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Design and Development of Automated Nutrient Regulation System for Hydroponics Unit

Rana Prathap, K. Krupavathi, K. Madhusudhan Reddy, A. Ashok Kumar

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ABSTRACT

Hydroponics is a method of growing plants without soil. Hydroponics, a subset of hydro culture, is a growing plant without soil, using mineral nutrient solutions in a water solvent. In soil less culture especially, hydroponics, the problem of regular maintenance of nutrient solution and required technical knowledge. The automation in hydroponics further helps to boom up the hydroponic cultivation. Automated nutrient regulation in hydroponics environment with automatic nutrient feed technology was developed and tested in the present study. The experiment was carried out an automated controlling and regulation of pH, TDS, temperature in polyhouse hydroponic system using Arduino-Uno controller, solenoid valves containing nutrients, water, pH-up, and pH-down and sensors. In this study, the sensors are connected to Arduino-Uno controller in which liquid crystal display (LCD) of Arduino-Uno circuit controls and regulates the system based on the coding which has been programmed previously. Calibration was done for all the parameters in the automated system. TDS and pH values of nutrient solution were recorded by using TDS and pH sensor probes respectively were fed to Arduino which adjusts the values, if required, through actuators. The prototype model was able to monitor and control the pH and TDS of hydroponic water in the required range with high accuracy.

Keywords pH, EC, Arduino Uno, Solenoid valves, Hydroponics, Sensors.

Rana Prathap[1]*, Dr K. Krupavathi[2], Dr K. Madhusudhan Reddy[3], Dr A. Ashok Kumar[4]

[1]PhD Scholar
Department of Soil and Water Engineering, Dr NTR College of Agricultural Engineering, Bapatla 522101, India

[2]Assistant Professor
Department of Irrigation and Drainage Engineering, Dr NTR College of Agricultural Engineering, Bapatla, India

[3]Associate Professor
Department of Soil and Water Engineering, SV. Agricultural College, Tirupati, India

[4]Principal Investigator
AICRP on FIM Scheme, Dr NTR College of Agricultural Engineering, Bapatla, India

Email : ranaprathap9898@gmail.com
*Corresponding author

INTRODUCTION

Soil is the most important component for plant growth that supports plant roots, supplies water, air and nutrients. However, soil do impose severe constraints like unsuitable conditions, unfavorable soil compaction, poor drainage, soil borne diseases, room for disease causing microorganisms. Growing demand for land, water and labor are other constrains in urban areas. According to recent research, current agricultural yield improvements will not be enough to meet world food demand as expected to grow by 2050 and that an expansion of agricultural areas will be required to ensure global food security. To meet the Millennium Development Goals, total food production will need to increase by more than 70% in the coming decades (FAO 2009). Hence, the conditions directed to soil less culture in small- and large-scale production of crops. Hydroponics is a method of growing plants without the use of soil. Hydroponics, a subset of hydro culture, is a growing plant without soil, using mineral nutrient solutions in a water solvent. The nutrient solution or the fertilizer mixture used must contain all micro and macro elements necessary for plant growth and development. In any hydroponics system the basic requirement is to maintain nutrient solution at optimum levels of pH and TDS (Total Dissolved Solids).

The benefit of hydroponics system is to boost production of crops by controlling nutrient supply through the management of pH, TDS, water requirement and temperature. Crops in hydroponic system are not influenced by climate change therefore, can be cultivated year-round and considered as off season (Manzocco *et al.* 2011). Timely monitoring of pH and TDS within the suitable range is key and vital in the maintenance of hydroponic system. There has been massive growth in hydroponic cultivation in a number of forward-thinking countries. This technique is very useful for the area where environmental stress (cold, heat, dessert) is a major problem (Polycarpou *et al.* 2005). Further, commercial hydroponic systems are automatically operated and expected to reduce labor and several traditional agricultural practices can be eliminated, such as weeding, spraying, watering and tilling (Jovicich *et al.* 2003). Due to technological advancements within the industry and numerous economic factors, the global hydroponics market is forecast to grow from US$226.45 million in 2016 to US$724.87 million by 2023.

