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Development of Automatic Hydroponic Plant Watering Based Arduino Microcontroller

Anita Susilawati[1,*] M. Abdi Mauliwarman[1], Dodi Sofyan Arief[1] and Herisiswanto[1]

[1)] Mechanical Engineering Department, Universitas Riau, Pekanbaru, Indonesia

ABSTRACT – This paper aims to develop a design for an automatic hydroponic plant nutrient sprinkler. This plant watering device used an Arduino Mega 2560 microcontroller as the interface and an LCD (Liquid Cristal Display) as a display to indicate nutrient levels. The device design deployed a time system set using an Arduino microcontroller and RTC (Real Time Clock) based watering time settings. The development of this automatic nutrient watering device was equipped with a TDS (Total Dissolve Solid) sensor, which reads the value of the nutrient solution content in the water. The LCD displayed monitoring system performance and the relay functions to turn on and off the water pump connected to the hydroponic media watering pipe installation. The benefits of the device can save time and energy. Therefore, the device is more efficient than the manual watering system.

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1. INTRODUCTION

Hydroponics is a system of growing plants without using soil, only utilizing water for the nutritional needs of plants [1-3]. Hydroponic nutrients are substances needed by hydroponic plants in order to grow correctly. In hydroponic plant cultivation, nutrient watering is still widely applied manually. It could be more efficient because it cannot control the nutritional needs of hydroponic plants and requires a relatively long time for watering. Providing water in the right amount is very helpful for plant growth [4-5]. Hydroponic plant cultivation activities require control of the concentration of nutrients by the nutritional needs of plants [6-7]. If the level of nutrients needed is not appropriate, the plant can die, or problems occur in its growth. Therefore, it is necessary to monitor and control periodically and continuously to determine the nutritional water conditions directly related to plant growth [6-15].

In the Dutch Bucket hydroponic system technique, the nutrient water is fed continuously to the plant roots, and then the solution is circulated back to the reservoir (closed circulation) [16-18]. The Dutch Bucket System (DBS) hydroponic system has advantages [16-18]: (1) easy maintenance, namely just controlling the availability of nutrients; (2) regulated water; (3) plant roots are kept moist; (4) the crop yields are excellent, (5) the best system for growing vines of fruit and vegetables, (6) plants are more fertile and productive, due to the circulation of water and nutrients, which allows there to be more oxygen in the nutrient solution and the plant roots quickly absorb it, (7) the harvest can be continuous. The hydroponic plant cultivation activities require control of the concentration of the nutrient solution so that the concentration is to the plant's nutritional needs. If the required level of nutrition is not appropriate, the plant may die simultaneously, or problems may occur with its growth. Therefore, it is necessary to monitor and control periodically and continuously to determine the condition of the nutrient water, which is directly related to plant growth, and the environmental conditions in which the plant grows.

According to [9], [19-22], a device for controlling nutrient water circulation is needed to make it easier for hydroponic farmers. The device can be used to determine the water's pH condition and the nutrient solution's concentration level value to adjust nutrient needs according to the phase of plant growth. The automatic device can sprinklers of the hydroponic' plant based on a control system, one of which is the Arduino Mega. The Arduino Mega is employed as a microcontroller driver [23-24], and a sensor is used for object detection, such as the TDS (Total Dissolve Solid) sensor.

The TDS sensor is a standard tool used to describe the amount of solute in ppm or equal to milligrams per litre (mg/l) shown in digital display numbers. The display tool is LCD. The LCD is an electronic component that displays data in characters, letters or graphics. Furthermore, to open and close a current required a relay. The relay is an electrical switch that opens or closes a circuit under certain conditions [25]. The hydroponic watering is required a high-pressure water pump [26-28]. The high-pressure water pump is a device that converts mechanical energy from power (drive) into kinetic energy (speed) [29-31]. Therefore, the device system efficiently performs metered and automatic watering capable of flushing nutrient fluids to all plant parts.

*Corresponding author: anitasusilawati@lecturer.unri.ac.id
Penerbit: Jurusan Teknik Mesin, Universitas Riau, https://proksima.ejournal.unri.ac.id

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The purpose of this research is to develop a design of a device that can perform automatic watering for hydroponic plants by a predetermined time. It can make it more accessible to know the levels of nutrient fluids, watering time and water level in the tank and control. So, the automatic device can automatically serve as a nutrient pattern suitable for hydroponic planting.

