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SUSTAINABLE SOILLESS CULTIVATION PRACTICES FOR FLOWER CROPS: CURRENT INSIGHTS AND FUTURE DIRECTIONS

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ABSTRACT

The global floriculture market is continually meeting trends that call for low environmental impact sustainability without compromising yield and quality, so there is increasing pressure to produce flowers sustainably. Soilless systems, such as hydroponics and aeroponics, are potential solutions for most problems associated with modern-day agriculture, especially where practice involves cultivation in soil, such as soil erosion, reduction of water resources, and nutrient leaching. A survey of recent literature on soilless flower crop cultivation reveals new advances with emphasis on resource use efficiency, environmental soundness, and economic importance. It explores the substrate, nutrient, water, pests, and diseases management innovative strategies to address the challenges as part of the strong cultivation systems. Examples are given of benefits and drawbacks, including but not limited to, high cost of installations, and skills level, which are likely to deter uptake. Technologies such as precision agriculture, artificial intelligence and bio-based materials among others, are reviewed in order to assess their contribution towards sustainability in floriculture. The review closes with a summary of what additional studies need to be undertaken, such as geographical diversification, LCA, and policy development, all of which seek to enable stakeholders adopt sustainable and appropriate soilless techniques in floriculture.
***Keywords* :** Soilless cultivation, Hydroponics, Organic substrates, Plant health

Introduction

Soil is usually the most available growing medium for plants. It provides anchorage, nutrients, air, water, etc. for plant growth (Ellis *et al.*, 1974). However, it has some significant drawbacks, the existence of disease-causing organisms and nematodes, unfavorable soil reactions, unfavorable soil compaction, poor drainage, erosion degradation, etc. which results in poor soil fertility, poor yield and quality of flower crops and ornamentals (Sengupta and Banerjee, 2012). Soilless culture is a method of growing plants in soilless media that helps to reduce the problems of traditional crop cultivation related to soil (Murumkar *et al.*, 2012).

Soilless culture is characterized as plant cultivation in in-situ systems without soil (Savvas *et al.*, 2013). Soilless culture is the practice of growing plants with their roots submerged in nutrient solution in a soilless environment (Maharana and Koul, 2011). In protected agriculture, it has been widely introduced to improve the growing climate and provide optimal supply of water and nutrients for cultivated crops. Soilless culture can potentially improve cropping systems by optimizing the use of inputs such as nutrients, pesticides and water, controlling diseases more efficiently and make it possible to increase crop production regardless of the climatic condition (Putra and Yuliando, 2015). The growing interest in sustainable soilless systems is also driven by advancements in technology, including precision agriculture, smart sensors, and data-driven approaches that enhance monitoring and control over environmental parameters. As the floriculture industry adapts to evolving consumer preferences for sustainably produced flowers, soilless systems offer a path forward, balancing economic profitability with environmental responsibility. This review aims to provide a comprehensive overview of current insights into soilless cultivation practices for flower crops, analysing their advantages, challenges, and future directions. Emphasis will be placed on recent innovations, sustainability assessments, and the potential role of soilless systems in reshaping the floriculture industry for a more resilient future.

History of Soilless Culture

Soilless culture is considered as a modern-day practice, but growing plants in containers above ground has been tried at various times throughout the ages. Wall paintings found in the temple of Deir el Bahari appear to be the first documented case of container-grown plants (Savvas *et al.*, 2013). They transfer mature trees from native countries of origin to the king's palace and then grown as soilless culture, where local soils were not suitable for the particular plant. Egyptian hieroglyphic records dating back several hundred years B.C. shows growing of plants in water. The hanging garden of Babylon is also a fine example of soilless culture.

The earliest published work on soilless culture, the book *Sylva Sylvarum* published in 1627 by Francis Bacon, and after that water culture became a popular research technique. In 1699, John Woodward published his water culture experiments with spearmint. By 1859-65, discoveries of the German botanists Julius von Sachs and Wilhelm Knop, resulted in a development of the technique, soilless cultivation. In 1929, William Frederick and Gerick Berkeley publicly promoting that solution culture is used for agricultural crop production.

Hussain *et al.* (2014) has grown tomato vines twenty-five feet high in mineral nutrient solutions rather than soil. He also coined the term hydroponics for the culture of plants in water (from the Greek hydro-, water", and ponos, "labour"). In the 1960s, Allen Cooper of England developed the Nutrient Film Technique. In India, Hydroponics was introduced in the year 1946 by an English scientist, W. J. Shalto Duglas and he established a laboratory in Kalimpong area, West Bengal. He wrote a book on Hydroponics, named as "Hydroponics-the Bengal System".

