CHAPTER I

INTRODUCTION

The earliest reference to banana plant seems to be originated between 8000 to 5000 BC from South East Asia and the South Pacific region. The plantain's major importance as a crop during the ancient and early modern world was majorly for local consumption as food crop. However, in case of Japanese production, where banana plants were cultivated for use in textiles and not as a foodstuff, the banana was grown for local markets. By the 1800s, and especially into the early twentieth century, shifts in modes of production and consumption moved banana from a local to a global commodity. (http://www.nhm.nic.in/archive/bananafibre.pdf)

During the same period, after the industrial revolution, synthetic component and chemistry developed to increase efficiency to fulfil the needs in textile production. It became one of many industries highly affecting on the environment, especially water and soil pollution. Textile production processes release some chemicals that contaminate water and soils resources, including fume emission. Some of chemicals used during the process are toxic, not-biodegradable and thus change the physical environment. These unbalance natural resources resulting draught, heat, and high temperature of the world's atmosphere.

Hence, it is time textile production processes shape toward the concept of environmental-friendly and sustainable development. These ideas are not very new in textile industry. The progresses have been improving ranges of natural and environmental (eco)-friendly textile processes. Many efforts have been made in science and technology to develop environmental-friendly process to sustain relationship with the ecosystem. One option could be the banana fiber, by-product from banana fruit cultivation, obtained from left over banana trunk could also be considered.

The use of natural fibers has increased significantly in the last few years, largely because of the environmental benefits. Natural cellulosic minor fibers have been appreciably used as an agent of reinforcement. Their abundance in nature combined with the ease of their processing has an attractive feature, which makes them an

important substitute for synthetic fibers. These ligno-cellulosic fibers possess many characteristics which make their use advantageous: low cost, low density, biological degradability, renewability, good mechanical properties and non-toxicity.

To understand and formulate the objectives for the present study and to relate the effect of softening treatment on fiber and its resultant on yarn and fabric, the following has been discussed below;

1.1.a) Need for substitution of common raw materials

Changing to a bio-based economy requires substitution of common raw materials that are currently largely produced from fossil (petrochemical) or mineral resources, by products produced from renewable (plant and animal based) resources. Development of a sustainable global economy, which permits improving purchasing power and living standards without exhaustion of resources for future generations, requires a fundamental change in attitude. The benifit of those sustainable resources is that they can be grown again within the foreseeable future, without negative side-effects on global bio-diversity. Therefore, competitive products based on renewable resources need to be developed that have high quality, show excellent technical performance and harm the environment less than current products based on petrochemical materials.

1.1.b) Government support to enhance minor fibers

- The year 2009 has been assigned by the UN to be the international year of natural fibers. Natural fibers industries employ millions of people all over the world, especially in the developing countries. As the major non-food commodity natural fibers and their products are processed in many small and large industries and consumers all over the world.
- From the economic division data source of India which was updated last on 18/03/2014 reports that there is scope for enhancing the production of other Natural Fibres such as Banana, Pineapple, Agave/ Sisal, Hemp/ Nettle and Flax etc. The Government and other stakeholders should encourage the production of such fibres.

- Eight functions described under the strategic plan 2012 – 2017, by Ministry of Textiles: one of it states to formulate appropriate policies and schemes for all sectors of textiles and fibres and improve production, productivity and quality of cotton, jute, silk, wool and other natural fibres. (http://nhb.gov.in/report_files/banana/BANANA.htm)
- The recommendations/policy interventions suggested by the sub-group with respect to the selected five fibers approved by the government fiber policy proposed to achieve the desired results for each of the selected fibre; the sub-group proposes a Focus Fiber, Focus State (FFFS) approach for implementation. This will enable promotion of the selected fibers in a localized format, and allow the development of critical mass for these focus fibers. This also allows for most efficient utilization of funds, easy monitoring of the progress made and ensures better rate of return on investments made. The leading fibre-producing states for each of the fibers were identified and based on intensity of cultivation (area of the fibre to total area), the states for each fiber was short listed and Banana fibers were one of the five fibers. The FFFS approach is specific for each selected fibre, as the selected fibres/plants are either already cultivated in large quantities (Banana and Pineapple) or are available, but not commercially exploited or needs to be promoted (Sisal, Flax, Hemp / Nettle). (http://www.agrifarming.in/banana-farming)
- The current Prime Minister Shri Narendra Modi had initiated Make in India campaign, and also has formulated 5F theory, which states Farm-Fiber-Fabric-Fashion –Foreign. It means to promote natural fibers and develop fabrics to be exported rather than to import.