2. METHOD

This paper employed the qualitative method and descriptive analysis techniques. The data was collected by field observations and literature studies or narrative reviews under the required data. Design development of automatic sprinklers consists of (1) the sizes of the design development of automatic hydroponic sprinklers obtained from field studies (2) the length and width of automatic hydroponic sprinkler systems obtained from literature and field studies. It was finally creating the design with the inventor application.

In this paper, the Dutch Bucket System (DBS) of the hydroponic system was adopted. The DBS was a hydroponic farming technique emphasising circulation and efficient water use. Nutrient solution levels refer to Wibowo, 2021 [32-33]. In this paper, vegetable plants were intended to have a nutrient solution level of <6.0 pH [32-33]. The vegetable plants can be cultivated as short-sized plants, including cherry tomatoes, lettuce (Lactuca Sativa), mustard greens (Brassica Juncea), etc.

Then, the mechanical system design consisted of the automatic nutrient watering device adjusted to the hardware requirements and placement of the automatic nutrient watering system. The process of designing automatic nutrient watering was carried out as follows:

1. The nutritional watering equipment

In designing the component requirements for automatic nutrient sprinklers, it was divided into two parts, namely mechanical and electronic design.

a. Mechanic: PVC pipe, Tank

b. Electronic: RTC (Real Time Clock), TDS sensors, Stepper motor driver, Arduino Mega 2560, Float level switch sensor, Liquid Crystal Display, Power Supply and High-pressure water pump.

2. The components were used in the design as follows:

a. RTC (Real Time Clock) Sensor: an electronic clock in the form of a chip that can accurately calculate the time (from seconds to years) and keep/store the time data in real-time.

b. Arduino Mega 2560, using Arduino Mega 2560 was to be more practical and efficient in spraying time.

c. High-pressure water pump to increase the water pressure directed to the mist sprayer.

d. PVC (Polyvinyl Chloride) pipe. In this paper, the PVC pipes were used to adjust the size of the water flow from the high-pressure water pump.

e. TDS/EC sensor used an Electrical Conductivity (EC) method connected to an Arduino where the probe was dipped into a liquid or solution and then, with a signal processing circuit, can produce an output that showed the amount of dissolved nutrient levels.

f. Tank was used to availability of water reservoir, which the water supply can safely control. It was proposed that if suddenly the water source was not running correctly, a reserve of water in the reservoir could be used.

g. Power Supply. It was an electrical device that could provide electrical energy for electrical or other electronic devices. This power supply requires electrical energy, converted into electrical energy that other electronic devices need.

3. RESULT AND DISCUSSION

This research produced a design for a hydroponic plant nutrient sprinkler that works automatically. This research used the device's design only for hydroponic vegetable plants such as cherry tomatoes, lettuce, etc. The development of an Arduino-based nutrient plant watering design for hydroponic plants was an electronic system that used the Arduino Mega 2560 microcontroller. The development design for automatic plant watering devices revealed several requirements, as explained in the following sections.

A. Mechanical System

1. Hydroponic frame

The hydroponic frame used wood as a development for designing automatic hydroponic plants. The wood for hydroponic shelves was cheap. Then, it is polished using wood paint. The design size for placing hydroponic equipment was 780 mm x 800 mm, and the support height on the hydroponic frame was 400 mm. The frame design consisted of 3 pairs of rack mounts, as depicted in Figure 1, each of which has a distance of 200 mm between the rack mounts. The diameter of the upper support shelf for placing hydroponic plant media pipes was 37 mm in diameter.

2. PVC pipe

The PVC pipes were used to convey nutrient fluids to hydroponic plants. The vegetable plants can be cultivated as short-sized plants, including lettuce (Lactuca Sativa), mustard greens (Brassica Juncea), etc. Then, the length of the PVC pipe was 830 mm. The distance between the plants was 80 mm. The hole for the hydroponic plant was designed to be 35 mm in diameter. Then, there were nine holes, a hole for the flow of nutrient fluid of 20 mm in diameter. The sizes of hydroponic pipe systems for flowing nutrient fluids can be seen in Figure 2.