Growing Media and Its Characteristics

Growing media has major role to support plants while holding nutrients, water for the plants to use during growth (Gohil *et al.*, 2018). The rooting and vegetative growth of the section was affected by different media forms. Growing media should be considered as an essential part of the propagation system, because the rooting capacity depends on the type of medium used. The rooting medium directly affects the quality and the rooting percentage (Farooq *et al.*, 2018). The selected components to make the growing mix will have an impact on its physical and chemical properties.

Criteria For Selecting Media

- It should serve as reservoir of plant nutrients.
- Sufficiently firm enough to support the plants.
- It should provide aeration for exchange of gases.
- The media used should not shrink or expand easily.
- It should have good drainage, porosity, aeration, etc.
- It should be easily available and economic.
- It should be sterilized easily.
- It should be free from pathogens, pests and weed seeds etc.

Desirable Properties of Growing Media

- It should possess high organic matter content that will not diminish quickly. The organic matter content should be more than 0.5%. The carbon and nitrogen (C: N) ratio should be narrow (10:1 to 20:1) to facilitate high rate of decomposition.
- Optimum pH for soil based and soilless substrate is 6.2 to 6.8 and 5.4- 6.04.
- EC levels of 0.4 to 1.4 ds/m is optimum.
- Sufficiently porous to permit good aeration, mobility of water, root penetration as well as should retain enough water.
- It should possess high cation exchange capacity for nutrient reserve (6-15 me/100cc).
- Sufficient amendments and nutrients should be added to root substrate for better results.
- It should be readily available or easily formulated within the acceptable cost.

Types of Growing Media

- Soil based growing media and
- Soilless growing media

Soil Based Growing Media

Soil is the basic material/ ingredient of the media. It forms the major portion in the combination of different media. Soil is cheaply available, economic and easy to handle. Most soils on the average are composed of 46-49% mineral particles (often called separates), 1-6% organic matter and 50% air and water. The mineral particles of soil are sand, silt and clay.

Table 1 : Size and Characteristics of mineral particles

Mineral Particle	Size	Characteristics
Sand	0.05-2 mm	Relatively inert; small total surface area; forms large pores; increases drainage and aeration; poor nutrient holding capacity.
Silt	0.002-0.05 mm	Intermediate between sand and clay.
Clay	less than 0.002 mm	Chemically and structurally complex (negatively charged and laminated); large total surface area; forms very small pores; increases water and nutrient holding capacity; may decrease aeration and drainage if poor structure.

Soilless Growing Media:

Soilless growing media is of two types:

1. Organic growing media (derived from living things i.e.plants).
2. Inorganic growing media (mined or man-made).

Organic Growing Media

Organic growing medium amendments usually are derived from plants or plant products that occur naturally (peat moss from peat bogs), or are the by-products of processing plants or mills (sawdust, cedar chips, bark, bagasse, rice hulls) or waste disposal plants (compost, processed sewage sludge, biosolids). The main purpose of using organic amendments is to loosen the soil and create large pores to increase. These media provide aeration, drainage, usable water holding capacity, nutrient holding capacity and decrease growing medium weight (Kumari *et al.*, 2023).

(a) Peat

It is one of the most used components of potting mixes. The upper and younger layer of a peat land is called “white peat” and lower layers of peat are called “Black peat”.

It has high water holding capacity, easy to handle and is commonly free of weeds and pathogens (Gohil *et al.*, 2018). Peat is derived primarily from plants and is focused on bio-decomposed matter. It consists of nutrient and oxygen deficiency accumulation, acidity and water logging conditions.

At low temperatures, such as subarctic and boreal zones, the peat is mostly composed of mosses, shrubs, small trees and herbs, decreasing the decomposition ratio (Joosten and Clarke, 2002). It has a major structural feature that, even under heavy use is long-standing and biodegradable .

(b) Sphagnum Moss

It is produced by the genus sphagnum from dehydrated acid bog plants. It is light weight and has the ability to absorb water 10-20 times its weight. Sphagnum moss has ability to inhibit damping off the seedling because it contains specific fungistatic substances. It helps to maintain acidic conditions for acid-loving plants and promotes beneficial microbial activity. It is used to cover seeds because it controls the disease and light in weight (Gohil *et al.*, 2018).

(c) Shredded Bark

This type of plant material from pine, cedar, fir and red wood can be used for raising ornamental plants. The growing medium consisting of pine bark can be used to raise a few terrestrial orchids successfully. The nutrients can be derived from the breakdown products of these organic materials (Gohil *et al.*, 2018).

Fig. 1 :*Phalaenopsis* on open-growing tables (left) and after sprinkler irrigation (right) in the vegetative growth period. Bark is used as substrate.

