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# Prospects of Natural Fibre Crop Based Plant Growth Substrate in Soilless Crop Production System: A Review

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## ABSTRACT

The human population in the world will reach about 9 billion by the year 2050, so food security is one of the pivotal themes of the new millennium which is the most urgent challenge for the agricultural sector. Food production relies on the availability of resources, such as land, freshwater, fossil energy and nutrients. Due to problems such as pests and diseases in soil, lack of suitable soils or great variations in soil types and shortage of fresh water for irrigation, using soilless culture systems for vegetable production are increasing in the world. In a country like India, due to rapid urbanization, adoption of soilless culture is gaining momentum for improving the yield and quality of the produce. Various reasons persist for the continued growth of soilless production as part of agriculture. Hydroponic is a method of growing plants without soil using water, other soilless media, and nutrient solutions. Several characteristics are considered in selecting materials for soilless growth media such as good draining, high water holding capacity, high ionic exchange capacity and their devoid of weeds, pests, and pathogens. The material used in the media should also be inexpensive, accessible, and preferably organic to be better recycled in nature. Natural Fibre Crop Based Plant Growth Media are lighter in weight, biodegradable, eco-friendly, sustainable and cheaper compared to currently available material like Zeolite, Perlite, Rockwool etc. This review explores the prospects of natural fibre based substrate and their waste by-products like coir, wool waste, pineapple leaf fibre waste, banana pseudostem fibre waste, wood fibre etc., in a holistic manner. More involvement of substrate producers and end-users in educational and planning efforts could improve the quality of growing media by introducing added-value characteristics. This review attempted to provide an overview of hydroponic systems, soilless culture, their types, various popular substrate used and prospects of inexpensive, locally available natural fibre crop based growth media or substrate for soilless crop production systems.

## HIGHLIGHTS

- Soil degradation, availability of suitable soils, high pests and disease problems lead to the increased adoption of soilless culture for improved crop production throughout the world.
- In India, due to rapid urbanization, adoption of soilless culture is gaining momentum for improving the yield and quality of the produce.
- Types of hydroponic systems, popular growth media used in soilless systems have been discussed.
- Natural Fibre based Plant Growth Media are biodegradable, eco-friendly, sustainable and cheaper compared to commercial media.

**Keywords:** Soilless culture, natural fibres, growth media, hydroponics, coir, wool waste

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With global climate change and increasing human population, agriculture crops are under constant stress of high yield and better quality. The conventional approach of heavy dose of synthetic fertilizers and pesticides is neither safe nor sustainable. The natural textiles can assist the tomorrow's agriculture needs. They can reduce the requirement of fertilizers/pesticides. They can withstand solar and UV radiation much better than synthetic fibres. They have potential to retain moisture for long time. Natural fibre textiles are source of fertilizer upon their degradation. Considering that the human population in world will reach about 9 billion by the year 2050 (Tilman *et al.* 2002), it appears clear that food security is one of the pivotal themes of the new millennium and, reasonably, the most urgent challenge for the agricultural sector. However, it should be considered that the progressive drop of fertile soil surface, due to environmental pollution and urbanization phenomena (Chen, 2007), greatly complicates the context. Due to problems such as pests and diseases in soil, lack of suitable soils, and shortage of fresh water for irrigation, using soilless culture systems for vegetable production are increasing in the world (Dorais *et al.* 2001).

