The role of soil properties and it’s interaction towards quality plant fiber: A review

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The role of soil properties and it's interaction towards quality plant fiber: A review

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ABSTRACT

In recent years, the use of plant fibers has increased tremendously due to the remarkable variations in chemical and physical properties. Plants require light, water, and nutrients for growth, reproduction and efficient crop production. Plant nutrients are mostly absorbed by plant roots from soil. For satisfactorily plant growth, it is urgency that soil provides a favorable environment for root development that can exploit the soil sufficiently. Water exists in soil as a thin film which has very different properties to that of a bulk volume of the same water. The organic part forms complex interactions with the water, minerals, solute, and microorganisms of the soil, compounding the complexity of the system. Furthermore, soil is a dynamic open system, continually subject to inputs and losses of energy, water, organic and inorganic materials, and supports the plant structurally. The physical, chemical and biological properties of soil lead to a series of physiological, biological and chemical changes along with growth, yield and quality of the plant biomass, and thus of fibers. The purpose of this review is to summarize the impacts of the soil properties on the physical and morphological structure of plant fibers growth. The present study further demonstrated the interaction effects and sustainability of soil properties to produce quality plant fibers.

Contents

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1. Introduction

Plant fibers have recently gained researchers attention due to the environmental concerns, sustainability. technological advancement, flexibility and availability for diversified industrial products including pulp and paper, rope, cords, reinforcement in composite matrices [1]. The uses of plant fiber reinforced composites have been increasing significantly because of their improved property, which is competitive to the synthetic composites [2,3]. Moreover, the natural fibers have become promising viable alternatives to glass fibers either alone or in combination with many other materials [4]. Each fiber consists of long cells with thick cell walls which make them stiff and strong with low density due to the presence of cellulose. Like other biological products, it has also a wide range of variations in their properties coming from various sources such as genotype, soil, climate and agronomic practice, which influence the chemical composition and structural organization of the cell wall polymers and thereby the fiber properties [5].

Soil is one of the most important natural resources for crop production [7]. For efficient crop production, it is important to understand the soil environment to identify the limitations of the environment and ameliorate the possibility without damaging the soil quality. Soil consists of mainly clay, silt, sand, gravel sized particles, organic materials arising from the growth of flora and fauna [7,8]. The root system of a plant absorbs water and nutrients from soil and maintains the supply of it to the plant root for continuous growth and development of the plant. However, plant roots do not have an intrinsic ability to find water and nutrients in soil. Most plant root systems have a symbiotic relationship with soil mycorrhizal fungi, which influences on plant growth. Thus, the growth of plant largely depends on the quality of the soil where it grows, and different species respond and express their tolerance in a different ways.

Fiber growth and development is affected by most factors which influence plant growth [8]. Since the fiber is primarily cellulose, any influence on plant production of carbohydrate will have a similar influence on the fiber growth [7,8]. Moreover, the factors influence the chemical composition and structural organization of the cell wall polymers, ultimately affect the properties of plant fibers [6]. Soil is one of the most important factors which influence plant growth [7]. Soil composition, physical, mechanical, chemical and biological properties affect the plant physical, physiological and chemical properties, thus, affecting the fiber quality. There are limited studies have been conducted on the interaction effects between plant fibers and soil properties. Therefore, the present review article was conducted with the aim to evaluate how the soil and its component influence the physical and morphological properties of the plant fibers. The best soil type, which most influences the good quality of fiber, was determined. Moreover, the interaction between soil properties and plant fiber was also assessed in the present study.

2. A brief review of the plant fibers

In nature, there is a wide range of natural fibers which can be eminent by their origin. Precisely, natural fibers can be divided into three categories including animal fibers, mineral fibers, and plant fibers. Plant fibers are renewable natural resource, which are biodegradable, recyclable and eco-friendly [9]. Generally, plant fibers are sophisticated in structure. It is referred as cellulosic or lignocellulosic fibers due to compose mainly of cellulose, hemicelluloses and lignin [10]. The plant fibers consist of a group of macrofibrils arranged in the cell wall layers, which are composed mainly of elementary fibrils consisted 30–36 cellulose molecule chains that cross-linked by other components of the cell wall [11]. The schematic design of cellulose fibers and its properties is shown in Fig. 1.

Fiber derived from plants can be defined as a dead cell, hollow at maturity, exists in bundle in all types of fiber except in seed [12]. Bast fiber consists of filament groups and each group has 15–30 pieces linked by middle lamellae [4]. The middle lamellae consist of various substances including pectin, lignin, and hemicelluloses. According to Olesen and Placket [13], the structure and combination of these substances have given the plant fiber unique properties like

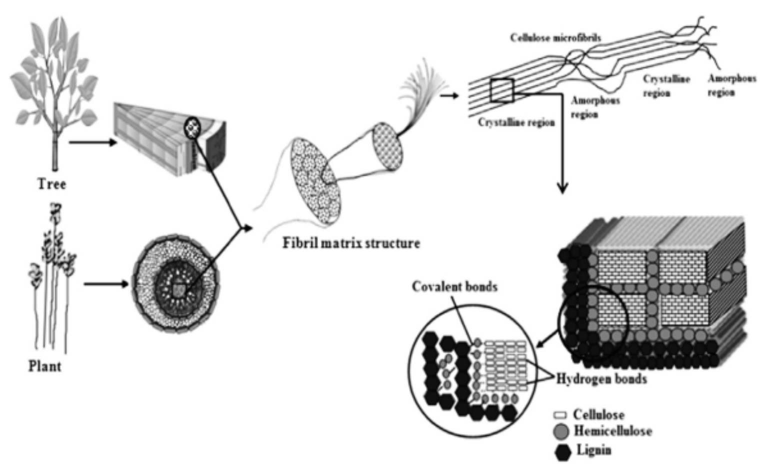

Fig. 1. The schematic design of plant fiber and its structural properties.

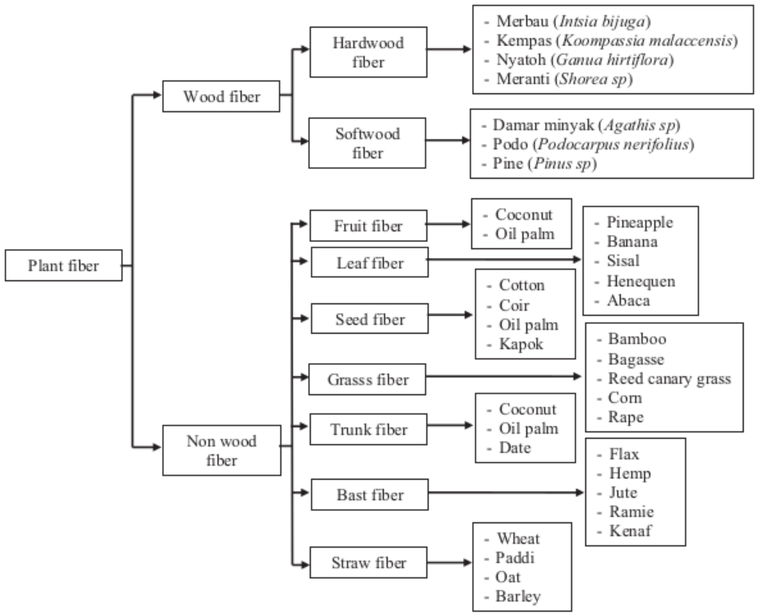

Fig. 2. The classification of plant fibers.

excellent strength, superior heat and sound protection, higher energy, readily biodegradable as well as good dimensional stability. Providing unsmooth surfaces for superior adhesion in a composite matrix is another unique property of the fibers [14]. Many factors determine the efficiency of the properties of plant fiber. These are physical, chemical, morphological properties such as plant fiber origin, cellulose content, crystal structure and diameter cross-sectional area of the fiber [15]. Generally, all plant fibers are single cell materials and exist as bundles except seed fibers [16].

