Empowering Agriculture with IoT Enabled Hydroponics System

A PROJECT REPORT

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The success and outgrowth of this design needed a lot of guidance and backing from numerous people, and I'm extremely fortunate to have their support each along the completion of my design work. Whatever I've done is only due to similar guidance and backing, and I would no way forget to thank them.

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ABSTRACT

Growing plants in the soil can be challenging as the land for cultivation is decreasing rapidly due to high population. In this scenario we need a soil-less cultivation method that can fulfill our needs. The aim of this project is to design and construct an automatic hydroponic system that does not depend on the outside climate. The designed system is capable of growing common types of crops that can be used as a food source inside homes. The system's design was created by evaluating various hydroponic systems to determine their compatibility for automation. A microcontroller served as the system's central processor, connecting with various sensors to regulate system settings and reduce the need for human involvement. An IoT platform was utilized for storing and showcasing system parameters and graphical interface for accessing remotely. The system can sustain optimal plant growth conditions with little user intervention. The confirmation of the entire system's functionality was achieved by assessing the responses of individual system parts and tracking them on the IoT platform. This system offers real-time notifications to alert the hydroponic system user when the reservoir's water level is low as well as the status of the system. Additionally, the system offers a vast array of data that may be crucial for plant researchers and enhances comprehension of how the main factors of the hydroponic system relate to plant development. The platform being suggested can be utilized for quantitatively improving the configuration of indoor/outdoor farming as well as for automating some of the most labor-intensive maintenance tasks. Furthermore, this monitoring system has the potential to be utilized for making important decisions at a higher level, once a sufficient amount of data has been gathered. As mentioned, the system does not depend on the outside climate, therefore we can grow summer vegetables in winter also.

Keywords: soil-less cultivation; hydroponics; microcontroller; automation; IoT; indoor farming

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CHAPTER 1

1.1 INTRODUCTION

Hydroponics [1], a modern approach to agriculture [2], involves growing plants without soil. While it seems simple, mastering hydroponics requires some effort. Plants are suspended in water and provided with essential nutrients [3]. Studies suggest that hydroponically grown crops can be more productive and nutritious [4] than those grown traditionally. Unlike soil-based [5] methods, hydroponics provides a direct nutrient delivery system [6, 7] to plant roots through a water solution.

Although hydroponics [8] is gaining popularity worldwide, India is still catching up on this technology [9]. However, its potential is immense, especially considering the environmental [10] challenges we face today. Hydroponics [11] boasts several advantages. It requires less labor and produces higher yields [12] due to faster plant growth compared to traditional farming [13]. Additionally, hydroponics uses significantly less water – up to 90% less compared to conventional methods. This allows farmers to cultivate [14] crops even during off-seasons and experiment with unique combinations, ultimately offering consumers a wider variety of fresh and healthy produce.

Despite its benefits, hydroponics comes with a major drawback – the initial setup cost. Setting up a hydroponic system [15] is considerably more expensive compared to traditional farming [16] methods. The system requires sensors [17], controllers [18], pumps, and lights to ensure optimal plant growth [19]. Additionally, maintaining the correct temperature [20, 21], using purified water, and providing essential nutrients like nitrates, phosphorus, and potassium is crucial for successful hydroponic cultivation [22, 23], as plants lack the natural filtering and nutrient delivery capabilities of soil.

1.2 MOTIVATION & CONTRIBUTION

The world needs a revolution in agriculture. Our growing population, shrinking farmland, and unpredictable weather threaten food security. Thankfully, a cool solution is emerging, combining hydroponics with the Internet of Things (IoT). IoT-enabled hydroponics tackles the limitations of traditional farming. Using sensors and data, we can create perfect growing conditions for plants, allowing us to farm year-round and use way fewer resources. This isn't just good for food security, it's also a win for the environment. Our project is all about exploring the potential of IoT-powered hydroponics for sustainable agriculture. We want to use data, automation, and precision farming techniques to completely change how we grow food. Our aim is to develop a simple, automated, and scalable cost-effective system which can be used by general people for personal farming as well as large scale farming. External environmental conditions are not in favor of farming in all the seasons. That's why we built this hydroponics system that consumes 90% less water than normal soil based farming. It is more effective because it is an eco-friendly method and it produces more food for everyone. Everyone can grow the basic vegetables in their house utilizing a small space of the house without increasing water and power consumption. This is the major motivation of our project and following are our contribution-

- **Prototype Development:** A prototype polyhouse was constructed to serve as the housing unit for the hydroponic system.
- **Integration of Sensors:** To monitor and maintain the ideal growing conditions for the plants, the project equipped itself with a variety of sensors, including temperature, pH, TDS, and ultrasonic sensors. To keep the plants healthy and growing, real-time data collection and analysis is essential.
- **IoT for Remote Monitoring:** Our project utilized Blynk, an IoT platform, to monitor our hydroponic system. This user-friendly app lets us track key sensors (temperature, pH, TDS) for real-time data on plant growth. Blynk grants remote access, ensuring informed decisions and a healthy environment for our plants.
- **Analyzed the Data for optimal plant growth:** By constantly monitoring sensor data, we fostered a data-driven approach to maintaining ideal plant growth conditions. Temperature readings ensured a consistent and optimal range, while information from the pH and TDS sensors allowed for precise adjustments to the nutrient solution, maximizing nutrient uptake by the plants. This real-time monitoring empowered us to proactively regulate ventilation, lighting, and nutrient levels, ultimately creating a flourishing environment for our plants.

CHAPTER 2

2.1 LITERATURE REVIEW

S. Jain & et al. [1] The EC and pH values of a hydroponic system must be within the ideal range for optimal nutrient uptake and plant growth. Keeping these parameters within the ideal range always requires constant detection and precision, because the longer the parameters deviate from the range, the lower the nutrient uptake by the plants. Manually identifying and adjusting values requires regular human intervention. An automation algorithm, able to detect parameters at regular intervals and automatically act to keep them in the ideal range, is essential for quality crop production in aquaculture. The proposed system detects the TDS and pH levels through the sensors, chooses the action to take when the parameters are not in the required range, calculates the duration for which the action will be taken and finally applies. it to bring the parameters to the site ideal. Compared to manual monitoring and control, the proposed automation system is more reliable because it greatly reduces the possibility of human errors and the need for continuous human support.

Vineeth P & et al. [2] This paper proposes a fully automatic Internet of Things (IoT)-based hydroponic system that detects, monitors and controls important factors such as pH, dissolved solids (TDS), ambient temperature, humidity and lighting in green environment a house The choice of 7 sensors and 6 actuators contributed to the development of the proposed system. Using IoT a mobile application is developed to view environmental and nutritional variables in real time. The mobile application notifies the user when unusual conditions are detected in the greenhouse. A user could view the greenhouse through a mobile application using a camera connected to a live view. The MQTT protocol is responsible for exchanging data between remote devices and systems. The crop chosen to test the proposed hydroponic model is coriander, which was monitored for 18 days and good results were obtained. This proposed system represents a successful hydroponic system that is fully automated, reducing manual labor and growing completely chemical and pesticide free crops.

M. K. Shukla & et al. [3] In this script we have developed a method by which we can grow plants and vegetables indoors. We used a hydroponic system in this script. Hydroponics is a system where we grow plants and vegetables without using soil. We used microcontrollers and sensors to fully automate this system. We implemented things to analyze plant growth in hydroponic technology.

P. Anirudh & et al. [4] With the proposed method, pesticides can be sprayed with a separate container. Extend the model we provide We can also create an application that stores daily monitoring data and allows farmers to learn more about plant health. There are many techniques to boost plant growth. One such method involves machine learning algorithms that facilitate the user's operation.

Omolola & et al. [5] A review of existing research was conducted, focusing on the application of the Internet of Things (IoT) in smart hydroponic farming systems, particularly for monitoring and control purposes. The review highlighted the meticulous experimentation undertaken to comprehensively understand and effectively utilize various sensors within a hydroponics system. Each sensor fulfilled a specific function, contributing to the overall system's operation.The reviewed literature emphasized the potential of hydroponics as a superior alternative to traditional soil-based farming methods. This finding is particularly relevant given the ongoing degradation of soil quality observed in recent times.Despite the comprehensive nature of the research reviewed, opportunities for further development were identified. The inclusion of an additional sensor, such as a carbon dioxide (CO_2) sensor, was recommended to facilitate real-time monitoring of plant growth and development within the hydroponics system.

Shrinidhi & et al. [6] The reviewed literature describes the development of a plant analysis product with wide-ranging applications. This technology, adaptable to various scales from personal devices to large farms, offers the potential for accurate measurement of plant growth and physical characteristics.Furthermore, the review highlights the benefits of hydroponic farming. Studies cited demonstrate a significant reduction in water usage compared to traditional methods, with estimates suggesting up to 90% less water required. Additionally, the literature emphasizes the ability of hydroponic systems to maximize crop quality and yield. This is achieved through the provision of scientifically proven climatic conditions and tailored nutrient solutions specific to the crop being cultivated.