Plants do not need soil in order to grow and survive. Soil act as a medium for plant to help support it and to retain nutrients. However, any medium that is stable enough to support plant and can retain nutrients can do the same job as soil without being restricted to the ground. This is where hydroponics comes in; hydroponic is a method of growing plants without soil (Mason, 1990) using water, other soilless media, and nutrient solutions. The term 'hydroponics' was coined by Gericke (1937). The science of hydroponics is characterized by the fact that soil is not needed for plant growth butthe elements, minerals and nutrients that soil contains are definitely required. Soil is simply the holder of the nutrients, a place where the plant roots traditionally live and a base support for the plant structure. In a hydroponic solution, one provides the exact nutrients the plant needs in precisely the correct ratios so that they can develop stress-free, mature faster and, at harvest,are the best in quality acceptable both to customer and consumers liking. The kinds of plants that can be cultivated in a hydroponic system are almost endless, including house and flowering plants, vegetables, and herbs (Nicholls, 1990). Several characteristics are considered in selecting materials for soilless growth media such as good draining, high water holding capacity, high ionic exchange capacity and their devoid of weeds, pests, and pathogens (Cantliffe *et al.* 2003). The material used in the media should also be inexpensive, accessible, and preferably organic to be better recycled in nature (Shaw *et al.* 2004). Advantages of Natural Fibre Crop Based Plant Growth Media are: they are lighter in weight, biodegradable, eco-friendly, sustainable and cheaper compared to currently available material like Zeolite, Perlite, Rockwool etc. Natural fibre crop residue based plant growth media when combined with waste wool will not only provide physical support to plant growth but will also add nutrients to it (wool contains 16-17% nitrogen and 3-4% sulphur). This review attempted to provide an overview of hydroponic system and prospects of inexpensive, locally available natural fibre crop based growth media or substrate for soilless crop production systems.

## Hydroponics and Global Food Challenges

Food production relies on the availability of resources, such as land, freshwater,fossil energy and nutrients (Conijn *et al.* 2018), and current consumption or degradation of these resources exceeds their global regeneration rate (Van Vuuren *et al.* 2010). World agriculture has changed dramatically over the last few decades, and this change continues,since the driving forces for these changes are still in place. These forces consist of the rapid scientific, economic, and technological development of societies throughout the world. The increase in worlds' population and the improvement in the standard of living in many countries have created a strong demand for high-value foods and ornamentals and particularly for out-of-season, high quality produce. The demand for floricultural crops, including cut flowers, pot plants and bedding plants has also grown dramatically with the increase in life standard. The result of these trends was the expanded use of a wide variety of protected cultivation systems, ranging from primitive screen or plastic film covers to completely climate-controlled greenhouses (Raviv and Lieth, 2008). The major cause for shift away from the use of soil was the proliferation of soil-borne pathogens in intensively cultivated greenhouses. The ban on the use of methyl bromide (which is considered as a reducing agent of the atmosphere ozone layer) accelerated the move from soil to substrates growing systems. Soil was replaced by various substrates, such as stone wool, polyurethane, perlite, scoria (tuff) and so on, since theyare virtually free of pests and diseases due to their manufacturing processes. Also in reuse from crop to crop, these materials can be disinfested between uses so as to kill any microorganisms. The continuing shift to soilless cultivation is also driven by the fact that in soilless systems it is possible to have better control over several crucial factors, leading to greatly improved plant performance (Raviv *et al.* 2019).One of the main future challenges for global horticulture is to produce adequate quantities of affordable food in less-developed countries. Simple, low-cost soilless production systems may be part of the solution to the problems created by the lack of fertile soils and know-how.

## Growing Methods in Hydroponics

### *Circulating methods (closed system)/ Continuous flow solution culture*

**1. Nutrient Film Technique (NFT):** Nutrient film technique (NFT) uses an approach whereby roots are suspended in a trough whereby a thin layer of nutrient solution is continually recirculated. The NFT system was developed beginning in the late 1960s by Cooper (1975). Ideally, the bottom of the roots are exposed to the nutrient solution while the top arekept moist but not water logged. Since the plant roots are not in a growing medium, it is crucial that they are kept moist at all times. Inmost NFT systems, the nutrient solutions mixed ina primary reservoir, are cycled through the channels and back to the reservoir. NFT is ideal for short terms crops like lettuce, leafy crops and herbs.

**2. Deep flow technique (DFT):** Deep Flow or Deep water culture are basically a relatively large vessel filled with nutrient solution with the roots dispersed freely in this liquid. The plant is held above the water surface and all fertilizer nutrients are dissolved in the water. Generally commercial installations are aerated with both air pumps (or by injecting oxygen from tanks) and water pumps. Water movement is important to ensure proper mixing/replenishment of nutrients and dissolved oxygen. The flow rate and water movement are customized by the grower, increasing either if oxygen becomes deficient or the plant shows signs of nutrient deficiency.

