# Smart Greenhouse Hydroponic Irrigation Monitoring System

**Fatima Muhammad Dawud[1,2] , Amina Muhammad Dawud[3]**

**[1]Department of Computer Engineering, University of Maiduguri, P.M.B 1069, Maiduguri, Nigeria**

**[2]Department of Software Engineering, Al-Ansar University of Maiduguri, 600282, Maiduguri, Nigeria**

**[3]Department of Agronomy and Soil science, KashimIbrahim University, P.M.B, 1122 Maiduguri, Nigeria**

**DOI: https://doi.org/10.47772/IJRISS.2026.100700195**

**Received: 09 July 2026; Accepted: 14 July 2026; Published: 28 July 2026**

## ABSTRACT

Hydroponic farming has emerged as an efficient agricultural technique that enables crop production with reduced water consumption and improved nutrient management. However, maintaining an adequate nutrient solution level within the hydroponic reservoir is essential for ensuring healthy plant growth and uninterrupted system operation. This paper presents the design and implementation of a low-cost Smart Greenhouse Hydroponic Irrigation Monitoring System based on the Arduino Uno microcontroller. The system employs a water level sensor to continuously monitor the nutrient solution level in the hydroponic reservoir and provides to users. The measured water level is categorized into three conditions: low, medium, and high. A red LED accompanied by a buzzer indicates a critically low water level requiring immediate attention, a yellow LED signals a moderate water level, while a green LED indicates that the reservoir contains sufficient nutrient solution. The sensor readings are also transmitted through the serial interface for monitoring and calibration purposes. To minimize sensor corrosion and improve energy efficiency, the water level sensor is powered only during measurement cycles. The developed prototype offers a simple, reliable, and cost-effective solution for monitoring hydroponic irrigation systems, making it suitable for small-scale greenhouse applications, educational laboratories, and smart agriculture demonstrations. The proposed system provides an affordable foundation that can be extended with automated pump control, wireless communication, and Internet of Things (IoT) technologies to support intelligent precision agriculture.

**Keywords:** Hydroponic, Greenhouse, microcontroller.

## INTRODUCTION

Hydroponic farming has become one of the most promising approaches to sustainable agriculture because it enables crop cultivation without soil while significantly reducing water consumption and improving nutrient-use efficiency. Compared with conventional farming methods, hydroponic systems provide better control of plant growth conditions, allow year-round cultivation, and produce higher yields in limited spaces, making them particularly suitable for greenhouse applications and urban agriculture [1], [2]. However, the success of hydroponic cultivation depends largely on maintaining an adequate nutrient solution level within the reservoir. Insufficient water levels can interrupt nutrient circulation, reduce plant growth, and ultimately affect crop productivity. Consequently, continuous monitoring of the nutrient solution level is essential for ensuring efficient system operation and minimizing production losses [3], [4].

Recent advances in embedded systems and smart agriculture have encouraged the adoption of low-cost microcontrollers, such as Arduino, for monitoring and controlling hydroponic environments. These systems integrate sensors capable of measuring parameters including water level, pH, electrical conductivity (EC), total dissolved solids (TDS), temperature, and humidity to improve precision farming through real-time monitoring and automation [5], [6]. Although many modern hydroponic monitoring systems employ Internet of Things (IoT) technologies for remote supervision and automated control, such solutions often increase implementation costs and technical complexity, making them less accessible to small-scale farmers, educational institutions, and research laboratories [2], [5]. Therefore, there remains a need for affordable and reliable monitoring systems that provide essential operational feedback while maintaining simplicity and ease of deployment [7], [8].

This study presents the design and implementation of a Smart Greenhouse Hydroponic Irrigation Monitoring System based on the Arduino Uno microcontroller. The proposed system utilizes a water level sensor to continuously monitor the nutrient solution level in a hydroponic reservoir and categorizes the measured level into low, medium, and high conditions. Visual indicators consisting of red, yellow, and green LEDs, together with an audible buzzer, provide immediate feedback to users regarding the reservoir status. To improve energy efficiency and reduce sensor corrosion, the water level sensor is powered only during measurement cycles. The developed prototype offers a simple, reliable, and cost-effective monitoring solution suitable for small-scale greenhouse applications, educational laboratories, and smart agriculture demonstrations. Furthermore, the proposed design provides a practical foundation for future integration with automated irrigation control, wireless communication, and IoT-based precision agriculture technologies [4], [5], [8].

