Fabrication of Automated Hydroponic Farming Setup

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ABSTRACT

With the rise of civilization, open-field agriculture is encountering significant challenges, particularly the decrease in per capita land availability. In 1960, when the global population was 3 billion, the per capita land was 0.5 hectares. However, with the current 6 billion people, it has dwindled to only 0.25 hectares, and projections indicate it will further decline to 0.16 hectares by 2050. This decline is exacerbated by rapid urbanization, industrialization, and the melting of icebergs due to global warming, which further reduces arable land for cultivation. Another issue is the saturation of soil fertility and the stagnation of productivity despite increased fertilizer usage. In addition, certain cultivable areas suffer from poor soil fertility, with limited opportunities for natural fertility build up by microbes due to continuous cultivation. Frequent drought conditions, unpredictable climate, and weather patterns, rising temperatures, river pollution, inadequate water management, excessive water wastage, and declining groundwater levels also pose threats to conventional soil-based agriculture and food production.

In light of these circumstances, relying solely on open-field agricultural production will soon make it impossible to sustain the entire population. Consequently, soil-less culture has gained relevance in addressing these challenges. This method involves cultivating plants without soil, utilizing improved techniques that conserve space and water. Soil-less culture has demonstrated promising results worldwide as a means of food production. This paper discusses the way to automate a small-scale hydroponics system by building a computerized system consisting of:

- Microcontroller
- pH sensor
- EC sensor (to measure nutrient level in solvent)
- Temperature sensor
- Fluid pumps connected to pH- and nutrient reservoir

Keywords – Hydroponic system, Soil-less farming, Agriculture, Food, Production, Population

I. INTRODUCTION

New technologies are constantly emerging worldwide, and as the global population grows, the agriculture industry is adopting innovative methods to maximize food production with limited space and water resources. One such advancement is the hydroponic system, which enables soilless farming. Hydroponics involves cultivating crops without soil, utilizing a liquid nutrient solution or inert materials like Rockwool and Vermiculite to support plant roots. The liquid nutrient solution comprises essential plant nutrients dissolved in water. The roots can be submerged in a static liquid solution or exposed to a continuously flowing nutrient mixture. Compared to traditional farming, hydroponics demands regular crop monitoring and care.

Hydroponics, also referred to as aquaculture, soilless culture, or tank farming, is the cultivation of plants in nutrient-rich water, sometimes with the support of an inert medium like sand, gravel, or perlite. Initially used for scientific research on plant nutrition, the method of growing plants with their roots immersed in water and fertilizer was later adopted in early commercial hydroponics. However, due to challenges associated with plant support and aeration, gravel culture eventually replaced this technique, where plants are supported by gravel in a water-retaining bed or bench.

A. Hydroponics Cultivation System:

Hydroponics, unlike traditional farming, does not require soil to grow food. In this technique, plants are grown either on natural or man-made substrates, where the roots easily extract nutrients from a prepared nutrient solution. There are different methods for growing food using hydroponics, and their application depends on the specific plant, local climate, and budget, among other factors.

B. NFT (Nutrient Film Technique):

This technique, called NFT (Nutrient Film Technique), resembles the floating root system. However, instead of fully submerging the plant roots in the nourishing solution, they are exposed to a liquid stream that flows through a piping system. NFT utilizes smaller quantities of the nutrient solution than the floating root system, but it requires extra energy and components for operation. The surplus solution is returned to the storage tank through gravity, and the nutrient solution flow can be continuous or periodic.

C. Drip Irrigation:

For plants like tomatoes and peppers, this method is ideal. It entails directly pumping a nutrient solution to the roots of the plant to maintain a controlled flow. In closed systems, any remaining solution is returned to the storage tank after being administered at predetermined intervals.

D. Deep Water Culture:

In this system, the root of the plant is immersed in the nutrient solution, while the rest of it is supported above water level using polystyrene, cork bark or wood, among other materials.

