Sisal

A Golden Revolution in Pakistan

Lok Sanjh Foundation

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Acronyms

TSB	Tanzania Sisal Board
NARC	National Agriculture Research Centre
PMAS-AAUR	Pir Mehr Ali Shah; Arid Agriculture University Rawalpindi
UAF	University of Agriculture Faisalabad
ARI	Agricuture Research Institute
LSF	Lok Sanjh Foundation
RBDC	Rural Business Development Centre
PJMA	Pakistan Jute Mills Association
MRI	Malingano Research Institute
SRP	Sisal Research Programme
RRI	Range Research Institute
SRF	Sisal Research Fund
UET	University of Engineering and Technology
SUA	Sokoine University of Agriculture

Chapter 1: Introduction

In changing climate, there is either too little rain, no rain or too much rain. As a result periodically many areas in Pakistan face drought or flood like situation that causes a loss of livelihood for small farmers and affecting agriculture in many ways. If it rains too much there is rapid soil erosion in Potohar's arid region and flood in other areas. If it does not rain, there is danger of drought. Pakistan being water stressed country is likely to face negative effects on its agriculture. In this regard, the challenges are many. For example, how to enhance livelihood opportunities for farmers and take appropriate measures for mitigation and adaptation to climate change.

The livelihood of most population in Pothohar region of north Punjab depends on agriculture, which is rain fed. Wheat is the main crop grown with some minor crops, such as, mustard, maize, sorghum, millet and seasonal vegetables. As most of the smallholder farmers go out in search of off farm jobs, it is mainly women farmers cultivating crops and taking care of livestock. The area is facing severe water crisis due to changing climate. There is too little rain, no rain or too much rain. As a result periodically the area faces drought like situation and loss of livelihood for small farmers. If it rains too much there is rapid soil erosion. The challenges are: how to enhance resilience of farming systems, empower women farmers and take appropriate measures to stabilize soil and introduce climate resilient crops.

In South Punjab area, cotton, citrus, mangoes and vegetables are generally grown by small farmers while new cotton varieties demand more water. With climate change, water supplies are decreasing. Canal water is the only source of irrigation and underground water is not fit for irrigation. There is a challenge to adjust and re-adjust cropping patterns with increasingly more uncertain water supplies.

Similarly in adjacent areas of Thal desert, farmers are facing challenges to grow food, fodder and fiber crops to meet the family needs. With the climate change, shifting patterns of rainfall are further making food production more challenging and risky. Particularly, shifting sand dunes make it more difficult and costly.
Many countries are encouraging farmers to shift to crops that require less water. For instance, Tanzania made good efforts to enhance area under Sisal (agave sislana) crop that can grow under extremely harsh conditions and with very little water. Both China and India also introduced Sisal in their water stressed areas and now exporting Sisal fiber and products.

Sisal is a fiber plant that can grow on poor soils, requires no fertilizers and can survive in extreme moisture stress. There is generally no pest attack on the crop. With one time cost of planting, Sisal offers harvests twice a year for about 14 years. Then suckers growing around the plants are used for replanting. Virtually with no cost of external inputs, Sisal offers returns quite comparable with existing crops like cotton, wheat etc. Sisal plants are most important in terms of the production of cordage fibers which are scraped mechanically from leaves. Agave plants are conventionally propagated by the bulbils which arise from the axillary meristems on the inflorescence after flowering. However, it takes approximately 20-30 years of vegetative growth until the adult plant reaches the generative stage and begins flowering. Most plants seldom set seeds; therefore sexual
reproduction through true seeds is usually inconvenient. Another way of propagation is based on the stolon cuttings. Each stolon terminates in a young plantlet. Under suitable conditions each adult Agave plant can only form a few stolons every year. For the new planting of large areas, a large number of seed plantlets (4000 plants per ha) is needed, therefore the development of a new propagation technique using in vitro culture methods was of practical value.