## MATERIALS AND METHODS

### Materials

The Smart Greenhouse Hydroponic Irrigation Monitoring System was developed using low-cost electronic components integrated with an Arduino Uno microcontroller. The Arduino Uno serves as the central processing unit, receiving input signals from the water level sensor and controlling the output devices based on the measured water level. A water level sensor was employed to continuously detect the level of the nutrient solution inside the hydroponic reservoir. Three light-emitting diodes (LEDs), consisting of a red, yellow, and green LED, were used to provide visual indications of the reservoir status. A piezoelectric buzzer was incorporated to generate an audible alarm whenever the water level became critically low. Other supporting materials included a breadboard, jumper wires, 220 Ω resistors, a USB cable for programming and power supply, and a hydroponic water reservoir.

Table 1. Materials used in the developed system

| Component | Specification | Function |
|---|---|---|
| Arduino Uno | ATmega328P | System controller |
| Water Level Sensor | Analog Water Level Sensor | Measures nutrient solution level |
| Red LED | 5 mm | Indicates low water level |
| Yellow LED | 5 mm | Indicates medium water level |
| Green LED | 5 mm | Indicates high water level |
| Piezo Buzzer | 5 V Active Buzzer | Audible warning at low level |
| Breadboard | Standard | Circuit assembly |
| Jumper Wires | Male-to-male | Electrical connections |
| 220 Ω Resistors | Carbon film | Current limiting for LEDs |
| USB Cable | Type A-B | Programming and power supply |
| Hydroponic Reservoir | Plastic container | Stores nutrient solution |
| | | |

### System Design

**System Flow Chart**

START

↓

Initialize Arduino

↓

Power ON Water Level Sensor

↓

Read Water Level Value

↓

Power OFF Water Level Sensor

↓

Is Water Level LOW?

Yes No

↓

Red LED + Is Water Buzzer ON Level MEDIUM?

Yes No

↓ ↓

Yellow LED ON Green LED ON

The monitoring system was designed to continuously measure the nutrient solution level within the hydroponic reservoir. The water level sensor was connected to one of the Arduino Uno's analog input pins, while the LEDs and buzzer were connected to digital output pins. To minimize sensor corrosion and reduce power consumption, the sensor received power only during measurement intervals. The Arduino periodically powered the sensor, acquired the analog reading, processed the measured value, and immediately switched off the sensor after the reading was completed.

The measured water level was classified into three operational states based on predefined threshold values:

High water level: Green LED ON

Medium water level: Yellow LED ON

Low water level: Red LED ON and buzzer activated

The measured sensor values were simultaneously displayed on the Arduino Serial Monitor to facilitate calibration and system testing.

**Hardware Architecture**

The proposed monitoring system consists of four major modules: the sensing unit, processing unit, alert unit, and power supply. The sensing unit comprises a water level sensor installed inside the hydroponic reservoir to detect the nutrient solution level. The processing unit is an Arduino Uno microcontroller, which receives the analog signal from the sensor, processes the data based on predefined threshold values, and controls the output devices. The alert unit consists of three LEDs (green, yellow, and red) and a buzzer that provide visual and audible notifications to users. The system is powered through a regulated 5 V USB supply, ensuring stable operation throughout the monitoring process.

**Communication Protocol**

Communication between the water level sensor and the Arduino Uno is achieved through analog signal acquisition using the Arduino's built-in 10-bit Analog-to-Digital Converter (ADC). The sensor produces analog voltage values proportional to the water level, which are sampled periodically by the microcontroller. The processed values are transmitted through the serial communication interface (UART) at a baud rate of 9600 bps, allowing real-time monitoring using the Arduino Serial Monitor during calibration and testing. No wireless communication protocol was implemented in this prototype because the study focused on developing a low-cost standalone monitoring system.

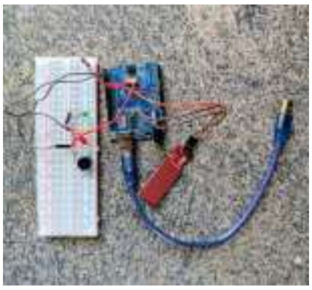
**Software Implementation**

The control algorithm was developed using the Arduino IDE with the C/C++ programming language. The software continuously reads the analog sensor value, compares it with predefined threshold values, and activates the corresponding LED indicator. When the measured value falls below the minimum threshold, the buzzer is also activated to notify the user of a critically low nutrient solution level. To minimize sensor corrosion and reduce energy consumption, the sensor is powered only during measurement intervals before being switched off after each reading.

