Smart Hydroponics System through IoT

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***Abstract*— Hydroponics is the method of cultivating plants without soil. Water with oxygen and required minerals acts as the cultivation medium. Hydroponics improves the quality of crops and increases crop yield, but it requires skilled labor and knowledge about hydroponics to monitor and control it. Hydroponics is a method of Controlled Environment Agriculture (CEA), which involves cultivation of plants in a closed and controlled environment for a better and successful yield where the factors like cultivation medium, temperature, nutrient supply etc. are artificially modified considering the plant under cultivation. Smart hydroponics system allows automation in the field of hydroponics to monitor and regulate growth conditions for the plant. The proposed system aims at automating the Hydroponics setup using an ESP 8266 and sensors through IoT. Use of ESP 8266 significantly reduces the cost of build. Hydroponics, although efficient and useful can be a costly affair with each batch of crop requiring specified electronic hardware for monitoring. Making existing system cost effective so as to benefit the cultivators and farmers to opt for this means of advanced farming shall remain a priority while designing the system.**

Keywords*— IoT, ESP -8266/Node MCU, pH sensor, Temperature and Humidity sensor, MQTT protocol, Smart farming.

I. INTRODUCTION

The advancements in the field of Controlled Environment Agriculture (CEA), particularly Hydroponics has demanded the need for a technology to automate and monitor the same. Introduction of hydroponics technique has aided in the cultivation of crops in areas where they don't grow naturally. Implementation of smart hydroponics system not only helps the cultivators and farmers, but also provides data for research purposes. Requirements of different plants are monitored and later the research team can analyze through the data stored on the server to understand different crops and their requirements and help in the study to maximize the yield. Automation in hydroponics can reduce human work as well as human error. The requirements for the plants are monitored and required amount water, nutrients and light are provided by automated systems at the right time.

Various methodologies for automating an Hydroponics setup have been proposed till date, but the main aim of this model is to build a cost-effective system. Use of ESP8266, considering its ability to act as a microcontroller and a WiFi chip, can help in reducing the cost of proposed system. Use of other economically effective sensors help us build an effective system for a reasonable cost. ESP8266 is a Wi-Fi micro-chip with microcontroller ability. For a small-scale module, the use of PVC pipes can be used as containers. The DHT 22 temperature sensors are used in the proposed module, which are easily available. A suitable pH sensor to check the acidity of the growth environment is used. Water pumps are used to supply the right amount of water at required intervals. MQTT communication protocol is used for sensor is used to facilitate communication between the user and the system. The user can monitor and control the system through a Web application.

II. LITERATURE REVIEW

Till date, various methodologies have been adopted by Engineers to increase crop yield and to automate the process. In this modern era of technology, it has become a necessity to adopt newer and efficient systems to carter the needs of the society. Some of the existing articles are studied below.

In [1], the author has proposed an approach for monitoring hydroponic systems using Bayesian networks to predict outcomes with the current observations and to counteract whenever necessary. Bayesian networks are used to calculate the probability of an uncertain cause given some observed evidence making the system more efficient.

In [2], the authors have briefed a methodology to automate a Hydroponic setup using an Arduino Microcontroller through a Mobile Application. The communication protocol used is MQTT.

In [3], design of an effective and inexpensive automatic hydroponic system using AVR microcontroller is discussed. AVR microcontrollers are inexpensive compared to Arduino and are equally efficient in terms of processing, making the system less expensive.

In [4], an efficient approach for designing a remote monitoring system by implementing HTTP communication protocol discussed. HTTP is document centric. MQTT is observed to be better than HTTP. Approximately 93 times faster than HTTP. The former has three levels of quality services, whereas HTTP has none of these features.

In [5], An IoT based monitoring approach to conventional farming by using sensors and Arduino microcontroller is discussed. The system is efficient and inexpensive monitoring module for farms. Also fairly increases crop production. Soil moisture sensor, temperature and humidity sensor, light sensor and pH sensor are used in this module.

From the above literature survey, we have proposed a superior and fully automatic stand-alone module to monitor and efficiently automate a Hydroponic setup. The system can be easily installed and is engineered in such a way that even laymen can easily understand and use it.

III. SYSTEM DESCRIPTION

The Hardware consists of an ESP 8266 or a Node MCU coupled with an analog extender, pH sensor, DH22 sensor, DS 18B20 temperature sensor, LED lights, water pump, relay switch. These sensors are installed at appropriate locations for data acquisition. They monitor different parameters like temperature, pH, humidity etc.

A. ESP 8266/ Node MCU

The ESP 8266 is a WiFi microchip with microcontroller capabilities. It has 16 GPIO pins. And the maximum operating voltage of ESP 8266 is 5V. The operating voltage is 3.3V and it can handle up to 5V. It has a USB connector, a power jack and a reset button. It serves as an interface between internet and the hardware components.

