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Development of Smart Hydroponic System using Internet of Things

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Abstract: The introduction of IoT technology into hydroponics has resulted in considerable changes in traditional farming methods. By seamlessly integrating IoT capabilities, farmers may rigorously monitor and adjust critical environmental variables. The goal of this work is to build an intelligent hydroponic system that uses IoT to fine-tune temperature, humidity, water levels, and pH levels, assuring an optimal environment for plant growth. Sensors strategically placed throughout the hydroponic setup are used to actively monitor and manage these factors. This system includes several key features, such as automatic control of water pumps to maintain adequate hydration levels, fan activation when the temperature reaches 34°C, as signalled by the Blynk app, and real-time pH level monitoring via the same app to maintain proper acidity levels. Automation and control features are also evaluated to certify the precise responsiveness of sensors, pumps, and other components in accordance with set requirements. This evaluation aids in determining the system's effectiveness as well as the general health of the farmed plants. Finally, the combination of IoT technology and hydroponics emerges as a viable technique for improving plant growth circumstances. The resulting smart hydroponic system is not only a practical solution, but also an effective alternative to modern agricultural methods.

Keywords: Hydroponic System, IoT, Monitoring System

1. Introduction

Hydroponics is not a new technology, but it is not a new practice either. Accordingly, although hydroponics has been studied recently, its underlying principles have existed for a long time. It was once thought that the Hanging Gardens of Babylon, one of the Seven Wonders of the Ancient World, was believed to have implemented some of the hydroponic principles [1]. Furthermore, hydroponics is a farming method that uses water as a medium to meet the requirements of plant nutrition. In contrast to a soil-based cultivation method, hydroponic systems use water more efficiently. Water containing mineral nutrients needed by plants continuously flowed into the plants. This hydroponic technology requires

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minimal space and can be done vertically in a small location, such as a garden or seating area. Hydroponic growing media must meet the following criteria: water absorption, air circulation, and low cost [2].

2. Materials and Methods

In this section, the methodology is discussed in more detail about the process and hardware or software used to fulfil the objectives of the work including the block diagram, flowchart for the main system and the process of planting in the system [3]. The system runs as a semi-closed system. This implies that, while it actively monitors and controls many environmental conditions, certain operations require manual intervention. The process within this system is temperature control (ambient temperature), by using sensors, the system continuously monitors the ambient temperature and keeps it within a predetermined temperature range. If the ambient temperature rises over a certain threshold, such as 34°C, the system activates a cooling fan to bring it down. As for the pH level control, by using a pH sensor, the system continuously monitors the pH level of the nutrient solution and strives to keep it within the appropriate pH range of 6 to 7 for optimal plant growth. If the pH level exceeds this range, the system will respond by displaying the result in the Blynk application and the user will do the nutritional solution. Next, a water pump controls from the main tank directly to the hydroponic system to prevent overflow, a water level sensor is used to monitor the water level in the main tank. When the water level in the main tank reaches a certain threshold, the water pump, which transfers water from the main tank to the hydroponic system, should be manually shut off via the Blynk application. When the main tank is full, shutting the water pump in the Blynk application prevents overfilling and potential system damage. This user-initiated step offers an added degree of safety and control to guarantee that the pump does not run unnecessarily when the main tank is full, preventing water waste and potential system difficulties.

The block diagram in Figure 1 presents the overview of the proposed system. To meet all the requirements, the ESP32 is used. The temperature and humidity sensors monitor the environment, the water level sensor keeps the system running, and the pH level sensor determines the solution's pH. Furthermore, the fan is used to control the plant's humidity and temperature. Meanwhile, water pumps play a part in delivering water to the plant. If the pH value is too alkaline or acidic, the user will manually modify it by increasing or decreasing the nutrient value in the water. The pH level should be suitable for the plant to be unaffected. When the pH has been set, the water pump will give water to the plant based on the water level that has been set. The output data is interfaced with Wi-Fi so that the data can be stored on Blynk and monitored remotely and conveniently.

