J. Cotton Res. Dev. **36**(1), 9-18 (January, 2022) **ISSN No. 0972-8619**

Window of opportunity in natural fiber for *Atmanirbhar Bharat*

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The use of natural fibers is recorded from pre historic era and recorded between 3000 to 2000 BC, and the weaving of cotton was well established in unified India. Improvements in machines for spinning, weaving, etc., beginning in the 1700s and revolutionized Eli Whitney's invention of the cotton gin in 1793 helped cotton become king of the fibers (Fisher, 1981). Natural fibers have been used for centuries to protect human against warm and cold weather. Until the last 100 years or so, the only fibers used by mankind were natural fibers. Hemp, the oldest cultivated fiber plant, originated in Southeast Asia, then spread to China, where reports of cultivation date to 5000-6000 years ago. The art of handmade weaving and spinning linen was already well developed in Egypt by 3400 BC, indicating that flax was cultivated sometime before that date. Reports of the spinning of cotton in India date back to 3000 BC. The manufacture of silk and silk products originated in the highly developed Chinese culture during 2640 BC. New fiber plants were also discovered and their use explored. In the 18th and 19th centuries, the Industrial Revolution encouraged the further invention of machines for use in processing various natural fibers, resulting in a tremendous upsurge in natural fiber production.

The introduction of regenerated man made cellulosic fibers rayon formed of cellulose material that has been dissolved, purified, and extruded in 1865 but not commercially manufactured until 1905. Followed by the invention of completely synthetic fibers, such as nylon which was not commercially manufactured until 1931, challenged the monopoly of natural fibers for textile and industrial use. In 1939, 80 per cent of all the fiber used was cotton. In the last 50 years, man made fibers have accounted for an increasingly large percentage of fiber manufactured. Presently, about 30 per cent of the textile fibers come from natural fibers, the rest comes from man made fibers. Recognition of the competitive threat from synthetic fibers resulted in intensive research directed toward the breeding of new and better strains of natural fiber sources with higher yields, improved production and processing methods, and modification of fiber yarn or fabric properties. The considerable improvements achieved have permitted increased total production, although natural fibers' actual share of the market has decreased with the influx of the inexpensive, synthetic fibers requiring fewer man-hours for production.

Classification of natural fibers

Fibers are normally classified into three main classes *i.e.* natural, animal and manmade fibers. Based on their origin natural fibers can also further classified as cellulosic (plants/vegetables) and protein (animals). Mineral fibers such as asbestos that occur naturally but are not bio-based. Vegetable fibers are generally comprised mainly of cellulose have certain common properties like low resilience, high density, and good conductor of heat, besides, they are highly absorbent and are resistant to high temperature (Sabesh and Prakash, 2019). Cotton, flax, jute, hemp and ramie are the examples of major natural fibers. Vegetable fiber are further classified into seed fiber; leaf fiber; bast fiber; fruit fiber; and stalk fiber (Chandramohan and Marimuthu, 2011).

The animal fiber like wool and silk are made up of protein molecules. The basic elements in the protein molecules are carbon, hydrogen, oxygen and nitrogen. Animal fibers have high resiliency but weak when wet because

