IoT based Automated Hydroponics System

Shreya Tembe, Sahar Khan, Rujuta Acharekar

Abstract— Over the years, traditional farming for harvesting with the use of soil takes longer time to decompose making it prone to diseases and expensive. Hydroponics system means growing plants without soil with better results, especially in areas with space and environment unsuitable. Commercial Hydroponics is the upcoming technology that grows plants through an inert media instead of natural soil. This system has no adverse effects on environment or quality on crops. In contrast, it provides better nutrient value and allows controlling the nutrients via nutrient solution. Its main aim is to save water, improve quality of crops avoiding the adverse effects of pesticides and factors affecting quality of soil and save land. This paper provides an overview about the cost-effective implementation of Hydroponics for small farmers in India.

Index Terms— hydroponics, IoT, soilless, automation, growth, nutrients, crops

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1 Introduction

Humans require air, food, water, and living space in order to survive. These things are not endless in nature and thus humans are dependent upon the optimization of land area and the preservation of biodiversity. The human population is increasing and predicted to expand from 7.0 billion to 9.5 billion people within the next 40 years (Sahara Forest Project, 2009). An ever-increasing demand for food species is implied, and it is estimated that food production will have to be doubled in order to compensate and provide availability to all.

The word "Hydroponic" defines as any means to grow plants via a medium that does not include the use of soil but involves inorganic nutrients or nutrient solution. Gericke who described methods of growing plants in liquid media (nutrient solution) introduced the term Hydroponics. Besides Gericke, many attempts were made to adopt the methods of soilless growing plants during thirties. However, technological progress was too inadequate due to insufficient knowledge about the nutrients and high cost involved in the process. Despite of all, countries like USA and others were keen to adopt this technology so that growing plants indoors without the favorable soil required as well as controlling the nutrient is possible.

One of the basic principles for vegetable production, both in soil and in hydroponic systems, is to provide all the nutrients the plant needs. Several chemical elements are essential for growth and production of plants, in sixteen elements: carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, manganese, iron, zinc, boron, copper, molybdenum and chlorine. Among the elements mentioned above, there is a division according to their origin: organic, C, H, O and minerals; broken down into macronutrients, N, P, K, Ca, Mg, S, and micronutrients, Mn, Fe, B, Zn, Cu, Mo, Ni, Cl (Malavolta, 2006). In hydroponic crops, absorption is usually proportional to the concentration of nutrients in the solution near the roots, being much influenced by environmental factors such as salinity, oxygenation, temperature, pH and conductivity of nutrient solution, light intensity, photoperiod and air humidity (Furlani et al.,1999). [4]

Besides these facts, the progress of Hydroponics is being encouraged in India commercially. Letcreta Agritech is Goa's first indoor Hydroponics start up that produces 1.5-2 tons of leafy vegetables of good quality and pest free. Bit Mantis Innovation provides IoT solution GREEENSAGE i.e. a micro edition kit using hydroponics method for water usage and nutrient suitable for individual's convenience. Junga Fresh n Green, a start up with 9.3 hectare of Hydroponics agriculture in Shimla district with a joint venture WPC, Netherland is progressing towards protected greenhouse environment.[9]

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2 Review of Research proposal

2.1 History

The idea of hydroponic cultivation is a dated back from the history of Hanging Gardens of Babylon. The modern hydroponics did not begin until the 17th century according to the High Times report on "The history of Hydroponics". In addition, following up on this report, "Willow Tree Experiment" was a booster to inspire scientists to dig deeper into these methods, by splitting up roots from soil and water source. This led to growing use of techniques that required only nutrients to nurture crops. A duo of German scientists W. Knop and Julius von Sachs contributed greatly in this field by discovering that, the three main elements for nutrient solution formula are potassium, phosphorus, and nitrogen. The High Times magazine has also said that a major leap in the technology of hydroponics took place in 1980's as an Israeli scientist from Volcani Institute of Ein Gedi discovered the aeroponics method, which transformed the desert into an immense oasis.