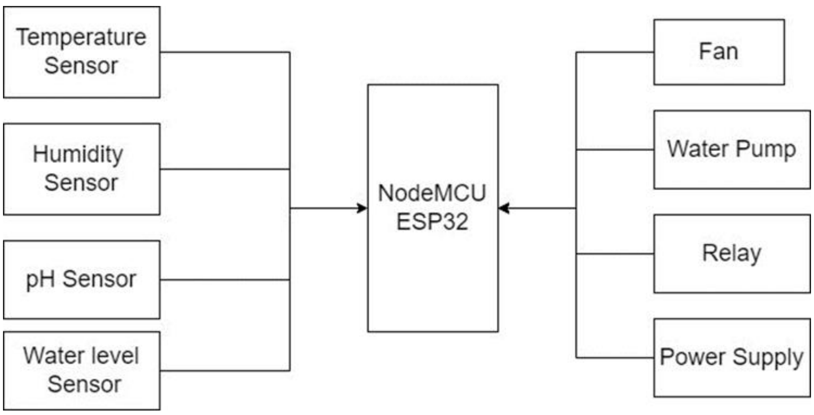


Figure 1: Block diagram of the proposed system

Figure 2 shows the system's general flowchart based on the monitored and controlled parameters. Initially, it displayed the progression of humidity levels. When the hydroponic system's humidity level exceeded 40%, the fan was turned off. In contrast, if the relative humidity fell below 40%, the fan was automatically activated to maintain the optimal level of moisture for the plants. Following the completion of the humidity control procedure, the system began monitoring and controlling the temperature parameter. If the temperature exceeded 34°C, the fan would automatically activate. The fan was deactivated once the temperature reached normal levels. Next, it shows the flow of pH value monitoring, which was configured based on the needs of the selected crop. The pH range specified was between 6.0 and 7.0. If the pH level became excessively acidic or alkaline, the application Blynk displayed the results. Lastly, the flow of water level monitoring and control was presented, with the water level determined based on the container's height in centimetres. The normal water level was 30 cm, while the low water level was 10 cm. If the water level exceeded 30 cm, the water pump stopped operating and the LED turned blue, reflecting the status on the Blynk application and allowing the user to deactivate the pump. If the water level fell below 10 cm, the LED on the hydroponic system turned red, and this status was displayed on the Blynk application, allowing the user to manually activate the pump through Blynk.