Plant in a hydroponics system is sharing the exact same nutrient and water borne diseases can easily spread from one plant to another. Hot weather and limited oxygenation can limit production and may result in crop loss. Nutrients in hydroponics system can be maintained by checking pH and TDS. Maintenance of pH, TDS and proper concentration of the nutrient solution is of prime importance. pH values of nutrient solution determine the alkalinity or acidity of nutrient solution. It can either slow down the photosynthesis process or burn the roots of plants. On the other hand, low TDS values effect plant growth and high TDS values are responsible for nutrient uptake blockage. Hence, constant monitoring of pH and TDS is heart of hydroponics cultivation. Keeping the above points in view the present research is proposed develop an automatic nutrient regulation hydroponic system to monitor and maintain the required water, pH and TDS levels automatically with the help of sensors and micro controllers to grow crops in a hydroponic system in the poly house environment.

MATERIALS AND METHODS

The present study conducted at Dr NTR College of Agricultural Engineering, Bapatla in the polyhouse in an area of 250 m^2. The hydroponic system A-frame type structures (Fig.1) were used for holding the nutrient channels and plants in position. The NFT (Nutrient Film Technique) pipes were arranged on holders in a pattern such that a stepped like structure was formed for free growth of plants and free passage of air and light to all plants. The structure is made up of hollow galvanized Iron (GI) pipe of 10 cm square. The height of frame is 2 m. Five holders were given on both sides of the frame at a distance of 30 cm to hold channels. NFT channels were made up of food grade plasticized polyvinyl chloride (UPVC) in the

Fig. 1. A frame structure hydroponic system.

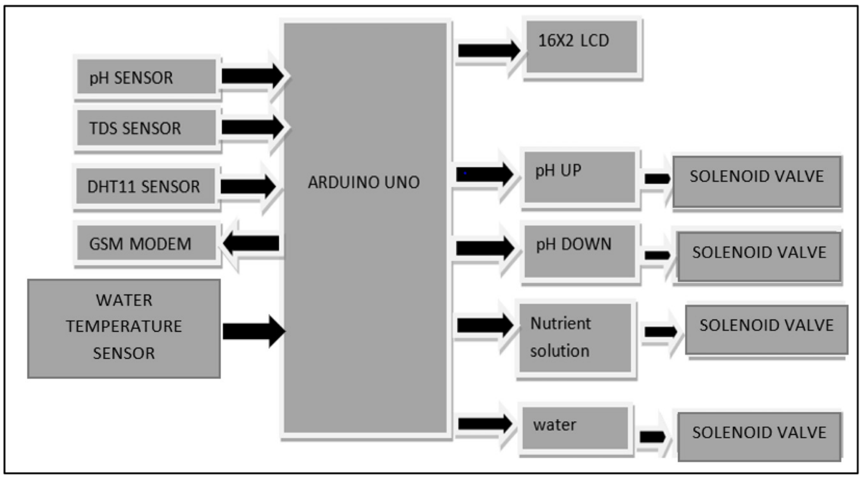

Fig. 2. The block diagram of automated nutrient regulation system.

form of rectangular channels. On each rectangular channel pipe, 20 holes for net cups were drilled at 10 cm distance. Holes were drilled with a size ranging from 7-9 cm diameter to match the size of the net cups used. For a A-frame, 5 rectangular channels arranged on each side. Single A-frame consists of 200 openings for net cups. Inside the polyhose, there are a total of eight A-frame structures were placed. Reusable net cups are webbed or slotted containers with holes in their sides and bottoms made of rigid plastic mesh to promote drainage and air circulation. Net cups allow liquid to flow freely past the roots of the plants they contain, facilitating the uptake of nutrients. As the plants grow, the roots extend out of the holes in the net cups and grow down through the cups in search of water.