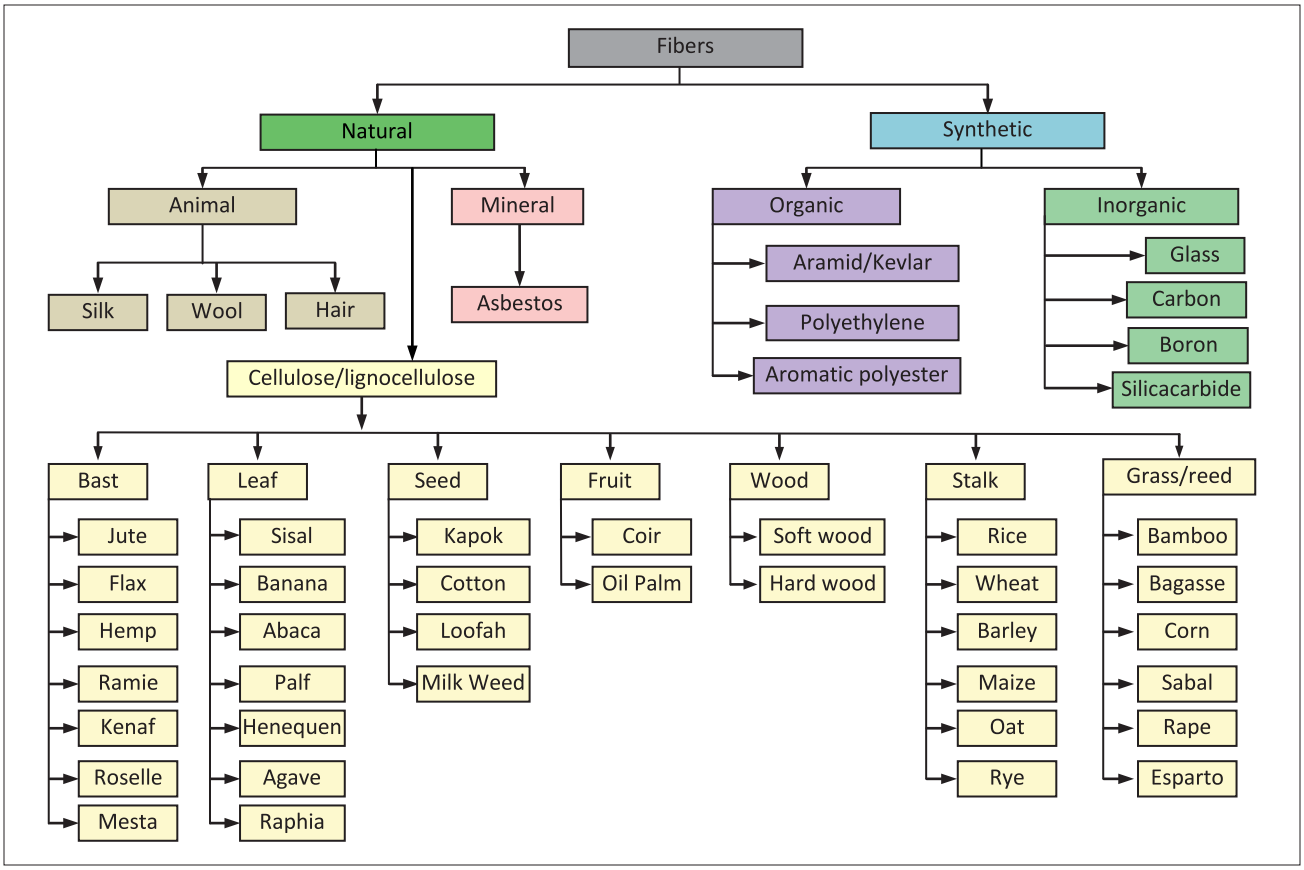


Fig. 1. Classification of matural and synthetic fibers

they are bad conductors of heat. All natural fibers are unique in their own set of characteristics, advantages and disadvantages and are more environment friendly than man-made fibers both in terms of production and process. Natural fibers are completely bio-degradable thus play a key role in the emerging green economy. The detailed classification of fibers presented in graphical form in Fig. 1.

During the past decade, world natural fibre production has ranged from 28 to 35 million tons, year to year variation caused by changes in yields linked to weather (Townsend, 2019). Globally, cotton is the largest natural fiber produced with an estimated production of 26 million tons and accounts for 81 pre cent; Jute, kenaf and allied fibers accounts for 7.8 per cent of the world natural fibers (Table 1).

