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Urban Oasis: Automated Indoor Farming for a Greener Future

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Abstract: With the growing demand for sustainable and space-efficient farming methods, hydroponics has emerged as a promising alternative to traditional soil-based agriculture. It allows plants to grow faster and healthier by providing nutrients directly through water solutions, reducing the need for large farmland and excessive water usage. The Smart Hydroponic System is designed to automate and optimize plant growth in a controlled environment using Arduino-based monitoring and control. The system integrates sensors such as DHT11, water level, TDS, and turbidity sensors to track temperature, humidity, nutrient levels, and solution quality. An air pump ensures root oxygenation, while a flexible lighting setup supports plant growth. Voice alerts and scheduled music playback via the APR33A3 module enhance interactivity, with real-time data displayed on a 16×2 LCD. This compact 2-foot model demonstrates an efficient, low-cost solution for sustainable, soil-less cultivation.

Keywords: Smart Agriculture, Remote Monitoring, Sustainable Farming.

I. INTRODUCTION

As the popularity of hydroponic systems continues to rise for cultivating plants, there's a growing need for efficient maintenance solutions due to their dependency on precise environmental control. This paper introduces an embedded-driven smart hydroponic system designed to address these challenges. By deploying sensors to monitor vital parameters like temperature, humidity, and nutrient levels, the system dynamically regulates water flow and nutrient concentrations to ensure optimal growing conditions.

The system integrates various sensors such as DHT11 for temperature and humidity, soil sensors for monitoring the hydroponic and nutrient tanks, and TDS and turbidity sensors for checking nutrient quality. It also includes an air pump for oxygen supply, a flexible light roof for adjustable lighting, and a voice module for alerts and music playback. With these features, the system ensures continuous monitoring, timely alerts, and a controlled environment—helping plants grow efficiently with minimal manual effort.

II. LITERATURE REVIEW

[1] Ravi Lakshmanan et al., discusses that to make the process of growing and monitoring food hydroponically easier, the Internet of Things concept has been integrated into the system. By offering a platform for monitoring the entire system from the cloud and lowering the cost of maintenance by a little amount, the Internet of Things addresses one of the major issues with automation that exists today: maintenance.

[2] Mohanty et al. Using a public dataset of 54,306 images of diseased and healthy plant leaves collected under controlled conditions, they trained a deep convolutional neural network to identify 14 crop species and 26 diseases. The trained model achieves an accuracy of 99.35% on a held-out test set, demonstrating the feasibility of their approach.

[3] Muhammad E. H. Chowdhury et al., have created a hydroponic system with machine learning algorithms that can be aided by the IoT platform's ability to extract data into CSV files, and the system can generate a significant volume of data appropriate for training both classical and deep learning algorithms to improve the performance of automated systems for regulating. The option of doing several other investigations has been made possible by this study. Through this wireless platform, it is also possible to study and track the comparative growth of field plants and organic plants.

[4] Savvas, proposed two alternative techniques for automatic nutrient replenishment in closed-loop hydroponic systems. Both proposed systems use electric conductivity and pH as input and addition of nutrients or freshwater as output. The

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first system uses several pumps (one for each nutrient and another for freshwater) while the second has only two pumps (one for fertilizer and the other for freshwater). The author concluded that both systems can be used in replenishing nutrients in hydroponic systems.

[5] Prathima et al. implements the hydroponic automation system. This research successfully makes a fully controlled and automatic hydroponic system with ESP32 and all sensors. This system is very suitable in all regions regardless of the environment and can be set up in a small space.

[6] Saenz et. al developed strawberries collecting a robot for greenhouse hydroponic systems. The proposed system uses artificial vision for identifying the stage of ripeness based on the redness of the strawberries. The system is developed using OpenCV libraries and Arduino Mega for the image processing (sensor), while PUMA manipulator simulates using Solidworks and MatLab for the robotic arm (Actuator). The authors focus their automation on harvesting crops rather than their cultivation. The proposed system automates the harvesting of crops, which helps reduce labor cost and the introduction of pests and diseases often brought in by workers into the hydroponic system. The system has shown good performance. It can also be used in harvesting other crops. The system's use of Arduino microcontrollers for image processing may cause an increase in the latency of the proposed system.

