor nutrient requirements in PPM (part per million) units, and an ultrasonic sensor to monitor water level levels at the reservoir. This system uses a servo motor actuator to stir the nutrient solution and pH acidity, an alarm as a water level indicator marker, and an LCD to display processed data. By making this system, it can make it easier for users of hydroponic media to monitor and control their plants, especially lettuce plants, to increase the results of their cultivation in quality and quantity.

2. Method

2.1 Hydroponic System Block Diagram

The block diagram is the most important thing for designing a system because it can describe a hydroponic system's flow or working principle to help realize the process. The block diagram used can be seen in Figure 1.

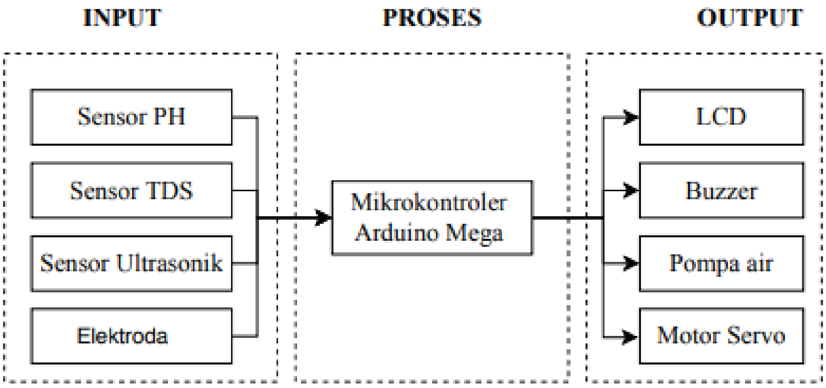

Figure 1. Hydroponic System Block Diagram

In **Figure 1**, it can be seen in the hydroponic system of lettuce plants using the ATmega 2560 microcontroller, which consists of three parts, namely input, processing, and output. The input of this system includes a TDS sensor, a pH sensor, and an ultrasonic sensor. Arduino Mega is a system processing part used as the system's primary controller. The LCD is used as an output to display the values of pH, ppm, and water level. Alarm or buzzer as an indicator of the ultrasonic sensor. A servo motor acts as an actuator for mixing nutrients and pH in water. The water pump is used to circulate water from the tendon to the hydroponic pipe.

2.2 Hardware Design

The mechanical design of the hydroponic system for lettuce plants using an ATmega 2560 microcontroller with a monitor and automatic control is shown in Figure 2. The hydroponic frame used is made of wood and has a height of 1.5 meters. For hydroponics, use four pieces of 2 1/2-inch pipe. Each paralon is 2 meters long. For hydroponic roofs, use a plastic roof. The TDS sensor and pH sensor are mounted on a 2 1/2-inch pipe. The LCD is installed at the top of the hydroponics. Four small plastic containers collect nutrients, water, and pH. The four containers are above the water reservoir. The ultrasonic sensor is mounted on top of the water reservoir. Hydroponic system design is presented on **Figure 2**.

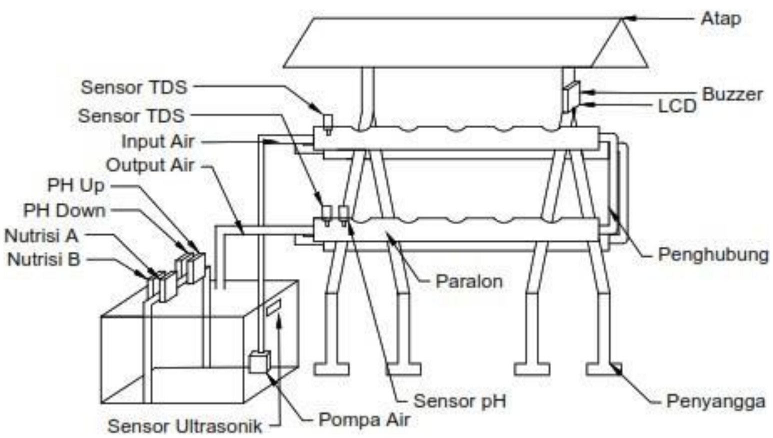

Figure 2. Hydroponic System Design

2.3 Software Design

The software design of the hydroponic system for lettuce plants using the ATmega 2560 microcontroller is based on a flow chart. Also, it considers the needs of the materials used.

