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Automated Hydroponics System

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***Abstract:** The purpose of this study was to control the factors that are responsible for plants growth in hydroponics systems and automate them to reduce the human effort with less space and electricity. In this paper we used a combination of two methods: Deep water culture and Nutrient film technique for the system. In this method plants will have continuous nutrient supply. We used a linear regression method to control EC and pH of the system and the microcontroller will send signals to the system to adjust them to desired value with the help of dozers by taking average EC and pH values.*
***Keywords:** Hydroponics, Electrical Conductivity (EC) and Potential of Hydrogen (pH), DWC and NFT, Linear Regression.*

I. INTRODUCTION

As the world population is rising, the supply and demand for different products is also rising, especially food products. Due to this increasing demand, there will be an expected crisis for food products in forthcoming years. The rise in human population has made researchers think for solutions on how to meet the need to feed the world. Furthermore, immigration from rural-urban has left the farms in the rural areas lacking farmers and the urban areas over-crowded. Farming is essential for the survival of a Human Being, as it provides basic requirements for living such as food and other necessaries. Earlier farming was done on agricultural farm lands and it has its own advantages and disadvantages. However, an efficient way of farming is developed now called hydroponics. A technique for growing plants without soil. Using this technology, roots absorb a balanced amount of nutrients dissolved in water to meet all requirements for plant development. This technique allows farmers to continue farming even in urban areas and even at home with less space required.

For healthy plants, the hydroponics system needs constant supervision and maintenance. Nutrient management is the method of using plant nutrients as efficiently as possible to increase productivity. Managing nutrients is a very important step in hydroponics. Total dissolved salt, pH level, alkalinity, and nutrient concentration ratios are some important characteristics to focus on when managing nutrients in a hydroponics system.

Plants require micronutrients, macronutrients, secondary nutrients and some other important nutrients from air and water. Nitrogen, Phosphorus and Potassium are classified as macronutrients. Zinc, copper, Manganese, Boron and Iron are micronutrients. Calcium, Magnesium, and sulfur are secondary nutrients. Hydrogen, Carbon and Oxygen are easily obtained through air and water.

In any type of hydroponic system Electrical Conductivity plays a major role in development of the plants because the EC value is nothing but the ability to conduct electricity. This ability is directly related to the concentration of conductive ions present in the solution. These conductive ions are produced by inorganic substances such as chlorides, alkalis, carbonates, sulfide compounds and dissolved salts. Mixing of minerals in water is termed as a nutrient solution. Measuring this EC value on a regular basis will help you in finding the optimum EC range for a given nutrient solution.

In hydroponics plant growth can also be affected by the acidity or alkalinity of the solution. This can be measured by pH value. The pH is the amount of acidity or alkalinity present in the solution. Proper pH is very important as it affects the availability of nutrients for growing plants. A pH value that is too high(alkaline) or too low(acidic) can interfere with the absorption of nutrients. In soilless culture it is preferred to maintain pH in the range of 5.5 to 6.5. The temperature of the nutrient solution considers an explicit association with the amount of oxygen absorbed and has a converse association between the amounts of oxygen dissolved in it. The temperature of root-zone portrays a significant impact not only on the growth of plants but also the composition of chemicals in a nutrient solution. Proper temperature is important because it affects the rate at which plants convert carbon dioxide, light and water into food (the process of photosynthesis). Incorrect temperatures can cause photosynthesis to be inefficient and could result in poor plant growth and yields. The ideal hydroponic temperature range is somewhere between 65°F (18°C) and 80°F (26°C) for truly optimal plant growth. The proper management of all the factors are very important for plant growth in Hydroponics. Manually it would be incredibly time-consuming and expensive to monitor the system. From this chapter, researchers see this problem and overcome it by making the system automatic for monitoring EC and pH values, and controlling them.

