

PAPER • OPEN ACCESS

## Development of a Control System for Lettuce Cultivation in Floating Raft Hydroponics

To cite this article: Lenni *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **542** 012067

View the [article online](#) for updates and enhancements.

You may also like

- [Hydroponic nutrient mixing system based on STM32](#)  
Riko Tandil, Johan Yapson, Wiedjaja Atmadja et al.
- [Fuzzy-based automated nutrient solution control for a hydroponic tower system](#)  
J A Dela Vega, J A Gonzaga and L A Gan Lim
- [Optimization of hydroponic technology for production of mycorrhiza biofertilizer](#)  
A Nurbaity, N Istifadah, B A Haryantini et al.



**ECS**  
The  
Electrochemical  
Society  
Advancing solid state &  
electrochemical science & technology

**DISCOVER**  
how sustainability  
intersects with  
electrochemistry & solid  
state science research

# Development of a Control System for Lettuce Cultivation in Floating Raft Hydroponics

Lenni<sup>1</sup>, H Suhardiyanto<sup>1,2</sup>, KB Seminar<sup>1</sup>, and RPA Setiawan<sup>1</sup>

<sup>1</sup>Department of Mechanical and Bio-system Engineering, Bogor Agricultural University (IPB University), Indonesia

<sup>2</sup>Corresponding author, email: herrysuhardiyanto@ipb.ac.id

**Abstract.** Developing a control system for hydroponics is gaining high attention because of the possibility to increase resource efficiency in producing high quality vegetables. Applying such a control system for nutrient solution in hydroponics requires less labour and operational cost. Therefore, it is important to develop a control system for nutrient solution in hydroponics. This research was aimed to develop a control system for lettuce cultivation in floating raft hydroponics. The control system has been developed to control temperature, EC, pH, DO, and ORP of nutrient solution in the controlled floating raft hydroponics by using Arduino Mega 2560 microcontroller as a control unit and micro SD card as storage media. The control system was found to be able to maintain the temperature of nutrient solution in the range of 20 to 25°C, EC in the range of 1500 to 1700  $\mu\text{S}/\text{cm}$ , pH in the range of 5.5 to 6.2, DO in the range of 4 to 8 ppm, and ORP in the range of 300 to 500 mV. The control system performed well in maintaining these parameters as showed by a better lettuce growth in the controlled floating raft hydroponics, as compared to that of without the control system.

## 1. Introduction

Lettuce plants have gained interest because of increasing demand for high quality green salads in Indonesia. Therefore, lettuce plants have become the most commonly cultivated plants in tropical hydroponics. Floating raft hydroponics enable the production of vegetable with high quality and productivity [1]. Using the hydroponic method, lettuce plants which were placed on styrofoam boards and floated on a pond containing nutrient solution have grown well [2, 3]. Parameters of nutrient solution necessary to be monitored in real time and controlled are Resistance Temperature Detector (RTD) [ $^{\circ}\text{C}$ ], Electrical Conductivity (EC) [ $\mu\text{S}/\text{cm}$ ], puissance negative de H [pH], dissolved oxygen (DO) [ppm], Oxidation Reduction Potential (ORP) [mV]. This is because these parameters affect the plant growth in hydroponics significantly.

Temperature of nutrient solution affects physiological process in root, such as the absorption of water, nutrients, and minerals [4]. The production of various plant metabolites is influenced by the temperature of root zone in many plants, including leaf vegetables [5]. High temperature in the root zone is one of the most significant limiting factors for lettuce cultivation in tropical hydroponics. Instead of cooling the entire greenhouse air, zone cooling system has been developed as energy-efficient cooling system for greenhouse [6, 7]. Having higher specific heat than greenhouse air, chilling the nutrient solution in a hydroponic system has the possibility to be the energy-efficient cooling system for tropical hydroponics. Furthermore, experiments of zone cooling for plant roots have been conducted in aeroponic system to grow potato [8] and in floating raft hydroponics for red onion [9] which resulted in a good plant growth.