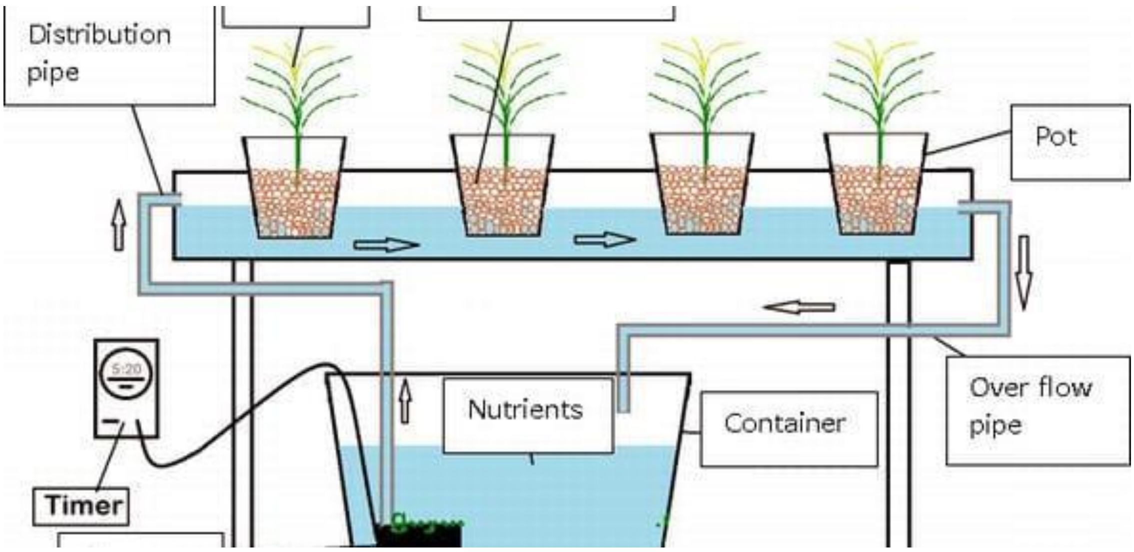


Figure 1: Cultivation Techniques

II. PROBLEM STATEMENTS

The demand for food is rising as well because India's population is growing every day. Agriculture uses a growing amount of water, which is also a result of the growing population. The use of freshwater for agriculture currently accounts for about 70% of the total. Additionally, 200,000 people die each year in India because more than 50% of the population lacks access to clean drinking water. By 2050, there will be 10 billion people on the planet, and water availability will likely worsen. Hydroponic technology claims to keep up with food production by giving a sustainable technique to produce crops without soil and employing vertically stacked layers while lowering water usage by roughly 90 %

Experts claim that hydroponic technology can conserve labour, land, and water resources. Since hydroponics does away with the need for available soil and permits multiple layers of farming in a relatively small area, it goes a step further and addresses this constraint as well, particularly in an urban and peri-urban context where space is at a premium.

Because traditional farming is becoming less profitable, water is becoming scarce, and soil is becoming less fertile, hydroponic farming is becoming more and more popular. As India's supply and logistics infrastructure has grown over the past several years, a lot of new businesses have entered this market. The market opportunity is tremendous since India's hydroponics market is predicted to develop at a compound annual growth rate of 13.53% between 2020 and 2027, said Abhishek Agarwal, managing partner, of Rockstud Capital.

III. PURPOSE OF THE SYSTEM

- Plant and grow food without soil
- Grow vegetables out of season to get more money
- Increase the effectiveness of water conservation by up to 90%
- Provide job opportunities through industrial farming
- Use this farming technique to generate passive revenue
- Increase location efficiency