II. OBJECTIVE

1) To develop a system for people with limited or no outdoor space, such as urban residents, apartment dwellers, or renters who can't have an outdoor garden, to grow plants Our aim is to develop a simple and scalable cost-effective system which can be used by general people.
2) To provide an extended growing season i.e. the systems typically result in faster-growing, higher-yielding plants.
3) A hydroponics system eliminates the need for soil by providing a nutrient-charged aqueous solution directly to the roots that keeps the plant fed and hydrated.
4) This system provides you to stimulate root growth and enhance nutrient uptake, leading to better harvest. By this system plants can grow anywhere i.e hydroponics systems are easily incorporated into many homes, regardless of their size or location.

Types of Hydroponic Systems:

Sr no.	Name of method	Mechanism
1.	*Wick System*	In wick systems, nutrients and water are delivered to plant roots through a wick. Plants are suspended in some kind of growing medium. One end of the wick is in solution and the other end of the wick is in the growing medium. Roots absorb nutrients from the wick whenever they are ready to absorb.
2.	*Deep Water Culture*	A DWC consists of a reservoir filled with water and a nutrient solution. Plants are suspended in reservoirs using net pots and growing media. The roots themselves are submerged in reservoirs, so they are constantly supplied with water and nutrients.
3.	*Ebb and Flow*	In a system of ebb and flow, also called "flood and drain," plants are periodically flooded with nutrients. This is less common as it is less flexible to the plant's needs.
4.	*Drip Systems*	In drip systems plants are held in separate channels. They are hanging in netting pots over a very thin layer of water and nutrient solution. A pump continuously moves water through the canal to improve oxygenation and nutrient uptake. The remaining solution is returned to the reservoir for reuse.
5.	*N.F.T. (Nutrient Film Technology)*	In NFT water and nutrient solutions are contained in large reservoirs with air pumps to maintain oxygenation. A water pump set on a timer pushes water into the canal. This provides the plant with a thin film of nutrients and water where the roots are not completely submerged. The solution returns to the main reservoir and is reused in the system.

III. LITERATURE SURVEY

1) The final frontier in hydroponics is automation. This paper provides a comprehensive survey on smart hydroponic systems developed to date. There are two levels of automation, first is semi-automated and second one is full-automated. The paper discusses several components that can be used to automate the systems which can reduce manpower as well as efficiently control systems over humans. There are several benefits of smart automation such as availability, computational power, and data can be analyzed and displayed in various IoT platforms for storing.
2) This paper reviews various hydroponic systems from the existing literature to understand the challenges and how it is enhanced further. The two main hydroponic nutrient supply systems are Ebb and flow systems where the nutrient water solution is periodically flushed across the roots of the plants and drip irrigation systems which involves carrying the nutrient rich water solution through long pipes with a small hole at the location of the plants. Other methods are the Nutrient Film Technique (NFT) where the plant roots are dipped in the water containing the nutrient and oxygen. Aquaponics where aquaculture and hydroponics is combined together and aeroponics that involves spraying the plant's roots with nutrient solution.