Fir Bark – most popular orchid potting medium. It is light, easy to handle, rough surface and does not compact. Fir bark allowing air and water to be obtained by the plant's roots. Fir bark is mainly available in 3 grades:

- Fine - used for orchid seedlings or mature plants with fine roots.
- Medium - used for epiphytic orchids.
- Coarse - used for *Vanda*s and large *Phalaenopsis* and orchids.

(d) Coco Peat

It is believed to be a byproduct of processing coconut husk as coir dust, coco peat, coir pith or simply coir. Coir is a flexible natural fibre derived from mesocarp tissue or coconut husk. It is natural soilless growing medium. It has high water holding capacity about 8-9 times of weight. It has physical characteristics like high total pore space, high water content,low shrinkage, low mass density and slow bio-degradability. The properties of coconut peat are resistant to bacterial and fungal growth and have high oxygenation properties that are useful for healthy root production. Coir has nitrogen, calcium and magnesium, but phosphorus and potassium are comparatively high (Gohil *et al.*, 2018).

(e) Compost

Composting is a process of getting well decomposed organic matter from biodegradable organic waste under aerobic/ anaerobic condition or converted to humus by indigenous microflora including fungi actinomycetes and bacteria. It is a rich or porous potting medium and has humidity with absorbent content and soluble minerals. A disadvantage of compost is costeffective to transport due to bulky and weight.

(f) Vermicompost

End result of organic matter breakdown by earthworm, also known as worm humus, worm manure/ worm casting. It is a clean organic material with sufficient amounts of N, P, K and many micronutrients that are important for the growth of plants. It helps in aeration and water holding ability of growing media. Vermicompost is important for sprouting and germination of bulb and seeds because it contains plant growth regulators like auxin and gibberellins.

Table 2 : Nutrient status of vermicompost

Major nutrients (%)			Minor nutrients (ppm)			Micro-organisms (per gram)		
N	**P**	**K**	**Cu**	**Fe**	**Zn**	**Fungi**	**Bacteria**	**Actinomycetes**
2.5-3.0	1.0-1.5	1.5-2.0	52.0	930.0	186.6	$2.65x10^4$	$11.37x10^7$	$10.43x10^4$

(g) Bagasse

Bagasse is a waste bi-product of the sugar industry. It may be shredded or composted to produce a material which can increase the aeration and drainage properties of container media. Because of its high sugar content, rapid microbial activity results after the incorporation of bagasse into a media. This decreases the durability and longevity of bagasse and influences N levels.

(h) Rice Hulls

Rice hulls are a bi-product of the rice milling industry. Although they are extremely light in weight, rice hulls are very effective at improving drainage. The particle size and resistance to decomposition of rice hulls and sawdust are very similar. However N depletion is not as serious of a problem in media amended with rice hulls.

(i) Leaf Mould

Leaf mould is a form of compost produced by the fungal breakdown of shrub and tree leaves. It is generally too dry, acidic, or low in nitrogen for bacterial decomposition. Leaf mould is essentially a soil conditioner. The addition of leaf mould increases water retention in soils by over 50%. It improves soil structure and provides a fantastic habitat for soil life, including earthworms and beneficial bacteria.

Maple, oak, and sycamore are among the principle leaf types suitable for the preparation of leaf mold. Layers of leaves and soil are composted together with small amounts of nitrogenous compounds for approximately 12 to 18 months. The use of leaf mold can effectively improve the aeration, drainage and water holding properties of a growing media. Although these materials are readily available at low cost, leaf mold is not extensively used in container production.

Inorganic Growing Media

Inorganic substances are vermiculite, perlite, charcoal and sand. In general, they must be bought, which makes them more expensive than organic amendments. Additionally, the industrial production process needs a great deal of energy. Therefore, these substances do not have the same degree of sustainability as organic amendments. Inorganic amendments are used to increase aeration, increase drainage, decrease excessive water holding capacity and decrease or increase weight of the growing medium (Reed, 2007).

(a) Charcoal

Charcoal is the blackish residue consisting of impure carbon obtained by removing water and other volatile constituents from animal and vegetation substances. Charcoal is produced by slow heating of wood, sugar, bone char or other substances in the absence of oxygen. It is commonly used as potting medium for growing Orchids.

(b) Rockwool

Rockwool is a horticultural growing medium made from natural ingredients - basalt rock and chalk. It is made from molten rock spun into fibers and compressed into cubes or slabs. Rockwool provides excellent water retention while allowing for good drainage and aeration. It is light weight so easy to handle and transport. These rockwool growing slabs or cubes are always ready-to-use for planting but it needs to be wet thoroughly.

Fig. 2 : Gerbera in a rack system to fix containers filled with rockwool cubes (left). Rose grown in a bent cane system (right) filled with rockwool.

