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Smart Farming of Leafy Vegetables Using Hydroponic System

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ABSTRACT: agriculture plays an important role in the development of a nation. By 2050, human population is expected to reach 8.9 billion and an increased population requires adequate supply of fresh produce. This problem can be solved by smart agriculture and modern implementation using Internet of Things (IoT) technologies. Hydroponics is a soil-less cultivation that uses minerals from nutrient solution. The parameters to be considered for hydroponic system include pH level, electrical conductivity (EC), dissolved oxygen (DO), water temperature, water flow rate and water level of nutrient solution. There are 6 types of hydroponic system: nutrient film technique (NFT), drip system, water culture, ebb and flow system, geophonic and wick.

KEYWORDS: Soil less culture, hydroponic, NFT, automatic, agriculture

I. INTRODUCTION

The world's increasing population and worsening environmental conditions pose significant challenges to the agricultural sector. However, the Internet of Things (IoT) offers hope for addressing these challenges through smart farming. By connecting "dumb" things to the internet, IoT devices can help farmers overcome obstacles such as climate change, pollution, and loss of soil integrity. Analysts predict that the smart farming industry will be worth \$23.14 billion USD by 2022, with 75 million IoT devices being used for agricultural applications. Traditional farming faces numerous challenges to boosting output, including a declining workforce, dead roots, clogging, and the risk of infection in hydroponic farms. However, growers can use IoT devices to monitor water temperature, nutrient solution pH, and electrical conductivity to identify nutrient shortfalls and detect problems early on. Overall, IoT has the potential to transform agriculture, ensuring sustainable food production for a growing population while protecting the environment.

In [1], The AI-SHES method is a system that integrates hardware and software components to monitor and manage hydroponic plant growth. It uses a Raspberry Pi connected to sensors such as sunlight, water temperature, pH, turbidity, and NPK soil sensors, along with a camera and output actuators such as fresh water pump, drain water pump, cooler, screen for data, and a shade motor. The Raspberry Pi collects and uploads plant statistics to an IoT cloud, which is served with the DLCNN algorithm. The Classification DLCNN model identifies plant diseases, while the Prediction DLCNN model compares nutrient data with input data to detect nutrient deficiencies. The IoT cloud monitors and saves data, and sends the user a message through the Agri-hydroponic mobile application in case of any problem. The user can then operate the farm manually or through automated mode, where the output actuators provide the necessary nutrients to the plants in the required amount specified by the user. Overall, the AI-SHES method helps in efficient plant growth monitoring and management for hydroponic farming.

In [2], a system for growing strawberries in a hydroponic environment, which uses IoT edge technology and Nano AI cloud to monitor and determine the timing for harvesting the plants. The system includes sensors and cameras connected to a Raspberry Pi, which collects data about the plant growth and stores it in a GPU workstation with AI cloud. The AI cloud compares the data to reference values and analyses the images to identify mature strawberries



ready for harvesting. The system was tested with over 1 million data sets over a 4-month period and was able to accurately detect harvest time using 1575 images.

Authors in [3] describes a hydroponic monitoring system that uses UV-Vis spectroscopy and AI to quantify the levels of nitrogen, phosphorous, and potassium in Hoagland solutions. The authors prepared stock solutions of N, P, and K and varied their concentrations to create a final matrix of 8^3 samples. Data acquisition was performed using LabVIEW-based software, and the proportions of each nutrient in the solution were determined. The system successfully achieved a balance between cost, reliability, and accuracy in nutrient absorption for hydroponic plants.

Paper [4] examined the effects of different pH modifiers on the growth and nutrient uptake of lettuce, basil, and Swiss chard in an Ebb and Flow hydroponic system. The pH modifiers used were pH Down, lime juice, and vinegar. The study found that a slightly acidic pH is preferable for hydroponic production. The results showed that pH Down had the highest fresh shoot weight for lettuce, basil, and Swiss chard, and also had a lower production cost compared to the other two modifiers. Therefore, pH Down is highly recommended as a modifier for hydroponic production.

