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Hydroponics: An art of soil less farming

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Abstract
By 2050, the world population is projected to reach 9.8 billion people, which raises serious concerns about the global food security. At the same time, farming land is expected to decline alarmingly and fertile soils will disintegrate due to urbanization, industrialization and climate change. Furthermore, the production of crops is hampered by various biotic and abiotic stresses, which result in great economic loss in conventional agriculture. Therefore, in order to overcome the current situation and to ensure the future, it becomes vital to develop novel technologies in combination with specialized production techniques. Hydroponics is one such technique that could be adopted to address the above-mentioned challenges. It not only restores the cultivated land, but recycles 85-90 percent of irrigation water, grows almost every vegetable successfully with high yield and nutritional value. Hence, it can be considered as a component to overcome the threat to global food security. The implementation of this technology can, however, be hastened by government action and research institute interest.

Keywords: Abiotic, hydroponics, nutrient solution, soil less culture

Introduction
Agriculture frequently uses 70 percent of the fresh water available for irrigation, rendering it unfit for drinking owing to contamination from fertilizer, pesticides and herbicides. This population could run out of drinking water if the trend continues. Numerous greenhouse gases are released into the atmosphere as a result of human activity, raising temperatures and severely lowering groundwater levels, making it impossible for farmers to feed an additional 3 billion people by 2050. Due to these issues, such as limited land and water availability, alternate methods of production must be developed by utilizing vertical agriculture (Butler and Oebker, 1962) [1].

Growing plants without the use of an inert medium, such as sand, gravel, rock wool, peat moss, or sawdust, in nutrient-rich solution is known as soilless farming. Vermiculite, perlite, coconut fibre, and other materials are used to provide mechanical support to plant. The word hydroponics comes from the Greek words' hydro, which means water, and Ponos, which means labour, or water work. It was coined by a professor, William Gericke, who described that roots suspended in nutrient-rich water can be used to grow plants. Various crops, including lettuce, cucumber, tomatoes, herbs, and other kinds of flowers, have been successfully grown using hydroponics (Asao, 2012) [2]. In comparison to a traditional cultivating system, it provides advantages including quick growth, high yield, ease of handling, effective water use, and reduced fertilizer use (Rana *et al*., 2011; Cuba *et al*., 2015) [3, 4].

In traditional farming, the soil is essential for the development of the crops. The least expensive medium for plant culture is a well-drained, pathogen-free field, however the soil is not always a perfect solution. Existing abiotic and biotic stress in soil affects agriculture and horticulture production. In addition, the productivity of agriculture is impacted by the diminishing of land brought on by rising urbanization and industrialization. To overcome these problems, hydroponics is a better alternative to produce crop without any soil medium. This review article deals with different types of hydroponic system, factors affecting it, growth medium and its qualities, merits and de-merits.

Hydroponics
Plants are grown in water without the use of soil using a simple technology called hydroponics. It works on the concept that plants don't need soil to thrive; instead, they need nutrients, light, water, carbon dioxide, and oxygen close to the root zone. Therefore, a

hydroponics system needs inert growth media, such perlite or pumice, where the nutrient-rich solutions are fed with macro- and micronutrients required for the growth of their plants (El-Kazzaz and El-Kazzaz, 2017) [5].

Types of circulating system in hydroponics
The hydroponic system can be mainly divided into two major groups such as-

1. Open system
2. Closed system

Open system
The nutrient solution in touch with the root system is only used once in an open hydroponic system. It denotes the absence of circulation or recycling of the nutrient solutions. The primary benefit of this technique is that the plant system won't be at risk of infection as a result of frequent nutrient solution changes (Jones, 2005) [6].

Closed system
In a closed system, the entire nutrient solution given to the plant roots and used for plant growth will be periodically collected and returned. Thus, this nutrient solution will undergo regular recycling. In this technique, either a liquid medium or a solid substrate, such as sawdust, rice husk, charcoal, sand, gravel, or pumice, is used to grow plants. While it is being regularly recycled, water and nutrients are being regulated. This system's primary drawback is that it is dependent on energy (Lee and Lee, 2015) [7]. Deep Water Culture (DWC), Wick System, Ebb and Flow system, Nutrient Film Technique (NFT) are some of the closed hydroponic systems.

Types of hydroponics or soilless system
Wick or passive system
It is a significantly less expensive method in which the plant system absorbs nutrients by the capillary action of the roots and fibres that carry water to plants instead of recycling the nutrient solution (Ferrarezi and Testezlaf, 2016) [8]. In areas where access to electricity is a major issue, the wick system is highly helpful because it doesn't require electricity to transfer nutrient solution. It is not suggested to utilize this approach for the long-term growing of crops; it is mostly employed for small-scale production (Lee and Lee, 2015) [7].

