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Sustainability and Microbial Components of Growing Media: A Review

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Abstract

Growing media is mandatory for the future sustainability of agriculture, especially horticulture. The use of microbial elements in growing medium to enhance plant development and growth, particularly productivity, has received more attention nowadays. Efforts are made to add beneficial microbes to the growth medium as inoculation agents or soil amendments. However, using microbial components in growth media has many obstacles, such as the necessity of moisture control and the risk of infection. Overall, the incorporation of microbes in fruit production growth medium showed encouraging results for increasing plant performance as well as sustainability. Deep insights are required to recognise the benefits and drawbacks of this strategy. Moreover, growers are seeking advanced future technology that would provide them with a healthy plant with a well-developed root system that may retain fertiliser and require fewer crop inputs. Furthermore, various non-renewable resources can have significant environmental consequences; the sustainability of growth, medium generation, and disposal remains an essential topic.

Keywords- *Growing media, advancements, sustainability, and microbial components*

1. Introduction: -

Soilless crop cultivation refers to the approach of establishing plants that do not rely on the soil as a supporting medium (Fussy & Papenbrock, 2022). This relatively basic description requires the encapsulation of plant roots within a permeable growing material known as a 'substrate' or 'growing medium'. Because of the limited area, it is possible for soilless farming to be more affordable than soil-based agriculture, resulting in higher earnings and earlier agricultural harvests (Nabi *et al.*, 2022). Moreover, such systems are more efficient in terms of water and fertiliser utilisation (Gonnella *et al.*, 2021).

Containerized plant growth presents two major hurdles to effective root growth. Against a traditional soil profile, a potted culture displays an extremely thin layer of growing media that rapidly goes through saturation upon watering. Furthermore, the smaller volume of containers limits the reservoir's potential between watering episodes (Barrett, 2016). In order to avoid root hypoxia and stress due to drought, an efficient medium of cultivation needs to possess an internal framework with the ability to maintain an optimal balance between water and air accumulation throughout and following watering episodes (Patil *et al.*, 2020). In fact, such media have become a breakthrough, allowing producers to precisely manage the flow of nourishment, air, and water to plant roots, eliminating diseases transmitted from the soil (Dhanasekaran *et al.*, 2020). Although the concept of an 'effective growth medium' varies depending on the situation, there are certain common factors that relate to all soilless growing media. A growth medium must provide optimum microbiological and chemical-related conditions. It must, moreover, fulfil the grower's functional and financial expectations.

A normal culture medium is made up of vitamins, glucose, amino acids, inorganic salts, and serum, which serves as an intermediary for growth factors, hormones, and attachment factors. Aside from providing nutrients, the environment also aids in controlling pH and osmolality. Culture medium is a combination of glucose, amino acids, vitamins, salts, and other nutrients that is obtainable from reputable sellers in either granular or liquid form (Banwo *et al.*, 2023).

Table 1. Merits and demerits of cultural media

Aspect	Advantages	Disadvantages
Composition	Adapted to the needs of a microorganism.	The cost of complex formulations could be high.
	May simulate the development conditions found in nature.	All microorganisms' growth may not be supported.
Preparation	May be made rather easily.	Needs must be sterilized to avoid contamination.
	Sterilisation is required to prevent contamination.	Controlling quality can be difficult.
Selectivity	Differential media may help in microbial identification. Promotes the isolation of particular microorganisms.	Selective media might stop desired organisms from growing. May ignore slow-growing or uncommon microorganisms.
Transparency	Provide a visual evaluation of growth.	Restricted to microorganisms that don't show any signs of growth.
	Characteristics of the colony are simple to see.	Limited usefulness for microscopic analysis.
Longevity	Suitable can be kept for a long time.	May deteriorate or become polluted over time.
	Long-term trials are suitable.	The media type affects shelf life.

