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Hydroponics as a modern technique: An overview

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Abstract

Hydroponic farming is gaining global popularity due to its efficient resource utilisation and ability to produce high-quality food. Traditional soil-based agriculture faces challenges like urbanisation, natural disasters, climate change, and chemical overuse, leading to depleted land nutrients. This report explores various hydroponic systems, including NFT, DFT, ebb-and-flow, drip irrigation, and deep water culture. Leading countries in hydroponic technology include the Netherlands, Australia, France, England, Israel, Canada, and the USA. However, successful commercial implementation requires low-cost, user-friendly methods with minimal labour and reduced setup costs.

As civilization advances, open-field agriculture encounters challenges such as limited land availability, shrinking from 0.5 hectares per person to 0.25 hectares due to a growing global population. This trend, exacerbated by factors like climate change and industrialization, threatens food accessibility. Soil fertility has plateaued due to continuous cultivation, impacting natural microbe build up. Climate change-related factors like droughts and rising temperatures, coupled with ineffective water management and river pollution, worsen soil quality. Groundwater levels decline, posing risks to conventional agriculture. Soil-less farming techniques offer a solution, saving space, conserving resources, and showing promising international results, providing hope for global food security amidst these challenges.

Keywords: Hydroponic farming, soilless agriculture, nutrient film technique (NFT)

Introduction

The term hydroponics was derived from the Greek words "hydro," which means water, and "ponos," which means labor. Hydroponics, a plant cultivation method that uses nutrient-rich water solutions instead of traditional soil, was coined by Professor William Gericke in the 1930s [1].

This technique allows plants to grow without relying on fertile land and has become an alternative to conventional farming methods like aeroponics. Hydroponics is especially useful for areas with limited arable space or resources, where it has gained global recognition over time since automated farms and home kits became increasingly popular as early as the 1980s. The efficiency of this approach results in resource conservation while producing high-quality crops like vegetables and ornamental plants. In light of urbanisation challenges coupled with environmental concerns, the hydroponic system offers sustainable possibilities capable of feeding our ever-growing population's needs.

Technique of Hydroponics

Hydroponic systems can either be liquid or aggregate.

1. Liquid Hydroponic System: (Circulating Methods/Closed System)

When plants are grown in a solution culture, their roots are directly suspended within the nutrient solution.

- a) Nutrient Film Technique (NFT)
- b) Deep flow technique (DFT)

2. Aggregate Hydroponic System: (non-circulating method or open system)

- a) Root dipping technique
- b) Floating technique
- c) Capillary action technique

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Nutrient Film Technique (NFT)

In hydroponic systems, the plant's nutrient needs are fulfilled by supplying the nutrient solution with water ^[1]. One of the techniques used for this is the Nutrient Film Technique (NFT). In the NFT technique, the plants are contained in a plastic tube with holes for the roots, and a pump circulates nutrient solution through this system while the plants are inside. It doesn't require a timer for the submersible pump.



Fig 1: Nutrient film technique Mariyappillai 2020 ^[11]

Deep Flow Technique (DFT)

This method utilizes water as its growing medium, shallow ponds are employed to supply nutrients to plants. Unlike other techniques where roots are not continually buried, it involves growing plants in irrigation channels with a nutritional solution that is about 4-6 cm deep. As a result of the nutrient solution running continually via channels, the roots of plants obtain an unbroken supply of essential nutrients and oxygen. After feeding the plants, any extra liquid is routinely put back into circulation via distribution pipes connected to planting pools after being gathered in a central basin. This process ensures that plant growth thrives by maintaining an optimal balance between essential nutrients - leading to healthy crops with sturdy vitality ^[2].