IV. FABRICATION OF THE HYDROPONIC SETUP

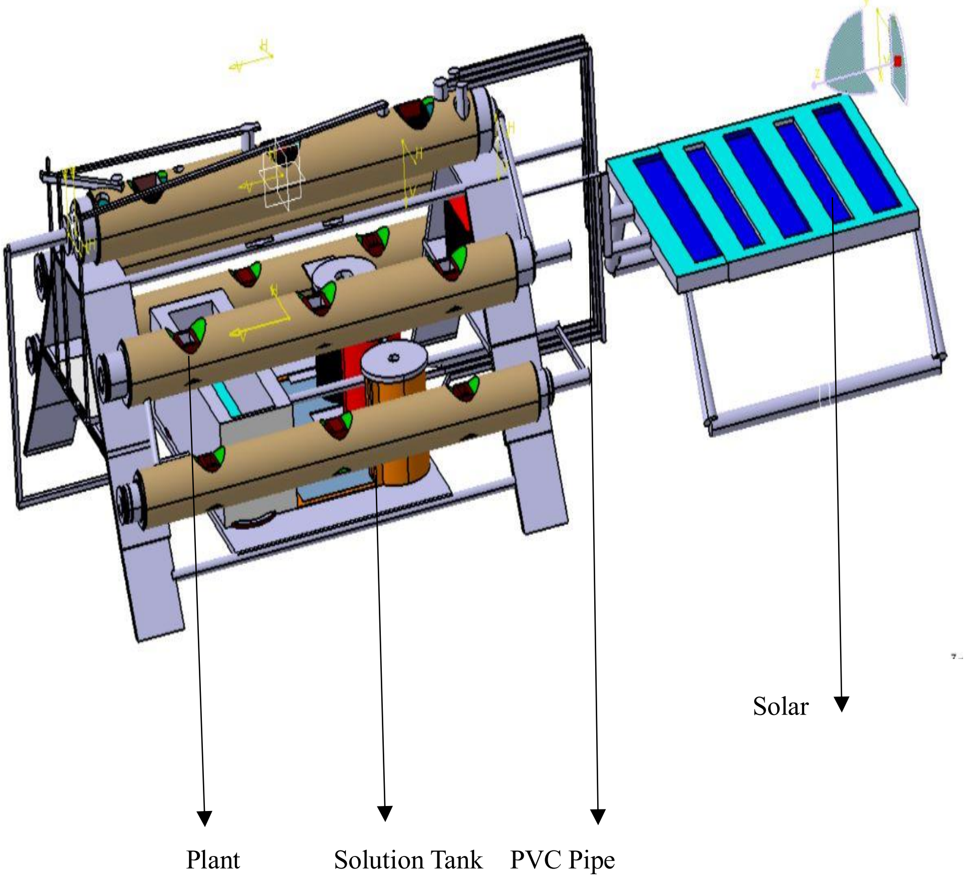


Figure 2: Design of the setup

Figure 3: Final Model

V. COMPONENTS OF HYDROPONIC SETUP

A. Pipes fittings:

- PVC Pipe (4 inch): This pipe serves as the hydroponic system's main line pipe. The flow of nourishment occurs in this pipe. The necessary hole is made on the upper surface, and the net cup is then placed inside.
- CPVC Pipe (1 inch)**:** Only this pipe is used to transfer nutritive solvent from a higher position to a lower one.
- Elbow: The pipe run can be changed by using this CPVC fitting.
- Tee: The direction flow of two outputs is combined at the bottom of the arrangement using this fitting.
- Cap: It is installed at the end of the main pipe to prevent leaks. It is made of PVC. The elbow is fitted at the cap's outermost end.
- Pipe Adhesive: It is an adhesive substance that is used to bind the cap to the pipe as well as other fittings like the tee and elbow. By using this solvent, every joint becomes leak-proof.

B. Pumps and other equipment:

- Water pump: It is an 18-Watt centrifugal pump. This is immersed in a water tank and moves the fluid along the pipe.
- Air pump: The water in the tank and pipe is given oxygen by this pump. Water with dissolved oxygen encourages greater plant growth.
- Tank: The 40-litre capacity of this tank. A water pump forces the nutrition into the pipes after creating a solution of water and food in this tank.
- Net Cup: It is constructed of plastic. Baby plants are preserved in this cup by surrounding them with coco peat. The cup was then retained inside the main pipe's hole.
- Cocopeat: It serves as a medium for plants and is biodegradable. It supplies nutrition to the plants while also retaining and absorbing it.
- Weighing Machine: This is used to gauge how much micro and micronutrients should be dissolved in water.

C. Required instrument for Nutrient monitoring:

- TDS Sensor: A TDS meter is a tiny, portable instrument used to measure the amount of total dissolved solids (TDS) in a solution, often water. Due to the fact that dissolved ionized particles, such as salts and minerals, enhance a solution's conductivity, a TDS meter measures the solution's conductivity and infers the TDS from that value.
- pH Sensor: A pH meter measures the activity of hydrogen ions in solutions, or, more simply put, the acidity or alkalinity of a solution. In the end, the pH level, which typically ranges from 1 to 14, is used to describe the level of hydrogen ion activity.
- EC Meter: The EC meter is made up of a 1000-ohm resistor and an EU power wire that serves as a probe. The Arduino microcontroller's analog A1, A2, and A3 pins are then connected to the cord's two terminals. While the A1 pin provides electricity to generate a voltage between the cord terminals, the A2 pin acts as a ground reference for one of the cable terminals voltages across the A1 and A2 pins are measured by the A3 pin in conjunction with a resistor. The Arduino chip then transforms the incoming voltage into an analog value so that it can be used to determine the EC value for the water solvent.

