

### **Soil-Less Culture Technique in Horticulture Crops: A Review**

#### **Abstract**

Soilless culture, a modern greenhouse cultivation technology, has rapidly developed in the past 30-40 years and offers a closed-loop system with several benefits, including the recycling of 85-90 percent of irrigation water. As the world population continues to grow at a rate of over 1%, the reduction in land availability per capita for soil-based agriculture has become a major problem, particularly in countries like India with a high population density. Soilless farming offers a viable alternative for growing high-quality vegetables, fruits, and flowers year-round on a variety of substrates, requiring limited space. This approach also aims to eradicate greenhouse soil-related problems such as soil-borne infections, poor soil fertility, and salinity. With several advantages over traditional soil crops, including shorter growth times, year-round production, and fewer diseases and pests, soilless farming comprises various methods such as hydroponics, aeroponics, and aquaponics. The technique has the potential to improve people's lives and boost economic growth by encouraging innovative businesses to engage in agriculture. Therefore, soilless farming has gained traction as an innovative solution to address land scarcity issues while producing high-quality crops sustainably.

**Keywords:** Aeroponics, Economic growth, Hydroponics, Soilless culture and Sustainable agriculture.

#### **Introduction:**

In the 21st century, one of the most immediate agricultural challenges is to increase crops yield per unit surface while increasing both water use efficiency and nutrient use efficiency. There is a need to increase WUE in countries with limited water (Savvas and Gruda, 2018) and where irrigation water competes fiercely with other more competitive economic activities and human uses (Morison et al., 2008). There is a need to increase WUE in countries with limited water (Savvas and Gruda, 2018) and where irrigation water competes fiercely with other more competitive economic activities and human uses (Morison et al., 2008). It is essential to increase NUE so as to reduce nutrient losses, which are a source of pollution (Fageria et al., 2008). Producing fruit, vegetables, and flowers is a vital part of agricultural production, both in terms of human diet and economic status. In the present day, agriculture land is declining rapidly due to population growth, which makes it difficult for scientists and agriculture researchers to make available adequate and balanced diets for everyone. In order to produce high yields, soil less culture may be a significant technique that produces healthy and qualitative produce.

The soil is a natural growing medium for plants. For plant growth and development, it supplies nutrients, oxygen, water, and so forth (Ellis et al.

1974). Soilless culture refers to the growing of plants in a medium other than soil. An efficient use of water and nutrients is being maximized through the integration of soilless systems in horticultural production (Gorbe and Calatayud, 2010; Urrestarazu, 2013; Van Kooten et al., 2004). However, occasionally soil holds serious restrictions for the growth of plant because of several biotic and abiotic factors like soil borne diseases, insect larvae in soil, soil erosion, high salinity and alkalinity of soil and poor drainage system. Crop growing is generally difficult in urban or peri-urban areas due to adverse or unfavourable soil conditions and scarcity of cultivable arable land (Beibel, 1960). Soil-less culture can be practised effectively in such conditions (Butler and Oebker, 2006).

The crops grown in greenhouses conditions without soil requires high technology with skilled labour to operate efficiently and high initial investment for installation and maintenance. However, they are highly productive and ergonomic, uses water and space efficiently and in closed loop systems, it prevents soil and groundwater pollution (Resh, 2012).

Addressing the major difficulties and challenges in soil-less culture techniques for horticulture crops involves overcoming several key obstacles. Firstly, ensuring the appropriate nutrient balance in the growth medium is critical, as it directly impacts plant growth and productivity. Maintaining optimal pH levels and nutrient concentrations requires careful monitoring and adjustments. Secondly, the management of soil-less systems requires a thorough understanding of irrigation practices to prevent overwatering or underwatering, both of which can negatively impact plant health. Additionally, disease and pest management in soil-less setups can be complex, as the absence of soil may affect the natural biological controls. Therefore, implementing effective and sustainable pest control strategies becomes essential. Lastly, the initial investment and operational costs associated with soil-less culture techniques can be higher compared to traditional soil-based methods, which may pose financial challenges for growers. Despite these hurdles, mastering soil-less culture techniques can lead to higher yields, reduced water usage, and better resource efficiency, making it a promising approach for horticulture crop production.

