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Hydroponics: An Innovative and Sustainable Approach toModern Agriculture Technology in the 21st Century

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Abstract

Hydroponics technology is a soil-less agricultural technology that has gained significant consideration in recent years due to its potential for efficient and sustainable production. This innovative approach involves growing plants in nutrient-enriched water solutions and its ability to maximize yields, conserve water, and provide precise control over plant growth and essential elements such as nutrients,pH, and water makes it a valuable tool for addressing the challenges of food production in an urbanized world. Many different types of plants, crops, and vegetables may be produced with hydroponics. In general, hydroponically generated end products have superior quality yields, tastes, and nutritional values than naturally occurring soil-based agriculture. It is becoming more and more well-liked worldwide, in both developed and developing nations, because of its low cost, lack of sickness of the crops, and eco-friendly practices. Along with advanced space research, it has a lot of potential in many nations to fill the gap in arable land when suitable cultivable land is unavailable. Using hydroponics to meet the global nutrition demand will make a significant contribution to the future of food supply. Hydroponics is an emerging approach that might be used to feed the world's population in the future.

Keywords: Hydroponics, soilless, Sustainable, Nutrient enriched, Eco-friendly, and Sickness

Introduction:

Hydroponics is an approach to cultivating plants in nutrient-enriched water rather than soil, with or without the use of mediums such as vermiculite, coconut coir, perlite, peat moss, etc. (Radhakrishnan *et al.*, 2019). These mediums provide mechanical support to plant roots

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and ensure they have access to the required nutrients. Instead of obtaining nutrients from the soil, hydroponic plants receive a balanced mixture of water and nutrients. This allows for better control over the plant's nutritional intake, leading to faster growth and healthier crops. Hydroponics is also known as "aquaculture" or "tank farming."

History:

Hydroponics gets its name from the Greek word hydro, which means water, and ponos, which means labor (Beibel *et al.*, 1960). The earliest published study on growing plants without soil is in F. Bacon's book "Sylva Sylvarum", which was released in 1627, a year after his death (Ghatage *et al.,* 2019). John Woodward reported his spearmint water cultivation research in 1699. He discovered that plants growing in pure water sources outgrew those growing in distilled water. In the early 1930s, Professor William Gericke used the term "hydroponics" to refer to the practice of growing plants with their roots suspended in water that contains nutrients and minerals with or without the use of mediums such as vermiculite, coconut coir, perlite, peat moss, etc. (Jan *et al.,* 2020).

Nutri-culture was developed by researchers at Purdue University in 1940 for growing crops. During the 1960s, the nutrient film technique was first developed by Allen Cooper in England and was first used in the food industry, but it has now been widely adopted. Hydroponics has the largest market in Europe, where the top three manufacturers are France, the Netherlands, and Spain. The United States of America and the Asia-Pacific area are the next two largest markets, respectively (Jan *et al.*, 2020). According to Jensen and Collins' 1985 analysis, the global hydroponic market was predicted to grow at a rate of 18.8% between 2017 and 2023, with a projected value of USD 490.50 million.

In 1946, W. J. Shalto Duglas brought hydroponics to India and set up a laboratory in Kalimpong, West Bengal (Bhattacharya, 2017). Additionally, he is the author of the book "Hydroponics: The Bengal System".

Why hydroponics:

It is estimated that the global population will be 50% larger than it is today by 2050, while the demand for grain will double as well (Tilman *et al.*, 2002). Because of this, soil-based agriculture will face massive challenges for both the sustainability of food production and the sustainability of terrestrial and aquatic ecosystems, as well as urbanization and industrialization, in the upcoming decades. Nevertheless, at the same time, it is expected that

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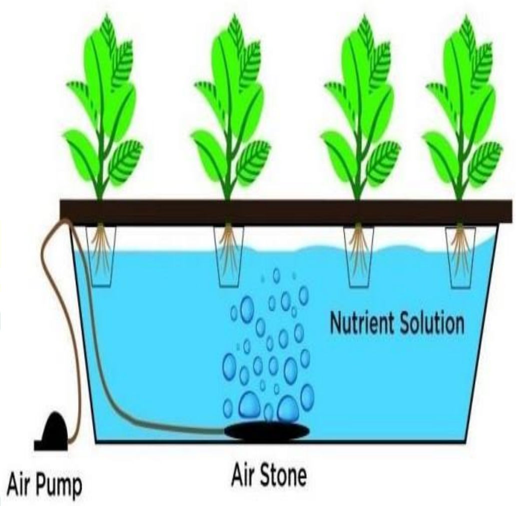
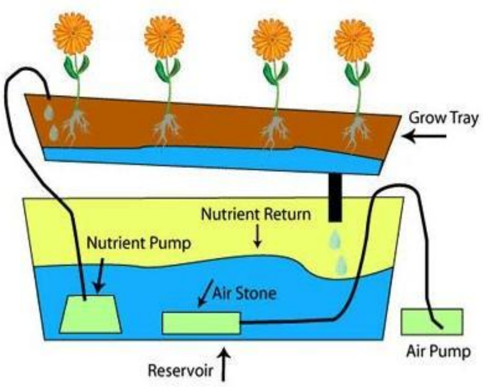
soil fertility and quality will also decline due to climate change, natural disasters, and uncontrolled use of chemicals for agricultural purposes. Consequently, to overcome the current situation and ensure the future of the country, researchers have developed an alternate method of growing plants called hydroponics, or soilless agriculture. Now, this type of agriculture is becoming more and more popular worldwide, in both developed and developing nations, as it is economical, disease-free, and eco-friendly. In many nations, it offers excellent potential in conjunction with high-altitude research to address the scarcity of arable land in situations where suitable cultivable land is unavailable. Therefore, hydroponics would be a better technique to fulfill the demand for nourishment in the world while also producing a variety of fruits, vegetables, and feed while advancing the future.