Paper [5] presents an IoT-based control system for monitoring and controlling water quality parameters like temperature, dissolved oxygen concentration, and pH values using various sensors. The system uses Node-RED, web resources, and Influx DB for data processing and storage. The system sends an alert message when the parameters are not in the specific range and uses a peristaltic pump to pump the pH buffer solution to increase or decrease the pH accordingly. The paper also studied the transient response of the pump for different rotational speeds and recorded the time taken to dispense the solution and stabilize the pH. The results showed that the lowest average time taken to dispense the solution and stabilize pH was at a rotational speed angle of 40.

Paper [6] discusses hydroponic plant growing, which yields high-quality products with the help of nutrient solution and controlled environment. It is a modern agricultural technique that requires less soil and nourishes the plant with a mineral nutrition solution dissolved in water. Six different hydroponic systems can be used, including nutrient film technique (NFT), drip system, water culture, ebb & flow, geponics, and wick. Water needs to be delivered directly to the roots of the planted plants. Hydroponically grown plants grow faster than soil-grown plants and can locate the vital nutrients they need. The mixing tank is equipped with various sensors that can detect the pH, electrical conductivity, water temperature, and water level.

Paper [7] describes six types of hydroponic systems used for fodder production under controlled conditions of moisture and temperature. These include wicking system, deep water culture (DWC), drip system, aeroponics, ebb and flow system, and nutrient film technique (NFT). Each system has its advantages and disadvantages, and some can be combined to make hybrid hydroponic systems. Wicking system is the easiest to install, while NFT is considered the classic hydroponic cultivation system.

Paper [8] discusses the evolution of hydroponic systems from 6000 BCE to 2019, with different classifications based on system design, nutrient solution function, and plant growth media. Two types of substrates, fibrous and granular, are important for plant yield. Nutrients also play a critical role in hydroponic systems, with only 16 out of 60 elements being essential for plant growth, classified as main nutrients, macronutrients, micronutrients, and secondary nutrients.

Paper [9] discusses the use of an IoT system with sensors and a camera to monitor the growth and health of locally grown crops. The system uses deep learning algorithms to detect and diagnose diseases in plants by comparing images taken by the camera to a dataset of healthy and diseased leaves. The dataset is pre-processed and downsized to train the CNN models, which can detect diseases in crops with a high degree of accuracy. The system can help improve crop yield and quality by identifying and addressing potential issues early on.

Paper [10] describes an automated hydroponics system that utilizes various sensors to monitor and control plant growth parameters such as nutrient levels, temperature, humidity, and disease detection. The system is comprised of hardware components such as tanks, pumps, and a sensory network, as well as software components that analyse and



acquire data using the LabVIEW graphical user interface. Plants are grown hydroponically using nutrient solutions, and the system uses sensors to collect data at key points throughout the hydroponic farm to ensure accurate monitoring of plant growth parameters. The system allows for real-time analysis of data collected regarding plant growth rate, nutrient level, health status, etc.

II. MATERIALS AND METHODOLOGY

2.1 Materials:

The nutrient solution was prepared by two sets of commercially available mineral fertilizers with some varying macro and micronutrients Thresholding.

The nutrient solution was prepared by dissolving both the mineral fertilizers of macro and micronutrients with 1L of water respectively to produce two different stock solutions. The ratio of the mineral fertilizers to the water is 1:100. Then, 25 mL from each stock solution were added into another 25L of water. This was how the nutrient solution which has to be added was made and the ph. buffer solutions was prepared for the system to control by diluting pH up solution which contains 25% potassium hydroxide and pH down solution containing 50% food grade phosphoric acid at a dilution factor of 1:8 and 1:6 respectively.