Munandar & et al. [7] It outlines the design, development, and implementation of a preliminary smart hydroponics system. The system utilizes the Internet of Things (IoT) concept to establish a connection with a cloud server. A data acquisition module was incorporated, and the data it collected was then serialized and transferred through a Wi-Fi module for transmission to the cloud server. This data can subsequently be displayed through a web application or a mobile Android app. Following a testing phase, the system was verified to function as intended and is now ready for deployment. This model has the potential to be utilized for both making decisions regarding actuator control and providing valuable user insights through data trend analysis and large-scale predictions.

Jordan G. & et al. [8] An implemented hydroponics management system was evaluated to assess its ability to sustain plant life. Data analysis and testing conducted by researchers demonstrated the system's potential to achieve this goal. A fully functional web application was developed to manage various aspects of the hydroponics system, including drainage, fan control, sprinkler operation, and water pump activation. The web application also successfully retrieved sensor data related to pH levels, water levels, and air temperature and humidity.However, some limitations were identified during the evaluation. The existing fan and sprinkler system were unable to maintain the optimal temperature and humidity range required for ideal plant growth. Additionally, the pH sensor data exhibited a larger margin of error when tested with standard pH 4 and pH 7 buffer solutions.

Table 1: Characteristics and limitations of the existing works

Paper	Characteristics	Limitations
[1] Swati Jain, Mandeep Kaur	● NodeMCU was used as the brain of the system. ● pH, TDS are automatically controlled. ● NFT technique is used.	● Totally depend on sunlight ● External grow light is not there. ● Air pump is not present. ● Lack of a closed and controlled environment.
[2] Vineeth P, Ananthan T	● Raspberry Pi & ESP12E was used as the brain of this system. ● pH, TDS, Float sensor, LDR, DHT11, DS18B20, Flow sensor were used. ● A mobile app was developed which shares the data over MQTT protocol to secure the data. ● Optimal input is the main feature.	● Air pump is not included in this system. ● Water loss is not controlled.

[3] M. K. Shukla, Archana Kanwar, Soumyadeep Raul, Agili Vishnu Sai, Bhupinder Verma	● Indoor farming is mostly focused. ● Arduino UNO is the heart of this project. ● Deep water culture technique is used. ● Thingspeak server was connected to fetch the data.	● Only one parameter (pH) is controlled. ● Missing of many sensors like TDS, ultrasonic. ● Grow light is missing. ● Lack of a closed and controlled environment.
[4] Pola Anirudh, G.A.E Satish Kumar, R Phani Vidyadhar, Gadwal pranav, Bathula Anil Kumar	● NodeMCU is used along with LDR, DHT11 and water level sensor. ● Camera is fitted to observe the growth of the plants. ● This is an open environment hydroponic system.	● Lack of pH, TDS sensors as they are the main sensor to read the main parameters of a hydroponic system. ● Controlled environment is not there.
[5] Omolola A OGBOLUMANI, Bonginhlanhla MABASO	● In this system a Raspberry Pi 3 Microcontroller is used instead an Adruino or Esp32 ● The control system will act independently and is not affecting the environment. ● Action can be done immediately making this system of hydroponic farming virtually doesn’t need labor.	● Water loss is not controlled

[6] Srinidhi H K ,Shreenidhi H S , Vishnu G S	● In this project, they tried to accurately measure the growth and physical traits of the plant. ● The quality and yield of the crops grown in this system are maximized by providing the scientifically proven climatic conditions.	● Different reports cannot be generated for different types of vegetables. ● pH value, water level, temperature, and humidity sensor cannot be read through application. ● Water loss is not controlled.
[7] Aris Munandar, Hanif Fakhrurroja, Irfan F. A. Anto, Rian Putra Pratama	● Open Garden is used as our data acquisition module. ● The data from Open Garden is serialized and then transferred to the WiFi module to be sent to the Cloud Server. ● From there the data can be displayed in the web using the frontend web app or in the smartphone using the android app.	● Water level management is absent and actuator can't be control through application
[8] Chris Jordan G. Aliac, Elmer Maravillas	● It can be inferred that the system is capable of sustaining life of plants based on the data gathered and tests conducted. ● The web application was able to control the actuators. ● The web application can also successfully gather data	● Water pump with good pressure should be used. ● Water loss is not controlled. ● ph management is not there

2.2 PROBLEM STATEMENT

Hydroponics is essentially a sustainable and efficient way to cultivate plants without soil, by utilizing water solutions with rich nutrients. However, conventional hydroponic systems depend significantly on hands-on supervision and modifications of essential environmental elements that affect the growth of plants. These factors consist of the nutrient solution's pH level, concentration of Total Dissolved Solids (TDS), and ambient temperature. Ensuring that every factor is at its best is crucial for plant health, however, managing it manually has its downsides such as time limitations, labor intensiveness, and the possibility of human mistakes. Inconsistencies in adjustments can result from human judgment. Plants can be harmed by deviating from optimal ranges by over-correcting or under-correcting. One more common aspect of the problem statement is developing a system that is cost-effective and environmentally friendly. Specific challenges might include preventing diseases, maximizing crop yield, and integrating technology for automation and monitoring. The goal is to address these challenges to create a successful and productive automated hydroponic system.

CHAPTER 3

3.1 PROPOSED METHOD

The block diagram of the automated hydroponics system consists of power supply, sensing and controlling system, hydroponic structure and online database. The block diagram of the designed system is shown in *Figure 1*. All the sensors connected to the hydroponic system can be monitored from the IoT platform on any smart device. Ebb & Flow hydroponics method is used as it is most efficient in water, nutrient and power consumption and also it is a simple and cost effective method.

In any hydroponic system, there are several parameters that should be maintained within a certain range, such as pH, total dissolved solutions (TDS), temperature of the greenhouse, and water level of the reservoir. All the above mentioned parameters should be kept in desired value by an automatic hydroponic system automatically/autonomously without user interaction. The sensors which are used with the microcontroller to monitor the physical parameters of the hydroponic system.The ESP32 module as a microcontroller was chosen . Grow lights, water pump, exhaust fan and the dosing pumps which add pH and nutrients to the water were controlled by a set of relays. Finally, all the acquired data from the central microcontroller circuit was sent wirelessly to Blynk IoT, an online database through Wi-Fi.

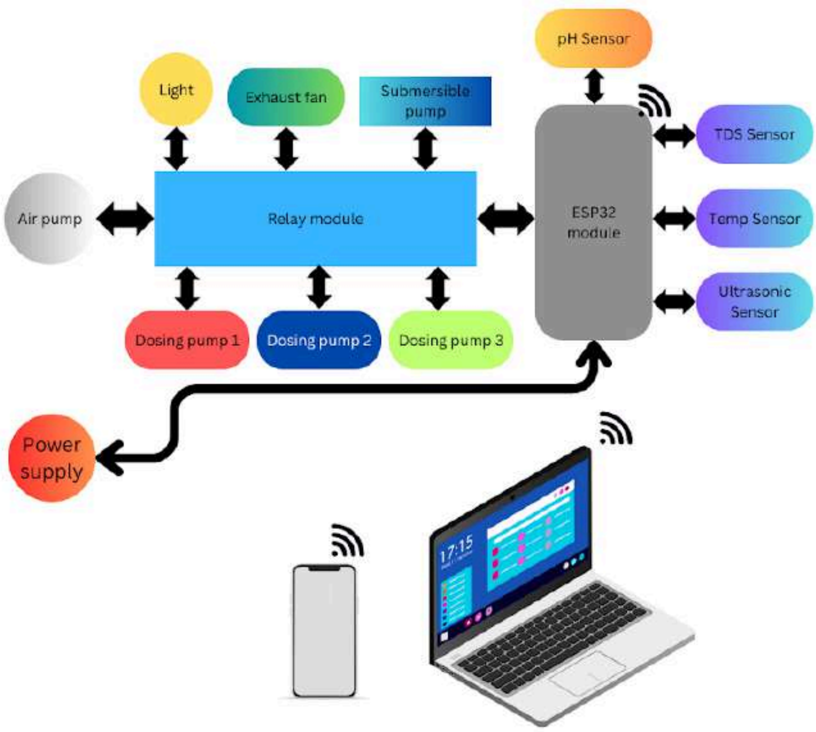


Figure 1. Block diagram of the designed system

3.2 PROPOSED HYDROPONIC SYSTEM

This structure will be used to house the hydroponics system, whose schematic diagram is provided in *Figure 2*. The Ebb and Flow hydroponics method was selected for implementation in this project. At first, the plants which are germinated with the wet tissue method were set to the growing medium with the help of net pots. Coco coir was used in the net pots to hold the small plants as well as to supply the nutrients mixture. Cucumber is chosen as it is grown well in summer. All the sensors including pH, TDS, temperature and ultrasonic sensors check the values and transmit the data. The pH and TDS sensors will monitor the pH and Nutrients concentration of the nutrient solution of the reservoir.

