HydroMAC: Development of Automated Indoor Hydroponics System with Remote Monitoring via a Mobile Application

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***Abstract*— Indoor hydroponics systems offer a promising solution to urban agriculture challenges such as limited space, soil quality, and seasonal variations. This study presents the design and implementation of an indoor hydroponics system optimized for spinach, bok choy, and romaine lettuce cultivation. The system incorporates parameter sensors, a corrective system, and a mobile application for real-time monitoring and control. Statistical analysis reveals no significant differences in average leaf length and number of leaves between hydroponically grown and soil-based crops over a three-week period. The hydroponics system offers advantages such as controlled environmental conditions, efficient resource utilization, and reduced water consumption. The constructed indoor hydroponics chamber provides an ideal environment for indoor farming, ensuring sufficient illumination, ventilation, and nutrient supply. The system allows for precise control of pH levels, total dissolved solids (TDS), and water temperature, optimizing nutrient delivery and uptake. Hydroponics offers a sustainable alternative to conventional agriculture by reducing reliance on arable land and mitigating climate change impacts. The research contributes to the understanding and advancement of indoor hydroponics systems for efficient and sustainable crop cultivation. This study highlights the potential of indoor hydroponics systems in providing controlled conditions for plant growth and presents insights into their advantages over traditional soil-based farming techniques.**

Keywords— ***Hydroponic, crop status, indoor monitoring, automate, Arduino Mega, Internet of Things***

I. INTRODUCTION

As the world's population rises and cities expand, food security is constantly affected. More mouths to feed mean more people to provide, and as agricultural lands are converted to suit urbanization, many people are now hungry and malnourished. By agglomeration, cities expand geographically into rural areas, swallowing rural communities, upending their actual means of living, and driving them to send their children to seek work in the city. In the current situation, soilless farming could be beneficial. It began successfully and is regarded as a different way to raise nutritious food plants, veggies, or crops [1]. Hydroponics is a method of farming where plants can be grown in nutrientfortified water instead of in soil [2]. Hydroponics and other forms of dynamically controlled environment agriculture, in combination with emerging agriculture technology interventions, provide practitioners and scientists with a wealth of opportunities to ask new questions and devise novel solutions that maximize food production while minimizing economic costs and environmental externalities [3]. Through the Internet of Things, the person can control and manipulate the devices remotely. People can use the Internet of Things (IoT) to live and work smarter and achieve complete control over their life [4].

II. RELATED STUDIES

Hydroponics is a form of horticulture and a subset of hydroculture that involves using water-based mineral fertilizer solutions in aqueous solvents to grow plants, mainly crops, without soil. Plants on land or in water can grow with their roots exposed to the nutrient liquid or with their roots physically supported by an inert medium like perlite, gravel, or other substrates. It is a method of growing plants in nutrient solutions (water with fertilizers) with or without the use of a mechanical support medium such as sand, gravel, vermiculite, rockwool, perlite, peatmoss, coir, or sawdust. There is no extra supporting media for the plant roots in liquid hydroponic systems; aggregate systems feature a solid medium [5].

Plant nutrients in hydroponics are generally inorganic and ionic forms, dissolved in water. These nutrients alter the pH level of the irrigation. Maintaining the proper pH values is vital in the optimal growth of crops. Table 1 shows the optimal range and pH values for several hydroponic crops [6].

In hydroponics, it is vital to keep track of and monitor TDS levels carefully. A good TDS level in hydroponics not only promotes plant growth, but it also reduces the likelihood of plants suffering from too little or too many nutrients. TDS levels also assist you maintain an appropriate concentration of salt in your water, which influences your plants' capacity to absorb enough water, air, and nutrients [7].

In a hydroponics system, submerging the entire roots of crops can cause adverse effects to their health. Maintaining the right water temperature is vital for the optimal productivity of the crops. In a study done by Thakulla, et al [8], they found that lettuce grows best at a temperature of 21.1°C. Furthermore, Nxawe, et al [9] found that hydroponic spinach grows optimally at 28°C.

III. METHODOLOGY

A. Structural Design and Building of Indoor Hydroponics Chamber

An indoor hydroponics system was constructed and deployed in a barangay hall in Brgy. San Miguel Taguig City. The system was optimized for spinach, bok choy, and romaine lettuce.

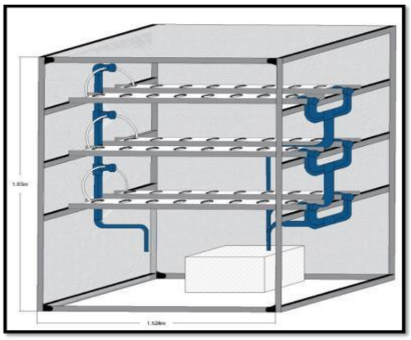

Fig. 1. Design of the System

The dimensions of the hydroponic system are 1.524 x 0.76 x 1.83 meters. The dimensions of the structure are designed to accommodate the distance between the plants and the camera. The researchers provide a 15-inch or 0.38 m space between each layer for plant growth and the camera.