The classification of plant fibers is presented in Fig. 2. Based on their origin, plant fibers can be classified as wood fibers and non-wood fiber [17]. Wood fibers are usually cellulosic elements; those are extracted from trees and used to make materials including paper. Wood fiber can be classified as hard wood fiber and soft wood fiber. Non-wood fiber can be classified according to its origin into agricultural by-products, naturally growing plants and industrial crops. Wherein, agricultural by-products can be categorized by a moderate quality non-wood fiber. High quality fiber can be produced from industrial crops such as hemp, kenaf, sorghum, maize, etc.

2.1. *Plant fiber composition and their structural morphology*

The term fiber describes numerous botanical entities: a mechanical cell type belonging to the sclerenchyma (true fibers), long cells used to produce paper (true fibers and tracheids), vascular bundles used for textiles or to produce ropes (manila and sisal), long trichomes used for textiles (cotton), and the dietary fibers. Plant fibers consist of three major components, which are cellulose, hemicelluloses and lignin [9]. The cellulose, hemicelluloses and lignin present in plant fibers serve to form the cellulose superstructure as a matrix substance.

Cellulose is the most available renewable polymer that forms the basic structure of higher plant cell walls and about 40–45% of the dry weight of normal wood tissue [15,18]. It is a polysaccharide with long-chain linear sugar molecule, which composed of β-D glucopyranose units linked at 1–4 carbon [18]. However, the length of polymer chains varies according to the source of cellulose and part of the plant [10]. The function of the cellulose is not only provides the required strength in plant cells, but also to maintain the size, shape and division of plant cells, eventually the trend of plant growth [19]. Most cellulose occurs and produced in nature as crystalline cellulose which is known as cellulose (I) [4,20]. It is well known that the glucose chains in the cellulose (I) are arranged in parallel to each other and set side by side to form microfibrils, which is in most of the plants reach up to 3 nm thick, except in certain algae wherein it can reach 20 nm of widths [20–22]. Cellulose (I) is a combination of two crystalline forms with different hydrogen bonding patterns which are cellulose Iα and cellulose Iβ [21–23].

According to Chengjun and Qinglin [23], cellulose chain in plant cell wall contains 36 individual cellulose molecules, which are connected to each other through hydrogen bonding to form elementary fibrils and finally aggregated together to form microfibrils. These microfibrils have two regions (i.e., amorphous and crystalline). Amorphous region is unarranged (messy) and is distributed along the microfibrils. The second region is the crystalline region which is highly ordered and packed with a strong complex intra and intermolecular hydrogen bond network. The higher tensile strength of cellulosic fibers in axial direction is due to the high number of hydrogen bonds between the cellulose molecules of chains [24].

Hemicelluloses are polysaccharides, heterogeneous and branched structure with lower molecular weight that contains short chain of various pentose sugars. Further, hemicelluloses are amorphous therefore it's partially soluble in water. The role of hemicelluloses in the fiber cell walls is to cross linking between cellulose fibril aggregate by forming complexes with lignin. Moreover, hemicelluloses work as filling material (cement) in the cavities between the microfibrils, as its hydroxyl groups are much more accessible to water [25].

Lignin is an aromatic, three-dimensional polymer structure, with high molecular weight. It is a polyphenolic molecule and not soluble in water [26]. Its role is to work as a strengthening material between the cellulose microfibrils, and provides protection against attack by pathogens and consumption by herbivores, due to the presence of phenolic components [25]. However, hemicelluloses and lignin are the differences from cellulose. That is not only in molecular weight, but also cellulose displays in crystalline and amorphous structure [27]. Wherein, hemicelluloses and lignin displays in only amorphous structure [27].

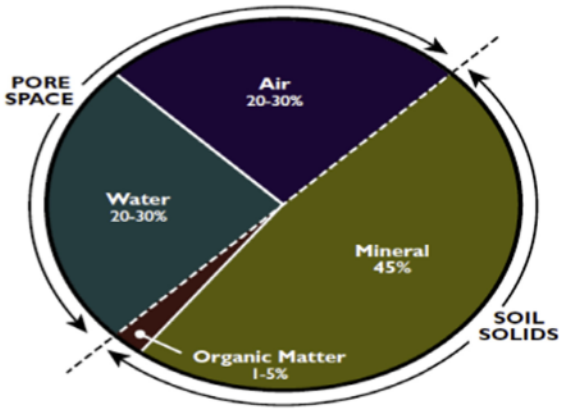

Fig. 3. Classification of soil components [29].

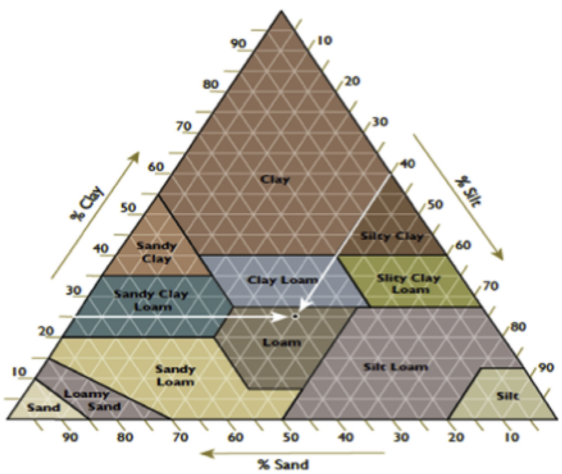

Fig.4. Soil's textural class according to the percentage of the particles [29].

3. Soil properties and plant growth

Soil is considered as a dynamic living natural body, which has a vital role in the global ecosystems by a balance between living and dead [28]. Soils can be divided into four main textural groups such as sands, silts, loams and clays. Depending on these components, soil can be classified into different types, as presented in Fig. 3. A healthy soil contains sufficient air, water, minerals and organic particles [30,31]. In general, soil contains 2–5% organic particles 20–45%, minerals, 10–25% water and 15–25% air. However, these proportions of these components may vary in different types of soil due to locality and climate [30]. The quality of soil varies due to the variation of its components. Not all types of soil are suitable for all types of crops. Thus, the assessment of soil quality is very important. According to Stamatiadis et al. [32], soil quality can be assessed by analyzing the physical, chemical and biological properties of the soil.

3.1. Physical properties

Soil physical properties can be affected by the constituents and concentration of the soil components [28,32]. However, soil physical properties can be classified into soil structure (gathering the small soil particles to form clusters) and texture (the rate of soil components such as clay, silt and sand), porosity (ratio of soil pores volume to the total soil volume) and moisture content. Soil textural class in accordance to the percentage of the three different types of particles is shown in Fig. 4. Soil physical properties affect plant growth, which determines the quality of fiber [32–39]. Many researchers reported the soil physical properties and it role on plant growth, as summarized in Table 1.

3.2. Chemical properties

The soil is a chemical entity and it is composed of solid, liquid and gas; soluble and insoluble; and organic as well as inorganic substances. The chemical properties of soil can be divided into two groups: organic (decomposition of plant and animal), and inorganic (N, NH3, Fe, Ca, Al, etc.) [45]. The chemical properties of soil such as nutrient contents, pH, and salinity can be defined as the presence of the major dissolved inorganic solutes in the soil [45–49]. These chemical properties have great importance in soil formation and in crop production [47–50]. Cation exchange is used as a good indicator for determining the soil texture. The main role of soil chemical properties is summarized in Table 2.