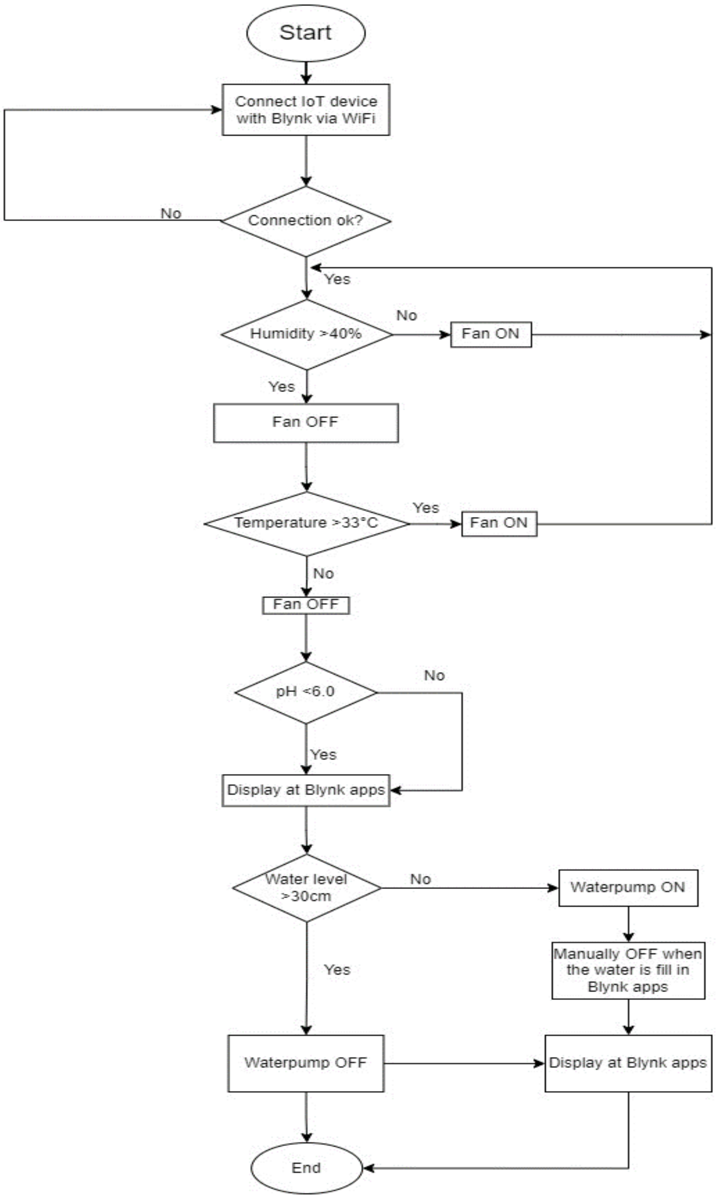


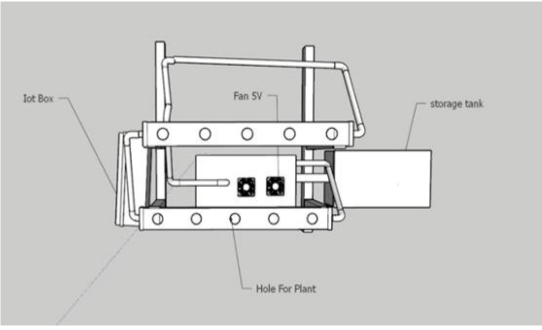
Figure 2: General flowchart of the system

2.1 Process of planting

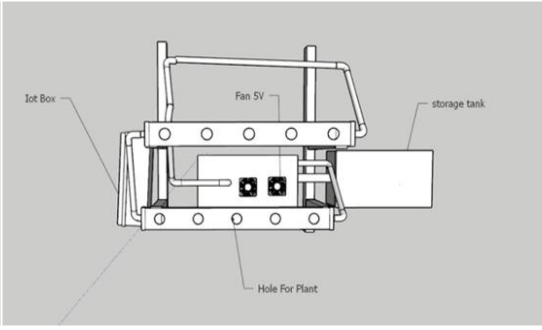
The process started with the seed selection. Once the seed is selected which is Pak choy, the user needs to set the seedling tray with a proper drainage hole so that the root can grow. The user needs to fill it with the chosen growing medium. Next, replace the seeds in the seedling trays by ensuring the pH, and moisture level is within the recommended range. Monitor the seed in seedling trays for 2 weeks maximum and once the seedling has developed a strong root system and leaves, move the plants to the hydroponic system.

3. Results and Discussion

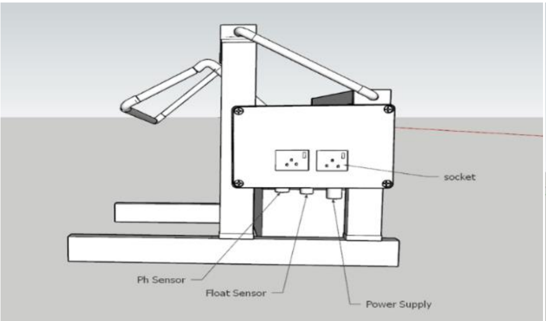
After all the sensors are completely installed in the prototype of the hydroponic system, the plant development, result and data analysis that have been collected are presented here. Figure 3 shows multiple angles of the 3D model. Each figure shows the model from a different perspective, providing a complete comprehension of its design and structure.



