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Study and Fabrication of A Small-Scale Hydroponic System with IOT Monitoring

(Kajian dan Pembuatan Sistem Hidroponik Skala Kecil dengan Pemantauan IOT)

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Abstract

This project presents the study and fabrication of a small-scale hydroponic system enhanced with Internet of Things (IoT) monitoring. Recognizing the critical role of agriculture in the developing of nations, this system addresses global challenges such as increasing food demand and the need for sustainable farming methods. Hydroponics, defined as growing plants in nutrient-rich water without soil, offers an innovative solution. This project utilizes a flood and drain hydroponic design, implemented using an ESP8266-based board as the main controller. The system communicates with various sensors, including pH, Total Dissolved Solids (TDS), and temperature sensors, and displays data on an LCD screen. An app called Blynk is employed for remote monitoring via smartphones. A Bell siphon device is also incorporated to regulate water flow within the system. In this IOT application, the Arduino collects data from sensors to send to the Internet and receives commands to control motors and actuators. The data collected from sensors is analyzed to evaluate system performance and efficiency. The pH and temperature of the water are maintained within the ranges of 6 to 7 and 25°C to 30°C, respectively, with nutrient levels between 1000 ppm 1400 ppm. The water flow rate to the grow bed is approximately 0.0295 litres per second. This hydroponic system conserves water and fertilizers while enhancing crop yields, demonstrating a promising approach to sustainable agriculture.

Keywords: Hydroponic IOT, water conduction, automation, growth, nutrients

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INTRODUCTION

Hydroponics is a method of cultivating plants without soil, relying on water enriched with essential nutrients. This approach offers several advantages over traditional soil-based farming, such as conserving water, maximizing space efficiency, reducing pesticide use, and enhancing both crop quality and yield. However, hydroponic systems demand precise monitoring and regulation of environmental factors like temperature, humidity, light, pH levels, and electrical conductivity (EC), all of which significantly affect plant growth and health. For optimal performance, these systems need to be automated and integrated with the Internet of Things (IoT), allowing a network of physical devices to communicate and share data via the Internet.

At Jantayu Strawberry Farm, Kuching, owned by Mr. Muhd Hossein, the current manual water conduction system is labour-intensive and time-consuming. Essential tasks such as fertilising, planting, and watering are performed manually, requiring significant physical effort to operate the water system and manage plant care. This manual approach leads to inefficiencies, including unsynchronised plant growth and wasted time and resources. Financial constraints further complicate the situation, as the high cost of automation machinery is prohibitive. Additionally, the inability to accurately monitor nutrient levels results in inadequate plant nutrition, adversely affecting crop fertility and yield. Without system to control parameters such as pH, fertiliser and temperature, plants can’t grow satisfactorily.

Recently, there are many studies have been focused on hydroponic. The application of Internet of Things (IoT) in automating hydroponic systems has gained significant attention in recent years, as highlighted in several studies. These studies collectively emphasize the role of IOTin improving agricultural productivity, reducing manual labor, and optimizing resource management. Lakshmanan et al. (2020) developed a fully automated smart hydroponic system using IoT, focusing on monitoring critical environmental factors such as water pH, temperature, and humidity through cloud services. Their system, controlled via MQTT protocol, allows users to make remote adjustments through a mobile app, offering a solution for increasing food demand while conserving resources. This is aligned with Deokar et al. (2021), who also describe an IoT-based hydroponic system, utilizing Deep Water Culture (DWC) to grow plants without soil. Their system integrates sensors for monitoring parameters like light, pH, and electrical conductivity, and uses Google Firebase for real-time database management. This system is particularly applicable in urban settings, where space and resources are limited, providing an effective means to optimize plant growth.