Table 1
Soil physical properties and their role in plant growth.

Properties	Role in plant growth
Structure	1. Increase soil strength and facilitate the movement of water through the preservation of porosity [33] 2. Improve the soil fertility [33]. 3. Facilities plant growth and root spreading to absorb water and nutrients [34]. 4. Improves the water and oxygen penetration [35].
Texture	1. Enhance physical and chemical elements of soil [36] 2. Impacts on the movement and availability of air, nutrients and water [37]. 3. Affect the bulk density of soil, stimulate crop production [38]. 4. Significant effect on the absorption efficiency of plant [39,40].
Moisture content	1. Higher soil moisture can cause soil damage [41] 2. Soil moisture content increment leads to reduce plant transpiration [42]
Porosity	1. Facilitate the plant growth and soil ventilation [43] 2. Macroporosity assist in the revitalize structurally damaged soils [44]

Table 2
Soil chemical properties and their role in plant growth.

Properties	Role in plant growth
Nutrient	1. Improve plant growth [45] 2. Improve soil structure, water penetration [46] 3. Increase soil biological activity, controls erosion and prevents surface sealing [47]
pH	1. Facilitate the decomposition of organic matter which leads to increase the presence of phosphorus, manganese and calcium in the soil [48] 2. Affects the soil physical properties. At the higher pH value the aggregation form of soil particle is larger [49] 3. pH value is an indicator of nutrient cycling. Increasing pH will increase the adsorption of minerals [50]
Salinity	1. Control the CO_2 absorption rate and slow plant growth, which leads to reduce the agricultural yield [51,52] 2. Affects plant growth [53]
Cation exchange	1. Positive correlation with organic matter [50]

Table 3
Soil biological properties and their role on plant growth.

Properties	Role in plant growth
Bacteria	1. Play an important role in ecosystem functioning [54] 2. Provide nutrients for plant, cycling of soil nutrient and organic matter decomposition [29,55] 3. Improve soil health and promote plant growth [55,56]
Fungi	1. Supports soil functions as a plant nutrient source [57] 2. Impact on plant growth and nutrients uptake [58] 3. Effect on soil productivity and plant health [59]
Nematode and protozoa	1. Improve plant growth and nitrogen uptake [60] 2. Affect bacterial populations [61] 3. Increase CO_2 evolution [62] 4. Increase nitrogen and potassium mineralization [63] 5. Increased substrate utilization [64] 6. Reduce leaching of phosphate [65]
Earthworm	1. Increases the amount of extractable nitrogen [66] 2. Modify plant growth and vegetation structure [67,68] 3. Increase the nutrient availability to plant [69,70]

3.3. Biological properties

Soils are diverse systems consist of highly diverse microhabitats which form complex arrangement of plant in soil microbial communities [54–64]. Soil contains a complex community of microorganisms include numerous groups of bacteria, fungi, viruses, and nematodes with a range of abiotic constituents. Despite of its usefulness to the plant growth, some of these microorganisms can also cause plant diseases [61]. Studies reported that the soil biological properties plays effective role in plant growth and development [54–70]. The finding of some research articles are listed in Table 3. Soil organisms play key role in the nutrient transformations [54,58]. Relative proportion of various soil microorganisms, those transformation nutrient in soil and enhance plant fiber growth and development, are: 83% Bacteria (i.e., *Rhizobium sp., Pseudomonas sp, Bacillus sp., Mesorhizobium sp.*, etc.), 13% Actinomycetes (i.e., Streptomyces *spp, Fusarium spp., Phytophthora spp., Pythium spp., Rhizoctonia spp., Verticillium spp.*, etc.), 3% Fungi or molds (i.e., *Glomus intraradices, Paenibacillus macerans, Paenibacillus polymyxa, Cucumis sativus*) and others (Algae Protozoa viruses) 0.2–0.8% [71–74].

4. Essential elements for quality plant fiber growth

Fig. 5 shows sustainable pathways of plant fiber properties. The plant fiber properties depend on the genetic characteristics of plant [55,69]. The genotypic characteristics are influenced by the abiotic and biotic components of the environment. The factor, which influences on plant growth, has similar influence on the quality of plant fiber growth. Soil properties are the most dedicated factors that determine the quality of fiber. After final use, fibers returns to the soil as a component and play a role in determining the physical, chemical and biological properties of soil, which ultimately influence plant growth and plant fiber quality [71].

The quality of plant fiber mainly depends on the genotype, growth conditions and location of the fiber in plant [69]. Soil physical, chemical and biological properties affect plant fiber properties by modifying the growth conditions. However, it is very difficult to estimate individual effect of one property on plant fiber as the soil properties are usually correlated spatially due to the inherent soil formation process [70]. Soil management practices affect the different properties of soil, which influence fiber quality. There are some others factors also influence on plant fiber quality [70–72]. Some of the important factors influences on plant fiber growth are describe below.

4.1. Soil physical properties

Since the fiber is primarily composed of cellulose, any influence on plant photosynthesis and production of carbohydrate will have analogous influence on fiber growth. By determining the amount and movement of air, nutrients, porosity and water which determines soil temperature, soil texture and structure influence the fiber growth. Higher amount of sand and clay tended to increase

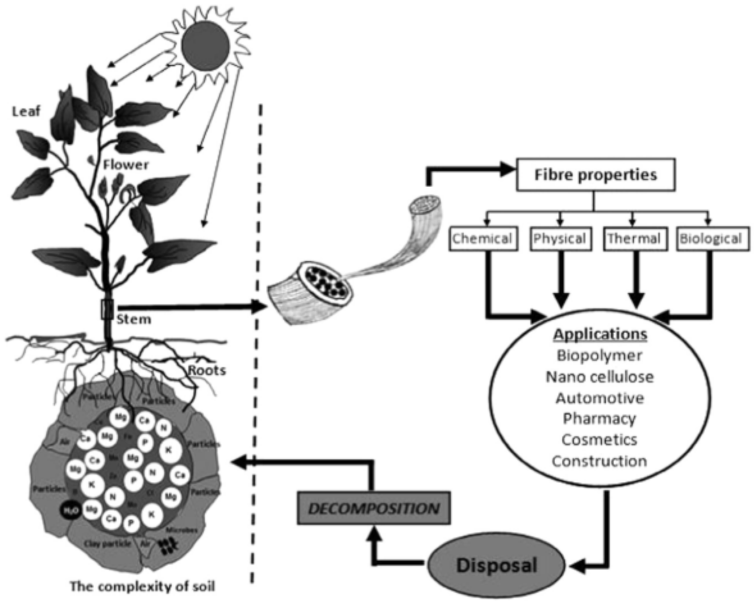

Fig. 5. Life cycle assessment of plant fibers properties.

fiber length and strength [73]. Johnson et al. [75] observed that the organic matter significantly influenced fiber quality. Changes in the soil organic matter drive many of the other changes in soil physical properties [29]. Higher nutrient and water availability with the addition of organic matter results in longer and stronger fibers [76,77]. Soil moisture influences the growth of fiber and ultimately fiber length [75,78]. Excessive water supply and drought may reduce the length of fiber [74]. As the expansion of cell is strongly driven by turgor pressure, so plant water relation affects fiber elongation in the period immediately following anthesis.