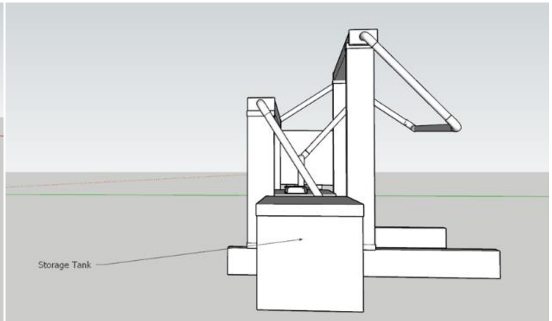
(a) Top view



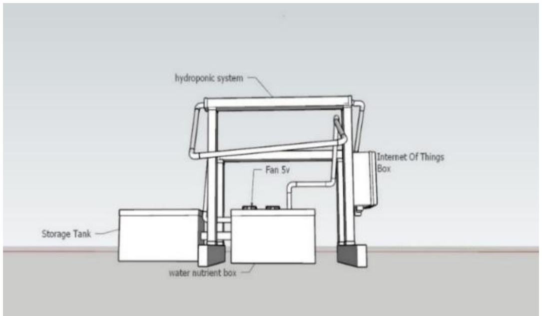
(b) Front side



(c) Left side



(d) Right side

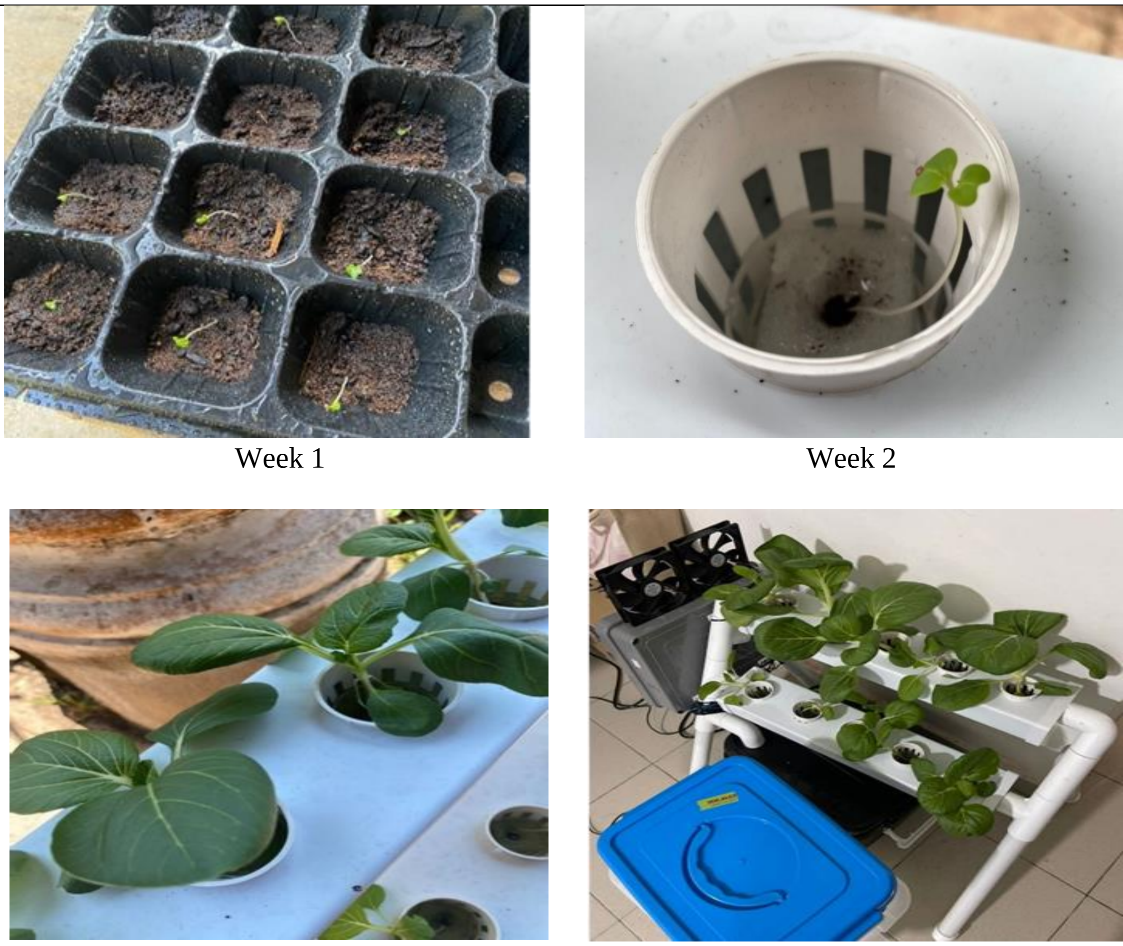


(e)Rear side

Figure 3: 3D model

3.1 Weekly development

Figure 4 shows the plant's weekly development in the hydroponic system, indicating its robust and healthy growth. This growing plant is a solid monument to the work's success, with harvest readiness marking a significant goal.



Week 1 Week 2

Week 3 Week 4

Figure 4: Plant's weekly development

3.2 Temperature level

Figure 5 shows that the fan will be automatically ON when the temperature has risen the percentage of the humidity has decreased and the fan is OFF indicating that the temperature and humidity is at normal level. All the information was displayed in the Blynk.

Figure 6 shows the real-time monitoring temperature data that were collected by days. The temperature depends on the heat from the sun it can rise up to 36°C and decrease to 24°C. This graph, it shows that the dark grey colour bar is when the temperature is in normal condition so the fan is OFF and the red colour bar is when the temperature rises and the fan is in ON condition.

3.3 Water level

Figure 7 shows the LED red is turned ON because the water level is in low condition. So, when the LED red is turned ON the water pump in a storage tank will transfer the water automatically to the main tank.

3.4 pH level

Figure 8 in the Blynk application displays a graph indicating the pH. The graph shows that the pH level remained in the neutral range, which is ideal for plant growth but decreased drastically from Tuesday to Thursday from a range of 6.52 to below than range of 3.0. Furthermore, the graph displays changes in the pH value from time to time, with both increases and decreases occurring regularly depending on the condition of the water.