The above mentioned are few examples stating that even the government is also supporting the growth and development of minor fibers, and banana fibers are one of the most expected potential fiber in the field of textiles.

1.1.c) Futuristic fibres of textile world (Ali 2015)

As a famous Scandinavian economist said, - It is very dangerous to make predictions, particularly about the future! Whenever the term futuristic is described, it deals with expressing the vision of future. With advancement of science & technology, products beyond our present perception can be produced. Innovations in fibers called as bio-

degradable and high performance fiber & high functional fiber will be the fibers for tomorrow. With the invention of hi- performance fiber and bio degradable fibers the spectrum of application of fibers high functional fiber and textile materials were substantially widened. Three categories of futuristic fibers have been given by Ali (2015)

1. High performance fibers & high functional fibers.
2. Bio-Degradable fibers.
3. Multi-material fibers.

Biodegradable fibers:

With increasing concerns regarding the effect the textile industry is having on the environment, more and more textile researchers, producers and manufacturers are looking to biodegradable and sustainable fibers as an effective way of reducing the impact textiles have on the environment. The emphasis in biodegradable and sustainable fibers is on textiles that are beneficial by their biodegradation and come from sustainable sources. Biodegradable and sustainable fibers open with a discussion of microbial processes in fiber degradation. And natural fibers are by definition biodegradable.

1.1d) Life cycle assessment of biodegradable fibers

The life cycle assessment (LCA) of biodegradable fibers begins with the growing plant from which the fiber comes from. The LCA consists of plants growth by usage of carbon dioxide, water, and the interaction with the sun's energy via photosynthesis. The next stage is the extraction of the plant fibers through mechanical and chemical processes to separate unwanted components from the fiber material (i.e. cellulose). The third stage consists of polymer production where the material is cleansed or washed in different ways. This can be achieved with dissolving the materials (done with natural fibers), or melting the materials (done with synthetic fibers). Once changed into polymers, the liquefied material is extruded through specially made spinnerets to get different size and shape fibers. Wet, dry, and melt spinning are the three different ways of fiber extrusion. The finished fibers are then treated and cleansed to then be used to make yarn. At the end of its use (i.e. clothing, home furnishing, etc.), the fiber becomes waste. The other more preferred option is the change in the third stage. Instead of converting the minor fiber into regenerated fibers

which leaves with a question of "whether these fibers are now really natural", use of the extracted fibers the way they are by applying some softening treatment.

1.1.e) Application of natural fibers in agro textiles

Agriculture has been amongst the most primal occupations of the humankind and is still a major industry, globally. The stress on the production of agricultural crops has been increasing substantially with the continuous rise in world population. Present situation demands high yield and quality of agro-products in order to meet this rising need of population with limited land resource. However, the traditional way using pesticides and herbicides to achieve this stringent need is difficult. Moreover these methods are expensive and have long lasting ecological impact on soil as well as in living beings and agro-products.

With increasing environmental awareness and specified knowledge of various inter-disciplinary technologies, considerable attention has been given on non-conventional technical applications like using textile structures in agriculture and horticulture sectors to enhance quality and yield of the agro-products. Textile structures in various forms are used in shade house, green house and also in open fields to control environmental factors like temperature, water and humidity. Use of agro textiles like sunscreen, bird net, windshield, mulch mat, hail protection net, harvesting net, etc are gaining popularity now-a-days. (http://www.agrifarming.in/banana-farming)

1.1.f) Categorization of vegetable fibers

(a) Fiber occurring on the seed (raw cotton, java cotton)

(b) Phloem fiber (flax, ramie, hemp, jute and banana)

(c) Tendon fiber from stem or leaves (Manila hemp, sisal, hemp etc)

(d) Fiber occurring around the trunk (hemp palm)

(e) Fiber of fruit/ nut shells (coconut fiber – Coir) cotton and linen are the most important among them.

Phloem fibers (also called bast fibre or skin fibre) is plant fibre collected from the phloem (the "inner bark", sometimes called "skin") or bast surrounding the stem of certain plants. They support the conductive cells of the phloem and provide strength to the stem. The present study focuses on banana fibers.