Root activity of Oncidium Gower Ramsey by TCC method. The root activity didn't have obvious variance when cultured in rock-wool and mixed media. The root activity of oncidium was higher at cultured in rock-wool and lower in sphagnum (Fig. 3). The reason maybe sphagnum had acidification, and affected the environment of cultured medium.

Fig. 3 : The plantlets of *Oncidium* Gower Ramsey cultured in rockwool.

(c) Perlite

Perlite is origin of grayish-white salicaceous volcanic rock, mined from lava flows. It improves drainage and aeration in the mix. It is free from disease and weeds. Perlite is odourless,clean and simple to use and its pH is almost neutral. Disadvantages of perlite is containing very less nutrient and cation exchange capacity is very low.

Fig. 4 : Amaryllis in perlite (left), and Freesia in sand beds mixed with perlite (right) with a polystyrene cover for light reflection.

Advantages of horticultural perlite:

- It improves aeration and drainage.
- It makes moisture and nutrients readily available to plants.
- It is neutral in pH (6.5 to 7.5).
- It serves as an insulator to reduce extreme soil temperature fluctuations.
- It is clean, odorless and safe to handle.
- It is light in weight about 5 to 8 pounds per cubic foot (80-128 kg/m^3).

(d) Vermiculite

Vermiculite is a natural micaceous mineral that expands with the application of heat. The expansion process is called exfoliation. Chemically it is hydrated magnesium, aluminium- iron silicate. Vermiculite is mainly formed from certain basaltic minerals. Vermiculite is a suitable growing medium for hydroponics and is good soil conditioner. Vermiculite has excellent exchange and buffering capacities as well as the ability to supply potassium and magnesium. Although vermiculite is less durable than sand and perlite, its chemical and physical properties are very desirable for container media.

Advantages of Vermiculite

- It has high water holding capacity.
- It is sterile in nature.
- It is suitable growing medium for hydroponics.

Table 3 : Various growing media used for different floricultural crops.

S.No.	Cut Flowers	Growing Media Used (In Different Combinations)	References
1	Rose	Perlite, Zeolite and Cocopeat	Samartzidis *et al.* (2005)
2	Vanda	Brick pieces, Charcoal, Coir dust	Jawaharlal and Rajamani (2001)
3	*Dendranthema grandiflora*	Sand, Soil, FYM, Leaf mould, Sawdust, Municipal solid waste	Reshma (2002)
4	*Gladiolus x grandiflorus*	Sand, Silt, Clay, Leaf mould	Khan *et al.* (2002)
5	*Eustoma grandflorus*	Cocopeat, Sand, Soil	Mathew (2002)
6	*Gerbera jamesonii*	Sand, Soil, FYM, Sawdust and Cocopeat	Dien (2003)
7	*Dianthus caryophyllus*	Soil, FYM, Sand, Cocopeat, Sawdust	Bhatia *et al.* (2004)
8	Cut Roses	Soil, FYM, Sand, Cocopeat, Sawdust	Thakur (2005)
9	Tulip	Soil, Saw dust, Poultry manure, Sheep manure	Jhon *et al.* (2005)
10	*Gerbera jamesonii*	Cocopeat, Perlite, Vermicompost, Compost, Rice husk	Barreto and Jagtap (2006)
11	Oriental lily	Sand, Sawdust, Vermiculite, Moss	Sharma *et al.* (2007)
12	Freesia	Leaf mould, Mushroom compost, Poultry manure, control	Ali *et al.* (2011)
13	*Hydrangea macrophylla*	Soil, Fym, Sand, Rai forest soil, Rhododendron, Chir-pine	Latpate (2011)
14	Cymbidium	Soil, sawdust, cocopeat	Barman *et al.* (2012)
15	*Alstroemeria hybrid*	Sand, Soil, FYM, Rhododendron Forest soil, Rai forest soil	Jujhar Singh *et al.* (2013)