In the 1920s, New Jersey Agricultural Experiment Station improved the existing ways and making sand & water hydroponics capable enough for large-scale crop production. According to NASA space mission reports, space hydroponics has been initiated since 2002. They have replicated the environmental ambience by implementing powerful LED lighting system, a green house that will control these moisture, humidity and temperature automatically. Growing crops in low latitude areas of Mars, where the sunlight acquired is adequate, have successfully conducted series of experiments. Now, this form of agriculture has also been introduced in India. With

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reference to Statistics Times, India accounts for 7.68% GDP of the total global agricultural output.

2.2 Need

According to the World Population Prospects, India ranks number 2 in the list of countries by population. This population is growing at the rate of 1.2% every year. The major necessity of every human being is food. In order to meet up to the food demands of this growing population, it is necessary to implement vertical gardening, which will give optimum produce in a limited space. As we know, states like Madhya Pradesh, Uttar Pradesh, Telangana, Orissa, Karnataka and Maharashtra face severe drought conditions. This has an adverse economic impact on the agricultural sector of India. As mentioned in the Economic Survey of Maharashtra, there was a 2.7% decline in the economy of agriculture sector in 2015-16. However, if the above-mentioned techniques are implemented, the farmers shall not remain dependent of the climatic changes, lack of water and challenges faced due to fluctuating moisture conditions. As said earlier, the income of an average farmer in India is approximately 6426 INR, which shall limit him from implementing such a beneficial technology. [11]

3 Types of Hydroponics

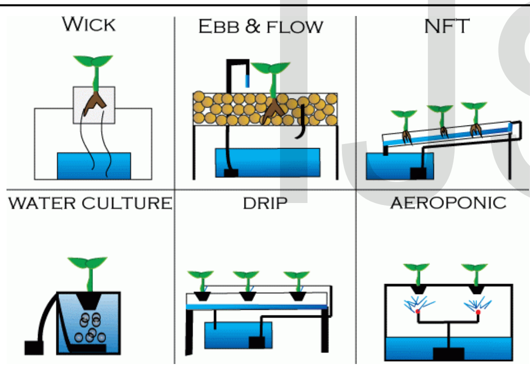

Fig. 1. Types of Hydroponics (Image source: Google)

a) **Wick system**: The simplest technique compared to all the above is wick system, as it does not consume electricity, use pumps or has any moving parts.

b) **Ebb and Flow (flood and drain):** This is the most uncommon method, also known as Ebb and Flow technique. The plant roots are not exposed like done in Nutrient Film Technique (NFT)

c) **Nutrient Film Tehnique:** A structure similar to PVC pipes is implemented in this technique. A series of plants are grown in line using this form of structure. The nutrient solution is pumped into the pipe like formation and then collected back into the reservoir through the other end, where an outlet is created for the solution to flow out. In other words, recirculation is applied and at the same time, water conservation is proved from this method.

d) **Deep water culture:** A reservoir acts as the container to store the nutrient solution. Oxygen, water and nutrient supply is provided by suspending the roots of the crops in this solution.

e) **Drip system:** In this system, the nutrient solution is released onto the base of plants and e-nutrient solution is collected and resused.

f) **Aeroponics:** This is very similar to Nutrient Film Technique. However, the only difference is that, instead of using a recirculation method, it is replaced by sprinklers. These sprinklers do the task of misting the root zone with nutrient solution

4 Advantages

To define the purpose of this topic it is essential to know about the outcomes and benefits of Hydroponics. It works best for areas unsuitable for conventional farming such as arid, degraded or deserted, it is independent of the weather thus allows cultivation throughout the year. To serve the world population, it can add to the fast economic return including optimal use of water and other resources. Thus with increase in production it allows gives better standardization of cultivation and cultivation time making better use of land , thereby increasing total yield in the greenhouse. Hydroponics is the alternative to soil sterilization to combat the chemical side effects resulting toxicity and other harmful effects. The best part about it is, the nutrients can be better controlled and monitored than in crops cultivated in soil. The recycling of greenhouse effluents reduces fertilization and eliminates nutrient leaching. The reuse of the nutrient solution effluents in closed soilless culture systems entails the risk of disease spread via the recycled leachate. A disinfection system should be installed to avoid infections in the reused water. Wohanka extensively outlines this topic in a recently published review. Due to the above characteristics, which enable an appreciable restriction in pesticide use and nutrient leaching, hydroponics is considered not only compatible but also strongly favourable and supportive to the application of integrated crop management in greenhouses.