The growing medium used in horticulture has a significant influence on rhizosphere microbial communities, plant nutrition and development, product quality, and eco-sustainability (Grunert *et al*., 2016). Growing media, also known as "substrates" or "plant substrates, that give roots a starting environment free of plant-borne diseases and with elements allowing for proper transpiration, water, and nutritional content delivery. Mixtures of growth medium ingredients and additives are frequently employed in the horticulture business. Constituents may have organic and inorganic white additives, which can be fertilisers, liming materials, bio-control agents, or water-absorbing substances (Savvas *et al.*, 2016). The particle size of these GM (growing media) and the container shape must be carefully adjusted to balance the amount of water and air circulation around the roots. Depending on the hydraulic qualities of the substrate, the height of the layer of substrate should be particularly high to allow for proper drainage and aeration (Heller *et al*., 2015). The physiological and chemical qualities of the growth medium are critical for the effective cultivation of container-grown crops in greenhouses and nurseries. Weeds and diseases must not grow on substrate yet be sufficiently lightweight to allow for straightforward transportation and shipment (Schaberg, 2019).

Growing media are extremely important in determining the microbial populations found near plant roots. Research on enhancing the microbial component of growth media to improve fruit sustainability, however, is lacking, and more research is required to comprehend how various microbial species interact and how this affects plant development, nutrient uptake, and disease suppression. Using this information, specialised microbial inoculants or amendments for certain fruit crops can be created (Elnahal *et al.*, 2022)

The review paper highlights the current improvements in the growth medium. It has a special emphasis on long-term viability and the microbiological proportion. It contributes to the research understanding of agricultural sustainability and displays practical information. It aids in the distribution of information, the identification of research gaps, and the advancement of ecologically friendly techniques in the fields of agriculture and horticulture.

Culture media/Growing media, examples of both: -

Culture media: -

Microbiology has advanced significantly because of the discovery of media optimisation for culture. Louis Pasteur invented the first liquid synthetic medium for culture in 1860 (Bonnet *et al*., 2020). A culture medium is a substance or chemical mixture used in a laboratory setting to encourage the growth and development of microorganisms. It offers all the nutrients, minerals, and additional growth elements that microorganisms require to thrive and reproduce. Culture media can be liquid or solid and can be selective or non-selective, according to the microorganism being grown. Isolation, verification, or the use of an appropriate culture medium is required for the characterization of microorganisms, which is a fundamental method in microbiology.