Figure 5: The temperature level in (a) high and (b) normal condition

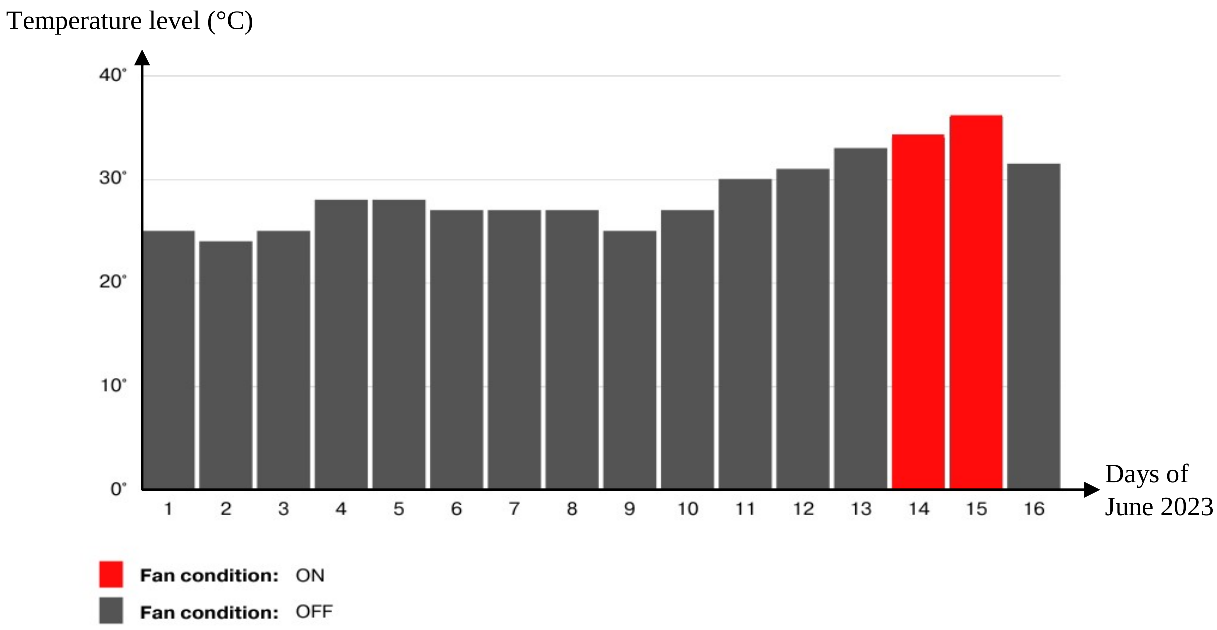


Figure 6: Graph of temperature levels by days

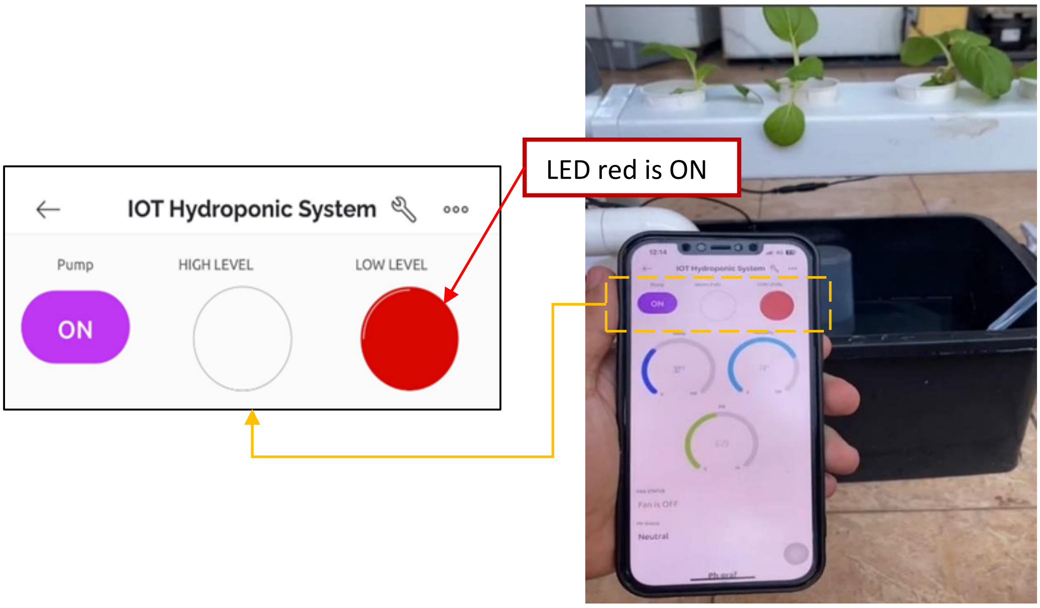


Figure 7: The water level low-level condition

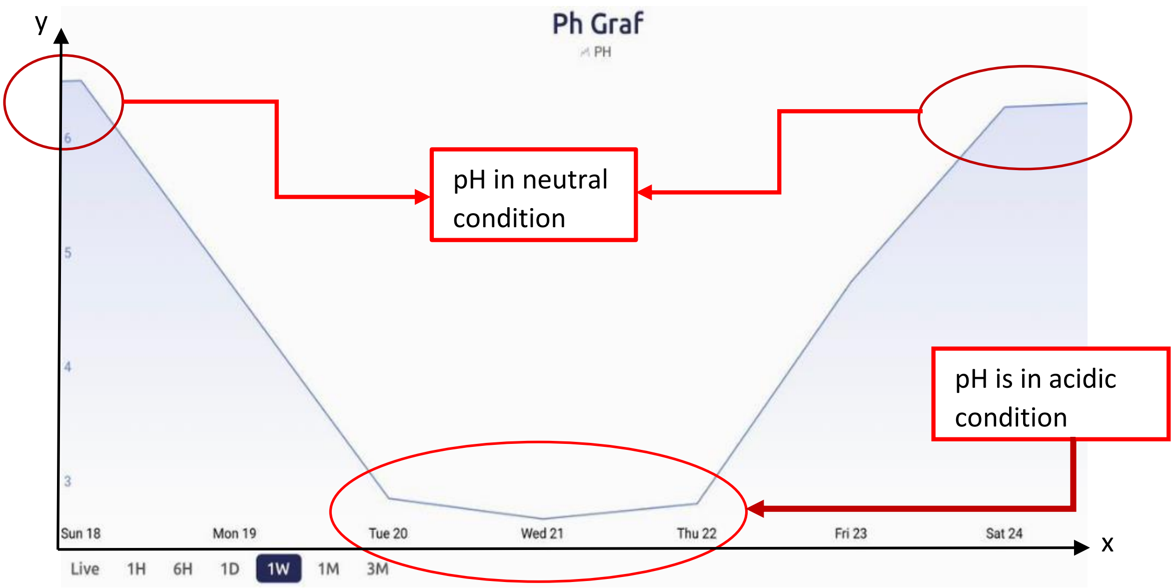


Figure 8: pH graph as displayed in the Blynk application

3.5 Discussion

The expected outcomes of the system's development include the design and implementation of a software simulation model capable of processing the hydroponic system that is connected to the IoT platform. The hydroponic system indicates that plants grown using this method are able to thrive and produce healthy yields [4]. Temperature, pH levels, water levels, and water pump management in this hydroponic system are all tightly tied to plant growth. The system's ability to monitor and adjust these parameters ensures that plants receive optimal conditions for photosynthesis, nutrient absorption, and overall health, resulting in successful plant growth and cultivation without the need for soil. This suggests that hydroponics could be a viable alternative to traditional gardening and agriculture methods. However, further testing and monitoring of the system is needed to fully evaluate its long-term performance and potential for commercial use. Since the system now monitors and adjusts pH levels, future research could focus on developing more sophisticated and automatic pH adjustment processes [5]. These systems could dynamically and precisely manage pH levels within the specified range, requiring less manual intervention and providing more constant and optimal plant health. Furthermore, advanced nutrition formulations can increase the system's nutrient delivery. Research should focus on developing specialised nutrition solutions for various plant kinds and growth phases. This customization would ensure that each plant obtains the optimal combination of nutrients for growth while minimising surplus nutrients and potential waste.

4. Conclusion

In conclusion, this work presents on the development of a smart hydroponic system using IoT technology. By effectively controlling and monitoring temperature, humidity, pH levels, and water levels in the hydroponic system, the technology has proved its ability to improve agricultural efficiency and productivity. Farmers have been able to produce optimal conditions for growth and supply exact nutrients for plants by doing the installation of sensors and implementing advanced algorithms. Experiments and demonstrations have proven the system's performance in maintaining ideal parameters**.** However, there are some challenges that must be addressed before this smart hydroponic system can be widely used. To begin, the system's cost and affordability should be evaluated in order to make it accessible to all farmers. Second, constant maintenance and monitoring of sensors and IoT devices are important for ensuring the system's smooth functioning. Finally, farmers must gain expertise and training to efficiently use the system and comprehend the provided data. Overall, the development of a smart hydroponic system using IoT technology has huge potential to enhance agriculture, but it must be approached with caution to solve the obstacles associated with affordability, maintenance, and user education.

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