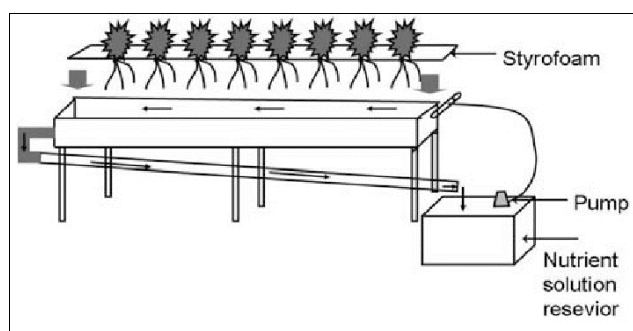


Fig 2: Deep flow technique Vimolmangkang, et al. 2009 ^[12]

Root Dipping Technique

Plants are cultivated in small pots filled with a small growing medium in this method. The pots are positioned in a way that the lower 2 - 3 cm of the pots are submerged in the nutrient solution ^[11]. Some roots are submerged in the solution while others remain exposed for nutrient and air absorption, respectively. This technique is straightforward and can be implemented using readily available materials. This low-tech cultivation method is cost-effective to construct and requires minimal maintenance. Importantly, this method does not necessitate expensive items such as electricity, water pumps, filters, etc. However, for root crops such as beets and radishes, an inert medium must be utilized.

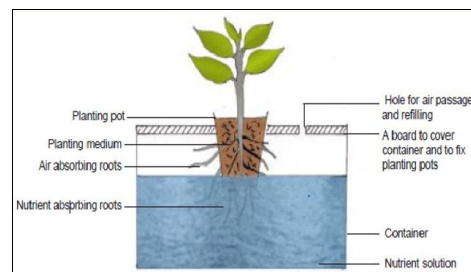


Fig 3: Root dipping technique Mariyappillai, 2020 ^[11]

Floating Technique

The method is similar to the box technique, but it permits shallow holders that are 10 cm deep ^[11]. To implement this process, plants grown in small pots get attached onto a Styrofoam sheet or any other light tray and then floated on top of a nutrient solution filled into the container. The solution gets aerated artificially.

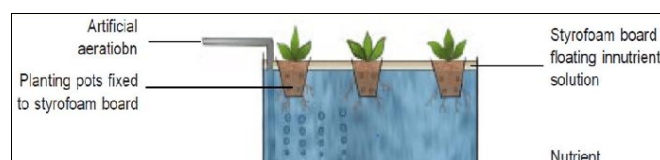


Fig 4: Floating technique Mariyappillai, 2020 ^[11]

Capillary action technique

The cultivation of seedlings or seeds in a dormant media uses planting pots of various sizes and shapes with openings at the base. The full pots are put in shallow compartments with nutrient solutions, which, with the help of adequate air circulation and capillary action, reach the inactive medium. For indoor plants, including decorative and floral species, old coir dust combined with sand or gravel can be used to facilitate this process ^[13].

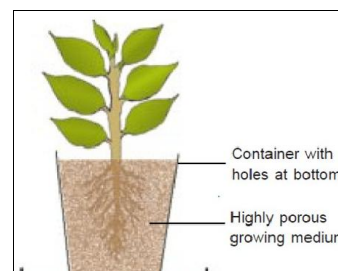


Fig 5: capillary action technique Mariyappillai, 2020 (11)

EBB and Flow System

In the hydroponics approach, a "nutrient solution," which is just water that has been enhanced with dissolved vital elements, gives plants the nutrition they need for growth. In a hydroponic garden, either the passive force of gravity or the active force of an electromechanical pump can be used to move the nutritional solution around the roots. In order to overcome the restricted agricultural land, hydroponics is frequently used. The measures that can promote the optimization in the growth and development of plants are likewise inextricably linked to hydroponic systems. Ebb and flow hydroponic systems is one of the most widely used system. The hydroponic substrate/aggregate culture incorporates recede and stream

hydroponic frameworks, which utilize the recede and stream concept within the solution's watering approach. The system's two phases—the sets period, amid which the plant is overwhelmed with supplement arrangement, and the subsiding stage, amid which the supplement arrangement depreciates—are the reasons why it is considered to have ups and downs [3].