The value of EC is required to be controlled to ensure nutritional elements needed by plants is fulfilled. Conductivity reflects the concentration of nutrient in solution. The more concentrated a nutrient solution is, the higher conductivity, thus resulting in higher EC. The value of EC depends on the temperature of nutrient solution, if temperature increases, solution resistance will further decrease along with electricity. Furthermore, increasing conductivity in nutrient solution may reduce water absorption by plants and decreasing photosynthesis [10]. The value of pH of the nutrient solution that affects plant growth [11] should be controlled through the addition of acidic solution to decrease pH or alkaline solution to increase pH of the nutrient solution. Roots of loose-leaf lettuce grown in a floating raft hydroponic system were found to have better condition with oxygen enrichment done in nutrient solution up to aeration pressure of 0.012 mPa and concentration of 600 ppm, with indicators of increasing length and total root surface area [12]. Sensors for EC, pH, and ORP which uses microfabricated platinum electrode could simultaneously measure EC up to 8000  $\mu\text{S}/\text{cm}$  at a temperature range of 10 to 50°C, pH in a range of 4 to 10 and ORP from 150 to 800 mV [13].

The rapid development of computer and controller have enabled the opportunity of application the controller in hydroponics [14]. The microcontroller could be used to control these nutrient solution parameters by using relevant sensors. On the other hand, providing nutrient solution manually is subject to errors and less accurate for these parameters due to tiredness. Therefore, it is important to develop a control system for these variables. This research was aimed to develop an automatic control system based on microcontroller to control temperature, EC, pH, DO, and ORP of nutrient solution. It is expected that the application of such a system would increase the quality and productivity of lettuce cultivated in zone-cooled floating raft hydroponic.

## **2. Materials and Methods**

### **2.1. Materials and Tools**

The microcontroller used in this research was Arduino Mega 2560 microcontroller module with EEPROM 4 KB. The control system was composed of the microcontroller, LCD display module, 10 electric sockets, micro SD card 2GB module, 10 4x4 matrix-relay keypad of 220 volt, opto coupler MOC3020, adaptor 5 volt, GSM modem wavecom, temperature sensor (RTD) Atlas Scientific, EC sensor Atlas Scientific, pH sensor Atlas Scientific, DO sensor Atlas Scientific, ORP sensor Atlas Scientific, ultrasonic sensor, serial port expander, 10 LED lightbulbs 3W, 1 water pump Yamano PSP-7, 2 water Resun SP-5200, 2 pumps Resun LG-4000, 6 water pumps Aquila P3000, aerator pump Resun LP-100. Calibration apparatus were used to calibrate these sensors, included dissolved oxygen test kit for titration, infrared thermometer Benetech GM550, chlorophyll meter SPAD-502Plus, lux meter digital LX1010B, ORP meter Kedida CT-8022, EC meter HM Digital COM-100, and pH meter HM Digital COM-200.