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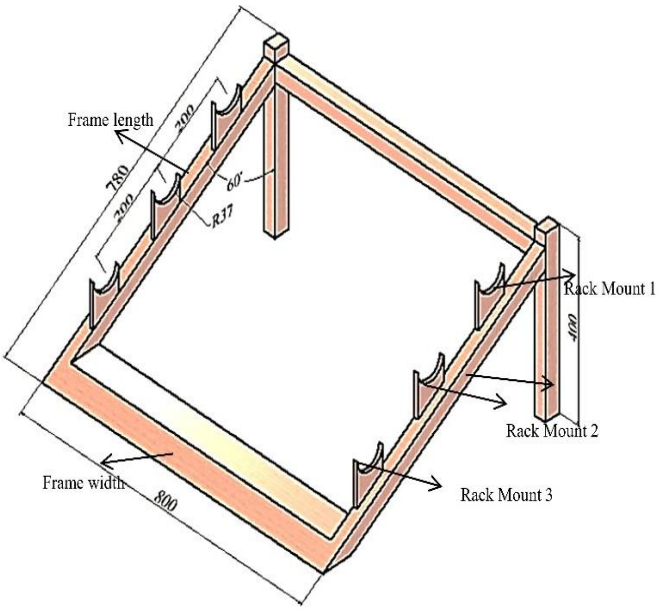

Figure 1 *Frame of hydroponic*

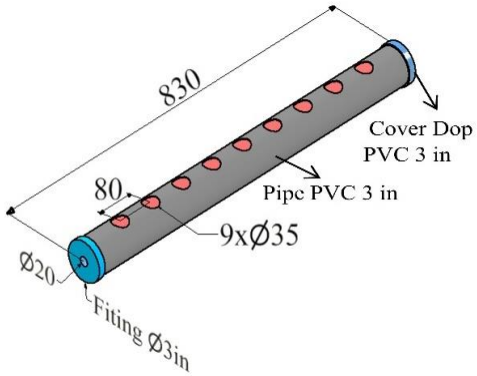

Figure 2 *Hydroponic pipe system for flowing nutrient fluids*

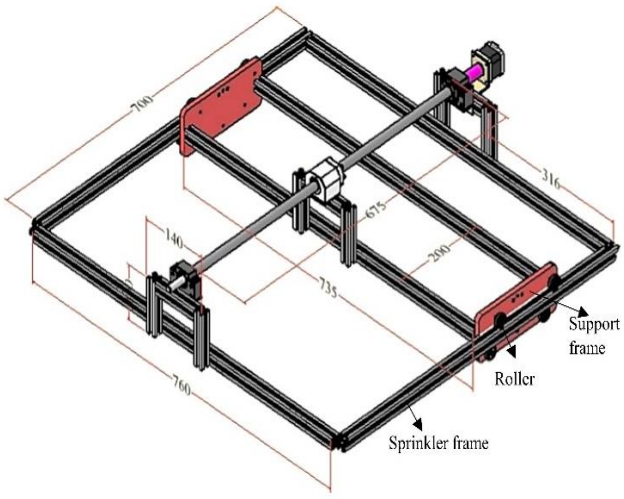

Figure 3 *Frame of watering system design*

3. Sprinkler frame

The sprinkler frame used aluminum, which was generally light corrosion resistant. Sub-sequence, the assembly of the sprinkler components was more accessible to install. The sprinkler frame design used by hydroponics was 700 mm x 760 mm. Then, the support height for the automatic sprinkler was 100 mm x 140 mm. The supporting frame for the automatic plant waterer was 735 mm long and 200 mm wide, as seen in Figure 3.

4. Tank

Tanks were used to store nutrient fluids for hydroponic plants. In this design, the tanks were divided into two types: watering tank and flow tank.

a. Watering tank

The watering tank design used a 200 mm x 200 mm x 100 mm acrylic. One hole in the top tank cover. In the upper tank, one hole was made for installing a pipe from the lower storage tank from the nutrient-liquid water pump for hydroponic plants. The watering tank is shown in Figure 4.

b. Flow tank

The flow tank design used the acrylic of 300 mm x 400 mm x 100 mm. On the top tank cover, two elbows were made for installing pipes from the storage tank from the water pump and for the hydroponic plant nutrient flow. The first elbow was used to install the pipe to the holding tank, and the second was used to install the pipe from the nutrient circulation tank. One hole on the right side of the pump for installing a pipe to the circulation tank with a diameter of 20 mm, as depicted in Figure 4.