B. Analog Extender

The ESP 8266 is equipped with only one analog in port, so to increase the number of usable analog ports, the ESP is coupled with an analog extender through i2c.

C. pH sensor

pH is the measure of hydrogen ion concentration of a solution, identifying the acidic or alkaline nature of the solution. pH sensor is an instrument used to measure the pH value of the solution. It has a reference electrode and a measuring electrode, the voltage produced between the electrodes is proportional to the pH of the solution. An ideal pH sensor outputs 0 volts at neutral pH, a positive voltage at acidic range and negative voltage at basic range.

D. DH22 temperature sensor

DH22 is a digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the atmospheric temperature. This sensor outputs a digital signal to the microcontroller.

E. DS18B20 temperature sensor

DS18B20 is a digital temperature sensor capable of recording temperature values underwater. It looks like a probe placed underwater and outputs a digital value to the microcontroller.

E. LED grow lights

Lighting influences the plant growth to a considerable extent. Combination of Red, Blue and Green LEDs are used to provide the required lighting for plants. The RGB spectrum is modified according to the requirements of the respective plant being cultivated.

F . Water pump

Water pump is used to pump water from the reserve tank to the hydroponic gully to the plants. The water pump is controlled by the microcontroller through a relay switch.

G. Relay switch

The relay is an electronically operated switch which can be controlled by the microcontroller's 5V output to operate any appliance.

IV. SYSTEM IMPLEMENTATION

A. General Working Principle

The design designates about the working of a fully automatic hydroponic setup with remote monitoring capabilities. Figure 1 shows the system architecture of the proposed module.

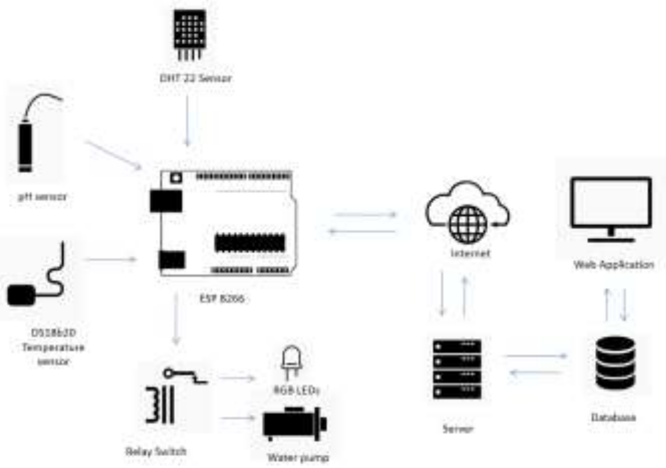

Figure 1: Architecture diagram of Smart Hydroponics System.

The setup has an ESP 8266 microcontroller, pH sensor, DS18B20 sensor, DH22 temperature sensor and a water pump controlled through a relay. LED lights are used to provide lighting to the plants, a combination of red, blue and green lights is used for lighting. The individual intensities of red, blue and green colour are varied depending upon the crop under cultivation. Different crops require different periods of light exposure. Lighting plays a vital role in maximising crop yield. The proposed module operates to improve crop yield by maintaining the conditions like temperature, pH and wavelength of lighting as per the requirements of the user. The user is expected to manually define the range of values for these parameters. The module can be divided into three parts based on functionality. Remote monitoring and control through a Web dashboard, automating the unit to operate without human intervention and varying RGB light spectrum to improve plant growth.

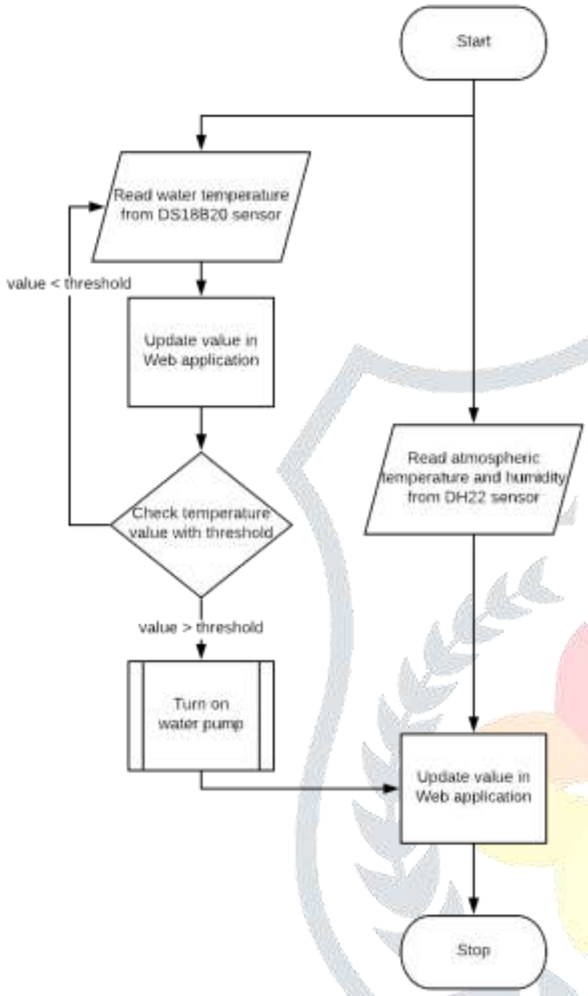

Figure 2: Functional block diagram of temperature monitoring module.