Patil et al. (2020) proposes a more practical approach, implementing IOT technology to monitor pH levels, temperature, and humidity in hydroponics using NodeMCU and cloud computing. Their system enables water and nutrient management based on sensor feedback, with the aim of reducing water usage while increasing productivity. The study underscores the potential of automating agriculture to alleviate labor-intensive tasks and improve resource efficiency. Similarly, Sudharsan et al. (2019) presents an automated hydroponic system that controls environmental factors such as light intensity and water temperature. This system highlights the use of sensors and actuators to ensure optimal crop conditions, reducing the need for human intervention and making it suitable for urban agriculture.

Further expanding on IOT applications, Fajri et al. (2022) emphasize web-based control of hydroponic systems, allowing users to remotely monitor and manage nutrient levels and water pumps. This system is particularly valuable for modern farmers with limited access to arable land, offering a user-friendly solution for small-scale farming. Tembe et al. (2018) provide a detailed technical analysis of IOT implementation in hydroponics, outlining the use of Arduino and sensors to control key variables such as pH and humidity. Their approach offers a cost-effective solution for small-scale farmers by reducing manual labor and improving crop yield.

In conclusion, these studies illustrate the growing importance of IOTin automating hydroponic systems. By leveraging smart technologies, farmers can enhance crop production efficiency, reduce resource wastage, and minimize manual intervention, contributing to more sustainable agricultural practices. The objectives of this project are to study, design and implement a hydroponic system integrated with IOT for real-time monitoring and control of key parameters such as pH levels, nutrient concentrations (using TDS sensors), and temperature. The project also aims to study the IOT system, collect and analyse data, and design and implement a bell siphon device to regulate water flow. The system aims to save water, reduce pesticide use, improve crop quality, and enhance environmental sustainability by automating the monitoring and control processes using IOT technology. This research systematically solves the outlined challenges, contributing to more efficient and sustainable agricultural practices.

METHODOLOGY

Figure 1 shows the Flow chart of the Hydroponic System with IOT Monitoring Control. This includes discussion with the group, material selection, task division, project assembly, pretest equipment and programming for monitoring, automation and evaluation of the system. Several studies about hydroponics systems and sensor applications related to controlling temperature, pH, fertilizer, water flow, and water level have contributed to providing necessary theories and concepts for constructing the core idea of this study. This study needs to gather data through the collection of the components in research which includes scientific methods necessary for obtaining information from certain experiments. This process will provide interpretation and analysis of the data obtained. Through this process, necessary adjustments can be identified to provide necessary requirements of plants.