[7] Dbritto et. al developed an automated hydroponic system for growing Tomato F1 Hybrid Suhyana seeds. The system is an indoor hydroponic system where the amount of water, light, nutrients, and temperature are controlled using Raspberry Pi 3 model B. The authors classify readings from the sensor as follows; Temperature Levels (Cold, Warm, Hot), Water Levels (Low, Normal, High), pH levels (Acid, Neutral, Alkaline) and Light Intensity Levels (Low, Normal, High). They argue that categorizing the reading will make it easier for researchers to develop a model to automate a system whose output is still appropriate or inappropriate. The paper concluded that their taxonomy system can be used for an AI-controlled hydroponic system. However, classification of data to universal categories may be difficult since each plant has a different requirement which may not necessarily fall in the range of other plants.

[8] Arif et al. argue that plants require different nutrients as they age. Therefore an automated hydroponic system needs to be able to determine the age of a plant in order to ensure accurate nutrient supply. The authors investigated the performance of 3 classical machine learning classifiers: decision tree, Naive Bayes, Multi-Layer Perceptron; and one type of deep neural network in detecting the freshness of vegetation harvested from a hydroponic system. The proposed system uses image processing and machine learning technologies to detect fresh and withered vegetables. The experiment shows that the decision tree (J48) model was found to have the best accuracy of 98.12%. This system can be used in harvesting and/or monitoring the health of crops grown in a hydroponic system. Also, develop a system that determines the age of plants from their picture using digital image processing technique. The proposed system uses Raspberry Pi 3, a camera module to acquire and process that information which is then saved in a web server. The system is deployed in an NFT (Nutrient FilmTechnique) hydroponic lettuce farm. The authors used vegetation cover to deduce the age of the plant. Vegetation cover is obtained using pixel count after masking to isolate the plant. The proposed system requires neither training nor a dataset. The proposed system is able to predict the age of plants with an accuracy of 80%. However, the correlation between the age of a plant and its vegetation cover must be known.

[9] Chowdhury, Muhammad EH, et al. The aim of this work is to design and construct an indoor automatic vertical hydroponic system that does not depend on the outside climate. The designed system is capable to grow common type of crops that can be used as a food source inside homes without the need of large space.

[10] Amit Kumer Podder et al. In this paper, an IoT based Smart AgroTech system is proposed in the context of urban farming that considers humidity, temperature, and soil moisture as necessary farming parameters. The proposed system decides whether the irrigation action should begin or stop depending on the farming land condition and provides the monitoring facility and remote control to the farm owner.

III. METHODOLOGY

The proposed Smart Hydroponic System begins with system initialization where the Arduino microcontroller coordinates all connected hardware. Sensor data including temperature, humidity, water level, TDS, and turbidity are continuously read and processed, while the real-time values are displayed on a 16×2 LCD for user monitoring. Whenever the water or nutrient level decreases below the threshold, the system triggers a voice alert through the APR33A3 module to notify the user. An air pump is automatically activated at predefined cycle intervals to ensure proper oxygen supply to plant roots. Lighting is manually adjusted according to plant height using a flexible roof-mounted bulb system. Additionally, the system is programmed to play recorded music automatically in the morning and evening via the voice module. This entire

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monitoring and control cycle operates in a continuous loop to maintain the optimal growth environment for plants.

