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Cultivation investigation of Brazilian Spinach through Indoor Hydroponic System

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Abstract

Agriculture is a vital sector for a nation's livelihood. However, in the near future, the agricultural sector faces various challenges, particularly related to environmental and cultural issues. In this era of digital transformation, technology plays a crucial role in the agricultural field. Research is conducted to control the quality of nutrition and water intake for hydroponic plants to ensure their healthy and high-quality growth. The controlled parameters for nutrition include pH and nutrient solution availability, while water intake involves temperature, acidity (pH), electrical conductivity, and nutrient dosage. These parameters are detected by pH sensors, temperature sensors, EC (electric conductivity) sensors, and controlled by microcontrollers. The sensor detection results control the pump operation, ensuring a continuous and quality water intake rate. The growth of Brazilian spinach plants under study is observed with water pH controlled at 6.5 – 7 and nutrient electrical conductivity at 2 – 2.1 ms/cm. Test results demonstrate that the growth of plants in the research growth medium and the comparison growth medium significantly improves, even though the growth is not uniform across all plants. Plants in the research growth medium exhibit significantly better growth compared to those in the comparison growth medium.

Keywords: temperature, pH, electrical conductivity, sensor, microcontroller

1 Introduction

The advancement of the Fourth Industrial Revolution is propelled by fields such as Artificial Intelligence, Robotics, Internet of Things, Autonomous Vehicles, Biotechnology, Nanotechnology, 3-D Printing, Material Science, Quantum Computing, and Energy Storage [1]. One of the government's efforts to face the agricultural challenges of the Fourth Revolution era is through the development of

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Volume 5, Issue 2, pages 345-354
p-ISSN 2655-8564, e-ISSN 2685-9432

online-based applications like Smart Farming, Smart Irrigation, and Smart Green House applications. The global demand for agricultural products is projected to increase by 55 percent by the year 2050. Precision agriculture is one way to meet this demand [2].

Recent data from 2018 regarding global organic farming continues to grow, reaching its peak in terms of organic farming land and retail sales. Over 71.5 million hectares or approximately 1.5% of the world's agricultural land is dedicated to organic farming, including conversion areas. Asia ranks fourth with around 6.5 million hectares or 9%. There has been an increase in organic farming land across all regions. In Asia, the area has grown by nearly 8.9 percent or an additional 0.54 million hectares. While organic food sales are growing at a healthy rate, the demand for organic food remains concentrated in North America and Europe. Even though the market share of these two regions is decreasing, they still constitute the largest portion of global sales. Conversely, strong local markets pose challenges for development in Asian countries [3].

Currently, farmers still face difficulties in manually monitoring and observing hydroponic plants, especially in controlling factors such as temperature, air humidity, and water quality for hydroponic plants [4]. Smart agriculture that involves sensor technology and wireless network integration through IoT (Internet of Things) technology presents a solution to these challenges and requires further exploration in the future [5].

One of the impacts of industrialization in Indonesia is the agricultural sector. Alongside global warming, the traditional agrarian way of life has shifted due to changing societal patterns. However, with the current trend of digital transformation, innovative opportunities are opening up for Indonesian society, particularly millennials, to embrace agrarian culture through digital agricultural technology.

A microcontroller-based system for precision greenhouse agriculture has been developed by Amshu Vinayak.T and Yasha Jyothi M Shirur [6] for measuring and controlling four crucial plant growth parameters: temperature, humidity, soil moisture, and nutrients such as nitrogen and pH. Carlos Lizardo Corzo Ruiz and Daniel Alexander Velazco Capacho [7] conducted research on a greenhouse drying system

Volume 5, Issue 2, pages 345-354
p-ISSN 2655-8564, e-ISSN 2685-9432

implemented with fuzzy logic control and a user interface accessible via mobile phones. The cocoa bean drying process aimed to achieve acceptable moisture levels for commercialization. The obtained results demonstrate the effectiveness of the application in achieving good grain quality with 8% moisture content over a six-day drying period.

Carlos Cambra et al. [8] conducted research using an automatically calibrated pH sensor connected to a wireless node to detect and adjust pH imbalances in the nutrient solution used in hydroponic farming. The sensor regularly measures the pH levels of each hydroponic support and sends information to a database that stores and analyzes the data to alert farmers to necessary actions.

Research using a Wireless Sensor Network (WSN) was carried out by Mohamed Saad Azizi and Moulay Lahcen Hasnaoui [9] to collect data on temperature, sound, vibration, pressure, movement, or pollutants from monitored areas, then send the data back to a base station. A system designed by Laxmi Goswami [10] remotely controls an agricultural water pump wirelessly using a microcontroller as the control system and a GSM module for communication needs. A 1.5 HP water pump was connected to the control system and operated regularly for 30 days, responding optimally each time a user sent operation instructions to the control unit.