Development of automated nutrient regulation system for hydroponics cultivation

The regulation system for pH and TDS of the nutrient solution in the hydroponic greenhouse prototype consists of a combination of hardware and software. The hardware design consists of a Temperature sensor, Humidity sensor, pH sensor, and TDS nutrition sensor combined with Arduino Uno software connected to four solenoid valves. These valves function to control the water, nutrient solution (TDS), pH-up, and pH-down. The block diagram of the proposed model is given in (Fig. 2).

Figure 3 shows an Automated nutrient regulation system, it consists of Arduino Uno, which is a microcontroller board based on the ATmega328P (datasheet). The Arduino Uno board can be powered via a USB connection or with an external power supply. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or with a battery. The adapter was connected by plugging a 2.1 mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the GND and VCC in pin headers of the power connector. The recommended range is 9 to 12 volts.

pH sensor, TDS sensor, water temperature sensor, air humidity and temperature sensors were used in the present study for sensing pH, TDS, temperature of water, temperature and humidity of air. The DHT11 temperature and humidity sensor has a temperature and humidity sensor probes with a calibrated digital signal output. The sensor was placed the near the tank which records the temperature and humidity of the polyhouse continually. When MCU sends a start signal, DHT11 changes from the low-power-consumption mode to the running-mode, waiting for MCU completing the start signal. After completion, DHT11 sends a response signal of 40-bit data that include the relative humidity and temperature information to MCU. Once data is collected, DHT11 will change to the low- power-consumption mode until it receives a start signal from MCU again.

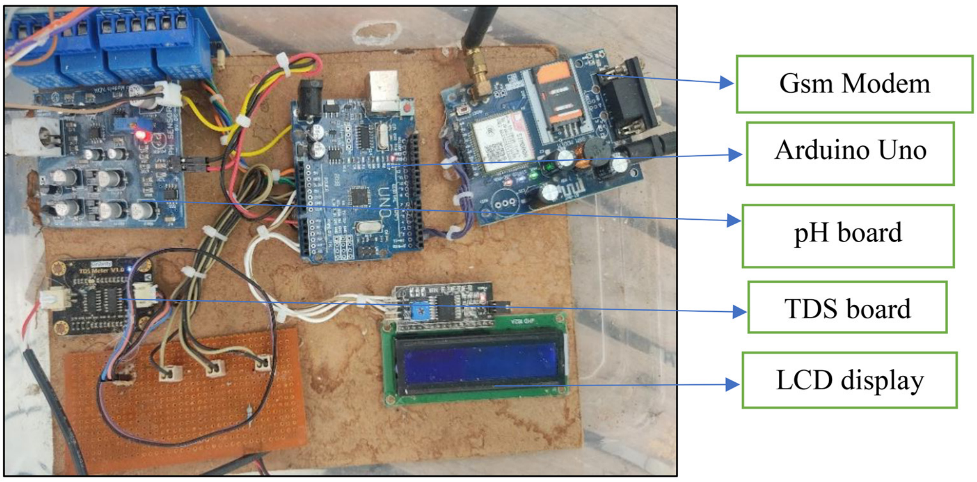

Fig. 3. Components of the automated nutrient regulation system.

The pH sensor is used for measuring the concentration of hydrogen ion concentration in a solution. The pH sensor model PHE-45P is used to measure the pH of the nutrient solution. The module has an on-board voltage regulator chip which supports the wide voltage supply of 3.3-5.5V DC, which is compatible with 5V and 3.3V of any control board like Arduino. The TDS sensor is used to measure the concentration of a solution for hydroponic nutrient solution which is expressed in units of ppm. The Grove-TDS sensors are specially designed to provide a relatively accurate and low-cost system used in the current study. The Grove connector and BNC probe interface made easy to use and very suitable for Arduino and Raspberry Pi projects. TO-92 package with transistor-like form-factor, Model DS18B20 water

