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Hydroponics - A Modernized Farming System

[1]Kodati Bhavana, [2]Ramchander S, Chandrasekhara Sarma M, Shivani D & Kavitha Reddy A

Abstract: -

Hydroponics is an advanced and modern farming technique for vegetable production, gaining global recognition for its efficient resource utilisation and high-quality food production. Soil-based agriculture faces challenges such as urbanisation, climate change, and the overuse of chemicals, which degrade soil fertility. There is an urgent need to explore climate-resilient alternative agriculture production systems that focus on resilience, resource efficiency, and disease management. Hydroponics, a soilless cultivation system, is gaining interest as it reduces the dependency on agricultural land and pesticides, and can be implemented in areas with poor soil quality, thus mitigating the negative effects of extreme weather events. While countries like the Netherlands, Australia, and the USA lead in hydroponic technology, challenges like high initial costs and technical requirements must be addressed for wider adoption.

Introduction:

Hydroponics, as a growing technique, has an old and honourable history starting long before W. F. Gericke first coined and published the term hydroponics in 1937 February(https://hydroponichorizons.com/history-of-hydroponics/). Hydroponics is a soilless agricultural technique that involves growing plants in a nutrient solution with or without the use of a solid medium. Hydroponics means "**working water**/ **solution culture**" and is derived from Greek words *hydro*, meaning "**water**, and *ponos*, meaning "**labor".** This is the most common method of growing crops in countries like Israel, the Netherlands, and America.

Types of Hydroponic Systems

[1]Kodati Bhavana, [2]Ramchander S, [2]Chandrasekhara Sarma M, [2]Shivani D & [2]Kavitha Reddy A

[1]M.Sc. (Department of Genetics & Plant Breeding), School of Agriculture, Kaveri University, Gowraram(V), Wargal(M), Siddipet district, Telangana- 502279.

[2]Department of Genetics & Plant Breeding, School of Agriculture, Kaveri University, Gowraram(V), Wargal(M), Siddipet district, Telangana- 502279.

Wick System - For indoor hydroponics, the wick method is the most straightforward technique. The system is passive, and since it lacks a water pump, it is regarded as a self-feeding system. With the aid of a wick, the nutrient solution from the reservoir is transported into the growth media via capillary action.

Drip system - This system growing media to provide regular nutrition and watering. This technology is similar to drip irrigation in soil gardening, gaining popularity and becoming the industry standard in hot, dry locations. Long pipes and hoses irrigate crops, save water, and decrease evaporation. The significant advantage of this method is less water consumption. Moisture levels can be easily controlled in a drip system.

Ebb & Flow System - It is considered a more popular system in which plants are kept in large grow beds, usually filled with growing medium. The timer regulates the flow of nutrient solutions in the environment. If the timer puts the pump on, it allows the nutrient solution in the growth tray, and if it shuts off, it pumps the nutrient solution back into the reservoir. The ebb and flow system is affordable, enhances nutrient recirculation, and requires low maintenance.

Deep Water Culture (DWC) - is a modified hydroponic system with an air stone, reservoir, air pump, tubing, and floating platform. This system includes a grow tank containing the nutrient solution and a pump to supply oxygen to the roots. In the presence of an air pump, more plants can be cultivated in a single grow tank. The system is reliable and cheap, and an air pump uninterruptedly supplies oxygen to the crop root zone.

Nutrient Film Technique (NFT) -The NFT technique requires only a thin layer of solution at the bottom of a deep tank. Consequently, the lower half of the roots will receive food and water, while the upper half will be allowed to breathe. This system exposes the root surface to the air during nutrient solution circulation. The pump is generally in a mode to monitor the nutrient solution constantly. The NFT hydroponic system enhances the recirculation of excess solution of nutrients and aids in the proper oxygen supply. Also, it is economical since it can be organized in multilevel, matrix farming, and vertical orientation. In addition, it minimizes land usage, labor and fertilisers compared to other systems. Water consumption is also very minimal, and it is climate-resistant.