3) In this study, an Arduino Uno Microcontroller-based irrigation automation system for hydroponic plants is demonstrated. It has been accomplished to use a sensor distance-based nutritional water flow system. A basic rule for whether or not to water can be made by adjusting the water level in the hydroponic tube to suit the needs of the system. They use an Arduino Uno microcontroller to automatically control the flow of nutrient solution with logic if needed. Also we understand the use of Ultrasonic sensors can be used for measuring level and solenoid valves can be used.
4) This paper discusses the various types of IoT platforms which can be used such as, Wyliodrin, Firebase, Domoticz, MySQL, and Thingspeak. A system made up of hardware and software that is used to manage IoT devices is known as an IoT platform. Systems that enable user interaction with intelligent things are referred to as IoT platforms. For analyzing data, storing, and displaying data coming from IoT devices, IoT platforms are helpful.
5) The process of the actuators checks that valve and its control system function properly even in the process of data has demonstrated that the tool is able to regulate pH conditions in the intended range of 6.5 to 7.5. pH fluctuations during retrieval do not happen frequently, making this feature invisible on the chart. This is because to the tiny amount of hydroponics, which prevents the pH from changing too much, and will change if the hydroponics area is expanded.
6) In this study suggested a highly dependable wireless tomato hydroponic control system. They utilised the 400 MHz band and the IEEE 802.15.6 standard technique for a highly reliable WSN to address the issue of employing wireless sensor networks in an agricultural field. In a high temperature, high humidity environment, we also implemented software for a variety of fault-tolerant or interoperable hardware. After that, they set up the hydroponic tomato control system and ran it in a greenhouse. The trials demonstrate the 400 MHz band's practical impact.
7) In this paper, authors have examined two farming systems to compare and find the best system. . As the world population grows, the demand for food is increasing. The use of soil systems cannot meet the world's growing food needs, developing a new cultivation and planting system. We need technology to avoid future food crises. The aim of this study was to investigate an efficient technique for growing the plants. An alternative planting system is found that is termed as a hydroponics system. Statistically the design of experiments was used for analysis between soilless culture and the regular soil system. For these two types of seeds were planted cucumber and armenian to observe the expected results. The results were compared and the hydroponic system has a higher growth rate as compared to soil culture.
8) This paper discusses the methods to control EC and pH of the Hydroponic system automatically with the help of Linear Regression. The paper uses a linear regression equation to control EC and pH, there are 3 variables that need to be observed: Target value, Input value, and Adjusted value of these parameters. Then avg values of EC and pH from the dozing tank per sec taken from the list of experiments and then calculate the amount of time required for dozers to match the target value.
9) A review paper discusses the technology used in hydroponic systems using IoT, machine learning, cloud computing, and fog computing to improve crop yields and reduce input costs. By connecting to IoT, farmers can collect data and see informed statistics and analytics. Machine learning algorithms ensure farmers with crop selection and forecasting, weather forecasting, crop disease prediction, and intelligent irrigation systems. With the exponential growth of Internet of Things (IoT) applications, cloud computing faces several challenges such as High Latency, Low Capacity, and Network Failures. Therefore, these problems can be minimized by using fog computing. With fog computing, IoT data is sent between the cloud and IoT applications, rather than directly to the cloud, resulting in greater efficiency, faster response, and better quality.
10) This paper presents a locally developed automation and control system for an indoor hydroponic system to control and monitor electrical conductivity (EC) and pH of the nutrient solution. In this proposed control system, sensor networking, data collection and decision making are handled by Arduino Mega. EC and pH values are recorded with DF-Robot EC and DF-Robot industrial pH probes respectively. Recorded EC and pH values are sent to the Arduino Mega, which adjusts the values via actuators as needed. The recorded values are sent to the Raspberry Pi concurrently with the CAN bus protocol for data logging. The CAN bus protocol makes the system easy to expand and cost effective thus the system is inexpensive to implement on a large scale. Recorded values can be monitored by developing mobile applications and GUIs to provide users with clear control and information.

IV. METHODOLOGY

In this project we used a combination of 2 methods: Deep Water Culture System and Nutrient Film Technique.

A. *Deep Water Culture (DWC)*

In the deep water culture method, plant roots are suspended in nutrient-rich water and air is forced directly into the roots through air stones. In this technique we have to Place the plant in a net pot and suspend the roots in the nutrient solution for rapid growth.

Algae (also called scum) and mold (or moisture) can grow rapidly in reservoirs, so monitoring oxygen and nutrient levels, salinity, and pH is essential. This system is suitable for larger crops that produce fruit, especially cucumbers and tomatoes that grow well in this system. Flow of DWC method starts with the detail of the study that aims to find the solution of the problem i.e the importance of pH value in the water tank required to maintain the quality needed. In this method the pH values are continuously monitored and adjusted until it requires a change. The water level in the tank is also measured by an ultrasonic sensor. This sensor will determine the level required in the tank. Next step is the hardware and software identification. The pH value is monitored by a pH module sensor. The pH sensor provides maximum degree of reliability, operating comfort and measuring certainty. Arduino Uno is a controller used to control a DWC system. Microcontroller will be attached with an LCD display to indicate the status of the system such as the pH value, water level condition and the action which needs to respond for the system.