The specified sensors are mounted at appropriate positions in the module to facilitate monitoring of the parameters like temperature, pH, water temperature etc. The microcontroller reads the outputs from the sensors periodically. The obtained values from sensors are combined into a string by the microcontroller. The string is then converted to JSON which is sent to the server through a Mosquitto broker over a WiFi network. The obtained data from the sensors is used for further processing. The values are compared with the threshold values of the respective parameters and corresponding action is carried out to counteract the deviations. This enables the module to operate independently making it completely stand alone. Figure 5 shows the Experimental comparison graph between soil grown tomato plant and hydroponically grown tomato plant in terms of crop yield.

The module starts by reading the value from the temperature sensor immersed in the cultivation medium and the temperature sensor used for detecting the atmospheric temperature. The temperature of the cultivation medium is compared with the threshold value and the water pump is turned ON if the temperature of the medium exceeds the threshold value. The pump causes flow of fresh water from the storage tanks to the containers thus reducing water temperature. The values of atmospheric temperature and water temperature are updated in the Web Application at fixed intervals of time. Figure 2 represents a functional block diagram of temperature monitoring module.

pH may be defined as the measure of the hydrogen ion concentration of a solution. pH affects the plant growth, so maintaining optimal pH levels is important for obtaining proper yield. The module starts by reading the input from the sensor which stays immersed in the cultivation medium. The pH of the growth solution is detected, and the obtained output is compared with a threshold value which varies depending upon the crop under cultivation. If the pH value is greater than the threshold value, the reading is updated in the Web Application and a solution for lowering the pH of the medium is pumped into the containers. The value of pH after addition of the solution is updated in the Web application. The same process is repeated if the pH value of the cultivation medium goes beyond the threshold value. The deviation is counteracted by adding a pH high solution into the container. The changes in pH before and after addition of pH high solution is updated in the Web Application. Figure 3 depicts a functional block diagram of pH monitoring module.

B. Influence of Growth lights in plant growth.

Grow lights play an important role in Controlled Environment Agriculture (CEA) particularly in indoor hydroponic farming. Plants need lights of wavelengths in visible region (400-700 nm). The requirement varies depending upon the plant which is being cultivated. It influences the photosynthesis process during which plants use water, CO_2 and light to produce glucose and oxygen. One of the major advantages of LEDs is that, the spectral intensity of the lights can be customized according to the different stages of plant growth.

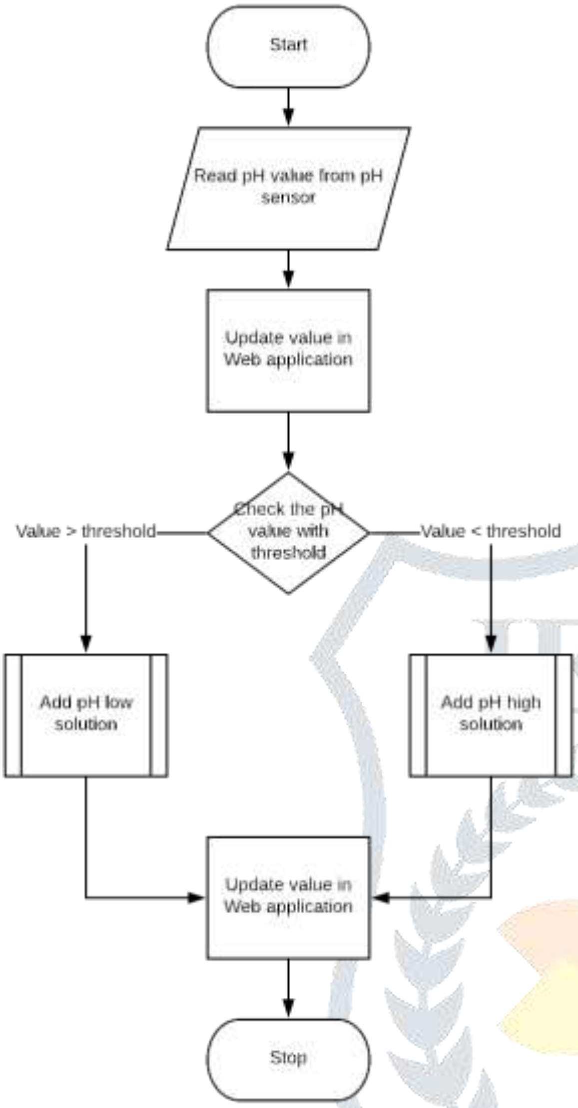

Figure 3: Functional Block diagram of pH monitoring module.

