Fully Automated Hydroponic System for Growing Tomato Plant

[1]Devvrat, [2]Rajeev Ratan
[1]Research Scholar, [2]Associate Professor
[1, 2]ECE Department
[1,2]MVN University, Palwal, India

Abstract

Growing certain plants and vegetables in remote areas such as deserts and the north and South Pole can be a challenge because of the extreme outside weather. Very few species of plants thrive in such situations and are often not used as a food source [1]. In this study, we created a system that can grow common plants and vegetables and can operate without depending on the outside climate. We achieved this by using a technique called Hydroponics. Hydroponics is a method of growing plants without using soil [2]. The system was automated using microcontrollers and sensors to keep human intervention at a minimum. An Internet of Things (IoT) network was created to improve reliability and allow remote monitoring and control if needed. The user is only required to plant a seedling and set initial parameters. Once done, the system is able to maintain the parameters and promote healthy plant growth.

Keywords: Hydroponics; Automation; Internet of Things.

1. Introduction

The purpose of the project is to expand and improve the utilization of hydroponics as well as to create an environmentally independent system for indoor plant growth. In a hydroponic system, a plant is placed in a solution composed of soluble nutrients and water as opposed to soil. In most conventional hydroponic systems, parameters such as EC and pH of the water solution are set to the desired value while setting up the system [3], [4].

There are several other parameters such as air temperature and humidity, lights, water temperature etc. which are not controlled or maintained. These parameters are important for a healthy and faster plant growth [2]. In this project, we built a system which monitors and controls all the parameters necessary for healthy indoor plant growth. In general, the process goes as follows: create a nutrient solution based on the plant being grown, apply this solution to a layer of water, and place a germinated plant into the water such that the exposed roots are touching the solution. If the parameters are maintained within optimum levels, the plant should grow faster and healthier than its natural growth. Typically hydroponic systems require human interaction when it comes to the regulation of certain elements that allow the plant to grow [4]. The goal of is to make a system that is cost-effective and, most importantly, is completely automated and requires virtually no human interaction after placing the germinated plant into the system. The other aspect is to create a system that can be used by a typical consumer; meaning that it is relatively small and simple to use.
This project accomplishes automation by utilizing Arduino Uno, sensors, and IoT technology for remote monitoring, and control. In the most basic description of its operation, the system takes inputs from the sensors and provides a controlling action to keep different parameters in the desired range.

Automated hydroponics systems currently on the market are either very expensive or don't control all the parameters necessary for a healthy plant growth[5] [6]. This study provides complete automation with monitoring and control of all the parameters necessary for the growth of a plant.

2. Methodology

The system uses two Arduino boards for the analysis of the received data and control. A Raspberry Pi is used to run open source automation software called Domoticz. Once the Raspberry Pi receives the input data, it updates the server. The system also uses a mobile app to enable monitoring and control from Android devices [7]. As the system is relatively small, it can be fitted into a small office space or a nook in the home. This accomplishes the second goal of the project. The complete automation and size are what make Titan Smartponics different from other hydroponic systems.

Hardware

In Fig. 1, the proposed system is presented. The system uses two Arduino microcontrollers acting as nodes. Nodes take the data from the sensors and send the data to a third Arduino acting as a gateway in the IoT network. NRF24L01+ radios are used for the communication between the nodes and a gateway. The gateway is connected to the Raspberry Pi running a local server which makes the data available on the web interface and mobile application. The LED's provide light to the growing plant. The lights are set to a 14 hour ON cycle to simulate daytime. A Real- Time Clock (RTC) is used to keep track of the time. The lights, along with a small exhaust fan, are controlled using a relay module. The camera mounted on the system can be accessed remotely through the Domoticz app as well as the web interface to monitor the state of the plant.