Sisal is produced with minimum pre and post- harvest losses and average yield of dried fibers is about 1 ton per hectare, although yields in East Africa can reach 3-4 ton per hectare. It is widely cultivated in Brazil which by far is the most important sisal producing countries, followed by Tanzania, Kenya and Mexico. China and India are on their way to become important producers. In East Africa, where sisal is produced on an estate basis, the leaves transported to a central decortication plant after which the fiber is dried, brushed and baled - for export or for use in the domestic mills. Planting and harvesting takes place all year so there is no element of seasonality to earnings. The farmers are paid monthly, and they are guaranteed a market for their product. There is little vulnerability to

environmental shocks since sisal is so drought resistant and sisal provides an income even if food crops fail, thereby increasing financial security of small farmers. Sisal uses bulbils to spread but also
runners are produced. Both can be used for new Sisal plants. Sisal is a renewable resource and can form part of the overall solution to climate change. Measured over its life-cycle, sisal absorbs more carbon dioxide than it produces. During processing, it generates mainly organic wastes and leaf residues that can be used to generate bio-energy produce animal feed, fertilizer and ecological housing material and, at the end of its life cycle, sisal is 100 percent biodegradable. By contrast synthetically produced fibers do not possess any of these traits. Moreover sisal plants reduce soil erosion through its extensive root system and contributes positively to watershed management.

Sisal plants used as hedges act as effective vegetative barriers/ fences to protect the crops lands and forests from predatory animals and intruders. In addition to offering economical returns in more challenging environment, sisal also helps in stabilizing land and local environment, reducing soil erosion and stabilizing sand dunes in desert areas as well. As a carbon sinking crop, it also helps mitigating climate change. Description of Sisal Plant Sisal with the botanical name Agave sisalana, is a species of Agave native to southern Mexico but widely cultivated and naturalized in many other
countries. It yields a stiff fiber used in making various products. The term sisal may refer either to the plant's common name or the fiber, depending on the context. It is sometimes referred to as "sisal hemp", because for centuries hemp was a major source for fiber, and other fiber sources were named after it. The sisal fibre is traditionally used for rope and twine, and has many other uses, including paper, cloth, wall coverings, carpets, and dartboards.

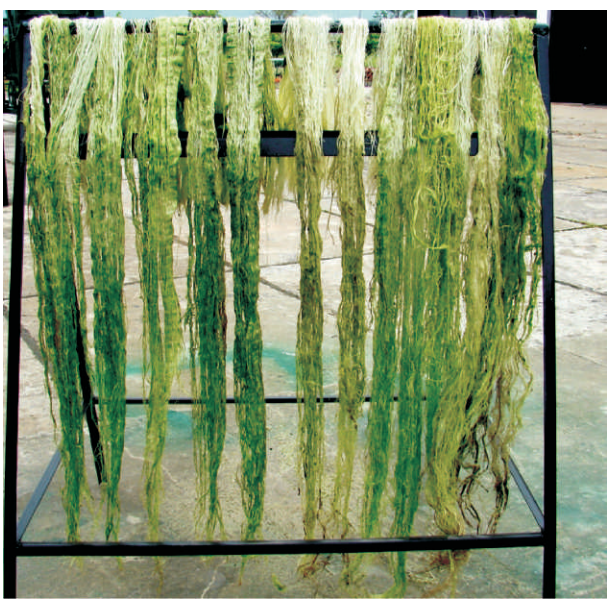
Sisal plants, Agave Sisalana, consist of a rosette of sword-shaped leaves about 1.5–2 metres (4.9–6.6 ft) tall. Young leaves may have a few minute teeth along their margins, but lose them as they mature. The sisal plant has a 7–10 year life-span and typically produces 200–250 commercially usable leaves. Each leaf contains an average of around 1000 fibers. The fibers account for only about 4% of the plant by weight. Sisal is considered a plant of the tropics and subtropics, since production benefits from temperatures above 25 degrees Celsius and sunshine.

Propagation

Propagation of sisal is generally by using bulbils produced from buds in the flower stalk or by suckers growing around the base of the plant, which are grown in nursery fields until large enough to be transplanted to their final position. These methods offer no potential for genetic improvement. In vitro multiplication of selected genetic material using meristematic tissue culture (MST) offers considerable potential for the development of improved genetic material.