Aeroponic System - plants produced by aeroponics thrive in an air or thick fog environment. It involves spraying a nutrient-rich water solution onto the plant's hanging roots. Lower stems occur in a closed or semi-closed environment using a high-pressure

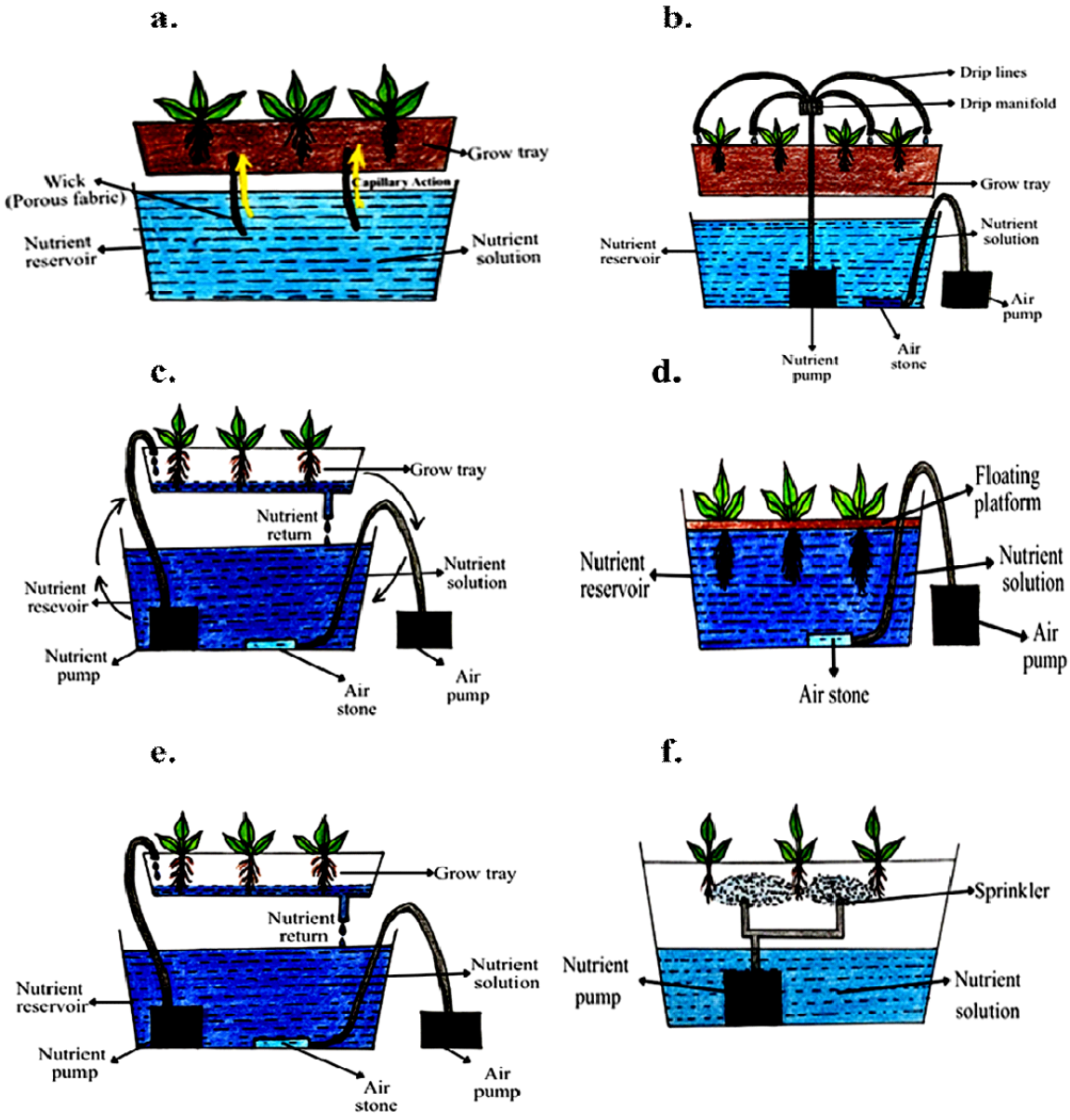

Fig. 1: Different Types of Hydroponic Systems

a. Wick System
b. Drip system
c. Ebb & Flow System
d. Deep Water Culture
e. Nutrient Film Technique (NFT)
f. Aeroponics

sprayer with a micro inject nozzle and an electronic timer. It provides highly oxygenated nutrients to the plants.