Figure 4: Components of setup

D. Microcontroller:
This section includes an overview of how the microcontroller Arduino Uno works.

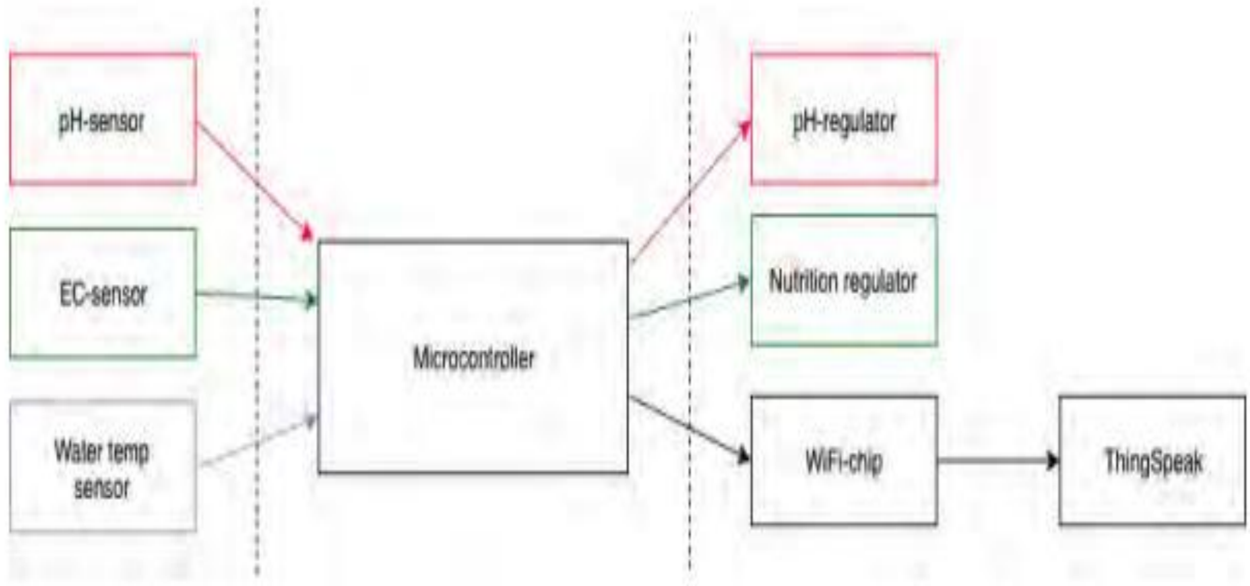


Figure 5: Block diagram

- Analog Pins - An analog-to-digital converter that can provide 10-bit resolution is included in the Arduino. Thus, these pins are capable of processing voltage inputs in the 0 to 5 V range and converting them to integer values between 0 and 1023. To accommodate different sensor readings, further processing can be applied to these integer inputs. The Arduino Uno, for instance, may receive an input integer from a pH sensor and use that information to run a script and get the appropriate pH value.
- Digital pins - Arduino Uno's digital pins have a variety of uses. You can choose whether the pin should act as an input or an output by specifying the pin mode. The digital pins of the Arduino Uno can be used in numerous ways. By selecting the pin mode, you can decide whether the pin should function as an input or an output.
- Serial pins - Two pins on the Arduino Uno are designated as the RX (receiving port) and TX (transmitting port). These ports make it easier for the Arduino to communicate with external devices like computers or other serial devices utilizing logic level signals. Signals are sent and received at voltage levels of either 0V or 5V, which are interpreted as binary instructions consisting of zeros and ones.

E. Data storage and analysis:
Here is a description of how to use an Internet of Things (IoT) platform to store, analyze, and visualize data. Figure 3.5 depicts the data flow.

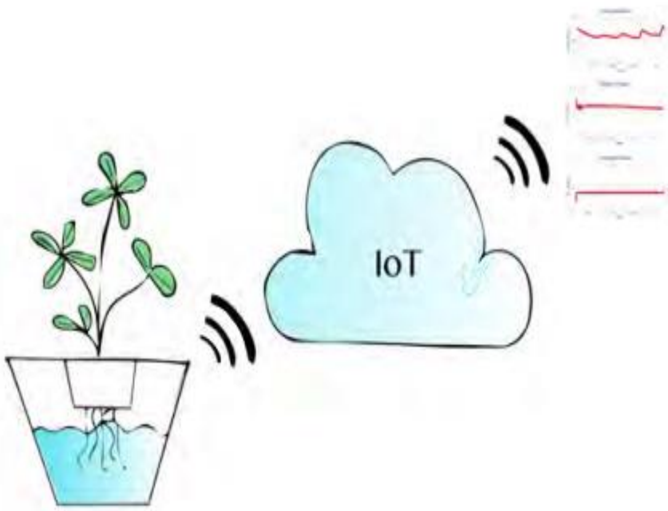


Figure 6: Data storage and analysis

- ThingSpeak- A cloud-based platform called Thing Speak was created as an IoT device analytics tool. It permits the visualization, examination, and dissemination of live data via a live streaming channel. Because every Thing Speak channel has a different API key, HTML instructions can directly read from and write to a certain channel. A web browser can be used to remotely view the data contained in these channels for graphical display.