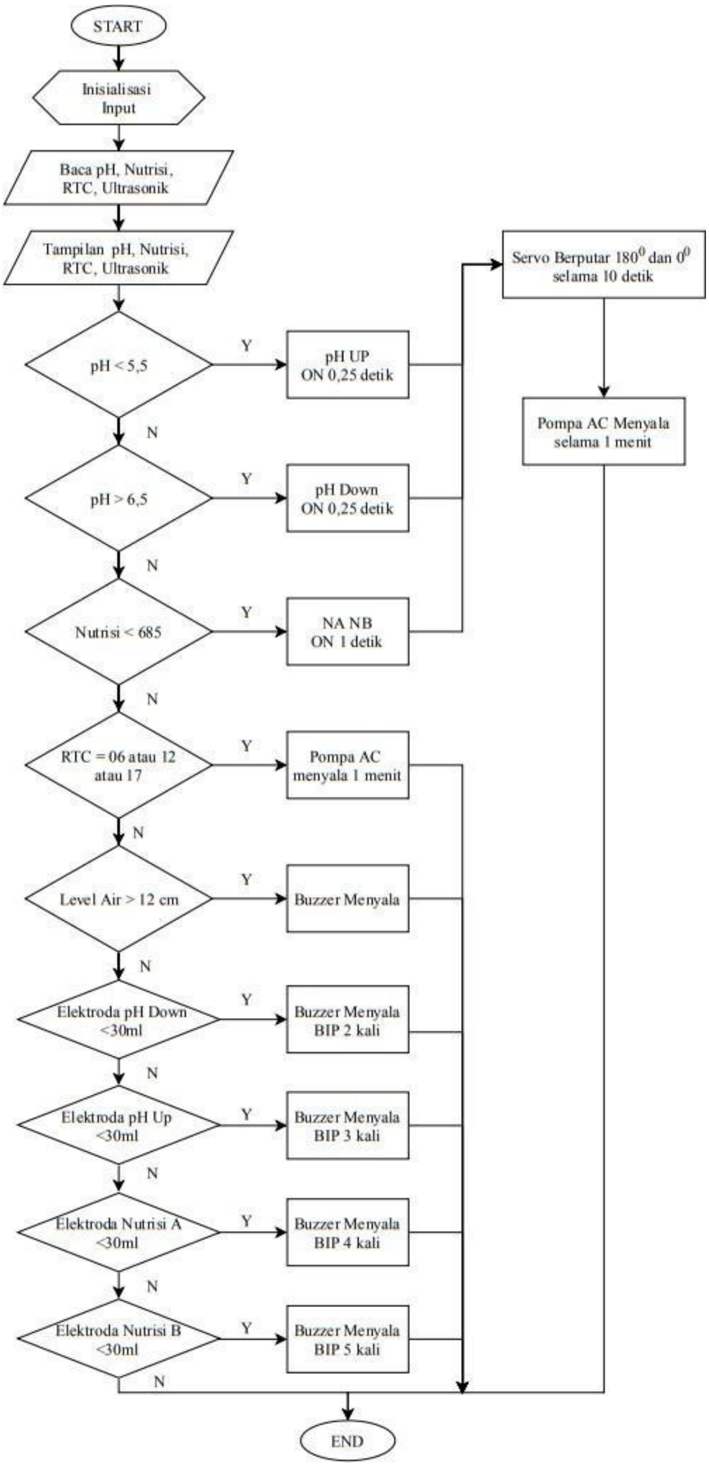

Figure 3. Flowchart of The Overall System Displayed on The LCD.

Figure 3 shows that the output from the pH sensor, TDS sensor, RTC sensor, and ultrasonic sensor is displayed on the LCD. If the pH value is below 5.5, the pH-up DC Pump will be active for 0.25 seconds. If the pH value is above 6.5, the pH-down DC Pump will be active for 0.25

seconds. Then the servo motor moves 1800 and 00 for 10 seconds to stir the DC pump's pH solution. After stirring, the AC pump will be active for 1 minute. When the nutritional value is below 685 ppm, the DC pumps for nutrition A and B will be active simultaneously for 1 second. Then the servo motor moves 1800 and 00 for 10 seconds to stir the pH solution from the DC Pump. After stirring, the AC pump will be active for 1 minute. If the ultrasonic sensor detects a distance of more than 12 cm, the alarm will activate as a sign of a lack of water in the reservoir. In four solution containers, each is given an electrode as a detector for the lack of water volume in the pump solution container. If the volume of water is less than 30 ml, the alarm will be activated with a different sound. For the pH electrode to go down, the alarm will beep twice. pH Up electrode will beep 3 times. Nutrient Electrode A, the alarm will beep four times. Nutrient Electrode B, the alarm will beep five times.