Fiber elongation and fiber thickening are affected by temperature and radiation [75]. At lower temperature or cloudy weather, reduction in fiber thickening occurs which leads to low fiber micronaire [80]. Soil temperature and moisture significantly increased the breakdown of lignin and cellulose [80–82]. There is a curvilinear relationship between the breakdown of cellulose and soil moisture. When moisture increased up to 40 to 60%, cellulose degradation increased significantly in a curvilinear trend and at higher moisture content [82]. Increase in soil temperature is associated with increase in cellulose decomposition [82]. Lignin decomposition shows similar relationship with soil temperature and soil moisture. Tuomela et al. [83] determined that the thermophilic phase is fundamental for faster lignocellulose degradation with increasing temperatures. Therefore, it can be concluded that the there is an inverse relationship between the fiber properties and the physical, microbial properties of soil [84]. Soil compaction decreases in macroporosity, and eventually leads to increase bulk density. Compaction can decrease the plant nutrients, specifically by the nitrogen uptake, which may affect the cell wall portions of some plant made of cellulose and lignin [85].

4.2. Soil chemical properties

Soil fertility is considered as one of the most influential factors for fiber quality [86,87]. Soil nutrient are essential element for plants growth and fiber production. Nutrient stress of 20–40 days post-anthesis is expected to impact fiber strength development [87]. Nitrogen (N) is a constituent of the chlorophyll molecule and hence affects the production of carbohydrates [87]. Beside this, nitrogen plays a key role in all metabolic activities of plants. Thus, by affecting plant growth, nitrogen also influences the fiber quality. Deficiency in Nitrogen results in low productivity, which is often associated with low fiber quality [88]. The quality of fiber tented to deteriorate with the excess nitrogen. Micronaire, length, uniformity, strength and elongation percentage properties are most strongly correlated with soil moisture and soil phosphorous [74,89]. Soil phosphorous is an essential element of nucleic acids (DNA and RNA), enzymes, proteins, lipids and several other compounds, those affect fiber properties along with controlling photosynthesis, respiration, cell division, and many other plant growth processes.

Reiter et al. [90] observed that micronaire improved significantly with the transformation of N/P_2O_5 proportion from 5:1 to 5:3. Potassium (K) impacts on productivity and fiber quality in direct consequences to water relations, photosynthesis, respiration, enzyme transpiration and activation [79]. Short plant fibers grow due to the insufficient *K* for plant growth [91]. Micronaire, an estimation of the fiber fineness, decreased with deficient K during growth [91]. Fiber length is positively correlated with Ca, Mg and Cation-exchange capacity [74]. Sawan, et al. [92] found a significant improvement in cotton productivity and fiber quality (fiber micronaire and strength) with the application of mepiquat chloride. Hossain et al. [93] examined that fiber length and fiber yield varies with carbon levels of soil. The other nutrient deficiencies can also reduce fiber length [92].

Johnson et al. [75] and Ping et al. [79] found a strong negative relationship in soil pH, fiber strength and fiber elongation. Lignin breakdown in acidic soils (low pH) as compared to the natural and alkali soil (high pH). Generally, soil salinity has harmful effect on the plant growth, fiber yield and quality [94]. Soil salinity reduced the fiber length of the cotton species. Khorsandi and Anagholi [95] reported that moderate to high salinity levels of soil delays and reduce seed cotton yield and fiber quality. Dong [96] reported a

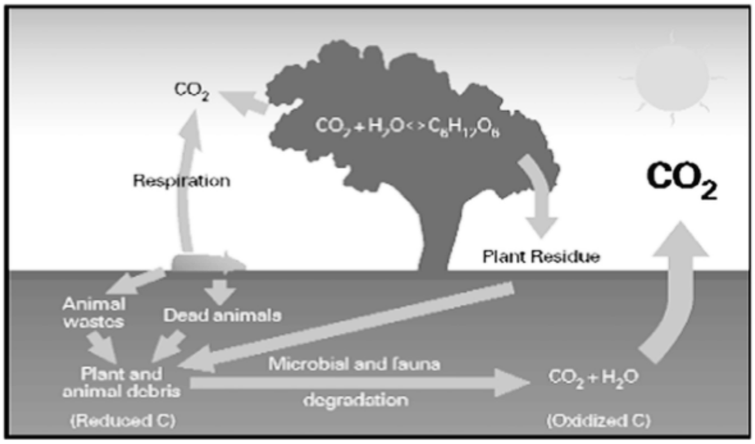

Fig. 6. The atmospheric carbon cycle processed and soil organisms and released into the atmosphere [71].

reduction in soil salinity increase cotton yield and fiber quality. Khattak and Muhammad [97] observed that chemical fertilizer supplementation with humic acid in soil salinity improves the plant crop production without compromising on yield and fiber quality.

4.3. Soil biological properties

Soil organisms balance the mineral with the organic nutrients, which ultimately support the plants growth and affect fiber quality. Soil microorganisms can cause fiber biodamaging, which increases with an increase of temperature, humidity and at limited air exchange [98]. Donnelly et al. [99] found a curvilinear relationship between the microbial biomass and soil moisture and temperature with the degradation of cellulose and lignin. Their result showed that the microbial biomass increase significantly with increasing soil moisture and temperature.

Entry et al. [100] found that microbial biomass and cellulose degradation rates were 3–6 times increased in soils treated with fungus than in non-treated soils. They suggested that the increasing microbiological activity results in higher lignin and cellulose decomposition. Entry and Backman [101] confirmed that active bacterial and fungal biomass correlated curvilinearly with both cellulose and lignin degradation. In addition, Cook et al. [102] confirmed the superior stalk fiber in nematodes infected soils. Therefore, it can be concluded that fiber quality and yield need a balance ratio between soil microorganisms which can be achieved by soil management.

4.4. Soil management practices

Management practices that delays crop maturity lead to reduced micronaire due to exposure of a crop to unfavorable conditions. Some example are early stress with subsequent recovery, or higher N fertility and different tillage or rotation systems [79,89], planting date [103], green manure crops [104], irrigation [8] and insect damage causing compensation and later fruit production [105]. Blaise [106] observed better fiber length and strength in the organic cultivation system (OCS) plots compared with the modern method cultivation (MMC). Repeated application of manure and mulch to the OCS plots increases the water holding capacity, infiltration rate and hydraulic conductivity than the MMC and as a result, quality of fiber quality improves in the OCS plots.

4.5. Other factors affecting fibers properties

Generally, chemical, physical and morphological properties of the plant species are quite different. This difference is due to the variation in soil, climate as well as few other factors [71]. Yet, this effect in one way or another involved the physiological and morphological properties of the plant fiber. In the previous discussing part the effects of the soil properties have been covered. However, climate and other factors such as age of the plant, part of plant which contains the fiber and the effect of heavy metal, these factors need to be cover as well.

4.5.1. Climate

Climate element such as rainfall, sunlight, temperature, humidity and carbon dioxide concentration has great effect on soil quality and plant growth [107]. It is known that 85% of the atmospheric CO_2 comes from decomposition of dead plants and animals by soil microorganism, as this will complete the carbon cycle by releasing the soil CO_2 into the atmosphere [72]. Fig. 6 shows the atmospheric carbon, which cycle is processed and reduced by soil organisms and released into the atmosphere.