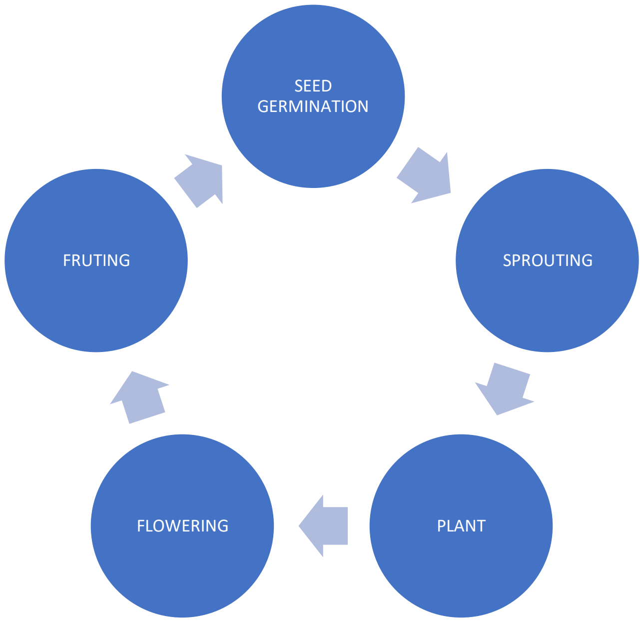
- Wi-Fi Module - A network solution particularly made with Arduino along with additional microcontrollers is the ESP8266. The ESP8266 will be used in this project to serve as a Wi-Fi adapter to make it easier for the Arduino to connect with a Wi-Fi network and access a Thing Speak channel. An Arduino board must include a script containing directions for the Wi-Fi chip's operation in order to establish a connection to the internet between the Wi-Fi module and a Wi-Fi network. The steps in these instructions include joining the specified Wi-Fi network and sending the data the Arduino collects to a Thing Speak channel.

F. Software setup:

- Program Start: The code library, sensor pin configuration, and pump relays make up this component of the software. Additionally, it contains the data required by the Wi-Fi chip to connect to Thing Speak. The Wi-Fi network login information, an Internet Protocol (IP) address for the Thing Speak API, and an URL-Get parameter linked to a Thing Speak channel to facilitate data upload are all included in this information.
- Wi-Fi Connection: At this point, the Arduino chip instructs the Wi-Fi chip to make a connection to the previously configured network through direct serial port communication. The program switches to the main loop if the connection drops.
- Main Loop: The automation process is managed by this cycle, which also continuously gathers sensor readings and posts the information via a Thing Speak channel. These readings let the system decide whether to utilize the pumps to add pH buffer or nutritional solution.
- Sensor Value Reading: The pH sensor collects 10 samples, which are delivered via a collection of ten integers through the analog connection to the Arduino to determine the ph. The software determines the average of all of the measurements and turns it into a pH value by sorting an array and choosing the middle six elements. Similar to how the temperature sensor works, the Arduino instructs the sensor circuit's board to take numerous measurements. The average is then computed by the Arduino and converted to a Celsius value. The Arduino adjusts its power supply to 5V for the EC sensor, enabling this to determine the drop in voltage between the probe's poles as an analog input. The Arduino transforms that input into the appropriate EC value using an algorithm.
- Sending sensor data to the Thing Speak channel: The data is transferred via the Thing Speak channel for storing after the sensors have produced a set of measurements. To connect to the Thing Speak channels using an Internet Protocol (IP) address, the Arduino connects with the Wi-Fi device using the serial ports. The Arduino then creates a text string URL Get-parameter and sends it together along with the pH, EC, as well as temperature measurements. The text string is then sent from the Wi-Fi chip to the Thing Speak channel.
- State 6, 7 & 8. Pump states: The liquids are administered in tiny amounts to avoid overcompensation. This is done by briefly engaging the pumps, which causes the pH to gradually drop and the electrical conductivity (EC) of the water as a solvent to gradually rise. On the basis of the following three states, the algorithm chooses which solution to add to the solvent:
- State 6: When the pH is greater than 6.6 and the EC level is below 1.4 mS/cm, the system solely makes up for this by injecting the nutritional solution.
- State 7: The system provides pH down buffer for acidifying the water if the EC level is higher than 1.4 mS/cm when the pH level is higher than 6.6.
- State 8: The nutrition solution is added if the pH and EC values are both less than 6.6 and 1.4 mS/cm, respectively. In the event of a decrease in the EC value, this state largely addressed the integration of nutrient solutions.
- Time delay: To ensure proper mixing, a solution must be added to the water's solvents within the loop cycle. This avoids inaccurate sensor readings during the following loop cycle. Therefore, at the conclusion of each Main Loop cycle, the 100-second delay in time is introduced.

VI. PLANT GROWTH PROCESSES AND NUTRITION MANAGEMENT

Various processes take place as plants grow. The germination of seeds is first, then sprouts appear. These sprouts eventually mature into full-grown plants. The plants develop further, reach the flowering stage, and eventually bear fruits.