### *Non-Circulating methods (open system)/ Static solution culture*

**1. Float system:** Float systems have the advantage of the economy and the surface for the nutrient solution. Most float systems are long, rectangular reservoirs built out of cement or wood and lined with a durable polyliner. Holes are cut in a foam board which floats on the surface of the water and plants in net pots are set in the holes. The plant roots dangle in heavily aerated nutrient solution.

**2. Aeroponics:** Aeroponics is a method of growing plants where they are anchored in holes in Styrofoam panels and their roots are suspended in air beneath the panel. The aeroponics culture is usually practiced in protected structures and is suitable for low leafy vegetables like lettuce, spinach, etc (Sardare *et al.* 2013). Aeroponics involves spraying the nutrient solution onto the roots by pushing the nutrient solution through misters either continuously or many times per hour within the root zone. The root zone is primarily air and the roots, the water quantity is similar to NFT in that only the floor of the root zone is wet and it is constantly draining back into a reservoir. The water is filtered as part of the continual reuse, so as to avoid clogging the misters in the root zone.

**3. Aquaponics:** In hydroponics, a specific nutrient formula is mixed in solution and is fed to the plants. In aquaponics, aquaculture (fish farming) is combined with hydroponic production. The nutrient-rich waste water from the fish tank is pumped through plant beds.

**4. Ebb and Flow system:** The Ebb and Flow (also known as flood and drain)method of hydroponics simply floods a growing area for 5 or 10 minutes and then the nutrient solution drains away. The nutrient solution is stored in a reservoir that can be located under the grow table. Ebb and Flow is common in hobby systems but not often found in commercial production. In an Ebb and Flow system, the plant roots are usually grown in a medium of perlite, rockwool or expanded clay pebbles.

### *Media culture*

The media culture method has a solid medium for the roots and is named for the type of inert medium, e.g. sand culture,gravel culture or rock wool culture. There are two main variations for each medium, sub-irrigation and top-irrigation. However, it is classified as follows:

- Hanging bag technique
- Grow bag technique
- Trench or trough technique
- Pot technique

## Popular Growth Media or substrate

### *Inorganic Media*

#### 1. Natural: Unmodified

***Sand:*** Sand can be steam-sterilized. With thin layers, the pores may rapidly fill with water, which disturbs the steaming process (Kipp *et al.* 2000). Sand is very durable because it is neither chemically nor biologically altered during the course of its use as a growing medium.

***Tuff:*** Tuff is a common name for pyroclastic (Greek pyro 'fire', and klastos 'fragment') volcanic material, characterized by high porosity and surface area. Rapid cooling of magma during eruption prevents the formation of primary minerals and, therefore, pyroclastic materials contain mainly vesicular, volcanic glass. Tuff is a stable material, which can last for many years. Growing plants may even improve the chemical properties of tuff due to the accumulation of organic matter and low-molecular-weight fulvic acid (Silber and Raviv, 1996).

***Pumice:*** Pumice, like tuff, is a product ofvolcanic activity and usually forms from silicic lavas developed in rhyolitic composition,rich in gases and volatiles (Challinor, 1996). Rapid releases of pressure during volcanic eruptions lead to gas expansion and the formation of low-density materials composed of highly vesicular volcanic glass.

#### 2. Natural: Processed

*Perlite:* Perlite is a glassy volcanic rock with a rhyolitic composition and 2–5 per cent of combined water (Dogan and Alkan, 2004). The main known world's perlite reserves (about 70 per cent) are located along the Aegean coast in Turkey. The commercial product is produced by heating the ground, sieved material to 760–110$^{o}$C. Perlite is frequently used in potting soil mixtures and as a standalone growing medium (Grillas *et al.* 2001; Gül *et al.* 2005). It is produced in various grades, the most common being 0–2 and 1.5–3.0 mm in diameter. Perlite is neutral with a pH of 7.0–7.5, but it has no buffering capacity and contains no mineral nutrient.

