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Smart Hydroponic System

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Abstract— Hydroponic farming is an emerging method for sustainable agriculture. With growing demands for variety of food, countries have to become self-sustaining in agricultural growth. Dependence on soil and weather for food production are reduced by using scientific methods like hydroponics. In this technology, plants are grown in water by providing necessary nutrients to the roots through nutrient solutions. This paper discusses the state of art in this technology and their work on development of smart hydroponic system. The authors have developed a prototype model using pH and electrical conductivity (EC) sensors to monitor the nutrients in water. Data from sensors using WIFI module and microcontroller is uploaded on a server and send to remote user through SMS. Three nutrition boxes are placed inside the water reservoir connected through a drip manifold which provides the solution to plants. The nutrition boxes are opened for specific time whenever nutrients are to be added to water by the user depending on the pH & EC. This technology has been recommended for growing certain type of vegetable plants, especially in the regions where the soil is not very fertile.

Keywords- pH sensor, Electrical Cconductivity sensor, Plant Nutrition, Internet of Things.

I. INTRODUCTION

Hydroponics is the science of growing plants in nutrient rich solutions, without soil. The roots of the plants are placed in gravel or sand soaked with water with required nutrients for the plants. In the conventional soil based farming, roots of plants grow in soil which has to be enriched with nutrients periodically. Some geographical areas the soil lacks the nutrients and frequent replenishment is difficult. Certain plants may require nutrients which may not be present in the soil for that region. Hydroponics is useful in such applications as the plants can be grown in water and the required nutrients can be added easily to make a solution which can be scientifically monitored. The method has been used to grow vegetables like lettuce, spinach, tomatoes and many other vegetables.

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Study of state of art reveals that few research groups are working on developing solutions for high yield of exotic crops so as to produce these locally and reduce the requirement for transportation and imports.

Scientist at Defence Institute of Bioenergy Research at Haldwani have developed hydroponic system for cultivating various vegetables like cucumber, tomatoes using rain water as well as river water added with nutrients [1]. They have studied the plant growth in these systems installed at various research centres at different altitudes and environmental conditions. Artificial lighting, temperature control, green house with ventilation and monitoring of Electrical conductivity and pH have been done for studying quality traits and yields in tomatoes. They have suggested that the hydroponic system can be used to grow many other crops as it is water efficient, high yield and can eliminate the need to transport food. However, it has been suggested that the solutions need to be customised for different crop as per local conditions so as to produce best yield.

Another research group at Horticulture University at Hyderabad [2] has studied the effect of nutrient disorders on plant *Gerbera Jamesonii* using hydroponic system. These plants were treated with water containing nutrients with one nutrient being intentionally made deficit. The effect of deficiency of each nutrient namely, Phosphorus, Potassium, Magnesium, Calcium, Iron, Sulphur, Boron, Zinc and Manganese were observed using qualitative techniques to detect individual nutrient's deficiency on the leaves and roots of plants. The study revealed that deficiency of Potassium, Phosphorus, Nitrogen, Magnesium and Zinc caused defects in older leaves while Calcium, Iron, Sulphur and Copper deficiencies effected the younger leaves. Boron deficiency effected the growth of shoot and root tips while Copper deficiency was manifested as distortion of young leaves. This study thus reveals that the deficiency of various macro and micronutrients can be determined by visual inspection of the plant. Nitrogen, Magnesium and Potassium were found to be essential for photosynthesis and growth of plant Thus these essential nutrients should be provided to all plants and specific nutrients may be added by observing the plants physically. The quantities of nutrients can be maintained by controlling the electrical conductivity and pH.

Few research groups are working on increasing productivity of specific plants using nanomaterials in hydroponic systems. One such group working in Pondicherry University is exploring the absorption on Iron Oxide in Spinach by using Fe_2O_3 nanoparticles in hydroponic system. The researchers used spectroscopy to study the uptake of Fe_2O_3 in the plants and found correlation between the plant growth and the dosage of nanoparticle [3].

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Certain plants grown in India are highly prone to pathogens and need controlled environment. Safflower is one of such plants and is grown in the Deccan Plateau and is used to provide seeds for extraction of edible oil. A genetic version of this plant has been grown hydroponically and studied by Botanist at University of Delhi and this genome is resistant to multiple germplasm [4]. Thus hydroponic systems can be used to develop genetic varieties of plants with higher productivity.
Hydroponics has been used for purifying water by removing heavy metals by absorbing them in roots of plants [5]. This method is called Rhizofiltration and has advantages over the conventional filtration. Nutrient film technique was used and medicinal plant *Plectranthus amboinicus* was grown. Thus the hydroponic system was used for growing medicinal value plant and at the same time for cleansing the water.

In the present decade many groups are working on applications using sensors and Internet of Things, Machine Learning and Artificial Intelligence so as to use technology for better control of Hydroponics[6-10]..