### **Historical background of soil-less culture**

Growing of the terrestrial plants without soil had been published firstly in book '*Sylva Sylvarum*' or 'A Natural History' by Francis Bacon after a year of his death. After that, it became a very popular technique for growing of the plants. In 1969, John Woodward grew the spearmint plant in water culture without soil in England. By 1842, 9 nutrients/elements had been assembled which were very essential for plants growth and its development and after the discovery of Julius Von Sachs (German Botanist) and Wilhelm Knop in the year of 1859-1875, they developed soil-less culture technique (Douglas, 1975).

Growing of terrestrial plants without soil in nutrient solution was later termed "solution culture" (Breazeale, 1906). In 1929, William Frederick Gericke of the University of California at Berkeley embark publicly promoting that solution culture be used for the production of agricultural crops (Dunn, 1926 & Thiyagarajan *et al.*, 2007). He firstly used "aquaculture" term for this culture but later he found that this term is already being used for culture of aquatic organisms, then he introduced the term "*Hydroponics*" in 1929 when he grew the tomato vine of 7.6 meters of length in nutrient solution instead of soil (Turner, 2008). The term "hydroponics" was derived

from Greek word hydro mean 'water' and ponos means 'working' factually called as water working (Resh, 1991). Nutrient solution technique was first established by Sachs and Knap in 1938. In India hydroponics was firstly introduced at Kalimpong of Darjeeling (W. B.) in 1947. On the other hand, many authors still use the term "hydroponics" as a synonym to "soilless culture" (Savvas, 2002). Soilless culture can be classified as (1) Water culture and (2) Substrate culture. In the 1960s, Allen Cooper of England developed the technique named as "Nutrient Film Technique (Cooper, 1979). In 1985, Jensen and Collins developed Aeroponics technique for spinach, lettuce or even tomato.

### **Advantages of soil-less culture**

There are a number of advantages to growing plants in a soil-less culture environment, including the following:

- There's no risk of infection from soil-borne pathogens or weed infestation,
- It's a suitable alternative to soil disinfection.
- Nutritional precision, especially in crops grown on inert substrates or in the pure nutrient solution.
- It eliminates the need for tillage.
- Higher temperatures in the root zone during the day increase early production in crops sown during the cold season.
- When nutrients are delivered directly to the roots, plants develop quicker with smaller roots, may be grown closer together, and use just 1/5th of the overall space and 1/20th of the total water compared to soil-based cultivation (**Raviv et al. 2008**).
- It is possible to harvest more than one or two crops.
- Environmental policies are respected (e.g., fertilizer application is reduced and nutrient leaching from greenhouses to the environment is restricted or eliminated). As a result, closed hydroponic systems in greenhouses are mandated by law in many countries, particularly in environmentally sensitive areas or areas with limited water resources.
- Overall, soil-less cultivation allows for more efficient planting density, resulting in higher yield per acre and healthier, higher-quality product. It's also useful in areas where there's a scarcity of arable or fertile land, as well as water for agriculture (Schwarz 2012).

### **Limitations of soil-less culture**

Despite its many advantages, soil-less culture has several drawbacks, which are listed below

- Expensive installation.
- A commercial application demands technical expertise and the services of a skilled professional.
- Proper maintenance was required.
- Energy inputs are required to keep the system running.
- In open systems of soilless culture, the danger of pathological injuries is low, whereas, in closed systems, the risk is high, necessitating extensive care and cleanliness (El-Kazzaz and El-Kazzaz 2017).

