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Hydroponics: Forging A Way towards Sustainable Agriculture

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Over the course of many generations, agriculture has shaped civilizations, economies, and cultures, serving as the cornerstone of human civilization (Safuri et al., 2022). However, given how quickly the modern world is changing due to factors like urbanisation, technological breakthroughs, and shifting environmental dynamics, traditional farming practises face new challenges.

One of the most important issues facing modern society is the severe limitation caused by the scarcity of agricultural land (Cifuentes Torres et al., 2020). There is less arable land available for agriculture as a result of population growth and urban area expansion. Considering the constant rise in demand for food production, the problem of shortage is complex. Due to a lack of available space, traditional agricultural methods—which usually require extensive expanses of land—face difficulties in supplying the growing demand for food production (Sabandi et al., 2021). This restriction, together with concerns about deforestation and ecological inequality, necessitates a review of what is being done in agriculture now.

In this evolving ecosystem, hydroponic technology has emerged as a disruptive solution. The agricultural method known as hydroponics, which includes growing plants in nutrient-rich solutions without the need for soil, has the potential to completely transform the agricultural industry (Wibowo et al., 2018). This method offers more versatility by enabling the cultivation of crops in controlled environments, such as cities and systems with vertical stacks. Through careful control of nutrients, water, and environmental factors, hydroponics maximises resource efficiency, reduces water usage, and increases agricultural yields (Khan et al., 2020). Hydroponics not only maximises the use of resources but also lessens the need for chemical inputs, which helps to mitigate environmental effects and promote sustainability. Furthermore, the establishment of a regulated atmosphere efficiently reduces the possible risks linked to pests and illnesses, leading to the generation of agricultural goods of exceptional quality. When all of these benefits are combined, hydroponic technology becomes a compelling option for addressing the various problems that modern agriculture faces.

Hydroponics

Plants are grown hydroponically in nutrient-rich water, either with or without the mechanical assistance of an inert media like perlite, sand, or gravel. For scientific investigations into plant nutrition, plants have long been grown with their roots submerged in water and fertiliser solutions. This culture technique was used in early commercial hydroponics (Greek hydro- meaning "water," and ponos- meaning "labour"). However, gravel culture—in which gravel supports the plants in a waterproof bed or bench—replaced this technique due to the

challenges of maintaining the plants in a normal upright growing position and aerating the solution. Numerous substrate types have been effectively employed, such as fused shale, sand, pumice, perlite, rice husks, granite chips, molten rock spun into fibres, clay pellets, and coconut coir. Periodically, a fertiliser solution—often made of synthetic fertilisers or fish or duck excrement—is pumped through; the frequency and concentration of this solution vary based on the type of plant and environmental factors like temperature and light. Pumping is often automatic, and the solution empties into a tank.

The fertiliser solution is made up of different chemical compounds that are graded for use in agriculture or horticulture and contain different amounts of major elements required for plant growth, such as potassium, phosphorus, and nitrogen, as well as various trace or minor elements like sulphur, magnesium, and calcium. Tests conducted on a regular basis reveal whether more chemicals or water are required, although the solution can be used indefinitely. Typically, the chemical components can be combined dry and kept in storage. The solution's concentration and pumping frequency increase as the plants get bigger.

With a hydroponic system, a large range of vegetables and flower crops can be grown successfully. Lettuce, kale, tomatoes, peppers, cucumbers, radishes, strawberries, and cannabis are examples of common crops. This method is also occasionally used to grow the model organism *Arabidopsis thaliana* for genetic studies.

Types of Hydroponic System

- **Ebb and Flow:** This method makes use of hydroponics kits with a pump, growth bed, and reservoir. Hydroponic farming utilising ebb and flow technique involves cultivating plants in a broad bed using a growing media such as rock wool. The reservoir's nutrient-rich water is periodically flooded onto the bed and then allowed to return to the reservoir. The right amount of water and nutrients are given to the plants by repeating this process multiple times a day.
- **Wick System:** This kind of hydroponic system is the simplest and least common; it doesn't need a pump, aerators, or electricity. Plants receive water or fertiliser solutions by capillary action. If you use a larger or wider wick, or more than one, you can regulate the amount of water that reaches the plant. This technique does not work well for plants that require a lot of water; it is best suited for small plants, herbs, and spices.
- **Nutrient Film Technique:** Plants are grown hydroponically using nutrient film technique (NFT), which employs a shallow stream of nutrient-rich water. In order for the roots to absorb the nutrients they need to grow, they are suspended in the water. Growing plants with NFT is an extremely effective method that can yield large amounts of plants in a little area. The NFT hydroponics kits are easy to assemble and maintain. They need a grow bed with a shallow channel for the water to flow through, a pump to circulate the water, and a reservoir of fertiliser solution. The plants are put in pots with net cups or other openings that let their roots drop into the water.
- **Drip System:** A drip hydroponic system feeds nutrient-rich water straight to the roots of plants via a system of tubes. This technique of watering helps to avoid waterlogging and nutrient deficits while guaranteeing that the plants receive an adequate amount of water and nutrients. Hydroponic drip systems are very simple to install and operate. Numerous types of plants can be grown with its hydroponics kits.
- **Deep Water Culture:** Plant roots are suspended directly in a nutrient-rich fluid using the deep-water approach. Plants are put in containers that let the solution reach the roots of the plants. The roots receive oxygen through diffusers or air stones. For nutrient balance to be maintained, the nutrient solution is usually changed on a regular basis.