Types of hydroponics:

1. **Deep water culture:** In DWC systems, roots are immersed in nutrient-enriched aerated water with plants floating in a nutritional solution. The roots are supplied with oxygen via air-stones and an air pump. In reservoirs, oxygen, nutrient concentrations, salinity, andpH must be monitored to avoid algae and mold growth (Jones, 2005).





2. **Nutrient film technique:** It was developed by Dr. Allen Cooper in England in the 1960s. In this system,a thin layer of nutrient solution constantly flows over the roots of the plants in a shallow, sloping channel (Morgan, 2009). There is a small amount of water around the roots of the plants, which is the main reason for naming this method NFT.

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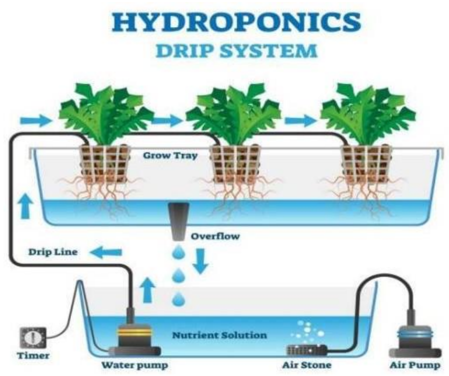
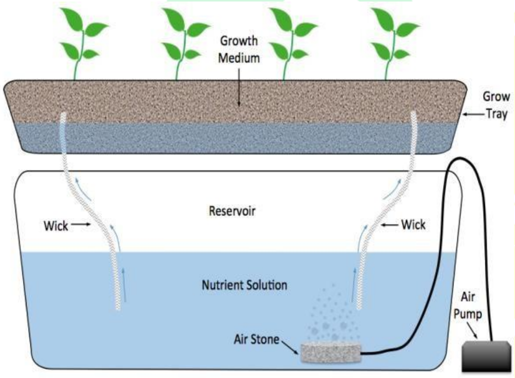
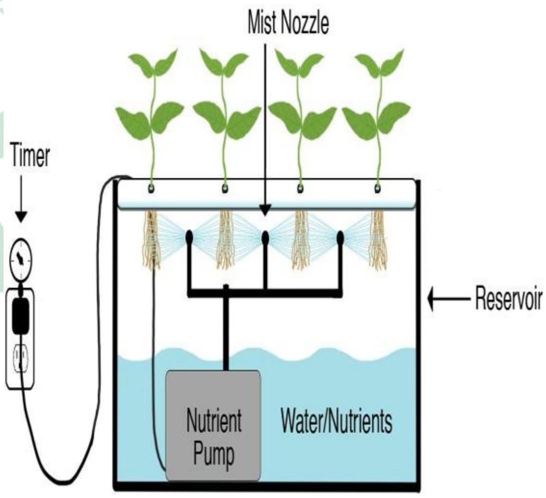
3. **Drip system:** In this system, the plants are grown independently in a soil-less medium, and thenutrient solution is kept separate in a reservoir. Dripsystems supply nutritional solutions or water to the roots of the plants via emitters or nozzles to slowly drip nutrients and any excess solution may be collected, recycled, or even let to drain off.





4. **Wick system:** The wick system is one of the simplest hydroponic systems. They use a wick (usually made of cotton or felt) to draw the nutrient solution from a reservoir to the plant's roots. This method is suitable for small-scale, low-maintenance operations (Lee and Lee, 2015).

5. **Aeroponic technology:** It is a newer and more advanced method of technology for growing plants. This approach doesn't require a growing medium like the nutrient filmtechnique. The plant roots are directly suspended in an environment, and the plants are misted with a nutrient-enriched water solution as they grow to keep the environment moist (Kumari and Kumar, 2019).



