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FABRICATION AND DEVELOPMENT OF IOT BASED MONITORING SYSTEM FOR HYDROPONICALLY GROWN PLANT

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ABSTRACT

Hydroponic farming has emerged as a sustainable and efficient method of agriculture, offering precise control over environmental conditions for plant growth. However, to maximize yields and ensure optimal plant health, continuous monitoring of key parameters such as temperature, humidity,pH level, nutrient concentration, and light intensity is essential. In this context, IoT-based monitoringsystems present a promising solution by providing real-time data collection and remote access capabilities.

This paper outlines the fabrication and development of an IoT-based monitoring system tailored specifically for hydroponically grown plants. The system integrates various sensors to capture environmental parameters, a microcontroller for data processing and communication, and a cloud-based platform for data storage and visualization.

The first step involves defining the requirements of the monitoring system, including selecting appropriate sensors based on the parameters to be monitored. These sensors are then integrated with amicrocontroller board, such as Arduino, which collects data from the sensors and transmits it to the internet using Wi-Fi connectivity.

Data is subsequently stored and processed on a cloud platform, enabling users to access real-time information and historical trends through a user-friendly interface. The interface provides insights into the health and growth conditions of the plants, facilitating informed decision-making and timelyintervention when necessary.

Through rigorous testing and deployment in a hydroponic setup, the developed monitoring system demonstrates its efficacy in optimizing plant growth conditions, improving resource utilization, andultimately enhancing yields.

Overall, this IoT-based monitoring system offers a scalable and cost-effective solution for hydroponic farmers, empowering them to achieve greater efficiency and productivity in theiragricultural endeavors while minimizing environmental impact

INTRODUCTION

Tomato (Solanum lycopersicum L.) is a widely cultivated vegetable belonging to the Solanaceae family, predominantly self-pollinated with large global production. It is botanically classified as a fruit due to its berry structure and is known for being low in fat and cholesterol while rich in lycopene, a beneficial antioxidant.

Hydroponic farming, a soil-less growing technique, is gaining popularity due to its efficiency, requiring less space, water, and pesticides compared to traditional methods. This report focuses on automating a small-scale hydroponic system for growing sweet basil, considering vital parameters such as pH, nutrient levels, oxygenation, and sunlight exposure.

The project scope involves developing a mechatronic-based hydroponic system capable of housing six sweet basil plants. The system will monitor and adjust pH and nutrient concentrations automatically to maintain optimal growth conditions. The chosen method, Deep Water Culture (DWC), keeps plant roots submerged in nutrient-rich water, ensuring

Key components of the system include an electric conductivity (EC) sensor to measure nutrient levels, and an air pump for oxygenation. Nutrient solutions, essential for hydroponic growth, provide macronutrients and micronutrients vital for plant health.

The report outlines the benefits of active hydroponic systems, which use pumps to circulate nutrient solutions, versus passive systems that rely on gravity or capillary action. The DWC method offers highly oxygenated water, reducing maintenance needs and nutrient consumption.

Specific objectives include automating system regulation, understanding measurement techniques for key parameters, and optimizing nutrient levels for sweet basil growth. The project aims to demonstrate the feasibility and benefits of hydroponic technology for efficient, controlled indoor farming.

METHODOLOGY

1. System Design and Planning:
- Define the objectives and requirements of the hydroponic system, including the types of plants to be grown and the desired environmental conditions.
- Select appropriate equipment, such as containers, pumps, sensors, microcontrollers, and communication modules.
- Design the layout of the hydroponic setup, considering factors like space availability, sunlight exposure, and accessibility to power sources and internet connectivity.

2. Hardware Setup:
- Assemble the hardware components according to the system design, ensuring proper connections and placements.
- Install the microcontroller (e.g., Arduino Uno) and connect it to sensors for monitoring parameters like pH, nutrient levels, temperature, and humidity.
- Integrate actuators such as pumps and relays for controlling nutrient solution circulation, pH adjustment, and other system operations.
- Configure the communication module (e.g., WiFi module) to enable data transmission between the hydroponic system and IoT platform.

3. Sensor Calibration and Testing:
- Calibrate sensors to ensure accurate measurement of environmental parameters.
- Conduct preliminary testing of sensors and actuators to verify their functionality and performance.
- Validate sensor readings against known standards or reference values to ensure reliability.