Culture media types: -

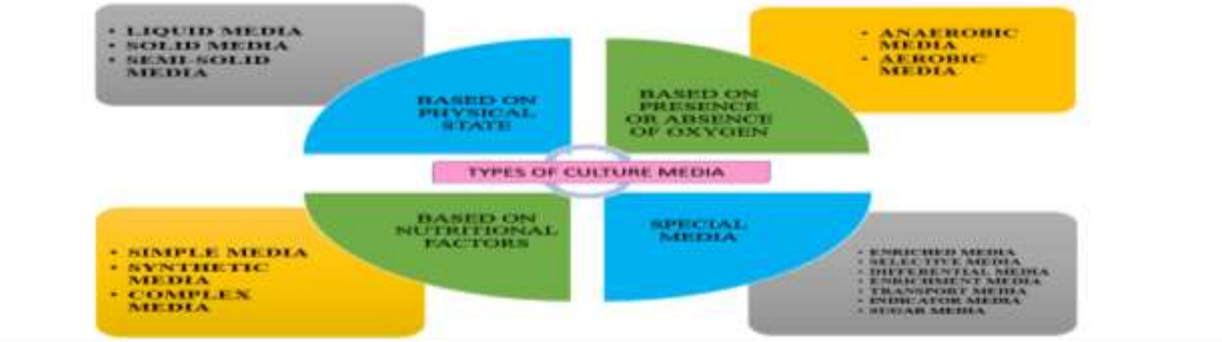

Fig.1 Different types of culture media

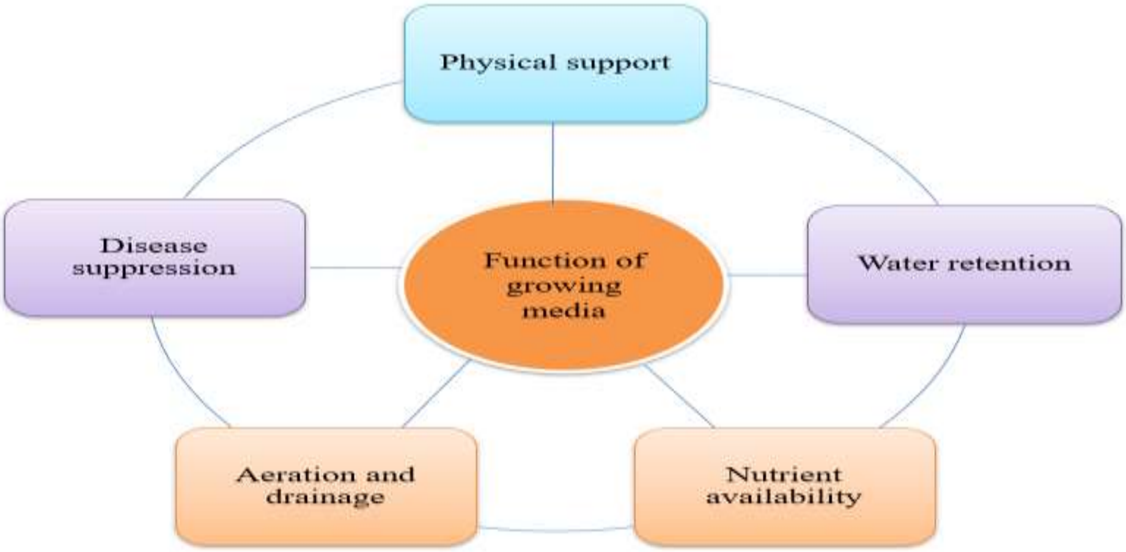

Fig- 2 Function of growing media

Shrinkage and Stability of Growing Media

Horticultural crops have small rooting volumes, they have requirements when it comes to growth medium. Aqueous absorption, buffering, availability, and oxygen diffusion must all be controlled. Furthermore, the pH and amount of nutrients and other ions should be according to the plant. The biological process of growing media does not compete with the plant. A steady growing medium is required for the effective and overall development of various crops. (Gruda *et al*., 2019). Stability may be described in three ways: a) physically, b) chemically, and c) biologically. Growing media's physical stability shows that its composition is stable, as is its ability to hold water, retention of moisture, aeration, and so forth, which are seldom changing. On the other hand, chemical stability includes buffering for pH as well as cations and anion in terms of cation exchange capacity (CEC) and anion exchange capacity (AEC). (Bar-tal *et al.*, 2019) also described that these properties may be influenced by the degradation or decomposition of the substrate. Biological stability is primarily concerned with the decomposition of organic materials. When organic material is susceptible to disintegration, nitrogen is immobilised, physical structure is lost, and chemical behaviour changes.

For long-duration crops, the substrate must exhibit little shrinkage, avoiding changing the root region's environment in a way that negatively affects plant growth and aesthetic appeal. Although moss made from peat is typically thought to be a rather stable substrate, new peats can shrink significantly over time (Gruda, 2019). Peat types differ in terms of structural stability: peats with greater levels of degradation (H5-6) are more durable than new peats (H2-H3). In some cases, it was found that coir is more stable than peat (Saha *et al.*, 2021), and coir shrinks by 19 or 21% after just 8 to 10 weeks. In a review evaluating peat-based and peatland-free media mixes, the high lignin degradation (not susceptible to microbial attack) concentration of peat was linked to the durability of peat-based media and revealed that the decomposition of the materials is inversely linked with the amount of lignin (Carlile *et al.*, 2019). Some compost kinds, such as peat and coir, may be prone to excessive contraction and negative changes in the medium's physical properties (Van *et al.*, 2020). Composts made up of dairy manure and seasoned pine bark have been shown in some situations to be consistent and shrinkage-resistant (Stewart-Wade *et al.*, 2020).