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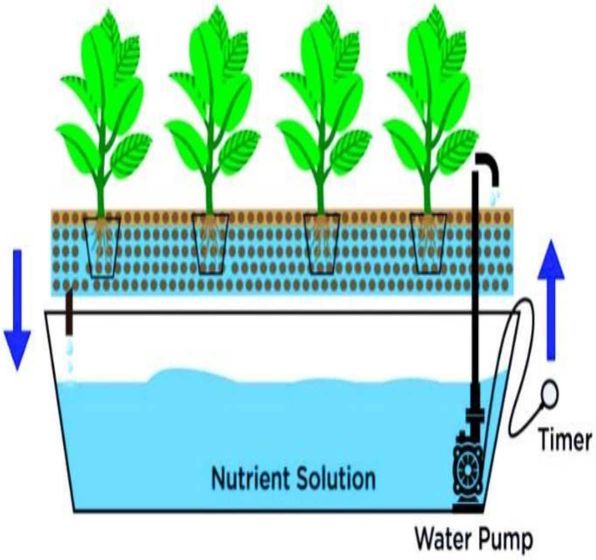

6. **Ebb and flow technology:** It is also known as "flood and drain hydroponics". According to this system, plants are grown in a soil-less medium and periodically flooded with a nutrient- enriched water solution by using a pump that is placed into the reservoir and allowing it to drain back into the reservoir. It supplies oxygen to roots, and it helps to prevent over-watering.

Hydroponics techniques- Basic requirements:

1. **Growing medium:** Medium doesn't provide any nutrients for the plants; it provides only mechanical support to the roots. Ex: vermiculite, coconut coir, perlite, peat moss, etc.
2. **Nutrient solution:** It is a vital component in hydroponic systems, where plants are grown without soil. It provides a total of essential nutrients like macro-nutrients (N, P, K, Ca, Mg, S, etc.) and micro-nutrients (Mn, B, Fe, Mo, Na, Co, etc.) directly to the plant's roots in a water- based environment.
3. **Water:** It could be essential to measure the pH and ensure that no contaminants or diseases are present.
4. **Temperature and Humidity:** Maintaining the temperature and humidity is essential for healthy plant growth.
5. **Mineral nutrients:** According to De Saussure and Boussingault (1800), carbon, hydrogen,oxygen, and nitrogen play a significant role in the growth of plants. After that, in 1860, Sachs and Knop, added phosphorus, potassium, calcium, magnesium, and sulfur to the list of De Saussure and Boussingault, and grew plants in aqueous solutions. Later, research in plant physiology has revealed that plants require other micronutrients, such as zinc, copper, manganese, boron, molybdenum, iron, and boron, to grow properly (Velazquez-Gonzalez *et al.*, 2022)

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Macro-nutrients	Micro-nutrients
1. **Carbon:** The building block of biological substances 2. **Hydrogen:** Water Formation 3. **Oxygen:** Sugar's energy release 4. **Nitrogen:** The synthesis of proteins,amino acids, and chlorophyll 5. **Phosphorus:** Essential for ATP synthesis and photosynthesis 6. **Potassium:** Essential for the activity of the enzymes and osmotic regulation 7. **Calcium:** The building block of the cell wall, cell development, and cell division 8. **Magnesium:** An ingredient of chlorophyll, an enzyme that activates 9. **Sulfur:** Essential proteins and aminoacids synthesis	10. **Boron:** Essential for procreation. 11. **Manganese:** Component of chlorophylland is used to activate enzymes 12. **Iron:** A component of photosynthesis 13. **Copper:** Activation of enzymes 14. **Zinc:** An ingredient in auxins andenzymes 15. **Sodium:** Essential for the movement of water 16. **Chlorine:** Activation of enzymes 17. **Cobalt:** Fixation of nitrogen 18. **Molybdenum:** Fixation of nitrogen 19. **Nickel:** For nitrogen release

6. **Aeration and Pumps:** Many hydroponic systems require the use of water pumps to circulate the nutrition solution as well as air pumps to oxygenate the solution and prevent rootrot, which is one of the biggest problems.
7. **Lighting:** In hydroponics, proper illumination is essential to plant development. Either natural sunshine or artificial grow lights, including fluorescent, high-intensity discharge (HID), or light-emitting diodes (LEDs), can be used.

Advantages of hydroponics:

1. High water usage efficiency.
2. A small area is needed for hydroponics.
3. Plants may be grown vertically to maximize yield per square meter.
4. Hydroponic plants develop more quickly and are less susceptible to diseases and pests.
5. There is no need for soil tillage, and it is an odorless approach without the use of fertilizers.
6. Reduce pesticide use.

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7. Soil conservation or prevent soil erosion.
8. Crops are cultivated throughout the year.

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