### **Classification of soilless culture**

## **1. Hydroponics**

Hydroponics is the practise of growing plants in nutrient solutions (water with fertilizers) with or without the use of an inert medium (sand, gravel, vermiculite, rock wool, perlite, peat moss, coir, or sawdust) to provide mechanical support (Sharma *et al.*, 2018). The phrase hydroponics comes from the Greek words hydro', which means water, and ponos', which means labour, and literally translates to "water work." Hydroponics was coined in the early 1930s by Professor William Gericke to explain the growing of plants with their roots floating in water containing mineral fertilizers.

### **Different types of hydroponics structure**

#### **Wick or passive system**

This is the simplest hydroponic system because it doesn't require any electricity, a pump, or aerators (Shrestha and Dunn, 2013). The wick system, also called a passive system, is a low-cost form of nutritional solution absorption in which the plant system absorbs the solution by the capillary action of the roots and fibres that transport water to the plants (Ferrarezi and Testezlaf, 2016). The Wick method is particularly advantageous in locations where electricity is scarce since it does not rely on energy to transmit nutritional solution. This method is best suited for small scale production and should not be used to cultivate crops for a long period of time (Lee and Lee, 2015).

#### **Deep water culture (DWC)**

Deep Water Culture, also known as Deep Flow Technique, is a method of growing plants in a container with a 10-20 cm nutritive solution and a floating or hanging support, such as rafts, panels, or boards (Van *et al.*, 2002). The roots of the plants are constantly immersed in the nutritious solution with proper aeration. Oxygen content, conductivity, and pH must all be controlled for optimal development (Jones, 2005).

#### **Drip hydroponic system**

Two containers, one on top and one below, make up the drip hydroponics system. In this setup, plants are placed on top of the top container, and nutritional solutions are poured into the bottom container (Lee and Lee 2015). The addition of aquarium stone to the nutritional solution aids in the oxygenation of the water (El Kazzaz *et al.*, 2017). Plants with a large root system can be grown in this drip hydroponics system.

#### **Ebb and flow system**

The Ebb and Flow hydroponics system comprises two containers, one with plants at the top and the other with nutrient solution at the bottom, similar to the drip hydroponics system. In this hydroponics system, nutrients are bombarded to the plant roots rather than being poured through drippers (Mohammed 2018). Again, with such a nutrient solution delivery method, the roots are exposed to a changing environment, which may not be ideal for optimal plant growth and development; yet, plant performance is usually good with this hydroponic strategy (Jones, 2014).

## **Nutrient film technique (NFT)**

The Nutrient Film Technique is a closed hydroponic system in which nutrient solution is recycled and recirculated through a channel of PVC pipe configurations to provide a highly oxygenated nutrient solution to plant roots. In the 1960s, Allan Cooper invented this approach (Cooper, 1988). In this arrangement, the plant absorbs critical nutrients and oxygen from the thin layer of nutritional solution via its roots. The nutrient solution is normally pumped from a holding tank to a slanting pipe where the roots are suspended, with run-off solutions collected and returned to the holding tank at regular intervals (Morgan, 2009).

## **2. Aeroponics**

The terms 'aeroponic' are derived from the Latin words 'aero' (air) and 'ponic' (labour) (work). This is a viable option to soilless culture in growth-controlled circumstances. The aeroponic culture technique is optional equipment for soilless production in growth-controlled environments such as greenhouses (Deeptimayee Sahoo, 2020). Because plant roots in aeroponics are exposed to the air and receive their nutrients from an aerosol mist, they develop in an air/mist environment. A continual spray is required to keep the plant roots moist and aerated and prevent them from drying out (Nandwani 2018, Lee and Lee 2015). Potato seed tubers have been successfully produced using an aeroponic system in Korea. Aeroponic systems use water more efficiently than hydroponic systems. Nutrient solutions are sprayed directly on suspended roots using sprinklers with various types of nozzles at regular intervals to avoid root zone dryness. To spray the developing roots with nutritious solution, various nozzles are employed, including ultrasonic atomization foggers, High-Pressure atomization nozzles, and pressurized airless nozzles. A static pressure of 60-90 psi is maintained and controlled using an automated system (Liu *et al.*, 2018). Aeroponics is mostly used for small horticultural crops and is not commonly used because to the high initial investment and administrative expenditures (Rakocy, 2012).