Fiber Extraction

Fibre is extracted by a process known as decortication, where leaves are crushed and beaten by a rotating wheel set with blunt knives, so that only fibres remain. In East Africa, where production is typically on large estates, the leaves are transported to a central decortication plant, where water is used to wash away the waste parts of the leaf.



The fibre is then dried, brushed and baled for export. Proper drying is important as fibre quality depends largely on moisture content. Artificial drying has been found to result in generally better grades of fibre than sun drying, but is not always feasible in the developing countries where sisal is produced. In the drier climate of north-east Brazil, sisal is mainly grown by smallholders and the fibre is extracted by teams using portable raspadors which do not use water. Fibre is subsequently cleaned by brushing. Dry fibres are machine combed and sorted into various grades, largely on the basis of the previous in-field separation of leaves into size groups.

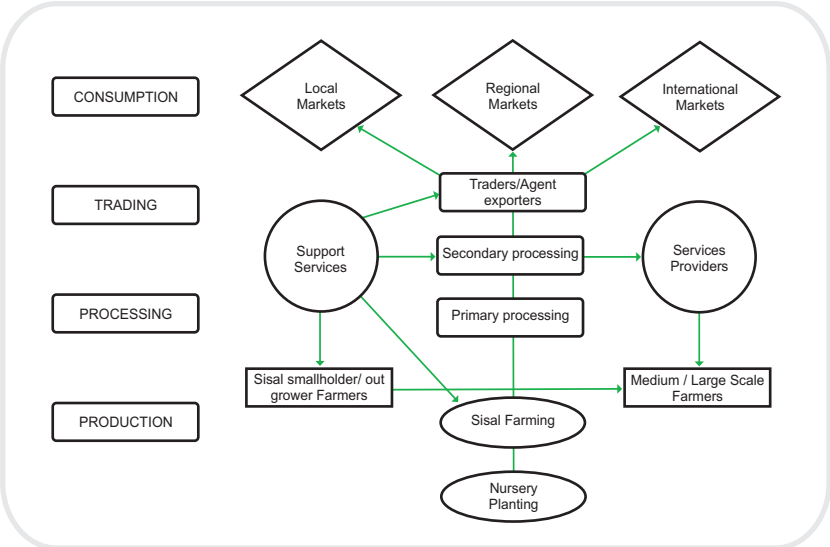
Sisal Promotion in Pakistan:

There is a vast scope of Sisal production in dry and rainfed areas of Pakistan and it can be an excellent solution for smallholders' livelihood affecting from changing climatic conditions. It can be grown while intercropping with different crops like maize, sun flower, peas, beans etc. Sisal is a renewable resource and can form part of the overall solution to climate change. Measured over its life-cycle, sisal absorbs more carbon dioxide than it produces. During processing, it generates mainly organic wastes and leaf residues that can be used to generate bioenergy, produce animal feed, fertiliser and ecological housing material and, at the end of its life cycle, sisal is 100 percent biodegradable. By contrast synthetically produced fibres do not possess any of these traits. Moreover sisal plants reduce soil erosion through its extensive root system and contributes positively to watershed management. Sisal plants used as hedges act as effective vegetative barriers/fences to protect the crops lands and forests from predatory animals and intruders.

Business Value of Sisal

Pakistan has a strong position in sisal cultivation as it has comparative and competitive advantages, such as the weather, soil and human capital which is a catalyst to the growth of the industry. The future in sisal is the commercial use of the total plant instead of the raw materials only and research results indicate the viability of transforming sisal waste into energy and industrial products. The improvement of food security, crop diversification and farming systems are ensured through the development of smallholder schemes which see value in using the same land and labour to produce more than one crop by mixing sisal with food crop production. In sisal growing areas, better yields on food crops have been recorded in sisal fields than on pure crop land as there is always some moisture around sisal plants. Mixing sisal with food

crop production may reduce the investment costs as well as those of maintaining the crops while at the same time giving higher returns . Competition from synthetics has weakened demand for sisal in traditional applications , however new consumer demands for natural fibres are expanding the markets for sisal in more high -value applications such as in paper , reinforcing composites and plastic composites .



