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Soil-Less Culture (Hydroponics) – A Review

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Abstract

Soil-based agriculture faces major challenges with the advent of globalization, such as reduced land availability per capita. Apart from this, due to the rapid growth of urbanization and industries and the threats of climate change and its negative impact associated with this, land tenure will have to deal with challenging threats. Under such conditions, shortly it will be difficult to complete the requirement ofthe entire population using products from the land system. Naturally, a landless culture is becoming increasingly important in the current context, to address these challenges. Soilless culture is the growth of plants without soil that mimic soil gardens through a wide variety of growing media such as inorganic substances, organic substances, and synthetic substances. Landless culture is a fast-growing agricultural sector and could be a catalyst for future food production. The industry is expected to grow significantly in the future, as soil growth conditions become more difficult. The use of artificial soil systems using substrates can lead to better and more efficient use of water and fertilizer and reduce the use of chemicals to control pests and diseases. Plants are planted withthe culture is a consistently high quality, high yield, fast yield, and high nutrient content. But in the case of less developed countries, there is a lack of cultural awareness and poor distribution of their existing technologies. To increase soil-free culture at the global level, it is very important to provide scientifically proven technology to farmers and raise awareness.
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Introduction

Soil is often found mainly in plant areas. Provides anchorage, nutrients, air, water, etc. in plant growth (Ellis *et al.*, 1974). However, the soil puts serious restrictions on plant growth, sometimes. Among them, the presence of pathogens and pests, improper soil reaction, poor soil compaction, poor drainage, erosion and so on. In addition, open field agriculture is complex as it involves, a large area, large staff and a large volume of water. In many urban and industrial areas, the soil is less available for crop cultivation, or in some areas, there is a lack of fertile cultivated areas due to their poor natural environment or environment (Beibel, 1960). Another major problem is hiring workers regularly to open up farmland (Butler &Oebker, 2006). Under such conditions, a soilless culture can be successfully introduced (Butler &Oebker, 2006). Soilless culture is a method of planting plants in a subsoil environment with their roots immersed in nutrient solution (Maharana&Koul, 2004). Landless planting systems can be classified according to the strategies used. It provides fresh vegetables in countries with limited agricultural land and small, densely populated countries. It would be helpful to provide enough fresh vegetables for indigenous peoples and tourists in countries where tourism plays an important role in their economy. Typical examples of these regions are the West Indies and Hawaii, each with large tourism industry and a small vegetable garden (Resh, 1993). In soilless land, other cultural practices such as soil cultivation and weed control are avoided, and land suitable for soil cultivation can be used (Polycarpou*et al.*, 2005). Plants grown by hydroponics were consistently high quality, high yield, fast yield, and high nutrient content. The key elements of producing a better soil-free culture are illustrated in Figure 1. Landless culture can be used to grow certain popular local crops using food safety standards and values (Paul, 2000). This plan will also help address the challenges of climate change and also assist in managing the production system to make better use of natural resources and reduce malnutrition (Butler &Oebker, 2006). A soilless culture can provide important crop growth needs with equal growth and yield results compared to field soil. Soil plants can be grown with their roots in a solution of mineral nutrients only or an inactive environment. When the nutrients in the soil dissolve in the water, the roots of the plants can absorb them. When the necessary mineral nutrients are added to the plant's water artificially, the soil is no longer needed for the plant to grow. The simplest and oldest form of soilless culture is a container of water in which inorganic chemicals are dissolved to provide the nutrients that plants need. Various changes to the culture of the clean solution have taken place in the past. The retention of nutrients and water can be further enhanced by the use of sphagnum peat, vermiculite, or chip bark. These are the most commonly used materials, but others such as rice husks, bagasse (sugar cane), sedge peat, and sawdust are sometimes used as nutrients in soilless compounds. Grass bears are used for growing in England and Canada and rock-wool (porous stone fiber) is used in Europe.