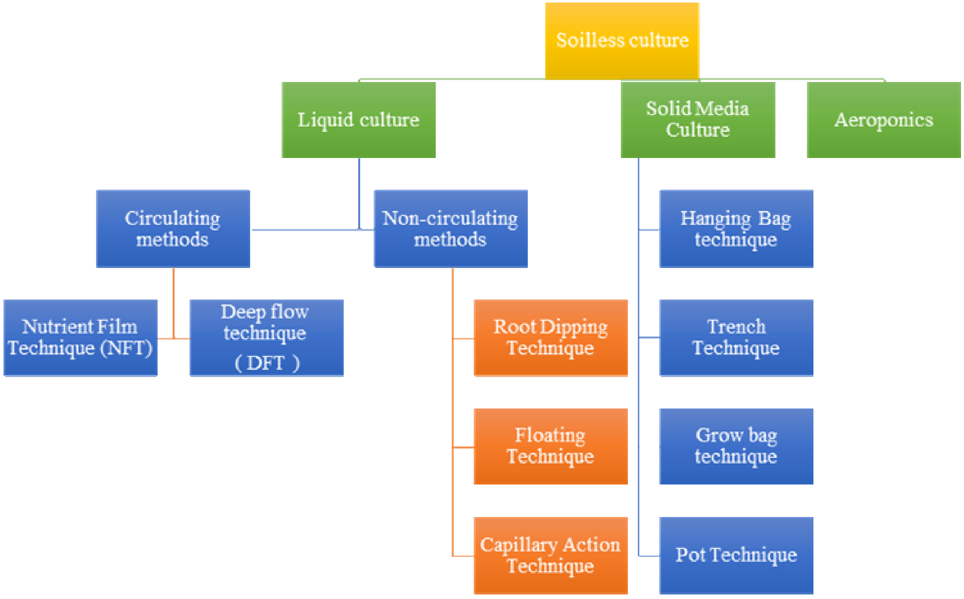


Fig. 5 : Flow chart about soilless cultivation

Liquid Culture or Hydroponics

The word hydroponics was derived from combination of two greek words, hydro, meaning water, and ponos, meaning labor (i.e., working water). It may be defined as the technique of growing of plants in nutrient-rich solutions instead of soil. In hydroponics, non-soil growing media can be used to provide mechanical support to the roots which support to the plants weight and hold it upright. Sand, gravel, river rock, floral foam, vermiculite, rockwool, perlite, peat moss, coir, coco-peat and sawdust are commonly used media in hydroponics.

Types of Hydroponic Structures:

1. Drip System:

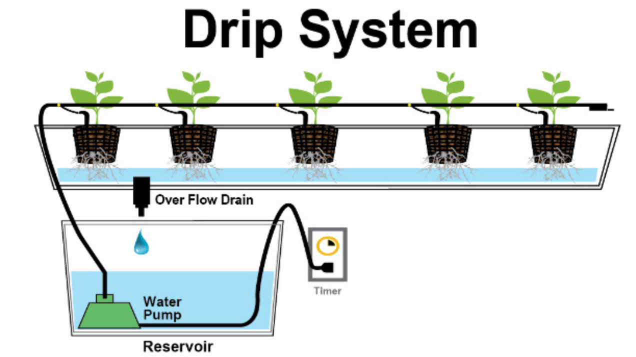


Fig. 6

In this system, the nutrient solution is being pumped directly to the roots of the plants with regulated flow. Nutrient solution from the tank or reservoir is provided to individual plants roots in appropriate proportion with the help of pump (Rouphael and Colla, 2005).

Wick System

This is simplest, least used type of hydroponic system requiring no electricity, pump and aerators (Shrestha and Dunn, 2013). Water or nutrient solution supplied to plants through capillary action. You can control the amount of water getting to the plant by using a larger/wider wick, or more than one. This system works well for small plants, herbs and spice and doesn't work effectively that needs lot of water.

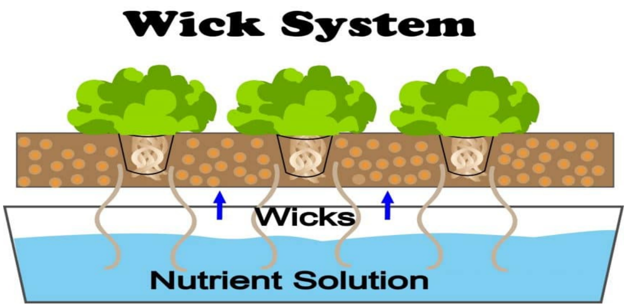


Fig.7 : Wick system

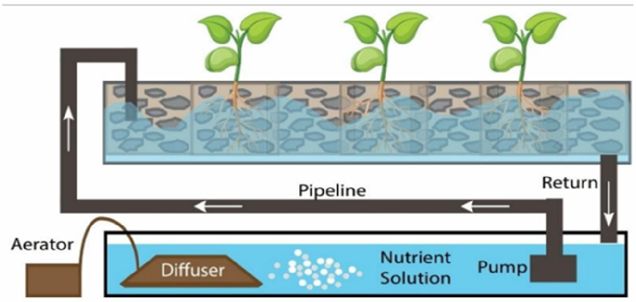


Fig. 8 : Ebb and flow system

2. Ebb-Flow (Flood And Drain) Systems:

Flood and drain systems can vary quite a bit in design and supposed to be first commercial hydroponic system which works on the principle of flood and drain. Nutrient solution from reservoir swamped through a water pump into system. The system uses gravity to return the excess water to the reservoir to be reused.