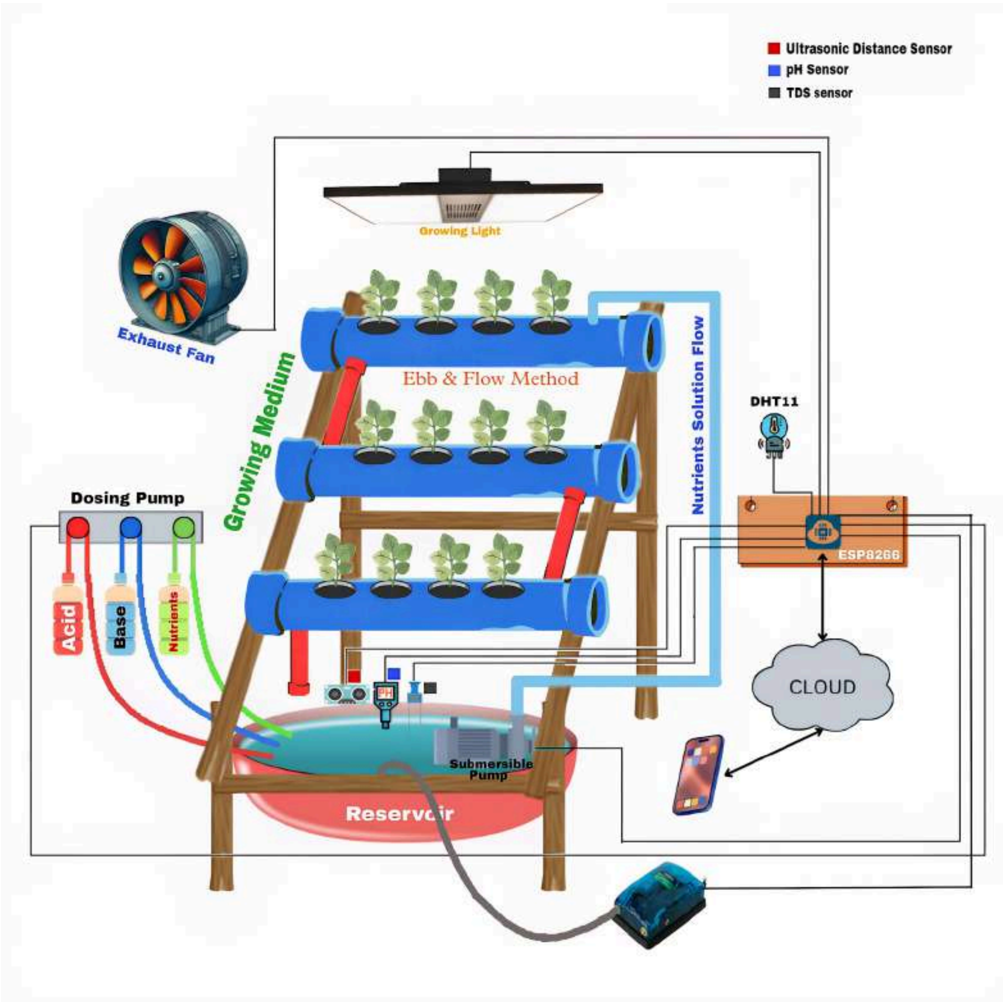


Figure 2. Schematic diagram of the hydroponic system

Threshold values for pH and TDS will be established. If the measured pH and TDS fall below these thresholds, the dozer pump will automatically activate and deliver the necessary amount of nutrients to the reservoir. The submersible pump will automatically turn on for a certain amount of time and flood the growing medium with nutrient mixture. This ensures that the roots of the plants have enough water and nutrients to grow. This cycle will run automatically within the interval of 6 hours. The air pump in the reservoir provides oxygen to the nutrient solution which provides oxygen to the roots of the plant. Also the air pump is used for mixing acid, basic, nutrient solution with the water. It will automatically turn on and off within the interval of 1 hour. There is a temperature sensor to monitor the temperature value of the polyhouse. The overall algorithm used in this proposed hydroponic system is shown in *Algorithm 1*.

Algorithm 1. Algorithm of the proposed hydroponic system

```
Start
if (connection = OK){
 continue;
loop (){
input(pH)
if (float pH < low_threshold){
 basic pump = ON;
}else if (float pH > high_threshold){
 acidic pump = ON;
} else {
 acidic pump = OFF;
 basic pump = OFF;
}
input(TDS)
if (int TDS < tds_threshold){
 nutrient pump = ON;
} else {
 nutrient pump = OFF;
}
input(temp)
if (int temp < low_temp){
 fan = OFF;
}else if (int temp > high_temp){
 fan = ON;
}else {
 fan = OFF;
}
input(water)
if (float wlevel > wlevel_threshold ){
 notify;
}else {
```

```
  nothing;
}
if(time>= 6pm && time =<7am){
  light = ON;
}
else{
  light = OFF;
}
loop(time){
  sub pump = ON;
  sleep(time);
  sub pump = OFF;
}
loop(time){
  air pump = ON;
}
}
}
else {
  display ("Offline");
  end;
}
```

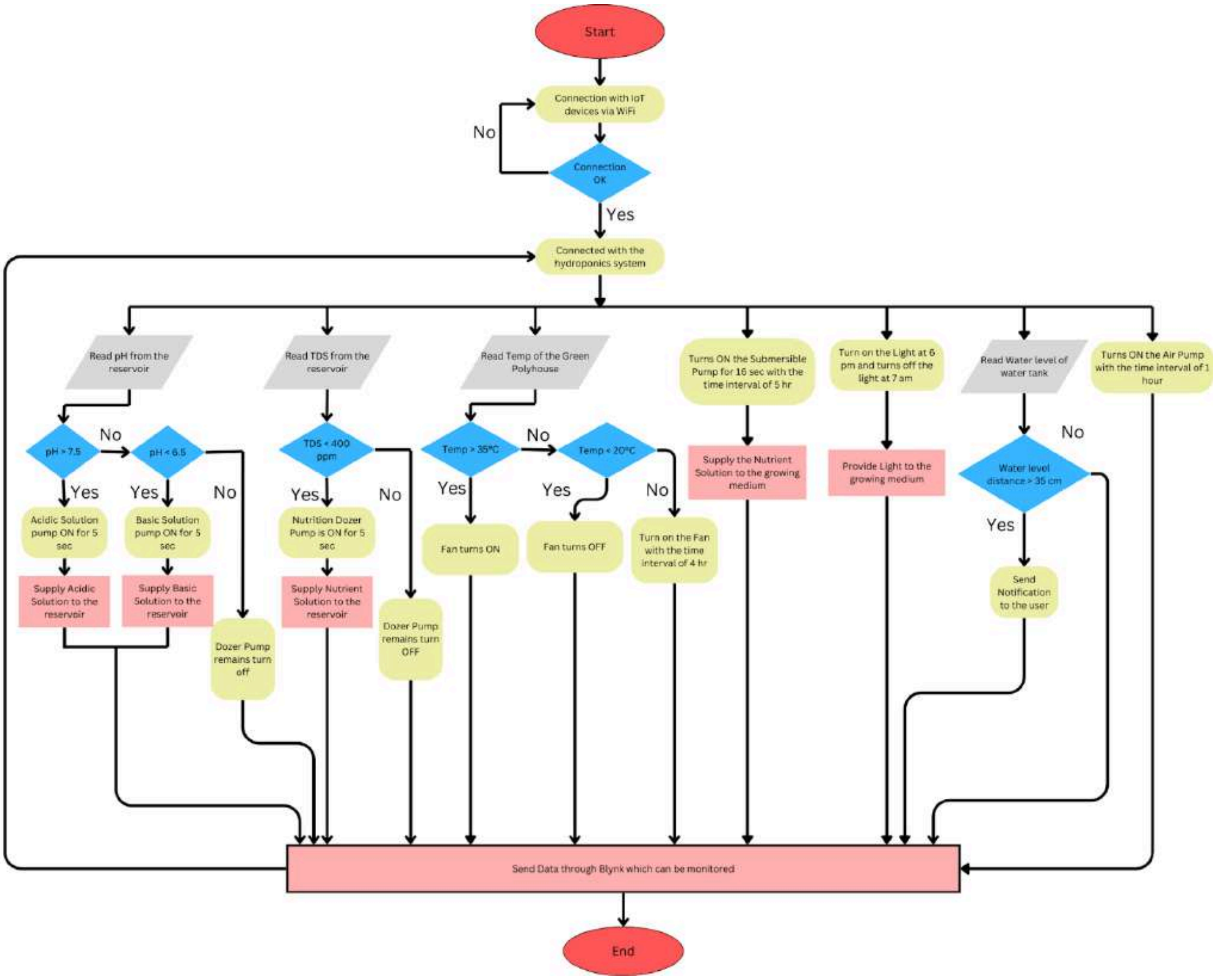


Figure 3. Flowchart of the hydroponic system

Figure 3 describes the whole working process with the conditions. The data will be relayed back to the microcontroller, which will then autonomously regulate the fan's operation to ensure proper aeration within the polyhouse. There is also a grow light which is used to help in the plant photosynthesis and grow the plants faster. It will automatically turn on and off in an interval of time. The ESP32 microcontroller is used to control all components like light, fan, sensors, pump, dozer pump etc. The microcontroller is connected to the Blynk IoT platform through WiFi as it allows the user to monitor and control the system remotely.