The state of the system is monitored by using various sensors. An air pump is used to infuse the water with oxygen for the plant to absorb through its roots. The system contains four sensors: an electrical conductivity probe, a pH sensor, a water temperature sensor, and an air temperature/humidity sensor, shown in Fig. 2. The electrical conductivity probe allows us to estimate an amount of salts or nutrients in the water. The pH probe must be calibrated using calibration liquids [8]. Measuring the pH allows us to properly adjust the pH of the water before putting the young plant into the system. The EC and pH probes are connected to a transmitter to convert the information received by the sensors into pH and EC values. Distilled water was used to have base pH value close to 7 and adjusted to be between 5.6 pH – 6 pH after adding nutrients. Measuring the pH of the water at consistent temperatures is vital since the pH is dependent on temperature [9]. The water was heated up to 25°C and then the pH was adjusted using acidic and basic solutions. A water heater heats up the water and automatically maintains the water at a temperature of 24°C and 25°C which is optimum for healthy root growth [2]. Carbon dioxide is supplied to the system by a carbon dioxide releasing pad.

Fig (1) . NFT System

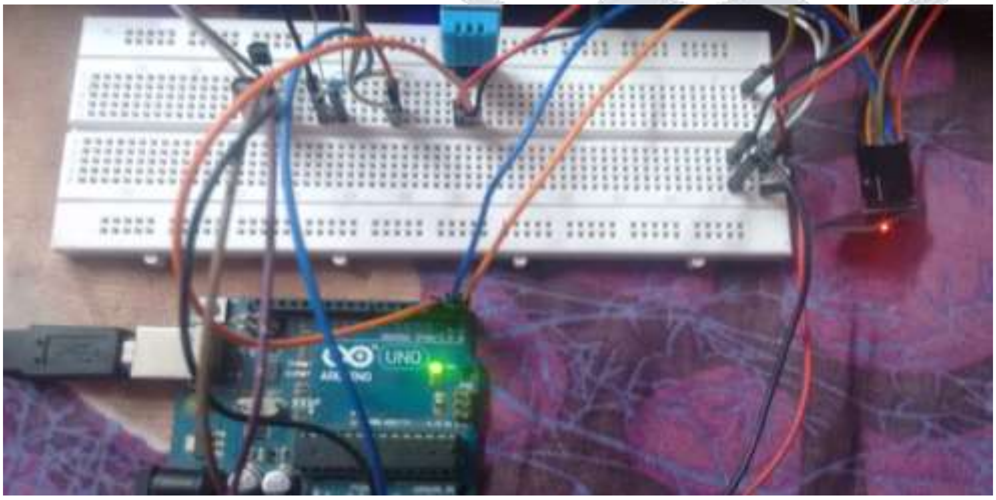

Fig. 2. Different sensors and parameter inducers.

Software

The system uses Arduinos which are programmed using the Arduino IDE.. This software is responsible for operating the sensors and lights. The system was configured as a sensor network in Internet of Things by using an open source API called MySensors.

This enables the creation of nodes, gateway, and communication between them. The system uses a Raspberry Pi which is running a local server to enable remote monitoring and control of the system. A small script runs on Raspberry Pi to automatically monitor the state of the server and restarts it if necessary.

Domoticz has a web interface that allows the user to visualize the data that is received. This interface can also take user inputs, this was used to allow the user to toggle the lights ON and OFF if they wanted. Each box represents either a sensor, actuator, or lights. The values presented are changed when an update in the values is reported by the system.

The main source of monitoring comes through the web interface; however, Domoticz also offers a mobile phone application that allows for more accessibility. Through the application users can monitor the same parameters as well as view the camera and maintain a control over the lights if needed. Fig. 4 shows the message sent by the system.

Figure.3 Android Application

The system also notifies the user if values of the parameters drift out of the bounds abnormally. This can be caused by not closing the system properly, sensor failure, or a node failure. This piece of code runs on the local server which is independent of all the electronics that are responsible for the operation of the system. This means that a failure in the electronic components controlling the system will not cause these messages to be disrupted. The alert messages are achieved using a Pushbullet API and are supported by Domoticz.. These messages can be configured to be sent to the Pushbullet application on a mobile device or a desktop machine.

Fig 4. Sensors Readings in Mobile App

The smart greenhouse is connected to an android application hosting a web server. The sensor information is provided to the user so that the plants can be monitored from anywhere. This is done through a button showing the live readings \ of the plants and through graphs plotting the values for the past week or so. This means that a user will be able to see if something has gone wrong with the system. o the bloom cycle (once per plant cycle). Currently the android application is an HTML webpage, that if connected to the proper internet connection could be available anywhere.