Table 1: Comparison of growth parameters in Soil and Hydroponically grown Lettuce					
	Plant height (cm)	**Root length (cm)**	**Number of leaves**	**Leaf length (cm)**	**Leaf width (cm)**
Hydroponically grown lettuce	27.85±0.767	21.52±0.254	32±0.894	19.45±0.82	11.23±0.39
Soil-grown lettuce	20.47±1.025	14.02±0.525	19.4±0.510	15.96±0.69	8.98±0.61

Table 1.1: Comparison of phenolics, flavonoids and antioxidant capacity in soil and hydroponically grown Lettuce. (Chamoli, N., et al. (2024). Comparative Analysis of Hydroponically and Soil-Grown Lettuce.)		
	Hydroponically grown lettuce	**Soil-grown lettuce**
Total phenolics	2513.4±43.6	3061.5±60.59
Total flavonoids	530±25.4	716.8±41.9
ABTS (mg/100g)	721.6±12.6	811.9±10.1
IC50 (µg/ml)	157.0±2.1*	153.1±1.8*

Table 2: Comparison of growth parameters in Soil and Hydroponically grown Tomato. (Giri, L., et al. (2020). Enhancing Tomato Yield Through Hydroponic Cultivation.)		
Tomato Cultivation	**Hydroponically grown tomato**	**Soil-grown tomato**
Crop yield (tonnes/ha)	280-300 up to 650-700	36.98
Recommended density (plants/$m^{2)}$	10-14	2 to 3.7
Greenhouse gas emissions per kilogram of food product (kgCo2eq per kg)	n/a	8.24
Water usage(L/kg)	22(green house without recycling) 10(with recycling)	60
Energy input (megajoule/harvested kg)	4	0.8

Table 3: Comparison of growth parameters in Soil and Hydroponically grown Spinach. (Sahu, C., et al. (2024). An in-Depth Assessment of Morpho-physiological Traits in Spinach.)		
Spinach cultivation	**Hydroponically grown spinach**	**Soil-grown spinach**
Leaf area (cm^2)	221.6+/-5.59	181.4+/- 3.08
Leaf length (cm)	15.21+/-0.20	12.23+/- 0.06
Leaves per plant	14.2 +/- 0.30	47.28 +/- 2.12
Yield (kg/m^2)	3.43+/- 0.03	1.2+/- 0.03

a.

b.

c.

Fig. 2: Different Types of Crops Grown in Hydroponic Systems

a. Lettuce
b. Tomato
c. Spinach

Advantages of Hydroponics:

- Producing High-Quality Food for Higher Population
- Reduced Water Consumption
- Reduced Rate of Pest and Fungus
- Optimal Use of Area and Improved Yield
- Time Saving System

Disadvantages of Hydroponics:

- High Set-Up Cost
- Reliance on Constant Power Supply
- High Level Maintenance
- Requires Special Expertise

Conclusion - The benefits of hydroponics, including reduced growth time, year-round production, and water conservation, with commercial systems saving up to 90% of water. Particularly as global demand for food continues to rise, with further advancements in technology, reductions in costs, and greater awareness, hydroponics has the potential to play a pivotal role in meeting the world's food security and sustainability goals in the coming decades.

By embracing hydroponics, we could not only reduce our environmental footprint

but also foster a more resilient and adaptable agricultural future, capable of withstanding the impacts of climate change. As the system continues to evolve, it holds great promise for feeding the growing global population while conserving vital resources.

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