3.3 COMPONENTS REQUIRED FOR HYDROPONIC SYSTEM

3.3.1. pH sensors: pH sensor kit is used to measure the acidity or alkalinity of the nutrient solution. It operates at 9V 1A power supply which is provided by an external 9V adapter. This pH sensor is calibrated at 24°C room temperature. Calibrated values are: pH4 = 1.5V, pH7 = 2.0V and pH9 = 2.5V. The microcontroller can adjust the pH of the nutrient solution if it falls outside the suitable range for plant growth, potentially through a separate mechanism for adding acidic or basic solutions. Cucumber was chosen by us to grow in this hydroponics system, so the pH threshold between 6.5-7.5 was set by us as it shows the best results in production according to research papers and blogs.

3.3.2. TDS sensor: Analog TDS Sensor Water Conductivity Sensor is used for measuring TDS value of the water. It can be used for checking water quality in hydroponics, household water, and other areas. This TDS sensor supports 3.3 ~ 5.5V wide voltage input, and 0 ~ 2.3V analog voltage output, which makes it compatible with 5V or 3.3V control systems or boards. TDS (Total Dissolved Solids) simply defines the number of milligrams of dissolved solids in one liter of water. The higher the TDS value, the more soluble solids are dissolved in water and less pure it is. The TDS in the water is identified and measured through ppm (part per million) or milligrams per liter (mg/l), which in other words means to measure the total amount of several organic as well as inorganic substances dissolved present. Monitor the TDS in the nutrient solution, indicating nutrient levels. The system might add nutrients if the TDS level falls below a specific threshold, maintaining an optimal concentration for plant growth. As mentioned earlier the TDS value can vary upon the plants and its stage of growth. At the earlier stage of the plants the TDS threshold value was set to 400 ppm.

3.3.3. Temperature sensor: DHT11 Sensor is a versatile and affordable device that accurately measures both humidity and temperature. Ideal for various applications, from smart homes to hydroponics systems, it provides reliable data for improved automation and environmental control. Discover the reliability and cost-effectiveness of the DHT11 Sensor for precise temperature measurements. It tracks the environmental conditions inside the hydroponic chamber. If they deviate from the optimal range for the plants, the microcontroller might trigger exhaust fan for aeration. The desired value for fan activation was set to 35°C as the project implementation coincided with summer in the location and summer season vegetables were chosen for cultivation. Threshold values can be adjusted based on the specific plant types.

3.3.4. Ultrasonic sensor: A ultrasonic sensor module (HC-SR04) can be used for measuring water level of the reservoir. The module sends eight 40Khz square wave pulses and automatically detects whether it receives the returning signal. If there is a signal returning, a high level pulse is sent on the echo pin. The length of this pulse is the time it took the signal from first triggering to the return echo. An ultrasonic distance sensor was attached 20 cm from the top of a 25 cm reservoir. This configuration resulted in a distance threshold of 35 cm being set.A notification would be sent to the user if the water level fell below 15 cm from the reservoir's top level.

3.3.5. ESP32 module: The ESP32 MCU module, created by Espressif Systems, is a very flexible and robust microcontroller unit. This makes sense since it is designed for different purposes, most of all where low-power and wireless communications are required. It has an ESP32 CPU which is a very advanced 2-core or single-core speed and compute power. As is Bluetooth and Wi-Fi compatible, it is perfect for IoT projects and smart gadgets. The module boasts diverse peripherals and interfaces such as GPIO pins, ADCs & DACs, UART, SPI and I2C and PWM for interfacing with a wide range of actuators, sensors and devices. This served as the heart center of our system. Based on the sensor's reading, it controls the actuators and uses wifi to transmit the sensor's data to the cloud.

3.3.6. Water pumps: A 12V DC 8W submersible water pump is used to circulate the nutrient solution to the growing medium. It will automatically turn on in the interval of 6 hours, this value is decided randomly. The precision of the notification system can be further enhanced through analysis of the specific nutrient solution needs of the growing plants. This is because the ideal water level can vary depending on the plant's growth stage.

3.3.7. Dosing pump: It is used for precisely delivering nutrients and acidic or basic solution to the reservoir. We use 5V peristaltic pump to deliver the solutions precisely. For effectiveness the pump will turn on according to the sensor value and it will turn off only after 5 seconds to prevent the wastage of solution. The sensors check the value interval of 30 min.

3.3.8. Exhaust fan: Regulate air circulation within the greenhouse. A 12V DC CPU cooler is used as an exhaust fan in this project. The fan is controlled by the MCU automatically based on the temperature. In accordance with project requirements, a desired value of 35°C was established for fan activation. Upon reaching 35°C, the fan would automatically turn on. However, even if the temperature remained below the threshold, the fan would still be activated at predetermined intervals of 4 hours to facilitate air circulation.

3.3.9. Grow Lights: Red and blue spectrum lights were utilized to simulate optimal grow light conditions for the plants. Plants absorb red and blue light the most because these colors are important for photosynthesis and making energy. Plants require blue light for growth and it is most effective for seedlings. The chlorophyll absorbs blue light that catalyzes photosynthesis, and as a result, it thrives most under full-spectrum light. Red light is very ideal during the entire flowering step. Red light and blue light is a very good combination for plants. Red light with higher intensity can lead to higher yields.

3.3.10. Air Pump: A 240V AC air pump is used to circulate oxygen into the reservoir. It is also beneficial to mix the acid, base and nutrients with the freshwater. It will automatically turn on and off within the time interval of 1 hour.

3.3.11. Single channel relay: Relay acts as a switch. For turning on and off the actuators, 7 single channel relay is used in this proposed method. This single channel 5V control Single-Pole Double-Throw (SPDT) High-level trigger AC power relay board can be controlled directly via a microcontroller and switch up to 10A at 250 VAC. The inputs of the single Channel 5V Relay Module are isolated to protect any delicate control circuitry.

3.4 CIRCUIT DIAGRAM

Before implementing the whole system we need to draw a circuit diagram of the system that can help us to build the main circuit board. The Cirkit Designer application was chosen for its comprehensive library of sensors and microcontrollers. This software was used to design the circuit diagram, which is depicted in *Figure 4*. The diagram details all the components employed in the project's implementation. Following the design phase, all sensors and actuators were connected to the microcontroller using jumper wires.