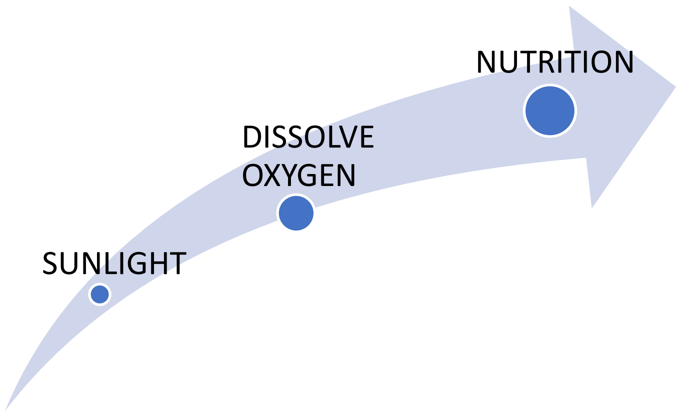


Figure 7: Growth process of plants

A. Nutrients required for hydroponic farming:

- Calcium nitrate: It assists in cell production first, and then it detoxifies the plant by neutralizing acids. The calcium nitrate's nitrogen component also stimulates the synthesis of proteins and encourages the growth of leaves. Stress from heat and moisture can cause calcium shortages in several crops, including tomatoes.
- (b) NPK 19:19:19, consisting of nitrogen, phosphorus, and potassium. The main nutrients in commercial fertilizers are nitrogen, phosphorus, and potassium. These three elements, also referred to by the phrase "Big 3," are essential for plant nutrition. Since plants absorb nitrogen more than any other nutrient, nitrogen is regarded as the most important nutrient among them.
- (c) Magnesium sulphate: commonly referred to as Epsom salt, serves multiple purposes in plant care. By increasing the production of chlorophyll and raising the roots' ability to absorb nutrients, it aids in the prevention of root shock. Producing more chlorophyll also makes fruits and vegetables sweeter and more flavourful.
- (d) Micronutrients: Micronutrients are essential for robust crop growth and must be carefully managed. Micronutrients are needed in smaller amounts even though macronutrients and micronutrients are both equally necessary. These nutrients, in spite of their modest requirements, directly affect crop development. Farmers frequently prioritize macronutrients, which infrequently leads to overapplication of micronutrients. Micronutrient deficits, however, can have a substantial impact on crop quality and development, underscoring the importance of managing crop nutrition well in order to satisfy the world's food demands.

Micronutrients include elements such as:

- Boron (B)
- Chlorine (Cl)
- Copper (Cu)
- Iron (Fe)
- Manganese (Mn)
- Molybdenum (Mo)
- Nickel (Ni)

Every micronutrient plays a different role in a plant organism. However, the most important micronutrients are boron, iron, manganese, and zinc.

Boron is a crop element important for:

Sugar transport

- Formation of cell wall
- Production of amino acids
- Crop reproduction
- Flowering
- Fruiting
- Crop quality

Depending on the kind of crop, boron deficiency will have different impacts. But these are the most typical sign: The effects of boron deficiency will vary depending on the type of crop. However, the most common symptoms include:

- Stunted growth of young crops
- The death of growing points
- Deformation of leaves
- Dark brown lesions on leaves
- Yellow chlorosis on leaves
- Poor flowering.

Table 1: Nutrition Management Table

STAGES	NUTRIENTS	QUANTITY FOR LEAFY PLANTS (gram /5 litre)	QUANTITY FOR FRUITY PALNTS (gram/5 litre)	TDS (ppm)	pH
STAGE 1	Only Water	-	-	50-150	5-6.5
STAGE 2	N:P:K - 19:19:19 Magnesium - Sulphate Calcium - Nitrate Micronutrients	4 1 2 0.5	5 1 2 1	400-450	5-6.5
STAGE 3	N:P:K - 19:19:19 Magnesium - Sulphate Calcium - Nitrate Micronutrients	8 2 4 1	10 2 4 1.5	800-900	5-6.5
STAGE 4	N:P:K - 19:19:19 Magnesium - Sulphate Calcium - Nitrate Micronutrients	10 3 5 1.5	12 3 5 2	1000-1200	5-6.5