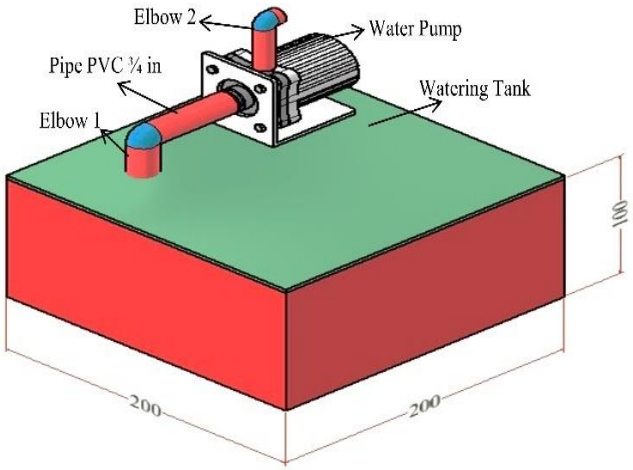

Figure 4 *Watering tank*

B. Electrical System

A microcontroller-based hydroponic watering system used several components such as a power supply, Arduino Mega 2560 as a controller, TDL sensor to regulate pH levels, RTC sensor, water level sensor, two relays to regulate the flow of pumped water and regulate plant watering. The block diagram of the automatic hydroponic plant watering system can be seen in Figure 5. The power supply was a DC 12 V

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voltage source. The TDS sensor detected the nutrients or water content for watering. Arduino Mega 2560 was a receiver of data sent from the TDS, RTC and float level switch sensors, which instruct relays and drivers (stepper motors). The relay driver was used to activate and deactivate the water pump. The water pumps were used to distribute water for watering plants.

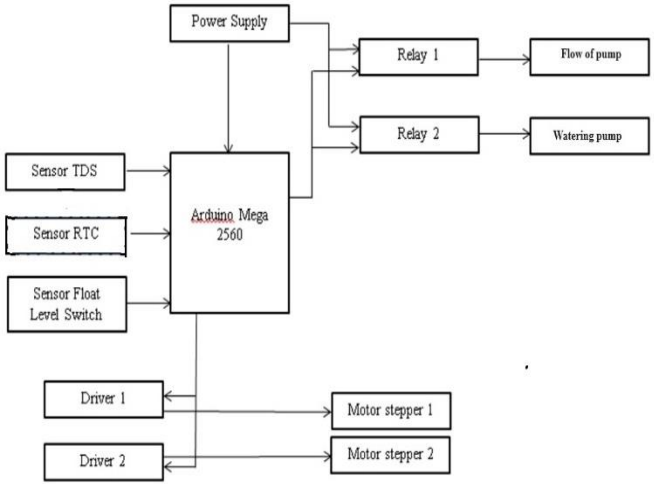

Figure 5 *System block diagram*

The Arduino system software was designed to execute the desired commands and process input data, which produces output on the Arduino Mega 2560 circuit. The algorithm program for the automatic hydroponic device can be seen in Figure 6.