Recent advances: Biochar, potential and scope

Biochar—the solid by-product of biomass pyrolysis—has been produced and used as charcoal for thousands of years. Biochar has several benefits, including the generation of heat and power, the purification of flue gases, metallurgical processes, use in agricultural and animal husbandry, building materials, and even medical applications. Recently, a replacement for fossil carbon carriers has appeared in a number of these applications (Riahi *et al.*, 2017). Biochar's chemical features span from its basic composition to reactivity, pH value, and the physiological properties of carbonised biomass. Fast pyrolysis and the gasification process, both of which are theoretically regarded as generating biochar, additionally produce a solid with a higher carbon concentration, but this is merely a by-product of the procedure, and the quality is typically improper for many applications (Quicker *et al.*, 2016).

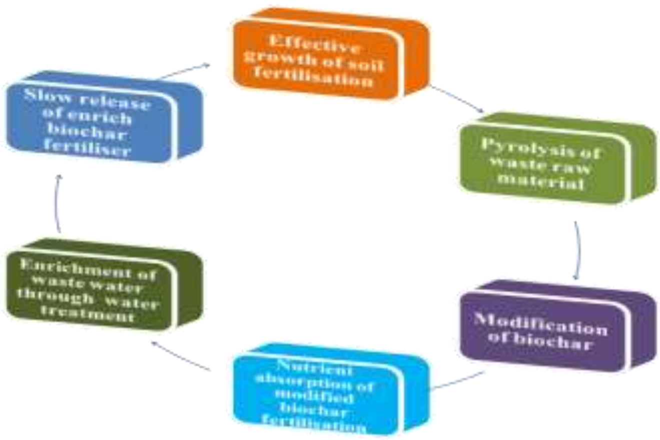

Fig:3 Recent developments in biochar research include the utilisation of sustainable biochar-based soil nutrients and additions.

Solid media culture (Aggregate system) The media material must be brittle, flexible, and capable of retaining air and water. Furthermore, it must be devoid of pests, illnesses, harmful compounds, nematodes, and so forth. Before using the medium, it must be sterilised. Techniques are:

A. Trench or trough technique B. Growbag technique C. Hanging bag technique D. Pot technique

A. Trench/Trough technique: Narrow trenches are utilised either beneath or above ground, with funnels made of tiles or any kind of asphalt material. Both troughs and trenches are coated with waterproof material to keep the growth medium detached from the exterior of the zone. The dimension of the trench varies according to the plants, with a minimum need of 30 cm. Coir dust, peat, vermiculite, sand or gravel, perlite, old sawdust, or a mixture of these can be used as ancient mediums. Water and nutritional solutions are delivered by drip irrigation or manually, depending on labour availability. Excessive compost solution is eliminated from the ditch or trough through a 2-2.5 cm diameter tube installed at the bottom. Tall vine plants, including tomato and cucumber, require extra support to sustain the great weight of the fruits. (Nisar *et al.*, 2020).

B. Grow bag technique: This approach employs 1 -- 1.5 m long white (within black), 6 cm tall, and 18 cm wide anti-UV polythene bags containing old, sterilised coir-dust. These bags are organised in horizontal rows from one end to the other, with walking space between them. If there are more plants, the tandem row approach can be employed. Squeeze saplings in growth media or coir debris through tiny openings on the upper side of the bag, and 2-3 plants per pouch will be maintained. On both sides of the bags, two tiny slots are cut for dissipation or leaching. Fertigation is performed on each plant using black capillary tube-like arrow drippers linked to the main supply line. To encapsulate the whole area ahead of laying the bags, white anti-UV polythene is used (Singh and Patel 2018).

