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Hydroponics – An Overview

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Abstract

Soil-based agriculture is now facing major challenges due to urbanization, industrialization and environmental degradation etc. Among different problems, the most important one is the decline in per capita land availability. With 6 billion people on earth, the per capita land availability is currently 0.25 hectares and by 2050 it will be 0.16 hectares. Climate change along with urbanisation and industrialization magnifies this negative impact. To counteract these threats, hydroponics has emerged as a viable option which is currently gaining popularity around the world due to its efficient resource management. Hydroponic farms offer a viable solution towards a more sustainable food production while avoiding hazardous chemicals due to controlled environments and strict certification laws. Far from being a dream, hydroponic farming is already integrated into sustainable agriculture in order to meet rising global food demand.

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1. Introduction

Today, 55% of the world's population lives in urban areas, a proportion that is expected to increase to 68% by 2050 and 593 mha of land will need to be turned into agricultural land to fulfil the estimated calorie demands of the worldwide population. Furthermore, the occurrence of second-generation problems, such as over-mining of soil nutrients, decline in factor productivity, lowering of groundwater tables and pest build-up, such as weeds, diseases and insects poses serious problems. To mitigate these problems, intensification and vertical expansion of agricultural land has been regarded as the only viable options in near future for meeting the rising food demands. Globally, 70% of water usage goes towards agricultural production, largely due to unsustainable irrigation practises (Worldbank.org). In this context, soil-less cultivation i.e., hydroponics, might be inaugurated successfully and considered as an alternative option for growing quality food plants, crops or vegetables (Butler, 2006). One of the most significant advantages of hydroponic farming is the ability to grow crops in near optimal conditions using Controlled Environment Agriculture (CEA) technology. It can be grown anywhere on the world at any time of year, regardless of weather, accessible cultivable land, or soil quality. Crop production can be kept in a controlled environment, allowing trained personnel to optimise water (saving up to 70% of water),

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nutrients and light to the plants using advanced climate control technologies. Light inputs are also optimized to ensure maximum plant absorption and yield outputs. Vertical farms expand upwards instead of outwards on a horizontal plane, allowing farmers to grow 3 to 10 times more crops in the same amount of space as unlike conventional farms. By stacking horizontal racks on top of each other, hydroponics increases the amount of space available on the ground. In a traditional farm, identification of pests, diseases in the field are much more difficult. But in hydroponics, the modular design allows for a highly efficient isolation of diseased or dying crops, as well as a quick and easy neutralization of compromised plants. Most hydroponic systems operate automatically to control the amount of water, nutrients and photoperiod based on the requirements of different plants (Resh, 2013).

Figure 1: Plants growing in hydroponics system

2. Hydroponics: History, Definition, Characteristics and its Components

2.1. History

Growing plants in soil-less condition is not a new concept. Hydroponics can be traced back to the ancient city of Babylon, which is now located in modern-day Iraq. The Hanging Garden of Babylon, one of the Ancient World's Seven Wonders, is the first known example of a plant grown without soil in 600 BC. Around 1100 BC, the Aztec Indians became more inventive with their gardening techniques, creating gardens that appeared to float (Folds, 2018). These "floating gardens" were known as "chinampas" and they were made up of a strong combination of roots and lashes that were laden with sediment from lakebeds, providing nutrients to the crops and plantations. It has been a frequent kind of cultivation in laboratories since then, but it has recently gained traction as a technique to grow food with a better yield using less land, water and energy.

2.2. Definition

Hydroponics can be defined as the science of growing plants without the use of soil, but by use of an inert medium, such as gravel, sand, peat, vermiculite, pumice, or sawdust, to which is added a nutrient solution containing all the essential elements needed by the plant for its normal growth and development (Resh,1998). The word "Hydroponics" has its derivation from combining the two Greek words *"Hydro"* means water and *"Ponos"* means labour. Hydroponics, the cultivation of plants in nutrient-enriched water, with or without the mechanical support of an inert medium such as sand or gravel (www.britannica.com). Plants grown hydroponically have no solid material beneath them at all, instead having a rich mix of nutrients dissolved in water. The main benefit of hydroponics is the cost savings from reduced labour costs, as it is usually done in enclosed areas with mechanical irrigation and fertilization. This farming model can result in 7 to 14 times more growth cycles than traditional practices. Almost any plant can be grown with hydroponics such as green beans, cauliflower, broccoli, mint, lettuce, carrot, beetroot, tomato, cantaloupe melon, strawberry, grape, lemon, pepper, cabbage, cucumber etc.

2.3. Characteristics

Traditional agriculture can be considered an art, while hydroponics is a science in which all of the factors that influence plant growth are regulated. Hydroponics qualities are listed below

2.3.1. Growing tray

A grow tray is a container designed to hold one or more plants in a hydroponic growing system and keep the plants safe and secure. Depending on the type of hydroponic system in use, these trays may have leach valves to allow water to drain out of the growing medium when necessary. A grow tray, also known as a "grow chamber" or "hydroponics tray". On a small scale, hydroponics can be cultivated in pots.