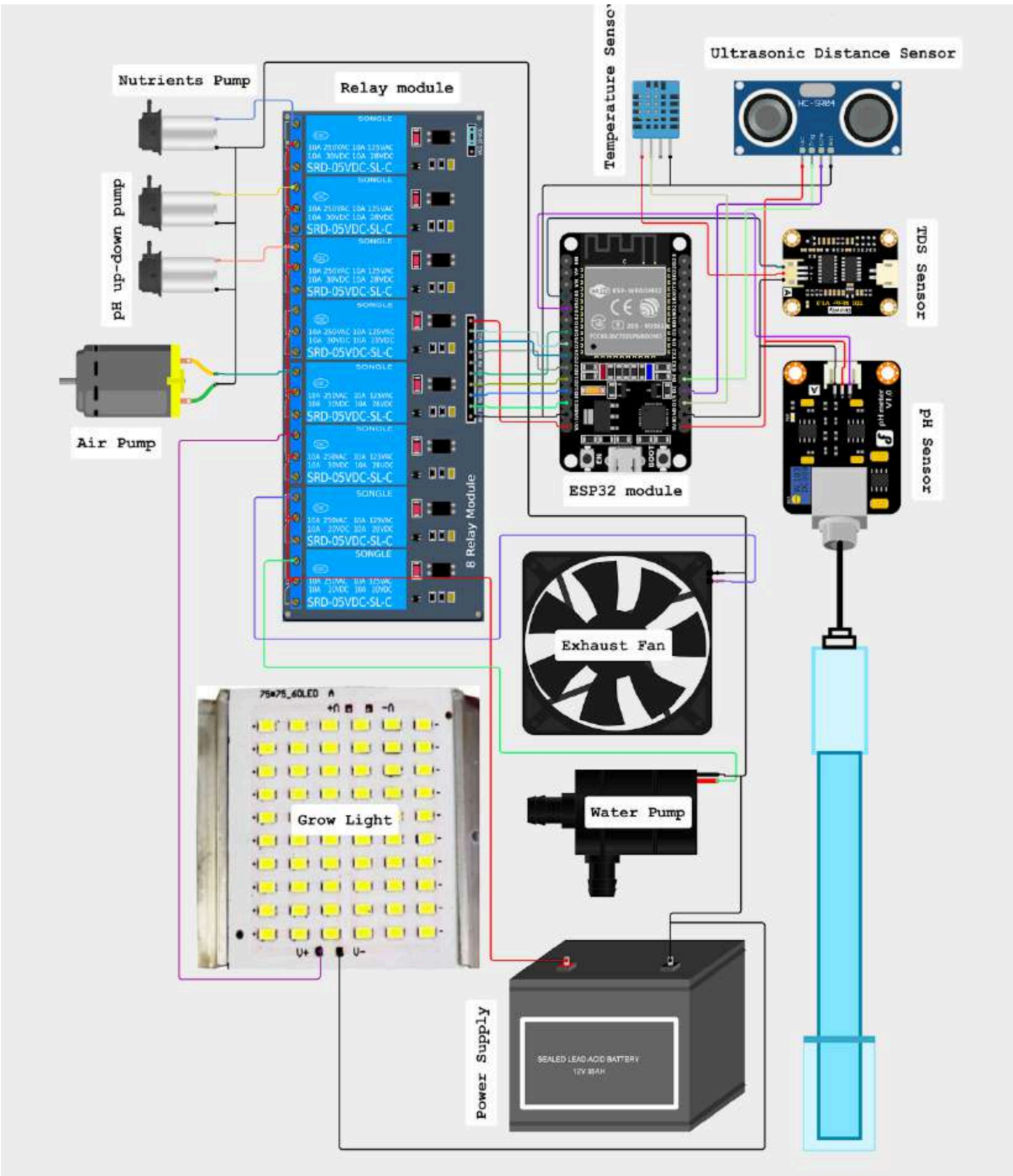


Figure 4. Circuit diagram of automated hydroponic system

CHAPTER 4

4.1 IMPLEMENTATION OF THE PROPOSED HYDROPONIC SYSTEM

4.1.1. Polyhouse and growing medium implementation: A polyhouse is a structure with a frame and transparent/translucent covering that allows crops to be grown in a partially controlled environment big enough for people to work in and tend to the crops. This polyhouse design facilitates the creation of a desired environment, enabling the cultivation of crops even during off-seasons and experimentation with unique combinations. The productivity of the crop has increased considerably due to the controlled environment of the polyhouse. Effective management of inputs such as water, fertilizers, seeds, and plant protection chemicals can be achieved in a polyhouse. Pests and diseases can be effectively controlled because the cultivation area is enclosed. Polyhouse reduces crop loss. Additionally, polyhouses can be automated for watering, applying inputs, and controlling the environment through the use of computers and artificial intelligence methods. All the advantages keeping in mind, we build a prototype of a 5 ft x 5 ft polyhouse. A combination of plastic sheeting, shade netting, and wood was chosen for the construction of the polyhouse. Plastic sheeting serves to maintain the desired internal environment, while a 75% shade net is implemented to block harmful UV rays from direct sunlight. To facilitate air circulation, holes were incorporated into the lower portion of the polyhouse, and an exhaust fan was installed in the upper corner to take advantage of warm air rising due to convection. For the light source there was grow-light hanging from the top which gives enough lighting condition to the plants to grow plants. A prototype of the polyhouse is depicted in *Figure 5*. This structure houses the implemented automated hydroponic system. The main growing medium for the hydroponic system was made by 2 ft long 75 mm pipes. 3 pipes were used and connected by 25 mm hard pipes. There are 4 holes in each pipe where the net pots are set to grow the plants. For better understanding growing medium is shown in *Figure 6.* In the net pot, coco coir was used to support the small plants and provide the nutrient mixture to the plants. The growing medium can hold approximately 3.5 liter nutrient mixture and overflowed in 16 seconds by the submersible pump. The 75 mm pipes are set diagonally for space and better growth of the plants. A wooden structure was built to hold the growing medium properly.

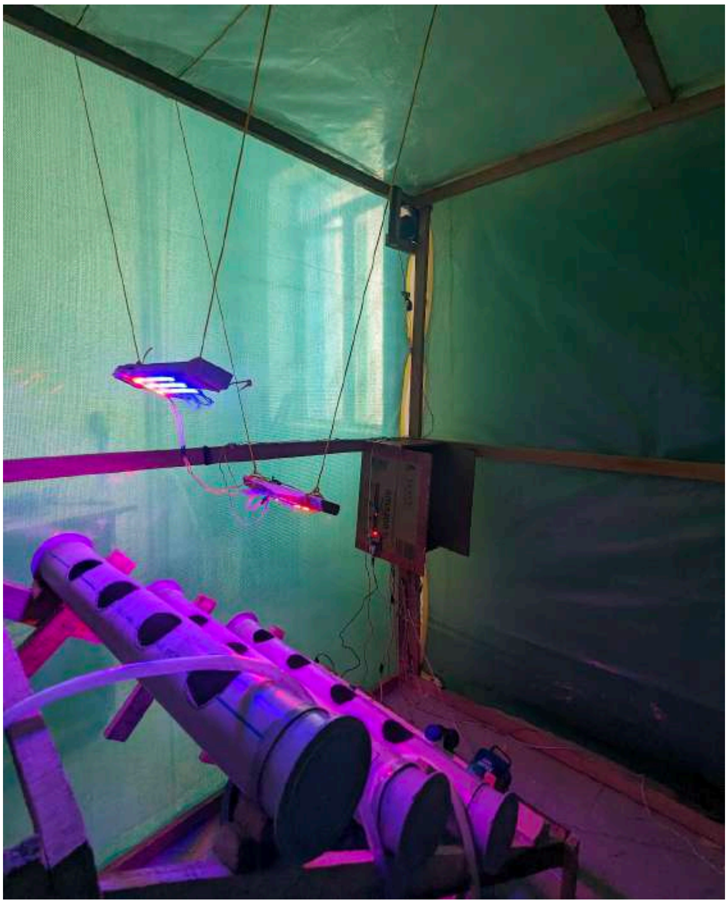


Figure 5. Implemented polyhouse

Figure 6. Growing medium

4.1.2. Circuit implementation: After setting up the growing medium and testing the sensors individually, the proposed circuit diagram was connected carefully. Jumper wire, flexible wires are used to connect all the components. For powering up the 12V DC pump, light and fan, a SMPS is used. And different adapters help to power up the microcontroller, dosing pumps and pH sensor. Single channel 5V relay was connected with all the actuators to control them. And then, all the relays and sensors were connected with a microcontroller. Thereafter, Microcontroller and relay modules were fitted into a box. The implemented circuit box is shown in *Figure 7.*