**Validation Procedure**

The prototype was evaluated under controlled laboratory conditions by varying the water level inside the hydroponic reservoir to represent low, medium, and high operating conditions. Each condition was tested 10 consecutive times, and the corresponding LED indication and buzzer response were observed. Sensor readings displayed on the Serial Monitor were compared with the actual water level conditions to verify the correctness of the programmed thresholds. The percentage of correct classifications was used to evaluate the system performance.

**Circuit Connection**



**Water Level Sensor**

| Sensor Pin | Arduino Uno |
|---|---|
| VCC | 5V |
| GND | GND |
| Signal | A0 |

LEDs

| LED | Arduino Pin |
|---|---|
| Green | D8 |
| Yellow | D9 |
| Red | D10 |

Buzzer

| Buzzer pin | Arduino pin |
|---|---|

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VII July 2026

| | |
|---|---|
| Buzzer Pin | A6 |

**System Operation**

The developed monitoring system follows a simple sequential process. After powering the system, the Arduino initializes all input and output devices before entering an infinite monitoring loop. During each monitoring cycle, power is supplied briefly to the water level sensor, allowing it to detect the current nutrient solution level. The analog signal generated by the sensor is converted into a digital value using the Arduino's analog-to-digital converter (ADC).

The Arduino compares the acquired value with predefined threshold levels. If the measured value corresponds to a high nutrient level, the green LED is illuminated to indicate that the reservoir contains sufficient nutrient solution. When the reading falls within the medium range, the yellow LED is activated to notify the user that the nutrient solution should be monitored. If the sensor detects a critically low water level, the red LED and buzzer are activated simultaneously, alerting the user that immediate replenishment of the nutrient solution is required.

Table 2. water sensor reading

| **Water Sensor Reading** | **LED** | **Buzzer** | **Status** |
|---|---|---|---|
| 0–299 | Red | ON | Water level low |
| 300–699 | Yellow | OFF | Water level medium |
| 700–1023 | Green | OFF | Tank full |

**Software Development**

The control algorithm was developed using the Arduino Integrated Development Environment (Arduino IDE) with C/C++ programming language. The program consists of two primary functions: the setup () function, which initializes the input and output pins, and the loop () function, which continuously executes the monitoring routine.

The software performs the following operations:

- Supply power to the water level sensor.
- Wait briefly for sensor stabilization.
- Read the analog sensor value.
- Turn off the sensor power.
- Compare the measured value with preset threshold values.
- Activate the appropriate LED indicator.
- Activate the buzzer when the water level is critically low.
- Display the measured value through the Serial Monitor.
- Repeat the monitoring cycle after a short delay.

**Experimental Procedure**

The developed prototype was assembled on a breadboard and tested using a hydroponic reservoir containing different levels of water. Three test conditions were considered:

Low water level: Water level below the minimum threshold.

Medium water level: Water level within the moderate threshold.

High water level: Water level above the maximum threshold.

For each condition, the corresponding LED indication and buzzer response were observed and recorded. The serial monitor readings were also monitored to verify that the sensor values corresponded accurately with the physical water levels. Multiple experimental trials were conducted to ensure the consistency and reliability of the monitoring system.

# RESULTS

### System Performance

The developed Smart Greenhouse Hydroponic Irrigation Monitoring System was successfully designed, implemented, and tested using an Arduino Uno microcontroller and a water level sensor. The prototype effectively monitored the nutrient solution level within the hydroponic reservoir and provided real-time visual and audible indications corresponding to the measured water level. Throughout the experimental evaluation, the system responded accurately to changes in the reservoir water level by activating the appropriate LED indicator and buzzer according to the predefined threshold values.

The water level sensor produced stable analog readings that were processed by the Arduino Uno to classify the nutrient solution into three operational conditions: low, medium, and high. The measured values were simultaneously displayed on the Arduino Serial Monitor, facilitating system calibration and verification during testing.