History

Landless culture is considered a modern practice, but the plants that grow on the surface of the soil are tried at different times over the years. The murals found in the temple of DeirelBahari appear to be the first written case of pottery (Naville, 1913). They transfer mature trees from native lands to the royal palace and grow into a soilless culture, where local soil is not suitable for a particular crop. Many ancient civilizations used a landless culture in their agricultural products. Egyptian Hieroglyphics records date back to a few hundred years B.C. indicating the growth of plants in water. The Aztecs used floating gardens to cultivate certain crops. The hanging Babylonian garden is also a fine example of landless culture. The first published work on soilless culture was the book Sylva Sylvarum published in 1627 by Francis Bacon, after which water culture became a popular method of research. In 1699, John Woodward published his water experiments with spearmint. In 1859-65, the discovery of German botanists Julius von Sachs and Wilhelm Knop, led to the development of a soil-planting system. It soon became a common method of research and teaching method and is still widely used today and is now considered a form of hydroponics. In 1929, William Frederick Gerick Berkeley publicly declared that the solution culture was used to produce agricultural crops. Gerick planted tomato vines 25 meters high in mineral solutions instead of soil. He also coined the term hydroponics in 1937 to understand the culture of plants in water (from the Greek hydro-, "water", and ponos, "work"). One of the first successes of hydroponics took place on Wake Island, where hydroponics was used to grow passenger vegetables. In the 1960's, Allen Cooper of England invented the film Nutrient. The Land Pavilion at the EPCOT Center for Walt Disney World opened in 1982 and showcases a variety of hydroponic systems.In India, Hydroponics was introduced in 1946 by an English scientist, W. J. ShaltoDuglas also established a laboratory in the Kalimpong area, West Bengal. He authored a book on Hydroponics, called Hydroponics The Bengal System. During the 1980s, several automated hydroponics and computer farms were established worldwide. In recent decades, NASA has conducted extensive hydroponic research on the Controlled Ecological Life Support System or CELSS. Hydroponics aimed at happening on Mars use LED light to grow in a spectrum of different colors and at very low temperatures.

Different soil-less medium

- **Perlite**- The most common type of media used in systems with soil-free culture containers is perlite (Boodley& Sheldrake, 1977). Perlite granules are very simple and come from the silicone minerals that form volcanoes. The facility is available to retailers in small to large bags to be added to growing areas to increase water flow and ventilation.
- **Coconut Coir-** Known by various trade names such as Ultrabeat, Cocopeat, and Coco-tek. It combines water retention of vermiculite with air retention of perlite. It is a complete source of organic matter made from activated coconut husks.
- **Vermiculite-** This compound contains both potassium and magnesium. It holds a lot of water and helps to drain water and get air into the soil, although it is slightly stronger than other materials, such as sand and perlite.
- **Peat Moss-** Peat moss retains moisture in growing areas.
- **Sphagnum Moss-** It is to be widely used because it will retain moisture and nutrients by not allowing water to flow.
- **Sand-** Sand is useful as a planting ground for plants that need dry, open soil. A lot of water will drain the flow and can be immersed in the sand as it would in the mud.

Separation of Soil Culture

The term landless culture originally meant a culture of resolving elements without supporting. However, a plant that grows in solid sources to hold on using a nutrient solution is included. This method is called an aggregate system. Hydroponics systems are further classified as open (*i.e.*, when a nutrient solution is introduced into the plant roots, it is no longer used) or closed (*i.e.*, the remaining solution is found, replenished and recycled). Current hydroponics systems of cultivation can be classified according to the techniques employed. A hydroponic technique refers to the method of applying the nutrient solution to the plant roots.

The various soilless culture systems for crop production used in some countries are as follows

A). Liquid or solution culture:-

1. Circulating Methods (Closed System):- The nutrient solution is pumped through the plant root system and excess solution is collected, replenished and reused.