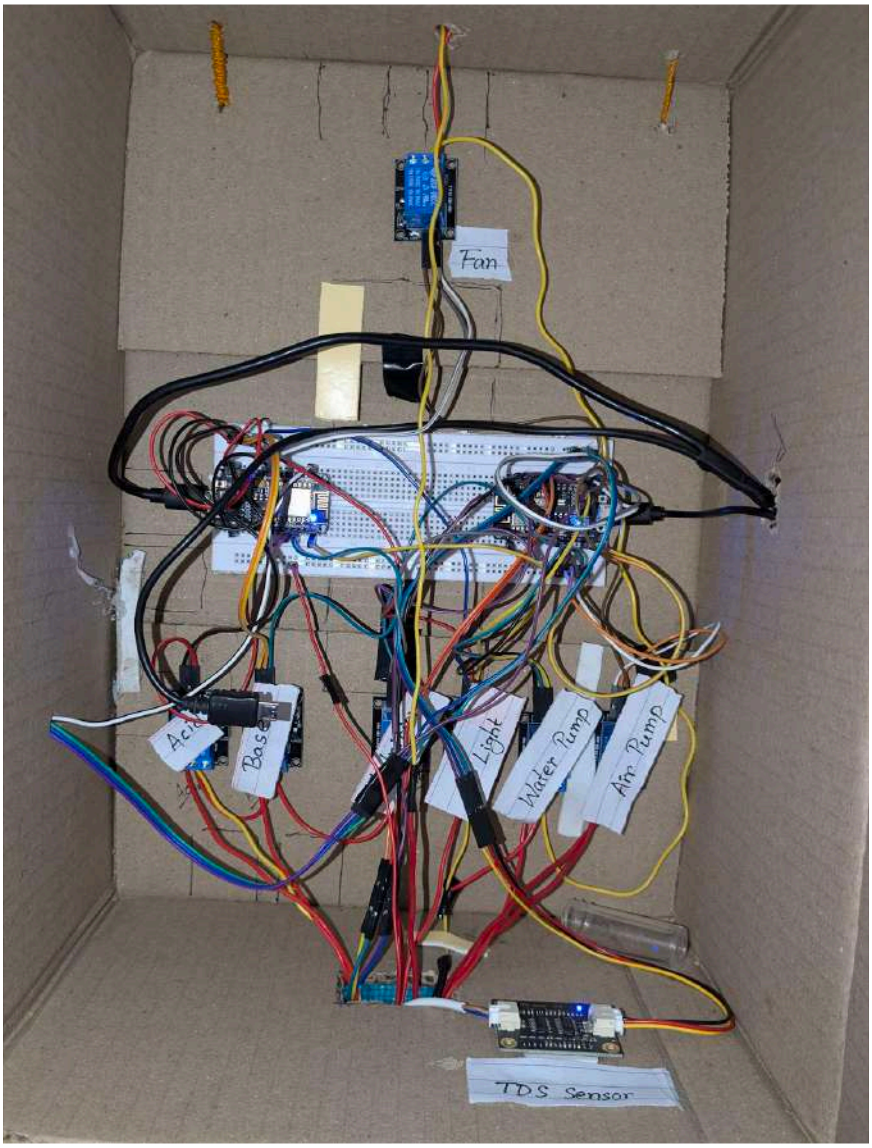


Figure 7. Implemented circuit box of the hydroponic system

4.2 IoT IN PROPOSED HYDROPONIC SYSTEM

For automation and remote access of the device an IoT platform is linked with the microcontroller code. Blynk IoT app is used here as it is the most reliable and commonly used platform to gather data from the system and control the system remotely. Web dashboard and android app dashboard are made including the sensor's value like pH, TDS, water level, temperature and a light control button is implemented if the user wants to turn on the light manually. In its free version we are able to add only 5 datastreams, that's why the other actuator control is not included in the dashboard. For connecting the platform with our system we had to include the template id, auth token in the microcontroller code. After reading the sensor's value, it is processed by a microcontroller that sends the data via the internet using the blynk library. Then, the blynk server gets the data and forwarded to the blynk app to display the values on widgets. Blynk platform work process which shown in *Algorithm 2* describes how the blynk IoT platform displays the data. A flowchart, how the process works is also given in *Figure 8.*

Algorithm 2. Algorithm of work process of the Blynk IoT platform

```
function sensorMonitor()
    while (true)
        sensorValue = readSensor()
        sendBlynk(sensorValue)
        delay(time)
```

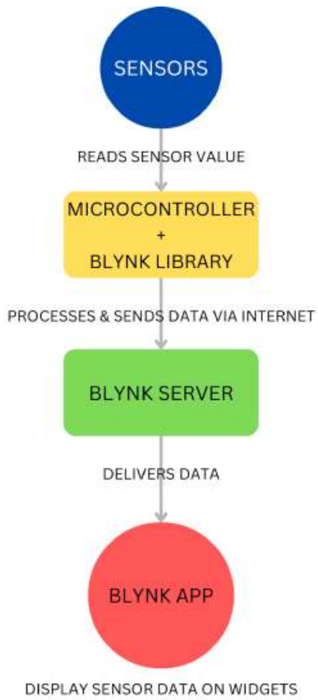
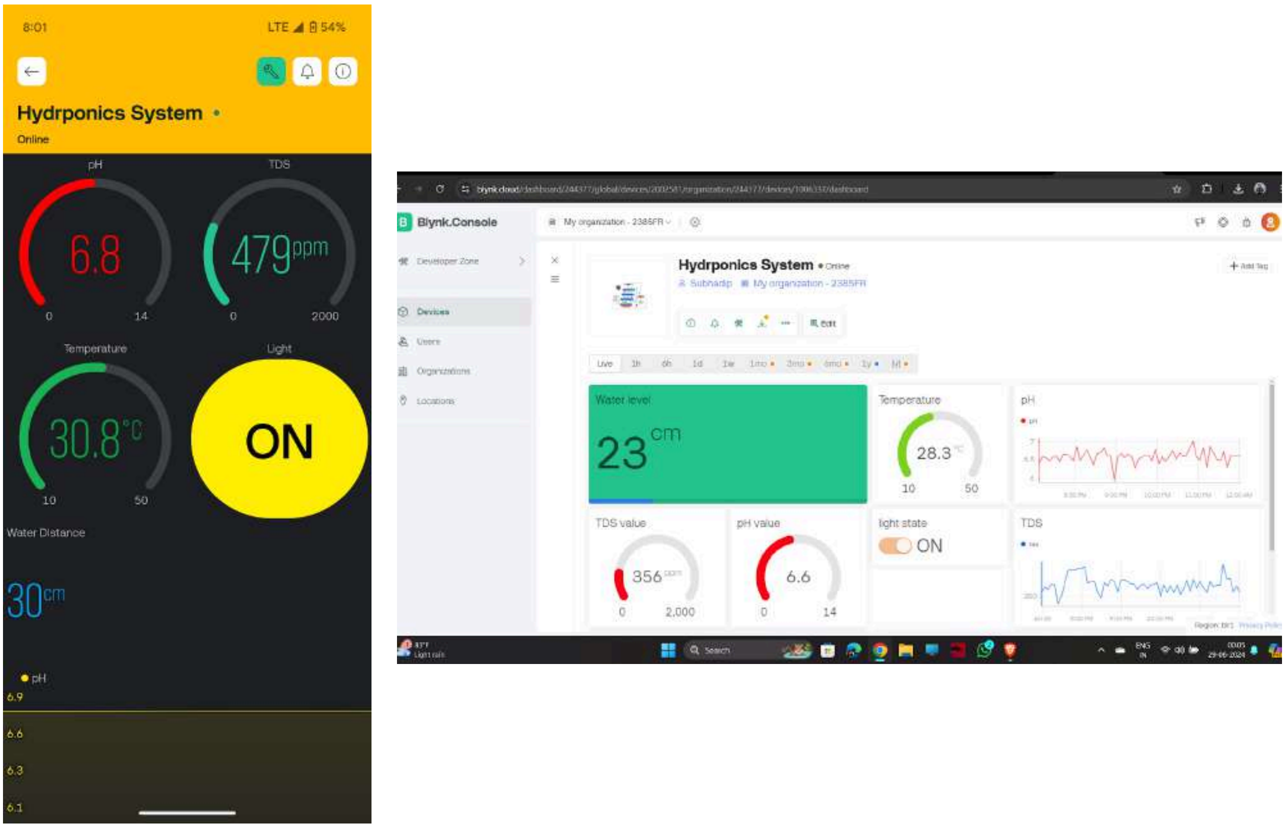


Figure 8. Flowchart of how blynk app display the data

A mobile app and web interface are made to fetch the sensor's data as well as limited control of light on and off. In *Figure 9* mobile app dashboard and web dashboard is shown. If any updation in threshold values is needed, users can update through over the air (OTA) update.



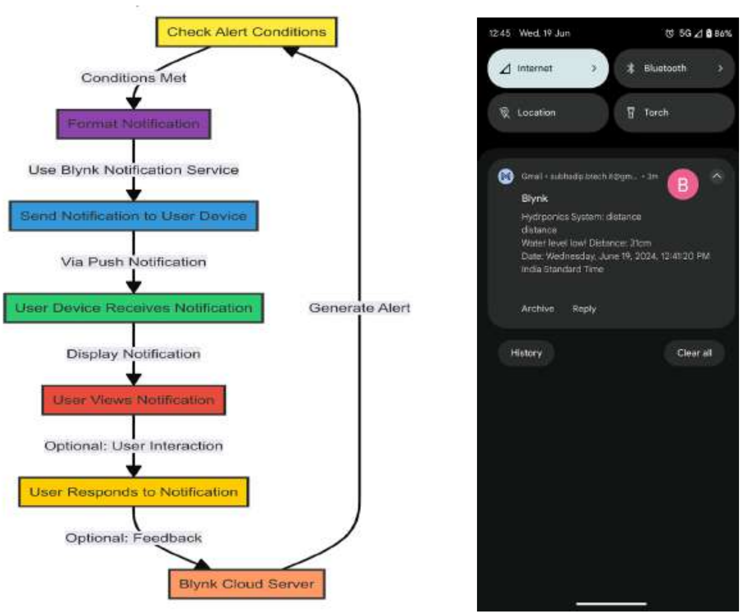
a ***b***

*Figure 9. **a)** App dashboard **b)** Web dashboard of the hydroponic system*

For pushing the water level alert to the user set a threshold value and an event was created. Whenever the ultrasonic sensor's value is greater than the threshold, the IoT platform checks alert conditions and if conditions met, blynk app uses its notification service and sends notification to the user via push notification in the phone and in email. Users can view notifications and respond to the notification as feedback. An algorithm shown in *Algorithm 3,* for generating alerts is mentioned below along with the flowchart and a screenshot of an email notification, shown in *Figure 10.*

Algorithm 3. Algorithm of the notification generation process

```
check_alert_conditions()
if (conditions_met) then
  format_notification()
     choose_delivery_method()
     if (delivery_method == BLYNK_NOTIFICATION_SERVICE) then
     send_notification_blynk()
     else
     send_notification_push()
     endif
     user_receives_notification()
     display_notification()
     user_views_notification()
     user_responds_to_notification()
     if (user_provides_feedback()) then
     send_feedback()
     endif
endif
```



a ***b***

Figure 10. ***a)*** *Flowchart of notification generation* ***b)*** *Screenshot of email notification got by user*

CHAPTER 5

5.1 RESULT & DISCUSSIONS

5.1.1 Data collected from the sensors: After the calibration of the sensors and actuators, the complete automated hydroponic system was implemented and tested. During this project, it was used to cultivate cucumber in an indoor area as shown in *Figure 11.* The sensor data was exported from the IoT platform and represented into graphical format to understand the scenario of the hydroponic system. The sensor's value is given as tabular format as shown in *Table 2* and the graphical representation of the individual sensor as shown in *Figure 12*.

