Construction of an Automatic Hydroponic Nutrient Control System Based on Arduino Uno

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Abstract. This work designs a hydroponic nutrient control system using Arduino Uno as the control center. This control system is not directly applied to hydroponic installations but is only limited for observing the performance of control system within a predetermined nutrient range. When the system starts working, the TDS sensor will read the suitability of the nutritional value in the container with the preset TDS value range. From the experimental results, the control system can work according to the commands given. The nutrient valve turns on when the nutrient level in the container is less than 1000 ppm and the valve will stop when the nutrient level is more than 1200 ppm. The stability of this control system was also evaluated by providing an annoyance into container. The result shows that the control system has good stability because it can maintain nutrient value according to the organized set point.

Keywords: Nutrient control system, Arduino Uno, TDS value, Control system stability.

1. INTRODUCTION

Hydroponics is a plant cultivation system that utilizes water without using soil with an emphasis on meeting the nutritional needs of plants [1]. The water used should meet certain criteria such as acidity levels, turbidity, and chemical elements (nutrients) that are in accordance with plant needs so that plant growth and productivity can be optimal. Nutrients, as one of the most crucial parameters in hydroponic plants, must be continuously monitored and maintained according to the range of nutrients needed by the plants. Excess nutrients can cause root shrinkage and osmotic stress, while nutrients deficiencies can lead to reduced fruit production and increased risk of disease and pests [2], [3]. This conditioning of nutritional value is performed throughout the plant's life cycle, from the beginning to the end of the plant, so that this occupation cannot be effectively carried out by employing human power. Therefore, this condition requires a nutrients control system that can automatically perform to satisfy plant nutrient needs.

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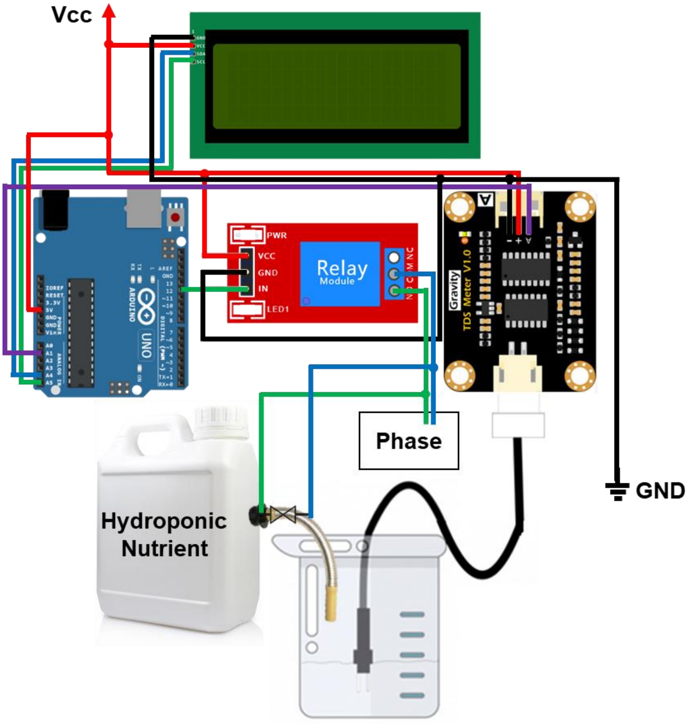
Currently, the level controlling of hydroponic nutrients has been extensively developed using various methods such as PID technique [4], [5], Fuzzy Logic Control [2], [6], and automatic on-off control [7], [8]. Among them, the automatic on-off control technique is considered a convenient method to implement in controlling the nutrient levels of hydroponic plants because it can be simply done by compiling commands or codes in an Arduino program. In the detector section of the system, a total dissolved solid (TDS) sensor will be used for measuring the number of particles dissolved in water. The TDS sensor works by utilizing two electrodes that are given different potentials so that an electric current flows through the plate. The conductance of a solution will be proportional to the concentration of ions in the solution, thus the nutrient content dissolved in the water can be detected [9]. Based on studies, hydroponic nutrients that are automatically controlled have better growth and harvest results compared to hydroponic nutrients that are not controlled [2], [10]. Sholihat, *et al.* compared the results of hydroponic water spinach treated with and without nutrient control. The results stated that spinach plants with nutrient control treatment were superior in every measurement parameter compared to water spinach without nutrient control treatment [10]. Herman, *et al.* stated that the proposed nutrient control system plays an important role in producing large lettuce and Chinese cabbage leaf sizes [11].