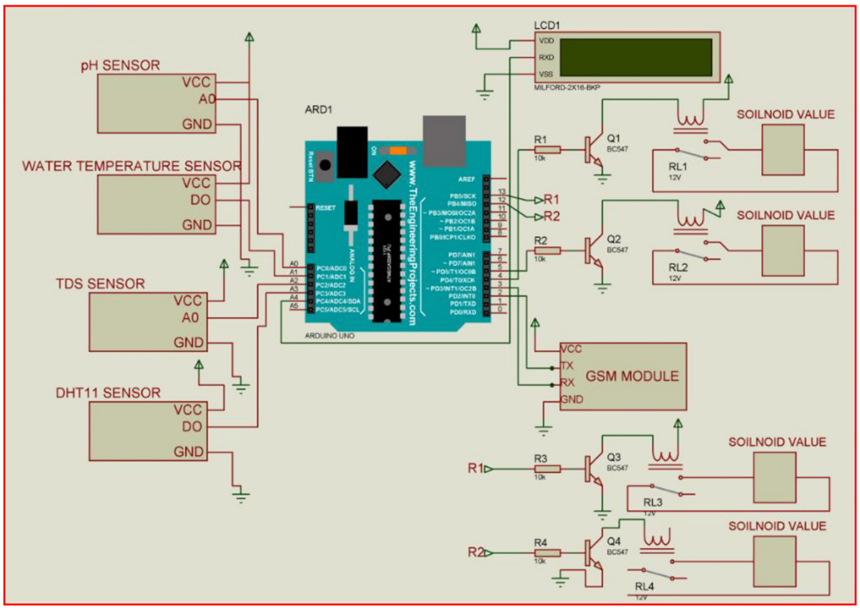

Fig. 4. Relay circuit diagram of the automated hydroponic system.

Fig. 5. Developed automated hydroponic system.

temperature sensor is selected for current study. All these sensors installed in the polyhouse hydroponic system is connected to the Arduino-Uno, using the IDE software and libraries in the Arduino Uno. LCD display with backlight size 16×2 (2 rows and each row consists of 16 characteristics) was selected to display the parameters. The SIM800A Quad-Band GSM/GPRS module with RS232 interface is a complete Quad-Band GSM/GPRS solution in an LGA (Land grid array) type was embedded in the present application. Solenoid valve function involves either opening or closing an orifice in a valve body, which either allows or prevents flow through the valve. These are used to replace manual valves for remote control. This process shown in relay circuit diagram of the automated hydroponic system (Fig. 4).

Polyhouse hydroponic system based on the coding programmed on Arduino-Nano. Fig. 5 shows a relay circuit on the Polyhouse hydroponic system.

Automated observations ThingSpeak IoT platform

ThingSpeak is an IoT platform which allow one to collect, visualize, analyze live data. The main component of ThingSpeak is channel, which stores data send from various devices. Each channel can save up to eight fields along with device location, url. The channel was made to public so that anybody can be see the data.

The software of the proposed system was developed in the same coding configuration in the same platform. After including the associate libraries, accessing the configuration of the ThingSpeak IoT platform, and constant/variable declaration, the GSM module access and the start of the pH/TDS sensors were initialized. Then, the temperature, pH and TDS sensors measure and send data of the water temperature, air temperature, humidity and pH/TDS levels, to the corresponding ATC. The values of water