5 Disadavantages

The major disadvantage of Hydroponics is its costing that is higher than natural soil process as it requires soilless culture setup including controlling and monitoring equipments and technical skill to cope up with it. It also requires constant supervision i.e. water-based microorganism can be easily introduced or in case of power outage setup must be handled manually. Above listed are of minor importance in comparison to cultivation on an industrial scale.

International Journal of Scientific & Engineering Research, Volume ÑÔ(ÚÚÜ Ì ÌÔ% ÌÉÙÜÈÙàıÌÝ
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5 Equipments

In order for the controller to be used for growing and automation and for people to use it, following are the requirements as mentioned below.

a) **Arduino Mega 2560**: Arduino Mega 2560 is used as we are interfacing several sensors to the board. It has graced with up to 54 digital I/O pins, 16 analog pins, a 16MHz crystal frequency and 4 hardware serial ports. It has pins to access interrupts and has EEPROM i.e. permanent storage is possible, thus satisfying the interfacing requirements.

b) **Temperature and Humidity sensor**: DHT11 performs this task. For temperatures up to 80 degree Celsius, they provide an accuracy of ±0.1% and a fair response speed of 2 seconds. Their humidity measuring range is 0 to 100%, which is sufficient for this system. The plants are very sensitive to fluctuating temperature and humidity, if both of these parameters are high; the plants lack their ability to transpire. Thus, it has an adverse effect on their growth. However, they adapt to a higher humidity range once their roots have matured. An RTC (Timer circuit) can be implemented in order to keep track of the time, such that the system will detect whether it is day or night.

c) **Real Time clock (RTC):** DS3234 RTC can be used via SPI interface. It comes with in-built power sense to detect power fails and set battery automatically. The clock being the centre of the controller used to power up at certain intervals. The accuracy of the timer is ±2ppm between 0 to 40 degree per C. it can support alarms giving flexibility for future uses.

d) **pH level and circuit:** Every child is born differently and has his own unique tastes. Similarly, the crops have their own preferences in pH levels. The control of pH is important to avoid nutrient loss. If we have to select one range of pH, most of them require an acidic environment (between 5.5 to 6.0). However, most of them adapt to survive up to the range of 7.5. The pH is constantly reported. There are several methods to monitor these values of hydrogen ion concentration such as litmus tests. However, in gardening, these levels need constant monitoring and this is achieved by using pH probes. These devices can be interfaced to an Arduino. The major challenge faced in this stage is the pH module, which is used to amplify the output of the pH probe (which is just 59mV per pH unit). These modules require amplifiers with very high input impedance; if this need is not satisfied then loading effect on the probe will be very high. There are varieties of amplifiers that can be considered in the designing part of this step (LMC6001, TL072, and TL062).

e) **EC level and circuit**: Nutrients are made of mineral salts, which are then dissolved into water. The strength of the nutrient solution can be detected by an electrical conductivity meter. As each nutrient has different salt content, it may lack some nutrient or have abundance of one of the nutrients, etc. This makes EC measured at constant pH.

f) **Air temperature:** The controller reports air temperature on real time basis to the screen. In case if the level falls out of range, a red light is indicated. However air temperature can be controlled, possibly a fan can be used for extensions.

g) **Light level:** Light level can be a problem for the growth of plants in Hydroponics. LEDs can be controlled and customized to any desired color temperature for nurturing the vertical hydroponics garden. Environmental ambience can be replicated by the use of a LED grow light system. According to a journal report "Growth and photosynthesis of Chinese cabbage plants grown under light-emitting diode-based light source" conducted in 2009, LEDs can be scientifically used and implemented to grow crops.[10]