Climate has great effect on soil salinity, structure, formation and fertility, which in return effect plant growth and thus the fiber quality [104]. Plants are highly sensitive to climate as the climate can determine the type of plant that grows based on the quantity of light, temperature and moisture [104,108]. Moreover, high concentration of carbon dioxide leads to increase the atmospheric temperature which will have many impacts on plant [108]. There is a strong and direct relationship between atmospheric CO_2 and plant fiber, as the fiber yield increases with CO_2 fertilization, that process by soil microbs. Campbell et al. [109] reported that the fiber yield increased 52 to 56%, when the plant was treated with doubling CO_2 in open field plot and growth chamber. On the other hand, atmospheric temperature effects on the fiber yield.

Reddy et al. [110] found that fiber quality was not significantly affected by increasing CO_2. Wherein, temperature increment was found to have some impact on fiber yield. Pettigrew [111] found that fiber production and cell wall fiber sucrose reduced in light environments compared with rich sunlight environments. Low light insufficient photosynthetic assimilates are the cause the fiber quality reductions and the reduced sucrose levels occur during fiber secondary cell wall deposition that match the lower fiber micronaire produced under shade. However, Pettigrew [85] found that fiber production was 3% stronger in the warm temperature regime than in the control treatment. Increasing temperatures and ovule fertilization might become concession, which may lead to fewer seeds per boll, smaller boll masses, and ultimately lint yield reductions.

4.5.2. *Age of the plant*

Harvesting age is a crucial factor that affects the fiber properties, yield, and quality. Many studies have shown that physical properties of plant fiber influenced significantly by the age of plant [71,112–114]. Rowell et al. [113] found that both bast and core fiber length and width decrease significantly with increasing the plant age as well as lumen width.

Jahan et al. [77] studied the effect of harvesting age on the chemical and morphological properties of dhaincha plant as potential fiber source. They found that there was slightly increment in the fiber length, holocellulose and alpha-cellulose content while the lignin decreased with increasing age of the plant. Physical properties of unbleached pulp increased significantly with increasing plant age, wherein the bleachability of pulp was improved with the increase of plant age. Conversely, Huang et al. [114] found contrary result in their study of the effect of plant age on fiber mechanical properties of Moso Bamboo. The study parameters include tensile strength, modulus of elasticity (MOE), and other mechanical related properties such as the microfibril angle and fiber cross-sectional area. The result showed no significant variation with increasing age in average MOE and fracture strain of the bamboo fibers. Belkheiri and Mulas [115] observed that fibere content of harvested plants increased with increasing plant age and reached to the optimum at 120 days. Subsequently, the fiber content decreased at 150 days. They relate this result to the continued plant height with increasing age up to full maturity and accounted for differences in yield. Thus, it can be concluded that the effect of plant age on plant fiber properties significantly varied with plant type.

4.5.3. *Part of plant that contain the fiber*

Natural plants fibers properties depend on the type of cells from which part the fiber was taken. Furthermore, fiber chemical and physical properties also depend on the cell wall properties, as these properties determine the function of cell wall content within the plant [6,12]. Plants fibers physical properties depend on many factors including the part of the plant are taken [37,69]. Physical properties of fibers also vary from top to bottom of the plant, distance from the center. Studies determined that the fiber content and the fiber strength are highest in the middle of the stem of the plant, and the morphological structures and chemical composition varies between top and bottom of the plant [69]. Jahan et al. [77] reported that the presence of higher α-cellulose and lower lignin content with longer fibers length in the stem samples compared to the branch samples of *Trema orientalis*.

4.5.4. *Heavy metals content in soil*

The devastating effects of heavy metals on plants growth and fiber quality have been described by numerous authors [38,116]. Heavy metals contamination by plants strongly depends on several soil and plant factors [117]. Plant genotype is considered as the most important plant factors, among all the factors affecting heavy metal contamination. Studies found that some genotypes respond sensitively to Cd changes in soil. Wherein, the genotype differences are restricted to Cd, and no general phenomenon of sink source transport of micronutrients, e.g., essential metals Zn and Cu [45,91]. Bada, et al. [40] studied the effect of heavy metal cadmium (Cd) presence in the soil on the growth, fiber yields and Cd absorption of kenaf (*Hibiscus cannabinus* L.). The study observed that Cd significantly reduced the plant height, stem girth, bast and core yields compare to the control. Moreover, there is a significant ($p < 0.01$) positive correlation between the absorption and the presence of Cd by kenaf.

4.5.5. *Soil's electrical conductivity*

Soil's electrical conductivity (EC) can affect nutrient supplies within a soil environment and to the plant fiber growth [118]. Soil acts as home from plants nutrient, provides the plant fiber stability and essential nutrients. The healthier the soil, the more likely a plant will thrive and grow. The electrical conductivity of soil is one of the ways of determining healthy or suitable soil an environment for the plants and quality plant fiber growth [119]. EC actually takes place inside the pores that reside in between soil particles. As a result, the EC levels can vary depending on soil density and chemical compositions. As different plants require different types of soil physical, biological and chemical properties, knowing a soil's electric conductivity level can help to determine the essential soil environment for plants. Soil's pH level is directly related to its electrical conductivity level [118,120]. The chemical composition within a plant's environment can be determined by measuring the pH level present within the soil.

5. Conclusion

In recent years, the used of plant fibers in various industrial products have gained popularity due their sustainability, environmental friendly, flexibility and availability. Soil is one of the most important resources for plant fiber production. The present review was conducted in order to summarize the information of the impact of soil properties on quality plant fiber growth. It was observed that soil physical, chemical and biological properties have lead to a series of physiological, biological and chemical changes along with plant growth, yield and quality of the plant fibers. However, it is very difficult to estimate individual effect of plant fiber as the soil properties are usually correlated spatially and among them due to the inherent soil formation process. In addition, fiber quality and yield need a balance ratio between soil properties, which can be achieved by efficient soil management. Soil management practices affect the different properties of soil, which influence the plant fiber quality. Nutrient, water availability, microbial and organic matter of soils results in the production longer and stronger plant fibers. Harvesting age, climate, presence of heavy metals in soil is also important factor that affects the fiber properties, yield, and quality. Thus, it is crucial to understand the soil environment to identify the limitations of the soli environment and ameliorate the possibility without damaging the soil quality. Therefore, the present study recommends conducting further researches to determine the diverse effect of soil properties on plant fibers yield, its sustainability, morphological properties, physiological properties and quality.

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References

[1] Hill CAS, Abdul Khalil HPS. Effect of fiber treatments on mechanical properties of coir or oil palm fiber reinforced polyester composites. J Appl Polym Sci 2000;78:1685–97.