Hydroponic plants are grown in a medium that uses nutrient-rich water. The growth of hydroponic plants thrives when the quality of water intake and nutrient proportions are appropriate. Currently, farmers still struggle to manually monitor the growth of hydroponic plants, especially in managing water intake requirements and the appropriate nutrient quality. Therefore, a hydroponic growth tool is needed to control the quality of water intake and nutrients.

The parameters for the quality of intake water in hydroponic plants include temperature, acidity level (pH), electrical conductivity, and nutrient dosage. Meanwhile, the parameters controlled for nutrition are pH and the availability level of the nutrient mixture. The quality of the AB mix nutrient solution is regulated by its acidity level, which is adjusted using pH-modifying fluid. Nutrient availability is controlled by employing a peristaltic pump. The quality of the intake water, which serves as the medium for hydroponic plant nourishment, is managed in terms of its

Volume 5, Issue 2, pages 345-354
p-ISSN 2655-8564, e-ISSN 2685-9432

acidity level, temperature, and electrical conductivity through the incorporation of nutrients. High-quality intake water contributes to the growth rate and continued life of hydroponic plants. The temperature of the hydroponic plant intake water is equally crucial to ensure that plants effectively absorb the intake water.

The purpose of this research is to develop a control system for the quality of nutrition and water intake in cultivating Brazilian spinach through hydroponic methods. Additionally, the study aims to observe the progress of hydroponic cultivation of Brazilian spinach with controlled nutrition and water quality. The results of cultivating Brazilian spinach using controlled nutrition and water quality will be compared with the cultivation of Brazilian spinach without such controls.

The parameters controlled for nutrition are pH and the level of nutrient mixture availability, while the quality parameters for the intake water in hydroponic plants include temperature, acidity level (pH), electrical conductivity, and nutrient dosage. The acidity level of the AB mix nutrient solution is controlled through pH adjustment using pH-lowering fluid, and nutrient availability is managed using a peristaltic pump. The intake water, which serves as the medium for hydroponic plant nourishment, is managed in terms of its acidity level, temperature, and electrical conductivity through the incorporation of nutrients. High-quality intake water contributes to the growth rate and continued life of hydroponic plants. An optimal acidity level for hydroponic plants, especially curly lettuce, is within the pH range of 6-7 [11]. The temperature of the hydroponic intake water is equally important to ensure that plants effectively absorb nutrients. The suitable temperature range for hydroponic plants, especially curly lettuce, is between 25-27°C [12].

2 Research Method

Research materials. The materials used in the research are nutrient A, nutrient B, water intake, and Brazilian spinach.

Stages of the research project. The stages of work in this research are: designing the prototype control system, assembling the prototype control system and hydroponic system, assembling the sensors used, running the prototype control system, planting

Volume 5, Issue 2, pages 345-354

p-ISSN 2655-8564, e-ISSN 2685-9432

hydroponic plants in the prototype hydroponic system and conventional soil (as a comparison), observing and analyzing the growth rate of hydroponic plants.c.

Control system for the quality of nutrient and water intake in hydroponic plants. In broad terms, the operation of the control system for the quality of nutrient and water intake in hydroponic plants used in the research can be explained from the research tool schematic (Figure 1) as follows:

