ICIC Express Letters
Part B: Applications
Volume **16**, Number **7**, July **2025**

ICIC International ©2025 ISSN 2185-2766
pp. **791–796**

THE DEVELOPMENT OF IOT-BASED HYDROPONIC SYSTEM OF STRAWBERRY PLANT IN INDONESIA

Widodo Budiharto*, Heri Ngarianto
Alexander Agung Santoso Gunawan and Edy Irwansyah

Computer Science Department
School of Computer Science
Bina Nusantara University
Jl. K. H. Syahdan No. 9, Kemanggisan, Palmerah, Jakarta 11480, Indonesia
heri.ngarianto@binus.ac.id; { aagung; eirwansyah }@binus.edu
*Corresponding author: wbudiharto@binus.edu

Received October 2024; accepted December 2024

Abstract. *Strawberry is one of the favorite fruits for health and a source of vitamins. In Indonesia, many strawberry farmers plant imported types because they are sweeter and bigger. However, excellent, jumbo, and sweet strawberry is not resistant to the weather in Indonesia and usually only can grow optimally in the highlands. Therefore, the development of an IoT-based hydroponic system that can handle the humidity of the root, nutrient and enough photosynthesis process is urgently needed for strawberry in lowland in Indonesia. We proposed a low-cost system of IoT-based system for hydroponic with UV Lamp, temperature and humidity sensor, pump for watering and providing enough oxygen to optimize growth of strawberry. We also propose an algorithm for controlling the condition of the environment that is suitable for strawberries. Based on experiments, the IoT system can control the photosynthesis process and improve plant, berry's growth and health with minimum intervention from farmer.*
Keywords: Hydroponic, Strawberry, Humidity sensor, Smart farming, IoT

1. **Introduction.** In Indonesia and throughout the world, it can be said that strawberry is one of the most favourite fruits because of its freshness and health benefits. Together with grapes, are ancient fruits that have existed for thousands of years. Strawberries are low-growing herbaceous plants with a fibrous root system and a crown from which arise basal leaves. The leaves are compound, typically with three leaflets, sawtooth-edged, and usually hairy. The cultivated large-fruited strawberry originated in Europe in the 18th century. Most countries developed their own varieties during the 19th century, and those are often especially suitable for the climate, day length, altitude, or type of production required in a particular region [1]. The Food and Agriculture Organization (FAO) predicts that by 2050 the world population will be 9.6 billion. That means agricultural production must increase by 70% in that year to meet the needs of the population with this amount. Yet as we know, there is a classic problem of food, namely the population increases but the amount of agricultural land is getting narrower. Therefore, increasing agricultural technology-based productivity is very urgent, one of which is based on the Internet of Things (IoT) [2].

Usually, strawberry plants are grown on the ground, but much labor and painful work are required for cultivating and harvesting them manually. Recently, some strawberry plants have been started being cultivated on hydroponic system in which flumes are lifted to a height of human waist position to reduce the painful work and strawberry fruits are hung down from the flumes [3]. Hydroponics is the technique of growing plants using a water-based nutrient solution rather than soil, and can include an aggregate substrate,

DOI: 10.24507/icicelb.16.07.791

or growing media, such as vermiculite, coconut coir, or perlite. Growing plants in water culture or sand culture without soil are procedures that have been used by physiologists studying plant nutrition and by other plant scientists for more than a century [4]. In a greenhouse, both aerial and root zone environments can be maintained in an optimum range that maximizes plant productivity – less water and nutrients required.

Recently, several studies claimed that the Internet of Things (IoT), especially in vineyards for urban farming, is very useful. IoT smart farming solution is a system that is built for monitoring the crop field with the help of sensors (light, humidity, temperature, soil moisture, crop health, etc.) and automating the irrigation system [5]. The global agriculture IoT market is estimated to grow from USD 11.4 billion in 2021 to USD 18.1 billion by 2026 at a CAGR of 9.8% during 2021-2026. The growth of the agriculture IoT market is driven by factors such as increasing adoption of the Internet of Things (IoT) and artificial intelligence (AI) by farmers and growers, growing focus on livestock monitoring and disease detection, high demand for fresh produce, population growth, loss of arable land, surging adoption of aquaculture monitoring and feed optimization devices in developing countries [6]. The growing medium made of wood fiber from Norway spruce trees can be advantageous for strawberry growth, compared to plants cultivated in peat and coir soil. Plants grown in wood fiber had fewer unripe fruits and no nutrient deficit [7].