4. IoT Platform Setup:
- Choose an IoT platform or develop a custom solution for data management, visualization, and control.
- Configure the IoT platform to receive data from sensors, display real-time measurements, and enable remote monitoring and control.
- Implement security measures to protect data integrity and prevent unauthorized access to the system.

5. Data Acquisition and Processing:
- Set up data acquisition routines on the microcontroller to collect sensor readings at regular intervals.
- Process sensor data to extract relevant information and identify patterns or anomalies.
- Implement algorithms for decision-making, such as threshold-based control for automated actions based on sensor readings.

6. Remote Monitoring and Control:
- Access the hydroponic system remotely through the IoT platform, using web or mobile interfaces.
- Monitor real-time environmental conditions and receive alerts for any deviations from predefined thresholds.
- Control system parameters remotely, such as adjusting nutrient levels, pH, or activating irrigation pumps as needed.

7. Maintenance and Optimization:
- Regularly inspect and maintain hardware components to ensure proper functioning of the hydroponic system.
- Calibrate sensors periodically to maintain accuracy and reliability of measurements.
- Optimize system settings and algorithms based on feedback and performance data to improve efficiency and productivity.

8**. Data Analysis and Decision Support:**
- Analyze historical data collected from the hydroponic system to identify trends, correlations, and areas for improvement.
- Use data analytics techniques to optimize resource usage, maximize crop yield, and minimize operational costs.
- Utilize decision support tools to make informed decisions regarding nutrient management, crop scheduling, and system maintenance.

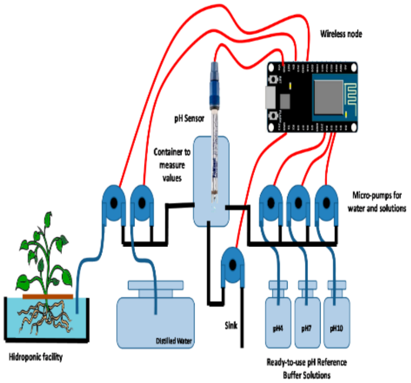
EXPERIMENTATION

In common, the clean drinking water has the following water quality parameters. Thisis shown in Table 4.3. These water quality parameters were used as set point values ofPRC to observe the water quality of water resources. These setpoint values were programmed into the Arduino Uno controller using Prominent Rule model-basedControl and IoT script monitoring algorithm (PRC) with Arduino programming language.

Parameter	Set Point Value	Water Quality
pH	7.0	Pure drinking water
	Less than 7	Acidic water
	Greater than 7	Basic
Temperature	25degree to 99degree Celsius	Drinking water
Conductivity	5 to 50ms/m	Pure drinking water
	Greater than 50ms/m	Sea water
Turbidity	Less than 5NTU	Pure drinking water

The PRC initially started the process, all four sensors sensed the water quality parameters such as pH, temperature, conductivity, and turbidity of water resources andtransferred the sensed data to the Prominent Rule Controller through TDM. The PRC made a comparison between the set point value and the measured value, based on the error it took control action by sending an SMS alert to the nearby Water Quality Monitoring Center. It also stored the measured water quality parameters in the cloud ofIoT through the PRC algorithm. Data storage space was received from Azure. A separate DNS (Domain Name System) was introduced for this water quality monitoringresearch. The DNS created is given as follows.

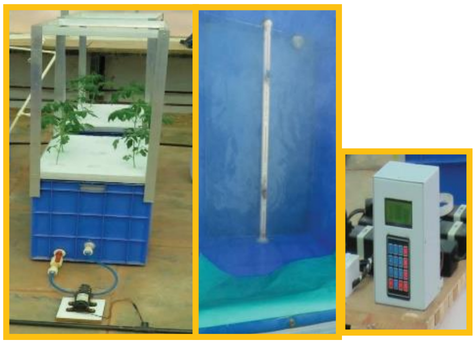
A separate Internet Protocol (IP) address was assigned for this research with a securitykey to store data in the cloud. So we can store the data in the cloud in a secure manner.Any person who knows the IP address and security key can easily monitor the water quality of water resources from any place in the world. The data flow of the PRC algorithm to store data in the cloud is shown in Figure 4.15. The control and monitoringprocedure of Prominent Rule Model-Based Control and IoT script monitoring Algorithm is explained in Table 4.4. In the framework script of AQUA CARE-IoT, theservices are composed of different parts like Sensor Devices, Agent Servers, Agent Clients, and Hosts as applications. Hydroponic crops allow to produce without depending on the soil and therefore on its quality and condition. In this way, we could produce anywhere, enabling production closer to the place of sale and/or consumption. Among the advantages of this, we find:



CLOUD STORAGE

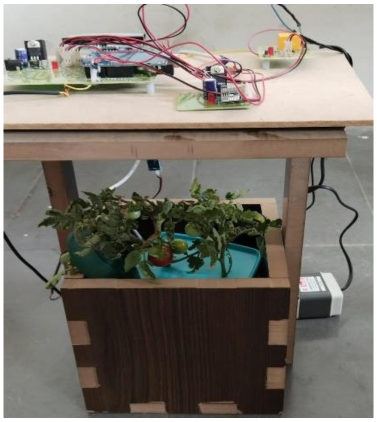
Cloud storage is a cloud computing model in which data is stored on remote servers accessed from the Internet. It is maintained, operated, and managed by a cloud storageservice provider on servers built on virtualization techniques. A separate cloud was developed to store the measured parameters from PRC. A separate Internet Protocol (IP) address and user authentication security key were developed by the PRC algorithm.So. any person who knows the IP address and security key can view the stored data online. If the measured value exceeds the set point value the PRC immediately sends an alert SMS (Short Message Service) to the nearer water quality monitoring center. In offline (that is no Internet connection) conditions also the water quality monitoring center can receive an SMS alert from this PRC water quality monitoring system.

The received data from PRC are stored in the hard disc of cloud storage, for this researchprivate cloud was used. Its allowable memory capacity is 10GB. So the water quality monitoring center can use the stored data for future reference also.



SAMPLE WATER ANALYSIS

A container of water was taken as a model, and all four sensors were immersed in the water. The sensor senses parameters such as pH, temperature, conductivity, and turbidity. The sensed values were transferred to the TDM through a Signal conditioner.If the measured values were weaker in magnitude signal conditioner was used to amplify the signal level. If the measured values have a very high magnitude, an attenuator circuit in the signal conditioner was used to reduce the signal amplitude to the appropriate level. If the measured value is contained with noise it gets removed bya filter circuit present in the signal conditioner. The conditioned signal is transferred tothe TDM. It receives all four signals and it allows only one input to reach the output. Based on the different time slots (milliseconds interval) all the water quality parametersreach the Prominent Rule Controller (PRC).



The PRC makes a comparison between a measured value and a set point value. Basedon the deviation, it shows the water quality results on the LCD. If the water quality parameter exceeds the threshold value, immediately the system sends the SMS alert tothe nearer Water Quality Monitoring Center in that particular area. In this model, a new Prominent Rule Model-

Based Control and IoT script monitoring Algorithm (PRC) was developed, to store the data in the cloud atmosphere and also used to secure the data from unauthorized access. Figure 4.17 shows the sample water analysis of the PRC model. The same analysis is performed for ten different water samples.

RESULTS AND DISCUSSION

The water quality monitoring system using Prominent Rule model-based Control and IoT script monitoring algorithm web page display snapshots are given in Figure 4.18.

The results of the investigation entitled "Innovative approaches through hydroponics and aeroponics for hybrid seed production in tomato (Solanumlycopersicum L)" are presented and discussed under the following headings

6.1 Standardization of nutrients and pH for hybrid seed production of tomato.

6.2 Comparison of conventional, hydroponics, and aeroponics systems of seedproduction.

6.3 Economics of hybrid seed production through aeroponics, hydroponics, andconventional systems in tomato.

6.1 Standardization of nutrients for hybrid seed production of tomato underaeroponics

Tomato is an important vegetable crop that is in demand throughout the year. High-quality hybrid seeds are in greater demand, but meeting this demand on time is a challenging task by conventional methods. Thus, hydroponics and aeroponics methods

are way ahead for hybrid seed production. Among factors affecting hydroponics and aeroponics production systems, the nutrient solution is considered to be one of the mostimportant determining factors of seed yield and quality. Therefore, standardization of nutrient solutions is an important task for potential quality seed harvest in soil-less agriculture systems (Trejo-Tellez and Gómez-Merino, 2012). Different nutrient solutions viz., Chikkaballapur, CPRI, Hoagland's, Ethiopia, USDA, and Komosa(Table 3.3) were studied to understand the effect of the different nutrient combination for tomato hybrid seed production by recording plant growth parameters at everyday intervals from the date of transplanting up to 25 days after transplanting.