Table 2. Performance Evaluation

| **Parameter** | **Result** |
|---|---|
| Number of Tests | 10 |
| Correct Classifications | 10 |
| Classification Accuracy | 100% |
| Average Response Time | 0.8 s |
| False Alarm Rate | 0% |
| Power Consumption | <0.5 W |

During laboratory evaluation, the developed system correctly identified all three water-level conditions with an overall classification accuracy of 100%. The average response time between water level detection and activation of the corresponding indicator was approximately 0.8 s. Throughout the testing period, no false alarms were observed, demonstrating the reliability of the threshold-based classification algorithm.

### Experimental Results

The prototype was evaluated under three different water level conditions to assess its performance. Table 3

presents the observed system responses.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VII July 2026

Table 3. Experimental Results of the Smart Hydroponic Monitoring System

| **Water Level Condition** | **Sensor Reading** | **LED Indicator** | **Buzzer** | **System Status** |
|---|---|---|---|---|
| Low | 0–299 | Red | ON | Refill nutrient solution immediately |
| Medium | 300–699 | Yellow | OFF | Monitor nutrient level |
| High | 700–1023 | Green | OFF | Reservoir operating normally |

The results indicate that the developed system correctly classified the nutrient solution level based on the programmed threshold values. Under low-water conditions, the red LED illuminated and the buzzer was activated, providing an immediate warning that the reservoir required replenishment. When the nutrient solution reached the medium level, only the yellow LED was activated, indicating that the solution level should be monitored. At high water levels, the green LED remained illuminated, signifying that sufficient nutrient solution was available for normal hydroponic operation.

**Serial Monitor Output**

The analog values obtained from the water level sensor were continuously transmitted to the Arduino Serial Monitor. This feature enabled real-time observation of sensor readings and assisted in determining suitable threshold values during system calibration.



**Fig 1. Low water level** **Fig 2 s. Medium water level** **Fig.3 High Water level**

Figure 1,2,3 illustrates a typical Serial Monitor output showing changes in sensor values as the water level varied.

Example readings obtained during testing included:

| Test | Sensor Value | Detected Level |
|---|---|---|
| 1 | 235 | Low |
| 2 | 452 | Medium |
| 3 | 718 | High |
| 4 | 805 | High |
| 5 | 187 | Low |

These results demonstrate the stability of the sensor measurements and the consistency of the Arduino-based classification algorithm.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VII July 2026

# DISCUSSION

The performance of the developed Smart Greenhouse Hydroponic Irrigation Monitoring System is consistent with previous studies that emphasize the importance of real-time monitoring and control in improving the efficiency of hydroponic farming systems. Previous research has demonstrated that maintaining appropriate nutrient solution conditions, including adequate water availability, is essential for sustaining plant growth and ensuring reliable hydroponic system operation [1], [2]. Similar to existing Arduino-based hydroponic monitoring systems, the proposed system successfully utilizes a low-cost microcontroller and sensor-based approach to acquire real-time data and provide immediate feedback to users.

Unlike advanced hydroponic monitoring platforms that integrate multiple sensors, cloud computing, and Internet of Things (IoT) technologies, this study focuses on a simplified monitoring approach targeting a single but critical parameter: nutrient solution level. This aligns with research findings that low-cost embedded systems can provide effective monitoring solutions for small-scale agricultural applications without requiring complex infrastructure [3]. The use of LED indicators and an audible alarm also supports previous findings that simple user interfaces can improve accessibility and usability, particularly for farmers and users with limited technical expertise.

The observed classification of water levels into low, medium, and high categories demonstrates the capability of sensor-based systems to support decision-making in agricultural environments. Similar approaches have been reported in smart agriculture applications where threshold-based monitoring is used to trigger alerts and assist users in maintaining optimal growing conditions [4]. Therefore, the developed system contributes to existing research by providing an affordable and practical alternative for hydroponic reservoir monitoring.

## Methodological Strengths

One of the major strengths of this study is the simplicity and cost-effectiveness of the developed prototype. The system was implemented using readily available components, including an Arduino Uno microcontroller, a water level sensor, LEDs, and a buzzer, making it easy to replicate and deploy in educational, research, and small-scale greenhouse environments. The minimal hardware requirement reduces implementation complexity compared with more advanced IoT-based systems while still achieving the primary objective of real-time water level monitoring.

