Design and Fabrication of Hydroponic Farming System for Capsicum Cultivation

Dr. Chinmay Pingulkar[1*]; Omkar Joshi[2]; Yash Ugale[3]; Saish Sable[4]

Department of Mechanical Engineering, VIVA Institute of Technology, India
*Corresponding Author

Abstract— *This research paper details the design and construction of a low-cost, automated hydroponic farming system for home use, addressing the need for sustainable, soil-free agriculture in urban settings. The primary objective is to create a self-regulating environment that fosters optimal plant growth with minimal human intervention. By integrating basic electronic components with a simple hydroponic setup, this system offers a practical solution for growing fresh produce indoors, highlighting the benefits of water conservation and space efficiency compared to traditional gardening. The system is constructed using a wooden plywood frame for stability, with PVC pipes serving as the channel for a nutrient-rich water solution. At its core is an Arduino Uno microcontroller, which automates the entire process. A 12V DC pump circulates the nutrient solution, a UV grow light provides the necessary light spectrum for photosynthesis, and a fan ensures adequate air circulation to prevent mold and strengthen plant stems. A moisture sensor is employed to monitor the water levels, ensuring the system operates efficiently. The expected outcome is a fully functional, automated hydroponic unit capable of sustaining plant life from seed to harvest within a controlled indoor environment. This research paper demonstrates a successful integration of simple technology and agricultural principles, providing a scalable and educational model for modern, small-scale farming.*

Keywords— Controlled Environment Agriculture, Hydroponic Farming, Capsicum Cultivation.

I. INTRODUCTION

Capsicum farming in India faces several major challenges that make it difficult for farmers to earn a steady income. One of the biggest problems is the crop's high sensitivity to weather. Capsicum plants need very specific temperature and humidity levels to grow well, meaning sudden heat waves or unexpected heavy rains can easily destroy the entire harvest. Because of this, many farmers try to grow them inside protective greenhouses or polyhouses, but building these structures requires a huge initial investment that small-scale farmers simply cannot afford.

This research paper outlines the construction of a compact, automated hydroponic system for growing plants at home. By eliminating soil, this method delivers a nutrient-rich water solution directly to the roots using a PVC pipe structure, promoting faster and more efficient plant growth in a limited space.

The system's automation is powered by an **Arduino Uno microcontroller**. This acts as the central brain, programmed to monitor and control all the essential components. It ensures the plants are consistently cared for, creating an optimal growing environment with minimal manual effort.

Key electronic components include a 12V DC pump for water circulation, a UV light to aid photosynthesis, and a fan to maintain airflow. By integrating these parts, this research paper demonstrates a practical and self-sufficient solution for modern, indoor agriculture.

II. LITERATURE REVIEW

Sharma et al. (2018) [1] presented a practical and low-cost design for an automated hydroponic system controlled by an Arduino Uno. The system effectively uses sensors to monitor critical parameters such as water level, humidity, and temperature, activating actuators like a water pump and fan to maintain optimal conditions. The research emphasizes affordability and simplicity.

Lestari et al. (2021) [2] advanced the concept of automated hydroponics by integrating the Internet of Things (IoT) for remote management using a Node MCU ESP8266. The system enables real-time data visualization and control through the Blynk application, allowing users to monitor the system from a smartphone.

Subawa et al. (2020) [3] focused on maintaining correct pH levels in hydroponics using an Arduino Uno and pH sensor. The system reads pH values in real-time and displays them on an LCD screen, alerting users when levels go outside the optimal range (5.5-6.5).

Kumar (2022) [4] centered on developing an affordable automated hydroponic system using Arduino Uno, integrating sensors to monitor temperature, humidity, and water level. The paper serves as an excellent practical guide for building a budget-friendly setup.

Halim et al. (2020) [5] detailed a "smart" hydroponic system using Node MCU ESP8266 and ThingSpeak IoT platform for remote monitoring. The research demonstrates how IoT can transform a simple automated system into an intelligent, data-driven one.

Al-Rizzo et al. (2020) [6] presented a thorough design for a "smart" hydroponic system centered on an Arduino Mega, integrating sensors for pH, water temperature, humidity, and light intensity.

Lakshan et al. (2019) [7] detailed a cost-effective automated hydroponic system using Arduino Uno to control a water pump based on a timer and water level sensor, as well as an LDR to activate LED grow lights.

Tauhid and Aznan (2021) [8] provided a clear guide to building a basic automated hydroponic system, focusing on nutrient delivery cycle automation using a timer relay and water level sensor.

Saputro et al. (2017) [9] outlined a foundational automated hydroponics system using Arduino Uno, integrating sensors for temperature, humidity, and moisture level to control a water pump.