The nutrient solution contained the below given elements in the table in their macro and micro nutrient

Potassium (K)	K ⁺	117.29	3.00
Calcium (Ca)	Ca ²⁺	80.16	2.00
Magnesium (Mg)	Mg ²⁺	24.31	1.00
Nitrogen (N)	Total N	105.06	7.50
	N(NH ₄ ⁺)	7.01	0.50
	N(NO ₃ ⁻)	98.05	7.00
Phosphorus (P)	Total P (HPO ₄ ²⁻ ; H ₂ PO ₄ ⁻) *	15.49	0.50
Sulphur (S)	SO ₄ ²⁻	32.08	1.00

Macronutrients:

Element	Ionic form	C(ppm)	C(mM)
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Table 2.1.1 list of Macronutrients

Micronutrients

Chlorine (Cl)	Cl ⁻	0.324	9.15
Boron (B)	BO ₃ ³⁻	0.250	23.12
Manganese (Mn)	Mn ²⁺	0.251	4.57
Zinc (Zn)	Zn ²⁺	0.025	0.38
Copper (Cu)	Cu ²⁺	0.0102	0.16
Molybdenum (Mo)	MoO ₄ ⁻	0.0053	0.06
Iron (Fe)	Fe ²⁺ ; Fe ³⁺ **	2.500	44.77
Sodium (Na)	Na ⁺	1.029	44.77

Table 2.1.2 list of Micronutrients



2.2Hardware:

The hydroponics system's temperature, light intensity, and pH values were measured by their respective sensor to collect the data. The sensors were calibrated following the manufacturer's instructions. A peristaltic pump was then utilized to regulate the addition of buffer solution to adjust the pH in the hydroponics chamber. This particular peristaltic pump includes a pulse position modulation (PPM) motor driver, which generates a control signal that is compatible with a standard motor. The peristaltic pump was controlled by microcontrollers. As a positive displacement pump, the peristaltic pump was capable of delivering up to 100 mL/min of fluid.

Sensors	Temperature Sensor	pH Sensor
Brand	GI Electronic	Inesa Scientific Instrument
Model Number	DS18B20	S 400
Operating Temperature (°C)	-55 to +125	0 to 105
pH Range	-	0-14
Power (V)	3 to 5.5	3.3 to 5
Accuracy	±0.5%	±0.1%

Table 2.2.1 list of Micronutrients

Motor Details:

Brand	Robotbanao
Voltage	8-12V
Flow rate	80-120 litre/hour

Table 2.2.2 list of motor details

Totally 3 water motors were used in this system, one was used for the flow of the nutrients solution in the whole system, and the other two were used for pH up and down flow respectively.