Critical factors for the development of the sisal business chain which are both opportunities and challenges are :

- Quality of produce
- Quantity and Consistency
- Energy
- Change of Mindset
- Public -Private Partnership

Before smallholders join any sisal schemes , they should be assured that the business venture will be profitable and enjoy market growth . Sisal smallholders need : access to markets and finance; extension advice to improve productivity, production and quality; access to information (market , technical and R&D) ; and generally, strategies to promote sisal production as a viable business .

In addition , support is required through the availability of appropriate resouces to finance production , extension , marketing and developmental activities along the chain , as well as access to R&D results and how they can contribute to improving production , product and market development , logistics , technology development and dissemination systems .

Sisal has a wide variety of applications including:

Traditional - Twine, ropes, string, yarn and which can also be woven into carpets, mats, and arious handicrafts. Competition from synthetics has weakened demand for sisal in these traditional applications, however new consumer demands for natural fibres are expanding the markets for sisal in more high-value applications such as in paper, reinforcing composites and plastic composites.

Sisal pulp and paper – As sisal biomass contains a high proportion of cellulose its pulp is a substitute for wood fibres and adds bulk to paper and cardboard as well as being absorbent and having high fold endurance characteristics making it a high quality input for paper products. Given its porosity, it can be used in cigarette paper filters and things like tea bags.

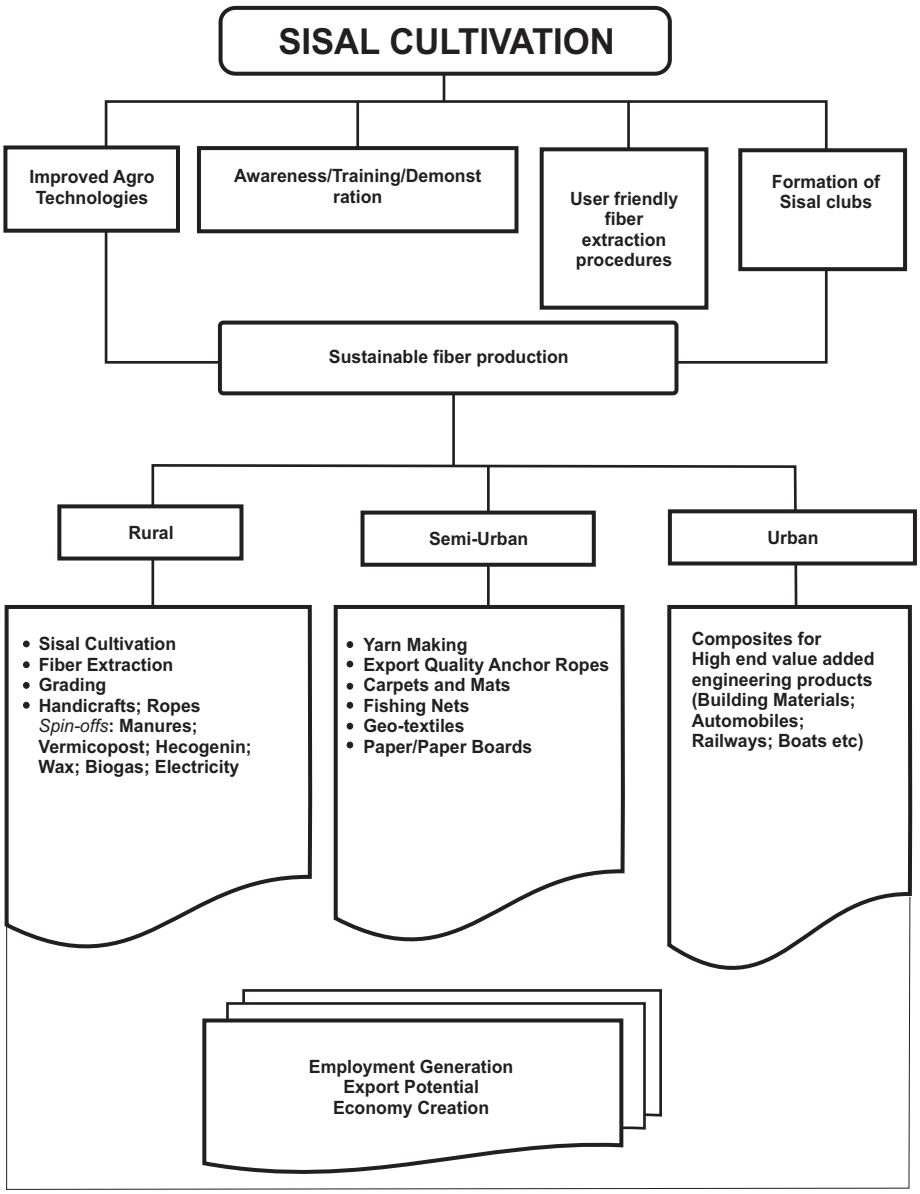
Textile - A major use of the fibre is in buffing cloth – because sisal is strong enough to polish steel and soft enough not to scratch it.