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a) N.F.T. (Nutrient Film Technique):- NFT is a true hydroponics system where the plant roots are directly exposed to nutrient solutions. N.F.T. systems have a constant flow of nutrient solution so no timer is required for the submersible pump. The nutrient solution is pumped into the growing tray (usually a tube) and flows over the roots of the plants, and then drains back into the reservoir. There is usually no growing medium used other than air, which saves the expense of replacing the growing medium after every crop. Normally the plant is supported in a small plastic basket with the roots dangling into the nutrient solution. N.F.T. systems are very susceptible to power outages and pump failures. The roots dry out very rapidly when the flow of nutrient solution is interrupted.

b) Deep flow technique (DFT)/ pipe system:- In this technique, 2-3 cm deep nutrient solution flows through 10 cm diameter PVC pipes to which plastic net pots with plants are fitted. The plastic pots contain planting materials and their bottoms touch the nutrient solution that flows in the pipes. Plants are established in plastic net pots and fixed to the holes made in the PVC pipes. Old coir dust or carbonized rice husk or a mixture of both may be used as planting material to fill the net pots. A small piece of net is placed as a lining in the net pots to prevent the planting material from falling into the nutrient solution. When the recycled solution falls into the solution in the stock tank, the nutrient solution gets aerated. The PVC pipes have a slope of the drop of 1 in 30-40 to facilitate the flow of nutrient solution. Painting the PVC pipes white will help reduce the heating up of nutrient solutions.

2. Non-Circulating Methods (Open System):- The nutrient solution is not circulated but used only once. When its nutrient concentration decreases or pH or EC changes, it is replaced. This system is of following types:

a) Root dipping technique:-In this technique, plants are grown in small pots filled with little growing medium. The pots are placed in such a way that the lower 2–3 cm of the pots are submerged in the nutrient solution. Some roots are dipped in the solution while others hang in the air the solution for nutrient and air absorption, respectively. This low-tech growing method is inexpensive to construct and needs little maintenance. Importantly, this technique does not require expensive items such as electricity, water pump, channels, *etc*.

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b) Floating Technique:-This is similar to the box method but shallow containers (10 cm deep) can be used. Plants established in small pots are fixed to a Styrofoam sheet or any other light plate and allowed to float on the nutrient solution filled in the container and the solution is artificially aerated.

c) Capillary Action Technique:-Planting pots of different sizes and shapes with holes at the bottom are used. The pots are filled pots with an inert medium and seedlings/seeds are planted in an inert medium. These pots are placed in shallow containers filled with nutrient solutions. Nutrient solution reaches inert medium by capillary action. Aeration is very important in this technique. Therefore, old coir dust mixed with sand or gravel can be used. This technique is suitable for ornamental, flower and indoor plants.

B). Solid media culture or aggregate system:-The media material selected must be flexible, friable, with water and air holding capacity and can be drained easily. In addition, it must be free of toxic substances, pests, disease-causing microorganisms, nematodes, etc. The medium used must be thoroughly sterilized before use. The following techniques involving inert solid media can be practiced using locally available materials.

a) Hanging bag technique (Open system):- About 1 m long cylinder-shaped, white (interior black) UV treated, thick polythene bags, filled with sterilized coconut fiber are used. These bags are sealed at the bottom end and tied to a small PVC pipe at the top. These bags are suspended vertically from overhead support above a nutrient solution-collecting channel. Therefore, this technique is also known as 'verti-grow technique'. Seedlings or other planting materials established in net pots are squeezed into holes on the sides of the hanging bags. The nutrient solution is pumped to the top of each hanging bag through a micro-sprinkler attached inside the hanging bags at the top. This micro-sprinkler evenly distributes the nutrient solution inside the hanging bag. Nutrient solution drips down wetting the coconut fiber and plant roots.The excess solution gets collected in the channel below through holes made at the bottom of the hanging bags and flows back to the nutrient solution stock tank. This system can be established in open spaces or protected structures. In protected structures, the hanging bags in the rows and amongst the rows must be spaced in such a way that adequate sunlight falls on the bags in the inner rows. This system is suitable for leafy vegetables, strawberries, and small flower plants. Black color tubes will have to be used for nutrient solution delivery to prevent mould growth inside.