## **3. Aquaponics**

Aquaponics is a soilless culture that blends circulation aquaculture and hydroponics in a symbiotic environment to produce both fish and vegetables (Rakocy 2007). Aquaponics is derived from the Latin and Greek names for water (aqua and hydro), which are used to define aquaculture (fish farming) and hydroponics in modern horticulture production (plant growth in water without soil). Aquaponics blends the two methods of production into a single feeding system that can grow both terrestrial and aquatic plants. In an aquaponics system, water is pushed from the fish tank to the plant growth container via a biofilter, where nitrifying bacteria can thrive and toxic compounds are broken down. Excess water in the growing container is recycled, and nutrients for plant growth are provided by fish-grown water, which contains ammonia-rich fish excreta. Beneficial bacteria such as *Nitrosomonas sp.* and *Nitrobacter sp.* convert ammonia to nitrites and nitrites to nitrates through metabolic mechanisms (Rakocy *et al.*, 2016). The top aquaponics nations have recently emerged as India, Israel, China, and Africa (Singh and Singh, 2012)

## **Media used in soilless culture**

Inorganic growth media are derived from natural sources, with just a small percentage undergoing industrial processing prior to use. Rockwool was developed

as an insulating material for the construction sector. It has become the dominating growing media for fruit and vegetable production in greenhouses all over the world due to its light weight and simplicity of handling (Gruda *et al.*, 2016b). Perlite is a well-known growing medium in Europe, however it is more widely utilised in the Mediterranean region due to its lower cost (Grillaset *al.*, 2001). Organic growing media can be artificial, such as polyurethane, or natural, such as peat or wood-based substrates. Peat (Schmilewski, 2009), composts, bark (Maher and Thomson, 1991), and wood wastes are among the most readily available and useful organic materials (Gruda and Schnitzler, 2004).

Any growth media that is suitable for use in a soilless cultivation method should have the following characteristics.

- a) The medium must provide enough nutrients for proper plant growth and development;
- b) It must have a large water holding capacity;
- c) It must simultaneously feed water and gases to the plant;
- and d) It must provide suitable support to the plant.

**Table 1: Characteristics of organic and inorganic media used in soilless cultivation**

Nature of media	Substrate/ media	Origin	Advantages	Disadvantages	References
Organic	Coco peat	Natural anaerobically processed plant residues	Physical stability, good air and water holding capacity: TPS (85–97% V/V), low microbial activity, light volume weight (60–200 kg m <sup>-3</sup> ). Improves soil aeration and increase soil buffering capacity.	Finite resource, environmental concerns and contribution to CO <sub>2</sub> release, increasing cost due to energy crisis, may be strongly acidic, shrinking may lead to substrate hydro-repellence	Xu <i>et al.</i> , 1995
	Rice hull	Plant based byproduct of rice milling industry	The rice milling business produces it as a by-product. Rice hulls, despite their low weight, are quite useful in improving drainage	Slow break down relatively resistant to decomposition	Xu <i>et al.</i> , 1995
	Bark	waste by-product of the wood-processing industry	It has high air content and water retention capacity, as well as a high total pore space (TPS) (75–90% V/V). However the	Slow decomposition in soil	Gianquinto and colleagues, 2006