Fig. 9 : Ferns being grown on an ebb- and-flood growing floor.

Fig. 10 : Pot plants on ebb/flood tables (left and middle) and on a concrete floor in clay granulates (right).

(a) Circulating Methods

In circulating culture systems, plants are typically grown in containers or trays filled with an inert growing medium. The roots of the plants are suspended or supported in the medium, and the nutrient solution is continuously circulated to provide water and essential nutrients directly to the plants.

Deep Water Culture System

In this system, the roots of the plant are being immersed in the nutrient media. A Styrofoam or similar kind of floating platform on the nutrient solution holds the plants.

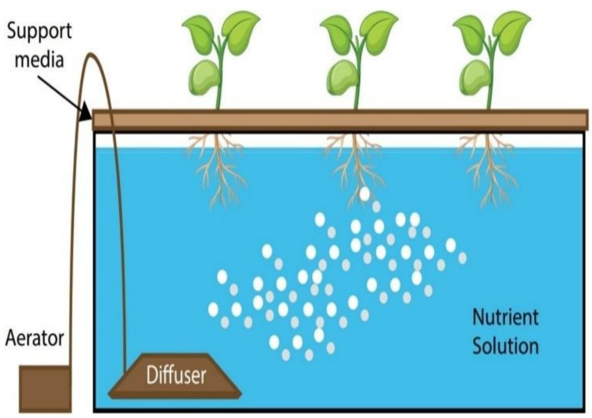


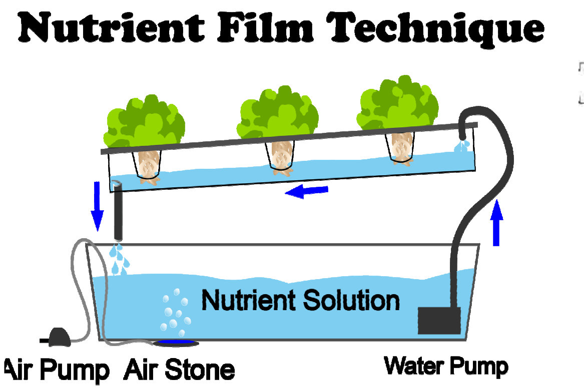
Fig. 11 : Deep water culture

Nutrient Film Technique (NFT)

NFT is a water culture technique in which plants are grown with their root systems contained in a trough or channel or gully which nutrient solution is circulated. The main features of an NFT system are a catchment tank containing the nutrient solution, a pump to circulate the solution and a series of pipes distributing the solution to the heads of the growing troughs, through which the solution falls by gravity down the catchment tank (Savvas *et al.*, 2013).

NFT has been reported to have many advantages as follows: Watering is greatly simplified, since it is no longer necessary to make day-to-day assessments of water requirements and the tedious task of cleaning blocked irrigation nozzles is eliminated. Uniformity of nutrient supply is ensured. Root temperature may be raised whenever required. The rapid turn-round of crops is readily achieved. Pollution of environment is minimized by reducing water and nutrient loss and using minimal substrate. However, it generally requires a higher grade of management; decisions have to be taken at relatively short notice since there is no buffer capacity.

In NFT, nutrient solution is circulated continuously or intermittently. Intermittent flow is practiced mainly to control the growth of plant and at the same time to save electricity and to reduce wear of the pumps. Intermittent circulation is based on time clock or solar integration. The time-clock offers a cheap but relatively inflexible system, whilst the solar integrator is a more expensive approach, which can compensate for changes in the light conditions.



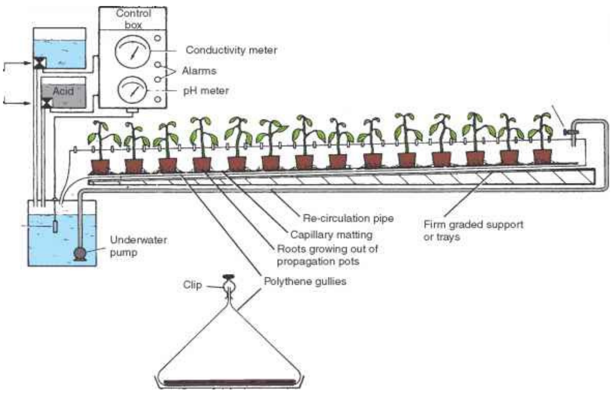


Fig. 12 : Nutrient film technique

B. Non-Circulating Method:

It refers to systems where the nutrient solution does not continuously circulate or flow throughout the growing medium.