b) Grow bag technique:-In this technique 1 – 1.5 m long white (inside black), UV resistant, polythene bags filled with old, sterilized coir-dust are used. These bags are about 6 cm in height and 18 cm wide. These bags are placed end to end horizontally in rows on the floor with walking space in between. The bags may be placed in paired rows depending on the crop to grow. Small holes are made on the upper surface of the bags and squeeze seedlings or other planting materials established in net pots into the coir dust. 2-3 plants can be established per bag. Two small slits low on each side of the bags are present for drainage or leaching. Fertigation with a black capillary tube leading from the main supply line to each plant is practiced. The entire floor is covered with white UV-resistant polythene before placing the bags. This white polythene reflects the sunlight to the plants. It also reduces the relative humidity between plants and the incidence of fungal diseases

c) Trench or trough technique:-In this open system, plants are grown in narrow trenches in the ground or above ground troughs constructed with bricks or concrete blocks. Both trenches and troughs are lined with waterproof material (thick UV-resistant polythene sheets in two layers) to separate the growing media from the rest of the ground. The width of the trench or trough can be decided depending on the ease of operation. Wider trenches or troughs will permit two rows of plants. The depth varies depending on the plants to grow and a minimum of 30 cm may be necessary. Old coir dust, sand or gravel, peat, vermiculite, perlite, old sawdust or a mixture of these materials can be used as the media for this culture. The nutrient solution and water supplied through a drip irrigation system or manual application are also possible subjects to labor availability. A well-perforated pipe of 2.5 cm diameter may be placed at the bottom of the trough or trench to drain out excess nutrient solution. Tall growing vine plants (cucumber, tomato, *etc*.) need additional support to withstand the weight of the fruits.

d) Pot technique:-The pot technique is similar to trench or trough culture but growing media is filled in clay or plastic pots. The volume of the container and growing media depend on the crop growth requirements. The volume ranges generally from 01 to 10 liters. Growing media, nutrient solution supply, providing support to plants, *etc.* is similar to that of a trough or trench culture.

C). Aeroponics:-Aeroponic is a method of growing plants where they are anchored in holes in Styrofoam panels and their roots are suspended in the air beneath the panel. The panels compose a sealed box to prevent light penetration to encourage root growth and prevent algae growth. The nutrient solution is sprayed in fine mist form to the roots. Misting is done for a few seconds every 2 – 3 minutes. This is sufficient to keep roots moist and nutrient solution aerated. The plants obtain nutrients and water from the solution film that adheres to the roots. The aeroponic culture is usually practiced in protected structures and is suitable for low-leafy vegetables like lettuce, spinach, etc. The principal advantage of this technique is the maximum utilization of space. In this technique, twice as many plants may be accommodated per unit floor area as in other systems. Another potential application of this technique is in the production of plants free of soil particles from cuttings for exports. The aeroponic system is probably the most high-tech type of hydroponic gardening. Like the N.F.T. system above the growing medium is primarily air. The roots hang in the air and are misted with nutrient solution. Because the roots are exposed to the air like the N.F.T. system, the roots will dry out rapidly if the misting cycles are interrupted.

Nutrient Solution for Soilless Culture

Plants require 17 essential elements for their growth and development. Without these nutrients, plants cannot complete their life cycles and their roles in plant growth cannot be replaced by any other elements. All essential nutrients are supplied to soilless culture plants in the form of nutrient solution, which consists of fertilizers salts dissolved in water. The soilless culture grower must have a good knowledge of the plant nutrients, as management of plant nutrition through management of the nutrient solution is the key to success in soilless culture gardening. The soilless culture methods enable growers to control the availability of essential elements by adjusting or changing the nutrient solution to suit the plant growth stage and to provide them in balanced amounts. As the nutrients are present in ionic forms in the nutrient solution and also, do not need to search or compete for available nutrients as they do in soil, soilless culture plants reach maturity much sooner. Optimization of plant nutrition is easily achieved in soilless culture than in soil.