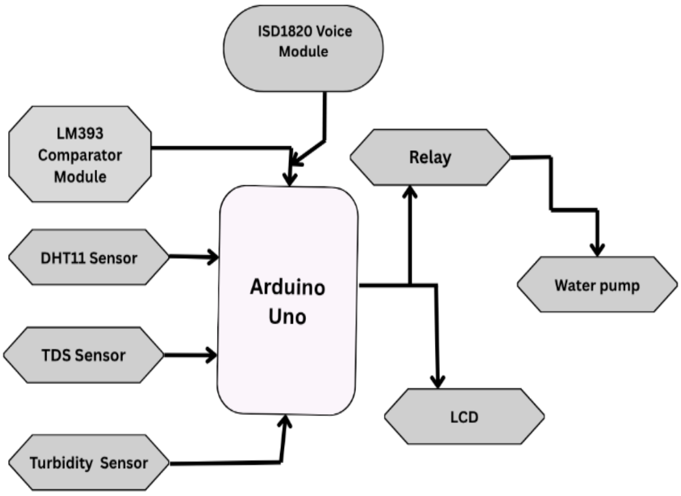

fig 1. block diagram of the system

FLOW CHART

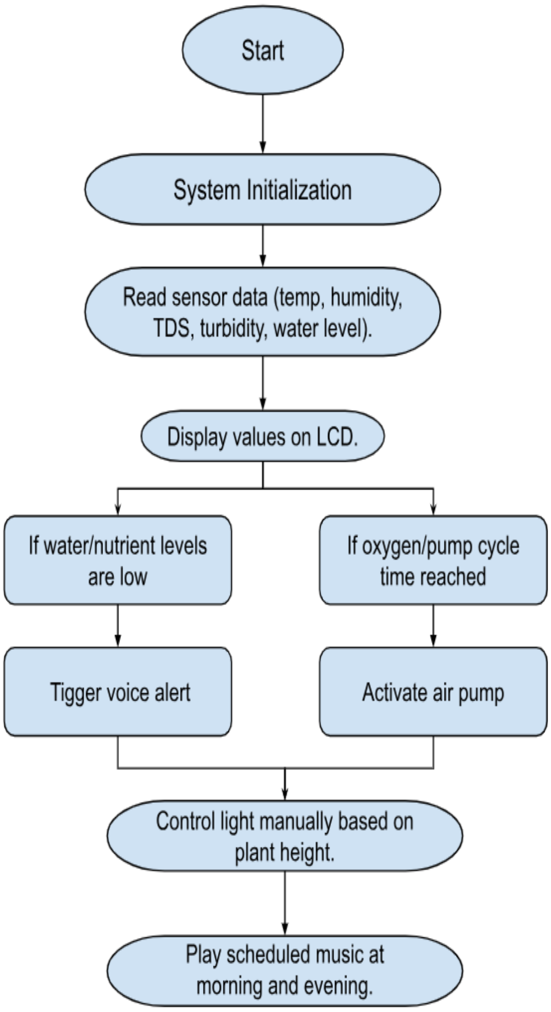

fig 2. flow chart of the system

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WORKING

The Smart Hydroponic System works by continuously collecting data from sensors that measure temperature, humidity, water level, TDS, and turbidity. The Arduino processes this information and shows the live readings on a 16×2 LCD so the user can easily monitor the plant environment. When the water or nutrient solution becomes low, the system automatically gives a voice alert using the APR33A3 module. The air pump turns on at set intervals to provide oxygen to the roots, while the lighting height is manually adjusted based on plant growth. The system also plays pre-recorded music at fixed morning and evening timings. All these actions run in a loop, helping maintain a suitable and healthy environment for plant growth.

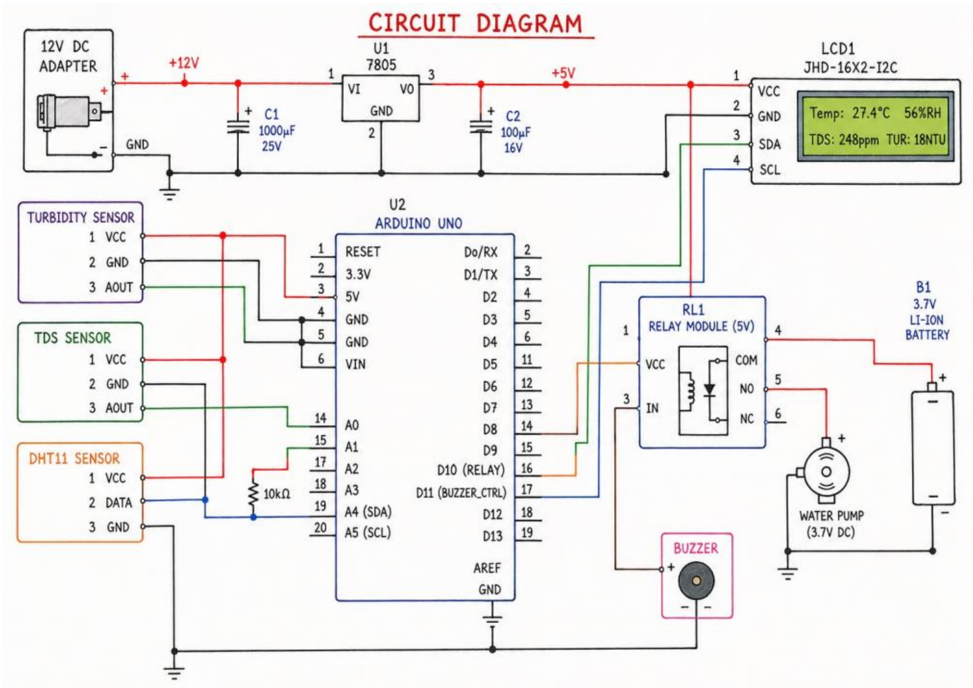

fig 3. circuit diagram of the system

IV. SYSTEM REQUIREMENT

HARDWARE REQUIREMENT

- Arduino UNO
- DHT 11 Sensor
- LM393 Comparator Module
- APR33A3 Voice Module
- Turbidity Sensor
- 16x2 LCD
- TDS Sensor
- Relay
- Pump
- LED