Figure 11. Cucumber grow in the automated hydroponic system

Table 2. Weekly report of individual sensor's value exported from the Blynk IoT platform

Date	Temp	pH	TDS	Water Dist.
4/22/2024	37.6°C	7.5	452 ppm	25 cm
04/29/2024	36.8°C	6.7	451 ppm	27 cm
05/06/2024	37.2°C	6.7	449 ppm	27 cm
05/13/2024	42.4°C	6.6	429 ppm	28 cm
05/20/2024	41.8°C	6.7	413 ppm	29 cm
05/27/2024	42.1°C	6.6	397 ppm	29 cm
06/03/2024	36.8°C	6.5	479 ppm	30 cm
06/10/2024	37.6°C	6.5	469 ppm	30 cm
06/17/2024	35.2°C	6.7	458 ppm	31 cm
06/24/2024	33.3°C	7.3	451 ppm	20 cm

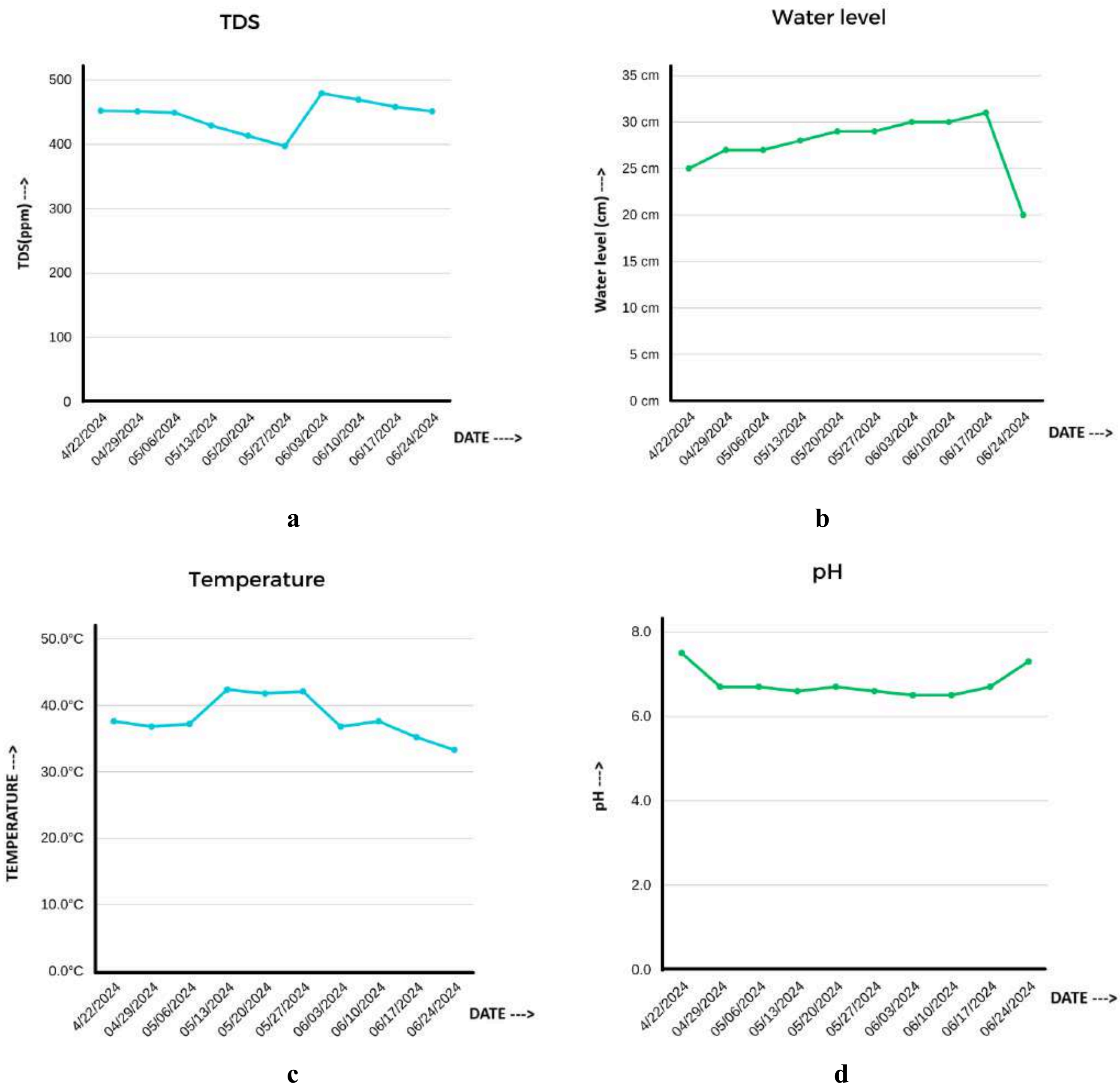


Figure 12. Graphs of the following parameters: ***a)*** *TDS* ***b)*** *Water level* ***c)*** *Temperature* ***d)*** *pH*

After analyzing the graphs it is noticed that TDS value was decreasing constantly, after 3 weeks there was a massive decreasing rate and to maintain the threshold the dosing pump was turned on and TDS value was increased. Like TDS value, water distance was increasing constantly, after 8 weeks the reservoir was filled and the water distance level was decreased. From the graph, it is said that the temperature of the polyhouse was inconsistent as the climate changed. And the pH value was almost constant, it was changed after the filling of the reservoir.

5.1.2 Data of the plant growth: After the germination from the cucumber seeds, the baby cucumber plants were transferred into the hydroponic system. In the initial stage the plant was approx 3 cm and had 2 leaves on it. After 1-2 weeks it grew rapidly with the initial 2 leaves. Few days later, its vertical growth was paused and it grew new leaves. After growing some new leaves it resumed its vertical growth and as per the last fetched data the plant's height was 10.8 cm. These data were collected manually as we have not included any camera and image processing technology onto the system. Some snapshot has been taken to show the growth of the plants which is shown in *Figure 14.*

Table 3. Growth chart of the plant

Date	Height	No. of leaves
4/22/2024	3 cm	2
04/29/2024	4.5 cm	2
05/06/2024	5.5 cm	2
05/13/2024	7 cm	3
05/20/2024	7 cm	3
05/27/2024	7 cm	4
06/03/2024	8 cm	4
06/10/2024	9.2 cm	5
06/17/2024	10.1 cm	5
06/24/2024	10.8 cm	6