C. Hanging bag technique (open system): This approach is referred to as the 'Vertie-Grow' technique. Lengthy, robust, cylinder-shaped UV-treated polythene bags filled with sterilised media, such as coconut fibre, knotted at the apex with PVC tubing, and packed at the bottom end of the bag. The fertiliser solution is pushed through a tiny sprayer placed inside the detachable bag's top and drops down, saturating the medium and plant roots. The excess solution is drained from the hanging bags via holes or outlets and returned to the stock tank.

This technique is more suited to growing green crops (Singh *et al.*, 2016). To avoid mould development within, black codes are commonly used to feed nutrition solutions.

Different kinds of media:

Organic Media:

Organic Media	Means of working	Prominent Feature	Used for/Suitable Plant	Reference
Vermicompost	Biologically mediated processes such as the supply of crop-growth controlling substances, and improvements in soil biological functions	Microbial activity, sustainable environment, High water retention capacity	Strawberry, blueberry and grapes	Singh *et al.*, (2020)
Coco peat	Provides with simple porosity for establishing roots as well as adequate aeration for healthy plant growth	Promote moisture retention and porosity	Raspberry, strawberry	Kaushal *et al.*, (2020)
Compost	Conversion of decomposing organic wastes into permanent humus by native microflora such as bacteria, fungus, and actinomycetes	Improve soil structure, soil fertility	Tomato, paper, beans, strawberry, and raspberry	Mironov *et al.*, (2021)

Inorganic media:

Inorganic Media	Mechanism	Features	Suitable plants	Reference
Perlite	Volcanic mineral that has been treated and baked to produce a thin material with high porosity. It swells when heated and helps in controlling soil water-holding capacity and aeration.	Good aeration, pH Neutral and good drainage	Mainly for vegetable productions	Singh *et al.*, (2020)
Vermiculite	Vermiculite-containing substances must be mixed dry; when wet, physical properties deteriorate because the particles fall flat. Vermiculite may hold positively charged nutrients including Ca, Mg, and K.	High water holding capacity, pH Neutral, Good aeration	Tomato, succulents and cacti	Pauwels *et al.*, (2023)
Rockwools	A rockwool growth mechanism slabs are arranged in rows; holes for plants are cut in the plastic enclosing each slab and stuffed with solution. The donor organs are put on the slabs after being soaked for about 24 hours. The watering system delivers a full nutritional solution to the Rockwool cubes.	Good water retention, pH stable, reusability, Good aeration	Mostly applied on hydroponic systems.	(Pimentel *et al.*, 2020)
Sand	Sizes ranging from 0.002 to 0.010 in (0.05 to 0.25 mm) are insufficient and will clog drainage holes and limit aeration. Sand has several drawbacks when used as a growing medium, one of which being its weight. This might lead to handling concerns and higher shipping expenses.	Good drainage and stability, pH Neutral, Inexpensive	Strawberries	Hoglund, (2022)

Microbial Activity in Growing Media:

Microorganisms can weakly or heavily colonize organic material prior to use in sterile media. Most peats have a low pH associated with a low natural microbial population. Peat microflora consists of only a few genera and species. Many may be inactive or resting, especially in deep marshes (Islam *et al.*, 2019). Several different microorganisms can abundantly colonize other organic materials in substrates before using them. Factors affecting bark composting, including details of the microbes involved in the process, are well described in a comprehensive treatise. Potentially phytotoxic organic matter may be destroyed during this process. In addition, the nitrogen requirement of a medium made from composted bark is lower than that of uncompacted bark (Carlile *et al.*, 2015).