2.4 Wiring

Wiring is an essential step in designing and building electronic systems, which involves organizing cables and other components so that they are easily accessible and can function optimally. It can be done using a variety of techniques and special tools. Figure 4 shows the wiring of the hydroponic system for lettuce plants using the ATmega 2560 microcontroller. Wiring system is presented on **Figure 4**.

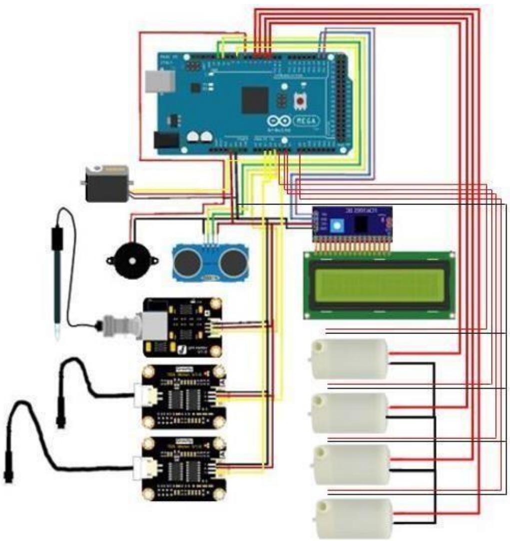

Figure 4. Wiring System

2.5 RTC design

The RTC (Real Time Clock) IC chip plays a role in accurately calculating time from seconds, minutes, hours, days, dates, months, and years. In this hydroponic system, the RTC is used to schedule the activation of the water pump. The water pump will be turned on three times a day at 6:00, 12:00, and 17:00. Figure 4 shows the RTC circuit connected to the Arduino Mega. RTC circuit is presented on **Figure 5**.

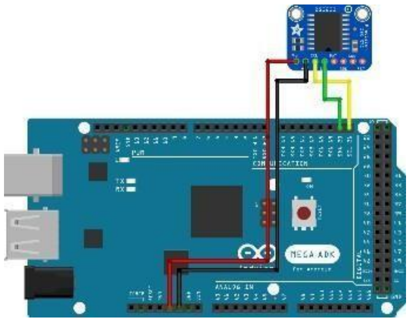

Figure 5. RTC circuit

3. Results and Discussion

3.1 Alarm Testing

The alarm or buzzer is used as an indicator from the ultrasonic sensor when measuring the water level to protect the AC water pump, which must be submerged in water when the pump is active. If the water level is low, it can cause the water pump to break down quickly. The buzzer test results can be seen on **Table 1**.

Table 1. Buzzer Testing

Testing	Ultrasonic Sensor	Buzzer	Information
1	9	Active	Succeed
2	10	Active	Succeed
3	11	Active	Succeed
4	12	Non-Active	Succeed
5	13	Non-Active	Succeed

Table 1 shows the results of the buzzer test. The buzzer will sound when the ultrasonic sensor detects a distance of more than 11 cm. If the ultrasonic sensor detects a distance of less than 11 cm, the buzzer will automatically deactivate.

3.2 DC Pump Testing

DC pumps are used as actuators that pump nutrient A water, nutrient B water, pH up, and pH down. The DC pump will activate if the TDS and pH sensors do not meet the setpoint. The results of the DC pump test can be presented on **Table 2**.

Table 2. TDS Sensor DC Pump Testing

Testing	TDS sensor	DC pump		Information
		Nutrition A	Nutrition B	
1	367 ppm	Active	Active	Succeed
2	523 ppm	Active	Active	Succeed
3	692 ppm	Active	Active	Succeed
4	955 ppm	Non-active	Non-active	Succeed
5	972 ppm	Non-active	Non-active	Succeed

In lettuce plants, the regulated ppm value is 685–950. The DC pump will be active when the ppm value is less than 685. If the ppm value is more significant than 950, then the DC pump will be disabled. pH sensor dc pump testing is presented on **Table 3**.

Table 3. pH Sensor DC Pump Testing

Testing	pH sensors	DC pump		Information
		pH Up	pH Down	
1	pH 4.9	Active	Non-active	Succeed
2	pH 5.2	Active	Non-active	Succeed
3	pH 6.1	Non-active	Active	Succeed
4	pH 6.8	Non-active	Active	Succeed
5	pH 7.3	Non-active	Active	Succeed

For lettuce, the pH is adjusted to a pH of 5.5 to 6.5. It can be seen in Table 6. When testing the pH sensor DC pump, when the pH value is less than 5.5, the pH up DC pump will be active. And if the pH value is more significant than 6.5, then the DC pH-down pump will be active.