***Vermiculite:*** The substrate, named expanded Vermiculite, is produced in a similar way named exfoliation to perlite by heating the grinded and sieved material to 1000°C. As result, expanded Vermiculite consists of granules with an accordion shape, light weight and high porosity (Kipp *et al.* 2000). Vermiculite is used as a sowing medium and as a component of potting soil mixtures. Fine grades are used mainly as a mulch in transplant production while coarse grades are frequently used in rooting media (Wright, 1989). Vermiculite is neutral clay, with a pH of 7.0–7.5 and low EC.

***Zeolite:*** Zeolites are crystalline hydrated alumino silicates of alkali and alkaline cations that possess infinite, three-dimensional crystal structures (Ming and Mumpton, 1989; Mumpton, 1999).Due to their ion exchange, adsorption, hydration–dehydration and catalysis properties, zeolites are widely used in agriculture and in numerous industries for the removal of pollutants from waste and drinking water (Ming and Mumpton, 1989; Mumpton, 1999). Zeolites possess extremely high CEC values (220–460 cmol $kg^{-1}$) as well as are latively high BD (1.9–2.3 g $cm^{-3}$) (Ming and Mumpton, 1989) and therefore the use of zeolite as a single component growing substrate is not recommended.

#### 3. Natural: Mineral Wool

***The stone wool or Rockwool:*** The stone wool that is used in horticulture is mainly used as slabs or blocks of bonded fibres, but is also available in granulated form as a component of potting mixtures. Stone wool is manufactured by heating a mixture of three natural raw materials: 60 per cent diabase (a form of basalt rock, dolerite), 20 per cent limestone and 20 per cent coke. After one or two crop cycles, stone wool is usually discarded, producing a high volume of waste (approximately, 125 $m^3$ per hectare of plant production). This environmental issue of the waste is one of the major problems in the horticultural use of mineral wool, as it cannot easily be returned back to nature. Disposal of used horticultural stone wool in landfill sites has been carried out in all countries where crops have been grown on stone wool; such disposal method is either increasingly less available or unsustainable (Bussell and McKennie, 2004).

***Glasswool:*** Glasswool is very light and can contain a lot of water and air. In contrast to stone wool, the fibre diameter of glass wool can vary, which affects the water-holding capacity. By having finer fibres in the upper part of the slab than the lower part, it is possible to obtain better water content distribution over the height of the slab.

### 2. *Synthetic Organic Media*

***Foam mats (Polyurethane):*** The product is a polymer that contains excess di-isocyanate groups, which react with water to release $CO_2$ and induce foaming of the polymer. The resulting foams are used in the furniture industry and the cutting residues provide the raw material for substrates. They are ground to granules, which are pressed together with additives to form a slab. Steam at 140°C is blown in during the process. Polyurethane is considered as a substitute for perlite in potting mixes (Cole and Dunn, 2002). It is a sterile product that can be steamed between crops for several growing cycles.

***Polystyrene Foam:*** Flakes or beads of expanded polystyrene foam are by-products of polystyrene processing. These are sometimes added to substrate mixes to improve aeration and drainage. Polystyrene beads are highly resistant to microbial decomposition because of their large particle size and hydrophobic nature (Anonymous, 1994).

*Polyester Fleece:* Polyester fleece is made from pure polyester fibres, which are mixed and thermally fixed. The water–air–solid ratio in polyester fleece medium at water retention of 0.5 KPa has been reported as 59:39:2 (Schroeder and Forester, 2000), which could be considered as optimum for growing horticultural crops.

## Prospects of natural fibre crop based plant growth media/substrate

Growing media must address the requirements of seeds and seedlings and must have the necessary physical, chemical, and biological characteristics required to germinate and grow plants in their early stages.

