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Growing Beyond Soil: An Introduction to Hydroponics for the Vegetable Production

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Abstract

Hydroponics is a soilless farming technique that is becoming increasingly popular among vegetable growers. This technique involves growing plants in nutrient-rich water solutions, providing better control over the plant's growth and the environment. There are different types of hydroponic systems, each having its unique advantages and disadvantages. Moreover, selecting the right rooting medium such as perlite, coconut coir, rock wool, sand, vermiculite, peat, *etc*. are essential for plant growth and development. By utilizing hydroponics, growers can produce more vegetables in less space, using fewer resources, and with higher yields compared to traditional soil-based farming. This article will provide an overview of hydroponics, the different types of hydroponic systems, and the rooting media used in hydroponic vegetable cultivation, highlighting the benefits of this technique for sustainable agriculture.

Keywords: Hydroponics, Inorganic growing media, Nutrient solutions, Organic growing media

Introduction

Hydroponics is a method of cultivating plant solutions that contain nutrients that can be used with or without a rooting medium such as sand, gravel, perlite, or peat moss (Sharma *et al*., 2018). The term 'hydroponics' comes from two Greek words 'hydro' and 'ponos' which means water and labour respectively (Swain *et al*., 2021). W.F. Gericke of the University of California pioneered hydroponics in the 1930s, and W.J. Shalto Duglas introduced it to India in 1946 by establishing a laboratory in the Kalimpong region of West Bengal and he published a book on hydroponics, "Hydroponics - The Bengal System" (Swain *et al*., 2021; Pant *et al*., 2018). An individual who practices hydroponics is called a 'hydroponicist'; a building or garden where hydroponics is practiced is referred to as 'hydroponicum' (Jones Jr, 2014).

Hydroponics can be used to cultivate crops such as leafy vegetables, tomatoes, cucumbers, peppers, strawberries, *etc*. (Swain *et al*., 2021). As the amount of cultivable land decreases due to population growth, urbanization, and industrialization, traditional farming methods face challenges resulting from abnormal climate patterns. Therefore, developing new and innovative techniques to sustainably produce enough food to feed the world's growing population is critical. Because of the rapidly depleting land and water resources, cultivating crops in soil-less growing media is one alternative strategy for sustainable crop production. As a result, hydroponic systems are increasingly popular worldwide.

Hydroponic Structures and Their Classification

Hydroponic systems utilize several techniques for growing plants without soil, such as the wick method, ebb and flow method, deep water culture (DWC) method, drip method, *etc*. (Swain *et al*., 2021) (Figure 1).

1. Wick System

The most basic hydroponic system is the wick system, which operates without the need for electricity, pumps, or aerators. In this method, growing medium such as coco coir, vermiculite, or perlite with a nylon wick connects plant roots to a nutrient solution reservoir and the plants absorb water and nutrients through capillary action. However, this system may not be appropriate for crops that require significant amounts of water (Swain *et al*., 2021).

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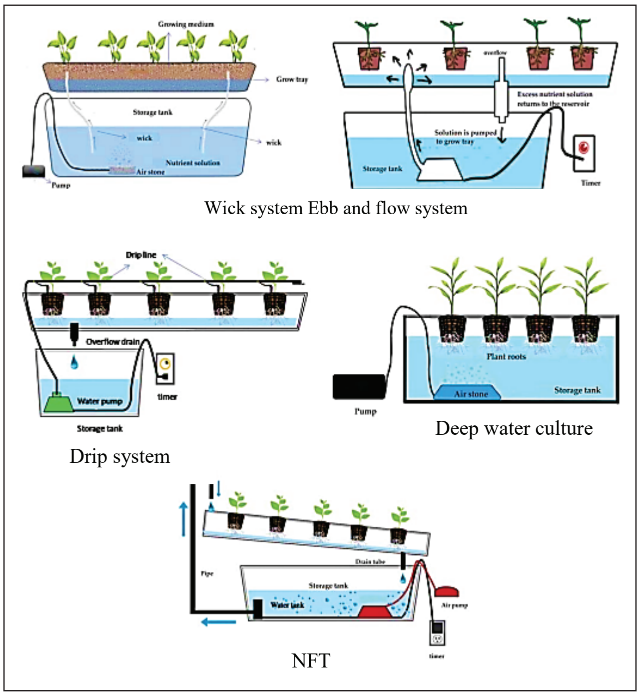

Figure 1: Classification of the hydroponic system (Sharma *et al*., 2018)

***2. Flood and Drain Method* (*Ebb and Flow*)**

The flood and drain system functions by transferring a nutrient solution from a storage tank into the growth medium, causing temporary flooding before permitting the solution to flow back into the tank. This cycle provides the plants with water and nutrients while also aerating the rooting bed through the outflow of nutrient solution. However, this changing environment may not be optimal for plant growth and can cause root rot, algae, and mold issues. To address this, a modified ebb and flow system with a filtration unit is often used (Swain *et al*., 2021).