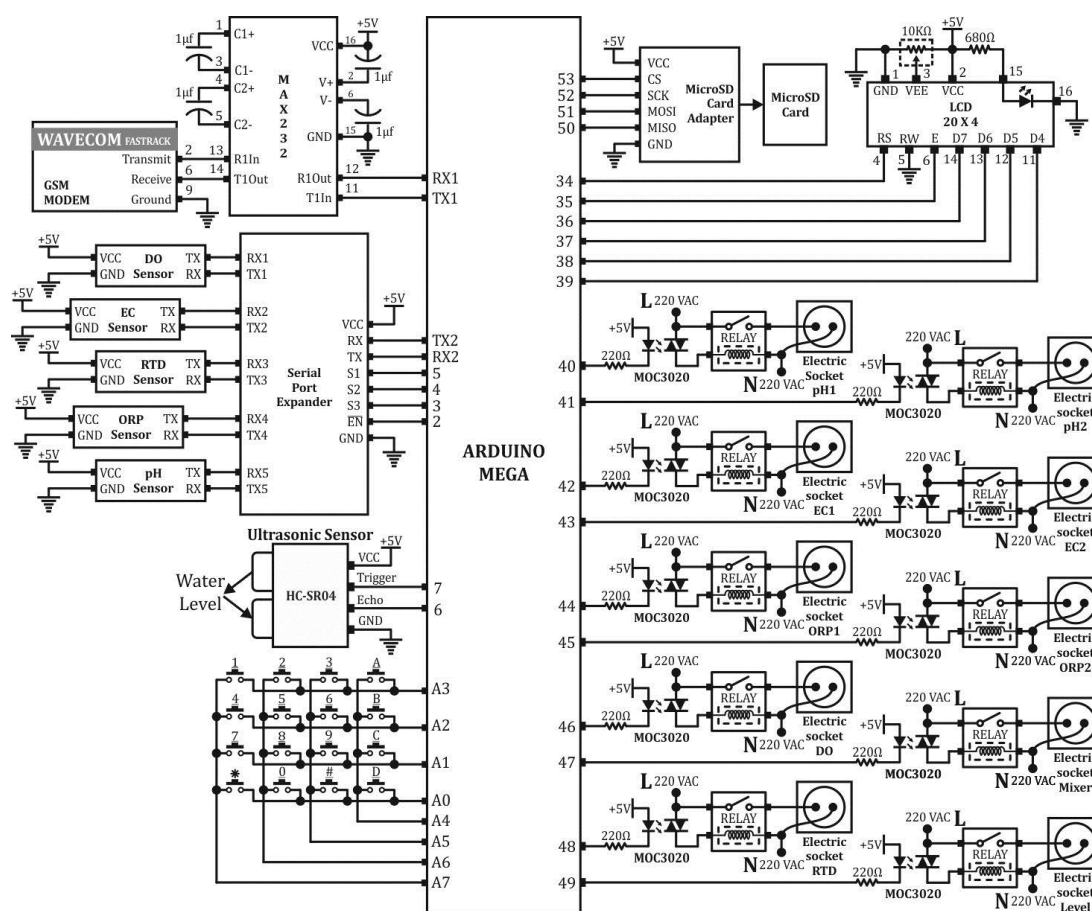
The zone-cooled floating raft hydroponic system was equipped with heat exchanger pipe, piping system, 2 cultivation ponds, 6 nutrient tubs, aeration tank, water tank, and water chiller tank. Root-zone cooling was conducted through cooling down the nutrient solution by flowing chilled water from chiller into the heat exchanger pipe placed in the nutrient solution. The heat exchanger pipe was made of galvanized pipe. Performance of the control system was evaluated in lettuce cultivation in the controlled floating raft hydroponic system. Materials used in this research included Grand Rapid lettuce seeds, fertilizer, water, and other necessary materials for hydroponic cultivation. Dry weight of lettuce plants was measured by using digital balance.

### **2.2. Design of System**

The design of hardware of control system, as presented in Figure 1, has been developed for seven inputs and ten outputs. The seven inputs included the sensors of RTD, EC, pH, DO, ORP, ultrasonic, and keypad, while the ten outputs covered pump for chiller, pump to increase EC, pump to decrease EC, pump to increase pH, pump to decrease pH, aerator pump to increase DO, pump to increase ORP, pump to decrease ORP, pump to increase the surface level of nutrient solution, and mixer pump. Furthermore,

the developed system has serial port expander, Arduino Mega microcontroller 2560, GSM modem, micro SD, LCD, opto coupler, relay, electric sockets, and pumps.

The design of software in Arduino Mega 2560 microcontroller has been developed by using C programming language. Moreover, coding was made in steps as follows: (1) draw detailed scheme of the hardware circuit to be designed, (2) determine the port used to control the LCD display, (3) determine the port used to detect the keypad, (4) determine the port used for the ultrasonic sensor, (5) determine the serial port used to detect sensors of RTD, EC, pH, DO, and ORP, (6) determine the serial port used to control 10 pump relays including chiller, and (7) determine the port used to communicate with micro SD card and SMS to send messages given by Arduino Mega 2560 microcontroller to cellphone number. Working flowchart of control system is presented in Figure 2.