B. Nutrient Film Technology (NFT)

In NFT technology, plant roots are placed in a shallow layer of water that circulates and contains nutrients. An advantage of using NFT technology is that plant growth is easier to control. The most important parameter to monitor is TDS/EC in hydroponics. Each plant requires a different balance of composition and amount of nutrients. The amount of nutrients supplied should correspond to the needs of the plant. The values of EC levels are affected by plant growth, development and yield. Too little or too much nutrient supply can lead to suboptimal crop yields and even crop failure. Therefore, a system capable of controlling the nutrient solution is required. The combination of these methods allows us to control the appropriate condition for plants to absorb nutrients from solution. And maintain water level throughout the system. These two methods work as a complete one cycle as water goes through the system and returns back to the container and the cycle continues.

C. Block Diagram of Proposed System

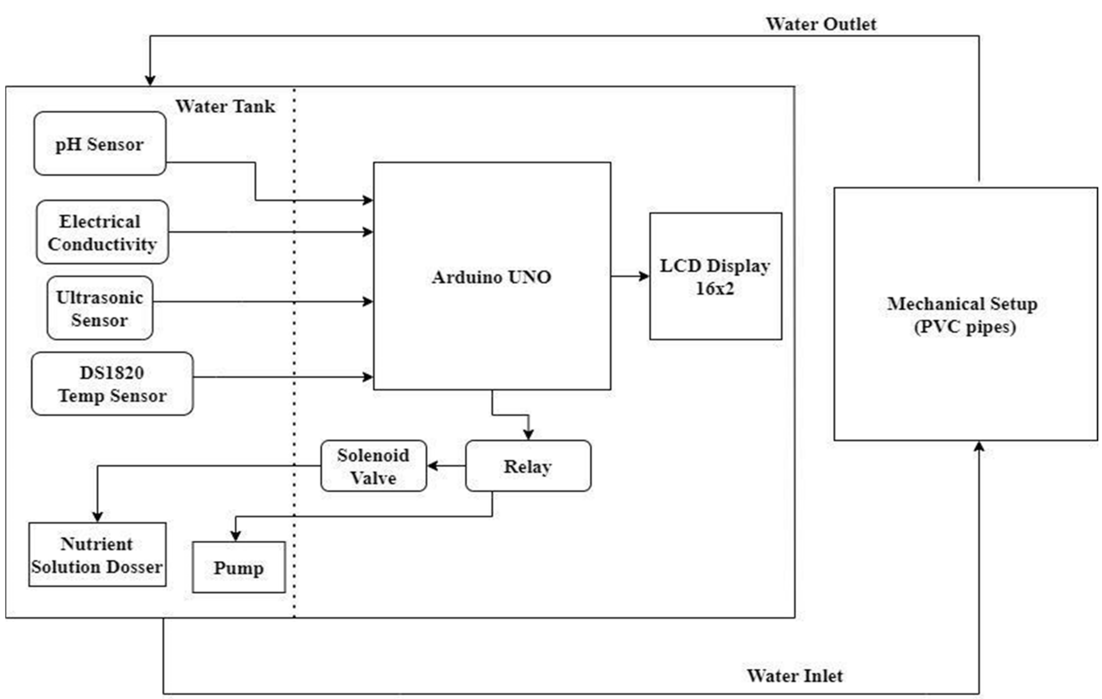

Figure 1: Block diagram of the proposed system

The hydroponic system consists of the main power supply, arduino UNO, pH sensor, electrical conductivity sensor, temperature sensor, ultrasonic sensor, relay module, sensing and control system, etc. All the sensors connected to the hydroponic system are continuously monitored and their readings are displayed on 16x2 LCD Display. When the system is on all the sensors extract reading, send them to Arduino. Water is pumped continuously throughout the system. As it's a closed loop system, excess water returns back to the system.