3. Deep Water Culture Method

In the deep-water culture (DWC) method, plant roots are suspended in a nutrient solution with air supplied directly to the roots through an air stone as in a hydroponic bucket system. The plant roots are in direct contact with water, algae and mold can grow quickly in the reservoir, which can impact plant growth. Therefore, careful monitoring of oxygen levels, nutrient concentrations, salinity, and pH is necessary. This method can be particularly successful for growing vegetables such as cucumbers and tomatoes (Swain *et al*., 2021).

4. Drip Method

The drip technique is extensively utilized in both domestic and commercial hydroponic farming. In this method, a pump distributes water or nutrient solution from a reservoir to individual plant roots in suitable quantities. Typically, the plants are cultivated in a moderately absorbent growing medium, enabling a gradual drip of the nutrient solution. Numerous types of vegetable crops can be successfully grown using this approach (Swain *et al*., 2021).

5. Aeroponics

Aeroponics is a hydroponic technique that holds immense promise for the future. It involves suspending plant roots in the air and showering them with water rich in nutrients. Studies have demonstrated that consistent exposure to a fine mist produces better outcomes than intermittent misting or spraying. Typically, a small reservoir of water is retained at the bottom of the rooting vessel in most aeroponic systems, enabling a part of the roots to access a steady supply of water. This approach is highly efficient and requires minimal water, making it an appealing option for sustainable crop production. However, establishing and sustaining an aeroponic system can be challenging. One of the applications of aeroponics is herb cultivation, particularly when the roots are collected as a constituent of the plant (Swain *et al*., 2021).

***6. Nutrient Film Technique* (*NFT*)**

The method was introduced by Dr. Allen Cooper during the mid-1960s. In this method instead of a static nutrient solution, the continuous flow of a thin film of nutrient solution through channels provides the nutrients to plant roots. At the end of the channels, the nutrient solution is collected and redirected back to the tank. By carefully selecting suitable cultivars and controlling solution temperatures, spinach can be cultivated year-round in a greenhouse using Nutrient Film Technique (NFT) (Swain *et al*., 2021).

***7. Deep Flow Technique* (*DFT*)**

In DFT, the nutrient solution flows through 10 cm diameter PVC pipes to a depth of 2-3 cm and planting materials are placed on plastic pots at the bottom of the pipe, in such a way that roots have access to the nutrient solution flowing through the pipes. The pots can be arranged in one plane or in a zigzag shape (Swain *et al*., 2021).

Non-Circulating Method

1. Root Dipping Methods

This method involves growing plants in small pots with a small amount of growing medium. The lower portion of the pots is submerged in a nutrient solution, allowing some roots to be submerged while others remain in the air (Swain *et al*., 2021).

2. Capillary Action Technique

In this technique, the nutrient solution is transported to the growing medium through capillary action. It is suitable for indoor plants, flowers, and ornamental plants (Swain *et al*., 2021).

Nutrient Solution

Plants require a total of 17 essential elements to support their growth and development, with the first three being carbon, hydrogen, and oxygen. The remaining 14 essential elements include:

• *Macro-nutrients*, which include primary nutrients such as nitrogen, phosphorus, and potassium and secondary nutrients such as calcium, magnesium, and sulfur (Swain *et al*., 2021).

• *Micro-elements*, which include iron, manganese, copper, zinc, boron, chlorine, molybdenum, and nickel (Swain *et al*., 2021).

Soil-Less Growing Media

Some common examples of soil-less growing media used in hydroponics include coconut coir, peat moss, perlite, vermiculite, and rock wool. Each type of growing media has its own positives and negatives in terms of water retention, nutrient absorption, pH stability, and plant support. For example, coconut coir is a renewable and environmentally friendly option, but it can be difficult to wet initially and may require additional buffering to adjust its pH. On the other hand, rockwool is a popular choice due to its excellent water retention and support, but it can be more expensive and may cause irritation to the skin and lungs if not handled properly. Overall, the choice of growing media in hydroponics depends on factors such as the type of plants being grown, the availability and cost of different media, and the specific requirements of the hydroponic system being used.