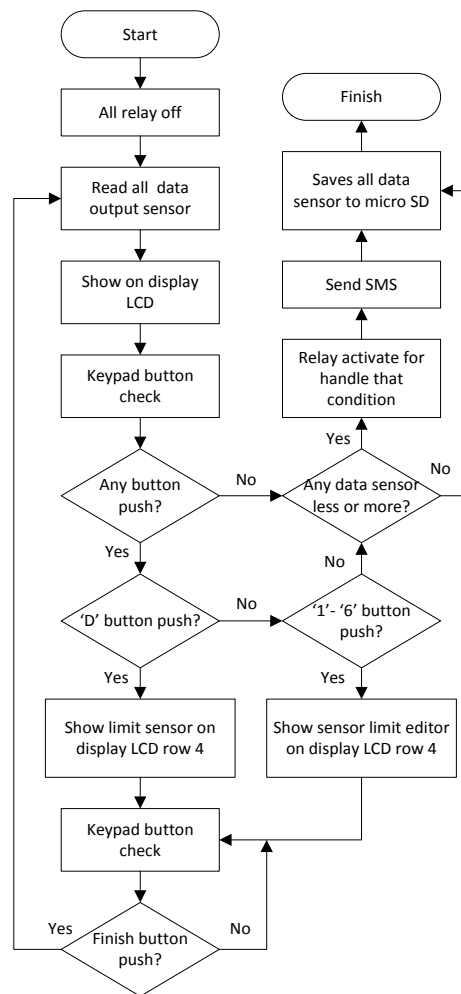


**Figure 1** Hardware circuit of the developed control and data acquisition system

### 3. Result and Discussion

### 3.1. The Developed Control System

Equipment of control system developed in this research is depicted in Figure 3. This system consisted of (1) LCD circuit to display the value of parameters read by the system, (2) keypad circuit to enter the desired parameters, (3) sensor circuit to detect the condition of nutrient solution in the floating raft hydroponics, (4) micro SD card circuit as data recorder, (5) GSM



**Figure 2** Working flowchart of the developed control system

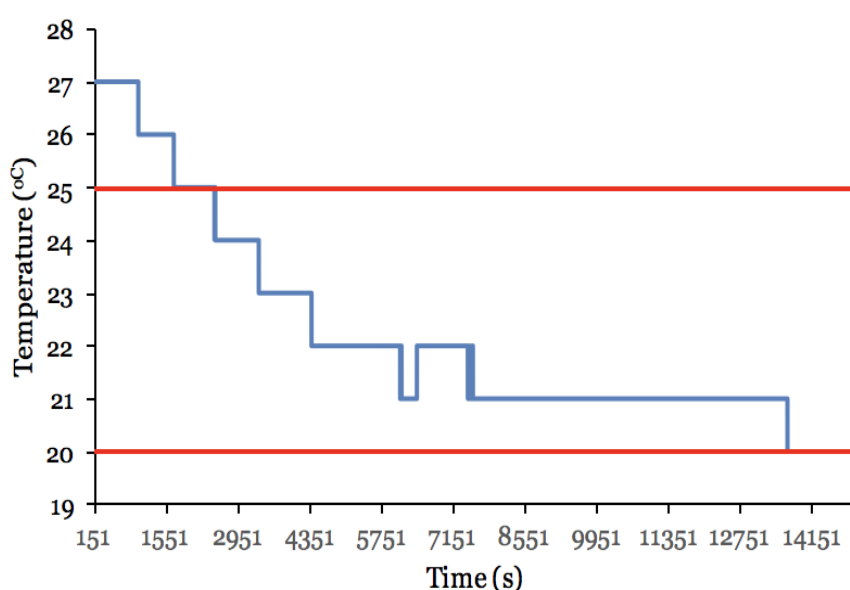


**Figure 3** The developed control system

modem circuit that is able to send SMS to provide notification, and (6) relay circuit to supply electricity to the electric socket used to start the pump.