### *Coir*

Coir is the material that forms the middle layers or mesocarp of coconut fruits (*Cocos nucifera* L.).These layers are composed of fibers embedded in the so-called coir pith, also referred to in its dry state as coir dust. Coir is one of the most abundant plant-derived organic waste materials in many tropical and subtropical countries. Traditionally this material was dumped and accumulated as a waste product, and the material is still considered as a problem in some areas (Indian Coir Board, 2016). However, these coir "dumps" have now mostly gone from major areas of production, and coir pith from freshly harvested coconuts is now predominantly used for substrate production. After separation of fiber, fresh coir is normally aged or "composted" for several months prior to preparation as a substrate for growing media (Indian Coir Board, 2016). Coir pith may contain high salt levels (predominantly Na, Cl, and K) and is washed with water and/ or solutions,for example, $Ca(NO_3)^2$ (the so-called buffered coir), prior to preparation for horticultural use (Poulter, 2014). After washing or leaching the dried coir pith is compressed from 5:1 to8:1 in volumetric basis (Ross *et al.* 2012) into blocks (5 kg) or briquettes (0.6 kg) having better transportability. The ligno-cellulose complexes of coir pith offers resistance to degradation associated with,formed of cellulose, hemicellulose, and lignin linked through covalent and noncovalent bonds, and which are highly resistant to degradation (Carr, 2012). Coir may also contain phenolic substances (Ma and Nichols, 2004). As with moist peat, coir pith is super hydrophilic (Koch and Barthlott, 2009). Coir from several sources has been shown to hold 510 times its weight of water (Arenas *et al.* 2002; Abad *et al.* 2005). Both peat and coir are renowned for their ability to absorb and retain not only water but also air, due primarily to their microporous nature (Tsuneda *et al.* 2001; Fornes *et al.* 2003) allowing internal retention of both water and air.

Processed and exported coir pith does not generally contain weeds or pests, although some exceptions have been reported (James *et al.* 2011). Coir extracts have been shown to inhibit growth of some wilt fungi (Hyder *et al.* 2009), although this work was conducted solely in vitro. Successful control of disease in coir-containing growing media following addition of biocontrol agents has been demonstrated (Castano *et al.* 2013). Coir is particularly valued as a rooting medium, but its water-holding ability and wet tability make it an attractive proposition for bedding and pot plants, where growth in the latter has often been shown to be superior to that in peat (Smith, 1995).

### Wood Fibre

Wood fibre is produced by mechanical defibrillation or more commonly steam-assisted thermal extrusion of clean wood chips through a thermo-screw press (Gumy, 2001). The product is heated to 80-90°C and is therefore free from pathogens and pests and volatile toxins due to the friction involved in the processing (Lemaire *et al.* 1989). Wood fibre can be produced as coarse or fine grades and can be compressed for ease of transport (Jackson, 2016). Wood fibre for use in growing media is characterized by low bulk density, high total porosity,and very high air content (Gruda and Schnitzler, 2004a; Domeno *et al.* 2010) with a consequent higher oxygen diffusion rate compared to peat (Clemmenson, 2004).

Wood fibre has been successfully used with a range of protected vegetable crops and showed superior growthin cucumber (Hardgrave and Harriman, 1995) and tomato (Gruda and Schnitzler, 2004b) over a range of other organic substrates, but slightly inferior with autumn-planted tomatoes (Domeno *et al.* 2010). Bohne (2004), working with several nursery stock species, found that plants grown in 25% and 50% (v/v) wood fibre substrates did not statistically differ in quality compared to peat, in contrast to plants grown in 75% and 100% fibre which were statistically better compared to peat. Gerber *et al.* (1999) demonstrated that geranium (Pelargonium 3 hortorum L.H. Bailey) could be grown in 100% wood fibre with similar growth to plants grown in peat if they were irrigated and fertilized more often than the plants grown in peat. Wood fibre is used extensively in mixture with peat to produce growing media for retail markets in the United Kingdom and Ireland, and as components of media for bedding plants (Drury, 2015).