Global production of all apparel and textile fiber reached 110 million tons in 2018, and natural fibers accounted for 29 pre cent, cellulosic fiber (6%), synthetic filament (45%), and synthetic staple (20%) of the total (Fig. 3). The synthetic fibers are dominated by polyester, which accounts for nearly 90 per cent of world filament production and 70 per cent of world synthetic staple production. The remaining synthetic fibers are composed mostly of nylon, acrylic and polypropylene (Townsend, 2019). DNFI (2019), estimates that about 60 million households worldwide are engaged in natural fiber production (Fig. 4).

Natural fibers in bio composites

Combining agro fibers (ligno cellulosics) with other resources represents a strategy for producing advanced composite materials that takes advantage of the properties of both types of resources. Natural fibers especially, plant fibers are increasingly finding applications in bio composite manufacturing for applications like automotive, marine and construction (Sunil

Table 1: Estimated global production of natural fiber

Fiber	Production (thousand tons)	Major producing countries
Cotton	26157	India, China, USA, Beazil, Pakistan
Jute, kenaf and allied fibers	3634	India, Bangladesh, China, Thailand
Coir	1239	India, Sri Lanka
Flax	868	Canada, France, China
Kenaf	221	India, Pakistan, China
Sisal	198	Brazil, China and some African countries
Silk, Raw	168	China, India
Wool	1974	Australia, China, New Zealand
Hemp, ramie,	168	China, France, Belgium, Belarus, Ukraine
Other natural fibers	239	

Source: Mohamad Midani *et al.*, 2021

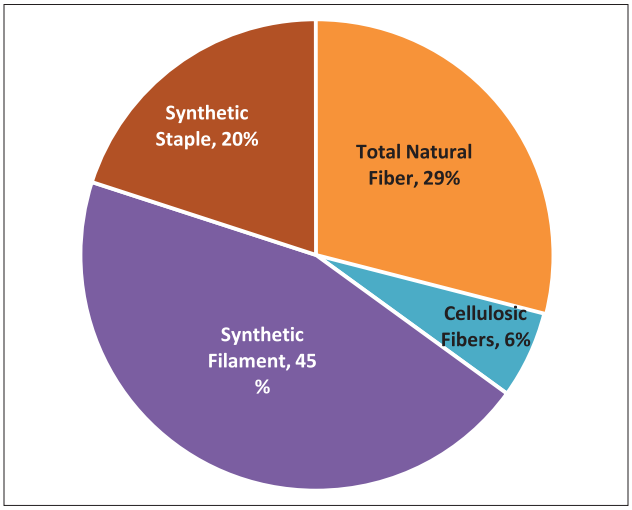


Fig. 3. World fiber production

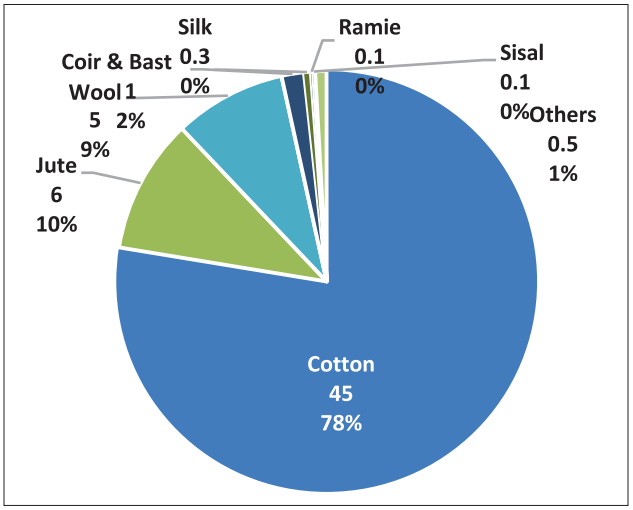


Fig. 4. Producing households in million (number and %)

Kumar *et at.*, 2014). Based on their sustain ability benefits plant and animal fibers are substituting synthetic fibers in composites. India sustained the use of natural fibers as reinforcements for composites in applications like pipes, panels etc. (Pal, 1984). Currently, there is a growing interest in utilising natural fibers as reinforcement for renewable polymers. One of the major problems of utilising natural fibers in composite materials is the high moisture uptake of natural fibers, which leads to poorer mechanical properties of the natural fibers reinforced composites (lee and Bismarch, 2011). The chemical and mechanical properties of the different natural fibers have been presented in Table 2 and 3. It shows that the natural fibers Flax, Jute, ramie, sisal and bamboo to some extent has better composition with cotton.