D. System Flowchart

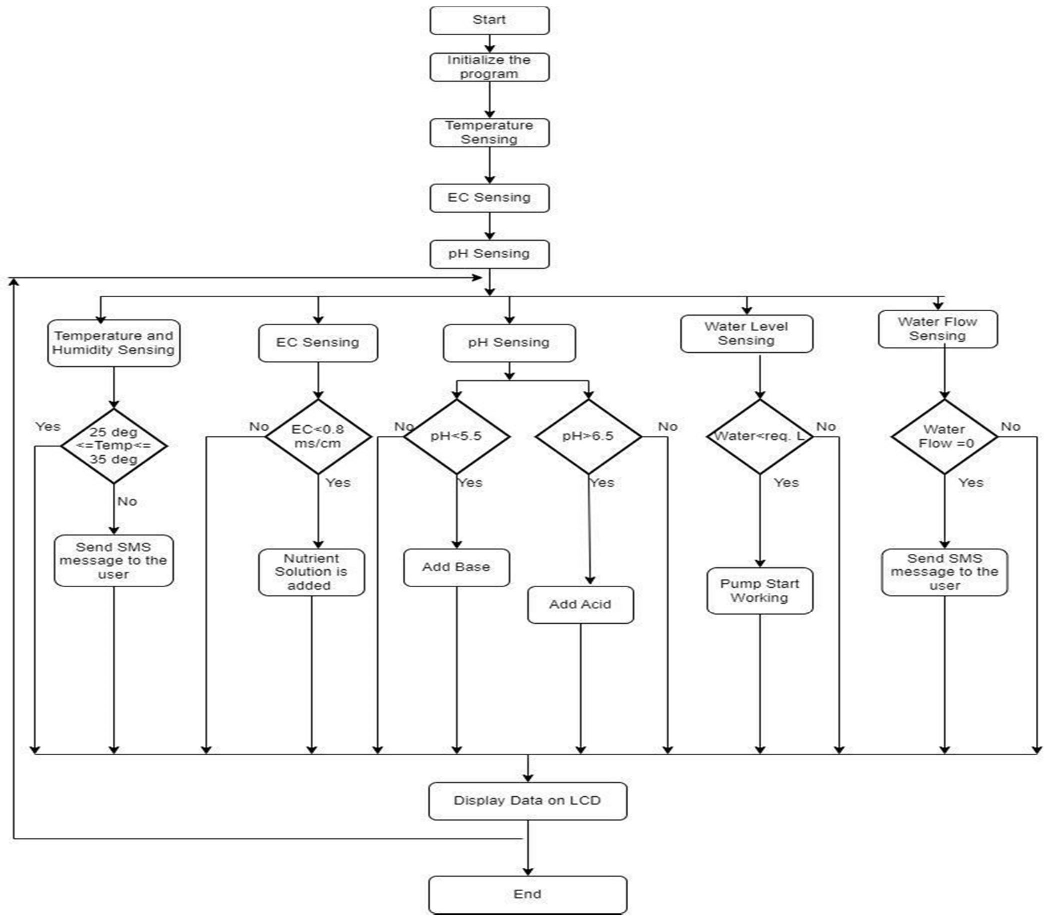

Figure 2: Flowchart of the proposed system

The system begins with initializing the program in arduino UNO as and when it gets the power supply. Once the program is initialized, the system starts working and a water pump starts to flow the water in the hydroponic structure from the water container and return back the excess water to the container. In this time, the system starts to monitor the various parameters like temperature, electrical conductivity and pH level. All these parameters are measured simultaneously and all the reported results are displayed on the LCD screen. In the flow of program, temperature and humidity sensing is carried out and if the obtained temperature is in the desired range from 25 degrees to 35 degrees then system directly displays the data on LCD screen , where as if temperature is out of the boundary condition , system sends an sms message to the user and the required actions needs to be taken. While performing EC sensing if the noted EC value is greater than 0.8ms/cm no action needs to be taken where as if it gets less than the specified value then nutrient solution is added automatically by the help of solenoid valve through dozers. In pH sensing if pH value is found to be less than 5.5 then the base solution needs to be added and if it is greater than 6.5 then acid solution needs to be added, but if pH is obtained in the optimum range then it is directly displayed on the screen. Continuous water flow is an important factor in the whole hydroponic system, if water level in the system gets decreased by the desired level then the pump will automatically start to work, and in case of some failure in the system, an alert message is sent to the user. All these readings are displayed on screen for monitoring purposes and controlling purposes.

