IRO Journal on Sustainable Wireless Systems (ISSN: 2582-3167)
www.irojournals.com/irosws/

Smart Hydroponic System for Petroselinum Crispum Growth Monitoring with Nutrition Automation

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Abstract

Hydroponics is a technique of growing plants using a water-based nutrient solution rather than soil and is well suited for small farmers, hobbyists, and commercial enterprises. It involves growing plants in a nutrient solution with or without a soilless substrate for physical support. A hydroponic system is an essential component of a plant factory. By using fewer resources, hydroponics is seen as a more sustainable option than traditional agriculture. This proposed study aims to provide a brief overview of hydroponic systems based on existing research and suggest an approach to enhance real-time monitoring of Parsley (Petroselinum crispum) plant growth. The research aims to develop an optimal environment for plant growth while minimizing resource wastage and maximizing yields by maintaining proper nutrient levels.

Keywords: Hydroponics, Farming, Nutrition deficiency Detection, IoT.

1. Introduction

Environmental conservation is one of the greatest challenges facing society today, and some current agricultural practices pose a significant threat. Hydroponics is being proposed as a sustainable solution to combat climate change, reduce environmental damage, and prevent species extinction caused by overexploitation and intensive farming. It also enables a more efficient use of water, an increasingly scarce resource[11].

DOI: https://doi.org/10.36548/jsws.2024.4.005
Received: 14.12.2024, received in revised form: 06.01.2025, accepted: 24.01.2025, published: 07-02-2025

Hydroponic farming is not only more profitable but also easier to control, making it a powerful tool in the fight against hunger and a means to enhance food security, especially in developing countries. While traditional agriculture is often considered an art, hydroponics is a science—one in which all the factors influencing plant growth are carefully monitored and controlled.

A essential aspect of hydroponic farming is nutrient management in soilless food production. Flow-through systems simplify nutrient control, but in water-scarce regions, they raise concerns about water usage and potential pollution. However, hydroponic farms generally use significantly less water than traditional soil-based agriculture. They do not contribute to soil degradation or suffer from its effects. Additionally, they provide higher yields in a smaller area, allowing for the production of fresh food in regions where traditional farming is less viable[12,13].

Hydroponics enables year-round cultivation of fresh, healthy food even in extreme environments such as deserts, tundras, and dense urban areas. As the technology becomes more widespread, it has the potential to reduce global food shortages. Furthermore, hydroponically grown food is not susceptible to soil-borne contaminants, which often lead to food recalls in conventional farming. This makes hydroponic crops safer and, in many cases, nutritionally superior to soil-grown alternatives [14,15].

Hydroponics is also at the forefront of smart farming, which integrates advanced technologies such as geolocation, big data, artificial intelligence, the Internet of Things (IoT), and drones optimize resource use, achieve precise environmental control, and increase crop yields.

The proposed study aims to provide an overview of smart farming methods used in hydroponics and propose an approach to enhance lettuce growth through real-time monitoring using IoT.

1.1 Objectives

- To present a brief overview of smart farming methods followed.
- To develop a smart hydroponics system for parsley plant.

2. Literature Review

This literature review explores the potential of hydroponic systems, their applications, and the design of suitable systems. Hydroponics involves growing plants in a soil-less medium, allowing them to absorb essential minerals directly from water-rich solutions. This technology reduces maintenance time and allows plants to grow in an automated system, recirculating water and nutrients from storage tanks to grow trays.

Hydroponics farming is a soil-less system that uses less water and resources compared to traditional methods. However, monitoring hydroponics farming is challenging due to various parameters, nutrition suggestions, and plant diagnosis systems. Artificial intelligence-based controlling algorithms can help. This research proposes an AI-SHES with IoT environment, consisting of three phases: real-time sensors, deep learning convolutional neural network models, and an Android-based mobile app. The system also has an automated mode for increased productivity. Simulation results show superior performance in disease detection and classification [1].

Macayana et al [2] proposes a hybrid IoT-based monitoring system for hydroponics, combining wired and wireless components. The system uses a controller area network for wired components, IPv6 over low power wireless personal area network (6LoWPAN) for wireless components, and Amazon Web Services for cloud services. Network simulations show that incorporating a wired system improves network performance, reducing packet loss from 12.23% to 5.62%.