Advantages Oo Hydroponic Farming

- **Farming without land**: It can even be placed indoors in tiny spaces, which contributes to the introduction of greenery into crowded areas.
- **Increased yields**: Compared to soil-grown plants, hydroponic plants can generate higher agricultural yields.
- **Less pest & disease problems**: In comparison to soil cultures, hydroponic farming carries a lower risk of pathogen contamination. Nonetheless, there exists a negligible possibility of contamination via the fertiliser tank. In order to combat this, ozone, filters, UV light, or heat-based sterilisation or disinfection devices are implemented in these systems.
- **Reduced water usage**: Less water is used in hydroponic farming projects than in conventional farming practices.
- **Better control over growing conditions**: Growers who use hydroponics enjoy greater control over the growth environment, including temperature, light, and nutrients. Plants that are healthier and more fruitful may result from it.
- **Year-round production**: No matter the weather, producers that use hydroponics can produce crops all year round.
- **Less manpower**: Because it makes use of automated equipment for fertilisation and watering, manpower is saved.
- **Technologically advanced**: Additionally, research is being done on its application on spacecraft.

Disadvantages of Hydroponic Farming

- The installation is expensive.
- It is dependent on electricity, and a few hours without it can completely ruin the crops.
- There must be regular testing of the nutritional solution.
- It calls for knowledge.

Hydroponic Farming in India

In recent times, hydroponics has garnered significant interest and acceptance in India. Given the nation's varied temperature zones and scarcity of arable land, hydroponics is a strong contender for an efficient and sustainable food production system. Among other advantages, hydroponics in India provides stable crop quality and production for the country's agricultural industry. The following factors make this farming technique significant to the Indian population:

Water Conservation: India has serious problems with water scarcity in several areas. In India, hydroponics provides a more water-efficient option than conventional soil-based agriculture by using less water. The hydroponic setup addresses the urgent problem of water scarcity by minimising water waste and enabling the reuse of nutrient solutions through recirculation systems and precise nutrient delivery.

Consistent Production: India has a wide range of weather patterns, including monsoons and extremely high temperatures. Because hydroponics offers a controlled environment, it is possible to cultivate plants year-round, minimising reliance on seasonal fluctuations and guaranteeing a steady supply of fresh produce. This skill helps maintain stability and food security in the face of climate instability.

Crop Quality: Growing consumer demand for pesticide-free and clean produce makes hydroponic farming advantageous. Because a hydroponic system gets rid of soil-borne pests and diseases, fewer chemical pesticides, herbicides, and fungicides are needed. It produces superior crops that are free of contaminants and adhere to stringent food safety regulations.

Hydroponic Farming in the World

In 2015, the hydroponic farming sector was valued at $21.4 billion worldwide, and it was expected to increase at a rate of 7% annually. It seems farming is evolving, however slowly. On the other hand, significant worldwide changes are approaching that may significantly hasten the adoption of controlled-environment agriculture. An additional 3 billion people may inhabit the planet by 2050, with more than 80% of them residing in cities. Since the vast majority of land that may be utilised for agricultural production is already in use, new producing sites must be discovered, especially in dry locations.

An option that has received a lot of attention is vertical urban farming, which involves setting up stacked hydroponic farms inside of structures, even large skyscrapers. In addition to resolving the issue of running out of arable land, this would locate farms in the centre of our future, densely populated cities, where crops are most required. Already, Michigan, Singapore, and even abandoned bomb shelters in south London are home to vertical farms. Additionally, NASA is looking into the possibility of using hydroponics to establish space farms that may provide astronauts with food as it planned human space missions that will venture farther and farther from Earth. It is attempting to develop a closed-loop system that feeds CO_2 and human waste into a hydroponic farm in order to produce food, oxygen, and water in collaboration with the University of Arizona.

Future Scope of This Technology

Agriculture is the fastest-growing industry, People will use cutting-edge technology like hydroponics and aeroponics to establish extra channels of agricultural production when population rises and arable land shrinks as a result of poor land management. In regions of Africa and Asia where both water and crops are scarce, hydroponics has the potential to feed millions of people.

Conclusion

The expansion of the agriculture industry is expected to grow exponentially in near future, there is no other choice but to embrace soil-less culture to enhance the yield and quality of the product in order to ensure food security for our nation, because growing crop in soil is getting difficult particularly in a country like India However, the adoption of this technology may be accelerated by government initiatives and research institute interest.

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