Sisal reinforcing composites - Sisal can substitute or enhance fibre-glass used to reinforce plastic in automobiles, boats, furniture, water tanks and pipes. Sisal can also be used to add strength in cement mixtures for the development of low cost housing and to replace asbestos in roofing and brake-pads. In addition it is an insulation material and can be made into fibre-board as a wood substitute.

Plastic and rubber composites - Sisal has good potential as reinforcement in polymer (thermoplastics, thermosets and rubbers) composites due to the low density and good welding specific properties. The use of sisal composites in automotive components and other furniture is gaining popularity. Sisal also continues to make the best material for dart boards.

Sisal waste products - By-products from sisal extraction can be used for making biogas, pharmaceutical ingredients and building material. The biomass left after fibres have been removed represents as much as 98 percent of the plant, and most is now flushed away as waste.
The waste produced by decortication such as sisal juice, particles of crushed parenchymatose tissue and fragments of leaves and fibres can be used as fertilizer or animal feed.

Market Outlook - Sisal has a promising future not only because of the new uses of this fibre but also because of growing public awareness that natural fibres, like sisal, are environmentally friendly. The growth of sisal for use in non-traditional markets indicates that sisal is becoming increasingly recognized as a valuable and diverse resource material. There may well be other potentially valuable by-products to be found in the fleshy waste discarded by sisal decorticators, apart from cattle feed and biogas.


SISAL CULTIVATION
Improved Agro Technologies
Awareness/Training/Demonstration
User friendly fiber extraction procedures
Formation of Sisal clubs
Sustainable fiber production
Rural
Semi-Urban
Urban
• Sisal Cultivation
• Fiber Extraction
• Grading
• Handicrafts; Ropes
Spin-offs: Manures; Vermicopost; Hecogenin; Wax; Biogas; Electricity
• Yarn Making
• Export Quality Anchor Ropes
• Carpets and Mats
• Fishing Nets
• Geo-textiles
• Paper/Paper Boards
Composites for High end value added engineering products (Building Materials; Automobiles; Railways; Boats etc)
Employment Generation
Export Potential
Economy Creation

Chapter 2: Lok Sanjh Initiative

Sisal Cultivation

With climate change, water supplies are decreasing. Canal water is the only source of irrigation and underground water is not fit for irrigation. There is a challenge to adjust and re-adjust ropping patterns with increasingly more uncertain water supplies. LSF, as a strategy to encourage farmers to shift to crops that require less water, is promoting sisal cultivation in water scarce areas. In last three years, LSF has developed sisal plant nurseries in Toba Tek Singh and Chakwal Districts. Plants from nurseries have been distributed to 500 Farmers from project villages.

Development of Sisal Nurseries and Plantation

LSF started work with development of a nursery of 300 plants at the PMAS-AAUR. In addition a main nursery was also developed at PMAS-AAUR's Koont Research Farm near Chakwal through collecting sisal plants which were found growing on roadsides in areas of North Punjab. For this, University had allocated 2.5 acres of land under its Sisal Research Programme with the collaboration of LSF. In this Nursery a total of 2,200 plants had been planted. Similarly, National Agricultural Research Centre (NARC) had allocated about 4 acres of marginal land at its premises where 20,000 sisal plants had been planted during March 2015. This sisal plantation at NARC will be used for further research. For example, NARC will determine agronomic characterization of available sisal plants in the country.

