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IoT-Enabled Hydroponics Farm

Siddhanth J Ajri, Abhishek Guragol, Adish S Rao, Rahul Suresh
CSE, PES Institute of Technology, Bengaluru, Karnataka, India

ABSTRACT

Farming in India is carried out through mundane, outdated methods. Most farmers lack the necessary knowledge or expertise to carry out effective agriculture and rely on predictions, which oftentimes, fails. This leads to low yield, poor quality crops grown year after year, thus, putting the consumer at a loss of essential nutrients in their diet and also leaving the farmers with a very low profit margin for their crops. Since we are aware of the benefits of proper soil moisture and its quality, air quality and irrigation in the growth of crops, such parameters cannot be ignored. With the aim of revolutionizing the Indian Agricultural Business and also optimizing natural resources to procure higher yield and profits for our Farmers, the paper proposes remote access, self-sustained IoT-enabled Hydroponics Farm as a viable solution to rising crises in the Agro-Business.
Keywords: Hydroponics, Indoor Farming, IoT, Sustainable Development, Energy Optimization

I. INTRODUCTION

Weather and Climate have become highly unreliable in India, and throughout the World. It is this predicament that calls for a move to more prudent Indoor Farming methods. Hence, we have chosen to explore the technique known as Hydroponics to utilize in our Indoor Farm.

Hydroponics is a technique used to grow plants without the use of soil, instead the root system is placed in a water-base nutrient rich solution that is supported using an inert medium such as rock wool, perlite, vermiculite, peat moss, or clay pellets. The basic premise behind hydroponics is to allow the roots of the plant to come in direct contact with the nutrient solution, while also having access to oxygen, which is essential for proper growth.

The reason we have chosen to implement Hydroponics is due to its various advantages, namely greatly increased rate of growth in plants. With the proper setup, plants will mature upto 25% faster and produce upto 30% more than the same plants grown in soil. Hydroponics also involves careful control of nutrient solutions and pH levels. A hydroponic system will also use less water than soil-based plants because the system is enclosed, which results in less evaporation and also due to the reuse of water. It also contributes to reduced waste and pollution from soil runoff and offers improved pest control.

One of the commonly cited drawbacks is that the initial cost of setting up a Hydroponics Farm is quite high. Our implementation is designed to eliminate this drawback by helping to optimize and increase the energy/cost efficiency of a Hydroponics farm by making use of setup called the 'Solar Flower.' Determining weather conditions based on sensor readings, the 'Flower' would be able to switch between functioning as a solar tracking system (thus increasing energy efficiency by 60%), as well as, a rain water harvesting system. The solar energy that is harvested and stored, would in turn be used to power the smart farm.

Plants use only certain regions of the light spectrum for growth. Hence using LED grow lights, we will be able to set up an indoor farm under a controlled environment, that can promote the 24*7 growth of crops by providing them with only their required light recipe for their optimal growth.

Making use of the best combination of hydroponic nutrient solutions in the implemented hydroponics system, the rate of growth of certain crops can be improved, compared to that achieved by traditional growing techniques.

Since all the components including the Solar Flower and all the electronic components for the farm are IoT-enabled, the entire farm can be controlled remotely through our Web Interface, thus, making this Self-Sustained Ecosystem facilitate maximum yield through minimal effort. This sort of Farming technique is especially useful in arid regions where water is scarce, as the same water is reused by replenishing the required nutrient solutions after every flow cycle, when the water passes through the Nutrient tank.

II. PROPOSED SYSTEM

All the necessary configuration and powering of the components was done using Arduino Uno and Node MCU 1.0 Microcontroller boards and the prototype model was implemented in the following manner.