Manan et al. (2020) [10] detailed a comprehensive automated hydroponic system using Arduino Uno to manage water and light, utilizing a water level sensor and LDR for automation.

III. METHODOLOGY

3.1 Planning

The planning phase focuses on designing a compact, efficient, and affordable hydroponic system for indoor use. The system layout is conceptualized to fit within limited spaces such as balconies, kitchen corners, or small greenhouses. The setup consists of:

- A wooden plywood frame for stability and durability
- PVC pipes (50–75 mm diameter) as channels for nutrient flow
- Evenly spaced holes on the pipes to hold net pots
- A water reservoir at the base to store the nutrient solution
- A submersible pump for continuous circulation

The design follows the **Nutrient Film Technique (NFT)** , allowing a thin film of nutrient-rich water to flow over plant roots, ensuring efficient nutrient and oxygen delivery.

3.2 Literature Survey

The literature survey highlights the importance of hydroponics as a sustainable and space-saving alternative to traditional farming. Studies show hydroponic systems can reduce water consumption by nearly 90% while achieving faster plant growth. Research indicates that automation using microcontrollers like Arduino improves precision and reduces manual effort. This research bridges the gap by creating a low-cost, easy-to-build automated hydroponic model suitable for home use.

3.3 Component Selection

Component	Specification	Purpose
Arduino Uno	Microcontroller	Central control unit for automation
12V DC Submersible Pump	—	Circulates nutrient solution through PVC channels
Moisture/Water Level Sensor	—	Monitors water level; sends feedback to Arduino
UV Grow Light	—	Provides artificial light for photosynthesis
12V DC Fan	—	Maintains air circulation, prevents fungal growth
Relay Module	—	Interfaces high-power devices with Arduino
PVC Pipes	50–75 mm diameter	Growing channels for nutrient flow
Wooden Plywood Frame	—	Structural support
Nutrient Solution & Reservoir	—	Contains essential macro/micronutrients
DHT11/DHT22 Sensor	—	Measures temperature and relative humidity

3.4 Assembly

The assembly begins with constructing the wooden frame to support the PVC channels and nutrient reservoir. The submersible pump is connected to the reservoir and linked to the PVC pipes using flexible tubing to form a closed-loop system. The Arduino Uno is wired to the pump, fan, grow light, and sensors through the relay module, allowing full automation. Each component is tested individually to ensure proper connectivity.

Once the setup is complete, the Arduino is programmed to control the timing and sequence of each component. The nutrient solution is prepared and added to the reservoir, and plants are placed in net pots filled with inert growing media (coco peat or clay pellets). After calibration, the system is monitored for several days to confirm stable operation.

Figure 1: Arduino Uno Wiring Connections with Display

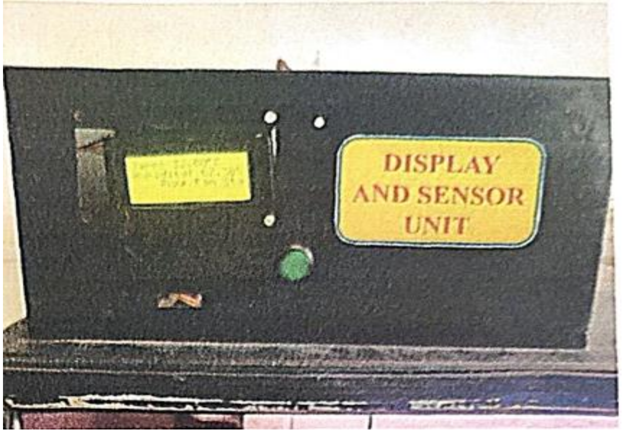

Figure 2: Display and Sensor Unit

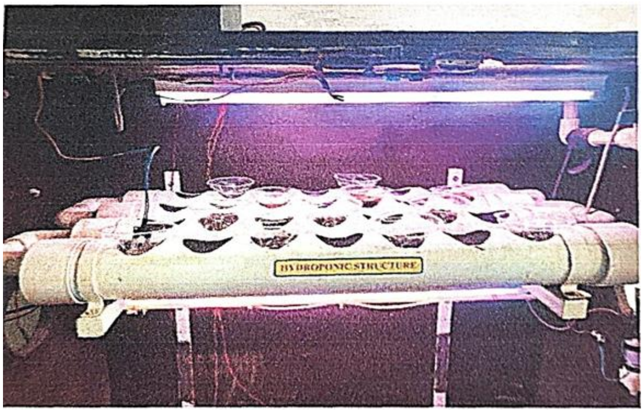

Figure 3: Working Model

TABLE 1
COMPONENT LIST

Sr. No.	Part Name	Description	Quantity
1	Arduino Uno	Programmable microcontroller brain	1
2	DC Pump	Direct current pump to circulate liquid	1
3	16×4 Display	Display to show data like temperature	1
4	Moisture Sensor	Electronic probe measuring soil moisture	2
5	DC Fan	Direct current fan to circulate air	1
6	UV Light	Promotes healthy plant growth	1

