

Vertical Hydroponics System using IoT

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Abstract— With the use of modern technology and intensive farming practices, production can be greatly increased. With the shortage of water, the effects of climate change, the manpower shortage, and the shrinking amount of fertile land, hydroponics farming is emerging as a solution. In areas where access to fresh produce is limited, hydroponics farming offers a job opportunity, helps the community economy, and produces nutritious food. The fundamental goal of hydroponic farming is to promote healthy plant growth without the need of traditional soil. It is an innovative way of making the agriculture smarter. Instead of using soil to produce plants, hydroponics uses a water solution rich in vitamins and minerals. With the use of modern technology and intensive farming practices, production can be greatly increased by vertical farming, thereby contributing to agriculture. Integrating hydroponics with IOT may surely make farming more easy for the farmers by automating and perfecting every stage in the farm. For a plant to grow, it needs specific nutrients, some water, and sunlight. IoT device can monitor those needs automatically and regulate hydroponic systems and operate effectively in any environmental conditions. This will allow the farmer or the user of the hydroponic system effectively by generating alert whenever needed.

Index Terms— IoT; soil-less farming; vertical farming; deep water culture; hydroponics.

I. INTRODUCTION

At least ten million hectares of arable land are eroded and abandoned annually throughout the world, according to a report by David Pimentel and his colleagues from ten years ago (1998). [1]. As a result, a significant amount of replacement land is taken from forests and other sources for agriculture and human habitation to make up for this loss. The natural landscape of the world has been rapidly converted to agriculture, and it is now known that this use of natural resources will soon exceed its carrying capacity by permanently harming its natural ecology. Due to a lack of food production, several nations may experience economic catastrophe. The preservation of water resources and the maximization of profit per square foot of land are problems that must be solved in order to provide higher quality and quantity yields that, either directly or indirectly, benefit farmers or the national or regional economy. [2]-[3]. The use of innovative or cutting-edge technology in the agricultural industry may greatly increase agricultural productivity and sustainability.

One such innovative technique is hydroponics. The majority of terrestrial plants may be grown using hydroponics, a farming method that doesn't require soil and simply uses water and nutrients. Using aqueous mineral fertilizer solutions, hydroponics is the practise of growing plants typically agricultural or therapeutic plants without soil [4]. The fundamental goal of hydroponic farming is to promote healthy plant growth without the need of traditional soil media. Instead of using soil to produce plants, hydroponics uses a water solution rich in vitamins and minerals. Tomatoes, peppers, cucumbers, strawberries, lettuces, and cannabis are plants that are typically grown hydroponically for commercial purposes.

In order to reduce agricultural production inefficiencies and increase performance, the integration of IoT technology into alternative farming techniques has received significant attention [5]. Internet of Things (IoT) can monitor and regulate hydroponic systems and operate effectively in any environmental conditions. In order to execute the appropriate levels of control, a grower does not need to be present all the time. This is made feasible through wireless IoT connectivity. As comparison to plants grown on soil, plants grown in nutrient solutions can mature up to 25% quicker and produce up to 30% more yield [6]. A crucial component of attaining these types of outcomes is wireless IoT systems. With hydroponics gardening, the crops yielded are healthier and requires comparatively less amount of space, water and is easy to implement. Thus, this is an approach to enhanced agriculture with the use of modern technologies like IoT.

II. DESIGN AND OPERATION OF HYDROPONICS

A. Why Hydroponics?

Plants often grow on soil because it is the most accessible growing medium. For the successful development of plants, it provides nutrients, air, water, and other elements. The expense of switching from one soil to another development media is usually high. A system for growing plants known as hydroponics or soil-less culture lessens some of the problems encountered in typical crop development. In the tropics, where these living things' life cycles continue to progress and the risk of invasion increases, it provides strategies for controlling soil-borne diseases and annoyances [7]-[8].

B. Requirements of Hydroponics?

1. A constant supply of water enriched with nutrient along with good air circulation.
2. Good amount of light for healthy growth of plant.
3. The temperature and humidity of the environment should be appropriate for plant.