Saprophytic microflora of soil less media: Several approaches have been used to identify and monitor the activity of saprophytic microflora. Most of them used developed techniques to monitor soil microbial activity. A common approach to soil patterning was to use the baffle plate technique. This technique was used in most cases to list viable bacteria. However, this technique estimates the number of nitrifying bacteria in peat. Plants are excellent hosts for microbial growth. Microbial growth thrives at plant interfaces and body tissues, particularly those rich in nutrients and water. Microbes can be useful, harmful, or neutral to the host species depending on their type and behaviour. Plant health and production are highly dependent on microbial populations (Francis *et al.*, 2022).

Different parts of the plant can create an ideal environment for microbial growth. Microbes can thrive in various parts that surround and cover plants, including the spermosphere (the part of the dirt that contains germinating seeds and contains food that promotes microscopic growth), the phyll2osphere (the outer epidermis of the plant, including alternation dependent on external variables such as precipitation, temperature and radiation) and the rhizosphere (the region containing plant roots and the soil or substrate adjacent to them). Because the zone (root) carries a substantial quantity of carbon and strength, the rhizosphere may develop deep links between soil, plant, and micro fauna. Organic stuff discharged by the plant's roots is created by photosynthesis and other plant activities. Plant-promoting rhizobacteria, commonly known as rhizosphere bacteria, contain plant-promoting capabilities. Due to their growth-promoting and biological control properties, several PGPR compounds have been used in agriculture. Plant interactions with PGPR have been demonstrated to improve plant health and development, minimise disease-causing microorganisms, boost nutrient availability, and accelerate nutrient digestion (Elnahal *et al.*, 2022).

Three distinct groups are defined to identify the relationships between beneficial microbes and flora.

1. The initial group consists of microbes, entrusted with plant nutrition and somehow cooperating with the plant, including nitrogen-fixing bacteria.

2. The next group is biocontrol molecules, which are organisms that indirectly promote crop development by inhibiting the growth of plant diseases.

3. The latter group of microorganisms effectively influence plant development by creating plant hormones, degrading phosphates, increasing iron absorption and/or producing volatile compounds. The main advantage associated with beneficial bacteria is their ability to consume phosphorus for their needs, which is therefore available in sufficient quantities in liquid form in the growing layer of the soil. Pseudomonas, Fusarium, Bacillus, Penicillium, Flavobacterium, Sclerotium, Aspergillus and Micrococcus have all been identified as bacteria involved in the entire digestive process (Izah *et al.*, 2013).

Sustainability In Growing Media

Soilless cultivation is well-known around the world for its capacity to sustain efficient and