In this paper, we proposed a low-cost system of smart IoT and hydroponic system with temperature and humidity sensor and sprayer to optimum growth of strawberry. The weaknesses of strawberry that require suitable soil condition and humidity were solved using this system. This paper consists of Part 1 Introduction, Part 2 Literature Review, Part 3 Proposed Method, Part 4 Experimental Result and Part 5 Conclusions.

2. **Literature Review.**

2.1. **Hydroponic of strawberry plant.** Hydroponic, also called aquaculture or tank farming, is the cultivation of plants in nutrient-enriched water, with or without the mechanical support of an inert medium such as sand, gravel, or perlite. There are some types of hydroponic systems to consider: Deep Water Culture (DWC), Nutrient Film Technique (NFT), ebb and flow, aeroponics, and drip systems. The first reason to use hydroponic is that traditional strawberry farming methods use enough water and exact humidity. With hydroponic, the strawberry plants are grown in a closed system where the water is reused. This means that less water is needed to grow the strawberries. The second reason is that hydroponic strawberry plants can be grown in any location and climate. This is because they do not need soil to grow. You need a water source and some support for the strawberry plant. This means that you can grow strawberry plants in your home, office, or balcony. The third reason is that hydroponic strawberry plants have a higher yield than traditional strawberry plants. This is because the plants are grown in ideal conditions as shown in Figure 1, where they can receive the efficient and perfect amount of nutrients, water and humidity [8].

The ideal pH level for strawberry plants is between 5.5 and 6.5. The fruiting stage is the stage where the strawberry plants produce fruits. The ripening stage is when the strawberry fruits are ripening and turning red. Hydroponic strawberry plants have a higher vitamin C content than traditional strawberry plants. Soil NPK Sensor for agriculture will measure the surface of the soil or be buried in the ground for a long time, and resistant to long-term electrolysis.

2.2. **IoT technology.** IoT technology has a huge role to play in such a landscape, as it can provide an unprecedented source of monitoring data with huge amounts of data that comes the ability to interpret it for a meaningful and business-viable purpose. Internet of Things (IoT) is a new paradigm that has changed the traditional way of living into a high-tech lifestyle. Smart city, allows farmers to monitor their farms (fish and livestock)

FIGURE 1. Optimal growth of strawberries can be achieved with many factors [7].

without necessarily being physically present. However, there are still a lot of challenges and issues that need to be addressed to achieve the full potential of IoT [9]. Based on information from China IoT company, the IoT management solution increased grape yield by 153 percent compared to standard production. Higher quality indicators were also observed, including fruits weighing up to 39 percent heavier, and greater levels of accumulated sugars, soluble solids, and vitamin C. Sourav et al. proposed smart system architecture in the field of precision agriculture based on IoT [10]. For example, an automated temperature and humidity control system for greenhouse strawberry production using solar system for the Malaysian climate has been developed. The system is designed to monitor and automate the control of water moisture and temperature of the greenhouse and no fog misting to control the humidity [11].

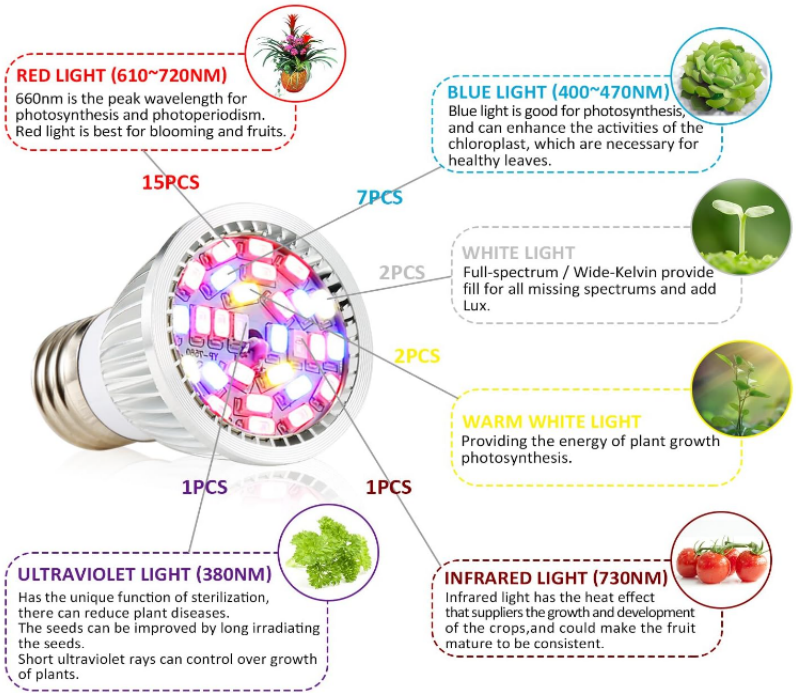

FIGURE 2. LED grow light bulb 28W, full spectrum grows lights for hydroponics. It helps when the plant needs an extra boost of light, or a few of sun, rain, snow and dark indoors. These growing lamps emit the wavelength of light which can be fully absorbed by the plant's photosynthesis; 627nm and 470nm are respectively 4 peaks of growth spectrum for maximum chlorophyll A and B production.