### 3.2. Performance of the System to Control Parameters

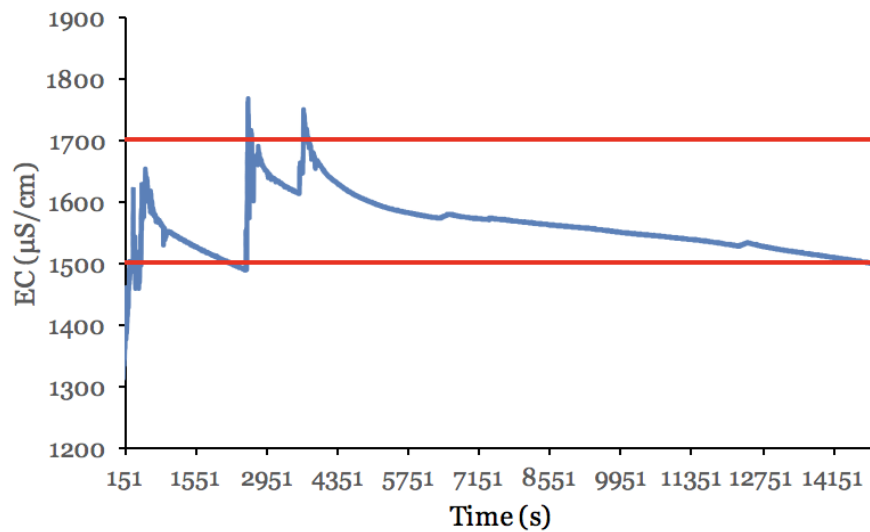
The performance of control system in controlling the temperature of nutrient solution in the floating raft hydroponic system is illustrated in the graph of temperature changes during the control process (Figure 4). The pond temperature treatment of 24 °C produced maximum growth of lettuce in floating raft hydroponics [15]. The developed control system was set to control the temperature of nutrient solution remained 20 to 25 °C by operating the chiller to cool the water circulated through cooling pipes in the root zone of the floating raft hydroponic system.



**Figure 4** Typical changes in nutrient solution temperature controlled by the developed system

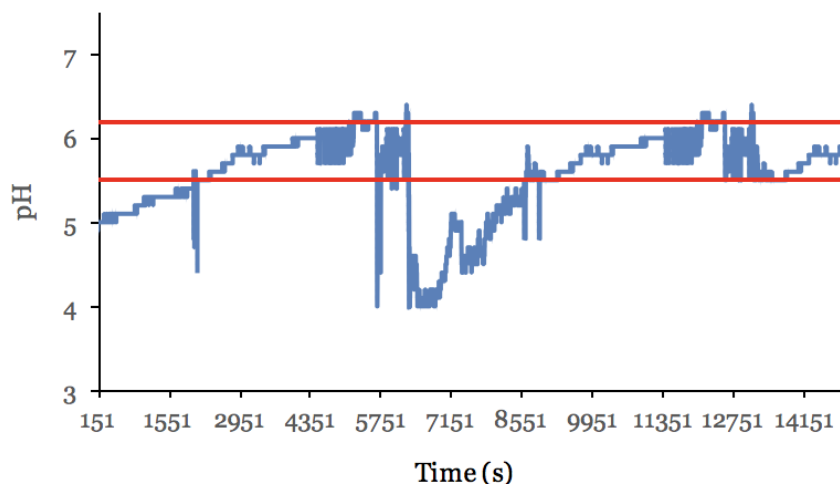
The increase in temperature of nutrient solution is due to increasing heat load from solar radiation while the decreasing temperature is due to heat exchange between the nutrient solution and the chilled water flowing inside the cooling pipe which is used as the heat exchanger. Temperature of nutrient solution was found to be between 20 to 25 °C. This finding was in line with the condition of nutrient solution in the floating raft hydroponics inside the greenhouse during sunny weather. The control system has operated the chiller to cool down the nutrient solution when the temperature reached 25 °C and stop chiller operation when the temperature of nutrient solution has decreased to 20 °C.

