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A comprehensive review on soil-less culture

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Abstract
With the increasing globalization, soil-based agriculture is facing significant, such as a reduction in land availability. Additionally, the soilless culture has been introduced as a result of the challenges caused by climate change, the fast rise of urbanization and industry, and other factors. In the current environment, soilless cultivation is becoming increasingly important to meet these issues. When compared to soil-based farming, the quality of the yield from soilless cultivation is significantly higher. Soilless agriculture is a new, practice to enhance the growth of various vegetable crops. It is a method for growing vegetables without the need for soil as a rooting medium, in which the roots are supplied with irrigation water and inorganic nutrients. Hydroponics and Aeroponics are examples of soilless farming cultivation. Crops are grown using hydroponic and aeroponic techniques, which supply nutrient solutions directly to the roots. These conditions provide more balanced and effective absorption of nutrient solution. In both systems, crop harvesting is less complicated. Both hydroponics and aeroponics are used commercially to grow a variety of food crops, including potatoes, yams, tomatoes, lettuce, and green vegetables.

Keywords: Comprehensive, soil-less, culture, vegetable, crops

Introduction
The population of the Earth is expected to rise by 2-3 billion people by the year 2050 [1]. Due to poor farm management and an unstable environment, it was discovered that feeding them using conventional agricultural methods would be impossible [2]. The management of resource usage must be improved to prioritize the consumption of food by humans as a result of high-priority issues [3]. Nowadays, irrigation is more common in agricultural practices, which depletes groundwater supplies and has a significant influence on soil. The loss of agricultural area and population increase brought by rapid urbanization and industrialization caused a reduction in the food shortage. Soilless farming is a solution that can solve these issues. The methods of soilless cultivating plants include hydroponics and aeroponics [4]. Around the world, numerous farms have adopted hydroponic and aeroponic crop cultures for research and agricultural production. The technique has made significant improvements over the past 50 years and may now be the most intense way of crop production used in the modern agricultural sector [5]. When compared to field soil, a soilless culture can produce crops with similar growth and productivity [6]. The most recent effective strategy to enhance cultivation tactics and boost productivity is soilless agriculture [8].
Growing food hydroponically could be the first step towards a more sustainable way of living [13]. In hydroponics, crops may be grown in any growing medium by supplying the nutrient solution [19]. A hydroponics plantation is a modern type of agriculture that gives the choice of having complete control over how the nutrients are distributed and delivered to the plants. The artwork on the wall of the Egyptian temple Dier El Bahari, which is more than four thousand years old, is the first known example of hydroponics [18]. The use of hydroponics in commercial agriculture decreases the amount of land needed for crops by 75%. Hydroponics techniques are used to efficiently and effectively to regulate the water and nutrients that are present in the system while maintaining correct environmental control. Hydroponics may be used to cultivate commercial crops, including green vegetables, tomatoes, cucumbers, peppers, strawberries, and many more [17].
Aeroponic is the branch of hydroponics that involves the spraying of nutrient solutions on plant roots that are suspended in a container [5]. Without the need for soil, aeroponic cultivation involves growing plants in a condition of mist environment [4]. A system for passing a nutrient solution from a nutrient tank is made up of pipes, spray nozzles, a pump, and a timer for misting inside the container [47].

The soilless culture method known as aeroponics is an optional tool for cultivating crops that are maintained under controlled growth environments like greenhouses [3]. The traditional field farming technique has several disadvantages that demand the usage of aeroponic greenhouses [32]. In water consumption, 99% of the water used in aeroponics is recycled. Since no pesticides or fertilizers are used, the fruits and vegetables produced are fresh and don't require washing before consumption. When it comes to spraying the nutrient solution to the plant roots, the aeroponic system has more benefits than the hydroponic system [27].

Soil-less culture

Water culture and substrate culture are two types of soilless culture, which is the practice of growing plants without using soil as a rooting medium [9]. When compared to soil-based farming, the quality of the yield from soilless cultivation is significantly higher [8]. There is no possibility of a weed infestation, pest or disease attack, or soil-borne insects. In soilless cultivation, nutrients are delivered precisely to plant roots, promoting faster plant growth [10]. When compared to field soil, a soilless culture can meet crucial crop growth demands while producing equivalent growth and yield production [6]. Growing media comes in a variety of forms, including coco-coir, hydro tons, perlite, vermiculite, peat moss, sawdust, and rock wool. Instead of soil, it uses an inert and non-organic substance as a soilless culture which acts as a medium [7]. It has a lot of different qualities, including porosity and an excellent ability to hold water. The amount of water needed for irrigation in soilless culture is precisely managed, i.e., 50% less water is utilized than in traditional soil-based vegetable growing [12]. The soilless culture system consists of a water culture system that only uses nutrient solutions to cultivate plants on porous growing media, resulting in a matrix that can hold both air and water in the proper proportions for plant development [13]. Because of its flexibility and ability to maintain suitable environments, soilless agriculture is particularly beneficial in metropolitan environments [14].