Smart farming is a modern farming managemental concept with IoT technology to increase productivity in agriculture [12], such as using LED grow light. LED grow light bulbs for indoor plants allow you to cultivate a wide variety of plants at any climate during any time of year. These growing lights are specially designed to substitute natural sunlight, stimulating photosynthesis, and providing the right color spectrum where the plant can grow and flourish. Red (627nm) and blue (470nm) can provide the most efficient wavelengths of light to enhance photosynthesis performance hence improving plants and other microorganisms healthy growing. Add extra sunlight to the plants, stipulate the photosynthesis, and help shorten the growth cycle. Sources rich in red light are more efficient and beneficial for photosynthesis, and best for blooming and fruit. The Chlorophyll and Carotenoid need blue much, good for the photosynthesis, and best for promoting the leaf.

3. Proposed Method.

3.1. **Architecture of the system.** We use Arduino controller as a main controller for the IoT system with LCD for displaying information to the user. Relays are used for controlling the lamp and pump. Real-time clock DS 3231 will be used as clock and timer to activate the UV Lamp at specific time. Based on the discussion with the farmer, strawberry needs long active UV Lamp for optimum growth. The architecture of the system is shown in Figure 3.

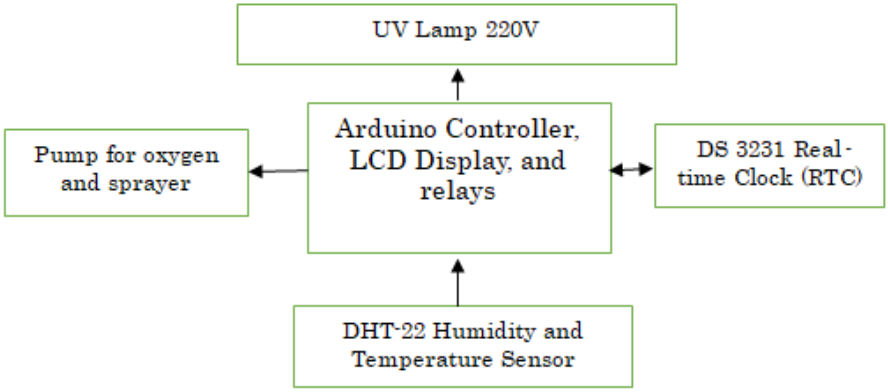

FIGURE 3. Architecture of the IoT system for strawberry using hydroponic

3.2. **Proposed algorithm.** We propose an algorithm for the IoT system to access the clock and activate the UV lamp and pump for strawberry with specific interval time based on our experiment as shown in Algorithm 1:

Algorithm 1. Smart IoT using hydroponic for strawberry.
import libraries.
declare variables.
Configuring 4 digits dot matrix 8×8, clock, and sensors
Activate pump.
begin
  read humidity and temperature from DS 3231.
  read soil sensors.
  Displaying welcoming message and information
  if clock == 5 PM or 6 PM or 7 PM. . . or 11 PM then
    Turn on UV Lamp for 5 minutes
  end if
  if clock == 7.00 AM then
    Turn on UV Lamp and oxygen for 5 minutes.

```
    end if
    if clock == 10.00 AM and humidity < 60% then
        Turn on UV Lamp, oxygen and sprayer for 5 minutes.
    end if
    if clock == 02.00 PM and humidity < 60% then
        Turn on UV Lamp, oxygen and sprayer for 5 minutes.
    end if
end
```

4. **Experimental Result.** We use several varieties of strawberry. We measure the health and the weight of the fruit before and after using IoT system and hydroponic as shown in Table 1. We also get result that using hydroponic sometimes the plant cannot grow successfully. Traditional farming in developing countries faces many challenges to increase the fruit quality and quantity. For instance, some of these challenges are limited arable land and high overall cost [13]. Based on our experiment, low-cost controller was proposed and implemented to enhance the overall traditional farming efficiently.

TABLE 1. Experimental result using hydroponic and IoT system for strawberry shows the weight of the strawberry in gram.