E. Working of Proposed System

First the system will take input of 220v AC supply from home connection. The pump uses 220V to supply water from the tank to the system. SMPS will convert 220V to 12v DC supply. 12V is supplied to a dc-dc buck converter to give an output of 9v to pH sensor and IC7850 to give an output of 5V to Arduino UNO, ultrasonic sensor, electrical conductivity sensor, temperature sensor and lcd display. A container is used to reserve the nutrient solution that would be supplied to the hydroponic system and since it is a closed system, all the excess solution would return to it.

Electrical Conductivity sensor is used to keep track of the amount of nutrition being added within the suitable range so that plants will have proper nutrients. The ultrasonic sensor will detect the water level in a hydroponic nutrition tank. If the water level is decreased, then the sensor will report it to the system and the buzzer will be turned ON, the user then needs to add the required amount of water in the tank to maintain the water level. The pump will be continuously ON to supply the nutrient solution to the plant. Here two relays are used. One is used to control the water flow from pump to the hydroponic system and another is used to control the nutrient solution flow from dozers to SV(Solenoid valve) into the tank. This SV is interfaced with the switch (potentiometer) which is used to adjust the nutrient dosing time in x mins. After x mins, it will automatically doze the required amount of nutrients for 4 seconds and this process will be repeated in a regular interval of time.
All the parameters are continuously monitored by the sensors to make the system more efficient.
Figure 3 represents the hardware model of the system.

Figure 3: Hardware Model of Proposed Structure

Our Structure consists of three horizontal rows made up of the pvc pipe and in each row three holes are made of specific diameter. In each hole plastic cups have been inserted and in that coco peat has been used to grow the plants in the hydroponic system. Coco Peat has the ability to store and release nutrients to plants for extended periods of time. It also has great oxygenation properties which is important for healthy root development and also has a pH of 5.0-6.8 which is neutral to slightly basic this makes it great for planting purposes. It does not contain any nutrients of its own hence nutrients need to be supplied externally. The high cation exchange capacity of coco peat allows quicker absorption of nutrients.

V. AUTOMATIC EC CONTROL

EC is the main component for any hydroponics system. To maintain its growth and nutrients requirement, continuous monitoring of these parameters is required. To find the equation for EC, we can achieve this by using the Linear Regression Method. In this method we will take the average values of EC per second from dozers solution through Solenoid valve. Minimum 10 readings required to take the average for EC.
We have to measure the actual EC of the system and then compare it with the optimum values of EC i.e. ECactual. Then we will require the adjusted values of ECadjusted and after that we will require the $EC_{desired}$ values by this equation:

$$EC_{desired} = EC_{actual} + EC_{adjusted}$$

VI. RESULT

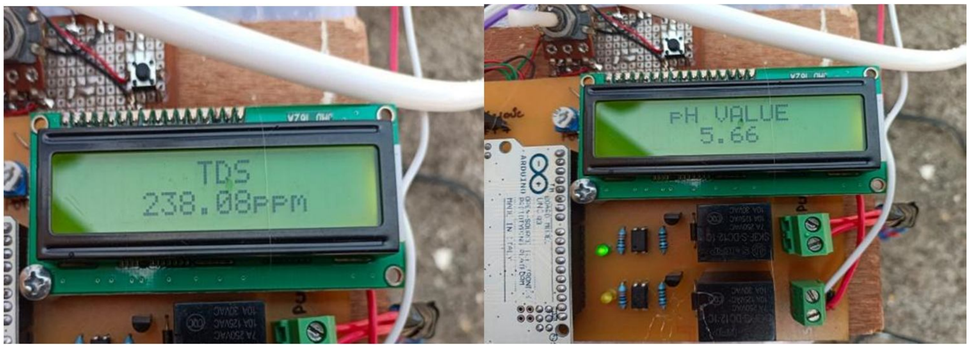

Figure 4: Displaying TDS and pH value on LCD Screen

Figure 4 displays the EC and pH value of the solution stored in the container.These are the continuous readings that are being monitored by the system . These value gets changed after certain interval depending upon the amount of nutrient solution being dosed in it, and the resulted effect on pH value of solution is also been observed for the same. To analyze the system we have calculated the average EC value of the nutrient solution being used. Table 1 depicts the amount of nutrition solution being dosed in the one second, and these readings are carried out for ten readings, and then the Mean value is being calculated. So, the mean EC value was found to be 354.7ppm. And the mean nutrient solution comes from the dozers is 7.538 ml. The Nutrient solution we have used for our Hydroponics system is FERTISIL NPK 16:16:12.