IV. CONCLUSION

The automated hydroponic farming system successfully demonstrates a practical and sustainable approach to modern urban agriculture. By integrating simple electronic components such as the Arduino Uno, sensors, and actuators, the system effectively automates nutrient delivery, lighting, and environmental control, ensuring optimal plant growth with minimal effort.

Key Outcomes:

- Successful automation of nutrient delivery, lighting, and environmental control
- Low-cost, efficient solution for soil-free indoor farming
- Water conservation and space efficiency compared to traditional gardening
- Minimal human intervention required for plant maintenance

Future Scope:

- IoT integration for remote monitoring and control
- Solar power utilization for energy independence
- AI-based optimization for predictive plant care
- pH and EC sensors for advanced nutrient management

This research reinforces the contribution to promoting sustainable urban agriculture and technological innovation in small-scale food production.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the management of VIVA Institute of Technology for providing a supportive academic environment and the necessary infrastructure to carry out this research work. The authors are especially thankful to the project guide and faculty members of the Mechanical Engineering Department for their valuable guidance, constructive suggestions, and continuous motivation throughout the research process.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest associated with this research work or its publication. The study was carried out independently without any financial support, sponsorship, or funding from commercial organizations or external agencies that could influence the outcomes of the research.

REFERENCES

[1] Sharma, R. R., Kumar, S., & Singh, A. K. (2018). Design and implementation of an automated hydroponic system using Arduino. In *Proceedings of the 4th International Conference on Computing, Communication and Automation (ICCCA)* (pp. 1–5). Greater Noida, India.

[2] Lestari, A. D., Riyadi, M. A., & Sumardi, S. (2021). IoT-based hydroponic farming system with real-time monitoring and control. In *Proceedings of the International Seminar on Application of Technology for Information and Communication (Semantic)* (pp. 165–170). Semarang, Indonesia.

[3] Subawa, I. G., Kumara, I. N., & Adnyana, G. A. (2020). Design of smart hydroponic system using Arduino Uno and pH sensor. In *Proceedings of the 3rd International Conference on Information and Communication Technology (ICOIACT)* (pp. 79–83). Yogyakarta, Indonesia.

[4] Kumar, S. S. (2022). Low-cost automated hydroponics system using Arduino. In *Proceedings of the International Conference on Advanced Smart, Secure and Intelligent Computing (ASSIC)* (pp. 1–6). Bhubaneswar, India.

[5] Halim, N. A., Rashid, M. F., & Hashim, M. H. (2020). Development of a smart hydroponic system with IoT monitoring. In *Proceedings of the IEEE 10th Symposium on Computer Applications and Industrial Electronics (ISCAIE)* (pp. 268–273). Penang, Malaysia.

[6] Al-Rizzo, M. A., Hussein, H. H., & Al-Azzawi, A. A. (2020). Design and implementation of a smart hydroponics system using Arduino. In *Proceedings of the IEEE 10th Annual Computing and Communication Workshop and Conference (CCWC)* (pp. 0477–0482). Las Vegas, NV, USA.

[7] Lakshan, K. D., Dharmagunawardhana, A. C., & Wijayakulasooriya, J. V. (2019). An Arduino based automated hydroponics system. In *Proceedings of the 14th Conference on Industrial and Information Systems (ICIIS)* (pp. 430–435). Kandy, Sri Lanka.

[8] Tauhid, N. S., & Aznan, N. F. A. (2021). Development of an automated hydroponic system using Arduino. In *Proceedings of the IEEE 11th Symposium on Computer Applications and Industrial Electronics (ISCAIE)* (pp. 177–181). Penang, Malaysia.

[9] Saputro, D. W., Iskandar, B. B., & Suripto, S. S. (2017). Design of a microcontroller-based automated hydroponic system. In *Proceedings of the International Conference on Electrical Engineering and Computer Science (ICECOS)* (pp. 273–277). Palembang, Indonesia.

[10] Marian, J. W., Bajuri, A. H. A., Abidin, Z. A., & Ali, M. M. (2020). Automated hydroponic system for smart agriculture. In *Proceedings of the IEEE Conference on Sustainable Utilization and Development in Engineering and Technology (CSUDET)* (pp. 94–99). Penang, Malaysia.