Hydroponics

The technique of hydroponics involves growing plants in a nutrient solution with or without the use of an inert medium to provide them support like gravel, vermiculite, rock wool, etc. [34]. The two systems of hydroponics are the Active system and the Passive system. Plant roots remain in contact with the nutrient solution in a passive system, and the substrate provides support for the plants. An example of a passive system is the Wick system. In an active system, the nutrient solution is supplied to the plant roots using motor pumps, and the excess solution is drained off using a gravity system so that it may be recycled and utilized again. NFT, Deep Water Culture, Ebb and Flow, Drip System, Aeroponic, and Dutch Bucket Method are examples of active system types [16]. The researchers claim that the active system is more effective than the passive system [22]. When compared to soil-based agriculture, hydroponics demonstrates greater benefits of soilless plant cultivation since it uses zero pesticides and herbicides, which reduces pollution in the environment [17]. In remote areas with limited access to proper technology, hydroponics has shown its efficacy on a wide scale [18]. The main benefit of hydroponics over soil-based farming is the saving of water. Comparing the plant grown on the soil, the plant needs 50% less water in hydroponics [19]. The fastest-growing area of agriculture, hydroponics, is expected to take over as the primary method of producing food in a few years [20]. The health and strength of the crop in hydroponics are greatly impacted by the pH and E.C. Essential minerals and micronutrients won't be accessible for plant absorption if the pH and E.C. are above the correct range [21]. When plants are kept in the same solution for more than a week, the dissolved oxygen, pH, and E.C. of the nutritional solution drastically change, which has an impact on plant development [23]. By reusing nutrients from agricultural waste that are not edible, crop production in the hydroponic system has also demonstrated satisfactory results [24]. Since the nutrient solutions used in hydroponic systems are based on chemical fertilizer, it is possible to produce vegetables using an organic nutrient solution [25]. Because it is made from organic ingredients that are acceptable for human consumption, liquid organic fertilizer may be used as a substitute for nutrients in hydroponic systems that do not utilize chemicals [26]. A hydroponic system may be used to cultivate a variety of plants, including vegetables, fruits, flowers, and medicinal crops [35].

Aeroponics

The technique employed in modern agriculture to grow plants without soil is called aeroponics [1]. The roots of the plants are misted with a nutrient solution in an aeroponic system by the atomization of the nozzle.

Every two to three minutes, a nutrient solution is misted. Crops may be grown in a soil-free media in an aeroponic system without natural light by using artificial light. A growing chamber, net pots, an irrigation system, a motor, a digital timer, and a nutrient tank are part of the aeroponic system. This method allows both the indoor and rooftop cultivation of fresh, nutritious fruits and vegetables [27]. If a plant in an aeroponic system is under attack by pests or diseases, it may be readily transplanted. The pH and nutrient density ratios in an aeroponics system must be constantly monitored. The aeroponics system needs extra management and attention to detail to create a partially to completely closed environment [28]. The plants cultivated in the aeroponics growth chamber ensure that the roots receive the most aeration, which causes the plants to develop rapidly. This method increases the amount of oxygen available at the roots to create a favorable environment for plant growth [29]. Growers in developed nations may have easier access to quality seed due to the aeroponics systems which as the ability to boost revenue and lower production costs [30]. The plant may reach a height of 15 to 30 cm within this system. The aeroponic system has the ability to cultivate plants during the off-season. Several different herbs may be cultivated in an aeroponic system using a single fertilizer solution [31]. Aeroponics is perfectly suited for the research of water stress and root morphology because it allows for exact control of the moisture content in the root zone and the quantity of water given [32]. Techniques for propagation, seed germination, seed potato production, tomato production, leaf crops, and microgreens have all been commercially successful using aeroponics [33].