### Banana pseudostem fibre waste

***Organic fertilizers and bio-fertilizers:*** The usage of organic fertilizers and bio-fertilizers have gained momentum as a substitute to chemically synthesized fertilizers due to its reported effectiveness, the increasing cost of some chemical fertilizers and the awareness towards the hazardous effects of chemical fertilizers to human and the environment (Aseri *et al.* 2008; Doran *et al.* 2005). Traditional method allows banana waste to decompose naturally in the farm to replenish soil nutrients or to act as an organic fertilizer. Recently, the utilization of banana waste as organic fertilizers and biofertilizers have been greatly improved by incorporating biotechnological methods (Doran *et al.* 2005). Phirke and Kothari (2005) discovered that turning banana waste into growth stimulating soil conditioner through solid-state fermentation and recycling it as fertilizers for banana farming greatly reduced the planted suckers' mortality, improving plant biomass and increasing fruit yield. It has been confirmed by Doran *et al.* (2005) that organic fertilizer prepared from composting banana waste also standout to be a cheaper and economical fertilizer with a significant effect on growth and yield of banana crop compared to chemical fertilizers and poultry manure. Banana waste was also reported to be a suitable carrier of *Azospirillum*, *Azotobacter* and phosphate-solubilizer bacteria to the soil cultivated with banana gave positive effects towards the availability of soil and banana foliar phosphorus content (Rivera-Cruz *et al.* 2008).

***Vermicompost:*** During fibre extraction from banana pseudostem, huge quantity of scutcher (about 30 to 35 t/ha) is generated. This scutcher is being converted to natural products like vermicompost by add in gother essential components in order to value addition in proper way (Oliveira *et al.* 2007 and Phirke *et al.* 2001). Process has been standardized for vermicompost preparation using pseudostem scutcher along with dung in ratio of70:30 (Patil and Kolambe, 2011).

***Liquid fertilizer:*** Sap can be utilized to prepare liquid fertilizer and nutrient spray solution (NSS) which is extracted from pseudostem of banana fibre can be used as liquid fertilizer for banana, papaya,sugarcane, etc. Studies indicate that it may save20-40% fertilizer. It also improves the yields of banana and sugarcane (Patil and Kolambe, 2011). Banana enriched sap is nothing but fresh sap with essential plant nutrients as well as growth promoting substances viz. gibbrelic acid (GA)and cytokin in which can be an alternative for plants vegetative growth (Patil and Kolambe, 2011). NSS can be used as a nutrient in vegetable nurseries under green-house condition. Spraying of enriched sap in combination with vermibed wash (1:1) on vegetable seedling resulted in achieving early transplantable stage by 8 to 10 days as compared to no spray. Another experiment showed that spraying of both sap and vermibed wash together (1:1)resulted in higher fruit setting in mango (6.59%) as compared to control (4.62%) (Patil and Kolambe, 2011).

***Growing substrate for edible mushroom:*** Apart from being used as a substrate for cellulase and cellulolyic enzyme production, by-products such as leaves and pseudostem of the banana were also noted to be a potential substrate for the cultivation of edible mushrooms. It is vital that available wastes are used and managed properly to ensure the efficient of recycling farm waste for environmental safety as well as to generate income for the country. Edible mushrooms are known to be a good agent in the degradation of cellulose. They are income generating, high in nutritional and pharmaceutical values (Wong and Chye 2009; Yim *et al.* 2011) as well as can grow rapidly on suitable substrates. Thus, they are considered as high value food products, which are capable for fast return of investments (Ukoima *et al.* 2009).

### *Pineapple leaf fibre waste*

***Vermicompost:*** Pineapple leaf contains only 2.5-3.5% fibre,covered by a hydrophobic waxy layer, which remains beneath the waxy layer (Paul *et al.* 1998). In India, pineapple is cultivated approximately in 87.2 thousand hectare of land and ₹ 600 thousand tons of pineapple leaf fibre can be extracted from this agro-waste leaves after harvest of the fruit (Doraiswami & Chellamani, 1993). During extraction of fibre, significant amount of succulent green biomass debris is left after scrapping out the waxy surface layer from pineapple leaf. This residual sludge can be utilized successfully for vermicomposting to make the total integrated system economically viable. Pineapple waste is one type of organic material containing a high C/N ratio (50%–70%) (Ridwan *et al.* 2018).