1.1.g) Banana

Banana is one of the rhizomatous plants and currently grown in 129 countries around the world. It is the fourth most important global food crop. Different parts of banana trees serve different needs, including fruits as food sources, leaves as food wrapping, and stems for fiber and paper pulp. Banana fiber, a ligno-cellulosic fiber, obtained from the pseudo-stem of false banana plant (Musa sepientum), is a bast fiber with relatively good mechanical properties (Matthews, 1954). The stem of the banana plant furnishes a very important fiber for cordage and sacking fabrics. Generally, banana plant can be classified into two groups, depending on the edibility of the starch found in it: edible and wild false banana plant having a species name *M. textilis, M. ensete, M. Fehi*. Musa is in the family *Musaceae*, part of monocotyledonous flowering plants. Some 70 species of Musa were recognized by the World checklist of selected plant families as of January 2013; several produce edible fruit, while others are cultivated as ornamentals. The classification of cultivated bananas has long been a problematic issue for taxonomists. Linnaeus originally placed bananas into two species based only on their uses as food: *Musa sapientum* for dessert bananas and *Musa paradisiaca* for plantains.

Banana is in Musa family. Banana plant is a large perennial herb with leaf sheaths that form pseudo stem. Its height can be 10-40 feet (3.0-12.2 meters) surrounding with 8-12 large leaves. The leaves are up to 9 feet long and 2 feet wide (2.7 meters and 0.61 meter). Its fruits are approximately 4-12 inches (10.2-30.5 centimetres). Different parts of banana trees serve different needs, including fruits as food sources, leaves as food wrapping, and stems for fiber and paper pulp. It is available throughout Thailand and Southeast Asian, India, Indonesia, Malaysia, Philippines, Hawaii, and some Pacific islands. This source of fibers provides great strength, used generally in particular products, such as tea bags and Japanese yen notes.

Typically, banana plants are grown in 3 types; (1) food source, (2) decorative plants, and (3) starch and fibers sources (abaca). Abaca fiber has a long history as a leading cordage fiber of the world, known as Manila hemp. Abaca is one kind of banana plants. The fiber is obtained from outer layers from the stalks of the abaca plant. It is light, strong, and durable. After extraction and dry, it provides a white lustrous colour

fiber. One particular characteristic of the abaca fiber over all other fibers of its class is the great strength and resistance to the action of water, therefore its particular adaptability for marine ropes. However, abaca's fruit is not human food source. It is specifically grown for fiber cultivation. Instead of growing banana tree only for fruit consumption and discard the trunks, the use of banana fibers after the fruits are harvested should be explored. Therefore, the focuses of this research is on banana fruit plant.

The fibers arise from phloem cells in the stems of a variety of dicotyledonous plant species. Fiber cells range from 1 millimetre in jute to more than 250 millimetres in ramie, and individual fibers may be comprised of thousands of cells extending up to 1 meter (3.3 feet) in length. Bast fibers from a number of plant species are employed in the weaving of fine textiles, the manufacture of cordage (rope and twine), and paper production. Bast fibers from flax (*Linum*) are used to make linen, the fabric used in wrapping Egyptian mummies more than four thousand years ago. Fibers from jute (*Corchorus*) have been used since biblical times, and it remains the world's most important source of bast fibers, yielding twice as much fiber as all other sources combined. Coarse cloths, rope, and twine are produced from hemp (*Cannabis*), ramie (*Boehmeria*), and sunnhemp (*Crotalaria*), while bast fibers from a number of plants such as hemp, sunnhemp, and *Urena* are important in paper production. (https://en.wikipedia.org/wiki/Banana)(http://www.nhm.nic.in/archive/bananafibre.pdf) (http://cwh.ucsc.edu/bananas/Site/Early%20History%20of%20the%20Banana.html)

1.1.h) Area and production

Banana and plantains are grown in about 120 countries. Total annual world production is estimated at 86 million tonnes of fruits. India leads the world in banana production with an annual output of about 14.2 million tonnes. Other leading producers are Brazil, Eucador, China, Phillipines, Indonesia, Costarica, Mexico, Thailand and Colombia.

In India banana ranks first in production and third in area among fruit crops. It accounts for 13% of the total area under production and 33% of the production of fruits. Production is highest in Maharashtra (3924.1 thousand tonnes) followed by Tamil Nadu (3543.8 thousand tonnes). Within India, Maharashtra has the highest productivity of 65.70 metric tonnes /ha. against national average of 30.5 tonnes/ha.