3. Results and analysis

Data analysis was done using the logs that were kept by the Domoitcz software. Each log is updated constantly and demonstrates the values that were reached each day. The air temperature log in Fig. 6 shows the progression of temperature from 24°C to 20°C as the day turns into night. Fig. 7shows the amount of time the lights were ON and at what time they switched state (from ON to

OFF or from OFF to ON). This is needed to make sure that the plant is getting the optimal amount of lighting. The water log keeps track of the water temperature that the plant is sitting in, shown in Fig. 8. The pH log shows the change in pH levels over time. As the plant consumes more and more nutrients from the water the pH value increases. Shown in Fig. 10. This is because of the acidic nature of the nutrients.

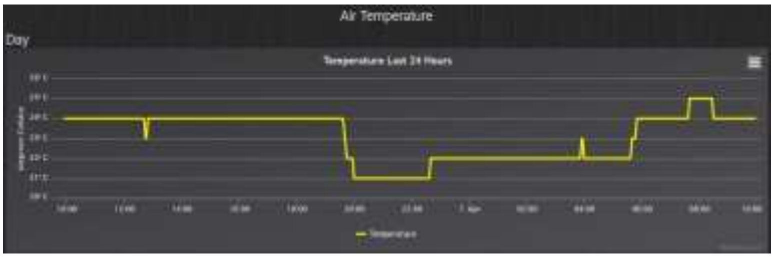

Fig. 5. Air temperature log.

Fig. 6. Light log.

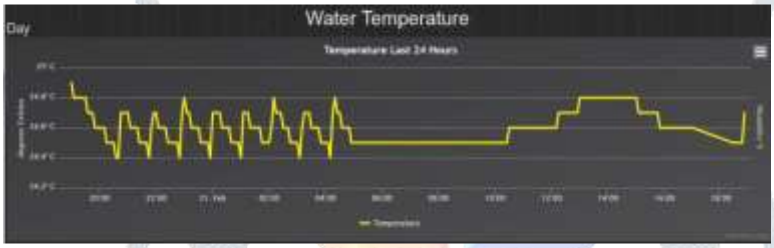

Fig. 7. Water temperature log.

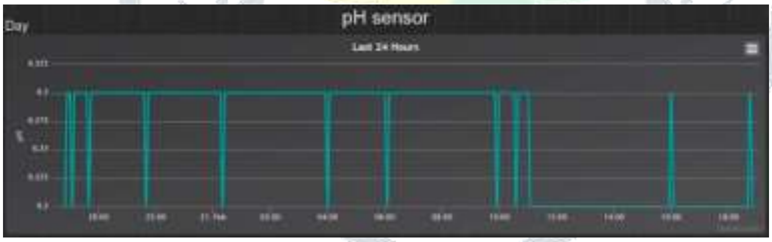

Fig. 8. pH log.

Plant needs five things: food, water, light, air and support. We can provide all five in a hydroponic system. Hydroponics plant grows well with less use of water and fertilizers. Growth rate of current hydroponics plant is 40-50 % faster than the soil system

Fig. 9. Comparison of plants (top image is of outside plant; bottom image is of the plant within the system).

Each log is important in making sure that the controlling actions are keeping all parameters at optimal levels and aids in making sure that the plant flourishes. Part of the analysis for this project was through the comparison of a plant within the system and a plant outside the system. The status of both plants was monitored over the period of four weeks. Pictures were taken 3 times per week to show the difference in growth. What was concluded from this analysis was that the plant within the system grew better than the plant outside the system. This was seen through factors such as the color of the leaves, the size of the plant, and the length of the stems. Fig. 10 demonstrates the difference between the growths of the plants. The image also shows the prior mentioned factors that were considered when judging the plants' health.