B. Design of the schematic diagram for the Parameter Sensors and Corrective System

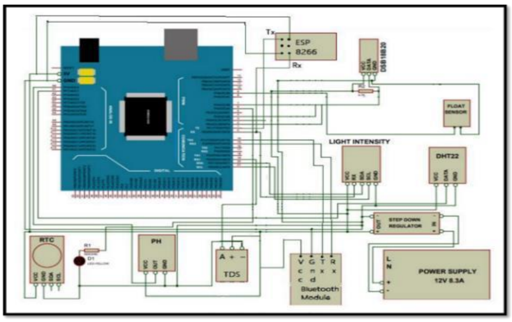

Fig. 2. Schematic Diagram

Fig. 2 depicts the connection of several parameter sensors, including light intensity, float, temperature, pH, and TDS sensors. On the connection were also the Real-Time Clock, which was responsible for the real-time transmission of data, a power supply, and a step-down regulator for the control of the supply voltage and the circuit.

C. Android Application

A mobile application was developed for the monitoring of the system using Thunkable.

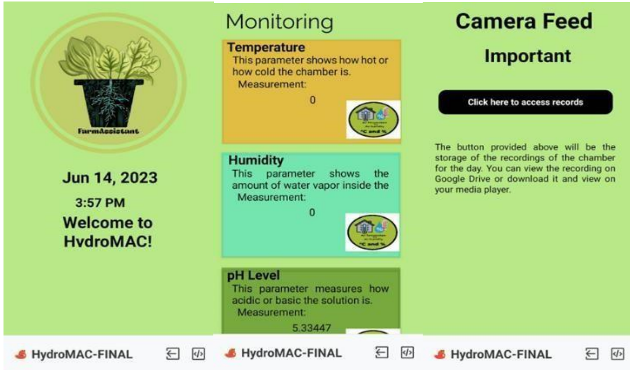

Fig. 3. User Interface of the Mobile Application

Fig. 3 shows the application interface of the project. This page visualized the data monitoring of specific critical parameters that needed to be maintained and the real-time data logs. The data received is stored on the database and displayed through the application. This mobile application shows as well as the Maintenance, Camera Feed Recorded Link, and other Necessary features needed for the system.

D. Database

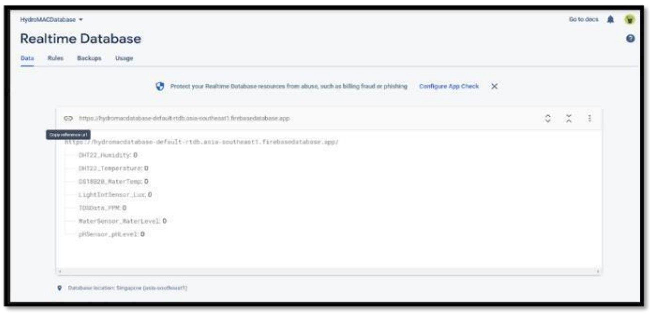

Fig. 4. Firebase Monitoring Database

Firebase is utilized in this study to facilitate real-time monitoring, data storage, and remote accessibility, enabling effective crop management, and providing a robust foundation for the automated indoor hydroponics system.

IV. RESULTS AND DISCUSSION

The project exhibits the capacity to correct the essential parameters crucial for the optimal growth of plants. Although the system is primarily designed to cater to spinach, bok choy, and lettuce, it can be adapted for plants with similar environmental requirements. However, the availability of image processing datasets specifically tailored to the crops is limited. Nonetheless, the image processing system can be supplemented with new datasets relevant to other plant species. The grow lights satisfy the necessary daily duration of illumination of plants through predetermined on and off timings. The project encountered is limited to comparing the growth of plants in the smart hydroponics system with those in conventional soil-based farming techniques.

The plants were germinated in damp tissue paper until they developed leaves and sufficient roots to sustain themselves. After a period of two weeks, the seedlings were deemed ready for transplantation into the growing bed. In traditional farming, the seeds were directly sown into the soil, while in the hydroponic system, the germinated seedlings were transplanted. In both setups, the average length of leaves and the number of leaves for each plant were manually measured on a weekly basis for three weeks following transplantation, allowing for continuous monitoring of plant growth. Statistical analysis was conducted using the F-test to compare variances and the unpaired T-test to determine significant differences in mean leaf length and number of leaves between different crops per week.