High-quality co-compost can be produced by co-composting pineapple leaves and chicken manureslurry and thus have potential to reduce environmental pollution that could result from poorly managed agricultural wastes (Ch'ng *et al.* 2013). According to the study conducted by Ch'ng *et al.* (2013) showed that the final co-compost had no foul odour and was low heavy metals content, and comparable amount of nutrients. Seed germination indices of phytotoxicity test were above 80% for the final co-compost. The initial C/N ratio of co-compost was approximately 30.0, and it decreased to 19.8 at the end of co-composting. Chicken manure slurry and chicken feed had a lower C/N ratio,high moisture and N content compared to the pineapple leaves. Biodegradable pineapple leaves was high in organic carbon and has good bulking properties. By combining the two, the benefits of each can be used to optimize the co-composting process and the product by balancing and compensating the C/N ratio of the co-composting materials.

***Biochar:*** Biochar can be described as carbonized product after pyrolysis process which can be obtained from residues or plant biomass which highly improves media properties and increases crop growth. Fu *et al.* (2016) indicated that the increase of pyrolysis temperature increased pH, electrical conductivity (EC), and carbon (C) content of pineapple biochar. Asbiochar holds nutrients more effectively, so there are more available nutrients compared to leaf, compost, and manure fertilizer. The study showed that the minerals contents in carbonized biochar such as K, N, S, Mg, and Ca also increased (Bohari *et al.* 2020). Biochar application has the potential of increasing the C content, water and nutrient retention (Mawardiana *et al.* 2013).

### *Wool waste*

Coarse wool has become an underrated and underused resource. Belly wool, even from fine-wool sheep, goes unsold and often referred to as 'waste wool'. It accounts for about 20% of the total wool from a sheep; and represents a fair amount of wool that does not generate return to producers (Hargreaves, 2017). Thus, waste and tag wool account a huge amount of wool that is a readily available, inexpensive and considered low-quality because of contamination and stains. Further, nearly 10 to 15% of waste wool produced in woollen industries during wool processes (carding, combing, spinning, wad weaving, etc) is usually discarded or dumped on the ground (Kadam *et al.* 2014). Wool is a biodegradable fibre, rich in nutrients and can be recycled in soil as a fertilizer for maximum benefits. Unclean sheepwool comprises of 50% carbon, 14.6% nitrogen, 5% sulphur and trace elements (cobalt, copper, iron, manganese, zinc and molybdenum) which play a vital role in plant nutrition (McNeil *et al.* 2007) and partial break down of waste wool by alkaline hydrolysis can make it a slow release fertilizer. Furthermore, waste wool also act as water conservation substrate in agriculture sector as it retains substantial amount of moisture (Mubarak *et al.* 2009; Kadam *et al.* 2013; Zoccola *et al.* 2015) when used as manure. Application of waste wool in tomato and pepper raised their yield by 30% (Zheljazkov, 2005) and also improved soil salinity and nitrogen content (Gorecki and Gorecki, 2010).