6 Contribution

Over the years, traditional farming with the use of soil medium consumes a lot of space and water; not on that, but it is also prone to pest attacks, resulting in higher use of pesticides. Hydroponic system means growing plants without soil with better results, especially in areas where, the environment is where seasonal changes are not promising or face drought conditions. Instead of soil, coco peat, rock wool, vermicompost are used. Our approach is to make an Automated Hydroponic System reducing labour cost as well as improving the quality of plants cost effectively. Our contribution is to make an Arduino based project the plant will be planted indoors and parameters such as pH level, temperature, and humidity electrical conductivity will be monitored. Based on the monitored data, the automated part includes sprinklers for pest, humidity adjustment unit and pH up/down pump accordingly. This again is interfaced with a Wi-Fi module making data easy to monitor. This Hydroponics system requires less pesticides, water and space than traditional agricultural systems. This may be stacked (if outfitted with led lighting) in order to limit the space usage (vertical farming). This makes them optimal for use in cities; where space is particularly limited and populations are high-self-sustaining city-based food systems mean a reduced strain on distant farms, the reduction of habitat intrusions, fewer food miles, and fewer carbon emissions.

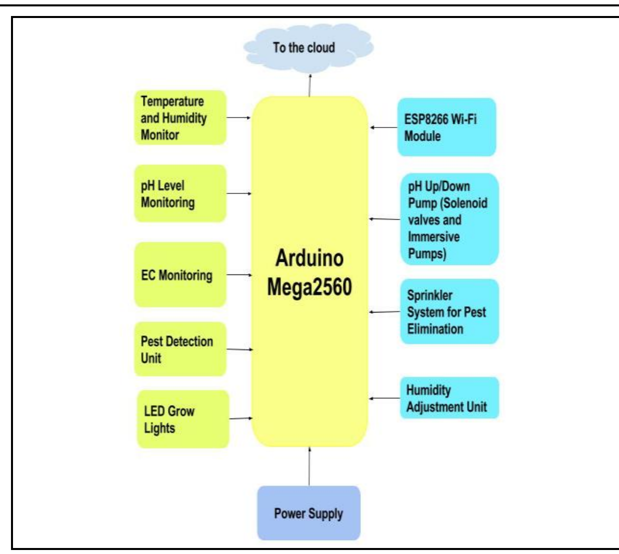

Fig.2 Proposed Block diagram

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Fig.2 shows the block diagram of the IoT Based Automated Hydroponic System. The system is divided into the following– monitoring (consisting of various sensors), controlling, automating and storing data sections. Arduino Mega 2560 is used to suffice the requirement of interfacing all these parameters together to perform in synchronization. The temperature and humidity sensors sense the surrounding environment, while the pH level sensor provides us with the pH value of the nutrient solution and the Electrical conductivity will check the nutrient value. In addition to this, based on Humidity adjustment unit will enable the water sprinklers to cool down and control humidity within the planting house. Sprinklers are needed for sprinkling the pH solution/nutrient solution/water in response to the humidity, pH and EC sensors. The pH pump will help in feeding the pH solution to the plant. The pH value should be between 5-6.5 so that the plant will remain unaffected. LED Grow lights are used to produce lights (red and blue) at two distinct spectrums simultaneously without bleeding into other wavelengths and minimal heat production. In addition, pest detection unit will detect pest on plants and sprinklers will be activated to sprinkle organic pesticides. The output data is interfaced with ESP8266 Wi-Fi module so that the data can be stored on cloud and monitored remotely and conveniently.