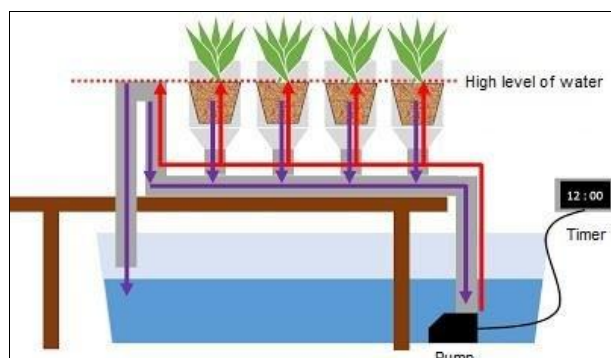


Fig 6: Ebb and flow system Muhammad Daud *et al* 2018 [3]

DRIP SYSTEM

The drip hydroponic system is a popular technique that is utilized by both commercial and residential gardeners.

In this method, a pump is used to deliver the appropriate volume of water or fertilizer solution to the roots of each individual plant. The plants are often placed inside a moist-retentive growth medium, allowing for a steady trickle of nutrient solution into the root zone. This technique aids in water resource conservation while promoting organized crop development.

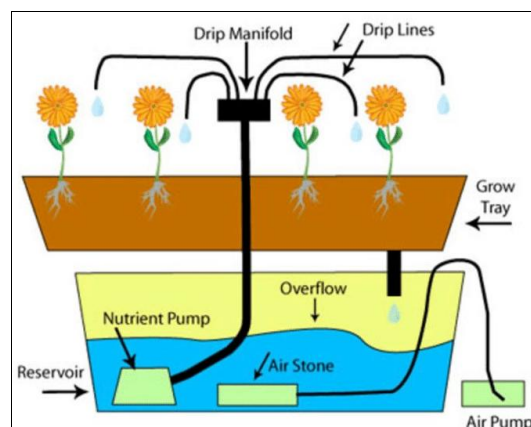


Fig 7: Drip system Incemehmetoğlu, *et al.* 2012 [4]

The Water Culture System

The Water Culture System is the most basic type of active hydroponic system. The plants in the system are held on a platform, which is often constructed of Styrofoam and floats immediately above the nutritional solution. In addition, an air pump adds oxygen to the nutritional solution by utilizing an air stone to form bubbles that deliver oxygen to plant roots.

The deep water culture method involves suspending plant roots in a nutrient-rich solution and delivering air through an air stone, similar to the hydroponic bucket system. This allows plants to develop quickly and provide bigger yields. However, it is critical to periodically monitor oxygen levels, salinity, pH balance, and nutrients because there is a possibility of algae or mould growth, which can reduce crop output.

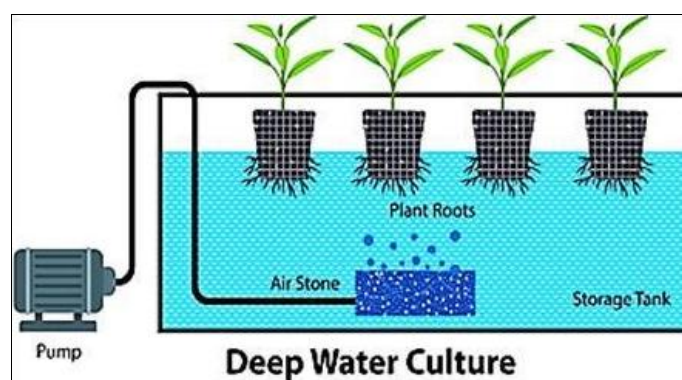


Fig 8: Deep water culture Bhagawati, Raktim, *et al.* (2020) [5]

Table 1: Various types of plants are grown using a hydroponic method without soil