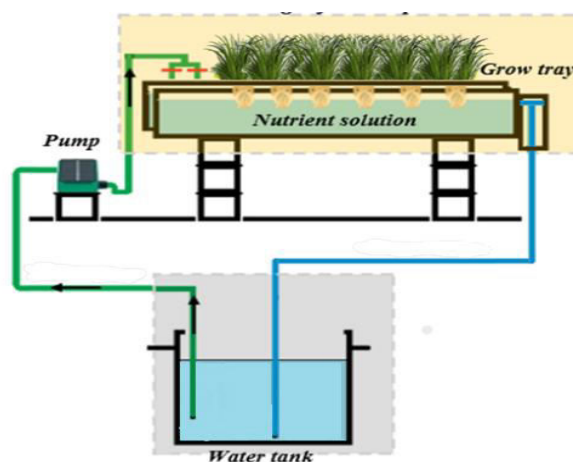


Fig 2.2 The Hydroponic setup



2.3 FLOW DIAGRAM

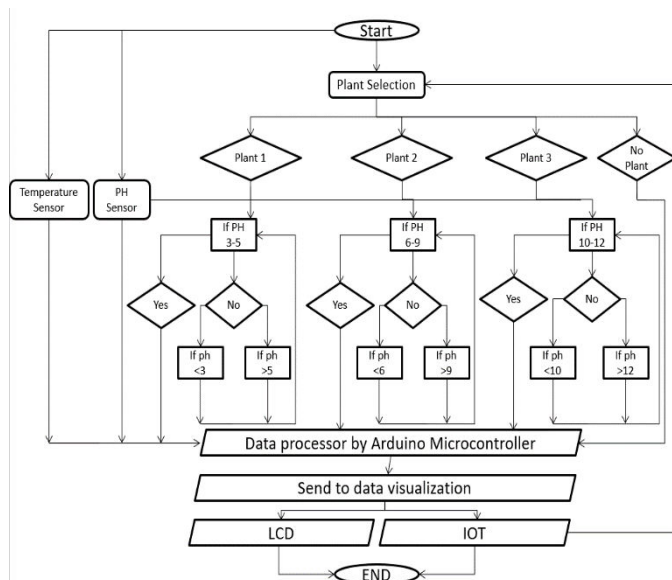


Fig 2.3 Flow diagram

The software and the Hardware will be integrated as mentioned in the above paragraph and then the further processing begins. According to the below given Block diagram the system will be functioning, firstly the temperature and the Ph sensor sense the temperature and Ph and further this data will be processed by the Arduino, which is used a processor. Then we have set up three different leafy vegetables, the selection of the plant which needs to be observed will be selected by the Blynk app.

For example, if we select plant 1, that plant will be set to some Ph between 3 to 5 and some temperature of 20 to 35 degree Celsius. If the Ph sensed by the sensor is not in the range of 3 to 5, Then the Up or down motor pumps the Ph up or Ph down solution Based on the condition of the solution respectively. It keeps on pumping the solution till the solution comes to its optimum range. There would be time delay of 3 seconds till concurrent checking of the solution. Then if the temperature is not in the given range, then Heater is used in order to increase the temperature of the solution. In the same way some Ph range is given to all the three plants and same process do happen with all the plants with respect to the Temperature and Ph of the Nutrient solution given to the Setup.

The second Plant used is Amarnath, which requires a Ph of 5.5 to 6.4 and the Optimum temperature required is 22 degree Celsius. The First Plant used is Meti, which requires a Ph of 7 to 9 and the Optimum temperature required is 24 degree Celsius. The First Plant used is Spinach, which requires a Ph of 6.5 to 8 and the Optimum temperature required is 24 degree Celsius. According to the above conditions the System will be working. Then a condition of NO PLANT is given in the Blynk app which is used to stop the process. All these data will be processed by the Arduino microcontroller used. Then it will be displayed in the LCD as well as the Blynk IOT app used and this app also provides the dataset of a week and we can also observe the graph of temperature and Ph fluctuating for analyses and for some further developments.

III. RESULTS AND DISCUSSION

3.1 TESTING AND FUNCTIONALITY

The system that was created followed a specific block diagram. To ensure that the device works as intended, testing was performed. This involved connecting the pH sensor and water temperature sensor to the control and monitoring device. Additionally, two mini water pumps were connected to the driver module device. These pumps are responsible for adding pH up or down solutions to the main solution based on the plant's needs. The main motor, which circulates the nutrient solution throughout the setup, is also connected to the driver module device. In summary, the system functions by monitoring the pH and temperature of the water, adjusting the pH levels with the mini water pumps, and circulating the nutrient solution using the main motor, all based on the specific requirements of the plants being grown.