RTC (Real Time Clock) accurately calculates time starting from seconds, minutes, hours, days, dates, months, and years. In an automatic hydroponic system, RTC is used to schedule plant watering. Watering is done three times a day, namely in the morning at 06.00, noon, and evening at 17.00. The RTC test results is **Figure 6**.

Figure 6. Morning RTC

Figure 6 shows the results of the first RTC test displayed on the LCD. When the clock shows 06.00, the system does the watering. When watering at 6:00, the LCD will show the information "Morning Watering". Afternoon RTC can be seen **Figure 7**.

Figure 7. Afternoon RTC

Figure 7 shows the results of the two RTC tests on the LCD. When the clock shows 12.00, the system does the watering. When watering at 12.00, the LCD will show the information "Daytime Watering". Afternoon RTC is presented on **Figure 8**.

Figure 8. Afternoon RTC

Figure 8 shows the results of the three RTC tests displayed on the LCD. When the clock strikes 17.00, the system does the watering. When watering at 17.00, the LCD will show the information "Afternoon Watering."

3.3 Development of Lettuce Plants

Figure 9 is a 7-day-old lettuce after the seeding process. After 12 days of age, the lettuce plants were transferred to the hydroponic system by separating the lettuce plants in the net pot and placing the net pot into the hydroponic system. The yield of lettuce seedlings for 7 days is presented on **Figure 9**.

Figure 9. The Yield of Lettuce Seedlings for 7 Days

After transferring the lettuce plants to the hydroponic system, the next step is to monitor the development of the lettuce plants by keeping the concentration of nutrients stable and not drying out or running out of nutrients. Table 4 is a table of test results that compares data on the development of lettuce plants through the cultivation of the hydroponic system and the development of lettuce plants with soil media. The following table compares the results of the development of lettuce plants using a hydroponic system with the development of lettuce plants using soil media. Development of lettuce plants is presented on **Table 4**.

Table 4. Development of Lettuce Plants

NO	Media	Age (Day)	ppm	pH	Lots Leaf	Results
1	Hydroponics	1	685 - 950	5,5 - 6,5	2 sheet	 Figure 10
2	Land	1	-	-	2 sheet	 Figure 11
3	Hydroponics	7	685 - 950	5,5 - 6,5	4 sheet	 Figure 12
4	Land	7	-	-	3 sheet	 Figure 13

The results of the development of lettuce plants in hydroponic media (Figure 10 and Figure 12) and soil media (Figure 11 and Figure 13) show that lettuce plants in hydroponic media that are given nutrients (685–950 ppm) with pH levels between 5.5 and 6.5 have growth two times faster than lettuce plants in soil media that are not given nutrients and pH solutions. Using a hydroponic system that allows the automatic regulation of nutrients and pH can increase the growth of lettuce plants. It is because the nutrients given to lettuce plants can be adjusted to their needs to grow better and faster. In addition, the automatically regulated nutrient pH can also affect the availability of nutrients in plants and increase nutrient uptake efficiency.

Using a hydroponic system also has advantages in terms of more efficient land use and higher production compared to cultivating plants in soil media. In a hydroponic system, the nutrients and water needed by lettuce plants can be controlled and adjusted correctly so that the use of resources such as water and nutrients can be optimized and waste can be reduced. Therefore, developing a hydroponic system with automatic regulation of nutrients and pH can be an alternative solution to increase production and efficiency in lettuce cultivation.

4. Conclusion

Based on the data that has been generated, it can be concluded that a hydroponic system with automatic regulation of nutrients and pH has excellent potential for increasing the growth and productivity of lettuce plants. The hydroponic system allows nutrients and nutrient pH to be adjusted according to plant needs, thereby increasing the efficiency of nutrient uptake and plant growth. The results also showed that lettuce grown on hydroponic media with regular nutrition had faster growth and higher productivity than those grown on irregular soil media. In addition, the use of hydroponic systems can also improve land use and the efficiency of resources such as water and nutrients. Thus, developing a hydroponic system with automatic nutrient and pH regulation can be a promising solution for increasing lettuce productivity and resource efficiency in agriculture. However, further research is still needed to optimize this hydroponic system and ensure it can be used effectively and economically.

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