Type of crops	Name of the crops
Cereals	Rice, Maize
Fruits	Strawberry
Vegetables	Tomato, Chilli, Brinjal, Green bean, Beet, Winged bean, Bell pepper, Cucumbers, Melons, green Onion
Leafy vegetables	Lettuce, Spinach, Celery, Swiss chard, Atriplex
Condiments	Coriander leaves, Methi, Parsley, Mint, Sweet basil, Oregano
Flower / Ornamental crops	Marigold, Roses, Carnations, Chrysanthemum
Medicinal crops	Indian Aloe, Coleus
Fodder crops	Sorghum, Alfa alfa, Bermuda grass, Carpet grass

Nisha Sharma, *et al.* 2019 [6]

Table 2: Average soil yields versus hydroponically produced average yield

Name of crop	Agricultural average per acre (in lb)	Hydroponic average per acre (in lb)
Wheat	600 lb.	5000 lb.
Rice	750-900 lb.	12000 lb.
Maize	1500 lb.	8000 lb.
Soybean	600 lb.	1500 lb.
Potato	8 tons lb.	70 tons lb.
Cabbage	13000 lb.	18000 lb.
Peas	2000 lb.	14000 lb.
Tomato	5-10 tonnes	180 tonnes
Cauliflower	10-15000 lb.	30000 lb.

Barman, Nirmal, *et al.* 2016 ^[7]**Conservation of Water in Hydroponic**

Obtaining water as a resource is becoming increasingly difficult and costly. Hydroponics can significantly reduce the requirement for water. As opposed to farming on soil, where most of the water supplied to plants is utilized for their growth. The soil has been so thoroughly penetrated by the material that it cannot be accessed.

During soil-based cultivation, plant roots spread out naturally in the ground. In contrast, hydroponic farming systems use only nutrient-rich water solutions to cultivate plant roots.

Either they are underwater or covered by a layer of nutrients. The root is constantly surrounded by filtered water. This procedure uses recovered, filtered, replenished, and recycled water, thus no water is lost unusable nutrient alternative water source is available as a result to cultivate crops using a hydroponic system.

By utilizing the Nutrient Film Technique (NFT) and allowing for runoff recycling, hydroponic systems have enabled a significant reduction in irrigation water consumption by between 70% to 90% ^[1]. Hydroponics is an efficient method for cultivating high-quality and valuable crops that require significantly less water, around 85-90%, when compared to traditional soil-based farming. Groundwater sources like dams or rivers often contain contaminants such as dissolved particles, salinity, and pathogens that can reduce the quality of plant yields. Certain elements in these waters may assist crop production while others must be controlled so as not to hinder growth performance.

Management of Contaminants

It is essential to keep the root-zone environment sanitary. In a culture without soil, it is crucial to achieve good plant vigour. It is crucial to reduce the plant population, yet doing so is difficult. Pathogens present in the root zone typically contain illnesses. Hydroponic systems wilt as a result of fusarium ^[8]. Verticillium can be wiped off by any species of Pythium or Phytophthora. However, there are currently no efficient fungicides that can target the principal roots. The only material that can be used in hydroponics without risk is metalaxyl. Pythium on vegetables has been successfully managed using this technique Crop heat treatment is not permitted to be used. It has been found that the nutritional solution works well for preservation. Tomatoes with strong, pathogen-free [root death] roots. Pythium was destroyed by heating nutritional solutions to a temperature of 20 °C. In an aeroponic system with a heated nutritional solution, the temperature is 22 °C. The ginger plant's roots matured more quickly and produced a little bit more ^[9]. Rhizomes harvested from the plants yielded more than those cultivated in the same conditions. Without bottom-source heat.