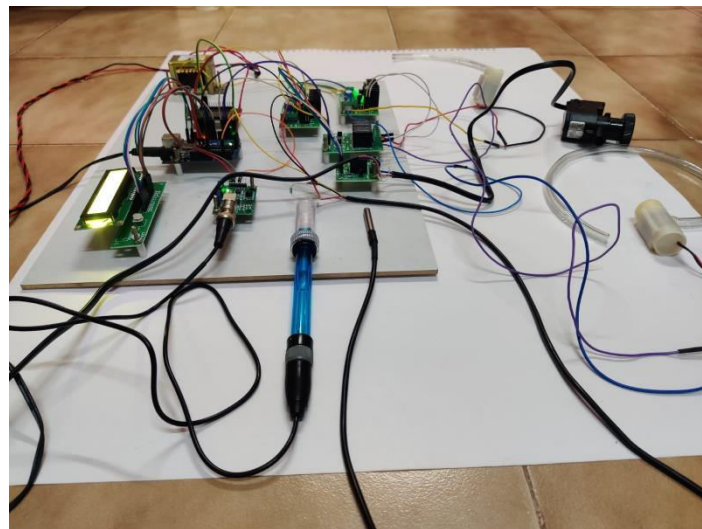


Fig 3.1 Control and Monitoring system of hydroponics integrated with sensors and actuators.

3.2 SYSTEM INTEGRATION AND EXPERIMENTAL SETUP

In the Hydroponic system, various sensors and actuators have been installed. This system was placed in an open environment, allowing for natural conditions. The Hydroponic control and monitoring system device, which was developed, was positioned on the growing support of the Hydroponic system.

To evaluate the effectiveness of the developed Hydroponic control and monitoring system, a field experiment was conducted. The experiment utilized the configuration as described previously. For this experiment, leafy vegetables were chosen as the cultivated plants.



Fig 3.2 the Hydroponic Setup

The Hydroponic control and monitoring system, along with its sensors and actuators, was tested in a real-world setting using a Hydroponic system placed outdoors. The experiment focused on growing leafy vegetables to assess the performance of the system.

3.3Growth of the plants



Fig 3.3.1 growth of the plants after 1 week in pH solution

After the germination in the soil, the spinach, amaranth, meti plants were transferred into the hydroponic system. The solution of 6-8 pH, 5-6 pH and 7-9 pH solution were supplied to the respective plants. After a week in the pH solution the plants were seemed to be growing healthy.



Fig 3.3.2 growth of the plants after 2 week in pH solution

The plants after a week in the solution, they had rapid growth as the nutrients required by plants was continuously being supplied by the hydroponic system.

3.3DISCUSSION

The functionality test conducted on the Hydroponic control and monitoring system yielded positive results. All sensors performed effectively in gathering the necessary parameters of the Hydroponic environment. The data obtained from these sensors was recorded in the charts for further analysis.

Furthermore, the functionality test revealed that all actuators responded appropriately to the signals sent by the controller. This indicates that the control system was able to successfully trigger the desired actions from the actuators.

During the four-week field experiment, leafy vegetables were grown in the Hydroponic grow tray. The developed device successfully maintained all the required growth parameters for the leafy vegetables, and these parameters were recorded for analysis. The pH and temperature charts captured the recorded data, which demonstrated that the control and monitoring system effectively maintained the nutrient solution parameters within the defined values, despite fluctuations caused by the nutrient absorption process.