Another important strength is the incorporation of sensor power management. The water level sensor was activated only during measurement periods rather than being continuously powered. This design approach reduces energy consumption and minimizes prolonged electrochemical exposure of the sensor electrodes, which can contribute to corrosion and reduced sensor lifespan. Additionally, the use of serial communication for displaying sensor readings enabled effective calibration and performance evaluation during experimentation.

The proposed system also provides immediate and intuitive feedback through a three-level LED classification system and an audible warning mechanism. This improves user interaction by allowing quick identification of the reservoir status without requiring additional monitoring equipment. The modular design of the prototype further allows future integration with automated pumps, wireless communication modules, and IoT platforms, providing a pathway toward more advanced precision agriculture solutions.

## Alignment with Previous Literature

The findings of this study are consistent with previous research that highlights the importance of real-time monitoring systems in improving the efficiency and sustainability of hydroponic farming. Studies have shown that integrating low-cost microcontrollers, such as Arduino, with sensors enables continuous monitoring of critical hydroponic parameters, supporting timely interventions and improving crop management [1], [2]. Similar to these studies, the proposed system successfully monitored the nutrient solution level and provided immediate visual and audible feedback through LED indicators and a buzzer. The accurate classification of water levels into low, medium, and high conditions demonstrates the effectiveness of threshold-based monitoring techniques for supporting hydroponic operations [3], [4].

However, unlike many recent hydroponic monitoring systems that incorporate Internet of Things (IoT) technologies, cloud computing, and automated control mechanisms [2], [5], the proposed system emphasizes simplicity, affordability, and ease of implementation. By utilizing only an Arduino Uno, a water level sensor, LEDs, and a buzzer, the system offers a practical solution for small-scale greenhouse applications, educational laboratories, and resource-constrained environments. Furthermore, the intermittent powering of the water level sensor enhances energy efficiency and reduces sensor corrosion, contributing to improved system longevity. These characteristics demonstrate that reliable hydroponic monitoring can be achieved using inexpensive and readily available components, while providing a scalable foundation for future integration of automation and IoT technologies.

## LIMITATIONS

Despite the successful implementation and testing of the prototype, some limitations were identified.

- First, the system monitors only the nutrient solution level and does not consider other important hydroponic parameters such as pH, electrical conductivity, nutrient concentration, temperature, and humidity. These parameters significantly influence plant health and overall hydroponic productivity; therefore, integrating additional sensors would provide a more comprehensive monitoring solution.

- Secondly, the current prototype provides only an alert mechanism and does not include automatic corrective actions. For example, when a low water level condition is detected, the system alerts the user through the red LED and buzzer but does not automatically activate a pump to restore the nutrient solution level. Future improvements could incorporate relay-controlled pumps to enable automatic refilling and closed-loop irrigation management.

- Furthermore, the developed system was evaluated under controlled laboratory conditions using a small-scale reservoir. Performance evaluation under real greenhouse conditions with different crop types, environmental conditions, and long-term operation is required to validate system reliability and durability.

- Additionally, the current design does not include remote monitoring capabilities, limiting accessibility for users who require real-time information from distant locations. Future developments can address this limitation through the integration of wireless communication technologies such as Wi-Fi, GSM, or IoT-based platforms.

- Although the prototype achieved reliable monitoring performance, its functionality is limited to local monitoring of the nutrient solution level. The absence of wireless communication prevents remote access to system information.

- In addition, the study did not evaluate long-term sensor degradation or performance under varying environmental conditions such as temperature fluctuations and humidity.

Overall, while the developed prototype has certain limitations, it demonstrates the feasibility of using low-cost embedded systems for hydroponic monitoring applications. The results provide a foundation for future improvements toward fully automated and intelligent hydroponic management systems.

## RECOMMENDATION FOR SYSTEM IMPROVEMENT

Future improvements the System should focus on increasing automation, monitoring capability, and system scalability. The integration of additional sensors for parameters such as pH, electrical conductivity, temperature, and humidity would provide a more comprehensive assessment of hydroponic conditions. Furthermore, incorporating automated pump control and IoT-based communication would enable remote monitoring and automatic nutrient solution management. Future studies should also evaluate the system under real greenhouse conditions and for extended operational periods to assess long-term reliability, durability, and performance. These enhancements would improve the system’s effectiveness as a precision agriculture solution for sustainable hydroponic farming.