Plantation at Field Level

Registration of Farmers

Lok Sanjh Field team in connection with village level working farmers committee had reached potential and willing farmers for their registration. Farmers showed keen interest in cultivating Sisal. Lok Sanh registered 500 farmers from South Punjab and 250 from North Punjab villages to grow Sisal as Hedge along their fields or uncultivated areas.

Farmers Trainings On Sisal Plantation/Cultivation

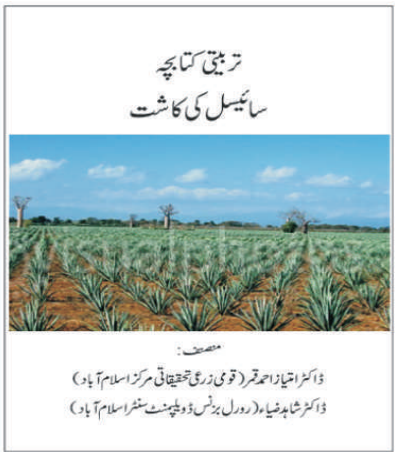
Farmers Trainings on Sisal cultivation and Production techniques were organized with following objectives:

1. To educate farmers about Sisal Plant, its importance and production and cultivation Techniques at farmers level
2. To show Sisal Fiber Extraction technologies
3. To display different Sisal by-products and economics of cultivating Sisal at Farmers level.

Audio visual material was used to facilitate training. Through questions and different queries farmers participated in the trainings displaying keen interest in cultivation.

These training sessions covered following aspects of nursery development whereas a training brouchure was also writeen by the training specialists.

SISAL NURSERY ESTABLISHMENT



- Sisal nursery should be well prepared in order to get good sisal planting materials which Will in turn produce good quality sisal fiber.
- Select a well-drained fertile soil, avoid deep slopes. The area should be accessible, near the field where Sisal will be planted.
- Land preparation – the selected area should be brush cut, ploughed and harrowed to obtain fine tilth, perennial weeds must be eradicated.
- Select the bulbils from healthy plants, cut off the poles from suitable plants and remove the bulbils bearing branches, shack the bulbils into a sack, to obtain plants which are uniform grade them before planting and discard the bulbils which are very small.
- Spacing – Plant the bulbils at the spacing of 50 cm x 25 cm. By using this spacing you will get 80,000 plants per hectare.
- Method of planting - Mark the row ends with sticks. Strike a planting chain between pairs of sticks. Dib in bulbils at tags on the chain, plant 1.0 to 1.5 cm deep.
- Time of planting – Planting should be completed just before the main rains period

Coordination with NARC for Trainings

Range Research Institute of National Agricultural Research Center (NARC), Islamabad also coordinated with LSF in training and capacity building with regard to sisal nursery development and maintenance .
Director Range Research Institute (RRI) and his staff imparted the trainings related to :

- Orientation of Sisal Crop and its usages , processing of fiber
- Agronomy of Sisal plantation
- Nursery Development
- Transplanting techniques
- Practical training of developing Sisal Nursery
- Use of Sisal Fiber to make different Products

After the trainings, all farmers participated in a farmer field school in which practical training was imparted on planting and developing sisal nursery and transplanting techniques. Afterwards, farmers were taken to the Sisal Progam of the NARC, where they were shown sisal plantation on 8 acre farm. Towards the end of this training they were taken to the Farm Machinery Unit of NARC where they have developed first Pakistani Decorticator and Brushing Machine in Pakistan with the assistance of Lok Sanjh Foundation. Practical demonstration was given by operating sisal decorticator to separate the fiber from biomass.

Farmers Exposure Visit

An exposure visit to Nursery developed at Pir Mehr Ali Shah; Arid Agriculture University was organized for registered farmers.

Farmers Exposure was quite helpful in learning directly from the field. Farmers have learned the techniques of nursery raising, selection of suckers and seedlings, agronomic practices to prepare fields for sisal crop and local knowledge about sisal crop.