Water irrigation remains a challenge in climate-affected regions, posing a risk to the global food supply chain. Smart farming systems, equipped with environmental sensors, can replace manual labor and control water irrigation rates. This research introduces a Raspberry Pi-powered IoT smart farming system (ISFS) that can monitor plant irrigation, temperature, humidity, soil moisture, and light intensity. The system also features a smartphone app for user-friendly monitoring and automatic control of drip irrigation systems. The prototype aims to address water irrigation challenges and meet the demand for smart farming applications [3].

The growing human population and urban-rural migration have led to a need for solutions to feed the world. Hydroponics, a method where crops grow without soil, allows farms to follow farmers to urban areas and saves space. Automation is the final frontier, allowing farmers to work multiple jobs and cultivate multiple farms simultaneously [4].

Hydroponics is a new farming method that uses water instead of soil for planting. The nutrient concentration in the solution, indicated by electrical conductivity, is necessary for crop production. This research has developed a nutrition feeding automation system for a prototype scaled Nutrient Film Technique (NFT) hydroponics. The system uses an Arduino UNO R3 board, proximity sensor, TDS sensor, and servo motor for water delivery and nutrient addition.

The nutrient film technique, which involves a thin film of nutrient solution over the roots of plants, can yield over three times more than traditional methods. An automated nutrient film analyzer (ANFA) has been developed to analyze the film for nutrients, monitor ion build-up, and measure pH[5,8].

This research presents a smart fuzzy logic-based control system for greenhouse climate control, promoting a comfortable micro-climate for plant growth and saving energy and water resources. The system is improved with temperature and humidity correlation measures and a wireless data monitoring platform for real-time data access [6].

Lettuce, a popular leaf vegetable, relies on nutrient solution composition for hydroponic growth. A lab-made software system has been developed to monitor conductivity and pH throughout the production cycle, allowing for automatic adjustment. The system's efficiency was evaluated by growing lettuce in greenhouse-controlled hydroponics and conventional soil cultivation. Results showed precocity in harvest, reduced labor, better control, and higher productivity. The system's data sequence demonstrates its efficiency in controlling conductivity and pH parameters, offering a viable lettuce production alternative [7].

A real-time detection and diagnosis system for mechanical, sensor, and plant failures in a deep-trough hydroponic system is developed using feedforward neural networks and genetic algorithms. The system uses a new technique for neural network design and training parameterization, based on genetic algorithms' heuristic optimization method. Sensor and actuator faults are detected and diagnosed quickly, but biological faults are not detected. The system can be applied to combinatorial problems [9].

A deep trough hydroponic system model is developed using Artificial Neural Networks. The Feedforward Neural Network Model uses 9 inputs and two outputs. The most accurate combination is the one-hidden-layer with 9 hidden nodes architecture, with predictions within 0.01 and 5 microS.cm-1 [10]. Based on the findings of the study, the proposed approach integrates smart farming into hydroponics to monitor the growth of parsley, minimize resource utilization, maintain nutrient levels, and increase yield.

3. Methodology

A. Smart Hydroponic System

Parsley (Petroselinum crispum) is well-suited for hydroponic farming due to its adaptability to controlled environments and relatively short harvest cycle. The cultivation process begins with seed germination, which requires soaking coco peat in water for 10–15 minutes to ensure proper moisture retention. Once fully hydrated, the coco peat is placed in a seedling tray, where parsley seeds are evenly sown. To maintain humidity and promote germination, the tray is covered with a polythene sheet and left undisturbed for about 7–14 days. After this period, small sprouts begin to emerge, at which point the cover is removed. The seedlings should remain in the tray for a few more days until they develop strong roots and multiple sets of true leaves. Once the seedlings are well-established, they are transplanted into the hydroponic setup using Deep Water Culture (DWC), which provides stability and support for the growing plants. For the efficient cultivation of parsley the hydroponic nutrient solution must be carefully maintained, with an optimal pH range of 5.5–6.5 and EC levels between 1.2–1.8 mS/cm to ensure healthy development. Additionally, environmental factors such as light exposure, temperature, and humidity should be monitored and adjusted accordingly. Figure 1 illustrates the block diagram of smart hydroponics