Nutrient Film Technique (NFT)
It is a closed hydroponic system in which the nutrient solution is recycled and pumped back to give the roots of plants a highly oxygenated nutrient solution through a channel of PVC pipe arrangements. This technique was developed by Allan cooper in 1960s (Cooper, 1988) [9]. Plants in this system absorbs the necessary nutrients and oxygen from the thin film of nutrient solution through its roots (Morgan, 2009) [10].The roots are suspended in a nutrient solution that is typically pumped from a holding tank to a sloping pipe, where the runoff solutions are collected and the cycle is repeated on a regular basis. Initially, plants are cultivated in opaque containers on inert growth material. This NFT system has recently been improved with numerous growing and supporting media.

Deep water culture (DWC) or Deep flow technique (DFT)
This technique involves cultivating plants on a floating or hanging support, such as rafts, panels, or boards, in a container that contains a nutrient solution that is about 10 to 20 cm deep (Van Os *et al*., 2002) [11]. This device uses a pump and an aeration arrangement to help plants expand their roots (Hoagland and Arnon, 1950) [33]. The plants' roots are continuously made to immerse in the nutrition solution with the right amount of aeration. To maximise growth, the levels of conductivity, pH, and oxygen must be kept under control (Jones, 2005) [6].

Drip hydroponic system
Two containers-one on top and the other at bottom, make up the drip hydroponics system. Plants are positioned on the top container in this arrangement, and nutritional solutions are positioned in the lower container. Oxygenated nutrient solutions are delivered up to drips close to the root zone using a pumping device. The used nutrient solution will be returned to the nutrient tank after filtering. Aquarium stones are placed in the nutrient solution to oxygenate the water (El-Kazzaz and El-Kazzaz, 2017) [5]. This drip hydroponics system can be used to grow plants with deep roots.

Ebb and flow system
This system is very similar to drip hydroponics system where there are two containers, in which one at the top has plants and the other at bottom has nutrient solution. This hydroponic system floods the nutrients directly to the plant roots, instead of pumping them through drippers. The top container has an overflow pipe that measures the level of the nutrient solution and distributes any excess to the bottom container. Similar to the drip hydroponics method, this system also grows plants with large root balls (Halveland, 2020) [12].

Aeroponics system
This is the most advanced type of hydroponic system. In this arrangement, plants are placed horizontally at the top of the growing container and supported by plastic or polystyrene panels. To suspend the root system, these panels are typically made of inert materials like plastic, steel coated with plastic film etc. (Maucieri *et al*., 2019) [13].
To prevent the root zone from drying out, the nutrient solutions are sprinkled repeatedly directly onto the suspended roots using a variety of nozzle types. Different nozzle types, such as ultrasonic atomization foggers, high-pressure atomization nozzles, and pressurised airless nozzles, are used to mist nutritional solutions onto the roots as they grow. A computerised system maintains and regulates the static pressure, which ranges from 60 to 90 Psi (Liu *et al*., 2018) [14]. This frequency depends on the type of crops, the period of cultivation, the stage of the plants' growth, and the time. The duration of the spray will be between 30 and 60 seconds. Due to its expensive investment and management costs, the aeroponics technique has not been widely adopted and is best suited for small horticultural crops (Rakocy, 2012) [15].