Based on these considerations, this study will design a hydroponic nutrient control system using Arduino Uno and the Gravity DFRobot TDS sensor as a control center and system detection equipment, respectively. This control system is not directly applied to hydroponic installations but is only limited for observing the performance of control system within a predetermined nutrient range. In addition, the hydroponic nutrient value will also be disturbed and we will observe how the sensor responds in maintaining the organized nutrient value.

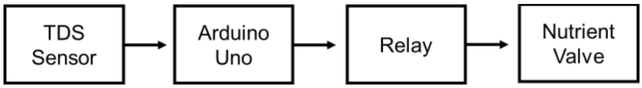
2. Experimental Section

2.1 Design of Nutrient Control System

This nutrient control system is designed using DFRobot TDS sensor, Arduino Uno, electric solenoid valve, relay, and liquid crystal display (LCD) 20 x 4. All components are arranged according to the circuit schematic shown in Fig. 1a. Based on the graph, a visual representation of all system components is well connected to each other. The Analog (A) pin on the TDS sensor is connected to A1 pin on the Arduino Uno, while the remaining pins + and – are connected to Vcc and ground, respectively [12]. Subsequently, in the control system section, the 5V pin on the Arduino Uno is linked to the Vcc voltage supply thereby activating and working in the circuit system [13]. In the switch section, input pin and commond terminal (COM) on the relay are connected to 12 pin of Arduino Uno and single-phase, respectively. Afterwards, pins 1 and 2 on the electric solenoid valve are associated to normally open (NO) pin on the relay and neutral pin netral on single-phase, respectively. Finally, in the output device of the circuit, the SDA and SCL pins on the LCD are respectively connected to pins A4 and A5 on the Arduino Uno [12], [14]. This summary of the stages of the nutrient control system works based on the block diagram system shown in Fig. 1b.



(a)



(b)

Fig. 1. (a) Wiring and (b) block diagrams of hydroponic nutrient control system.

2.2 Arrangement of Arduino Program

The creation of the Arduino Uno program for this nutritional control system was prepared based on previous studies by adjusting the TDS set point section. These codes were created using the Arduino software version 1.18.19. Fig. 2 presents the program that has been implemented into the nutrient control system.

Fig. 2. Arduino codes for nutrient control system.

2.3 Working Principle of Nutrient Control System

The program of nutrient control system initially organizes the nutritional set point range, namely at 1000 – 1200 ppm (parts per million). When the TDS sensor detects that the nutrient level in a container is less than 1000 ppm, the Arduino Uno will give a command to the relay to turn on the nutrient valve so that the nutrient level in the container will increase. When the nutrient level reaches more than 1200 ppm, the Arduino Uno again orders the relay to turn off the nutrient valve.

Overtime, the nutrient levels in the container will decrease due to absorption by the plant roots, so that the valve on-off activity will continue to work until the plant is harvested. In this research, containers that already have nutritional value according to the set point will be disturbed by adding water to the container so that the nutrient levels in the container will decrease. The nutritional control system will try to restore nutritional levels to the predetermined range.

3. Results and Discussion

3.1 Calibration of TDS Sensor

TDS sensor calibration is important to perform for obtaining measurement results that match the actual values. In this study, TDS sensor calibration was carried out using standard mineral water with a measured TDS value of 152 ppm. The TDS sensor calibration result is exhibited in Fig. 3. According to the graph, the nutrient value was initially at a value of 15 ppm, after calibrating the sensor the nutritional value stabilized at a value of 152 ppm.