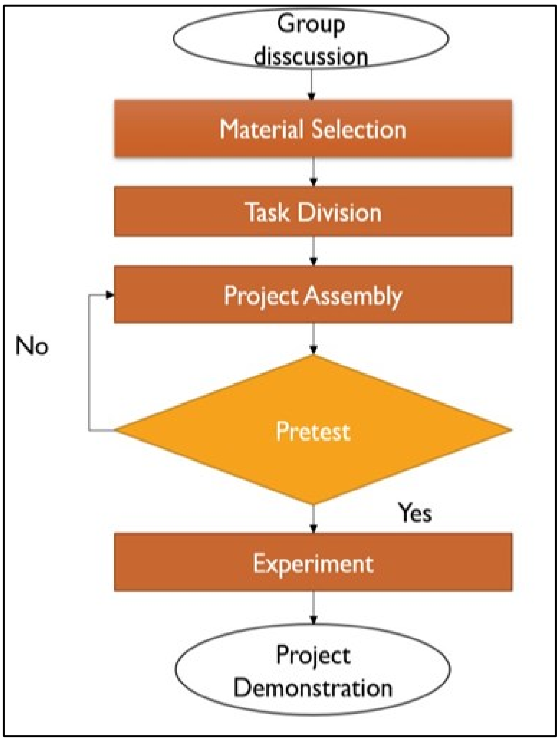

Figure 1. Flow chart of hydroponic system with IOTMonitoring Control

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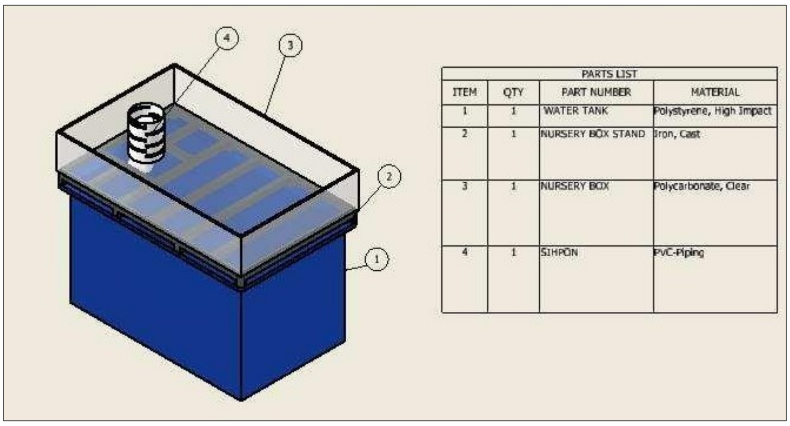

Figure 2. Final design using Autodesk Inventor

The hydroponic system was designed before fabrication, using Autodesk InventorProfessional Software. Subsequently, the fabrication consists of the tank, nursery stand, and fiberglass mold to make the grow bed. First, steel is welded to the base of the fiberglass tank, in (Figure 3).

Figure 3. The base is welded

Figure 4. The mold is covered using fiberglass

Figure 5. Spread resin on the fiberglass

The mould grow beds were initially painted to ensure a smooth surface and prevent fiberglass sticking. Figures 4 and 5 illustrate the painting and preparation process, providing a clean and well-prepared mould surface. The prepared mould was covered with layers of fibreglass sheets.

Fibreglass was chosen for its strength and durability, making it ideal for forming the channels or beds for the hydroponic system. Resins were then spread over the fibreglass to bond the layers and create a solid, waterproof structure. Figures 4 and 5 show the detailed process of applying fibreglass and resins, ensuring a robust and long-lasting mould. The nursery stand was constructed using an aluminum profile, providing a sturdy and corrosion-resistant structure to support the growing beds. The aluminium profiles were cut and assembled to form the frame of the nursery stand. This structure provides a stable platform for the grow beds, ensuring they are securely placed. Figure 6 shows the assembled nursery stand, highlighting the use of aluminium profiles for durability and stability.

Figure 6. The nursery stand & tank

The siphons are used to drain water from the grow beds, ensuring proper water levels and preventing water logging. Siphon helps maintain the nutrient solution's circulation, which is crucial for the health and growth of plants. The system was tested with each siphon to measure and compare the flow rates. The analysis aimed to determine which siphon diameter provided the best flow rate for maintaining optimal water levels in the grow beds. Factors such as drainage speed, consistency of flow, and the ability to prevent waterlogging were considered in the analysis. Based on the flow rate analysis, the siphon with the most effective performance was identified. It is shown in Figure 7.

Figure 7. Three types of siphons with different sizes

To enhance the functionality and efficiency of the hydroponic system, an IoT-based monitoring system using the Arduino ESP8266 microcontroller was integrated. This system enables real-time monitoring and control of various parameters, ensuring optimal conditions for plant growth. Sensors were placed strategically in the system to provide accurate water temperature, pH levels, and nutrient concentration readings. Figure 8 illustrates the sensors used in the IOT monitoring system.

Figure 8. Sensors in IOTsystem

The Arduino ESP8266 was programmed with the appropriate code to read data from the sensors and transmit it wirelessly. The coding involved setting up the microcontroller to interface with the sensors and process the data. Figures 9 and 10 show the process of coding the system and connecting it to the display for real-time monitoring.