Table 1: Calculating the Mean EC value for Nutrient Solution:

Sr No.	Time(sec)	Solution(ml)	EC (ppm)
1	1	7.81	421
2	1	7.60	367
3	1	7.62	380
4	1	7.54	339
5	1	7.58	320
6	1	7.43	348
7	1	7.40	352
8	1	7.49	359
9	1	7.50	342
10	1	7.41	319

The plants we have grown in the Hydroponic system are Tomato and Coriander and optimum range in ppm is 1400 -3500 and 768 - 1152 respectively.

Table 2 shows the EC value calculation for the plants Tomato and Coriander. Our aim was to achieve the desired EC level, after starting the system LCD screen displays the actual EC value for the plant. So to get the adjusted EC value we find the difference between desired EC and actual EC and result was the EC to be adjusted.

$$EC_{adjusted} = EC_{desired} - EC_{actual}$$

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Now, to calculate the dosing time we have used the linear regression method in which EC adjusted value is divided by the mean EC value and therefore the solenoid valve will automatically dose the required amount of nutrition for the obtained dosing time.

Table 2: EC Value results for Tomato and Coriander

Sr No	Plant	$EC_{desired}$ In ppm	EC_{actual} In ppm	$EC_{adjusted}$ In ppm	Dosing Time In sec	EC_{final} In ppm
1	Tomato	2450	237	2128	6	2365.2
2	Tomato	2450	269	2181	6	2397.2
3	Tomato	2450	333	2128	6	2461.2
4	Tomato	2450	397	2053	5	2170
5	Tomato	2450	436	2014	5	2209.5
6	Tomato	2450	477	1973	5	2250
7	Coriander	960	71	889	3	1135.1
8	Coriander	960	109	2	2	818.4
9	Coriander	960	161	799	2	870.4
10	Coriander	960	184	776	2	893.4
11	Coriander	960	260	700	2	969.4
12	Coriander	960	295	665	2	1004.4

Hydroponics system require the continuous water flow for the system , for that a container is used to store the water which circulates the water in the entire system with the help of pump, so by the help of ultrasonic sensor ,we depict the level of water available in the container, and if the tank gets full , or decreased by the desired level, then the system shows the message on the LCD screen as shown in figure 5.

Figure 5: Displaying available Water level in container

As discussed in the methodology, we can calculate the dosing time with the help of linear regression method and mean EC value and the dosers will automatically doze the required amount of solution and it will display the message on lcd screen as “Nutrient Dosing” as shown in the figure6.

Figure 6: LCD screen displays Nutrient Dosing

VII. CONCLUSIONS

An automatic system for Hydroponics is designed with the help of Arduino UNO in this paper, the system directly controls and monitors the dosing of the nutrient solution through dozers using a solenoid valve. There are various parameters in the hydroponics system to be monitored. We have analyzed the interfacing of pH Sensor, temperature sensor, ultrasonic sensor and Electrical Conductivity with the Arduino and have obtained the readings of all these sensors that are displayed on the LCD Screen continuously. These parameters will keep changing according to the concentration of the nutrients that will be added as per the requirements from the plants to be grown. To maintain the optimum conditions for hydroponics, we have to calculate the Mean EC value using TABLE 1. Now with the help of TABLE 2, we have obtained the actual and adjusted values of EC and time required to dose nutrient solution, by this we can achieve the desired value of EC for Tomato and Coriander. However in this system the automation is limited to EC control, in future researchers can expand for other parameters like pH, temperature and other aspects of hydroponics.

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