SOFTWARE REQUIREMENT

- Arduino IDE
- Proteus

V. DISCUSSION

The graph illustrates the growth of spinach and rosemary measured on Day 1, Day 7, Day 14, and Day 20 in a hydroponic system. It is evident that spinach grows more rapidly compared to rosemary under these conditions. From the early stages, spinach shows a noticeable increase in height, and this growth continues consistently throughout the observation period. On the other hand, rosemary exhibits a slower and more gradual growth pattern. Although it does increase in height over time, the rate of growth is not as high as that of spinach. The difference between the two plants becomes more prominent by Day 14 and Day 20.

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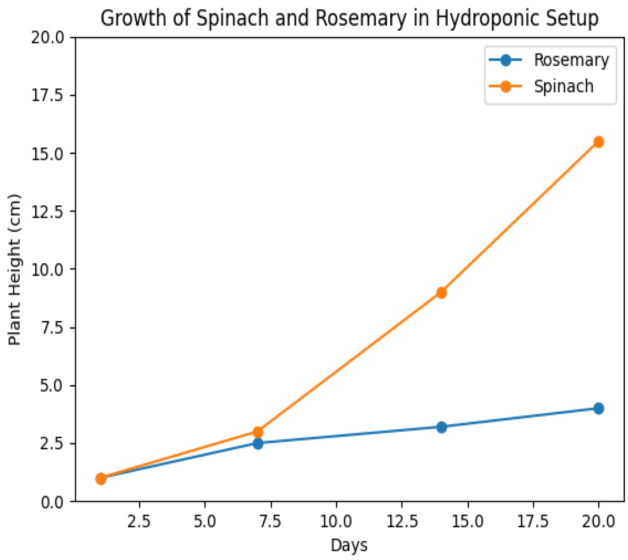
This variation in growth can be attributed to the nature of the plants. Spinach responds very well to hydroponic systems because it can quickly absorb nutrients directly from the solution, leading to faster development. In contrast, rosemary is naturally adapted to soil environments and therefore takes more time to adjust to hydroponic conditions.

fig 4. graph of spinach & rosemary in hydroponic setup



The graph shows the growth pattern of rosemary and spinach grown in soil over a period of 20 days. Both plants start at the same initial height on Day 1, but their growth trends begin to differ as time progresses.

In this setup, rosemary exhibits faster and more consistent growth compared to spinach. By Day 7, rosemary has already surpassed spinach, and this difference continues to increase through Day 14 and Day 20. At the end of the observation period, rosemary reaches the highest height, indicating better adaptation to the soil conditions.

On the other hand, spinach shows slower growth in comparison, with a more gradual increase in height. Although it continues to grow steadily, it does not match the growth rate of rosemary in this environment