Root Dipping Technique:

In this technique, plants are raised in small pots containing small amount of growing medium. Some of the roots are immersed in the solution while the rest remain hanging in the air above the solution for nutrient and air absorption.

Fig. 13 : Root dipping technique

Floating Technique

In this method, about 10 cm container are used in which pots are fixed in a thin and light sheet which floats on the nutrient solution filled in the container and solution is artificially aerated.

Fig. 14 : Floating technique

Capillary Action Technique

This technique works on the natural property of water to move through small spaces, such as capillary tubes or porous mediums, against the force of gravity. This technique promotes efficient nutrient uptake and minimizes water wastage in soilless culture systems.

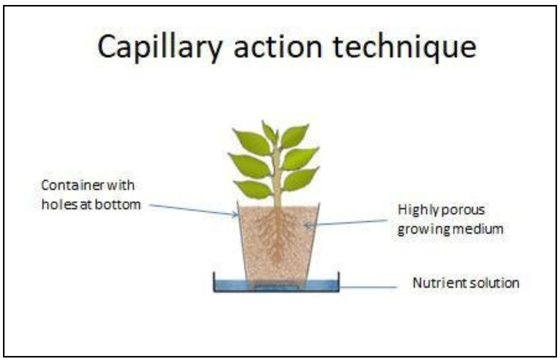


Fig. 15 : Pelargonium grown in capillary action technique.

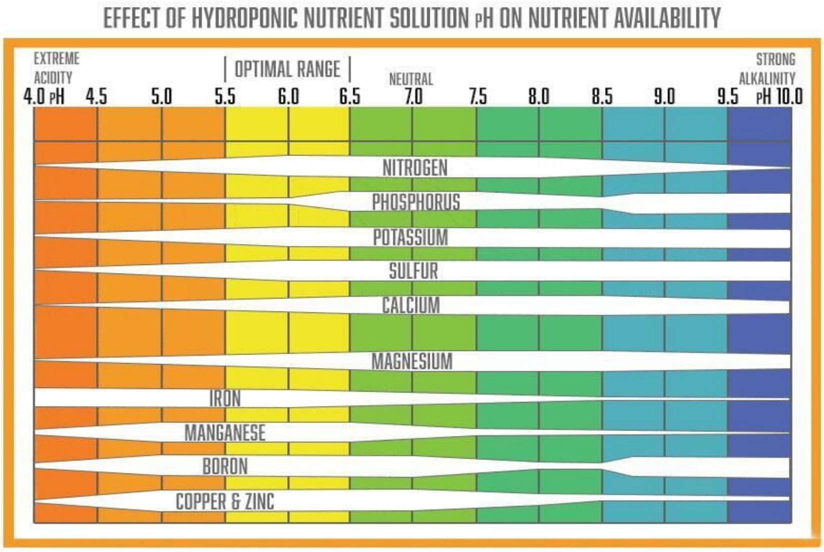


Fig. 16 : Nutrient solution pH

Advantages of Hydroponic Structures:

- Crops can be grown where no suitable soil exists or where the soil is contaminated with disease.
- Labor for tilling, cultivating, fumigating, watering, and other traditional practices is largely eliminated.
- Maximum yields are possible, making the system economically feasible in high-density and expensive land areas.
- Conservation of water and nutrients is a feature of all systems.
- This can lead to a reduction in pollution of land and streams because valuable chemicals need not be lost.

Disadvantages of Hydroponic Structures:

- The original construction cost per acre is great.
- Trained personnel must direct the growing operation. Knowledge of how plants grow and of the principles of nutrition is important.
- The reaction of the plant to good or poor nutrition is unbelievably fast. The grower must observe the plants every day.

Solid Media Culture

The media material selected for this culture 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 (Hussain *et al.*, 2014).

Trough Culture

In trough culture, the plants grow on plastic or plastic lined troughs built above ground. A drain pipe is placed on the bottom of the trough from one end to the other. Plants are placed at normal spacing and drip irrigation is used to feed each plant individually. The growing media used commonly in trough culture are coir, perlite, sawdust, sand and gravel.

Grow Bag Technique

Seedlings or other planting materials are planted in grow bags. On each side of the bags, there are two tiny drainage or leaching slots. Fertigation is used, with a black capillary tube connecting the main supply line to each plant. Before depositing the bags, the entire floor is covered with white UV-resistant polythene.

Hanging Bag Technique (Open System)

In this technique, UV treated thick polythene bags are used which are suspended above a nutrient solution-collecting channel. Therefore, this technique is also known as 'Verti-grow' technique. The openings on the sides of the hanging bags are crammed with seedlings or other planting materials that have been put in net pots. Inside the hanging bag, the nutrient fluid is dispersed uniformly by the micro sprinkler. The roots of the plants and the fiber of the coconut are moistened by the nutrient solution that flows down. Through holes drilled into the bottom of the hanging bags, extra solution is collected in the channel below and flowed back to the stock tank for nutrient solution. This system is suitable for both i.e. open space and in protected structures.