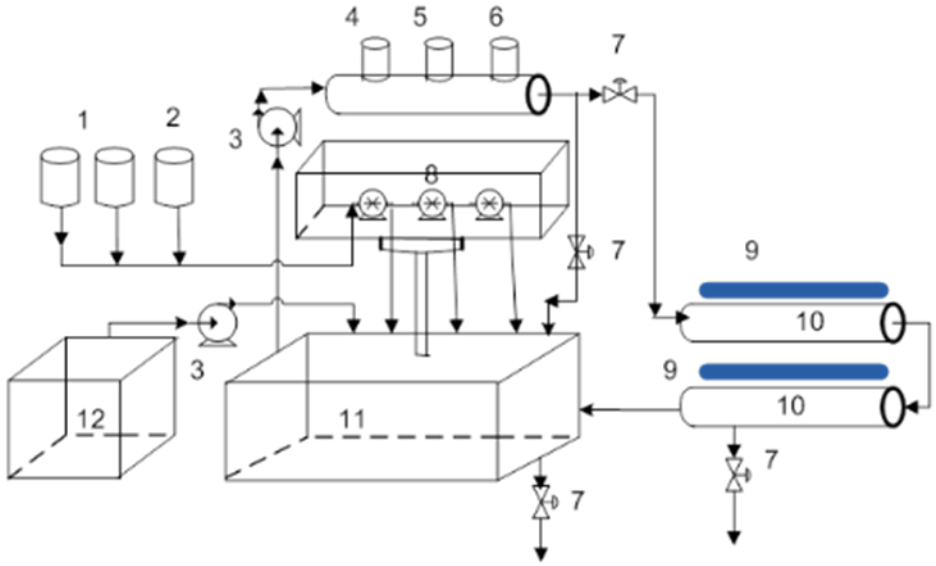


Figure 1. Scheme of the Control System for the Quality of Nutrition and Water Intake in Hydroponic Plants

Figure caption:

AB Mix Nutrient, 2. pH Lowering Fluid, 3. Hydroponic Centrifugal Pump, 4. DS18B20 Temperature Sensor, 5. Serial/I2C pH Sensor, 6. Serial/I2C EC (Electrical Conductivity) Sensor, 7. Valve, 8. Peristaltic Pump, 9. Grow Light, 10. Hydroponic Plant, 11. Water Intake Mixing Tank, 12. Water Tank.

The quality of AB Mix nutrient (1), which is directed to the nutrient container, is controlled for its acidity level (pH) by regulating the operation of the peristaltic pump (8). If the pH value of the intake water falls below the predetermined limit (usually 5.8 - 7.0 for vegetables), the peristaltic pump will activate, channeling pH-lowering fluid (2) into the nutrient container until the desired pH equilibrium is achieved. Additionally, the peristaltic pump for AB Mix nutrient operates according

Volume 5, Issue 2, pages 345-354
p-ISSN 2655-8564, e-ISSN 2685-9432

to the prescribed dosage, until the EC sensor (6) provides a reading within the specified range (1.2 – 1.8 ms/cm) [13]. The nutrient solution is then directed into the mixing tank (11) along with water from the water tank (12). The flow of water into the mixing tank is controlled by the centrifugal pump (3), which activates when the water level in the mixing tank falls below the predetermined threshold.

The intake water for hydroponic plants is monitored for its temperature using the DS18B20 sensor (4), acidity level (pH) using the serial/I2C pH sensor (5), and electrical conductivity using the serial/I2C EC sensor (6). Parameters such as intake water temperature, pH level, electrical conductivity (EC), availability of AB Mix nutrient, pH-lowering fluid, and the level of nutrient mixture in the mixing tank, all influence the operation of the centrifugal pump actuator, regulating the quality of intake water.

3 Results and Discussions

Research Control System. The components of the control system used in this research consist of Arduino Uno, DS18B20 temperature sensor, I2C serial pH sensor, serial/I2C electrical conductivity sensor, peristaltic pump, relay module, grow light, and exhaust fan. The schematic diagram of the research control circuit can be seen in Figure 2.

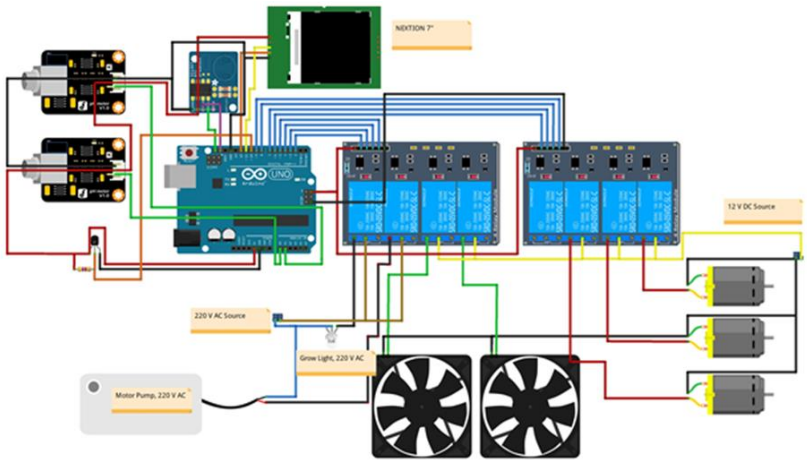


Figure 2. Schematic of the Research Control System

International Journal of Applied Sciences and Smart Technologies
Volume 5, Issue 2, pages 345-354
p-ISSN 2655-8564, e-ISSN 2685-9432

The research control system utilizes Arduino Uno to monitor the quality of water intake. Water quality is controlled by monitoring the pH level within the range of 6.5 – 7 using the I2C serial pH sensor and the electronic conductivity within the range of 2 – 2.1 ms/cm using the serial/I2C electrical conductivity sensor (EC). The water temperature within the range of 25 – 27 °C is monitored by the DS18B20 temperature sensor. The growth rate of Brazilian spinach is accelerated by turning on the Grow Light for 8 hours twice a day. Room temperature and humidity are controlled by activating the exhaust fan for 8 hours twice a day.