[2] Abdul Khalil HPSA, Hanida S, Kang CW, Fuaad NAN. Agro-hybrid composite: the effects on mechanical and physical properties of oil palm fiber (EFB)/

glass hybrid reinforced polyester composites. J Reinf Plast Compos 2007;26:203–18.
[3] Hariharan ABA, Abdul Khalil HPS. Lignocellulose-based hybrid bilayer laminate composite: Part I—Studies on tensile and impact behavior of oil palm fiber-glass fiber-reinforced epoxy resin. J Compos Mater 2005;39:663–84.
[4] Abdul Khalil HPS, Suraya NL. Anhydride modification of cultivated kenaf bast fibers: morphological, spectroscopic, and thermal studies. Bioresources 2011;6:1122–35.
[5] Cook CG, Chow P, Meimban RJ, Lambert RJ, Bajwa D, Nelson LR. Influence of cultivars, years, environment, and stem location on kenaf fiber properties. Tappi J 1998;81:135–40.
[6] Norton AJ, Bennett SJ, Hughes M, JPRE Dimmock, Wright D, Newman G, et al. Determining the physical properties of flax fibre for industrial applications: the influence of agronomic practice. Ann Appl Biol 2006;149:15–25.
[7] Friend JA. Achieving soil sustainability. J Soil Water Conserv 1992;47:156–7.
[8] Constable GA, Rochester IJ, Daniells IG. Cotton yield and nitrogen requirement is modified by crop rotation and tillage method. Soil Tillage Res 1992;23:41–59.
[9] Abdul Khalil HPS, Tehrani MA, Davoudpour Y, Bhat AH, Jawaid M, Hassan A. Natural fiber reinforced poly(vinyl chloride) composites: a review. J Reinf Plast Compos 2013;32:330–56.
[10] Siqueira G, Bras J, Dufresne A. Cellulosic bionanocomposites: a review of preparation, properties and applications. Polymers 2010;2:728–65.
[11] Martins DAB, HFAd Prado, Leite RSR, Ferreira H, MMdS Moretti, Rd Silva, et al. Agroindustrial wastes as substrates for microbial enzymes production and source of sugar for bioethanol production 2011.
[12] Vincent JFV. A unified nomenclature for plant fibres for industrial use. Appl Compos Mater 2000;7:269–71.
[13] Olesen, P.O. Plackett, DV. Perspectives on the performance of natural plant fibres. In: Natural fibres performance forum; 1999: May 27–28, vol 28.
[14] Bavan DS, Kumar GCM. Finite element analysis of a natural fiber (maize) composite beam. J Eng 2013;2013:7.
[15] Bledzki AK, Gassan J. Composites reinforced with cellulose based fibres. Prog Polym Sci 1999;24:221–74.
[16] Mwaikambo LY, Ansell MP. Mechanical properties of alkali treated plant fibres and their potential as reinforcement materials II. Sisal fibres. J Mater Sci 2006;41:2497–508.
[17] Madsen B, Gamstedt EK. Wood versus plant fibers: similarities and differences in composite applications. Adv Mater Sci Eng 2013;2013:14.
[18] Ramires EC, Dufresne A. A review of cellulose nanocrystals and nanocomposites. Tappi J 2011;10:9–16.
[19] Saxena IM, Brown RM. Cellulose biosynthesis: current views and evolving concepts. Ann Bot—London 2005;96:9–21.
[20] Jarvis M. Chemistry—cellulose stacks up. Nature 2003;426:611–2.
[21] Sugiyama J, Persson J, Chanzy H. Combined infrared and electron-diffraction study of the polymorphism of native celluloses. Macromolecules 1991;24:2461–6.
[22] Abdul Khalil HPS, Bhat AH, Ireana Yusra AF. Green composites from sustainable cellulose nanofibrils: a review. Carbohydr Polym 2012;87:963–79.
[23] Chengjun Z, Qinglin W. Recent development in applications of cellulose nanocrystals for advanced polymer-based nanocomposites by novel fabrication strategies, nanocrystals—synthesis, Characterization and Applications, , Dr. Sudheer Neralla editor; 2012: 103-120.
[24] Wu Q, Henriksson M, Liu X, Berglund LA. A high strength nanocomposite based on microcrystalline cellulose and polyurethane. Biomacromolecules 2007;8:3687–92.
[25] Bjerre AB, Schmidt AS. Development of chemical and biological processes for production of bioethanol: optimization of the wet oxidation process and characterization of products. Denmark: Risø National Laboratory; 1997.
[26] Demirbas A. Heavy metal adsorption onto agro-based waste materials: a review. J Hazard Mater 2008;157:220–9.
[27] Jonoobi M, Oksman Niska K, Harun J, Misra M. Chemical composition, crystallinity, and thermal degradation of bleached and unbleached kenaf bast (*Hibiscus cannabinus*) pulp and nanofibers. BioResourses 4, Apr; 2009.
[28] Doran JW, Zeiss MR. Soil health and sustainability: managing the biotic component of soil quality. Appl Soil Ecol 2000;15:3–11.
[29] McCauley A, Jones C, Jacobsen J. Basic soil properties. Montana State Univ Extension Serv 2005:1–12.
[30] Kuncoro PH, Kog K, Satta N, Muto Y. A study on the effect of compaction on transport properties of soil gas and water. I: Relative gas diffusivity, air permeability, and saturated hydraulic conductivity. Soil Tillage Res 2014;143:172–9.
[31] Teng Y, Wu J, Lu S, Wang Y, Jiao X, Song L. Soil and soil environmental quality monitoring in China: a review. Environ Int 2014;69:177–99.
[32] Stamatiadis S, Werner M, Buchanan M. Field assessment of soil quality as affected by compost and fertilizer application in a broccoli field (San Benito County, California). Appl Soil Ecol 1999;12:217–25.
[33] Nichols KA, Wright SE, Liebig MA, Pikul Jr JL. Functional significance of glomalin to soil fertility. In: A.J. S, editor. Great plains soil fertility. Kansas State University; 2004. p. 219–24.
[34] Pardo A, Amato M, Chiarandà FQ. Relationships between soil structure, root distribution and water uptake of chickpea (*Cicer arietinum* L.). Plant growth and water distribution. Eur J Agron 2000;13:39–45.
[35] Franzluebbers AJ. Water infiltration and soil structure related to organic matter and its stratification with depth. Soil Tillage Res 2002;66:197–205.