In recent years, the largest area of growth in the use of natural fibers is in the automotive industry. Plant fibers are attractive to car makers as they are light and mechanically strong, and plant fiber composites can be used instead of fiberglass to reinforce components. Moulding them into shape uses less energy than moulding fiberglass, which can considerably reduce production costs. The cars also weigh less and cost less to run. In addition, car seats padded with coconut fiber are more comfortable to use than those filled with plastic foam.

Cotton situation in India

Cotton cultivation, though centuries old, needs to be continuously refined based on scientific innovations for the betterment of all

Table 2: Chemical properties (in %) of some natural fibers

Fiber	Hemicellulose	Moisture	Cellulose	Lignin	Ash	Pectin	Wax
Flax	16.7	10.0	64.1	2.0	13.1	1.8	1.5
Jute	12.0	10.0	64.4	0.2	0.5-2.1	11.8	0.5
Ramie	13.1	10.0	68.6	0.6	NA	1.9	0.3
Sisal	12.0	10.0	65.8	9.9	4.2	0.8	0.3
Kenaf	18.0-24.0	NA	37.0-49.0	15.0-21.0	2.4-5.1	8.9	0.5
Hemp	12.0-22.4	6.5	5.0-80.2	2.6-13.0	0.5-0.8	0.9-3.0	0.2
Cotton	5.7	10.0	82.7	28.2	NA	5.7	0.6
Coir	11.9-15.4	0.2-0.5	19.9-36.7	32.7-53.3	NA	4.7-7.0	NA
Babmboo	12.5-73.3	11.7	48.2-73.8	10.2-21.4	2.3	0.37	NA