Observation of Brazilian Spinach Growth. This study involved ten Brazilian spinach (Alternanthera sissoo) plants, both in the research growth medium and the comparison growth medium. Water intake was controlled at pH 6.5 – 7, while nutrients A and B were controlled at EC 2 – 2.1 ms/cm. Data collection was performed twice a week over a seven-week period.

The plants exhibited significantly better growth in the research growth medium compared to the comparison growth medium, particularly in terms of width.

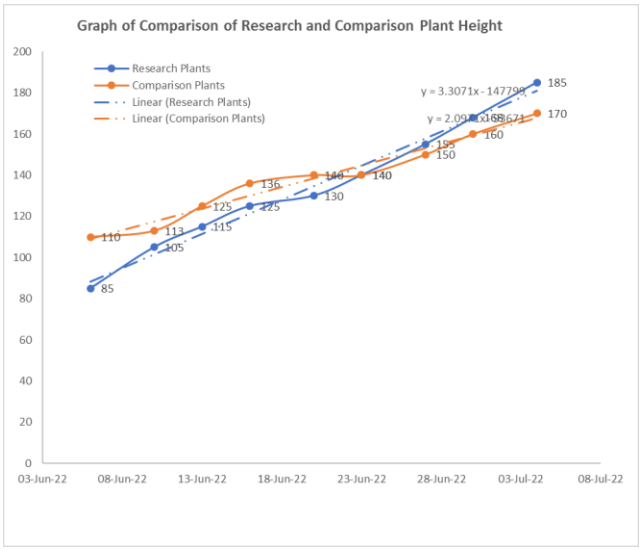


Figure 3. Height Comparison Graph between Research and Comparison Plants

Based on Figure 2, the height growth of plants in the research growth medium ranged from 85 mm to 185 mm, while in the comparison growth medium, it ranged from 110 mm to 170 mm. The graph indicates that plant height in the research growth

Volume 5, Issue 2, pages 345-354
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medium significantly caught up with that of the comparison growth medium after the fourth week.

Based on Figure 3, the width growth of plants in the research growth medium ranged from 130 mm to 210 mm, while in the comparison growth medium, it ranged from 108 mm to 150 mm. The graph shows that plant width in the research growth medium significantly outperformed that of the comparison growth medium.

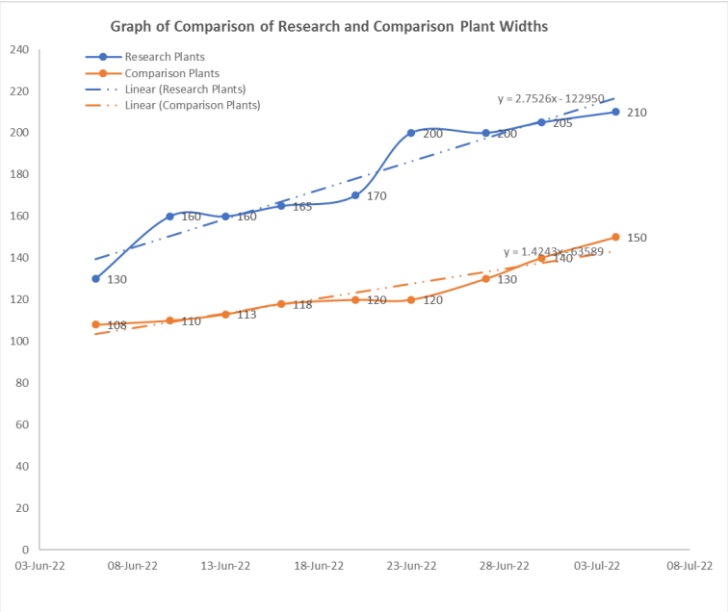


Figure 4. Width Comparison Graph between Research and Comparison Plants

4 Conclusions

In essence, the cultivation of Brazilian spinach through the control of nutrient and water intake quality in hydroponic systems is feasible and yields excellent results. Further research could explore other hydroponic plant varieties.

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Volume 5, Issue 2, pages 345-354

p-ISSN 2655-8564, e-ISSN 2685-9432

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Volume 5, Issue 2, pages 345-354

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