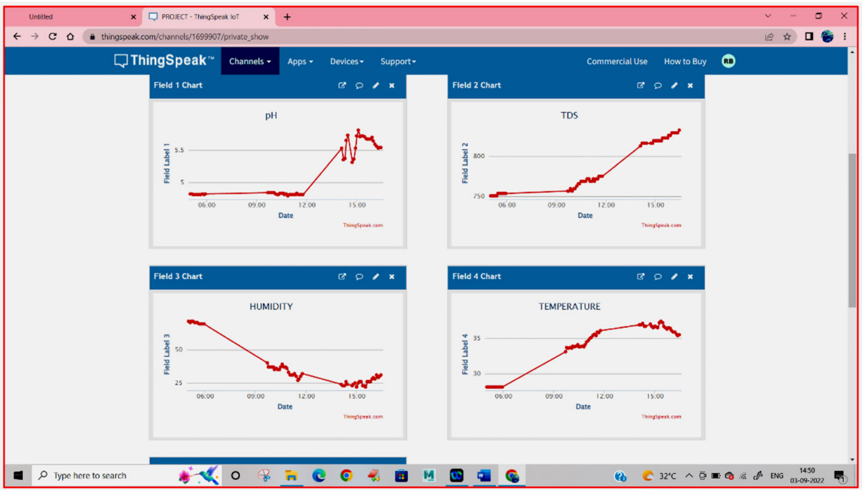

Fig. 6. Snapshot of ThingSpeak IoT for sensors monitoring system.

temperature, air temperature, humidity, pH, TDS were sequentially arranged and sent to the predefined channel in the ThingSpeak IoT platform. The observations were viewed in the ThingSpeak IoT platform and the observed data were analyzed (Fig. 6).

RESULTS AND DISCUSSION

After inserting the pH and EC sensor, the data obtained was not in the acceptable range. There were many fluctuations in the pH and TDS values. The automation system was calibrated by reprograming code and replacing the sensors and also checked the problem of relay circuit in opening and closing of solenoid valves. Thus, the automation system was calibrated for working the system correctly.

After calibration the data of the automated regulation system was recorded and monitored in the ThingSpeak IoT platform data channel. The data were also collected simultaneously by using hand held pH and EC meter. The monitored data were compared with manually collected data for depicting the variations in pH values over 24 hours data in the hydroponic system.

TDS sensor

The TDS value measured at each hour for 24 hours by sensors and also measured manually by using hand held EC meter. During 24 hours, the highest TDS measured was 712 recorded with EC meter and 715.26 with automated system. Similarly, lowest values were 692 and 700 with automated system and manual sensor respectively. The highest percent deviation observed was 14.142 %. The Automated recorded data constantly fluctuated in 700 to 750 ppm range. The deviation is acceptable for monitoring the hydroponics plants (Kurniawan and Arimullah 2021) conducted an experiment on monitoring and controlling of pH levels and plant nutrition. The TDS control is needed to keep hydroponic plant growth relatively stable. The automated and manual data of TDS for a 24-hour time interval for TDS is shown in Fig. 7.

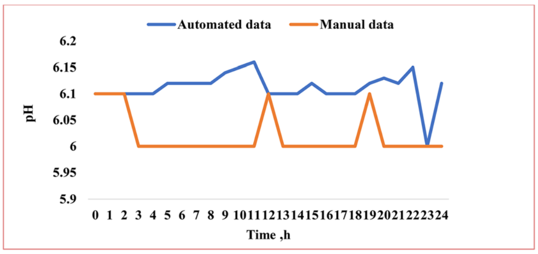

Fig. 8. Comparison of automated and manual data of pH for a 24 h time interval.

pH sensor

The pH value measured at each hour for 24 hours by sensors and also measured manually by using hand held pH meter. During 24 hours, the highest pH measured is 6.1 recorded with pH meter and 6.16 with automated system. Similarly, lowest values were 6 with automated system and manual sensor respectively. The highest percent deviation observed was 0.11 %. Comparison of auto-adjustment data and manual data at pH value, deviations are acceptable for monitoring hydroponics systems (Kurniawan and Amirullah 2021). The automated system was tested post calibration for pH is shown in Fig. 8.

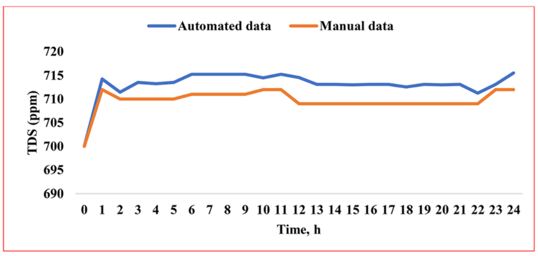

Fig. 7. Comparison of automated and manual data of TDS for a 24 h time interval.