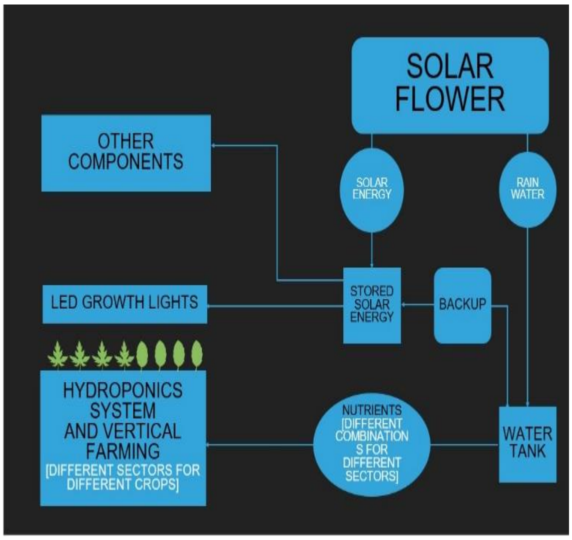

Figure 1. Block Diagram

The first sector in the farm will be the powering sector consisting of the Solar Flower. The Solar Flower setup consists of Solar Tracking Panels, constructed using LDRs, wherein based on the amount of light falling on the resistor the value of resistance varies. Using this varying resistance, the average of the four LDR's are calculated to determine in which direction the panel must rotate. The Solar Flower is provided with a Humidity sensor, and through its readings the Flower is able to detect if it is likely to rain or not, and accordingly configures itself to Rain Mode, wherein the Panels align themselves in the shape of an inverted umbrella, in order to harvest rain water which will be stored in Water tank, which is responsible for storing water that is used for irrigating the Crops being grown. Thus, both Solar energy and Rain water can be harvested successfully using this setup.

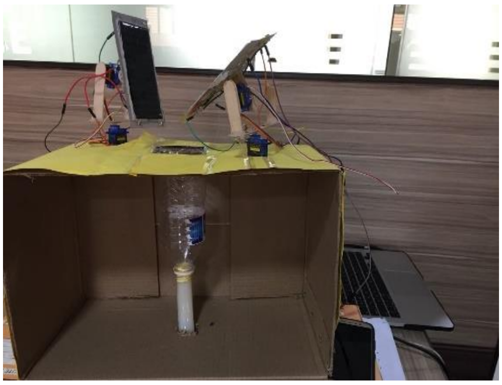

Figure 2. Solar Flower setup

Separate and preferably vertically arranged sectors for the growth of different plants are set up and pipes are laid from the Water Tank to each of these sectors. The pipes will have openings where the saplings will be placed. The water flowing to each sector was monitored and controlled in the prototype with the help of Hall Effect Flow Sensors and Solenoid Valves, which are powered by 12V Adapters. The water flowing through each valve can be monitored on the Webpage and adjusted so that each crop is provided with just enough water as needed.

LED Grow Lights are set up in each sector, with the colour of LED being used depending on the type of Crop being grown. These LEDs are powered by the Solar energy harvested by the Flower, failing which the Node MCU used to configure it is sufficient to power it.

Figure 3. Plantation sector, provided with LEDs

The final sector is the Nutrition Tank, that replenishes the nutrients that were drawn by the plants, and this water is then resupplied back to the Water tank and can be used for the next water flow cycle.

Each of the above functionalities are provided webpage access. All the webpages were written in HTML and connected to the Web through the ESP 12E Module of the Node MCU. The webpages are hosted on a local Server set up on a Raspberry Pi using Flask.

III. RESULTS AND DISCUSSION

A. Demonstration of Working Prototype

For the demonstration of the working of our prototype model, first, all the Arduino and Node MCUs were configured accordingly, and Water was poured into the setup to emulate the situation of rainfall. Water flowed through the pipes to reach the Valves, which remained open until a certain, predefined amount of water had flown through the Flow sensors. Upon reaching the flow limit configured earlier, the valves closed, preventing the excessive flow of water to Plantation sectors.

Each of the components could be controlled from the webpage successfully, i.e. the Switching between Rain Mode and Solar Energy mode, the Opening and closing of the valves, the LED Switching circuits etc. A home button was provided on each webpage to go back to the Home page of the Server, where the user again has the option to choose to control any of the functionalities of the Farm.

B. Nutrient Solution

The hydroponic nutrient solution is the only source of nutrients to the crop being grown and thus, it is of utmost importance to utilise a well-balanced solution, that contains all the organic and inorganic nutrients, as required by the plant.

Several factors have to be taken into account when choosing fertilisers for preparing a hydroponic nutrient solution:

- ✓ Water Quality - salinity, concentration of possibly harmful elements (like sodium, chlorides and boron).
- ✓ The nutrients required and their concentrations in the hydroponic nutrient solution.
- ✓ Proportional mix of the nutrients.
- ✓ The pH of the hydroponic nutrient solution and its outcome on uptake of nutrients by plants.