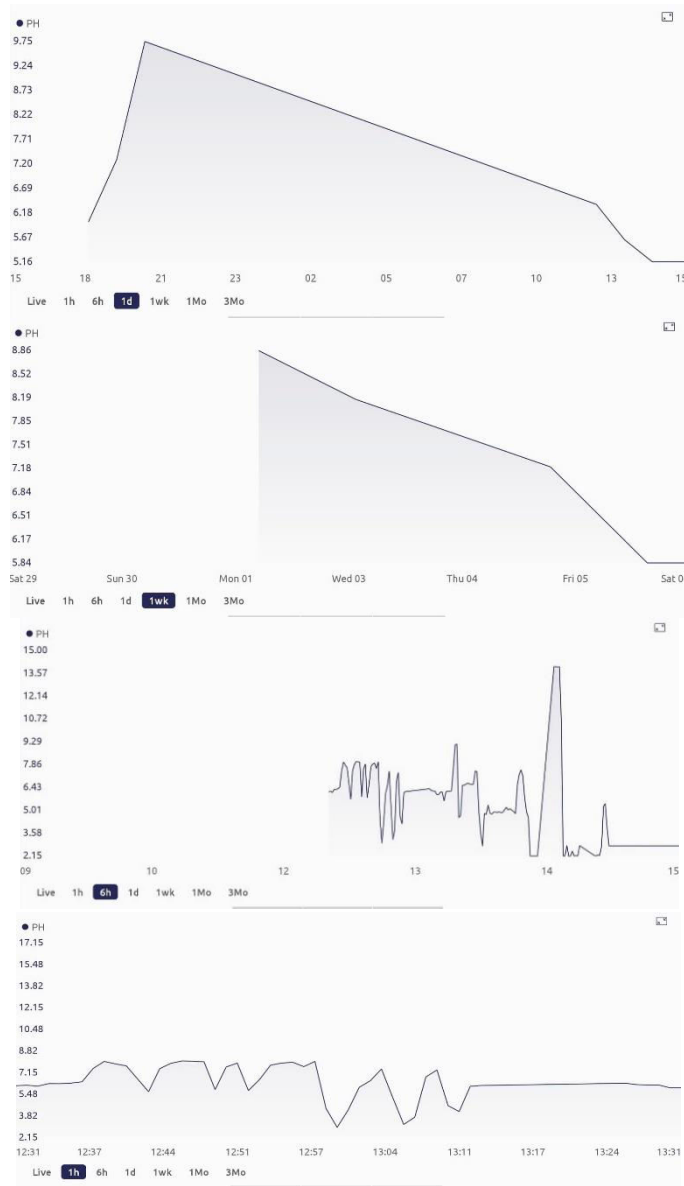


Fig 4.3.1 pH chart at various instances

These were the values of the pH solution absorbed by different leafy vegetables at various instances of time.

The field experiment results also highlighted the negative impact of uncontrolled Hydroponic nutrient parameters on plant growth. It was observed that when these parameters were not properly regulated, it had an adverse effect on the plants.

On the other hand, the field experiment demonstrated that the cultivation process was effectively controlled by the developed system. The leafy vegetables appeared fresh, healthy, and yielded a high harvest. The control and monitoring system significantly improved the quality of Chinese cabbages and shortened the time required for harvesting.



Fig 4.3.2 Temperature Chart at various Instances

Fig 3.3.2 shows the temperature values at the time of conducting the experiments which was required by the leafy vegetables.

In summary, the results of the field experiment confirmed the successful performance of the developed Hydroponic control and monitoring system. The system effectively maintained the necessary parameters for optimal plant growth, resulting in healthy and high-yielding leafy vegetables.

IV. CONCLUSION

The literature survey on AI-based soilless farming systems provided a comprehensive overview of the various techniques developed for cultivating crops without soil. These AI-based farming systems have proven effective in producing healthier crops, and they also offer the advantage of faster growth regardless of environmental conditions. However, the accuracy of these techniques relies on factors such as the nutrient solution and the specific environment created to provide optimal conditions for crop growth. Through analysis of the gathered information, it was determined that the accuracy levels, usage of algorithms, and key factors influencing the accuracy of these techniques were significant areas of study. Hydroponics is emerging as a promising solution for addressing polluted soil sites and preventing further degradation of the soil system. This sustainable and eco-friendly technology offers numerous advantages. While the initial capital expenditure may be high, hydroponics proves to be cost-effective in the long run due to minimal operational costs compared to conventional farming methods. It reduces labor costs through automation and utilizes sophisticated control devices that minimize maintenance expenses. Moreover, hydroponics addresses significant concerns related to food safety by eliminating issues like soil or water contamination and pesticide residues. As a result, the hydroponics industry is expected to experience exponential growth worldwide in the near future.

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