			pH range is slightly acidic to neutral, with a long-lasting average volume weight (320–750 kg m <sup>-3</sup> )		
	<b>Coconut coir</b>	by-product of fiber coconut processing	high water holding capacity, as well as a subacid-neutral pH (5–6.8)	May contain high salt levels, energy consumption during transport.	Gruda and colleagues, 2016b
	<b>Biochar and hydrochar</b>	Solid material derived from biomass pyrolysis	Production is energy-neutral, helps with carbon sequestration, biologically very stable, wet material can be used for hydrochar; hydrochar has low EC	hydrochar has low EC. Properties vary dependent on feedstock (biochar), high production costs, biochar often has high pH, can be dusty.	Gianquinto <i>et al.</i> , 2006; Gruda <i>et al.</i> , 2016)
	<b>Saw Dust</b>	Plant origin (Waste product of wood industry)	High water retention, Lightweight, Adaptable to fertilizer	Tend to clot, Chemical cleaning is required, Susceptible to biological breakdowns	Ashok and Sujitha, 2020
<b>Inorganic</b>	<b>Perlite</b>	Siliceous volcanic mineral sieved and heated to 1000°C	Light volume weight (90–130 kg m <sup>-3</sup> ), sterile, neutral in pH (6.5–7.5), no decay, TPS (50–75% V/V).	Low nutrient capacity, energy consuming product, expensive.	Maucieri <i>et al.</i> , 2019
	<b>Sand</b>	Natural with particles of 0.05–2.0 mm	Relatively inexpensive, good drainage ability	Low nutrient- and water holding capacity, high volume-weight (1400–1600 kg m <sup>-3</sup> )	Gianquinto <i>et al.</i> , 2006; Gruda <i>et al.</i> , 2016b
	<b>Vermiculite</b>	Mg <sup>+</sup> , Al <sup>+</sup> and Fe <sup>+</sup> silicate sieved and heated to 1000°C	Light volume weight (80–120 kg m <sup>-3</sup> ), high nutrient holding ability, good water holding ability, good pH buffering capacity, good aeration: TPS (70–80% V/V)	Compacts when too wet, energy consuming product, expensive.	Gianquinto <i>et al.</i> , 2006; Gruda <i>et al.</i> , 2016b. George and George,

					2016)
	<b>Rock wool</b>	Melted silicates at 1500–2000°C	Light volume weight (80–90 kg m <sup>-3</sup> ), high total pore space (95–97% V/V), ease of handling, totally inert, nutrition can be carefully controlled.	Disposal problems, energy consumed during manufacture.	Gianquinto <i>et al.</i> , 2006; Gruda <i>et al.</i> , 2016b

### Application of nutrient solution

Horticultural crops success or failure without soil (soil less) is totally dependent on the presence of balanced of nutrient solutions that are suitable for all stages of plant growth and development. Fertilizers for soilless cultures must include all 13 essential nutrients required for proper healthy growth development of plant. The pH range of solution culture ensure range between 5 and 6 is critical range follow the labels dilution rate of recommendations. Generally, tools for the pH test kits and pH modifiers are available at any fish supply store. Some nutrients in the fertiliser solution will be loosed faster than others depending on the stage of plant growth and development. As a result, it is essential to monitor the lack of nutrients of the farming system in soil less culture every two weeks and to provide this deficiency, as well as to confirm that the nutrient solution is saved at its original volume. The concentration of nutrients is rise and can harm the root system and its function due to lack of water in the system. Therefore, it is compensated for this deficiency by addition of purified distil water to raise the nutrient solution to its original form. In a Hydroponic system to be sure use of nutrient designed for hydroponics. plants which grown in soil get most of these nutrients from the soil. Because the composition of elements in nutrients designed for soil is totally diverse from that for soil less culture.

In the sense of hydroponics as well as soil less culture there is no soil to found the nutrients from, that's why two totally different composition because they are not make whole plant food and those not soluble in water. As an important example, urea is not immediately available to plants in soil less culture or hydroponics in the form of Nitrogen because generally urea is water insoluble. Behind this reason, plants uptake the nitrogen in the form of nitrate is utilized in soilless culture as well as hydroponics. Plant roots grow underground in nature. the critical temperature of root zone is keeping around 20-22 degree Celsius for replicating of roots. That isn't to imply that if the nutrient temperature exceeds 23 or 23.5 degrees Celsius, the plants would perish, but it should be kept as near to 20 – 22 degrees Celsius as possible. Flowers turning yellow and dropping off, damaged fruits, and a lack of new development are just some of the issues that plants with too high nutrient tempters might face.