[36] McKenzie N, Coughlan K, Cresswell H. Soil physical measurement and interpretation for land evaluation. CSIRO Publishing; 2002.
[37] Gil PM, Bonomelli C, Schaffer B, Ferreyra R, Gentina C. Effect of soil water-to-air ratio on biomass and mineral nutrition of avocado trees. J Soil Sci Plant Nutr 2012;12:609–30.
[38] Chaudhari PR, Ahire DV, Ahire VD, Chkravarty M, Maity S. Soil bulk density as related to soil texture, organic matter content and available total nutrients of Coimbatore soil. IJSRP 2013;3:2.
[39] Vetterlein D, Szegedi K, Stange F, Jahn R. Impact of soil texture on temporal and spatial development of osmotic-potential gradients between bulk soil and rhizosphere. J Plant Nutr Soil Sci 2007;170:347–56.
[40] Bada BS, Raji KA. Phytoremediation potential of kenaf (*Hibiscus cannabinus* L.) grown in different soil textures and cadmium concentrations. Afr J Environ Sci Technol 2010;4:250–5.
[41] Houlbrooke DJ, Paton RJ, Morton JD, Littlejohn RP. Soil quality and plant yield under dryland and irrigated winter forage crops grazed by sheep or cattle. Soil Res 2009;47:470–7.
[42] Staddon PL, Gregersen R, Jakobsen I. The response of two *Glomus* mycorrhizal fungi and a fine endophyte to elevated atmospheric CO_2, soil warming and drought. Global Change Biol 2004;10:1909–21.
[43] Sparling GP, Schipper LA. Soil quality at a national scale in New Zealand. J Environ Qual 2002;31:1848–57.
[44] Laurenson S, Houlbrooke DJ. The effect of soil aeration on the recovery of soil structure in the North Otago Rolling Downlands following winter grazing of sheep and cattle. Fertil Lime Res Centre 2012:1–9.
[45] Salehi A, Maleki M. Evaluation of soil physical and chemical properties in poplar plantations in North of Iran. Ecologia 2012;4:69–76.
[46] Boyle M, Frankenberger WT, Stolzy LH. The influence of organic-matter on soil aggregation and water infiltration. J Prod Agric 1989;2:290–9.
[47] Blanchart E, Albrecht A, Brown G, Decaens T, Duboisset A, Lavelle P, et al. Effects of tropical endogeic earthworms on soil erosion. Agric Ecosyst Environ 2004;104:303–15.
[48] Li S-X, Wang Z-H, Stewart BA. Chapter five—responses of crop plants to ammonium and nitrate N. In: Donald LS, editor. Advances in agronomy. Academic Press; 2013. p. 205–397.
[49] Boix-Fayos C, Calvo-Cases A, Imeson AC, Soriano-Soto MD. Influence of soil properties on the aggregation of some Mediterranean soils and the use of aggregate size and stability as land degradation indicators. Catena 2001;44:47–67.
[50] Bradl HB. Adsorption of heavy metal ions on soils and soils constituents. J Colloid Interface Sci 2004;277:1–18.
[51] Amouei A. Effect of saline soil levels stresses on agronomic parameters and fodder value of the halophyte *Atriplex leucoclada* L. (Chenopodiaceae). Afr J Agric Res 2013;8:3007–12.
[52] Ivlev AA, Pichouzkin VI, Tarakanov IG. Soil salinity effect on carbon isotope composition of plant biomass. Adv Stud Biol 2013;5:223–34.
[53] Munns R, Tester M. Mechanisms of salinity tolerance. Annu Rev Plant Biol 2008;59:651–81.
[54] King AJ, Farrer EC, Suding KN, Schmidt SK. Co-occurrence patterns of plants and soil bacteria in the high-alpine subnival zone track environmental harshness. Front Microbiol 2012;3:347.
[55] Hayat R, Ali S, Amara U, Khalid R, Ahmed I. Soil beneficial bacteria and their role in plant growth promotion: a review. Ann Microbiol 2010;60:579–98.
[56] Altieri MA. The ecological role of biodiversity in agroecosystems. Agr Ecosyst Environ 1999;74:19–31;
Johansson JF, Paul LR, Finlay RD. Microbial interactions in the mycorrhizosphere and their significance for sustainable agriculture. FEMS Microbiol Ecol 2004;48:1–13.
[57] Finlay R. Ecological aspects of mycorrhizal symbiosis—with special emphasis on the functional diversity of interactions involving the extraradical mycelium. Comp Biochem Physiol A 2007;146:S220–1.
[58] Finlay RD. Ecological aspects of mycorrhizal symbiosis: with special emphasis on the functional diversity of interactions involving the extraradical mycelium. J Exp Bot 2008;59:1115–26.
[59] Nadeem SM, Ahmad M, Zahir ZA, Javaid A, Ashraf M. The role of mycorrhizae and plant growth promoting rhizobacteria (PGPR) in improving crop productivity under stressful environments. Biotechnol Adv 2014;32:429–48.
[60] Ekelund F, Rønn R. Notes on protozoa in agricultural soil with emphasis on heterotrophic flagellates and naked amoebae and their ecology. FEMS Microbiol Rev 1994;15:321–53.
[61] Rønn R, Gavito M, Larsen J, Jakobsen I, Frederiksen H, Christensen S. Response of free-living soil protozoa and microorganisms to elevated atmospheric CO_2 and presence of mycorrhiza. Soil Biol Biochem 2002;34:923–32.
[62] Reardon CL, Strauss SL, Mazzola M. Changes in available nitrogen and nematode abundance in response to Brassica seed meal amendment of orchard soil. Soil Biol Biochem 2013;57:22–9.
[63] Stevnbak K, Maraldo K, Georgieva S, Bjørnlund L, Beier C, Schmidt IK, et al. Suppression of soil decomposers and promotion of long-lived, root herbivorous nematodes by climate change. Eur J Soil Biol 2012;52:1–7.
[64] Bonkowski M, Jentschke G, Scheu S. Contrasting effects of microbial partners in the rhizosphere: interactions between Norway Spruce seedlings (*Picea abies* Karst.), mycorrhiza (*Paxillus involutus* (Batsch) Fr.) and naked amoebae (protozoa). Appl Soil Ecol 2001;18:193–204.
[65] Tao J, Chen X, Liu M, Hu F, Griffiths B, Li H. Earthworms change the abundance and community structure of nematodes and protozoa in a maize