E. Comparison of Plant Leaf Length between Hydroponics System and Convential Soil-based Farming

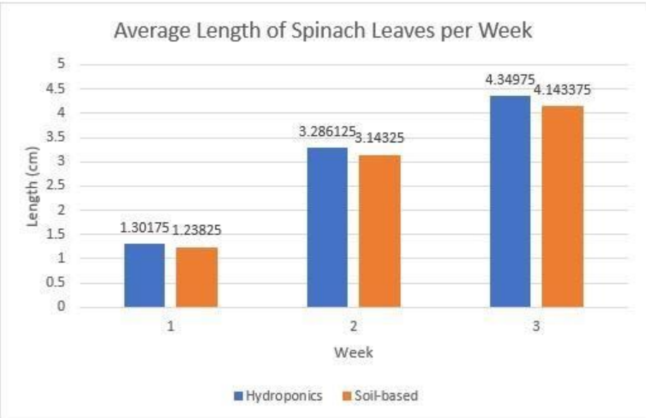

Fig. 5. Average Length of Spinach Leaves per Week between Hydroponics and Soil-based Farming Set-up

Fig. 5 presents a comparison of average spinach leaf length between hydroponically grown and soil-based spinach over a span of three weeks. T-tests were conducted to examine and compare the two farming methods for each week. The analysis generated P-values of 0.225, 0.161, and 0.142 for weeks 1 to 3, respectively. The findings indicate that there are no significant differences in average leaf length between the two farming methods throughout the three-week duration.

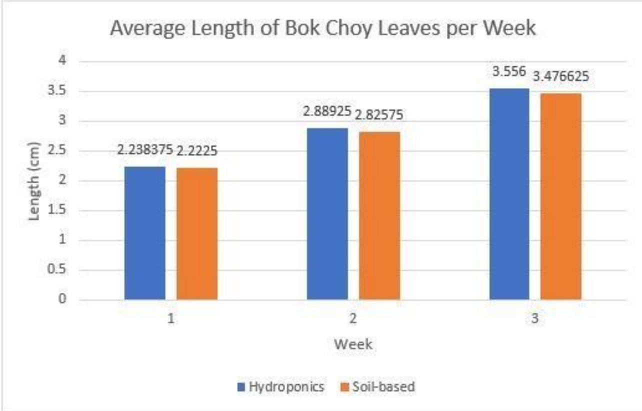

Fig. 6. Average Length of Bok Choy Leaves per Week between Hydroponics and Soil-based Farming Set-up

The results displayed in Fig. 6 demonstrate a comparison of average bok choy leaf length between hydroponically grown and soil-based cultivation over a period of three weeks. T-tests were utilized to assess and compare the two farming methods on a weekly basis. The statistical analysis yielded Pvalues of 0.469, 0.377, and 0.353 for weeks 1 to 3, respectively. These findings suggest that there are no significant differences in average leaf length between the two farming methods during the three-week timeframe.

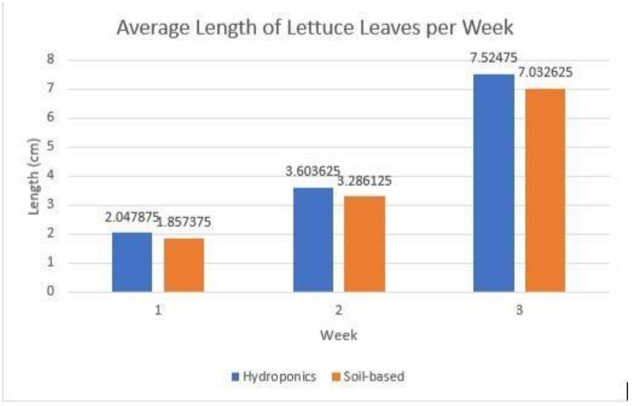

Fig. 7. Average Length of Lettuce Leaves per Week between Hydroponics and Soil-based Farming Set-up

Fig. 7 illustrates the comparison of average lettuce leaf length between hydroponically grown and soil-based cultivation over a span of three weeks. T-tests were employed to evaluate and compare the two farming methods on a weekly basis. The statistical analysis resulted in P-values of 0.063, 0.06, and 0.076 for weeks 1 to 3, respectively. These results indicate that there are no significant differences in average leaf length between the two farming methods throughout the three-week period.