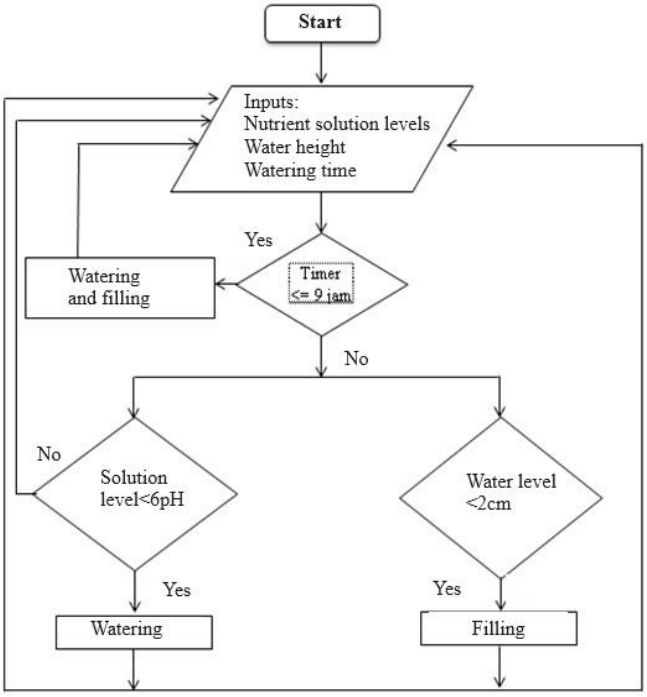

Figure 6 *Device work algorithm*

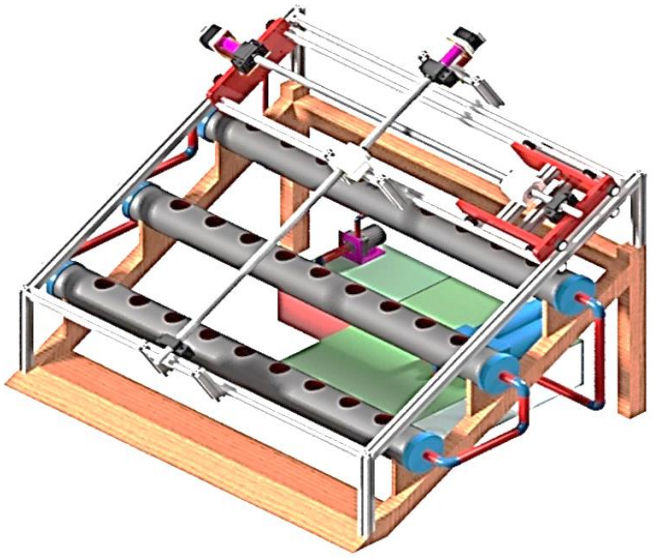

Figure 7 *Development design of hydroponic device*

The automatic nutrient sprinklers worked as follows:
- Input: Receives nutrient solution levels, water level, and nutrient watering time from sensors. If the ppm value is high on the TDS sensor and then the water level is low, the nutrient pump will be slow, and the water pump will turn on.
- Timer: If the time is more than specified, watering and filling are carried out; if not, continue with the following process.
- Nutrient solution level: If the nutrient solution level is <6.0 pH, then filling is carried out; if the pH of the nutrient solution is outside the permitted pH range, then it must be conditioned (increased or lowered) to match the recommended pH in hydroponic planting, if not, water it
- Watering: Turn on the stepper motor to water and then turn on the watering pump; watering the plants is done automatically by reading the conditions measured by the RTC sensor. This sensor reading will be processed by a microcontroller, instructing the pump motor to carry out the watering process; once finished, it returns to Data input.
- Water level: If the water level is <2 cm, then the water level is 2 cm, and the information is sent to the control panel; if not, return to the data input process.
- Filling: Turning on the pump in the lower tank until the specified water level and the start of filling is usually the same length as testing the reference to ensure the pump starts filling water after reaching the lowest point; if not, return to the data input process.

The result of the development design of the hydroponic device is shown in Figure 7. The development of an automatic nutrient watering system used a regular time system using an Arduino microcontroller and RTC-based watering time settings. The development of an automatic nutrient sprayer was equipped with a TDS sensor, which was used to read the value of the nutrient solution content in water. The LCD was

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displayed for monitoring system performance and a relay that turns on and off the water pump connected to the hydroponic media watering pipe installation. Watering hydroponic nutrients was carried out when the TDS sensor detected that the value of the nutrient solution content in the water media was below the lower threshold of the working system and stopped watering when the sensor readings showed that the content value of the hydroponic media of above the upper threshold of the working system.

4. CONCLUSION

This paper aims to develop an automatic hydroponic plant watering design to regulate the watering of plant nutrients. The results of the component device development consist of an Arduino box, nutrient water tank, planting media, sprinkler frame, TDS (Total Dissolve Solid) Sensor, RTC (Real Time Clock) sensor, Float Level Switch sensor, Nema 17 stepper motor driver, Arduino Mega 2560, power supply and high-pressure of water pump. In the Arduino box, some sensors were used to monitor hydroponic plants. The nutrient tank had a TDS sensor and a water pump, which was used to water hydroponic plants. Furthermore, there was an automatic watering framework and hydroponic planting media in the planting media section. The automatic plant watering device can monitor and regulate the pH levels of nutrient solutions, watering time and water level, where the data can change and be applied automatically. Thereby, it was saving time and being efficient in the process of watering hydroponic plants. Meanwhile, if the settings use a manual method, it can take a long time to manually check and adjust the nutritional conditions. Further research can be carried out to manufacture and test automatic hydroponic plant watering devices.

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*Corresponding author: anitasusilawati@lecturer.unri.ac.id
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