Table 1 - Comparison of Soil Based & Automated Hydroponic System

Technique for Cultivation (tomato)	Production (kg/m^2/crop)	Water Usage (L/kg/crop)	Time Duration (in months)	pH (moles/L)	EC (mS/cm)	Temperature (°C)	Relative Humidity
Soil Based System	1.5	450	4	Measurement is not required			
Earlier Hydroponic System	10	10-Aug	3	4.4 - 6.8	1.4-10.4	30-35	34-50%
Current Hydroponic System	12	5	3	5.5-6	1.2-4.2	25-28	55-60 %

With this hydroponic system, total yield is increased by 17% compared with the earlier hydroponic system.

4. Conclusion

This system aims at maintaining pH at optimum levels of 5.5 - 6 moles/L and hence no nutritional problems will be observed in plants cultivated in our re-circulating system. Hydroponics growth and productivity are considerably affected by prolonged recycling of nutrient solutions. This system can play an important part in helping conserve water i.e. only 5 L/kg/crop were used and electricity consumption is only 5 KW & yet derive yields of higher magnitudes of approximately 12 kg/m^2/crop. Initial Investment stands as one time investment and same system setup can be used to grow variety of crops. This improves the production rate by 87.5 % if compared with Soil based technique & 17 % if it is compared with earlier hydroponic system by controlling the conductivity 1.2 – 4.2 mS/cm with relative humidity of 55-60 %.

This system aimed to create a fully automated hydroponic system that was low cost and fairly easy for the average user to operate. Through the usage of Arduino Uno, open source software, and a few sensors this goal was accomplished. The automated hydroponic system maintained the parameters needed for the test plant to thrive and was able to incorporate an IoT network for remote monitoring and control.

A few advantages are that there is complete control over the aspects that allow a plant to grow, it can be customized to fit the need of a variety of plants, and it does not rely on the outside atmosphere or environment to succeed. When compared to other systems, this system proved its importance through its complete automation aspect as well as its ability to be small enough, and affordable enough, for consumer usage.

References

[1] "Arctic Studies Center - Resources - Frequently Asked Questions", Naturalhistory.si.edu, 2017. Online. Available: https://naturalhistory.si.edu/arctic/html/resources_faq.html.

[2] Brechner, M.; Both, A.J. Hydroponic Lettuce Handbook. *Cornell Controlled Environment Agriculture*; Cornell University. Available online: http://www.cornellcea.com/attachments/Cornell CEA Lettuce Handbook.pdf.

[3] Devvrat, Rajeev Ratan, Ajay Kumar "Automated Hydroponics System to deliver nutrients directly to the root of plants", 2017 IJERT, Special Issue, ISSN No. 2278-0181, Page No. 327-330.

[4] Growth Technology, *What is Hydroponic growing?*, Available Online: http://www.growthtechnology.com/growtorial/what-is-hydroponic- growing/.

[5] I Mohanraj, AshokumarKirthika, J Naren, "Field Monitoring and Automation using IOT in Agriculture Domain", *ScienceDirect 6th international conference on advances in computing & communications ICACC 2016*, 6–8 September 2016.

[6] Simply Hydroponics and Organics, *Getting Started with Hydroponics*, AvailableOnline: http://www.simplyhydro.com/getstart.htm.

[7] LEAF, Tech Specs, Available Online: https://www.getleaf.co/.

[8] SuperCloset, *What is the Best Grow Box For Me*, Available Online: https://supercloset.com/what-is-the-best-grow-box-for-me/.

[9] Robbert E. Peters. (February 2015). Available Online: http://www.domoticz.com/DomoticzManual.pdf.

[10] Atlas Scientific. (September 9, 2016). pH probe datasheet. Available Online: https://www.atlas- scientific.com/_files/_datasheets/_probe/pH_probe.pdf.

[11] John J. Barron, Colin Ashton, Leo Geary, "The Effects of Temperature on pH Measurement", 57th Annual Meeting of the International Society of Electrochemistry, September 2016, Available Online: https://reagecon.com/pdf/technicalpapers/Effects_of_Temperature_on_pH_v4-_TSP-01-2.pdf.

[12] hek. (February 7, 2017). *What's all the fuss about?*, Available Online: https://www.mysensors.org/about.

[13] hek. (January 18, 2017). *MySensors Library*. Available Online: https://www.mysensors.org/download.