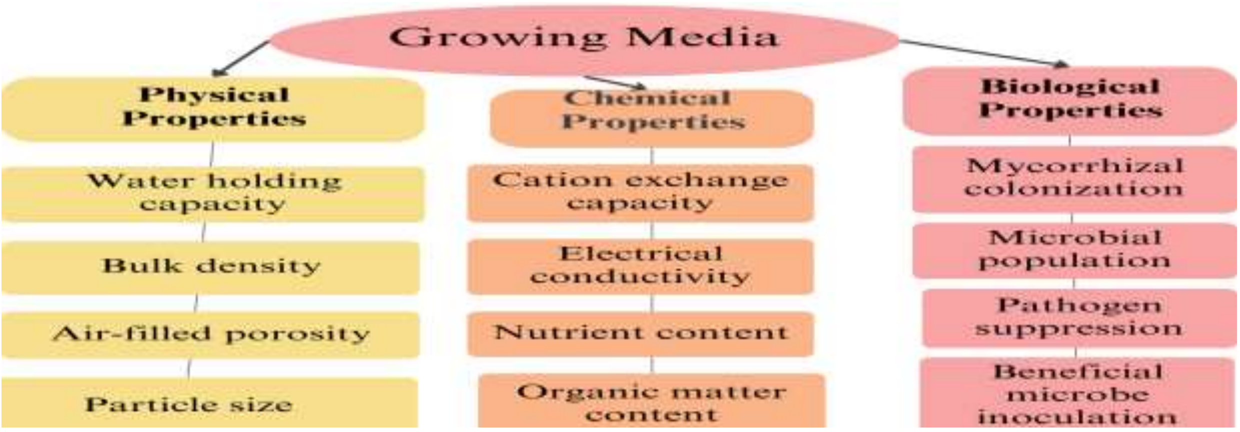

Fig:4 Sustainable growing media with different soil properties

intense plant production. Production techniques vary, but most rely on a porous substrate or growth medium to provide water and nutrients to the plants. The primary motivators for selecting component materials in growth medium are primarily performance and cost factors. However, growing awareness about the environmental implications of some regularly used materials has prompted researchers to seek out and evaluate more ecologically friendly alternatives. There has been an appropriate emphasis on renewable materials derived from agricultural, industrial, and municipal waste streams; yet, while many of these show promising outcomes at the experimental level, few have been commercialised. Implementation of more environmentally friendly manufacturing methods (Fouladi *et al.*, 2023). While tremendous progress has been made in the previous decade to better understand the environmental implications of various soilless growth media, major information gaps remain.

Impact Of Growing Media Used in Subtropical Fruit Crops

Name of Crop	Growing media used	Effect on vegetative growth	References
Litchi	(Orchard soil +rhizobacteria)	Nitrogen levels in leaves will be more	(Sar Sarita *et al.*, 2018)
Passion Fruit	(50%) FYM + (50%) Vermicompost	Maximum stem girth, number of tendrils/vines and vine spread observed at various time intervals.	(Lodhi *et al.*, 2022)
Strawberry (Fragaria × ananassa)	i)Perlite along with farmyard manure	Improved significant Plant height, leaf number, area of leaf and more resultant number of runners.	(Thakur and Shylla, 2018)
Strawberry (Fragaria × ananassa cv. chandler	ii)coco peat: vermiculite (25:75)	Maximum length of petiole, spread of canopy, diameter of crown, fresh weight of shoot, dry weight of shoot, number of leaves, total leaf area, fruit weight, diameter of fruit and observed length of fruit.	(Raja *et al.*, 2018)

Impact Of Growing Media in Tropical Fruits

Crop	**Growing media used**	**Effect on vegetative growth**	**Effect on Rooting**	References
Mango	a) Soil: FYM: Sand (1:1:1) b) Top soil: sand: FYM c) Sand: farmyard manure: soil (1:2:3) d) Vermiculite: peat moss: sand (1:2:1) e) Coir pith: compost: sand: soil (1:1:1:1) f) Mix of farmyard manure: sand: soil (1:1:2) g) Soil: Sand: Compost: Coir pith (1:1:1:1) h) Soil, sand and vermicompost (1: 1: 2) i) Cocopeat: leaf manure: compost (1:1:2) j) Soil: FYM: Sand (3:2:1)	a) Maximum plant growth b) More number of leaves c) largest leaf area measured d) Increased stem girth in 120 days after germination and180 days after germination. f) Mango cv. Master royal produced the largest stem diameter 180 days after germination g) Improved internode length of 10.38 centimetres h) Maximum height and leaf number. i) Maximum height improved node number, leaf number	h) Highest root number, maximum tap root length, maximum root girth and maximum length of root and root dry weight 1.Produced the longest root length	a) (Rani *et al.*, 2020), b) and c) (Iqbal *et al.*, 2022) d) (Rani *et al.*, 2020), e) (Gawankar *et al.*, 2020) f) (Dubey *et al.*, 2021) g) (Ma *et al.*, 2022) h) (Kaur 2017) i) (Let *et al.*, 2020) j) (Iqbal *et al.*, 2022)
Banana	Sand:Vermiculite:Vermicompost (1:1:1)	a) Improved height of plant, no.of suckers, leaf number and girth of pseudostem.	-	(Chamling *et al.*, 2021)
Guava	Vermiculite: sand: FYM (1:1:1)	More new shoots per plant with maximum height of	Highest root percentage	(Sharma 2022)