Source: Ranakoti *et al.* 2018

Table 3: Mechanical properties of some natural fibers

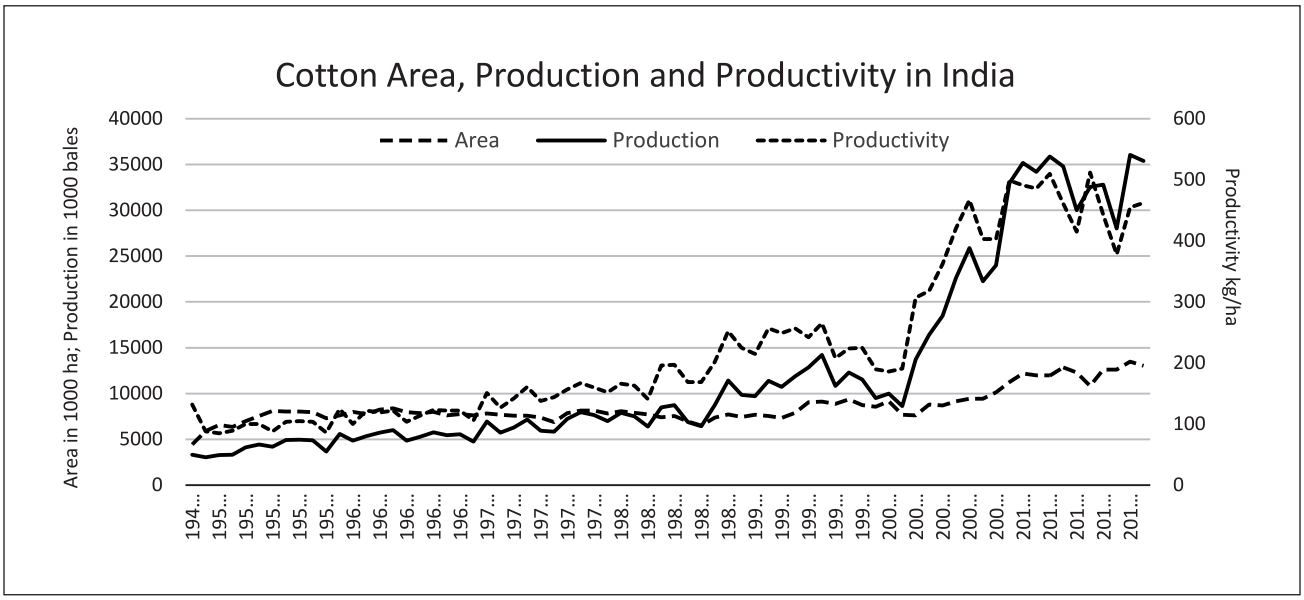
Fibers	Tensile strength (MPa)	Elongation at failure (%)	Young's modulus (GPa)	Density (gm/cm3)
Hemp	690	1.6	70.0	1.47
Flax	345-1500	2.7-3.2	27.6	1.50
Sisal	468-700	3.0-7.0	9.4-22.0	1.45
Ramie	400-938	1.2-3.8	61.4-128.0	1.55
Kenaf	295-1191	1.6	53.0	1.20
Jute	393-800	1.2-1.5	13.0-26.5	1.30-1.49
Cotton	287-800	7.0-8.0	5.5-12.6	1.50-1.60
Wool	50-315	13.5-35.0	2.3-5.0	1.30
Coir	131-220	15.0-40.0	4.0-6.0	1.15-1.46
Bamboo	140-230	2.5-3.7	11.0-17.0	0.60-1.10

Source: Ranakoti *et al.* 2018

stakeholders. People around the world mostly use cotton as the main fiber for textile needs. As the leading natural fiber, cotton is an important agricultural commodity, providing income to millions of farmers worldwide. Though the cotton improvement research in the country was initiated in 18th century, the systematic cotton research in India started in the year 1921 through Indian Central Cotton Committee (ICCC) sponsoring cotton research schemes. Indian Council of Agricultural Research (ICAR) took over the responsibility of research in all crops including cotton. It was in 1967 that All India Coordinated Research Project on Cotton was launched by ICAR with its headquarters at Coimbatore (Tamil Nadu) to improve both quality and quantity of cotton considering the needs of domestic textile industry and export. The research and development efforts of ICAR are focused on high value processed products, linking production with processing and marketing with focus on remunerative returns to small and marginal farmers and farm workers. In addition, establishment of quality testing/referral labs, developing high yielding varieties combining with good quality cotton fiber characteristics demanded by the domestic industries and importing countries, need to be mentioned.

In India, the conditions are favourable for growing all the four cultivated species of *Gossypium, viz.*, *Gossypium arboreum* and *G. herbaceum* (Asian cottons), *G. hirsutum* (American upland cotton) and *G. barbadense* (Egyptian cotton) besides hybrid cotton. *G. barbadense* is grown on a very little area in the states of Tamil Nadu, Karnataka and Andhra Pradesh. *G. herbaceum* is limited to the states of Gujarat and northern coastal part of Karnataka. Whereas, *G. hirsutum* and *G. arboreum* are gown in all the major cotton growing states in India. Gujarat, Maharashtra and Telangana are the major producer of cotton in India. India have

Fig. 5. Cotton Area, production and productivity in independent India



Characteristics and use of major natural fiber

achieved a significant improvement in delivering both quality and quantity cottons since independence. Abysmally, India have been playing significant role in cotton in terms of cotton cultivation and production in the world for the past six years. Also, it is to be mentioned that cotton productivity in the country stagnated around 500 kg/ha far the past 10 years despite availability of various improved cotton production technologies (Fig. 5).