History of Aeroponics system

In order to make it easier to examine roots, plants can be grown in water vapor, according to W. Carter's 1942 study on the subject. L. J. Klotz made the initial discovery of the vapor-misted citrus plant in 1944 while doing research on

citrus and avocado root infections. G. F. Trowel planted apple trees in a spray culture in 1952 and examined the roots. The air-growing method used in spray culture was given the term "Aeroponics" fifteen years after studies by Carter (1942) and Went (1957) [2].

Technical setup of Aeroponic system

In an aeroponic system, plant roots are suspended in an enclosed environment in a growing chamber. In order to help maintain ideal humidity and darkness in the chamber, the growing chamber is lined with a black poly sheet. In aeroponics, the nutrient solution is misted onto plant roots by nozzles that are fitted into uniformly spaced PVC pipes. The motor that pumps the nutrient-rich solution at high pressure is connected to the pipeline. A digital timer is connected to the pump to control the timing of the fertilizer spraying during a specific period. Depending on the size of the aeroponics unit system and the grown plant, the distance between the nozzle and their pressure, the spacing of net pots on the growth chambers, the pump capacity of the motor, the nutrient spraying, and the interval between the two consecutive spraying interval may vary. The growth chamber's pipe is connected to a nutrient tank that recycles the nutrient solution which drips from the suspended roots in the growth chamber [15]. The root zone environment, including temperature, nutrient level, pH, humidity, misting frequency and duration, and oxygen availability, may be completely controlled by the growing chamber and misting system [5]. Additional sensors can be used to monitor the duration of time and frequency at which a nozzle is "ON" and "OFF" in order to regulate the amount of nutrients that are delivered [35]. More than a hydroponic system, an aeroponic system can vary in both shape and size. Although they might be vertical or horizontal, they all frequently use the same kind of mist delivery method [36]. The availability and absorption of nutrients by roots will be reduced if there is a significant time distance between misting sprayers and the roots [37].

Working of the Aeroponic system

A nutrient solution is continuously or periodically misted onto the roots in an aeroponics system [47]. The nutrient solution is delivered via a motor through pipes connected to the irrigation system inside the growth chamber [38]. The type of crop and amount of water needed will determine the size of the nutrient tank. In the aeroponics system, the substrate is used to grow the plants in net pots. In the growing chamber, the plant roots are hanging [39]. The nutrient solution is misted over the roots of the plants and then drips back into the nutrient reservoir where it may be used again [4]. For optimum plant development, the temperature and humidity within the growing chamber can be adjusted [40]. To stop the growth of the algae, a black sheet is placed over the growing chamber to prevent sunlight [41]. Due to a clean atmosphere and there is availability of enough oxygen, plant roots grow quickly in the growth chamber, which enhances the yield of plants in the aeroponics system [48].

Droplet size for Aeroponics system

For the majority of plant species, a droplet size between 20 and 100 microns is appropriate. Within this range, the tiny droplets saturate the air, maintaining the growth chamber's humidity levels. Larger droplets between 50 and 100 microns in diameter make the most contact with the roots. Spray droplets smaller than 30 microns have a tendency to remain suspended as a fog. Any droplets larger than 100 microns usually fall to the before coming into contact with any roots. Less oxygen is accessible to the root system when the water droplets are too big [3]. The aeroponic system's ability to accurately control the nutrient solution's droplet size can enhance the conditions that encourage plant roots to develop successfully [42].

Nutrient solution used for the soilless culture

The nutrient solution is mostly made up of inorganic ions from soluble salts which are plants' essential elements. Eventually, organic substances like iron chelates could be present in the nutrients. Currently, 17 elements C, H, O2, N, P, K, Ca, Mg, S, Fe, Cu, Zn, Mo, Mn, B, Cl, and Ni are taken into consideration for the majority of plants. The necessary components are derived from the nutrient solution, with the exception of carbon and oxygen, which are found in the atmosphere [43]. It is possible that hydroponic and aeroponic growing use similar mechanisms for fertilizer and water absorption [44]. The amount and quality of produce will grow quicker and better with a constant supply of nutrients [45].

Conclusion

Future industrialization is expected to increase drastically as soil conditions for cultivation become more challenging. Since metropolitan areas are expanding daily, adopting a soilless culture is the suitable way to increase plant productivity and quantity. Both hydroponics and aeroponics have the capacity to produce high-quality and large-scale yields. Additionally, it can significantly boost per capita access and consumption of fruits and vegetables. In comparison to conventional farming, hydroponics and aeroponics systems minimize water losses and improve water usage efficiency. By adopting the advanced new technologies and techniques it can be next-generation vegetable cultivation science.

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