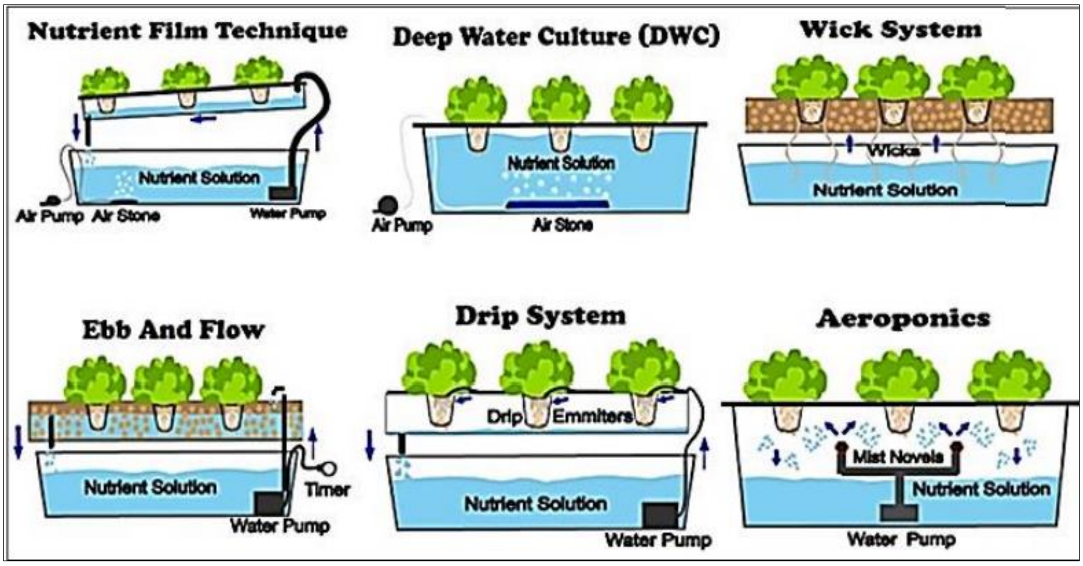

Fig 1: Types of hydroponics or soilless system

Nutrient solution for the hydroponic system

The aqueous solution of water, oxygen and nutrients are required for plant growth and development. Currently, 17 nutrients including carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, copper, zinc, manganese, molybdenum, boron, chlorine, and nickel—are thought to be necessary for their growth (Salisbury and Ross, 1992) [16]. Inorganic salts are dissolved in water to create the nutrient solution, which evaporates when ions are taken up by the plant's roots. It is ideal to monitor the solution's level of nutrients during the hours of 6:00 and 8:00 in the morning. The amount of water and nutrients needed vary each day depending on the age of the plant and the type of crop. This nutrient solution should be administered to the plant's roots only; it should not be applied to the foliage because it scorches leaves.

Table 1: List of Typical Fertilizers and Acids used in Hydroponics

Fertilizers	Nutrient percentage	Solubility g/l at 20 °C
Calcium nitrate	N: 15.5; Ca:19	1290
Potassium nitrate	N:3; K:38	316
Magnesium nitrate	N:11; Mg:9	760
Ammonium nitrate	N:35	1920
Monopotassium phosphate	P:23; K:28	226
Monopotassium phosphate	N:12; P:60	226
Potassium sulphate	K:45; S:18	365
Magnesium sulphate	Mg:10; S:13	111
Ammonium sulphate	N:21; S:24	754
Potassium chloride	K:60; Cl:48	330

Factors affecting nutrient solution in hydroponic system

The main medium for transferring nutrients to the plant system is the nutrient solution, which is affected by a number of factors namely,

1. pH
2. EC
3. Temperature
4. Oxygenation
5. Light
6. Water quality

pH and EC of nutrient solution

pH is a crucial factor in determining whether a solution is acidic or alkaline. The availability of nutrients to plants is determined by pH value. Due to the soilless system's reduced ability to act as a buffer, regular pH adjustments are therefore required (Urrestarazu, 2004) [17]. The ideal pH range for soilless culture is between 5.8 and 6.5 (Sonneveld and Voogt, 2009) [18]. Hussain *et al*. (2014) [19] reported that pH and EC are important factors required for optimum growth in leafy vegetables, tomatoes and cucumber. The total number of ions in the dissolved salts determines the osmotic pressure of the nutritional solution, which also determines the water potential (Taiz and Zeiger, 1998) [20]. The total amount of salts in a solution can be calculated indirectly by measuring electrical conductivity, which measures the osmotic pressure of the nutritional solution. Therefore, the solution's EC is a reliable sign that nutrients will be more readily available. It may vary from crop to crop, but the optimum EC range for a hydroponic system is between 1.5 and 2.5 dSm^{-1}. Due to a shift in osmotic pressure, nutritional absorption is decreased as EC level rises (Caliskan and Caliskan, 2019) [21].

It is crucial to control the pH of the nutritional solution chemically by adding acids such as nitric acid, sulphuric acid, or phosphoric acid alone or in combination. EC can also be regulated by regular water recycling (Libia *et al*., 2012) [22].