PH Levels that are Ideal for Nutrient Absorption

The growth and nutrient uptake of the plants cause a constant shift in pH in hydroponic systems. pH changes of fewer than 0.1 units do not significantly affect growth. In hydroponics, pH management is crucial since it has a big impact on plant growth. The solutions should have a pH between 5.5 and 6.5 ^[10]. The bulk of nutrition solutions normally have nutrients readily hand. Despite the fact that they are all members of the same species, they all differ greatly from one another and many are able to grow.

Advantages

1. This technique can be used in that where agriculture and gardening is not possible.
2. It gives high crop yield.
3. It do not require weeding and cultivation.
4. There are less chances of disease.
5. It results in greater control over nutrient content, pH and growing environment.
6. Crop rotation is not required.

Disadvantages

1. The costs associated with starting up and running a hydroponic system are greater compared to traditional soil-based farming.
2. Skill labour is required for operation techniques.
3. Fusarium and Verticillium are two diseases that have the potential to rapidly spread throughout a system.

International Status of Hydroponics

Area covered by hydroponics and CEA during the 1950s and 1960s, began to grow significantly in Europe and Asia, and big In the, hydroponic systems were created. Californian, Arizonan, and Abu Dhabi

and Iran (1970) ^[14] In these arid regions, the benefits of the technology included Additionally, due of the length and appeal of solar radiation, which photosynthesis is the process.

At present, "Euro fresh" Farms in Wilcox, Arizona, which sold 125 million pounds of tomatoes in 2005, is the largest commercial hydroponics facility in the world. With 318 acres (1.29 km²) of land covered in glass, Euro fresh accounts for nearly one-third of all commercial hydroponic greenhouse space in the US.

Although they are devoid of pesticides, Euro fresh does not consider its tomatoes to be organic. They are cultivated using top irrigation and Rockwool. Since there hasn't been any significant economic interest in hydroponics for nearly 20 years, producers are once again motivated to set up CEA/hydroponic systems. Nearly 40 acres of greenhouses have been constructed in Colorado, Nevada, and Arizona over the past four years. There are plans for many more hectares not just in Mexico but even in the Southwest. More than at any other moment in the last 50 years, the future of hydroponics appears bright ^[15].

National Status of Hydroponics

India did not adopt hydroponics technology prior to 1946. The journey began at an Experimental Farm of Bengal at Kalimpong. At first, there were a multitude of locations within the Darjeeling district which faced a few challenges. During 1946-47, hydroponics was established as the Bengal System. The development represented efforts to meet the requirements of India. In 2008, complying with the needs of Indian standards, approximately seven farmers in south Gujarat implemented this technology to cultivate exotic hybrid tea roses by the owner of

'Best Roses' - Mr. Kumar Patel. At present, the production of rose stems amounts to 10 million valued at around Rs. 5 crore, comprising of everything being shipped to floral markets in Japan, New Zealand and Europe. To increase the rose production to 20 million, which is double the current amount. The hydroponics system is installed to grow stems in Kuched village of Navsari on 12 acres. It has been demonstrated that novel crops such as, strawberries, green garlic and tomatoes can be grown using this technology.

Flora Consult, a Pune based turnkey who had assisted in setting up Best Roses' system three years back is now helping vitrified tiles. The industry plans to establish a group of seven related projects in north Gujarat, district sabarkantha. The second major project is Agrotech, a hydroponics project is underway in Gujarat is presently being implemented ^[10].

Conclusion

Hydroponics is a creative means of growing plants without soil, making it useful in small places and in difficult settings such as deserts. Surprisingly, arid sand serves as a good foundation for plants, and desalinated seawater supplies the nutrients. This strategy is especially important for developing countries dealing with food scarcity as well in Indo-Pacific region. There has recently been a boom in interest in hydroponics, which has resulted in an increase in experimentation and study. This has broadened its applicability, both indoors and outdoors, and provides a sustainable alternative for food production even in areas where traditional farming is difficult. In essence, hydroponics is a paradigm changer in global agriculture, promising more efficient and robust food production methods. It will help India to achieve sustainable goals.

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