### Methods of Application of nutrient solution

#### 1. Nutrient Film Technique (NFT)

The NFT technique is considered as the typical as well as universal technique of hydroponic cultivation system. In this system nutrients solution flow along and circulates with 1-2 cm layer of water (Cooper 1979; Jensen and Collins 1985; Van Os *et al.* 2008). The main advantages of the Nutrient Film Techniquesystem are recirculation of the nutrient solution and the absence of substrate.

## 2. Fertigation system

Fertigation is a method of fertilizer application in soil-based cultivation as well as soil less culture in which method fertilizers applied within the water by drip irrigation system. It is best technology for fertilizers application. In this system fertilizers distributed in judicious manner to the crops grown in side grow bags and containers in soil less cultivation medium. Fertigation schedule are very quiet sensitive to varied soil-less medium, necessitating proper fertigation management. Through fertigation water and nutrients are supplied at near root zone which results higher absorption of nutrients by the crops. Generally, 80 to 90% fertilizer efficiency through fertigation which helps to save 25% of nutrients.

**Table 2: Sources of nutrient elements with their characteristics used in fertigation**

Source	Nutrients	Characteristics
Ca (NO <sub>3</sub> ) <sub>2</sub>	N, Ca	higher soluble salt
H <sub>3</sub> BO <sub>3</sub>	B	Good source of boron
Iron chelates	Fe Cit	Good sources of iron
KH <sub>2</sub> PO <sub>4</sub>	P, K	Deficiency of phosphorus
MgSO <sub>4</sub>	S, Mg	highly soluble, Cheap and pure salt
KNO <sub>3</sub>	N, K	higher soluble salt
NH <sub>4</sub> NO <sub>3</sub>	P, K	Good soluble in water

**Table 3: List of crops grown in soil less cultivation (Hydroponics)(Khan *et. al.*,2018)**

	Group of crops	Name of crops	Scientific Name
1	Vegetables	Vegetable Peas	<i>Pisum sativum var. hartense</i>
		Tomato	<i>Lycopersicon esculentum L.</i>
		Bell pepper	<i>Capsicum annuum L.</i>
		Beet	<i>Beta vulgaris L.</i>
		Chili	<i>Capsicum frutescens L.</i>
		Green bean	<i>Phaseolus vulgaris L.</i>
		Potato	<i>Solanum tuberosum L.</i>
		Onion	<i>Allium cepa L.</i>
		Cucumber	<i>Cucumis sativus L.</i>
		Cauliflower	<i>Brassica oleracea var. botrytis</i>
		Lettuce	<i>Lactuca sativa L.</i>
		Kang Kong	<i>Ipomea aquatica</i>
		Radish	<i>Raphanus sativus L.</i>
		Cabbage	<i>Brassica oleracea var. capitata</i>
		Melons	<i>Cucumis melo</i>

2	<b>Fruits</b>	Strawberry	<i>Fragaria ananassa</i>
3	<b>Flowers</b>	Chrysanthemum	<i>Chrysanthemum indicum</i> L.
		Marigold	<i>Tagetes patula</i> L.
		Carnation	<i>Dianthus caryophyllus</i> L.
		Roses	<i>Rosa indica</i>
		Bermuda grass	<i>Cynodondactylon</i> L.
4	<b>Condiments</b>	Parsley	<i>Petroselinum crispum</i> Mill.
		Mints	<i>Mentha spicata</i> L.
		Sweet basil	<i>Ocimumbasilicum</i> L
5	<b>Medicinal plants</b>	Aloe	<i>Aloe vera</i> L.
		Coleus	<i>Solenostemonscutellarioides</i>

### Government of India (GOI) initiatives for soilless culture

Soilless culture holds a lot of promise for Indian agriculture. It's one of the technologies that could treble a farmer's income. As eating preferences and fads for green vegetables, herbs, and fruits evolve, hydroponics technology will become increasingly important in ensuring sustainable and year-round production in urban and peri-urban areas. Because this technology requires a lot of finance and technical know-how, the Indian government has set up a variety of programs to promote it through various agencies.