The other major banana producing states are Karnataka, Gujarat, Andhra Pradesh and Assam. (http://gpktt.weebly.com/classification-of-textile-fibers.html)

Gujarat is the second major Banana producing state in the country and accounts for 13.4% of the total production of banana in the country. In Gujarat, during the year 2013-14 banana crops is cultivated in an area of about 66496¬ ha. & having production of 42.25 Lakhs tons with productivity of 63.55 Mt/Ha., which is highest in the country. According to Ministry of Agriculture & Farmers Welfare

1.1.i) Characteristics of banana fibres

- Banana fibres have great potentialities for paper making because of its high alpha-cellulose and lignin content.
- These fibers have excellent tensile strength, they are strong fibres.
- They have low elongation and light weight
- They posses strong moisture absorption quality. It absorbs as well as release moisture very fast.
- They are biodegradable and has no negative effect on environment hence categorized eco friendly fibre.
- Banana fibers also possess fire resistance property.

1.1.j) Potential of banana fibre

- Banana fibre has great potentialities for paper making special demand of handmade paper.
- Banana fibers are used for rope, mats and other composite materials.
- Banana fibre has recognised for apparels made by joining filaments together by weavers knot. However, spun banana yarns are still at research phase.
- Polypropylene reinforced with banana fibre is used by automobile companies for making under floor protection panels in luxurious cars like Mercedes.
- Composite material of banana fibre used in building boards and fire resistance boards.
- Banana fibre is used for making handicrafts and home decorative which includes products like paper bags, filter paper, greeting cards, decorative papers, pen stands, lamp stand and many more.

- Banana fibre in used for currency notes in Germany and trial run in India also. During the research, it was found that paper made out of banana fiber has shelf life of over 100 years as it is the strongest of the long fibres ever found amidst natural fibres. It can be folded for as many as 3,000 times. It can used currency and value-able documents like manuscript document preserver.

1.1.k) Myriad uses of banana pseudostem

"A Value Chain on Utilization of Banana Pseudostem for Fibre and Other Value Added Products" was project sanctioned during June 2008 under World Bank funded - NAIP (Component II), ICAR, New Delhi in consortium mode with Navsari Agricultural University, Navsari (Gujarat) as lead centre and Central Institute for Research on Cotton Technology (ICAR), Mumbai (Maharashtra), Manmade Textile Research Association, Surat (Gujarat) and J. K. Paper Mills Ltd., Songadh (Gujarat) as partners.

Banana pseudostem components included banana fibers, yarns and fabrics, quality papers, microcrystalline cellulose (MCC) used in pharmaceutical industries. Also handicrafts scutcher, vermicompost, handmade papers and board, SAP (Liquid fertilizer and nutrient spray as mordant) can also be obtained. Even the central core can be used for making candy and pickles. Hence, banana pseudostem which was thrown as waste can be used to develop the above mentioned products. The banana plant has been traditionally used for fruit and fibers (generations ago). But banana has immense potential. The farmers are still not aware of the potential of fibre from an acre of banana plantation.

There is wide bibliography about the production of composite materials with natural fibers (flax, hemp, jute, and banana) in woven and non-woven fabrics; however, no references have been found in the use of banana fibers to produce finer variety of fabrics. Furthermore, the use of banana fibers to produce yarns for textile products has not been reported.

Minor fibers being lignocellulosic in nature have an inherent drawback of stiffness. Softening treatment can improve its hand and can be used in apparel section or home furnishings. However, this concept is at an inception stage in India. Researchers are being conducted all over the country to obtain the finest variety of fibers but this does not limit the use of potential minor fibers. They are used as in several other areas like

handicrafts, paper industry, packaging, geo-textiles, technical textiles, medical textiles etc. Banana is one of the probable fibers which will prove its potential as jute and linen.

1.2 STATEMENT OF THE PROBLEM

- Textiles and clothing have been an integral part of culture in the history of every society. Textile weaving was a part of everyday life. During the latter half of 19th century and the early 20th century industrialization dominated the society. Machine made clothes decreased the need of weavers. Natural fibers faced amplified competition with the development of synthetic fibers since 1960's. However, the pendulum is shifting back towards natural fibers. Natural fibres are more environment friendly than synthetic fibres both in terms of production and their disposal. Natural fibres are made of renewable resources and are completely bio-degradable. Amongst natural fibers, 90 per cent are of vegetable origin and among them 80 per cent is constituted by cotton, but it is one of the most environmentally expensive agricultural crops. It is the need of the hour to utilize fibers that are responsive to the environment. The present study focuses on utilization of banana fibers in textiles.