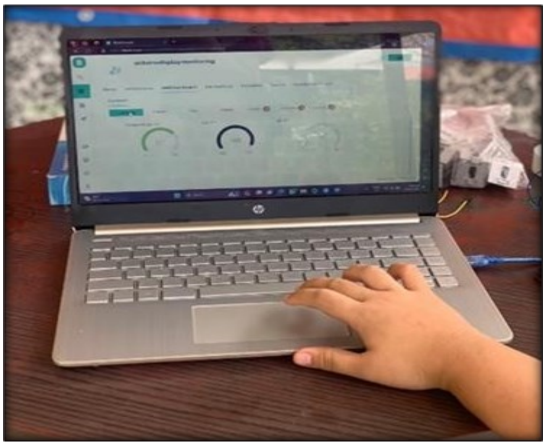

Figure 9. Coding in Arduino and Blynk

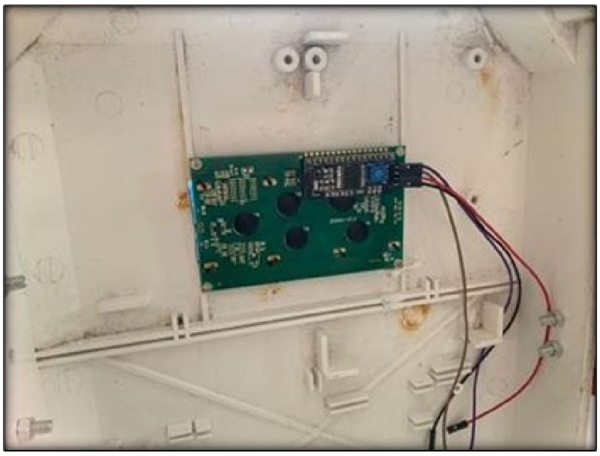

Figure 10. Connect to the display

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RESULTS

Figure 11 shows the operation of flood and drain hydroponics. Type of This hydroponics system utilizes a water pump to periodically flood plant roots with nutrient-rich water, and then drain the water away. This process is repeated multiple times throughout the day, depending on the specific needs of the plants being grown. This system is made up of several components, including a water reservoir, a submersible pump, a timer, and a grow tray (grow bed). This system usually controls and monitors with IOT system. The grow bed tray is typically filled with a growing medium such as clay pebbles or rocks, and plant roots are placed into the medium. When the water is pumped into the grow bed tray, the growing medium and plant roots become saturated, providing plants with the nutrients they need to grow. Then, once the water has reached a certain level in the grow bed tray, the bell siphon activates, allowing the water to drain back into the reservoir. This process is repeated multiple times throughout the day, providing plants with a consistent water supply, oxygen, and nutrients.

This hydroponic system is also designed for simplicity and efficiency, offering time-saving features and remote-control capability via various devices such as smartphones, laptops, and more. It provides valuable insights into plant and water conditions, including temperature, nutrient levels, and pH, and is facilitated by the "Blynk" application for data retrieval. **For** Initial Setup, download the "Blynk" application to access real-time data from the hydroponic system. Ensure the system components are properly assembled and connected. **For the** startup procedure, activate the main switch to power the system. Observe the water flow inside the tank to verify operational status. Use the water control mechanism (as shown in Figure 11) to regulate flow rate—increasing or decreasing water flow as needed. Direct the water flow from the control mechanism into the hose within the grow bed structure. Monitor the distribution of water to ensure proper coverage of the growing medium. Utilize the siphon mechanism to facilitate water drainage from the grown bed structure back into the tank. This process ensures continuous nutrient circulation and prevents water stagnation. The system operates in a cycle where water is continually circulated through the growing bed structure and tank. Monitor the system via the Blynk application to track parameters such as water temperature, nutrient levels, and pH throughout the operation.