		plant and more leaves and maximum stem thickness.		
Papaya	Soil: Pond Soil: cocopeat (1:2:1)	Improved leaves per seedling, seedling length, girth, seedling vigour index, seedling fresh and dry weight.	Root dry weight.	(Jiya *et al.*, 2020)
Papaya cv. Pusa Nanha	Pond soil: vermicompost: Vermiculite: Perlite (1:3:3:3).	Increased seedling vigour, maximum stem girth, leaf number, maximum shoot fresh weight.	Length of root, maximum root fresh weight, and maximum shoot root ratio	(Dash *et al.*, 2019)

Impact Of Growing Media on Temperate Fruit Crop

Crop	Growing media use	Effect on vegetative growth	Effect on rooting	References
Apple (HRMN-99)	Vermicompost leaf compost and farmyard manure (2:1:1)	1. The maximum plant height, leaf number, and bud break have taken a minimum of days. 2. The maximum plant spread area was achieved.	—----------	1. (Verma *et al.*, 2010) 2. (Kamatyanatti *et al.*, 2019) 3. (Meena *et al.*, 2017) 4/5. (Kumar *et al.*, 2017) and (Dwivedi and Agnihotri 2018)
Grapes	1. Sand + 10 or 20% coco peat (Dogridge and 1613C) 2. Agricultural soil and sand (75:25 v/v) 3. Canal silt and bagasse (1:3)	1. Maximum amount of leaves per stem cutting	1. Better rooting hardwood the highest percent of rooted cutting was observed.	1. (Jaleta *et al.*, 2019) 2. (Haile 2017) and (Galavi *et al.*, 2013)

Conclusion

Recent advancements in growth medium sustainability have concentrated on lowering the environment in contrast to conventional growing methods. This has resulted in the discovery concerning various fresh materials and procedures that are more environmentally friendly and sustainable. Insertion of microbes is one such strategy that can promote plant development while reducing the requirement for artificial/synthetic fertilisers. Such elements can also help to increase soil health and minimise plant disease risk. Overall, these advancements may help to the development of a more environmentally friendly/beneficial and efficient approach to plant cultivation that is healthier for both the environment and the economy, including plant health.

Future Outlook: -

With the growing demand for sustainable growth and environmentally friendly methods, the concentration of focus on invention of new, improved, and innovative materials and techniques are becoming more efficient and effective. Such experiments will lead to development of some novel growing media which have potential of better and improved plant growth with reduction of the necessity of synthetic fertilizers. Furthermore, there will be a greater emphasis on the usage of renewable resources.

Research Gap And Future Directions

Incorporating a microbial component inside these growing media has led to positive results in terms of promoting plant growth, nutrient availability, and disease resistance. However, there is a research gap in understanding the specific role and impact of microbe communities' diverse growth conditions on fruit production sustainability. Although microbial communities have been integrated into growing media in studies, more research is needed to determine the diversity and makeup of these microbial communities regarding various growing media. Understanding the particular microorganisms and how they interact with plants might help us better understand their functional roles, capacity for nutrient cycling, and potential for disease control. Additionally, it is essential for maximising sustainable fruit production practices to comprehend that different plant growth phases, fruit development, and shifting environmental conditions affect microbial community dynamics. Methods through which microbial populations interact with plant roots, affect nutrient availability, control plant immune responses, and support general Plant production and health need to be clarified through additional study. Deep insights are required to fill the information gap in recent improvements in fruit growing media, especially with respect to the microbial element and its implications on sustainability. For sustainable fruit production practices to be optimized and long-term environmental and economic benefits to be realized, Understanding the composition, dynamics, processes, and management approaches associated with microbial communities in the growth medium is critical. Filling in these gaps will help to discover innovative methods for raising fruit quality, yield, and sustainability.

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