Variety	Before using hydroponic + IoT (gram)	After using hydroponic + IoT (gram)	% of still growth using hydroponic + IoT
Korean	8	9	80%
Jumbo X Bali	10	11	90%
Sagahonoka	8	9	70%
California Jumbo	9	10	80%

Figure 4 shows our hydroponic system and the result of berry that needs 15 days to ripe.

(a) (b)

FIGURE 4. Our hydroponic system (a) and average result of strawberry 8-15 grams in lowland (b)

5. **Conclusions.** To grow strawberry in hydroponic, adequate nutrient and photosynthesis are needed, with the right moisture content (not too wet and not dry); therefore, regulating LED growth using Internet of Things (IoT) is important to produce optimal strawberry production. Based on our research, the IoT system for strawberries can improve the height of the seeds significantly more than irregular spray from the farmer. Users can optimize, monitor, and control the humidity and temperature through our system. Hydroponics also eliminates soil and soil-borne pests and diseases, so there is no

need to use large amounts of pesticides. The size of the berry can be improved if the system runs well. For future work, researchers can continue to add deep analysis of the effect of dissolved oxygen for the strawberry plant.

Author Contribution. The study was conceived and designed by Widodo Budiharto and Heri Ngarianto. The experiments are performed by Widodo Budiharto. The writing is guided by Alexander Agung Santoso Gunawan and Edy Irwansyah. All authors read and approved the manuscript.

Data and Materials Availability. This study utilized data obtained from the experiment and accessible at www.widodo.com/strawberry.zip.

Acknowledgment. This work is supported by Bina Nusantara University, Jakarta, Indonesia and grant from BINUS Initiative Projects 2024.

REFERENCES

[1] *Introduction of Strawberry*, https://www.britannica.com/plant/strawberry, Accessed on 9 June, 2023.
[2] W. Budiharto, Digital innovation in the smart farming industry: Concept and implementation, in *Prosiding Seminar Nasional Lahan Suboptimal 2019*, S. Herlinda et al. (eds.), Unsri Press, 2019.
[3] N. Kondo, M. Monta and S. Arima, Strawberry harvesting robot on hydroponic system, *Engineering, Agricultural and Food Sciences, IFAC Proceedings Volumes*, vol.31, no.5, pp.181-185, 1998.
[4] U.S. Department of Agriculture, *Farms and Agricultural Production Systems*, https://www.nal.usda.gov/farms-and-agricultural-production-systems, Accessed on 20 March, 2024.
[5] *IoT for Vineyards*, https://www.evineyardapp.com/blog/2018/08/23/why-to-implement-iot-in-the-vineyard/, Accessed on 20 March, 2022.
[6] *Introduction of IoT*, https://www.marketsandmarkets.com/pdfdownloadNew.asp?id=573, Accessed on 8 February, 2022.
[7] T. Woznicki, B. E. Jackson, A. Sønsteby and K. Kusnierek, Wood fiber from Norway spruce – A stand-alone growing medium for hydroponic strawberry production, *Horticulturae*, vol.9, 815, 2023.
[8] *How to Grow Hydroponic Strawberries for a Sweet, Juicy Treat?*, https://hydroponicway.com/how-to-grow-hydroponic-strawberries-for-a-sweet-juicy-treat/, 2022.
[9] S. Kumar, P. Tiwari and M. Zymbler, Internet of Things is a revolutionary approach for future technology enhancement: A review, *J. Big Data*, vol.6, 111, https://doi.org/10.1186/s40537-019-0268-2, 2019.
[10] A. I. Sourav, A. W. R. Emanuel and D. B. Setyohadi, Smart system architecture design in the field of precision agriculture based on IoT in Bangladesh, *ICIC Express Letters*, vol.16, no.10, pp.1111-1118, https://doi.org/10.24507/icicel.16.10.1111, 2022.
[11] A. B. U. B. Ibrahim, Automated temperature and humidity control system for strawberry plantation using solar panel, *Proc. of the 36th the IIER International Conference*, Bali, Indonesia, pp.14-19, 2015.
[12] J. Doshi, T. Patel and S. K. Bharti, Smart farming using IoT, a solution for optimally monitoring farming conditions, *Procedia Computer Science*, vol.160, pp.746-751, 2019.
[13] F. Y. Abdullah, M. T. Yaseen and Y. S. Sheet, Smart eco-friendly and low-cost farming control system, *2023 5th International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA)*, Istanbul, Turkey, pp.1-5, DOI: 10.1109/HORA58378.2023.10156672, 2023.