Cotton : Cotton has been grown for fiber, oil and animal feed for years. Cotton is one of the most breathable and absorbent fibers, having the ability to engross both heat and perspiration; cotton fabrics are also easy to print and dye (Geoff, 2021).The fabrics dated approximately 3000 BC, recovered from Mohenjodaro excavation in Sind (Pakistan) (Santhanam and Sundaram, 1997). An estimated 60 pre cent of cotton fiber is used as yarn and threads in a wide range of clothing. Cultivated in around 80 countries, cotton is one of the world's most widely produced crops and uses about 2.5 pre cent of the world's arable land area. The world produces around 25 million tons of cotton every year. Six countries - China, Brazil, India, Pakistan, the USA and Uzbekistan - account for more than 80 pre cent of total production.

Jute : Jute is extracted from the bark of the white jute plant, Corchorus capsularis and to a lesser extent from tossajute (*C. olitorius*) grown in Asian countries including India, Bangladesh, China, and Myanmar (Shahinur and Hasan, 2019a). Jute fibers are a long, soft, shiny bast fiber that can be spun into string and coarse yarns, mainly used to weave and produce gunny sacks, rugs and carpets, and ropes. Historical documents show that the jute fibers were used predominantly in India during the era of Mughal Emperor Akbar (1542–1605) (Kundu *et al.*, 1959, Chakrabarty *et al.*, 2000). Jute is mainly grown for its fiber and it is one of most important natural fibers after cotton (Pan *et al.*, 2000). Jute fiber has moisture regain, low thermal conductivity, insulating and anti-static properties. Geotextiles made from jute are biodegradable, flexible, absorb moisture and drain well. The global production of jute fibers is around 2500 million ton and major portion of it is contributed by India and Bangladesh (Table 1). India produces 60 per cent of the world's jute, and almost rest of it produced by Bangladesh.

Flax : Flax or linseed, is cultivated as a food and fiber crop in many parts of the world. Reports claim that the flax fibers were used for many applications well before 5000 BC in Egypt and Georgia (Kvavadze *et al.*, 2009). Flax fibers obtained from the stems of the plant Linum usitatissimum, which is pest resistant and does not require pesticide and fertilizer to grow. Linseed (for oil) and Flax (for fiber) cultivated exclusively for seed oil and fiber in India. Flax fiber is used mainly to make fine fabric woven is known as linen, which is a soft, lightweight, breathable material and are stronger than most other natural fibers. Fine flax used for manufacturing good quality suiting, shirting materials, bed sheets, curtains, writing paper, tents, canvas. Flax fibers are stronger, crisper and stiffer to handle compared to cotton. Canada is the largest producer of flax fiber (Martin *et al.*, 2013) and in India produced in Madhya Pradesh, Uttar Pradesh Bihar, Chhattisgarh, Orissa and Jharkhand.

Ramie : Native to East Asia (China, Japan and Malaysia) and commonly known as China grass, ramie (*Boehmerianivea*) is a flowering perennial plant of the nettle family. Ramie does not require fertilisers to grow and resistant pests and does not require pesticides or herbicides and can be harvested multiple times in a good environmental condition. Ramie fiber is one of the strongest natural fibers, white in color with a silky luster, has low elasticity and dyed easily, suitable to make wide range of garments, ranging from sweaters in combination with cotton (Sen and Reddy, 2011) dresses to jeans. Coarse ramie fibers are suitable for making twine, rope and nets. Ramie is commercially produced in Assam, Maharashtra and north Bengal.