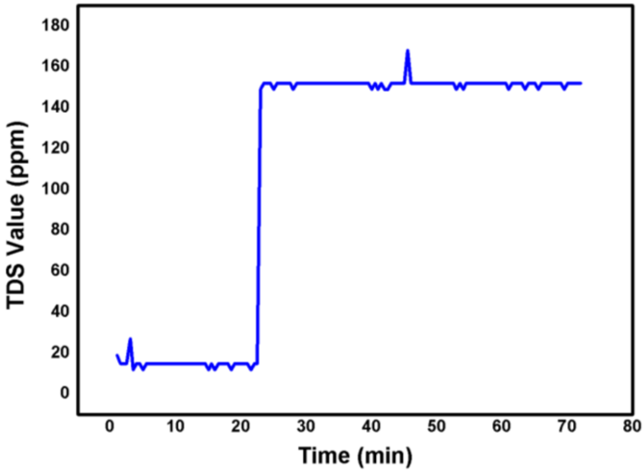


Fig. 3. Calibration curve of TDS sensor.

3.2 Measurement of TDS Sensor

The measurement of the TDS sensor is carried out by setting the TDS value in the range 1000 – 1200 ppm. This range was taken because it corresponds to the nutritional needs of rice plants [15]. Initially, the TDS level in the container is less than 1000 ppm, then as the nutrition valve actively flows liquid into the container, the TDS level increases, until in a condition where the TDS value in the container reaches more than 1200 ppm, the nutrition valve will stop. Table 1 shows the sensitivity of the nutritional control system to detect TDS levels in the container.

TABLE I. The Measurement Result of TDS Sensor.

Time (min)	Measured TDS Value (ppm)	Valve Condition
24	729	On
24,5	760	On
25	830	On
25,5	890	On

26	916	On
26,5	909	On
27	927	On
27,5	946	On
28	950	On
28,5	1078	On
29	1107	On
29,5	1158	On
30	1193	On
30,5	1204	Off

The stability of this control system was also evaluated by providing interference in the form of adding water to the container so that the TDS value decreases below 1000 ppm. This condition causes the nutrition valve to turn on again to drain the liquid into the container so that the nutritional value returns to the preset range. Fig. 4 exhibits the stability of the sensor system which can maintain nutritional values in the range of 1000 – 1200 ppm.

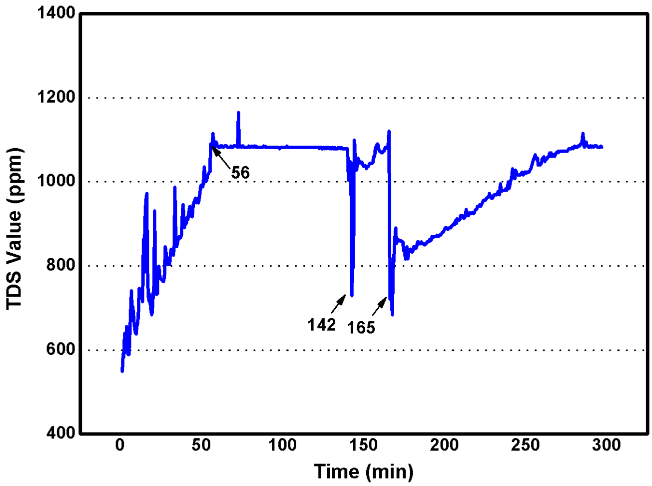


Fig. 4. The stability of nutrient control system.

In the initial minutes, the TDS value profile tends to increase due to the opening of the nutrient valve so that liquid can flow into the container. At 56 minutes, the TDS value tends to stabilize because the nutrient levels have reached the regulated TDS range. At 142 and 165 minutes, water was added to the container because of which the TDS value decreased very significantly. Afterwards, the system immediately turns on the nutrition valve so that the TDS value can return to the organized value range. This phenomenon shows that the designed control system has good stability in maintaining the nutritional value as desired.

4. Conclusions

The designed nutritional control system can perform according to the commands given. The nutrient valve turns on when the nutrient value in the container is less than 1000 ppm and the valve will stop when the nutrient value is more than 1200 ppm. This system also has good stability because it can maintain nutritional value when disturbed by adding water to the container.

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