TABLE I. REQUIREMENTS OF HYDROPONICS

pH requirements	5.8-6.5
Light requirements	13-16 hours per day
Temperature Requirements	20 °C -30 °C

III. PROPOSED SYSTEM

A. Main Components

1. NodeMCU
2. Microcontroller Module
3. Arduino UNO
4. Ultrasonic Sensor
5. Water Level Sensor
6. DHT11 Sensor
7. pH Sensor
8. Relay Module

B. Flow Chart

The overall system flowchart is shown in Figure 13. The Hydroponics framework is connected with the IoT devices. Different sensors are deployed to monitor the condition of the plants and notify the user accordingly. If the nutrient level of plants goes below the threshold value, the user is notified via the mobile application and the motor is turned on. Similarly, if the temperature and humidity falls below the threshold, the user is notified and the fan gets turned on. Based on the requirement of the plant, the light is provided. pH of the plant is also checked and regulated if needed. The system is monitored continuously and the values are displayed in the mobile application, making it convenient for the user to track the growth of the plant.

C. Experimental Setup

The setup consists of a frame structure which holds two different plants - lettuce and coriander which are grown vertically. The frame has six solution containers having nutrient solution and on top of it net pot is embedded to hold plants. A 12V pump is attached to the frame to supply nutrient solution from the nutrient tank. The frame also consists of fan, LED light and the IoT setup to monitor the growth of the plants. The water pump motor, electrical components and sensor, and their supporting system are also shown in Fig14.

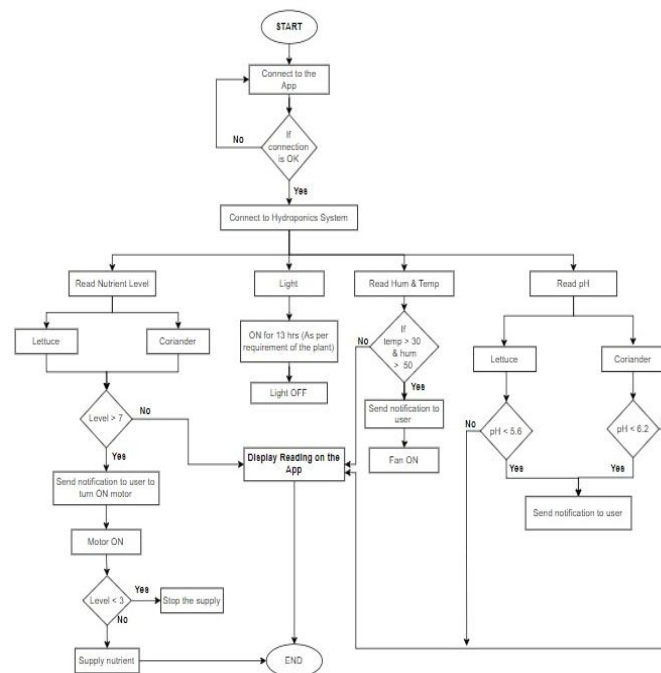


Fig 1: Flow Chart



Fig 2: Setup of Vertical Hydroponics

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D. Environmental Condition for Plants

The hydroponics system consist of Lettuce and Coriander plants:

a. Lettuce

The hydroponic lettuce crop grows in about a month and expands very quickly. In addition to being very easy to grow hydroponically, the crop itself is highly versatile in the kitchen. The small seeds are able to grown quickly in

a hydroponic system that uses only nutrient-rich fluid by first germinating in a soil-less medium. Studies show that some lettuce kinds, particularly leafy types and in addition to those with deeper or redder colors contains bio-active substances with anti-inflammatory, cholesterol-lowering, and even anti-diabetic activities. [13].