A. Tomato Plant Growing Progress:


Planting


After 20 days


After 30 days


After 55 days

After 85 days

Figure 8: Tomato Plant

B. Bottle Gourd Plant Growing Stages:

After 6 days of seedling

After 30 days

After 45 days

Figure 9: Bottle Gourd Plant

C. Chilli Plant Growth:

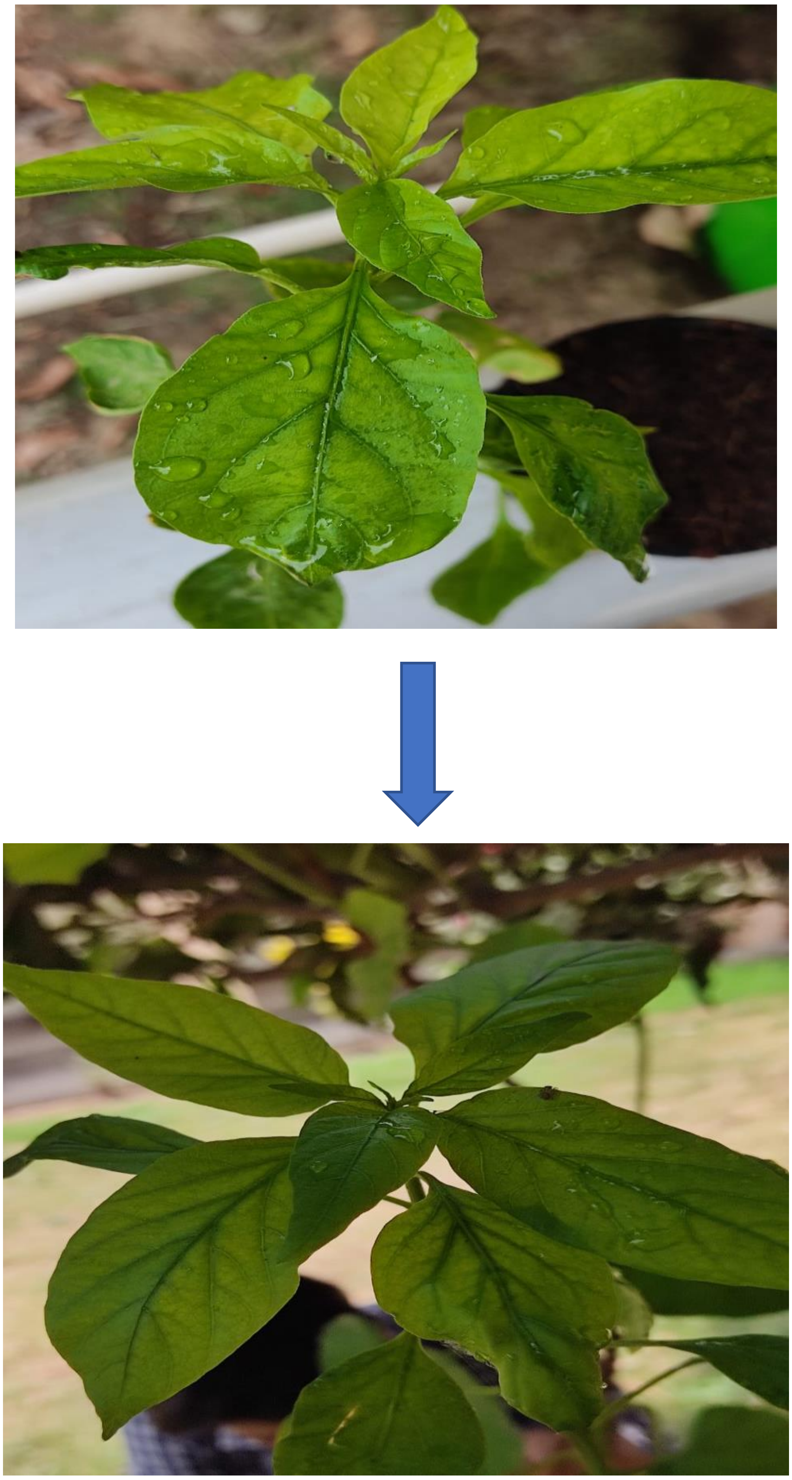


Figure 10: Chilli plant

SAFETY MEASURES AND PRECAUTIONS IN HYDROPONIC FARMING

(a) Maintaining Cleanliness and Sanitation

To keep all surfaces and equipment used in your hydroponic activities clean and hygienic, regular cleaning is necessary. This covers a variety of items, such as cleaning supplies, gear, clothing, sinks, and tables. The main objective is to stop the spread of infections to your hydroponic plants, food products, personnel, or clients.

While it is essential to consistently clean every section of your facilities, extra care must be taken with any surfaces or equipment that come into contact with the food you grow and harvest on a daily, if not multiple times per day, basis. You can utilize hydrogen peroxide or bleach solutions, which are both secure and efficient for cleaning and sanitizing food-related surfaces, to accomplish proper cleaning and sanitization.

(b) Maintaining Detailed Records and Logs

In spite of the fact that it might not at first glance seem to be relevant to safety and compliance in a greenhouse, keeping detailed records and logs is essential for your hydroponic greenhouse business. You may protect your company and prove responsibility in the event of outbreaks or other incidents by keeping detailed records of the growing, harvesting, cleaning, packaging, and distribution procedures. These thorough records assist a hygienic and clean hydroponics system and also act as proof for your assertions.

(c) Regular Treatment, Maintenance, and Flushing of Lines

Regularly holding water makes hydroponic tubing a potential breeding ground for harmful microorganisms. It is essential to routinely clean, sanitize, and sterilize these water-filled settings to stop these disease vectors from affecting your clients and, in certain situations, your hydroponic crops. Dilutions of food-safe cleaning agents can be added to the water in your hydroponic system to carry out daily cleaning and sanitizing. To maintain total safety and compliance, extensive cleaning, sterilization, and disassembly are required on a regular basis.