2.3.2. Nutrient management

Appropriate concentrations of nitrogen, potassium, phosphorus, calcium, magnesium and sulphur, as well as smaller amounts of other elements, are required in the nutrient solution's composition. Generally, nutrients come from salts but organic fertilizers like cattle manure, bird guano, fishmeal, wood or grain scraps, or seaweed can also be used. The amount depends mainly on these two factors- number of plants and their age. With an

increase in the number of plants and their age, the amount nutrient consumption will increase.

2.3.3. Water management by submersible pumps

Almost all hydroponic systems require a submersible pump to transport the water containing the nutrient solution from the reservoir to the growing chamber/root zone, where the plants can easily access it. Submersible pumps are widely available online, as well as at hydroponic supply shops and most home improvement stores that sell garden supplies. They come in a variety of sizes to suit your needs. Sprinkler system of irrigation is most effective.

2.3.4. Aerators or air pumps

Oxygen is one of the essentials for plant growth. Growing plants in a soil-less culture needs a constant level of oxygen. The purpose of air pumps is just to provide air and oxygen to the water and then to the roots of the growing plants.

2.3.5. Grow Lights

To increase yield, use natural light, artificial light, or a combination of the two. Because of their low power consumption, LED lights have become more popular in recent years. Grow lights differ from the lights that are used at home. Grow lights are made to produce a specific colour spectrum that mimics sunlight as per our consumption needs or commercial requirements. For example, an increase in far-red (750-780 nm) can help stimulate cannabis stem growth and flowering, whereas necessary blue light, in minimal amounts, can prevent uneven elongation of stems and leaf shrinkage.

2.3.6. Substrates

The plants in hydroponic crops absorb nutrients from the solution, but they still require support and adequate aeration of the roots. The following are some of the most commonly used substrates: 1. Perlite, pumice, or vermiculite: Perlite, pumice, or vermiculite are light, porous stones that retain water while allowing air to circulate through the roots. 2. Rice husk, wood fibre, or wool: these decompose slowly but effectively keep the roots aerated. 3. Rock wool: Rock wool is created by melting basalt rock and extracting filaments, which form a non-degradable sponge.

2.3.7. Other elements

Common tools used to manage hydroponic solutions include electrical conductivity metres, which measure how well a solution transmits an electric current to estimate nutrient ppm. A pH metre is a device that measures the concentration of hydrogen ions in a solution using an electric current. An oxygen electrode is an electrochemical sensor that measures the oxygen concentration in a solution. Measuring spoons or graduated cylinders for premixed commercial hydroponic solutions.

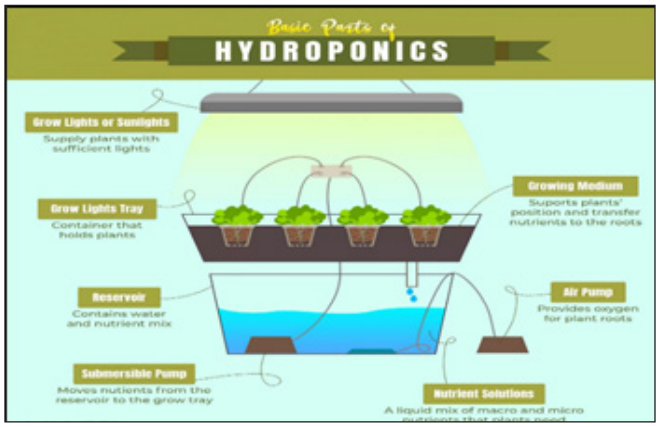

Figure 2: Different components of hydroponics

3. Advantages of Hydroponics

- Plants grown in hydroponics systems tend to grow faster and yield more due to the quality nutrition, higher oxygen levels and the carefully controlled ambient variables
- It uses 20% less space for growing with respect to conventional system
- Because hydroponics systems deliver a nutrient-rich solution directly to the root zone, plants can be grown closer together without competing for root space
- Farmers can grow 3 to 10 times the number of crops in the same amount of space as traditional farms
- Compared to traditional farming methods, this farming model can produce 7 to 14 times more growth cycles
- Unlike traditional gardens, which necessitate outdoor space for plants, hydroponics systems can be easily integrated into a variety of residences, independent of size or location
- Compared to typical farms, hydroponic farms can save up to 90% of water usage
- A quick and easy way to isolate diseased or dying crops
- Mature plants are easier to harvest at this height as plants are generally grown on counters, benches, tables, etc
- Less or meager weed menace in soilless hydroponic farming

Figure 3: A commercial hydroponics farm

4. Hydroponics and Agricultural Sustainability

Hydroponic and aeroponic growing have received a lot of attention in recent years as the future of farming (Miller, 2011). Hydroponics protects and improves environmental quality to provide long-term productivity and profitability. The definition of sustainable agriculture integrates the three pillars of sustainability- environmental health, economic profitability and social equity (Liao et al., 2020). Hydroponics fulfils all aspects of sustainable agriculture

• It encourages 7 to 14 times more growth cycles and 3 to 10 times a greater number of crops in the same area with harsh climate and less fertile soil, like in the desert (more production so, economically viable)

• It can save water up to 70-80 %, require less fertilizer, low chemical use and less erosion (environmentally secured)

• It is highly profitable and sophisticated farming system (social security).