Figure 5 shows changes in EC of nutrient solution of floating raft hydroponics during the control process. The developed system was set to control the EC value between 1500 and 1700  $\mu\text{S}/\text{cm}$  by adding nutrient solution or water. As seen in the figure, EC value of nutrient solution was between the lower and upper limit of 1500 and 1700  $\mu\text{S}/\text{cm}$ , respectively. The value of EC increased rapidly when control system operated the addition of saturated solution, but it tended to decline slowly when control system added water. The control system was found successfully in controlling the EC of nutrient solution.



**Figure 5** Typical changes in EC of nutrient solution controlled by the developed system

Performance of control system in controlling the nutrient solution pH by adding acid or base solution is seen from changes in pH during the control process (Figure 6). Based on the figure, it is noted that the pH of nutrient solution fluctuated between the lower (5.5) and upper (6.2) limit. Fluctuation of pH is a response of the addition of alkaline or acidic solution according to the difference between the recorded value of nutrient solution pH and the lower and upper limit for pH control set in the developed system. It was noted that the changes of nutrient solution DO and ORP were also between the upper and lower limit for control set for the respective parameters.

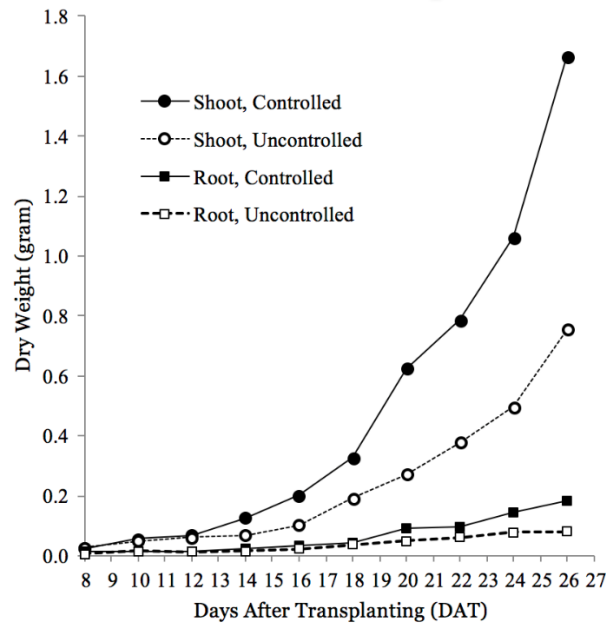


**Figure 6** Typical changes in pH of nutrient solution controlled by the developed system

### 3.3. The Growth of Lettuce in the Controlled Floating Raft Hydroponics

Performance of the control system has been evaluated to control temperature, EC, pH, DO, and ORP of nutrient solution in lettuce cultivation in two two cultivation ponds of floating raft hydroponics. Seedlings (180 plants for each cultivation pond) of “Grand Rapid” lettuce plant were placed in rockwool-filled plant holder cups in styrofoam board of 4 cm thick at plant spacing of 20 cm x 20 cm.

The first pond was for lettuce cultivation with controlled nutrient solution while the second pond was for uncontrolled one. Observation to the growth of lettuce plant was done by measuring dry weights of three plant samples every two days. The average values of dry weight of the lettuce plants during cultivation period are presented in Figures 7. As can be seen from these figures, the averages dry weight curves of shoot and root of lettuce plants were basically exponential.



**Figure 7** Dry weight of lettuce plants grown in controlled pond and in uncontrolled pond

Such exponential curves were normally observed in growth data of lettuce plants. Higher value of biomass of “Grand Rapid” lettuce was obtained under the condition of controlled nutrient solution in the pond, as compared to those in the uncontrolled pond. It was noticed that the developed control system performed well in controlling the nutrient solution for better growth of lettuce plants in floating raft hydroponics.