Hemp: Hemp fiber is obtained from plant *Cannabis Satvia* L. Recent development in the fiber technology the hemp fiber used to fabricate diûerent composites (Martin *et al.*, 2013).Hemp is good conductor of heat and has natural anti bacterial properties. There is an increasing awareness of hemp fiber and a wide spectrum of hemp products are now available in the market. Used to make rope, canvas, and paper, and also be woven to make linen like fabric. Cultivated in Europe and in India some part of Uttarakhand, Kashmir and Travancore. Hemp is used in several applications such as textile fiber, paper, composite fiber, seed food, oil, wax, resin, pulp, biofuel etc. (Shahzad, 2012).

Pineapple leaf : Pineapple leaf fiber is obtained from plant *Ananas comosus*. The pineapple plant is cultivated many parts of India and the leaf fiber is the by product after the fruit harvested. The processed fibers are used in various sectors including automobiles, textile, mats, construction, etc. The treated and surface-modiûed ûbers are used for making conveyor belt cord, air bag, advanced composites, etc. (Reddy and Yang, 2015).

Kenaf : Kenaf fiber is obtained from plant *Hibiscus cannabinus*. mainly used for paper and rope production (Hamidon *et al.*, 2019). Kenaf fibers are stiû, strong, and tough and have high resistance to insects. These plants are cultivated 4,000 years ago in Africa, Asia, America, and some parts of Europe(Shahinur and Hasan, 2019b). The kenaf fibers amenable to converted into ûne woven fabrics and are environmentally friendly and completely biodegradable. The ûbers were used for making textiles, cords, ropes, storage bags, etc.

Bamboo: Bamboo fiber is obtained from the plant *Bambu soideae*, requires less water to grow with minimal human intervention. Bamboo fiber is a natural glass fiber due to the orientation of fibers in the longitudinal directions plant structure (Wang and Chen, 2016). The cloth material made from bamboo fibers are highly absorbent. The ûbers extracted from bamboo are used as reinforcement for making advanced composites in various industries (Deshpande *et al.*, 2000).

Banana fiber: Banana fiber is extracted from waste stalk of banana plant. India is the biggest producer of banana across the globe. In India, Tamil Nadu, Maharashtra, Gujarat, and Andhra Pradesh states are the major producers. The banana fiber can easily absorb moisture as well as releases moisture. Banana fiber is used for manufacturing doormats, carpets, yarn, geotextiles, luggage carriers, interior decorative items. It can be exported to far east Asian and south Asian countries. India has the potential of producing around 2.2 million tons/year.

Sisal : Sisal is a perennial plant. Grown in arid and semi arid regions of Andhra Pradesh, Bihar, Orissa, Karnataka, Maharashtra and West Bengal. Sisal fiber used to make twines and ropes due to its strength also used to make papers, geotextile mattresses, carpets. It has the property of stretchability, affinity for dyeing and resistance to varied weather condition. Geotextile and automobile segment have huge potential for sisal fiber in India.

Coconut fiber (coir) : Coir is one of the thickest and most resistant natural fibers obtained from the husk of the coconut fruit. The fiber chiefly used for making products such as floormats, doormats, brushes, mattresses, floor tiles and ropes, as well as in upholstery padding, sacking, fishing nets and horticulture. The major portion of the commercially produced coconut fiber originates from India, Sri Lanka, Indonesia, Philippines, and Malaysia.

Silk : Silk is produced by the silkworm, *Bombyx mori*. Fed on mulberry leaves, it produces liquid silk that hardens into filaments to form its cocoon. Its filament is a continuous thread of great tensile strength measuring from 500 to 1500 meters in length, with a diameter of 10-13 microns (FAO, 2009). Silk's natural beauty and other properties such as comfort in warm weather and warmth during colder months have made it sought after for use in high fashion clothes, lingerie and underwear. It is also being used as surgical sutures and does not cause inflammatory reactions and is absorbed or degraded after wounds heal. Silk is produced in more than 20 countries. While the major producers are in Asia. During the year 2017-2018, India produced 32 MT of silk. India, Italy and Japan are the main importers of raw silk for processing and the unit price for raw silk is around twenty times that of raw cotton. The potential of silk is outstanding due to their structure and properties. It consists of highly structured proteins and wide range of properties; high tensile strength, high elongation and resistant to chemicals (Mussig, 2010)