residue amended rice–wheat rotation agro-ecosystem. Soil Biol Biochem 2009;41:898–904.
[66] Ilieva-Makulec K, Makulec G. Does the activity of the earthworm *Aporrectodea caliginosa* modify the plant diversity effect on soil nematodes? Eur J Soil Biol 2007;43(Suppl 1):S157–64.
[67] Mudrák O, Uteseny K, Frouz J. Earthworms drive succession of both plant and Collembola communities in post-mining sites. Appl Soil Ecol 2012;62:170–7.
[68] Chaoui HI, Zibilske LM, Ohno T. Effects of earthworm casts and compost on soil microbial activity and plant nutrient availability. Soil Biol Biochem 2003;35:295–302.
[69] Jusselme MD, Miambi E, Mora P, Diouf M, Rouland-Lefèvre C. Increased lead availability and enzyme activities in root-adhering soil of *Lantana camara* during phytoextraction in the presence of earthworms. Sci Total Environ 2013;445–446:101–9.
[70] Tripathi N, Lepcha STS, Singh CJ. Characterization of industrial Hempand Girardinia heterophylla and factor affecting fiber properties. Int J Fiber Text Res 2013;3:49–51.
[71] McGrath JM, Spargo J, Penn CJ. Soil fertility and plant nutrition encyclopedia of agriculture and food systems 2014:p. 166–184.
[72] Ahemad M, Kibret M. Mechanisms and applications of plant growth promoting rhizobacteria: current perspective. J King Saud Univ—Sci 2014;26:1–20.
[73] Goudjal Y, Toumatiaa O, Yekkour A, Sabaoua N, Mathieuc M, Zitouni A. Biocontrol of *Rhizoctonia solani* damping-off and promotion of tomato plant growth by endophytic actinomycetes isolated from native plants of Algerian Sahara. Microbiol Res 2014;169:59–65.
[74] Geitmann A, JKE Ortega. Mechanics and modeling of plant cell growth. Trends Plant Sci 2009;14:467–78.
[75] Johnson RM, Downer RG, Bradow JM, Bauer PJ, Sadler EJ. Variability in cotton fiber yield, fiber quality, and soil properties in a Southeastern Coastal Plain. Agron J 2002;94:1305–16.
[76] Bryan RB. Soil erodibility and processes of water erosion on hillslope. Geomorphology 2000;32:385–415.
[77] Jahan MS, Sabina R, Tasmin B, Chowdhury DAN, Noori A, Al-Maruf A. Effect of harvesting age on the chemical and morphological properties of dhaincha (Sesbania Aculeata) and its pulpability and bleachability. Bioresources 2009;4:471–81.
[78] Loynachan TE. American Geological Institute., Soil Science Society of America., United States. Natural Resources Conservation Service. Sustaining our soils and society. Alexandria, VA: American Geological Institute; 1999.
[79] Ping JL, Green CJ, Bronson KF, Zartman RE, Dobermann A. Identification of relationships between cotton yield, quality, and soil properties. Agron J 2004;96:1588–97.
[80] Kumar K, Goh KM. Crop residues and management practices: effects on soil quality, soil nitrogen dynamics, crop yield, and nitrogen recovery. In: Donald LS, editor. Advances in agronomy. Academic Press; 1999. p. 197–319.
[81] Thangarajan R, Bolan NS, Tian G, Naidu R, Kunhikrishnan A. Role of organic amendment application on greenhouse gas emission from soil. Sci Total Environ 2013;465:72–96.
[82] Fageria NK, Moreira A. Chapter four—the role of mineral nutrition on root growth of crop plants. In: Donald LS, editor. Advances in agronomy. Academic Press; 2011. p. 251–331.
[83] Tuomela M, Vikman M, Hatakka A, Itavaara M. Biodegradation of lignin in a compost environment: a review. Bioresour Technol 2000;72:169–83.
[84] Sampathkumar T, Pandian BJ, Rangaswamy MV, Manickasundaram P, Jeyakumar P. Influence of deficit irrigation on growth, yield and yield parameters of cotton–maize cropping sequence. Agric Water Manage 2013;130:90–102.
[85] Pettigrew WT. The effect of higher temperatures on cotton lint yield production and fiber quality. Crop Sci 2008;48:278–85.
[86] Clement JD, Constable GA, Stiller WN, Liu SM. Negative associations still exist between yield and fibre quality in cotton breeding programs in Australia and USA. Field Crops Res 2012;128:1–7.
[87] Burns RG, DeForest JL, Marxsen J, Sinsabaugh RL, Stromberger ME, Wallenstein MD, et al. Soil enzymes in a changing environment: current knowledge and future directions. Soil Biol Biochem 2013;58:216–34.
[88] Drewnik M. The effect of environmental conditions on the decomposition rate of cellulose in mountain soils. Geoderma 2006;132:116–30.
[89] Kautz T, Amelung W, Ewert F, Gaiser T, Horn R, Jahn R, et al. Nutrient acquisition from arable subsoils in temperate climates: a review. Soil Biol Biochem 2013;57:1003–22.
[90] Reiter JS, Krieg DR, Green CJ. Cotton response to applications of nutrient mixtures. In: Dugger P, Richter DA, editors. Nat Cotton Council of Am; 1999. p. 1272–3.
[91] Pettigrew WT, Heitholt JJ, Meredith WR. Genotypic interactions with potassium and nitrogen in cotton of varied maturity. Agron J 1996;88:89–93.
[92] Sawan ZM, Hafez SA, Basyony AE, Alkassas AR. Cottonseed, protein, oil yields and oil properties as affectedness by nitrogen fertilization and foliar application of potassium and a plant growth retardant. World J Agric Sci 2006;2:56–65.
[93] Hossain MD, Hanafi MM, Jol H, Hazandy AH. Growth, yield and fiber morphology of kenaf (*Hibiscus cannabinus* L.) grown on sandy bris soil as influenced by different levels of carbon. Afr J Biotechnol 2011;10:10087–94.
[94] Higbie SM, Wang F, Stewart JM, Sterling TM, Lindemann WC, Hughs E, et al. Physiological response to salt (NaCl) stress in selected cultivated tetraploid cottons. Int J Agron 2010;1:1–12.
[95] Khorsandi F, Anagholi A. Reproductive compensation of cotton after salt stress relief at different growth stages. J Agron Crop Sci 2009;195:278–83.
[96] Dong H. Technology and field management for controlling soil salinity effects on cotton. Aust J Crop Sci 2012;6:333–41.
[97] Khattak RA, Muhammad D. Seed cotton yield and nutrient concentrations as influenced by lignitic coal derived humic acid in salt-affected soils. Sarhad J Agric 2010;26:43–9.
[98] Perez J, Munoz-Dorado J, de la Rubia T, Martinez J. Biodegradation and biological treatments of cellulose, hemicellulose and lignin: an overview. Int Microbiol the official journal of the Spanish Society for Microbiology 2002;5:53–63.
[99] Donnelly PK, Entry JA, Crawford DL, Cromack K. Cellulose and lignin degradation in forest soils—response to moisture, temperature, and acidity. Microbial Ecol 1990;20:289–95.
[100] Entry JA, Donnelly PK, Cromack K. Influence of ectomycorrhizal mat soils on lignin and cellulose degradation. Biol Fertil Soils 1991;11:75–8.
[101] Entry JA, Backman CB. Influence of carbon and nitrogen on cellulose and lignin degradation in forest soils. Can J For Res 1995;25:1231–6.
[102] Cook PR. A chromomeric model for nuclear and chromosome structure. J Cell Sci 1995;108:2927–35.
[103] Pettigrew WT. Improved yield potential with an early planting cotton production system. Agron J 2002;94:997–1003.
[104] Bauer PJ, Busscher WJ. Winter cover and tillage influences on coastal plain cotton production. J Prod Agric 1996;9:50–4.
[105] Brook KD, Hearn AB, Kelly CF. Response of cotton, *Gossypium-Hirsutum* L., to damage by insect pests in Australia—manual simulation of damage. J Econ Entomol 1992;85:1368–77.
[106] Blaise D. Yield, boll distribution and fibre quality of hybrid cotton (*Gossypium hirsutum* L.) as influenced by organic and modern methods of cultivation. J Agron Crop Sci 2006;192:248–56.
[107] Larcher W. Physiological plant ecology: ecophysiology and stress physiology of functional groups. 4th ed.. New York, NY: Springer-Verlag Berlin Heidelberg; 2003.
[108] Banwart S. Save our soils. Nature 2011;474:151–2.
[109] Campbell BT, Saha S, Percy R, Frelichowski J, Jenkins JN, Park W, et al. Status of the global cotton germplasm resources. Crop Sci 2010;50:1161–79.
[110] Reddy KR, Koti S, Davidonis GH, Reddy VR. Agroclimatology—interactive effects of carbon dioxide and nitrogen nutrition on cotton growth, development, yield, and fiber quality. Agron J 2004;96:1148–57.
[111] Pettigrew WT. Environmental effects on cotton fiber carbohydrate concentration and quality. Crop Sci 2001;41:1108–13.
[112] Jahan MS, Mun SP. Effect of tree age on the soda-anthraquinone pulping of Nalita wood (*Trema orientalisis*). J Ind Eng Chem 2004;10:766–71.
[113] Rowell RM, Rowell J. Paper and composites from agro-based resources. Taylor & Francis; 1996.
[114] Huang YH, Fei BH, Yu Y, Zhao RJ. Plant age effect on mechanical properties of Moso Bamboo (Phyllostachys Heterocycla Var. Pubescens) single fibers. Wood Fiber Sci 2012;44:196–201.
[115] Belkheiri O, Mulas M. The effects of salt stress on growth, water relations and ion accumulation in two halophyte Atriplex species. Environ Exp Bot 2013;86:17–28.
[116] Baskin CC, Baskin JM. Chapter 11—Germination ecology of plants with specialized life cycles and/or habitats. In: Baskin CC, Baskin JM, editors. Seeds. San Diego: Academic Press; 1998. p. 459–557.
[117] Davies TC, Mundalamo HR. Environmental health impacts of dispersed mineralisation in South Africa. J Afr Earth Sci 2010;58:652–66.
[118] Corwin DL, Lesch SM. Apparent soil electrical conductivity measurements in agriculture. Comput Electron Agric 2005;46:11–43.
[119] Laishram J, Saxena KG, Maikhuri RK, Rao KS. Soil quality and soil health: a review. Int J Ecol Environ 2012;38:19–37.
[120] Valdes R, Miralles J, Franco JA, Sanchez-Blanco MJ, Banon S. Using soil bulk electrical conductivity to manage saline irrigation in the production of potted poinsettia. Sci Hortic 2014;1701:1–7.

The role of soil properties and it’s interaction towards quality plant fiber: A review

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