TABLE II. REQUIREMENTS OF LETTUCE

pH requirements	5.5-6.0
Light requirements	Between 10 and 14 hours of light per day.
Temperature Requirements	20 °C -24 °C

b. Coriander

Coriander sprouts easily and fast. Within 7–10 days, it will be prepared for transplantation into your hydroponic system. In comparison to other common hydroponic crops like peppers and tomatoes, coriander is a plant that is simple to produce. Like lettuce, Coriander doesn't take up as much room, uptake as much food, or require as much space as other common hydroponic plants. Coriander leaves have extremely good vitamin A and C preservation. Coriander leaves are a pot of nutrients, including dietary fibre, iron, manganese, calcium, vitamin K, phosphorus, and others. [14]

TABLE III. REQUIREMENTS OF CORIANDER

pH requirements	5.5-6.7
Light requirements	Between 12 and 15 hours of light per day.
Temperature Requirements	25 °C -30 °C

E. Data Gathering Procedure

The different sensors used in the system are Ultrasonic sensor, Water level sensor, pH sensor, Temperature and Humidity sensor. The process in which these sensors gather the data are as follows:

1. The ultrasonic sensor is calibrated according to the level of the nutrient tank being used. Once it is done, the threshold is set and the sensor is placed on top the nutrient tank.
2. The threshold of water level sensor is set based on the container size, and is submerged inside the container holding plant with nutrient solution.
3. The pH sensor is calibrated with the solution whose pH is already known. After this, the pH is submerged in the container to check the pH value of the nutrient solution is as per the requirement of the plant.
4. The temperature and humidity sensor is directly attached to the frame to calculate the temperature and humidity of the environment in which the plants are kept.
5. These sensors continuously gather the data and the reading is displayed on the mobile application.
6. If the ultrasonic sensor reading does not match with the threshold, the notification is sent to the user.
7. If the water level sensor, shows low reading, then the user is notified to turn on the motor pump, which will supply the nutrient solution from the tank to the container.
8. If the value of the pH changes, the user is notified to adjust pH of the nutrient solution.
9. If the temperature and humidity goes beyond threshold, it is adjusted by turning the fan on.
10. This process is done until the complete growth of the plants.

F. Android Application

The vertical hydroponics Gardening system can be monitor using Mobile Application. This mobile application is developed using React Native. The list of plants that we can monitor will appear when we start the application. A new screen with buttons to ON or OFF the fan, light, and motor will appear after choosing plant. Besides that, the readings for nutrient, PH, temperature, and humidity will also be displayed here. Using postman we can read the data of blynk using API and send it to our application. According to the notifications that are received on the application, the user can monitor motors, lights, and fans. The user can remotely control and monitor the vertical hydroponic system using this mobile application.

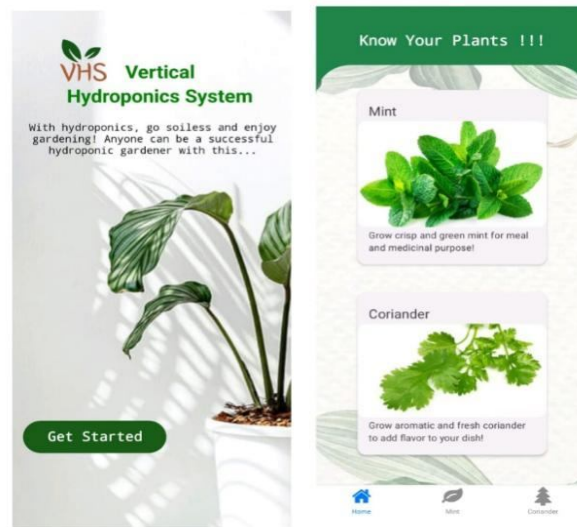


Fig 3: Screenshot of Application

G. Blynk Cloud

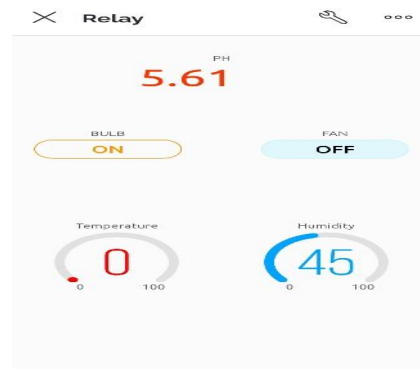


Fig 4: Screenshot of Blynk Dashboard

Blynk IoT Platform is a complete software package which is used to prototype, install, and remotely manage any type of connected electronic device. It can store data, visualise it, show sensor data, remotely operate devices, and perform many more useful tasks. Also, it is possible to share a project with friends or even clients so that they can access the associated devices but cannot alter the project [15].