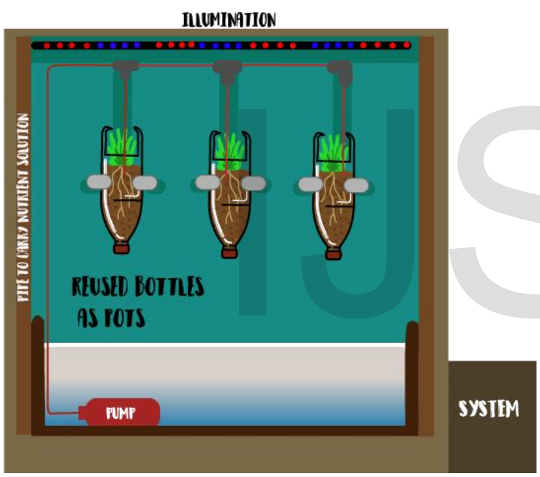

Fig.3 Proposed structure for Hydroponics

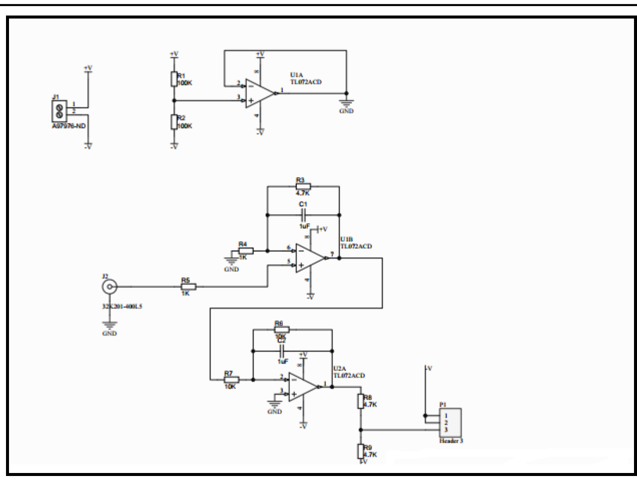

Fig.4 pH probe module Schematic

(A) COST EFFECTIVE IMPLEMENTATION OF PH PROBE MODULE

The pH probe modules available are extremely costly and since our main aim is to reduce the system cost

As shown in *Fig.4 pH probe module schematic layout, the* pH probe amplifier consists of IC TL072 which is a very high impedance operational amplifier (the impedance is 10^{12} Ω) Also, it consumes very low power as compared to other ICs (LMC6001, TL062) that we had shortlisted. A dual to single supply converter is made using the same IC, which splits the input 10V to ±5V. Hence, we do not have to use a separate power supply for both positive and negative swing of the OPAMP. An inverting amplifier with a gain of 4.7V is required to amplify the pH probe output voltage, which is in millivolts (0 to ±414mV). To scale the output to be less than 5V (as we are using arduino) we have used a voltage divider network. Finally, we will obtain a scaled and amplified output that can be applied to one of the analog pins of Arduino Mega 2560.

(B) PROPOSED IMPLEMENTATION OF LED GROW LIGHTS

From *Fig.5. Light spectrum for Hydroponics*, it is observed that plants require red and blue spectrum. A process called photomorphogenesis is a9 plant process completely related to light spectrums absorbed by the plants. Also, it is absolutely different from photosynthesis.Plants will be nurtured the best if grown under red and blue lights. From study, it is said that the LED grow lights should be kept at least 30 cms above the plants, to avoid leaf burns. [12]

A combination of red and blue LED strips is going to be used to achieve a lighting system that replicates the above mentioned behaviour. This stage is a very crucial stage, hence light intensity control through Arduino will also be added, to control the light intensity, similar to how the sun changes its intensity. This will allow us to grow healthy plants indoors, during odd climates that do not suit the plant we wish to grow. Hence, LED grow light system is extremely important, as it can help in nurturing plants that belong in a different time of the year or season.

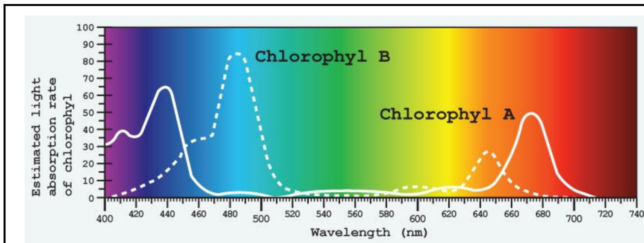

Fig.5 Light spectrum for Hydroponics. (Image Source: Google)

7 Conclusion

The aim of this paper is to show the details of hydroponics that is implemented using electronic circuit, water and nutrient solution i.e. soilless. The system automatically supplies nutrient and nutrients can be monitored. Once the monitoring is done corrections can be done i.e. it can be controlled accordingly leading to higher productivity. We are aiming to imple-

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ISSN 2229-5518

ment pest detection and connecting to Wi-Fi module (IoT based) to make the automated model more flexible. This system saves water and fertilizers, gives better yields as compared to soil system.

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