In India, several organizations and schemes promote soilless farming and contribute to the development and adoption of soilless culture techniques. Here are some of the important ones:

- 1. National Horticultural Board (NHB):** NHB works towards the overall development of horticulture in India and supports initiatives related to soilless farming and horticultural projects.
- 2. National Horticultural Mission (NHM):** NHM focuses on promoting holistic growth in horticulture and implements schemes like the Mission for Integrated Development of Horticulture (MIDH) to support soilless farming practices.
- 3. Horticulture Mission for North East & Himalayan States (HMNEH):** HMNEH aims to enhance horticulture productivity in the North Eastern and Himalayan regions by promoting advanced farming practices, including soilless techniques.
- 4. National Mission for Sustainable Agriculture (NMSA):** NMSA supports sustainable agricultural practices and provides assistance for the adoption of innovative techniques like soilless farming.
- 5. Integrated Horticulture Development Programme (IHDP):** IHDP aims to integrate various aspects of horticulture development, including soilless farming, to enhance productivity and income of farmers.
- 6. National Agricultural Innovation Project (NAIP):** NAIP, implemented by the Indian Council of Agricultural Research (ICAR), focuses on promoting innovation and technology adoption in agriculture. It supports research and development initiatives related to soilless farming, hydroponics, and other innovative agricultural practices.

- 7. Centre of Excellence for Vegetables (CoE):** CoE is a scheme implemented by the Ministry of Agriculture and Farmers' Welfare, Government of India. It establishes centers of excellence across the country that serve as model demonstration sites for advanced horticultural practices, including soilless farming. These centers provide training, technical assistance, and knowledge sharing platforms to farmers.
- 8. Indian Society of Soilless Agriculture (ISSA):** ISSA is an organization dedicated to promoting and disseminating knowledge about soilless agriculture in India. It conducts seminars, workshops, and training programs to educate farmers, entrepreneurs, and researchers about soilless farming techniques, technologies, and best practices.
- 9. State Horticulture Departments:** State-level horticulture departments across India play a crucial role in promoting soilless farming. They implement various schemes, provide financial assistance, and offer training and technical guidance to farmers interested in adopting soilless culture techniques.
- 10. Pradhan Mantri Krishi Sinchai Yojana (PMKSY):** PMKSY is a flagship program that encompasses various initiatives, including Per Drop More Crop (PDMC), Watershed development, Micro Irrigation, and Crop Insurance Scheme, which indirectly support soilless farming.
- 11. Vertical Farming Scheme under Kerala State Horticulture Mission:** This scheme provides subsidies to promote vertical farming practices, including soilless techniques, in Kerala.
- 12. Collective Farming Scheme:** This scheme encourages collective farming approaches, including soilless farming, to enhance productivity and income of small and marginal farmers.
- 13. Rainfed Area Development (RAD):** RAD focuses on enhancing productivity in rainfed areas through various interventions, including soilless farming, to ensure sustainable agriculture.
- 14. Tamil Nadu Irrigated Agriculture Modernization Project (TNIAMP) - IAMWARM:** TNIAMP aims to improve irrigation practices and modernize agriculture, which can indirectly support the adoption of soilless farming techniques.
- 15. Pradhan Mantri Fasal Bima Yojana:** This scheme provides crop insurance coverage to farmers, including those practicing soilless farming, to safeguard against crop losses.
- 16. Rashtriya Krishi Vikas Yojana (RKVY):** RKVY supports agriculture and allied sector rejuvenation, including the adoption of innovative approaches like soilless farming under the scheme's Remunerative Approaches for Agriculture and Allied sector Rejuvenation (RAFTAAR) component.
- 17. CHAMAN Project:** This project aims to assess and manage horticulture practices and provides support for the development and adoption of advanced farming techniques, including soilless farming.