The platform consists of three main parts:

1. *Blynk App* - allows you to use the many widgets we offer to build attractive interfaces for your projects.
2. *Blynk Server* - is responsible for monitoring all hardware-to-smartphone connections. You have the option of using our Blynk Cloud or setting up your own local Blynk server. It can even be started on a Raspberry Pi, is open-source, and has no trouble supporting thousands of devices.
3. *Blynk Libraries* - enable connectivity with the server and handle all incoming and outgoing commands for all major hardware platforms.

IV. RESULT AND DISCUSSION

The data collected by the sensors will be displayed at the mobile application as well as the Blynk Cloud. The Blynk Cloud can be accessed by both laptop and the mobile. The reading of the sensors is varied according to the changing environmental conditions and is displayed on the application as shown in the Fig 17. The user of the system monitors the plants using the application and control the system based on the conditions. As the reading goes above or below threshold, the user is notified by the push notification as shown in the Fig 18. Depending on the notification, the user can take actions.



Fig 5: Screenshot of Reading

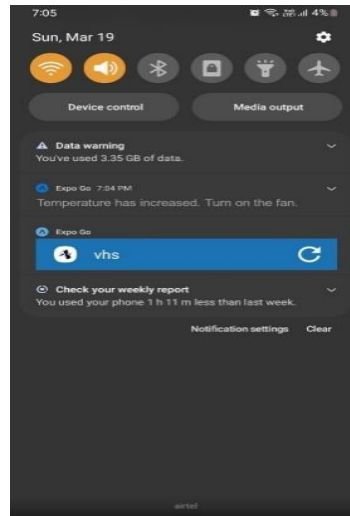


Fig 6: Screenshot of Notification Panel

Hydroponics system saves more than 50% water than the traditional farming, this is because plant's root absorb only 0.1 percent of the water, rest is lost by evapotranspiration. But in hydroponics, the water is re-circulated from the fixed tank. The usage of fertilizers and insecticides is eliminated, thus producing nutritious and healthy plants. Growing plants hydroponically is 30-40 % faster as the roots get nutrient directly from the nutrient solution. Taking up nutrients from the soil can be slower. The summary of these details is shown in Table 4.

TABLE IV. TRADITIONAL VS HYDROPONIC SYSTEM

Parameters	Traditional Soil System	Hydroponics Soilless System
Water Used	20L per kg	10-12 L per kg
Productivity (%)	100	120
Fertilizer (%)	100	0
Growth (%)	60	24

This method of growing plants soil-less is relatively new and is being explored. The integration of hydroponics with IoT which may make farming undoubtedly more convenient. The word vertical means growing the plants vertically one above the other, this saves a lot of space and varied other crops can be grown in parallel. With hydroponics gardening, the crops yielded are healthier and requires comparatively less amount of space, water and is easy to implement. Crops will be preserved from severe weather and other calamities like hurricanes, floods, droughts, snow, and which will reduce the efforts required by the farmer in protecting the crops. Thus, this is an approach to enhanced agriculture with the use of modern technologies like IoT. Hydroponics is thus an innovative way of making the agriculture smarter. The system has a very extensive future scope. AI can be used with hydroponics to enhance the system [16]-[17]. The integration of this system with AI can develop disease resistant plants and can prevent the spoilage of plants at an early stage. [18]. Furthermore, the system can be extended to grow rare farming plants such as saffron, which requires extreme special conditions for their growth [19].

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