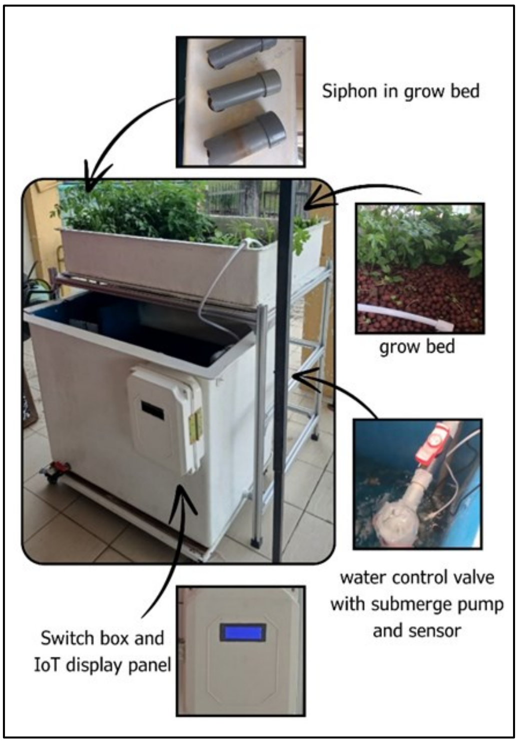

Figure 11: Operation of the project

To Shut down this system, turn off the main switch to conclude the operational cycle. Ensure all components are properly shut down and secured. By following these steps, users can effectively manage and monitor their hydroponic system, ensuring optimal conditions for plant growth while leveraging remote monitoring capabilities provided by the IoT-enabled setup with the Blynk application.

DATA COLLECTION

Data collection is a reading taken on each sensor. This data was taken within three weeks,equivalent to 21 days. This data is also taken at various times of the day, in the morning, noon, and even afternoon. There are different readings of the data on the sensors that are taken in various times. As a result of different conditions and times, the readings on each sensor are also different. This is influenced by weather and environmental conditions. Figure 12 indicates data taken on each sensor in 21 days.

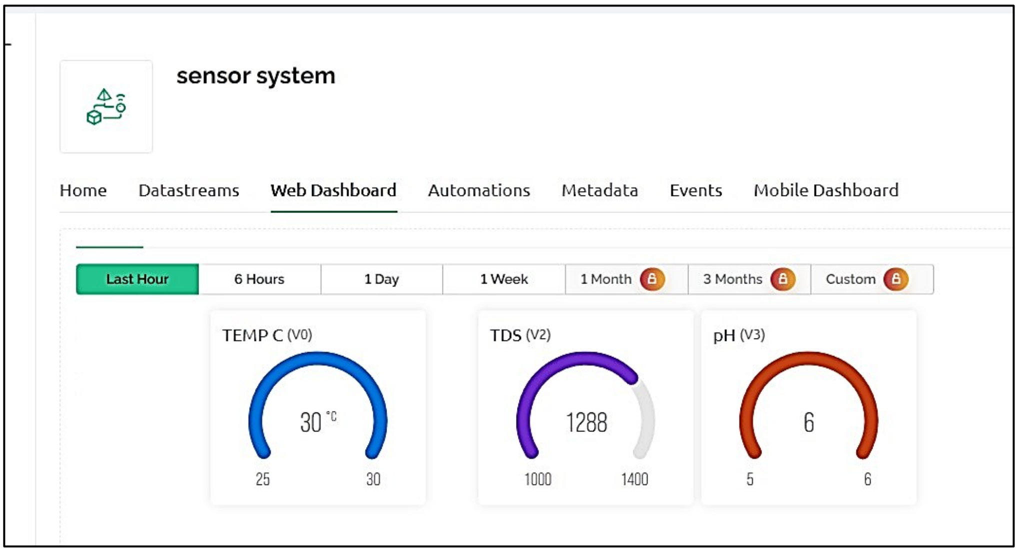

Figure 12. Sensor data

Figures 13 to 15 display sensor data collected via Blynk. This data was gathered every morning, afternoon, and evening over three weeks, enabling the creation of a comprehensive table comparing sensor readings. The optimal range for nutrient levels is typically set between 1000 to 1400 ppm, suitable for various vegetables. Figure 14 indicates that water temperature ranges from 20°C to 30°C, nutrient levels range from 1000 to 1500 ppm, and pH levels range from 6 to 7, demonstrating that all values are within normal conditions.