Waste wool surplus is also an organic waste, which is not useful for sheep farmers because of lack of demand and therefore, it is no longer a commercial viable product and its safe disposal is essential for the benefits of farmers and consumers (Zheljazkov, 2005), its use as manure in soil can be a viable option (Sharma *et al.* 2019). Utilization of protein-rich product such as waste wool and other organic by-products of sheep would offer additional advantages of waste reduction, resources conservation, and economic advantages to industries as well as sheep farmers. Waste wool have higher content of C and N than the rest used organic manures, so, its disposal in soil for agriculture production maybe good option for its use as a fertilizer apart from safe disposal. Sheepwool is made up of keratin (protein) and contains an adequate amount of essential plant nutrients viz., N, C and S (Gorecki and Gorecki, 2010), K, Na, P, Mg, Fe, Mn, and Zn (Zheljazkov *et al.* 2008) and it can be a more balanced organic fertilizer for plants. Priorresearch (Zheljazkov, 2005; Zheljazkov *et al.* 2008a) has demonstrated that uncomposted wool could be used as plant nutrient source. Composted wool has been used as a N source for crop plants such as chickpea and wheat (Tiwari *et al.* 1989). However, research has demonstrated that composting of protein-rich feed stocks usually results in a significant loss of N (Epstein, 1997).Wool is a rich source of important nutrients which are necessary for plant growth (McNeil *et al.* 2007). It contains high quantities of N, S and C. Sheep wool hydrolysate improves growing conditions by increasing contents of total N, C, and P in the soil (Govi *et al.* 1998). In an experiment with the hydrolysed wool, Nustorova *et al.* (2006) found that the C:N ratio in treated soil increased with increasing doses of wool. This was also reflected by an increased mineralization of hydrolysate by microorganisms in the soil. Pot experiment involving waste wool have proved it as a good source of N (Hodnik *et al.* 2008). Another advantage, wool soaks up in the soil, it fluffs up and expands, increasing soil porosity and improving the soil's ability to retain oxygen (Kadam *et al.* 2014; Hargreaves, 2017). Green hydrolysis using super-heated water is an emerging technology to turn waste wool into amendment-fertilisers for the management of grasslands and other cultivation purposes (Zoccola *et al.* 2015). In this way wool keratin is degraded into simpler compounds, increasing the release of nutrients to plants.

## The development opportunities and challenges

The focus on the utilization of any by-products or waste should always be transformed into high valued processed raw materials or products that meet market demands and creating substantial economic impacts (Jayathilakan *et al.* 2012). This is also the most important key aspects in the management of agricultural waste, as it will greatly determine the sustainability and viability of the by-product itself as a future commodity (Adinugraha *et al.* 2005; Uyen and Schnitzer 2009). In other words, the market value of the newly developed products must be able to cover internal and external expenses of its production. The quality of the product and processed raw materials from banana by-products must be comparable or better than its counterparts to ensure market competitiveness. The technology and innovation through creative improvement of the existing processes may also be a key to guarantee the survival of the by-products (Lew *et al.* 2011). One of the biggest contrasts between soilless and soil-based production is the spatial confinement of the roots into a specific, well-defined root zone. The smaller the root zone, the more intensive the production system needs to be managed within this volume. Sonneveld (1981) reported that the volume of medium, available to a tomato (*Lycopersicon esculentum* L.) plant grown in a soil bed in a greenhouse, is approximately 200 L, while the corresponding volumes for production in substrates are typically an order of magnitude smaller.

### Future Direction and Conclusion

The soilless industry is expected to grow exponentially in future, as conditions of soil for growing crops are deteriorating day by day. In a country like India, due to rapid urbanization, adoption of soilless culture is gaining momentum for improving the yield and quality of the produce. Various reasons persist for the continued growth of soilless production as part of agriculture. Some of these reasons may be attributed with the physical and chemical properties of substrates, stressing their superiority over soil cultivation, ease of control of water, oxygen and nutrient availabilities, and the resulting improved crop performance. Another advantage is the relative freedom from soil-borne pathogens and improved possibility of disinfestation of the medium among growing cycles. However, growing crops out-of-soil also impose some limitations which test the grower's skill to avoid losing the potential benefits offered by the advantages. Core research and development is improving the current technology by automating, expanding our understanding of the phytochemistry of plants, and driving plant phenotypic plasticity for the best-in-class crops.

Various studies and experiments established the notion that one can grow plants in virtually any porous material supported by the fact that plants will grow in a variety of substrates, as long as water and nutrient supply to plants' needs and the relevant characteristics of the medium are not restricted. This notion has led to an early routine exploration of various waste materials as growing media. Hence, the prospects of natural fibre based substrate and their waste by-products like coir, wool waste, pineapple leaf fibre waste, banana pseudostem fibre waste, wood fibre etc seems very bright. More involvement of substrate producers and end-users in educational and planning efforts could improve the quality of growing media by introducing added-value characteristics. However, Government intervention and interest of research Institute can propel this technology in a better way.

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