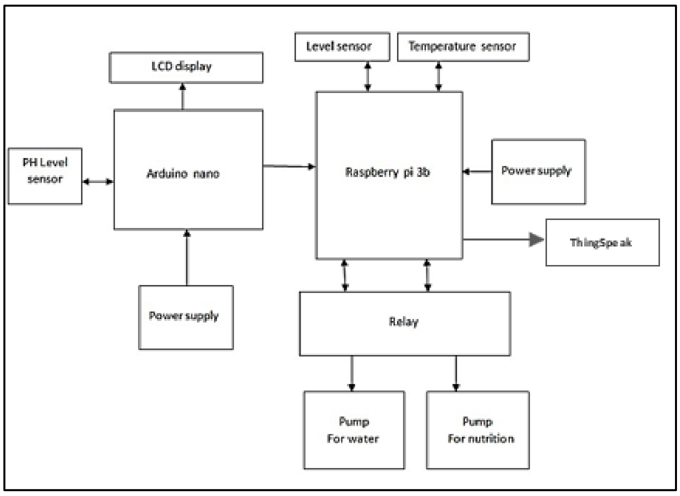

Figure 1. Block Diagram of Smart Hydroponics.

B. pH Interface.

The pH sensor is connected to an Arduino Nano, which can be connected to an analog input pin. An Arduino sketch is written to read the analog voltage output and convert it to pH value. The data is sent to a Raspberry Pi through USB cable. A Python script is written to read the pH data and extract the pH value. Data processing algorithms are implemented to mitigate interference and noise from the pH sensor readings. Figure 2 illustrates the flow chart to check the pH values.

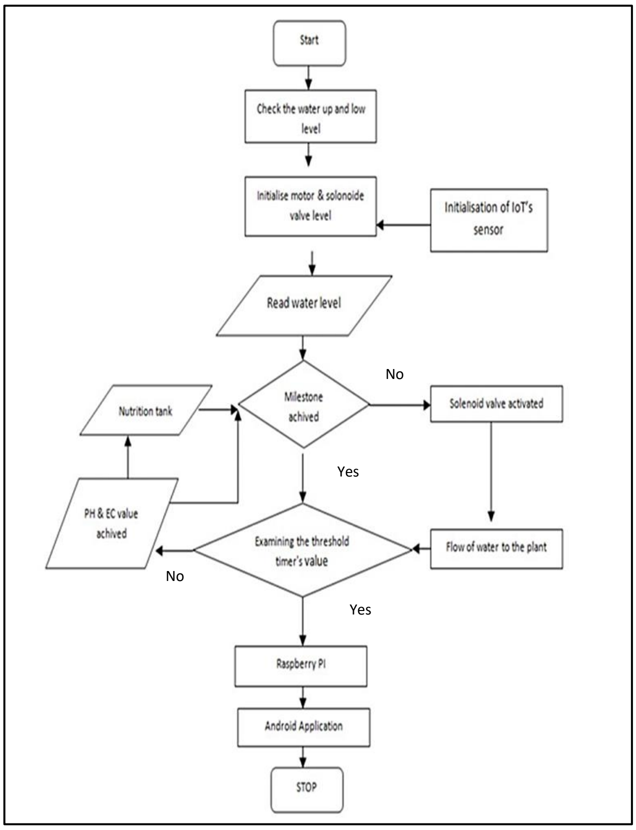

Figure 2. Flow Chart to Check the pH Values

C. Temperature Interface

Temperature sensor DHT11 Senses the temperature and converts it in to an electrical (analog) signal which is applied to the microcontroller of raspberry pi Board. The analogue value is converted into digital value. The sensed values of the temperature is compared, If the Temperature rises above 60 degree Fahrenheit, Then the controller turns ON Fan , The Fan is connected to raspberry pi Board through 12v Relay.

3.1Components Required

The Table.1 below depicts the hardware's and the software required.