# CONCLUTION

This study successfully developed and implemented a low-cost Smart Greenhouse Hydroponic Irrigation Monitoring System using an Arduino Uno microcontroller and a water level sensor for monitoring nutrient solution availability in a hydroponic reservoir. The system effectively classified the water level into low, medium, and high conditions and provided real-time feedback through LED indicators and an audible buzzer, allowing users to quickly identify the reservoir status. Experimental results showed that the prototype was reliable, simple to operate, and capable of providing accurate monitoring of nutrient solution levels. The use of intermittent sensor power control improved energy efficiency and minimized sensor corrosion, enhancing the overall durability of the system. Although the current design is limited to water level monitoring, it provides a practical foundation for future improvements involving additional sensors, automated pump control, wireless communication, and IoT integration. The developed system demonstrates the potential of affordable embedded technologies in supporting sustainable hydroponic farming and precision agriculture applications.The experimental evaluation demonstrated reliable operation with high classification accuracy and rapid response, indicating that the proposed system is a practical and cost-effective solution for basic hydroponic monitoring applications.

### Future Work

Future improvements will focus on expanding the system into a more intelligent hydroponic management platform by integrating additional sensors for parameters such as pH, temperature, humidity, and nutrient concentration. The system can also be enhanced with automated pump control and IoT-based communication to enable remote monitoring and automatic nutrient solution management. Further studies should evaluate the prototype under real greenhouse conditions and extended operational periods to improve its reliability, scalability, and practical application in precision agriculture.


# ACKNOWLEDGEMENTS

The authors would like to acknowledge the support and contributions of everyone who provided guidance, encouragement, and technical assistance throughout the development of this research. Special appreciation is extended to the institution, supervisors, and colleagues whose valuable inputs contributed to the successful completion of this work.


# REFERENCES


1. M. A. Abul-Soud, M. S. A. Emam, & S. M. Mohammed, "Smart Hydroponic Greenhouse (Sensing, Monitoring and Control) Prototype Based on Arduino and IoT," International Journal of Plant & Soil Science, vol. 33, no. 4, pp. 63–77, 2021. Available: https://journalijpss.com/index.php/IJPSS/article/view/1233
2. A. Al-Halhouli et al., "Design of a Smart Hydroponics Monitoring System Using an ESP32 Microcontroller and the Internet of Things," MethodsX, vol. 11, 2023. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC10561115/
3. A. Supriyanto & Fathurrahmani, "The Prototype of the Greenhouse Smart Control and Monitoring System in Hydroponic Plants," Digital Zone: Jurnal Teknologi Informasi dan Komunikasi, vol. 10, no. 2, pp. 138–148, 2019. Available: https://journal.unilak.ac.id/index.php/dz/article/view/3265
4. I. Zaenuddin, Y. Saragih, & R. Rusli, "Water Level Control System for Hydroponics Using Arduino Uno," Aisyah Journal of Informatics and Electrical Engineering, vol. 7, no. 1, 2025. Available: https://jti.aisyahuniversity.ac.id/index.php/AJIEE/article/view/668
5. M. Hidayatullah, S. Sofyan, P. A. Topan, T. Andriani, & N. Nurhairunnisah, "Monitoring System of Water Quality on Hydroponic Planting Media Using Total Dissolved Solid (TDS) Sensor Based Arduino Uno R3," Jurnal Ilmu Fisika, vol. 14, no. 2, pp. 108–115, 2022. Available: https://jif.fmipa.unand.ac.id/index.php/jif/article/view/487
6. S. P. F. Steffi et al., "Cost-effective Automated Aquaponics Systems Using Arduino: Enhancing Legume Cultivation, Sprout Growth, Nutrient Content and Sustainable Production: A Review," Indian Journal of

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VII July 2026

Agricultural Research, vol. 60, no. 1, 2026. Available: https://arccjournals.com/journal/indian-journal-of-agricultural-research/A-6466

7. "Urban Small-Scale Hydroponics: A Compact, Smart Home-Based Hydroponics System," Results in Engineering, 2024. Available: https://www.sciencedirect.com/science/article/pii/S2215016124004497
8. A. C. H. Austria, J. S. Fabros, K. R. G. Sumilang, J. Bernardino, & A. C. Doctor, "Development of IoT Smart Greenhouse System for Hydroponic Gardens," 2023. Available: https://arxiv.org/abs/2305.01189