(d) Test your water source for pathogens

It is essential to verify the purity and cleanliness of a water source before using it for hydroponic cultivation in a greenhouse by filtering, treating, screening, or employing a combination of these processes. It's also a good idea to perform a direct pathogen test on the water supply to check for bacteria, viruses, or amoebae that may be contagious. This is crucial in rural locations where the water supply—such as wells, spring-fed pipes, or open-air water sources—might be untreated. But it is advised to examine your water supply frequently, regardless of its type. Even if a water source is not connected to a hydroponic system, it is still imperative to evaluate it. This includes water sources used only for hand washing and producing food. Your complete crew must work as a unit to maintain a hydroponic greenhouse operation that is secure, hygienic, and compliant. Nevertheless, errors can happen. In these situations, having greenhouse insurance coverage can secure your way of life and business by offering protection against unanticipated mishaps.

(e) The nutrition solution needs to be kept between 25 and 30 degrees Celsius.

(f) Minimize frequent contact with plants.

(g) Make that the solution is consistently flowing through the pipes.

VII. CAPITAL INVESTMENT

Table 2: Component cost

COMPONENTS	QUANTITY	RATE {Rupees Per unit/piece/kg/ml/litre}	TOTAL PRICE
PVC pipe	15 ft	60	900
CPVC pipe	15 ft	20	300
CPVC elbow	11 piece	20	220
CPVC tee	1piece	20	20
Pipe adhesive	50 ml	150	150
Water pump	1	274	274
Water tank	40 litre	100	100
PVC pipe cap	10 piece	30	300
Temperature sensor	1	158	158
Ph sensor	1	2024	2024
EC sensor	1	525	525
Solar panel	1	1300	1300
Battery	1	750	750
Thermometer	1	180	180
Microcontroller	1	1000	1000
Iron pipes (stand)	15 kg	70	1050
Electronic timer	1	703	703
Cocopeat	4 kg	212	212
Relay module	1	84	84
Arduino	1	704	704
LCD display	1	600	600
Jumper wires	40	100	100
DC connector	2	40	80
pH buffer	1 litre	650	650
NPK solution	1 litre	1150	1150
Wire	5 m	10	50
			Total component cost = 13584

Table 3: Processing cost

Cost associated with frame (welding) and painting	₹ 700
Drilling in pipes	₹ 150
	Total processing cost = 850

Total Cost of Finished Setup = 14434

VIII. FUTURE SCOPE OF THE HYDROPONIC

Potential customers can learn everything there is to know about hydroponics. From 2020 to 2027, the hydroponics market in India is anticipated to expand at a CAGR of 13.53%.

The world's population must be fed through agriculture, but there is a shortage of arable land due to factors including growing urbanization, industrialization, and natural disasters. The world's population is also steadily growing at the same time. In 1960, two people could be fed from one hectare of fertile land. In contrast, four people need to be fed on each hectare of land today, and 6.25 people will need to be fed on each hectare by the year 2050. These connected elements consequently increase the demand for the same plot of land to feed a growing population.

A difficult future is predicted by the open-field agricultural production technique currently in use. The likelihood that feeding the entire world's population will be impossible in the near future is rising. According to common wisdom, sufficient amounts of water, fertile soil, and sunlight are required for profitable farming in order to meet the rising demand for agricultural products. While this was true for most of human history, recent developments have shown that these presumptions are not always accurate in the present. According to current knowledge, soil is not always necessary for effective agriculture, because plants only need certain wavelengths of sunlight rather than the entire sun's spectrum.

The most crucial elements for successful agriculture are high-quality seeds, water, and nutrients, according to a new study and their practical implementation. Techniques for soilless farming that save on both land and water have shown promise on a global scale. This idea has given hydroponics and aeroponics more currency in the current global food production. As traditional farmland continues to suffer from land degradation and overuse, more and more people are turning to cutting-edge agricultural techniques, which are helping hydroponics to flourish.

IX. CONCLUSION

The challenges offered by soil conditions are expected to propel the industry's expansion in the next years. Adopting soil-less farming is essential to increase agricultural output and quality, ultimately assuring food security, especially in nations like India where urban growth is growing quickly Government action and the active participation of research institutions can help this technology advance even more.

Hydroponics is recognized as a critical approach to address these problems in a sustainable and environmentally aware way in a world where freshwater and food supplies are in decline. In the upcoming years, the hydroponics business is anticipated to grow dramatically, especially as traditional soil-based agriculture encounters more and more challenges. Soil-less agriculture will inevitably displace traditional farming methods in a nation like India where urban growth is outpacing predictions, boosting national production, and enhancing food security. Government actions, as well as the focused efforts of research institutions, can generate greater interest in and support for hydroponics.

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