Nutrient Solution Management

While optimum nutrition is easy to achieve in soilless culture, incorrect management of the nutrient solution can damage the plants and lead to complete failure. The success or failure of a soilless culture garden, therefore, depends primarily on the strict nutrient management practicess.Carefully manipulating the nutrient solution pH level, temperature and electrical conductivity and replacing the solution whenever necessary, will lead to a successful soilless culture garden.

pH Level

The pH is a measure of acidity or alkalinity on a scale of 1 to 14. In a nutrient solution, pH determines the availability of essential plant elements. The optimum pH range for soilless culture nutrient solution is between 5.8 and 6.5. The further the pH of a nutrient solution from recommended pH range, the greater the odds against the success. Nutrient deficiencies will become apparent or toxicity symptoms will develop if the pH is higher or lower than the recommended range for individual crops.

Electrical Conductivity (EC)

The electrical conductivity indicates the strength of the nutrient solution, as measured by an EC meter. The unit for measuring EC is dS/m. A limitation of EC is that it indicates only the total concentration of the solution and not the individual nutrient components. The ideal EC range for hydroponics is between 1.5 and 2.5 dS/m. Higher EC will prevent nutrient absorption due to osmotic pressure and lower EC severely affects plant health and yield. When plants take up nutrients and water from the solution, the total salt concentration, *i.e.*, the EC of the solution changes. If the EC is higher than the recommended range, fresh water must be added to reduce it. If it is lower, add nutrients to raise it.

Advantages of Soil-Less Culture

There are many advantages of growing plants under soilless culture over soil-based culture (Savvas, 2004). Soilless culture offers opportunities to provide optimal conditions for plant growth and therefore, higher yields can be obtained compared to open-field agriculture, gardening is clean and extremely easy, requiring very little effort (Silberbush& Ben-Asher, 2001). Soilless culture averages compared with ordinary soil yields are given in Table 9. Soilless culture or soil-less culture offers a means of control over soil-borne diseases and pests, which is especially desirable in the tropics where the life cycles of these organisms continue uninterrupted and so does the threat of infestation. It is also effective for the regions of the World with having scarcity of arable or fertile land for agriculture (Sonneveld, 2000). It reduces the cost and time taken for various tasks which are avoided in the soilless culture of cultivation. It offers a clean working environment and thus hiring labour is easy.

Limitations of Soil-Less Culture

Despite many advantages, soilless culture has some limitations (Sonneveld, 2000). Application on a commercial scale requires technical knowledge and higher initial capital expenditure. This will be further high if the soilless culture is combined with controlled environment agriculture (Sonneveld, 2000). A high degree of management skills is necessary for solution preparation, maintenance of pH and EC, nutrient deficiency judgment and correction, ensuring aeration; maintenance of favourable conditions inside protected structures, etc. Great care is required concerning plant health control. Finally, energy inputs are necessary to run the system (Van Os*et al.*, 2002). Considering the significantly high cost, the soil-less culture is limited to high-value crops in the area of cultivation.

Conclusion

Soilless culture is rapidly gaining momentum and popularity and is the fastest-growing sector of agriculture. Soilless culture is more popular and accepted in some countries, especially in the commercial production of vegetables and is quickly catching on in other parts of the world. Soilless culture could well dominate food production in the future. As population increases and arable land declines due to poor land management, people will turn to new technologies like the soilless culture of crop production. There has already been a great deal of buzz throughout the scientific community for the potential to use soilless culture in third world countries, where water supplies are limited. Though the upfront capital costs of setting up soilless culture are currently a barrier in the long run, as with all technology, costs will decline, making this option much more feasible. In developing countries, this technique could not get popular among gardeners to date. The main bottleneck behind this is the lack of standard knowledge and poor dissemination of its available technologies. Although, more literature on soilless culture is available but standard, precise and authentic information's still lacking. Since the soilless culture industry is still rather small, and there is not sufficient marketing, but for the popularization of soilless culture, it is very important to provide scientifically proven technology of soilless culture to gardeners and create mass awareness in potential areas at the national level. Continuing research and development may lead to more cost-efficient structures and materials; to reduced requirements of purchased energy; to new cultivars more appropriate to controlled environments and mechanized systems; to better control (including improved plant resistance) of diseases and pests.

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