6.2 Comparison of conventional, hydroponics, and aeroponics systems of seed production

Parental lines TAG1F (P1) and TAG2F (P2) were divided into two halves and treated with thiram @ 2g kg-1 (S1) and chlorpyrifos @ 3g kg-1 (S2) were sown into portrays for twenty- eight days and then transplanted into conventional (M1), hydroponics (M2) and aeroponic (M3)system. Growth parameters like plant height, plant spread, leaf area index, and plant growth rate were recorded at 10-day intervals from the day of transplanting to 110 days after transplanting. The data on plant height at the 10th, 20th, 30th, 40th, 50th, 60th, 70th, 80th, 90th,100th, and 110th days after transplanting as influenced by different methods of hybrid seed production, parental line, and seed treatment are represented in Table 4.5-4.17.

Effect of pH on fruit formation under an aeroponic system in tomato

Economics of hybrid seed production in tomato through aeroponics, hydroponics, and conventional system

The cost and return analysis plays a significant role in farm economics as it supports decision-making at various levels: the farmers, researchers, policymakers, bankers, and administrators. As the hybrid seed production of tomatoes in the soil-less method is an innovative approach thus it is necessary to analyze the cost and benefit ratio. The cost and return structure of hybrid seed production of tomatoes in conventional, hydroponics, and aeroponics was calculated and presented in Table 4.34-4.35.

Based on the economic calculation, it was found that the total cost (variable + fixed) involved was found higher in aeroponic (Rs. 1547243/-), followed by hydroponic (Rs. 1507220/-) and lower cost in the conventional method (Rs. 887807/-) of hybrid seed production.

The variable cost involved the working capital cost and it was comparatively lower for the conventional method (Rs. 592503/-) followed by aeroponics (Rs. 626883/-) and it was found higher in hydroponics (Rs. 720944/-). As due to the cost incurred for nutrients was higher in hydroponics (Rs. 243424/-), followed by aeroponics (Rs. 90789/-), and lower was recorded in conventional (Rs. 22000/-) (Appendix-I). Fertilizer amount calculation was made based on the amount of nutrients consumed per plant for soil-less agriculture and for conventional method-based recommended dosage. The rate of insecticides, bactericides, and fungicides spray was 50 percent higher for the soil system than compared to the protected cultivation.

CONCLUSION

In conclusion, with evidence from our experiments and data, our hypothesis was proven to be incorrect. We believed that growing vegetables in hydroponics was better than growing vegetables in soil, but in fact, it was the opposite. Although most factors such as colour were the same, the pole beans in soil grew taller/faster than the ones in the hydroponic system and may have seemed healthier. Most of the bottom leaves from the beans in the hydroponic system had brown and yellow edges, while the ones in soil did not. On top of this, the beans growing in soil had much more activity than the ones in hydroponics. They intertwined with each other more, and always grew bigger after moving towards the light, while the ones in the hydroponic system did not have as much activity.

Even in terms of cost, soil uses less money. Hydroponic systems require lots of equipment and materials, some which could be quite pricey. An example of this would be the nutrient solution. The nutrient solution was the item that cost the most, and it could not have been omitted, as it was essential to the hydroponic system. Other equipment that cost money, was the electricity. We had the lamps on for 24 hours every day, which also could be pricey. Growing vegetables in soil would not require that much electricity, since they can simply be grown outside with natural sunlight.

With all these factors in mind, we can confidently say that growing plants/vegetables in soil is better than growing them in a hydroponic system.

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Lei, C., & Engeseth, N.J. (2024). Comparison of Growth and Quality between Hydroponically Grown and Soil-grown Lettuce under the Stress of Microplastics. ACS ES&T Water It can be concluded bran the above literature that the soil-less culture is efficient in producing tomatoes and other vegetables over a conventional system. Thus the present experiment was designed to standardize the hybrid seed production for tomatoes