Organic Growing Media

Coco Peat

Coco peat, a by-product of coconut husks, is widely used in soil-less crop production, such as tomatoes, eggplants, cucumbers, and capsicums. It is an environmentally friendly option, as it has no harmful impact. Moreover, its high-water holding capacity enables it to act as a buffer during high temperatures and high crop load demand, all while maintaining the proper air supply (Swain *et al*., 2021). Coco peat is also a pH-neutral medium; thus, it does not have an inherent acidic or alkaline quality, making it suitable for a wide range of plants. Another advantage of using coco peat as a growing medium is that it can be reused for multiple growing seasons with proper management. After each growing cycle, the coco peat can be sterilized and reconditioned before being used again, reducing waste and lowering overall production costs (Swain *et al*., 2021).

Rice Hulls

Rice hulls are the leftover material from rice milling. Despite being lightweight, they are effective in improving drainage. The size of the particles and resistance to decomposition are similar to sawdust (Swain *et al*., 2021). Using rice hulls as a growing medium doesn't lead to nitrogen depletion. They can be used as an organic material for growing plants, especially in hydroponics, as they decompose slowly like coco coir. Rice hulls can be fresh, aged, composted, parboiled, or carbonized. Fresh rice hulls should be avoided in hydroponic systems because of the possibility of contamination. Parboiled rice hulls (PRH) are obtained by milling rice hulls followed by drying which helps to kill microorganisms and makes the product sterile and clean (Swain *et al*., 2021).

Peat

Peat is a widely used growing medium that is made from decomposed plant matter found in bogs. It is known for its ability to hold water, which is beneficial for plants that require consistent moisture levels. However, peat is naturally acidic, with a pH of approximately 4, which can be unsuitable for certain plants. To address this, lime can be added to raise the pH and neutralize the acidity. Additionally, perlite can be mixed with peat to enhance drainage and prevent the medium from becoming compacted.

Inorganic Growing Media

Perlite

Perlite is a volcanic material that has a grey-white color and a neutral pH. When it is heated to about 1600-1700 ºF, it expands up to twenty times its original volume due to the presence of 2-6% combined water in the rock, causing it to pop like popcorn. The surface of each particle has numerous small cavities, providing a vast surface area that helps hold moisture and nutrients, making them available to plant roots (Swain *et al*., 2021). This also creates air passages that allow for optimal aeration and drainage.

Perlite is a great growing medium because it is sterile and free of any diseases, seeds, or insects. The manufacturing process uses high temperatures to eliminate potential contaminants. Perlite is lightweight and easy to handle, making it a perfect choice for container gardening. It is also reusable and can be sterilized and reconditioned for multiple growing cycles with proper management (Swain *et al*., 2021).

Rockwool

Rockwool is a type of growing medium made by melting a combination of basalt and limestone at a high temperature of 1600 °C, and then spinning the molten mixture into thin fibres with a diameter of only 0.005 mm. The fibres are then treated with certain additives, such as a resin, to hold them together and pressed into slabs of varying sizes (Swain *et al*., 2021).

This material can be used as a growing medium for potted plants, similar to peat, and can also be mixed with other media to improve drainage and aeration. Rockwool has a high water-holding capacity, making it a great choice for plants that need consistent moisture levels. Additionally, it is sterile and free from diseases, making it a reliable option for plant growth (Swain *et al*., 2021).

Sand

Sand is a growing medium that is frequently used in hydroponics. Its small particle size enables it to hold moisture without draining too quickly. It can also be combined with other media like perlite, vermiculite, or coco coir to increase moisture retention and root ventilation (Swain *et al*., 2021).

Vermiculite

Vermiculite is a type of micaceous mineral that is created by heating expanded, plate-like particles at around 745 °C. The resulting particles have an exceptional capacity for holding water and help to improve aeration and drainage. Vermiculite can exchange and buffer nutrients, making it a popular choice for container gardening. However, it is less durable compared to sand and perlite (Swain *et al*., 2021).

Conclusion

Hydroponics is a highly efficient and sustainable method of growing crops that can be practiced in any climate or location. By eliminating the need for soil, hydroponics saves water, reduces the use of pesticides and herbicides, and yields higher crop yields with faster growth rates. In addition, hydroponics allows for year-round crop production and reduces the need for transportation and storage, which further reduces costs and carbon emissions.

It has numerous benefits, including its potential to provide food security in urban areas where traditional agriculture is not feasible. Hydroponic systems can be set up in small spaces such as balconies, rooftops, and basements, making it an ideal solution for urban agriculture. It also allows for the production of fresh, locally grown produce, which reduces the carbon footprint of food transportation.

Hydroponic systems are ideal for growing crops that are highly sensitive to environmental conditions, such as temperature, humidity, and light. With the development of new technology and innovative growing techniques, hydroponics is becoming increasingly popular in the agricultural industry and is expected to play a significant role in sustainable food production in the future.

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