Table 1. Components Required

Hardware Requirement	Model used
Raspberry Pi 3b	
pH Sensors	DFRobot Gravity
Temperature sensor.	DHT22
Relays /Motor Controllers.	SainSmart 8-Channel 5V Relay Module
Level sensor.	Ultrasonic Distance Sensor (HC-SR04)
Arduino Nano.	Atmega328P
LCD Display.	16x2 LCD Display
8-channel ADC	MCP3008
Software's Used	
Raspberry Pi OS.	
MATLAB	

3.2 Model Working

In hydroponic systems, monitoring and controlling pH levels are paramount for the successful cultivation of plants. The pH level of the nutrient solution directly affects the availability of essential nutrients to the plants' roots. Typically, a pH range between 5.5 and 6.5 is ideal for most hydroponic crops, as it ensures optimal nutrient uptake and prevents nutrient deficiencies or toxicities. When the pH level deviates from this range, plants may suffer from stunted growth, nutrient imbalances, or susceptibility to diseases. Therefore, integrating a pH sensor interfaced with an Arduino Nano and Raspberry Pi allows for real-time monitoring of pH levels in the nutrient solution. Detecting acidic pH values below 7 prompts timely adjustments, such as adding pH-up solutions to raise the pH and restore balance.

4. Result and Discussion

By maintaining proper pH levels, hydroponic system can maximize plant growth, yield, and overall health, leading to successful cultivation and harvests. Using a pH level sensor in a hydroponic system provides valuable insights into the acidity or alkalinity of the nutrient solution, enabling growers to maintain optimal pH levels for plant growth. Here's how automation with a pH level sensor can enhance hydroponic systems: In summary, automation with a pH level sensor, water level sensors, and temperature sensors enhances the efficiency, precision, and reliability of hydroponic systems by providing real-time monitoring. This streamlined approach ensures optimal growing conditions for plants, leading to healthier crops and improved yields. While the hardware for the proposed hydroponics system is still under development, the ThingSpeak module has been successfully implemented. It updates the pH, water level, and temperature values to the ThingSpeak cloud platform every 5 seconds. Figures 3-5 illustrate the data stored in the cloud.

Figure 3. pH vs Time

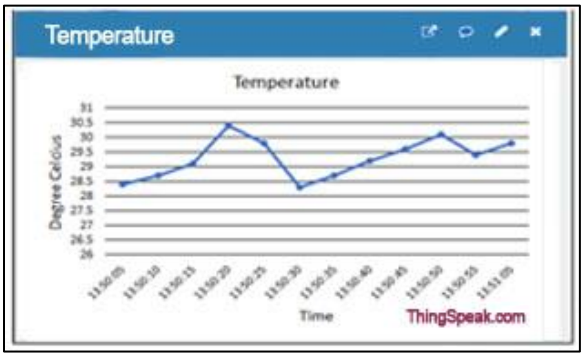

Figure 4. Temperature vs Time

Figure 5. Water Level vs Time

The data stored in cloud platform allows for remote monitoring and management of hydroponic systems, enabling farmers to track and adjust growing conditions from anywhere with an internet connection. This flexibility can reduce the need for on-site personnel and increase operational efficiency.

5. Conclusion

Integrating nutrition deficiency detection into automated hydroponic systems marks a significant advancement in agricultural technology. By seamlessly incorporating sensors the systems offer a real-time monitoring of plant health, detecting subtle signs of nutrient deficiencies before they escalate. This early detection serves as a proactive warning system, enabling growers to swiftly intervene and correct imbalances, thus averting stunted growth and potential crop failures. Moreover, the synergy between automated monitoring and prescriptive recommendations empowers growers to fine-tune nutrient formulations, pH levels, and environmental conditions, optimizing plant health and productivity. Beyond immediate benefits, the data generated by nutrition deficiency detection provides invaluable insights into crop responses and cultivation techniques. This knowledge enhances continuous improvement, enabling growers to refine their practices and enhance overall efficiency. Furthermore, the integration of remote diagnostics and support ensures timely intervention, even in remote or large-scale operations, enhancing operational resilience and minimizing downtime. Ultimately, nutrition deficiency detection, when seamlessly integrated into automated hydroponic systems, not only ensures optimal nutrient delivery but also enhances data-driven decision-making, driving productivity, quality, and sustainability in modern agriculture.

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