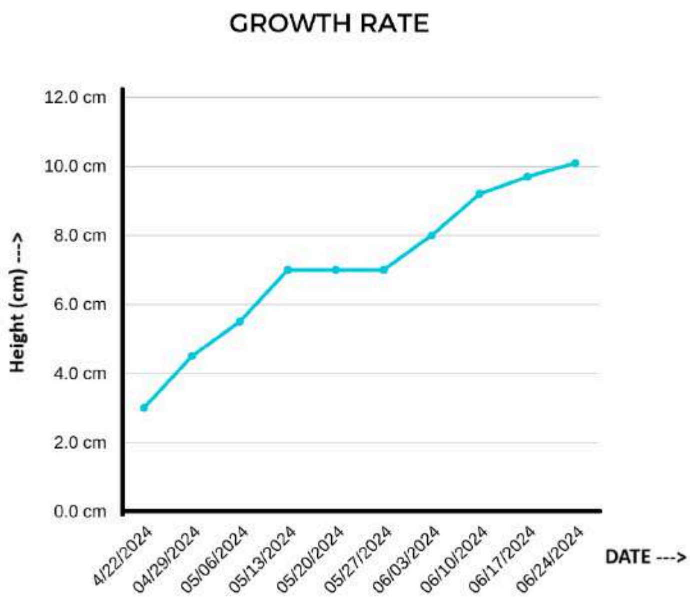


Figure 13. Graphical representation of the growth rate of the plant

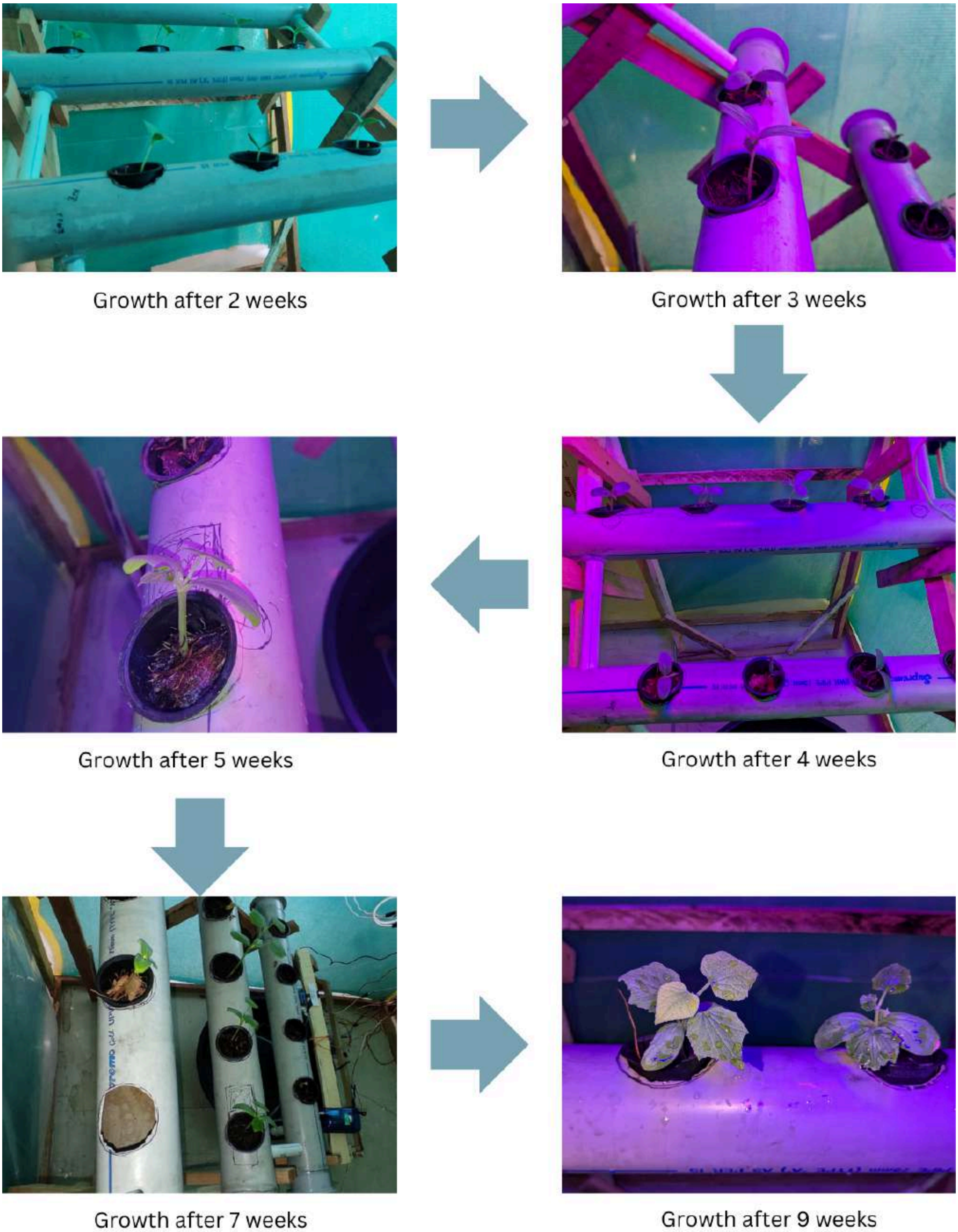


Figure 14. Snapshots of the plants in different growing stage

After analyzing all the graphs of the sensor's value with the growth rate graph, given in *Figure 13*, it can be easily said that high temperature and low amount of nutrients in the nutrient mixture affected the growth of the plants. pH was present in the right amount into the mixture, if the value was changed the result could be different. In the leaf formation process, the plants consumed more nutrients than vertical growth. On the other hand, the overall project idea was based on outdoor polyhouse farming but unfortunately the whole system was built in a room which does not have air conditioner or ventilator to circulate the air properly. For optimum growth of the plants air circulation is one of the most necessary things. Despite being a summer vegetable the growth of the cucumber plant in the hydroponic system was slower in high temperature like 42-43°C. Some other factors are also affecting the growth of the plants such as light, distribution of nutrient solution. In this area power cuts are too common things, it affects directly. As mentioned earlier the submersible pump is not dependent on any sensors, it will automatically turn on and off within the time interval of 5 hours, for that whenever power cut happens, the microcontroller restarts itself and the pump timer is started from beginning. If a power cut happens at night, the grow light remains off. As a suggestion it can be said that if you want to build this system indoors, then you have to be careful about the air circulation as well as the power supply and it is better to include an air conditioner in the system which can automatically turn on and off according to the need, improved environmental climate control is achievable through this approach. Despite being the weaknesses, the automated hydroponic system grew the baby cucumber plant into mature, if there are no weaknesses the plants have surely fruit on it now. After analyzing the results, it is definitely said that this automated hydroponic system provides a complete design including the implementation, testing, for monitoring the environmental conditions as well as the control of the nutritions and water supply for healthy growth of the plants.

5.2 COMPARATIVE STUDIES

Table 4. Feature comparison of some research paper with proposed solution

Feature	Proposed Solution	S Jain & et al. (2024)	Vineeth P & et al. (2023)	Archana K & et al. (2023)	P Anirudh & et al. (2023)	Omolola & et al. (2023)
Sensors	pH, TDS, Ultrasonic, DHT11	pH, TDS, Ultrasonic sensor	pH, TDS, Flow Sensor, DHT11, Light Intensity, Float sensor, DS18B20	pH, DHT11	DHT11, Light Intensity, Water Level Sensor, Camera	pH, TDS, DHT11, Ultrasonic, Light Intensity
Control Mechanisms	pH Up/Down (based on pH reading), Nutrient (based on TDS reading), Water pump (timed), Lights (timed), Air pump (timed), Exhaust Fan (based on Temp)	pH Up/Down, Nutrient (based on sensor value), Water pump (level-based)	pH Up/Down, Nutrient, Water pump (level-based), Lights (Intensity), Fan (Temp & Humidity), Reservoir pump (float)	pH Up/Down (based on pH reading)	Water pump (based on sensor value), Lights (Light Intensity), Fan (Temp & Humidity), Capture image	pH Up/Down, Nutrient, Water pump (level-based), Lights (Intensity), Fan (Temp & Humidity)
Monitoring & UI	Blynk IoT Platform Mobile App & Web Interface	ThingSpeak	Mobile App	ThingSpeak web interface	Mobile App	AWS web interface
Results - Efficiency Improvements	Improved plant growth due to precise control of pH, nutrient levels, and environmental conditions.	Significant improvement in plant growth and resource use efficiency	Significant improvement in plant growth due to precise pH, nutrients control, light control and other environmental conditions.	Due to the lack of precise nutrient delivery, the growth rate in this system is lower.	The main parameters of any hydroponic system was not present in this system, that's why the growth of the plant is slower.	Significant improvement in plant growth and resource use efficiency

Table 4 displays the attributes contrast of various research initiatives and the suggested resolution. The table illustrates that the proposed solution provides additional features, aiming to minimize reliance on human intervention and making it suitable for general people. There are budget-friendly options that are compact, and may not support adequate plant growth or lack essential monitoring and control features. Alternatively, there are also options that need significant investment and are not appropriate for indoor agriculture. Compared to some studies, this proposed solution lacks sensors for monitoring light intensity, which can be crucial for plant growth.

CHAPTER 6

6.1 CONCLUSION & FUTURE WORKS

The key aspect of a hydroponic setup is overseeing and regulating environmental conditions while providing necessary nutrients and water for plant growth. In this paper, a low-cost automated hydroponic system has been developed utilizing the Blynk IoT platform. The initial system structure has been put together and the necessary parameters for constructing an automated system were mapped out to choose the needed components. The parameters of the system were studied and calculated such as the suitable temperature, light, pH, TDS, and the required amount of water for the system. Finally, the parameters were displayed in Blynk IoT platform web-interface and mobile application to provide an easily accessible user interface. Users can monitor and visualize the parameters and the system can send alerts as a notification as well as an email in case of low level reservoir's water. Moreover, the hydroponically grown plants are organic plants as they do not consume any pesticides. In conclusion, this automated cost effective hydroponic system can provide an in-house vegetation solution as well as the large scale of production for the farmers. Its setup cost is a bit higher but that is a one time investment, after that you just have to pay for the seeds and nutrients.

Hydroponics is basically an example of precision farming, that's why all the work done must be more precise to betterment of this project. For more precise automation another pH and TDS sensor is to be used in the growing medium to gather the information that when the plants need nutrients. TDS sensor is totally replaced by NPK sensor as it shows the individual value of nitrogen, phosphorus and potassium. As mentioned earlier an air conditioner can be used to control the temperature of the polyhouse in a better way. Beside this image processing, machine learning can be implemented in this project. Image processing can be used for disease detection, and machine learning can help to predict the growth of the plants. Robotics can also be a part of this agricultural industry as it reduces the human labor and reduces the chances of human error. The IoT platform connected with the system, allows to extract data which can help in machine learning algorithm development while the system can produce a large amount of data suitable for training classical and deep learning algorithms to enhance the performance of the automated system for controlling. The proposed system lacks automation for refilling the reservoir when the nutrient mixture runs empty. An extra pump or rain water harvesting technique can be the solution to this problem. Pisciculture can be incorporated into the system, forming an ecosystem where water wastage is minimal.

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