II. HYDROPONICS SYSTEMS:

The hydroponic culture is primarily classified as open system, where the nutrient solution is circulated few hours and discarded or the closed system where the minerals rich water is recycled into a recovery tank where some parameters of water are checked and minerals are supplemented on requirement. Both the techniques are done in enclosed environments and may be developed as indoor garden. There are many advantages of the technique, the plants can be grown in any season, the plant density can be high and the yield can be achieved with minimum pesticide and preservatives. The culture can also be used to study the effects of various nutrients or controlled environment on plant growth [11-13].
Nutrients are the basis of hydroponic culture and must be scientifically selected for typical plant/vegetable. The composition of nutrients, ratio of minerals as well as their quantity must be managed scientifically. The requirement of these minerals may vary at various stages of plant growth and requires a good understanding on the agriculture science. Nitrogen, Potassium, Phosphorus, Calcium, Magnesium, Zinc, Molybdenum are some of the minerals required by plants for healthy growth [14]. The deficiency of these minerals is shown by various symptom can be observed are available commercially as mixtures or individually and the good gardeners and hydroponic experts can identify the lack of minerals easily. Various established books[15] mention the type of vegetable and the nutrients required to grow them. Expertise is needed to make judgement on whether the nutrient strength is low or there may be imbalance of the minerals used, or the surrounding conditions may be inhibiting absorption of some nutrients. The nutrients once identified may be supplemented with commercially available mixture of few minerals whose ratios may vary between different brands. Some of these mixtures may contain the essential elements as well as additional elements like Nickel, Cobalt and Selenium which are beneficial for many plants [16] . The mixture is usually available as powder or high concentration solutions and has to be mixed with water in specified amount so as to make solution of right strength for plant growth and development. The solution concentration is measured as Total Dissolved Solute (TDS) or by measuring the Electrical Conductivity (EC), the latter measurement being more commonly used. The EC for particular crop need to be optimized so as to achieve desired levels of total soluble solids in the vegetables. Optimization techniques using Artificial Neural Network and Genetic Algorithms are used for this are achieving the optimum ion concentration and thereby EC for specific vegetables/fruits[17][18] . The development of plant depends on right ranges of EC as either extremes (high or low) EC may hinder the growth of plants. Thus, the type of ions and their concentration need to be monitored scientifically for a good hydroponic culture[19]. Conductivity meters are commonly used to measure EC and these may be combined with smart processors to control the values using edge analytics.
The systems containing integration of various sensors, actuators and controllers are categorised mainly as the Wick, Water culture, Flood and Drain, Drip and Aeroponic, or combinations of these[20]. This section discusses the various systems and their suitability for different types of plants. In the Wick system the plant has roots grown in sand or gravel which is soaked with nutrient water by using wicks whose other ends are immersed in the nutrient water reservoir. Variety of plants of various sizes can be grown by using this system and by keeping a larger reservoir and many wicks, sufficient amount of nutrient rich water can be provided to the roots. The Deep water culture method is used for growing fast growing water loving plants like lettuce. The deep water culture method uses clay pellets or Styrofoam put in net-pots to hold the plants and these pots are dipped in nutrient water reservoir. The reservoir has air-pump to circulate oxygen and air stone at the bottom to allow air turn through the nutrient water. The circulating air also stirs the nutrients so as to make the solution uniform concentration throughout the reservoir. Lettuce, Coriander, Basil, Okra and Kale have been grown successfully using this method. Innovative idea of using microbubble generator in the hydroponic nutrient solution results in higher concentration of dissolved oxygen. Study for Lettuce shows that using microbubbles aerator with air pump in hydroponic culture resulted in healthy growth of the leafs which is attributed to the roots getting sufficient oxygen supply [21]..

Nutrient film technique (NFT) is an economic method of growing crops using hydroponics [22,23]. The system uses continuous flow of water in a tube which is kept at an inclination. The nutrient water flows through the roots and drain out from other end of tube into a reservoir. The plants are placed in net-pots and the roots are dipped in the water tube. The nutrients are absorbed by the root and the water recycled is supplemented periodically so as to maintain the desired levels. Air-stone and air-pump are used for the reservoir to ensure sufficient amount of dissolved oxygen which is required

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for the plant growth. Renewable source of energy such as solar cells may be used to run the pump during daytime so as to cut down power consumption as well as prevent the roots of plants from drying during long power interruptions.
level goes out of range so that the user may charge the reservoir.

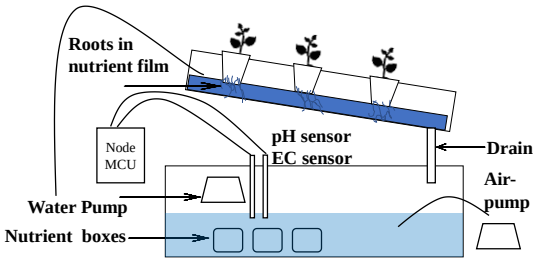

Fig.1 Schematic diagram showing Nutrient film technique, where roots of plants are dipped in nutrient film. The nutrient water overflows into a reservoir where it is replenished with oxygen and nutrients.