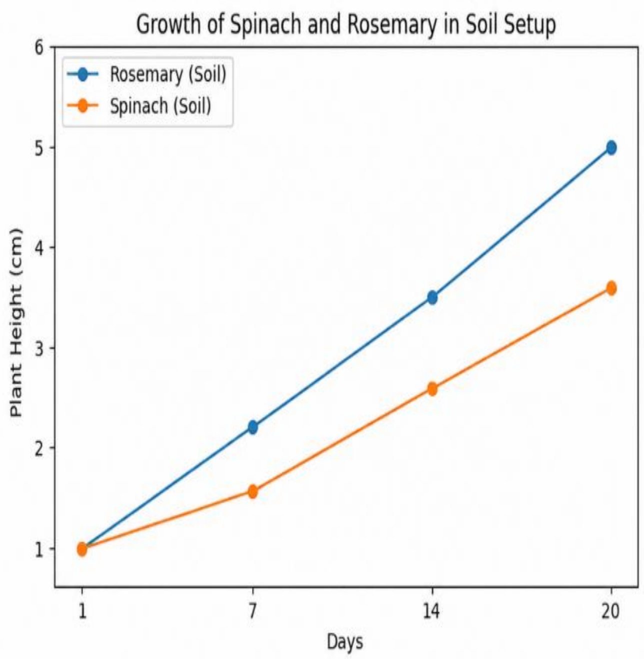


fig 5. graph of spinach & rosemary in soil setup

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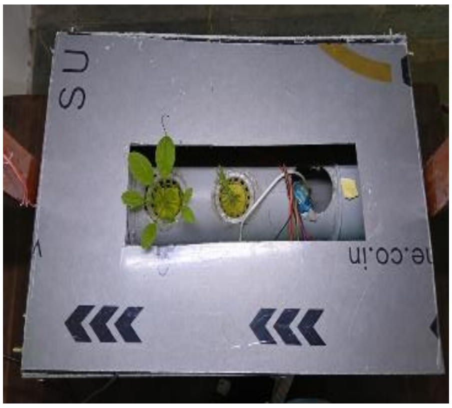
Day 1

Day 7



Day 14

Day 20

fig 6. hydroponic setup plants

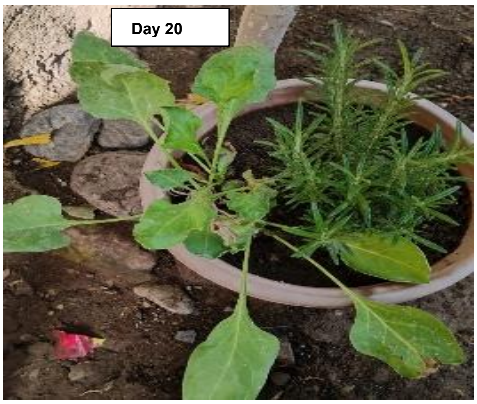


fig 7. soil based plant

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VI. EXPERIMENTAL SETUP AND RESULT

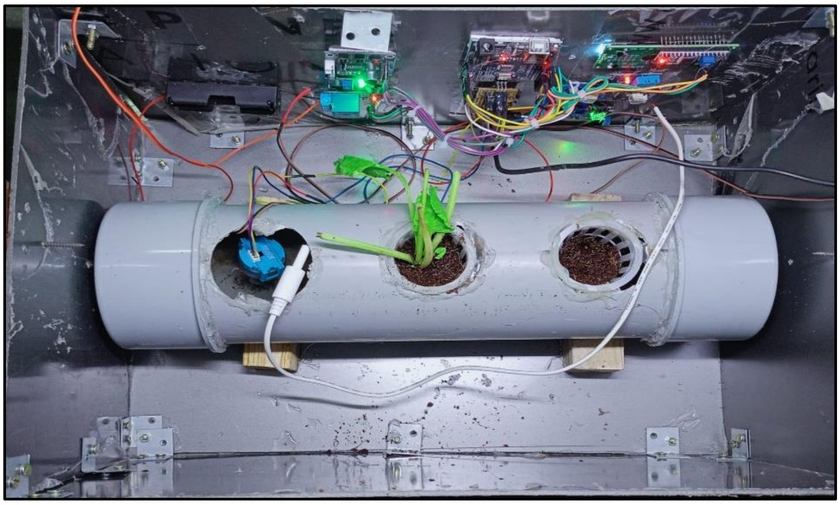

Fig 8.top view of the experimental system

fig 9. front view of the experimental setup

VII. RESULT

The Smart Hydroponic System successfully maintains an ideal growing environment by continuously monitoring and controlling key parameters such as temperature, humidity, water level, TDS, and turbidity. The system accurately displays real-time readings on the LCD and provides timely voice alerts whenever water or nutrient levels drop, ensuring immediate user action. The automatic air pump cycles improved oxygen supply to the plant roots, while scheduled music playback and adjustable lighting supported healthy plant development. Overall, the system demonstrated stable performance, reduced manual effort, and ensured consistent plant growth throughout the testing period.

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VIII. CONCLUSION

The implementation of a smart hydroponic system represents a significant advancement in agricultural technology. By integrating IoT-based monitoring and control mechanisms, this paper offers a sustainable and efficient solution for cultivating plants in controlled environments. The utilization of NodeMCU-based IoT frameworks enables real-time data collection and management, facilitating precise adjustments to environmental parameters such as humidity, temperature, and soil moisture. With its ability to optimize resource utilization, mitigate risks associated with traditional farming practices, and enhance crop productivity, the smart hydroponic system holds great promise for revolutionizing modern agriculture. Through continued research, development, and implementation efforts, this innovative approach to farming has the potential to address key challenges in food production and contribute to the development of more resilient and sustainable food systems for the future.

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