Plants consume more red and blue lights for photosynthesis than green light. The absorption spectrum of the plant being cultivated can be matched by using the right combination of LEDs. A combination of several LEDs operating at different wavelengths can be used as an ideal illumination source for a hydroponic setup. The microcontroller operates these LEDs through relay switches for specified time intervals such that crop yield is maximized. Table 1 depicts the effect of varying wavelength of light on plant growth.

The microcontroller detects the status of the grow lights and updates the same in the Web Application. The user can monitor if the lights are currently ON/OFF through the web application and manually turn ON and OFF the lights. Figure 4 shows the plant growth response to different wavelengths of visible light.

S.no	Wavelength of Light	Effect on plant growth
1	439nm	Blue absorption peak of chlorophyll a
2	450 – 460 nm	Peaks absorption of beta carotene
3	469 nm	Blue absorption peak of chlorophyll b
4	430 – 470 nm	Most optional for chlorophyll a, b absorption which influences vegetation growth.
5	590 nm	Increased carotenoid absorption
6	660 nm	Called super LED wavelength and is important for flowering
7	666 – 667 nm	Peak red absorption point of chlorophyll a

Table 1: Effect of varying wavelength of light on plant growth.

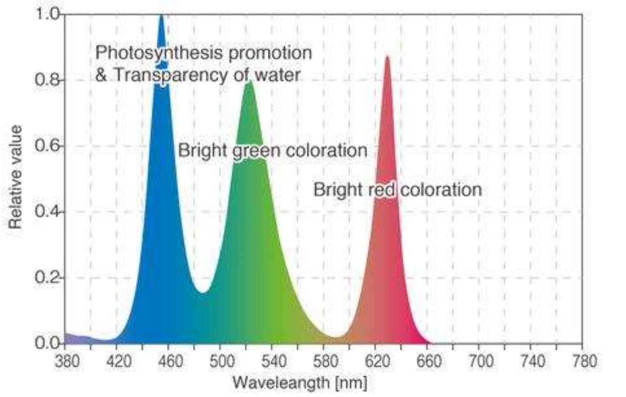

Figure 4: Plant growth response to different wavelengths of visible light. (Source – Google)

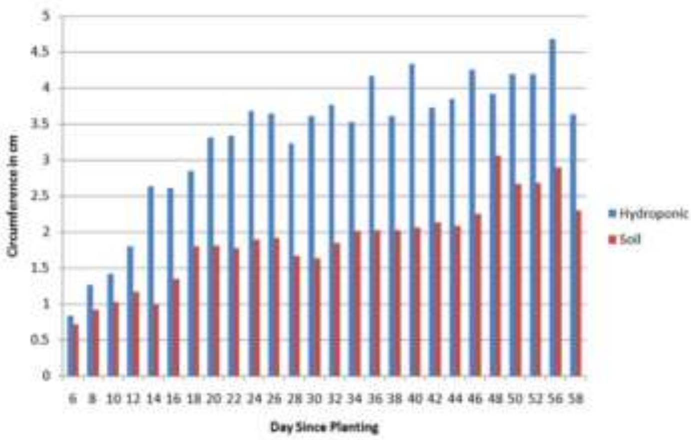

Figure 5: Experimental comparison graph between soil grown tomato plant and hydroponically grown tomato plant.

V. FUTURE SCOPE

This paper could be extended by replacing the sensors with wireless sensors forming a Wireless Sensor Network (WSN). The ESP 8266 microcontroller can be replaced with Raspberry Pi as it supports an in-built database and is better in terms of computing power. The data from the sensors can be analyzed to obtain valuable analytical information which can be used to further improve the efficiency of the system. The module can be further automated by Engineering the system to fetch data like optimal temperature, pH and lighting requirements for the crop under cultivation from the internet. This eliminates the need for the user to manually enter the threshold values for each parameter. This makes the system more efficient and completely stand alone.

VI. CONCLUSION

The IoT based Smart Hydroponics System follows an innovative and efficient methodology to automate a Hydroponic setup. The working principle and automated elements are reliable and fool proof and are expected to maximize productivity and crop yield. The cost of installation can be minimized by integrating various units in a zone. The use of evolving technology with technical excellence will affirmatively lead to the improvement in the efficiency of any engineered system.

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