Hydroponics is promoted as a means of combating climate change, as well as reducing environmental damage and species extinction caused by intensive farming. It also allows for more efficient use of water, which is becoming increasingly scarce. Hydroponic crops are also more profitable and easier to manage, making them an effective weapon in the fight against hunger and improving food safety, especially in developing countries. Herbicides and pesticides are commonly used in traditional agriculture to protect crops from natural threats, but these chemicals are increasingly being scrutinised for the negative effects they have on humans and the environment. Pesticides contaminate surface water, are toxic to a wide range of non-targeted animals and plants and can wipe out beneficial and healthy soil microbes. But in hydroponics, as the water is recycled in hydroponics, there is no risk of fertilizer or herbicide running off and poisoning local waterways. So, it doesn't affect the local environment and is more productive. Hydroponic greenhouses allow commercial growers to locate their greenhouses closer to their target markets or distribution channels. As a result, the need for expensive transportation is reduced. This increases the profits of hydroponics growers and reduces pollution caused by transportation.

5. Water Conservation in Hydroponics

As water becomes more precious and valuable resource, the use of hydroponics is urgently needed and is expected to become more popular in future time. Compared to soil cultivation, Hydroponics saves between 70-90% more water as it gets recovered, filtered, replenished and recycled. In soil farming, the majority of the water provided to the plants is leached down to the soil and unavailable to the plant's roots, whereas in hydroponics, plant roots are either submerged in water or a film of nutrients mixed in water surrounds the root zone at all times, keeping it hydrated and nourished. Waste nutrient solution can be used as an alternate water resource for crop cultivation under hydroponic system (Choi and Lee, 2012). Under controlled hydroponic conditions, it is feasible to grow high-value, high-quality crops while consuming 70-90% less water than typical soil-based agriculture. Salinity, dissolved solids and pathogens are all common factors in groundwater and dam/river water that can affect plant yield and condition, but this type of problem is totally avoided in hydroponics. Use of sprinkler also reduce the water requirement.

Figure 4: Sprinkler irrigation system in hydroponics

6. Disadvantages of Hydroponics

• Setting up a hydroponics system is expensive than traditional farming

• Hydroponics require proper monitoring and micromanagement than traditional plant cultivation

• If disease appears, it will affect all plants in the system

• Because the water is constantly circulated throughout the system, infections can quickly spread throughout the entire growing system, affecting the entire collection of plants

• Power outrages can be hazardous for hydroponic systems, which needs constant monitoring

7. Crops that Can be Grown in Hydroponics

Everything starting from flower to fruit crops to medicinal plants can be grown using soil-less culture. List of crops are listed in Table 1

Table 1: List of crops that can be grown on commercial level using soil-less culture

Type of crops	Name of the crops
Cereals	*Oryza sativa* (Rice), *Zea mays* (Maize)
Fruits	*Fragaria ananassa* (Strawberry)
Vegetables	*Lycopersicon esculentum* (Tomato), *Capsicum frutescens* (Chilli), *Solanum melongena* (Brinjal), *Phaseolus vulgaris* (Green bean), *Beta vulgaris* (Beet), *Brassica oleracea* var. *capitata* (Cabbage), *Brassica oleracea* var. *botrytis* (Cauliflower), *Cucumis sativus* (Cucumbers), *Raphanus sativus* (Radish), *Allium cepa* (Onion)
Medicinal crops	*Aloe vera* (Indian Aloe), *Solenostemon scutellarioides* (Coleus)
Fodder crops	*Sorghum bicolor* (Sorghum), *Medicago sativa* (Alphalfa), *Axonopus compressus* (Carpet grass)

8. Cost of Cultivation

The final cost of setting up a hydroponic farm on one acre of land will be Rs. 110 - 150 lakhs, excluding the price of land (Yadav, 2020). Water treatment, nutrient tanks, piping, lighting, pumps, reservoirs, air pumps, temperature, electrical conductivity and pH monitors are all items that will increase the overall cost of the hydroponic farm. After overcoming these initial costs, other hurdles must be solved in order to ensure a productive and secure hydroponic farm. Hydroponic farming is setting up roots all across India. For example, RISE Hydroponics is an Ahmedabad-based agritech start-up, a rising dynamic in the modern agriculture field of hydroponics, which has spread quickly and they currently have offices in 5 major cities in India (www.theprint.in).

9. Conclusion

Hydroponics has emerged as a promising method for growing a wide range of crops in recent years to feed a large portion of the world's population. In country like India, where urban conglomeration is rising day by day, there is no alternative other than adopting a soil-less culture i.e., hydroponics, to ensure the country's food security and the quality of produce. However, to stimulate commercial hydroponic farms and low-cost hydroponic technologies, government intervention and research institute interest are required.

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