- 18. Sub-Mission on Agricultural Mechanisation (SMAM):** SMAM focuses on promoting agricultural mechanization, which can indirectly support soilless farming practices.
- 19. National Committee on Plasticulture Applications in Horticulture (NCPAH):** NCPAH works towards promoting the use of plasticulture applications, including the use of plastic mulch in soilless farming, to enhance productivity and resource efficiency in horticulture.
- 20. Agricultural Universities and Research Institutions:** Agricultural universities and research institutions in India conduct research, develop technologies, and provide expertise in the field of soilless farming. They contribute to the knowledge base, conduct training programs, and disseminate information on soilless culture practices to farmers and stakeholders.

These organizations and schemes collectively contribute to the promotion and adoption of soilless farming in India by providing support, funding, knowledge-sharing platforms, and technical assistance to farmers, researchers, and entrepreneurs in the horticulture sector.

## **Conclusion**

As the world's population grows, more food will be needed in the next four decades than in the previous 10,000 years. As the world's population grows and the amount of arable land accessible for food production decreases, new crop production alternatives must be explored. The traditional soil-based farming technique will not be sufficient to meet the world's expanding food need. As a result, establishing a new farming approach is essential to avoid future food crises. Soilless culture's technologies and procedures can be referred to as next-generation agricultural science because they open the possibility to establishing a new civilization in space. In a world where clean water and a sufficient quantity of nutritious food are major concerns, Soilless farming is becoming more popular around the world, and such systems provide growers and consumers with a plethora of new chances to produce high-quality vegetables rich in bioactive compounds by displacing traditional farming. Hydroponic culture is the most intensive form of crop production in today's agriculture business, and it is mostly employed in industrialized and developing countries to produce food in small spaces. Aeroponics proved to be a very viable approach for producing aerial and root raw materials for the herbal dietary supplement and pharmaceutical industries. Aquaponics is a sort of soilless culture that uses a circulating aquaculture and hydroponics system to provide a double harvest of fish and vegetables in a symbiotic environment. It can also improve people's lives and boost a country's economic growth by encouraging inventive businesses to engage in hydroponic farming. The world needs to embrace the soilless culture as a vital solution to the growing demand for food. Its potential to produce high-quality crops in limited spaces, its resource efficiency, and its ability to adapt to different environmental conditions make it a promising avenue for

sustainable agriculture. By incorporating soilless farming techniques into our agricultural systems, we can meet future food challenges and pave the way for a more resilient and productive food production system.

### Future scope

Soilless culture is the fastest-growing area of agriculture, and it has the potential to become the primary source of food production in the future. People will turn to innovative technologies like hydroponics, aeroponics, and aquaponics to generate extra channels of crop production as the population grows and arable land shrinks owing to bad land management. We simply need to look at some of the early adopters of hydroponics to get a sense of the future of this science. Hydroponics has also shown to be successful in Israel's dry and arid climate. Using hydroponic systems, a business called "Organitech" has been growing crops in 40 feet (12.19-meter) long shipping containers. They're growing a lot of berries, citrus fruits, and bananas, which would ordinarily be impossible to cultivate in Israel's environment. The output produced by hydroponics techniques is 1,000 times larger than what a similar-sized plot of land could generate in a year. Best of all, the procedure is fully automated, with robots operating on an assembly line-style system similar to those used in manufacturing factories. Following that, the shipping containers are moved across the country (**Butler and Oebker, 2006**). The future scope of soil-less culture techniques in horticulture crops is bright and promising. With its ability to address challenges such as disease control, resource efficiency, year-round cultivation, and integration with technology, soil-less culture has the potential to revolutionize agriculture. By embracing this technique, farmers can enhance productivity, ensure food security, and contribute to sustainable and efficient agricultural practices in the years to come.

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