Fig. 17 : Hanging bag technique

Aeroponics

The science of plant cultivation without incorporation of the soil or a substrate culture. Where plant grows in the air with the assistance of an artificial support and no soil or substrate is required to support the plant. Basically, it is an air water culture cultivation system, the roots of plant are hanged inside a sealed container under darkness and openly exposed in the air to get water nutrient-rich spray through atomizers. The upper portion of the plant leaves and crown extend above the wet zone. The root and canopy of the plant are separated by the artificially provided structure. The system uses the nutrient-enriched spray in the air with the help of pressure nozzles or foggers to sustain hyper growth under controlled condition.

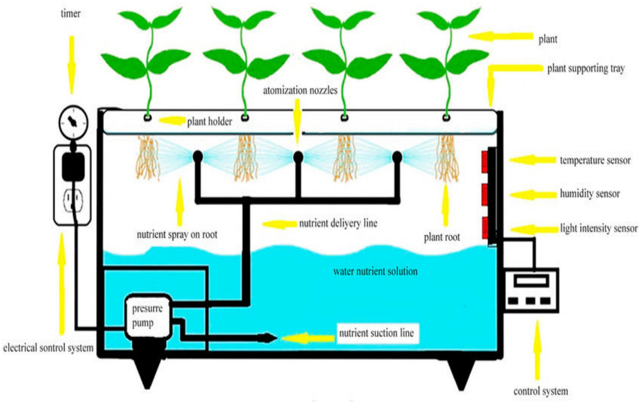


Fig. 18 : Aeroponics plant growing systems with computer-controlled techniques

pH and Electrical Conductivity Meter

In the aeroponics system, where water and nutrient solution is recycled repeatedly. Therefore, it is important to regularly measure the pH and EC value of the nutrient solution for successful plant growth. If the readings are not at the proper level, the grower needs to adjust them. The ideal pH and EC range for each plant depend on available environmental conditions Although, the pH and EC values of the prepared nutrient solution could not exceed than 7 and 2.5ds m^{-1} (Sonneveld *et al.*, 2009). The optimum EC and pH values of nutrient solution in aeroponics system lie between 1.5 to 2.5 ds m^{-1} and 5.5 to 6.5 and 5.0 (Chadirin *et al.*, 2007).

Light and Temperature

Temperature is the primary environmental factor that influences the frequency of plant growth and development. It influences not only on the initial growing stage but also on harvesting period. In the aeroponics system, both air and nutrient solution temperature should be controlled for quick plant maturation. As temperatures rise, the chemical processes proceed at faster rates and deteriorate the enzyme activities. The optimum temperature range for all plants is 15–25°C. However, the temperature of growth chamber should be not higher than 30°C and less than 4°C. The light intensity and quality, not only delivers the energy as well provide numerous morphogenesis and physiological responses for plant growth. To adjust the various light environments, recently a light emitting diode (LED) has spread as a new light source in the aeroponics system. The LED could be considered as the best light producer for plant growth in the aeroponics system. It provides multiple light qualities and effects of light on the plant growth in a controlled condition. Whereas, the light LED has smaller mass and volume, good life, energy-saving, single wavelength and narrow bandwidth.

Humidity and Dissolved Oxygen Concentration

Aeroponics system is the application of plant growth without soil by delivering water nutrient solution in the air. The system is based on 100% available moisture in the growth chamber. In addition, the humidity is the amount of available water in the growth chamber as water vapor content. In the aeroponics system, humidity is the main component required for successful plant growth and development. However, the plant growth is significantly affected by increase and decrease in relative humidity. It effects on plant physiological functions and creates diseases problems. Therefore, it is important to regularly maintain and control the required humidity concentration of growth chamber based on plant need. The aeroponics system provides best oxygenation environment for plant growth. It allows plant roots to grow in the air with a plentiful supply of oxygen. Hence, no any additional mechanism is required.

Conclusion

Soilless culture is rapidly gaining momentum, popularity and the fastest growing sector of horticulture. Soilless culture is more popular and accepted in some countries, especially in commercial production of flower crops. Though the upfront capital costs of setting up soilless culture is currently a barrier but in the long-run, as with all technology, costs will decline, making this option much more feasible. Continuing the process of research and development may lead to more cost-efficient structures and materials; to reduce 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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Conflict of interest

The authors declare no conflicts of interest relevant to this article**.**

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