- Banana is the second most important food crop grown in India. Major producing states are Tamil Nadu, Maharashtra, Karnataka, Gujarat, Andhra Pradesh, Assam and Madhya Pradesh. Gujarat ranks sixth in the area cultivation of banana in the country with the average cultivation area of around 46,500 hectares with a production of 1.9 million tonnes. Every year around a billion tonnes of banana plant stems are thrown on roadside after harvesting of the fruit. The biomass is either dumped on the roadside or burnt or left in suit causing detrimental impact on environment. Presently, waste banana stems pose problem of disposal and are available almost free of cost in Central and South Gujarat. Banana fibers can be extracted from these pseudostem (banana biomass) using Raspador machine which has been developed in recent past. Banana fibers hold more significance because they are extracted from disposed biomass of a food crop. Application of banana fiber for manufacturing textiles is a new concept in India. In India, only 10% of the banana waste (Pseudo stems) is used for extracting the fiber, rest is

wasted. Banana fibers have excellent strength and luster. It is extremely important to realize the potential of these fibers and put them into textile application. Hence, the purpose of the study was to confer the banana fibers to fabric stage by softening them and making them more pliable to be spun into fine yarns.

- Natural fibers industry provides employment to millions of people, largely small scale (marginal) farmers and processors. In India, banana being an industry of major importance to the national economy, can also significantly contribute to an additional income to the farmers. After harvesting the fruit, the pseudostem of the banana plant can be collected and fibers can be extracted on the field. This will provide an additional source of income to the farmers. Besides the farmers, banana fibers are potential fibers for cottage industry. A new dimension can be given to handloom fabrics by incorporating banana yarns. Inspired by these large perspectives of banana fibers, the researcher was keen to identify an appropriate end use of these fibers as textiles (apparel or home furnishings).

- The present market potential of banana fibers in India is majorly exporting and is mainly used by cottage industry in Southern India. From growing raw material to delivering a high ended fabric, we are in a position to contribute to the whole range of activities due to availability of cheap labours. We can create a lot of value by converting the raw material into final products for export rather than exporting them in raw material form. With this fact the Ministry of Textiles in India has identified five minor fibers for their developmental and promotional mechanism. Owing to the need for defining and promoting market niches, R&D would be required to develop new technologies to facilitate the use of banana fibers in new applications, where their natural advantages allow them to compete effectively with synthetics. Simultaneously promoting banana fibers will facilitates the required fiber availability to meet the growth targets of the textiles & garments sector as well. The research aimed to utilize the exclusivity factor of minor fiber and give a commercial perspective.

- The potential banana fiber that can provide farm and off-farm based employment to large section of the population, utilization of the so called waste to generate

wealth thus providing additional avenue for livelihood generation, allows for green economy. However, the inherent drawback of banana fiber is its poor quality and higher irregularity, owing to the multi-cellular nature of the fibers. There is need for optimization of processes from fiber to fabric stage of banana fibers. Hence, the investigator proposed a study titled "Banana fiber to fabric: Process optimization for improving its spinnibility and hand".

1.3 OBJECTIVES OF THE STUDY

1. To study the fine structure and physical properties of procured banana fiber.
2. To optimize chemical and enzyme treatment conditions for softening of banana fiber.
3. To test the physical properties and chemical composition of untreated and treated banana fibers.
4. To prepare hand spun yarn using untreated, enzyme treated, and chemically treated banana fibers and test their physical properties.
5. To obtain maximum blend percentage of chemically treated and enzyme treated banana fiber with regenerated cellulose fiber by machine spinning and test their physical properties.
6. To develop hand woven and machine woven fabrics using 100% banana yarn and banana and regenerated cellulose fiber blends and banana yarn spun on jute spinning system.
7. To test and compare the properties of the fabrics prepared and suggest their end use.

1.4 DELIMITATIONS OF THE STUDY

1. The study was limited to one variety of banana fiber: *Grand 9* from Gujarat
2. The study was limited to blending of banana fibers with regenerated cellulosic fibers only i.e. viscose, modal and excel.
3. The study was limited to make union fabrics with cellulosic warp yarns i.e. cotton and regenerated yarns.
4. The study was limited to plain weave fabrics.
5. The study was limited to ring spinning system for blending of yarns.

1.5 SCOPE OF STUDY

- The study was aimed to develop fabrics from banana fibers in order to add a new dimension to the potential banana fibers. These fabrics would be of immense value to the niche market as they are ecofriendly, biodegradable and are extracted from the biomass dumped after harvesting banana fruit.
- The study will also help the farmers by providing them an opportunity to generate additional income through extracting or selling the banana pseudostem.
- Banana fiber, yarn, and fabric would give new prospects to cottage industry. It will help to realize higher commercial value to both the cottage industry products and banana fiber, which are presently moreover exported.