III. SMART HYDROPONIC:

In this work we have used electronic circuits to measure and maintain the pH of water and initiate action for nutrient supplementing using Internet of Things technology. We propose to use NFT technique with roots of plants dipped in a nutrient film maintained in a tilted reservoir. A schematic diagram for this technique is shown in Fig.1. The nutrient water is pumped into the top reservoir where it flows slowly, typical flow rate being 1 Litre per Min [23] due to slight inclination and drips back into the lower reservoir

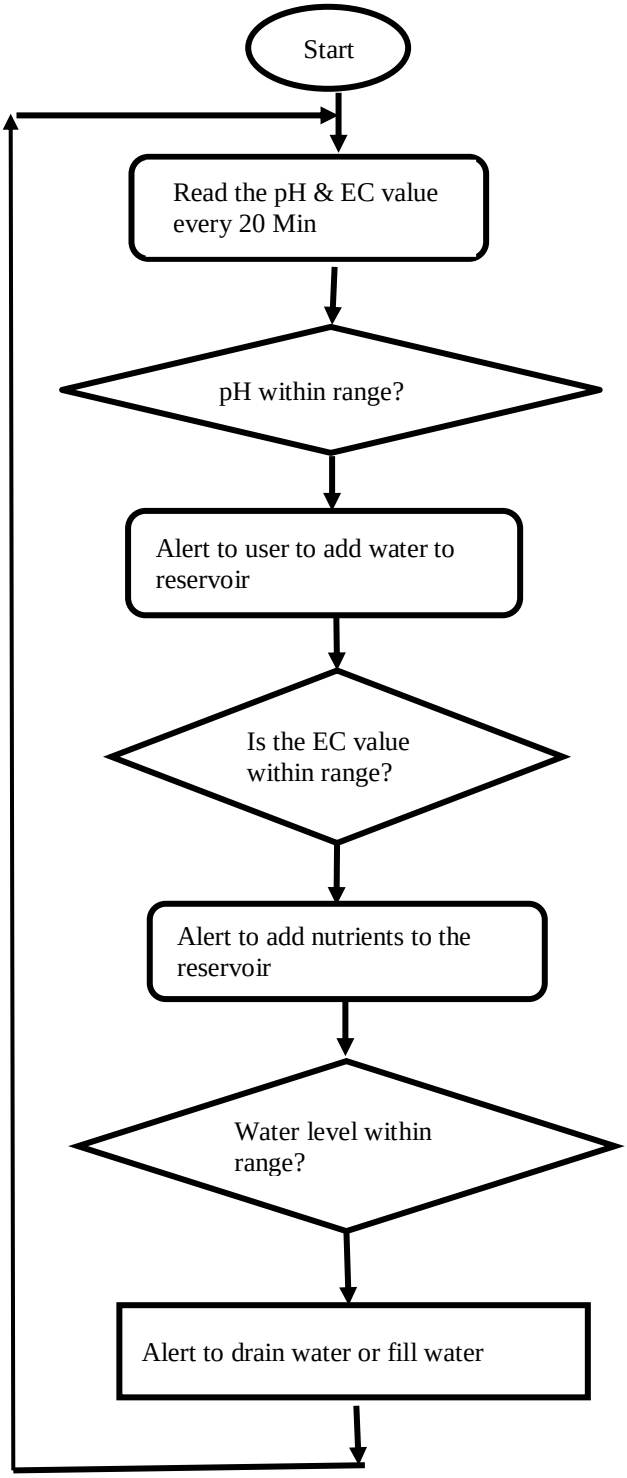

Fig2 .Flowchart for the smart hydroponic system showing the flow of program for checking nutrients and water in reservior1

The roots absorb nutrients from the thin film and the water drains into the lower reservoir. The lower reservoir containing nutrient boxes has sensors for measuring pH (MS pH 07 make) and Electrical conductivity (EC). The sensors are read by Node MCU microcontroller which runs an algorithm to verify that the pH and conductivity are within the range. The program shall generate alert to the user through internet server whenever the pH or EC values are out of range so that the nutrient boxes are

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opened by the user from remote. There are timers connected to the microcontroller shall allow the nutrient boxes to supply nutrient to water in the lower reservoir for specified time. The water level in the lower reservoir is maintained using ultrasonic sensor (HC-SR04) which generates alarm if water

The flowchart for the smart hydroponic system is shown in Fig.2. The conductivity of the nutrient solution decreases when the nutrients are consumed by plants and increases when the plants consume water faster, as in hot weather. The nutrient consumption varies at different stage of plant growth and the ranges of acceptable pH and EC is different for different plants. The pH value. For most of the plants is between 6.5 to 7.5 and depends on the presence of elements like Potassium, Sulphur, Calcium and Magnesium[24]. Although the sensors are continuously monitoring the pH and EC. The values at read into Node MCU every 20 minutes through the Analog to Digital Convertor (ADC). The values are compared with desired ranges and sms alert is created using Wi-Fi module (ESP 8266) of the microcontroller.

IV. CONCLUSION

Hydroponics is a scientific procedure for growing crops in water containing nutrients and elements that are essential for plant growth. We have developed a smart electronic system for controlling hydroponic culture in our campus as it is economic, easy to maintain and can be developed further to make a Greenhouse. Using this hydroponic culture, we plan to grow vegetables for our campus and also educate the farmers in the surrounding villages to use scientific methods for high yield agriculture.

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