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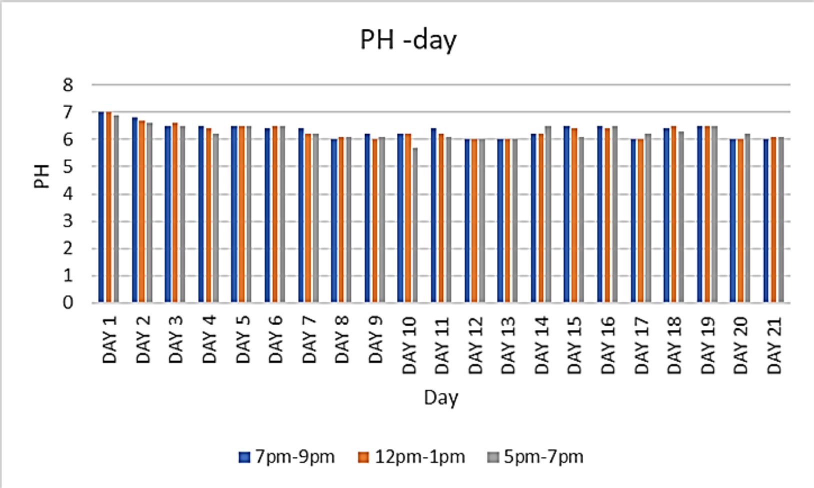