Table 2: The ideal range of EC and pH values for hydroponically grown vegetables

Crops	EC (dSm^{-1})	pH
Asparagus	1.4-1.8	6.0-6.8
Broccoli	2.8-3.5	6.0-6.8
Cabbage	2.5-3.0	6.5-7.0
Cucumber	1.7-2.0	5.0-5.5
Lettuce	1.2-1.8	6.0-7.0
Leek	1.4-1.8	6.5-7.0
Parsley	1.8-2.2	6.0-6.5
Spinach	1.8-2.3	6.0-7.0
Tomato	2.0-4.0	6.0-6.5

Temperature control of nutrient solution

The amount of oxygen the plants eat directly correlates with the temperature of the nutrient solution, but the amount of oxygen dissolved in it has an inverse correlation. The solubility of the fertilizer and the roots' ability to absorb it are both affected by temperature. Each plant species has an ideal temperature range for growth, which is maintained by incorporating a heating and cooling system into the nutrient solution (Sago *et al*., 2008) [23]. If the temperature rises above 23°–23.5 °C, plant root health will be significantly damaged. The ideal reported temperature for the nutrition solution is between 20°–22 °C (Libia *et al*., 2012) [22].

Oxygenation of nutrient solution

If the aeration is inadequate, there will be a sufficient rise in carbon dioxide in the root environment during the respiration process (Morard and Silvestre, 1996, Urrestarazu and Mazuela, 2005) [24, 17]. Based on crop demand and rising photosynthetic activity, oxygen consumption in the nutrient solution increases. Reduced dissolved oxygen below 3–4 mg/L slows root growth and change in brown colour is a sign of oxygen deficiency (Papadopoulos *et al*., 1997 and Gislerod and Adams, 1983) [25, 26].

Light

When the hydroponics systems are installed in a protected environment, light is necessary for the photosynthesis process to occur. The ability to grow plants is severely hampered when the necessary amount of sunshine is not obtained. The hydroponics system needs at least 8 to 10 hours of light every day. LED lighting uses less energy and is effective. Plants need blue spectrum with less red spectrum during the seedling and vegetative stages, and similarly, during the flowering stage, plants need red spectrum with a minimum of blue spectrum (Bayat *et al*., 2018; Kim *et al*., 2021) [27, 28].

Water quality

The major factor in the success of the soilless farming system is the quality of the water and freeness from pathogens. Verticillium wilt and Fusarium wilt are two diseases that are frequently observed in the hydroponics system (Sutton *et al*., 2000) [29]. The rapid spread of soil-borne pathogens in the re-circulating nutrient solution is one of the main drawbacks of the closed system of soilless farming because once the disease spreads in the hydroponic system, it is very difficult to control, so it is necessary to get rid of these pathogens (Ohtani *et al*., 2000) [30]. There are several disinfection methods available and some of them are ozone treatment, UV disinfection, heat treatment, slow sand filtration, electrolyzed water, hydrogen peroxide, membrane filtration, chlorination etc.

Fig 2: Cultivation of Strawberry under Hydroponics

Growth medium

In soilless culture, growth medium takes the place of soil. By giving water, nutrients, and oxygen to the solid medium, the plant's root system is supported physically. The primary purpose of the solid substrate is to provide nutrients and water to the plant without posing the risk of harmful and phytochemical compounds accumulation (Patil *et al*., 2020) [31]. The growth substrates are classified into the following types (Maucieri *et al*., 2019; George and George, 2016) [13, 32]

Substrate	Organic	Peat, coconut fibre
	Inorganic	Sand, pumice, vermiculite, perlite
	Synthetic	Polystyrene, polyurethane foam

Qualities of a good growth media

- It should not react with nutrition and be inert.
- Good drainage and aeration are required.
- Low-cost media should be used.
- It should be eco-friendly.
- It should have a minimum lifespan of three years.
- It should be recyclable.
- The pH of growth media should be neutral.

Merits and demerits of soilless farming

In comparison to conventional agriculture, it provides a suitable climate for plants and provides year-round output with less water and nutrient use. Additionally, the managed soilless farming technique lessens biotic and abiotic pressures, supporting crop growth. One of the many significant benefits of soilless farming is resource conservation and ecological sustainability.

Although it has many advantages, it also has some drawbacks, such as the need for technical expertise to operate the system, a greater initial investment, the need to monitor numerous plant growth factors (such as pH, EC, nutrient content *etc*.), and the need for energy.

Conclusion

The practice of soilless farming is spreading throughout the world to support the expanding population, and similar strategies provide both producers and consumers a variety of chances to produce high-quality fruits and vegetables enhanced with bioactive components by replacing traditional farming. Hydroponics can significantly contribute in areas with limited space and water availability because it is feasible to grow a variety of fruits and vegetables there. Additionally, it can stimulate and boost a nation's economic development by encouraging unique initiative. It also offers year – round yield due to the controlled system. In order to improve industrial soilless farming with lower investment and operational cost, low-cost soilless and other high-tech advances must be created. The implementation of this technology can, however, be hastened by government action and research institute interest.

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