F. Comparison of Number of Leaves of Plants between Hydroponics System and Conventional Soil-based Farming

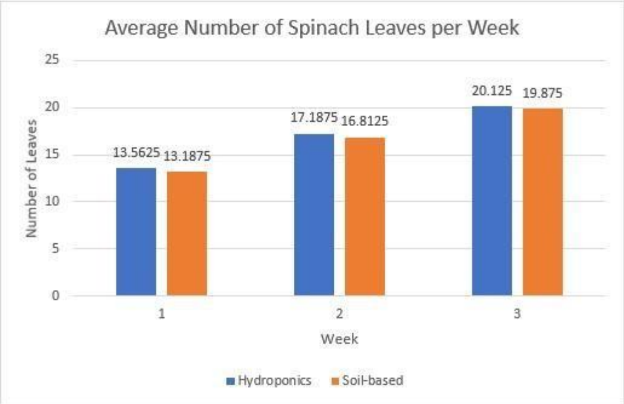

Fig. 8. Average Number of Spinach Leaves per Week between Hydroponics and Soil-based Farming Set-up

Fig. 8 depicts the average number of spinach leaves comparing hydroponically grown and soil-based cultivation over a three-week duration. T-tests were conducted, generating P-values of 0.315, 0.324, and 0.362 for weeks 1 to 3, respectively. These findings suggest that there are no significant differences in the average number of spinach leaves between the two farming methods throughout the three-week timeframe.

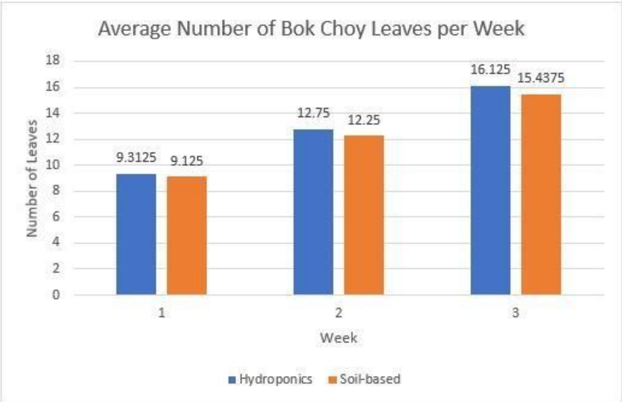

Fig. 9. Average Number of Bok Choy Leaves per Week between Hydroponics and Soil-based Farming Set-up

In Fig. 9, the average number of bok choy leaves is shown, comparing hydroponically grown and soil-based cultivation over a period of three weeks. T-tests were performed, resulting in P-values of 0.361, 0.120, and 0.177 for weeks 1 to 3, respectively. These results indicate that there are no significant differences in the average number of bok choy leaves between the two farming methods during the three-week duration.

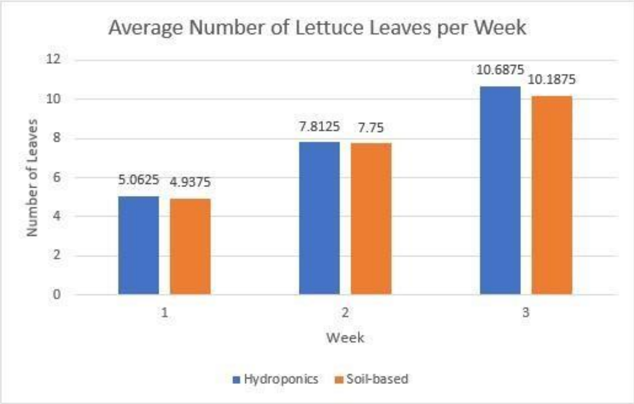

Fig. 10. Average Number of Lettuce Leaves per Week between Hydroponics and Soil-based Farming Set-up

Shown in Fig. 10 is the average number of lettuce leaves between hydroponically grown and soil-based cultivation over a span of three weeks. T-tests were conducted, yielding P-values of 0.363, 0.436, and 0.175 for weeks 1 to 3, respectively. These findings suggest that there are no significant differences in the average number of leaves between the two farming methods throughout the three-week timeframe.

V. CONCLUSION

The constructed Indoor Hydroponics Garden Chamber provides an optimal environment for indoor farming, providing controlled conditions that stimulate plant growth. The chamber's design assures sufficient illumination, ventilation, and nutrient supply, creating the ideal conditions for plant growth.

Hydroponics, as a soil-less cultivation method, offers significant advantages over conventional farming. The system harnesses these benefits by enabling precise control over environmental factors. Monitoring and adjusting pH levels, TDS, and water temperature ensures optimal nutrient delivery and uptake by plants. Controlled water levels, along with appropriate temperature and humidity, create an ideal growing environment.

The remote monitoring capabilities of the system enable growers to access real-time data and oversee their crops from anywhere. Continuous monitoring of pH, TDS, water level, water temperature, temperature and humidity, and light intensity enables informed decision-making based on the specific needs of the crops. It facilitates prompt action, ensuring crop health and minimizing the risks of nutrient deficiencies, water stress, and disease outbreaks.

Comparing conventional farming and hydroponics highlights the advantages of the latter, including efficient resource utilization, and reduced water consumption. However, this study found no significant difference in the plant leaf length and number of plant leaves between the two methods. Hydroponics offers a sustainable alternative to conventional agriculture by minimizing reliance on arable land and mitigating climate change impacts.

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