Figure 13: Bar chart showing the data collection on the pH sensor

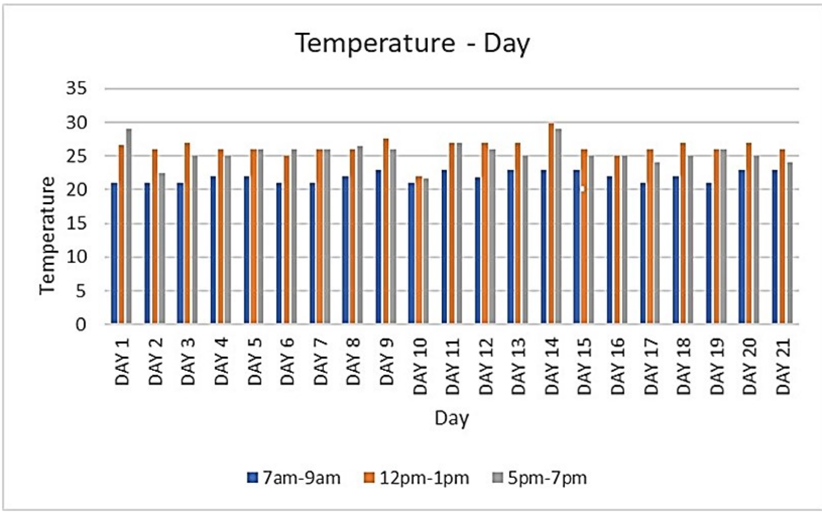

Figure 14: Bar chart showing the data collection on the temperature sensor

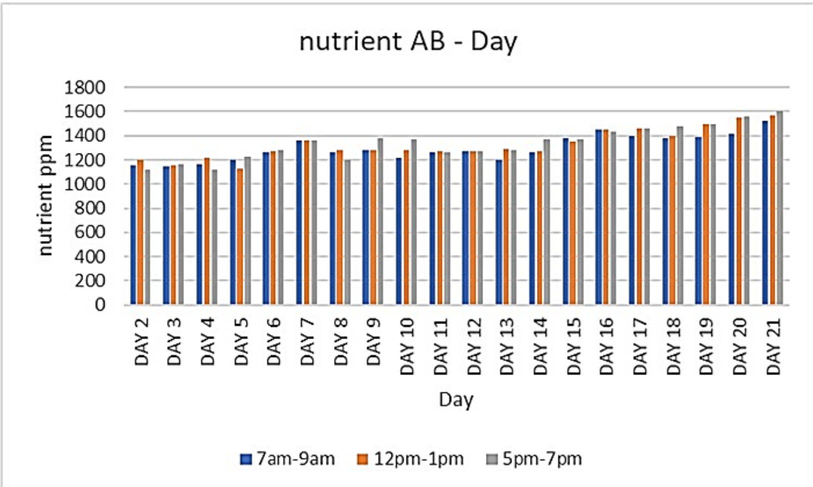

Figure 15. Bar chart showing the data collection on the TDS sensor

The pH values were recorded three times daily and plotted on a chart, showing stability within the range of 5.5-6.5, ideal for plant growth. Temperature readings were also taken three times daily, revealing higher temperatures during midday, ranging from 26°C to

30°C. TDS values were recorded three times daily, indicating increased nutrients due to water evaporation.

From this data collection, we can infer that water temperature, pH levels, and nutrient concentrations are within normal ranges suitable for hydroponic systems. These insights can guide decisions on optimal placement for hydroponic setups to maintain water temperature levels effectively.

Table 1. Shows the data collection for siphon.

siphon	Siphon 1	Siphon 2	Siphon 3
Diameter	50mm	40mm	32mm
Pump flow rate	0.0295l/s	0.0295l/s	0.0295l/s
Siphon flow rate	0.1455l/s	0.045l/s	0.0115l/s
Time for session	8:54:29	6:00:53	2:53:35

The bell siphon is employed in hydroponic systems to establish a flood and drain cycle, which enhances the oxygenation and aeration of plant roots. The bell siphon comprises three primary components: the standpipe, the bell, and the outlet. The standpipe, a vertical pipe, regulates the water level in the container. The bell, a larger pipe encasing the standpipe, generates a vacuum as the water rises. The outlet, a horizontal pipe, connects the bell to the drain. The operation of the bell siphon is based on the principles of gravity and air pressure. When the water level reaches the top of the standpipe, water flows into the bell and the outlet, initiating a siphon effect that rapidly drains the water. Once the water level falls below the bottom of the standpipe, air enters the bell and the outlet, disrupting the siphoning effect and halting the water flow. Table 1 presents data collected from siphons of varying diameters, demonstrating that an increase in the size of the siphon correlates with an accelerated rate of water flow to the plants.

CONCLUSION

In conclusion, this project successfully achieved its primary objectives of designing, fabricating, and implementing a small-scale hydroponic system enhanced with IOT monitoring capabilities. The system effectively monitored key parameters such as pH levels, nutrient concentration (TDS), and temperature using various sensors, ensuring optimal plant growth conditions. The integration of IOT technologies facilitated real-time data collection, remote monitoring, and control, which not only streamlined the management of the hydroponic system but also demonstrated the potential for scalable and sustainable agricultural practices.

The study of the IOT system highlighted the importance of interconnected devices in modern agriculture, providing insights into the capabilities and benefits of automated environmental monitoring. The use of components such as sensors, actuators, communication modules, and cloud platforms underscored the versatility and efficiency of IOTin enhancing agricultural productivity.

Furthermore, the bell siphon mechanism investigation provided valuable data on its effectiveness in regulating water flow within the hydroponic system. The findings indicated that the larger the siphon diameter, the faster the flow rate, thus optimizing the flood and drain cycle crucial for oxygenating plant roots.

Overall, this project not only advanced the practical application of hydroponic farming but also contributed to the broader understanding of IOT systems in agriculture. Future work could explore further optimization of the system, scalability to larger operations, and integration with additional IOT technologies to enhance precision farming techniques. The successful implementation of this project signifies a promising step towards sustainable and efficient agricultural practices, addressing the growing global demand for food production.

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