Wool : Sheep (*Ovisaries*) were first domesticated 10,000 years ago. Wool fiber is commonly a textile fiber which is obtained from sheep, goat, camel, rabbit and certain other mammals; while sheep wool is the most commonly used in commercial scale. After scouring to remove grease and dirt, wool is carded and combed, then spun into yarn for fabrics or knitted garments. Its ability to absorb and release moisture makes woolen garments comfortable as well as warm. Wool is used in the manufacture of garments, including sweaters, dresses, coats, suits and "active sportswear". Industrial uses of woolinclude sheets of bonded coarse wool used for thermal and acoustic insulation in home construction, as well pads for soaking up oil spills. The world's leading animal fiber, wool is produced in about 100 countries on half a million farms. In India woolen textiles and clothing industry is relatively small compared to the cotton and man made fiber based textiles and clothing industry. India has the 3rdlargest sheep population country in the world having 65.07 million sheep producing 43.50 million kg of raw wool in 2017-2018.

Rayon : Rayon, artificial textile material composed of regenerated and purified cellulose derived from plant sources. Developed in the late 19th century as a substitute for silk, rayon was the first man made fiber.

DISCUSSION AND CONCLUSION

Natural fibers have been largely displaced by manmade fibers since 1960s. In recent years, natural fiber production was estimated at 32 million tons, out of which cotton's share is around 26 million tons and rest by other natural fibers, representing just 31 per cent of total global fiber production of 103 million tons. Growing population pressure and increased demand for cloth, the cotton production around the world is not able to supply that the textile industries making use of man made fibers for textile production. At the same time the rise in petroleum price (where most of the man made fibers are produced from petroleum) along with growing environmental awareness is leading to revival for products made from natural fibers at the global level. There is great potential for production of natural fiber including cotton in India.

As the demand for the textile materials, the researchers have tried to complement polluting synthetic fiber with natural fiber obtained from fruits, seeds, leaves, stem, animals, etc. (Sanjay *et al.*, 2019a). It is understandable that natural fibers cannot be used for making and products as such and required some process and chemical treatments. The chemical and non chemical treatments of the natural fibers mainly enhance the properties of the fiber to make targeted products (Singh *et al.*, 2017). The less polluting chemical treatment is one of the important techniques used to reduce the undesirable and improves the desirable traits of natural fibers (Girijappa *et al.*, 2019). Increased customer demand for sustainable textiles and advances in eco friendly technologies may increase the quantum of natural fibers use in near future. The recommendation of the sub group under Ministry of Textile, GOI, for natural fibers other than cotton, in the first phase five natural fibers banana, pineapple, flax, sisal and hemp for intensive cultivation. The sub group also mentioned that India has presence of number other natural fibers other than cotton and jute have not been fully exploited commercially.

Natural plant fibers are more environmentally friendly than synthetic fibers for several reasons. Plant fibers do not contribute towards global warming as its production cycle is usually carbon neutral – it absorbs the same amount of CO_2 as they emit, consumes renewable resources and end product are biodegradable unlike the production of synthetic fibers which consumes non renewable resources leads to depletion of natural resources (Ragoubi *et.al.*, 2010). The biggest limitation in India is that production of natural fibers has to offset the food crops production, besides price competition from synthetic fibers.

There is great potential for production of natural fiber including cotton in India. Adequate policy decisions involving both the governmental and private agencies in research and development programmes would sustain natural fiber production in the country and assure remunerative return to farming community. In the present scenario of climate change, increased pollution in production and processes and exploitation of natural resources, it is need to revert back to produce products from renewable sources and eco-friendly manner. Textile products made from Natural ûbers ensures the sustainability of ecosystem.

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Received for publication : October 2, 2021
Accepted for publication : Novembe 26, 2021