#### 4. Conclusion

1. The proposed and developed control system could control parameters of nutrient solution of a floating raft hydroponics.
2. The developed control system was able to perform its function to control temperature, EC, pH, DO, and ORP of nutrient solution in floating raft hydroponics under the ranges of control set for the respective parameters.
3. By using the developed control system, average values of dry weight of the lettuce plants cultivated in controlled floating raft hydroponics were higher than those in uncontrolled floating raft hydroponics.

#### 5. Acknowledgement

The authors thank the Ministry of Research, Technology, and Higher Education, Republic of Indonesia for providing scholarships to the first author.



## 6. References

- [1] Pantanella E, Cardarelli M, Danieli PP, MacNiven A, and Colla G 2010 Floating Agriculture: is it a Valid Strategy to Raise Livelihood *Integrated Aquaculture* 1-8
- [2] Hussain A, Iqbal K, Aziem S, Mahato P, and Negi A 2014 A Review on The Science of Growing Crops Without Soil (Soilless Culture) A Novel Alternative For Growing Crops. *International Journal of Agriculture and Crop Sciences* **7** 833-842
- [3] Silva L, Gasca-Leyva E, Escalante E, Fitzsimmons KM, Lozana DV 2015 Evaluation of Biomass Yield and Water Treatment in Two Aquaponic System Using Root Floating Technique (DRF). *Sustainability* **7** 15384-15399
- [4] Chadirin Y, Hidada T, Takahashi Y, Sago T, Wajima M, and Kitano M 2011 Application of temperature stress to roots of Spanish. I. Effect of the low temperature stress on quality *Environment Control in Biology* **49** 133-139
- [5] Sakamoto M, Suzuki T 2015 Effect of root zone temperature on growth and quality of hydroponically grown red leaf lettuce. *American Journal of Plant Sciences* **6** 2350-2360
- [6] Suhardiyanto H and Matsuoka T 1992 Studies on a zone cooling system in a greenhouse (2) Evaluation of a system for microclimate modification in a plastic greenhouse during hot weather *Environment Control in Biology* **30** 143-151
- [7] Suhardiyanto H and Matsuoka T 1994 Uniformity of Cool Air Discharge along a Perforated Tube for Zone Cooling in a Greenhouse *Environment Control in Biology* **32** 9-16
- [8] Sumarni E, Suhardiyanto H, and Seminar KB 2013 Seed Potato Production Using Aeroponics System with Zone Cooling in Wet Tropical Lowlands *Acta Horticulturae* **1011** 141-145
- [9] Niam AG, Suhardiyanto H, Seminar KB, and Maddu A 2017 Simulation of Temperature Distribution on the Planting Hole of Floating Hydroponic for Shallot Production in Tropical Lowland *Jurnal Keteknik Pertanian* **5** 235-244
- [10] Cometti NN, Bremen DM, Galon K, Hell LR, and Zanolatti MF 2013 Cooling and concentration of nutrient solution in hydroponic lettuce crop *Horticultura Brasileira* **31** 287-292
- [11] Shah H, Taware P, and Bhalerao A 2017 Hydroponic cultivation using pH level controlling *IJARECE* **6** 522-525
- [12] Krisna B, Putra ETS, Rogomulto R, and Kastono 2017 The Effects of Oxygen and Calcium Enrichment on the Root Growth and Yield of Curly Lettuce (*Lactuca sativa L.*) that Grow under Floating Raft Hydroponics *Vegetalika* **6** 14-27
- [13] Lin WC, Brondum K, Monroe CW, and Burns MA 2017 Multifunctional Water Sensors for pH, ORP, and Conductivity Using Only Microfabricated Platinum Electrodes *Sensors* **17** 2-9
- [14] Domingues DS, Takahashi HW, Camara CAP, and Nixdorf SL 2012 Automated System Developed to Control pH and Concentration of Nutrient Solution Evaluated in Hydroponic Lettuce Production *Computers and Electronics in Agriculture* **84** 53-61
- [15] Thompson HC, Langhans RW, Both AJ, and Albright LD 1998 Shoot and Root Temperature Effects on Lettuce Growth in a Floating Hydroponic System *Journal of the American Society for Horticultural Science* **123** 361-364