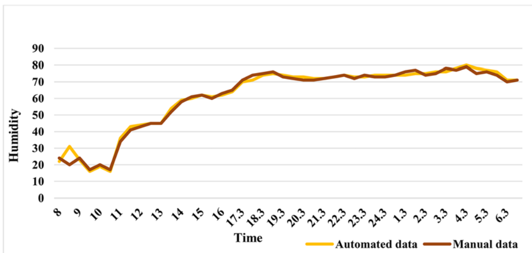

Fig. 9. Comparison of automated and manual data of humidity for a 24 h time interval.

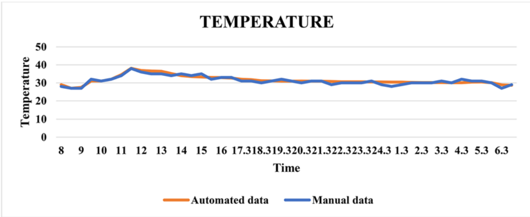

Fig. 10. Comparison of automated and manual data of air temperature for a 24 h time.

Humidity

The comparison of climatic humidity data recorded in the polyhouse is shown in the Fig. 9. The recorded data were almost on par with the actual data. The highest humidity value recorded was 80 % and lowest humidity value recorded was 18%.

Air temperature

The comparison of the air temperature recorded in the polyhouse by using automated system and manual record was presented in Fig. 10. The data recorded by automated system was near to the actual data. There no much deviation from the observed data and recorded data. The highest temperature recorded during study period was 38.3°C in the afternoon and lowest was 26.3°C in the morning.

Water temperature

The comparison of the water temperature in the reservoir recorded by using automated system and manually recorded was presented in Fig. 11. There is no much deviation between actual data and automated system data. The data recorded was in the normal range and the highest water temperature obtained was 34.01 °C whereas the lowest value obtained was 25.4 °C.

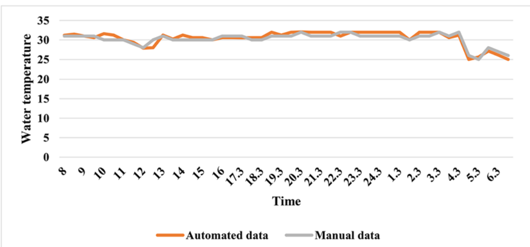

Fig. 11. Comparison of automated and manual data of water temperature for a 24 h time interval.

The advantage of the proposed model is that the character of the 16 × 2 LCD is wider so that besides being able to display pH and EC parameter measurements, it is also able to display data on temperature, time, and TDS value. The observed data with automated nutrient model is a far with measured actual data. The deviations are also in the allowable range for each parameter. Hence, the developed model can be used for continuous monitoring of the nutrients in the NFT system.

CONCLUSION

The prototype model to monitor and control the pH levels and TDS of plant nutrients on NFT hydroponic systems has been developed and evaluated. The two sensors (pH and EC) are connected to the Arduino Uno and relay control to drive four valves, i.e., the water flow valve, EC valve, pH up and down valve. Another two sensors air temperature cum humidity and water temperature sensors are also connected to Arduino Uno. Optimal plant growth in a hydroponic greenhouse system requires controlled TDS values between 710-720 ppm. The use of TDS-down sensor to control the TDS value so as not to exceed the 720-ppm value. The automated monitoring and controlling pH, TDS and temperature levels of stevia crop in hydroponic system was successfully developed and able to regulate nutrients in the desired range. The proposed model is able to neutralize pH and TDS levels if the present values of both pH and TDS detected were not within the desired range. Finally, the accuracy of the proposed system is also proven specifically with 100% response through experimental analysis.

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