The following figures illustrate the ideal nutrients that could be utilised to grow the various crops tested so far.

COMMON NUTRIENT RANGES IN HYDROPONIC NUTRIENT SOLUTIONS

Element	Ionic form absorbed by plants	Common range (ppm=mg/l)
Nitrogen	Nitrate (NO_3^-), Ammonium (NH_4^+)	100-250 ppm elemental N
Phosphorus	Dihydrogen phosphate ($H_2PO_4^-$), Phosphate (PO_4^{3-}) Monohydrogen phosphate (HPO_4^{2-})	30-50 ppm elemental P
Potassium	Potassium (K^+)	100-300 ppm
Calcium	Calcium (Ca^{2+})	80-140 ppm
Magnesium	Magnesium (Mg^{2+})	30-70 ppm
Sulfur	Sulfate (SO_4^{2-})	50-120 ppm elemental S
Iron	Ferrous ion (Fe^{2+}) Ferric ion (Fe^{3+})	1-5 ppm
Copper	Copper (Cu^{2+})	0.04-0.2 ppm
Manganese	Manganese (Mn^{2+})	0.5-1.0 ppm
Zinc	Zinc (Zn^{2+})	0.3-0.6 ppm
Molybdenum	Molybdate (MoO_4^{2-})	0.04-0.08 ppm
Boron	Boric acid (H_3BO_3) Borate ($H_2BO_3^-$)	0.2-0.5 ppm elemental B
Chloride	Chloride (Cl^-)	<75 ppm
Sodium	Sodium (Na^+)	<50 ppm TOXIC to plants

SUGGESTED NUTRIENT SOLUTIONS FOR VARIOUS CROPS

Crop	N	P	K	Ca	Mg
Concentration in mg/l (ppm)					
Tomato	190	40	310	150	45
Cucumber	200	40	280	140	40
Pepper	190	45	285	130	40
Strawberry	50	25	150	65	20
Melon	200	45	285	115	30
Roses	170	45	285	120	40

Figure 4. Nutrient solutions required by various crops

C. LED Grow Lights

Lighting mechanisms are used to create a specific light recipe for each plant, giving them the wavelength, intensity and frequency, they require for photosynthesis in the most energy-efficient way possible. This engineered lighting makes it possible for us to control size, shape, texture, colour, flavour, and nutrition with razor-sharp precision and increased productivity.

It was found that further investigation pinpointed the more specific effects of different light wavelengths on plants grown indoors. The findings of these studies provide the basis of LED light recipes:

- ✓ Light of wavelength 630 - 660 nm is essential for the growth of stems, as well as the expansion of leaves. This spectrum of red light also regulates seed germination, dormancy periods and flowering.
- ✓ Light of wavelength 400 - 520 nm needs to be carefully mixed with light in other spectra since long exposure to light in this wavelength may stunt the growth of certain plant species. Light in the blue range also affects the chlorophyll content present in the plant as well as leaf thickness.
- ✓ Light of wavelength 500 – 600 nm was once believed to be unnecessary for plants, but recently it has been proved that this wavelength penetrates through thick top canopies to support the leaves in the lower canopy.
- ✓ Light of wavelength 720 – 740 nm penetrates through dense upper canopies to support the growth of leaves located lower on the plants. Exposing plants to IR light reduces the time a needed to flower. Another benefit of far red light is that plants exposed to this wavelength tend to produce larger leaves than those not exposed to light in this spectrum.

IV. CONCLUSION

Agriculture is one of the oldest implementations of Mankind and yet has seen very slow advancements in technology. Thus, the digitisation of the Farming sector is the need of the hour. The use of Hydroponics indoor farms, that provide remote access to users through IoT and whose energy consumption has been optimised to reduce cost exponentially is bound to not only improve the Nutrition standards of the Country, due to the better quality of produce, but also offers a viable solution to desertification, as otherwise barren land in arid regions can now be utilised to set up such modular self-sustained indoor farms.

On the whole, it would positively influence the General Economy of the Country while also providing the platform to truly revolutionise the Agricultural business in India.

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