Farmers Field Day to Collect Sisal Suckers for Nursery Development

A Farmer field day was organized where staff and farmers collectively worked on sisal suckers collection. Around 2000 sisal suckers were removed, packed in bags and taken to plantation sites. These suckers have been successfully planted in nurseries and are growing successfully.

Sisal Plants Distribution

After completion of trainings, plants were distributed to 500 farmers in South Punjab and 250 farmers in North Punjab. These plants were sourced from the nurseries developed in cooperation with PMAS-AAUR and NARC.

Sisal Inauguration Ceremony

Sisal Value Chain Inauguration ceremony was held at Chakwal. Prize money was distributed among farmers who successfully planted sisal nurseries. Role of women at various stages of sisal women enterprise was highlighted by experts.

Growing Sisal Plant as Hedge Row

LSF had a target of planting more than 45,000 sisal plants as hedge row on over 250 farmers' land in Toba Tek Singh (TTS) which was completed during March 2015. Thus LSF has been able to make significant progress in production technology. Plants were sowed at 4 feet distance as hedge along one Kanal of farm to make better and dense hedge pants were sowed at thinner distance.

Muhammad Idrees lives in 153 Gb Village of Toba Tek Singh. He lived with his family comprising of 5 children and was doing agriculture on 2 Acres. He generally cultivates wheat, sugarcane and fodder crops along with sesame and Moong. Lok Sanjh Field team started working with him during April and May 2014. Initially he had not shown much interest, afterwards he realized that the said organization was not working to brand their product or sell their product but was purely farmers based organization working for well being of small farmers. He started participating in training and meeting sessions organized by Lok Sanjh Field team. Not only he gained useful information related to agriculture farming but also he keenly applied best management practices at his farm. He was further provided Sisal farming training at Islamabad and showed him Sisal nursery development and plantation at Field Level. He was then provided with Sisal plants that he grew at his farm as hedgerow. After two months he was again provided with larger no of plants, which he planted as, hedgerow and maintained a separate plot also. He keeps 1 Kanal of barren non-irrigated plot, which he along with help and support of Lok Sanjh Foundation was developed as Sisal Plot. Now, his main farm is saved from animals because of hedgerow and his barren land was brought into utilization which will start returning after two years.

Public and Private Sector Linkages

Stakeholders Meeting on Production and Promotion of Sisal

In a stakeholders meeting on the subject , nearly 30 representatives of OXFAM-NOVIB ,LSF , Pakistan Jute Mills Association (PJMA) ,Textile Mills , academia , students , researchers of Fiber Technology , University of Agriculture , Faisalabad (UAF) ,PMASAAUR and Ayub Agriculture Research Institute participated . Dr , Shahid Zia , MD , Lok Sanjh was the keynote speaker . The deliberations of the meeting concluded to :

- Continue propagation through tissue culture with the PMAS - Arid Agriculture University
- Support students and other research for taking it from Lab to farmers as a crop .For this it was proposed to establish Sisal Research Fund (SRF) through public private partnership .
- Establish Sisal Working Group (SWG) comprising representative of industry ,academia , LSF , and others for the purpose of its promotion and taking it up at the policy level with the provincial and federal government level .
- Visit of a delegate consisting of representatives of industry , university , LSF and farmer to Tanzania where sisal has been very successful . This visit will help in assessing and studying Tanzanian success model for adapting and replication in Pakistan .

Sisal Advisory Group Meeting/Forum

A Forum was held at the Department of Fiber Technology, Faculty of Agriculture Engineering, University of Agriculture, Faisalabad .The objective was to create awareness among students and faculty members for undertaking future research on sisal crop. More than 60 students of textile and fiber technology and faculty members participated in the forum. Dr. Allah Bukhsh, Dean Faculty of Agriculture Engineering and Technology chaired the forum. He welcomed the participants and appreciated the serious efforts of Lok Sanjh Foundation (LSF) for introducing and promoting sisal in Pakistan. Particularly, he emphasized the need of such crop in the wake of diminishing water resources in Pakistan and its importance. He also ensured co-operation and support of the faculty for any future research and development.

LSF representative gave presentation on Sisal drawing his experience from a visit to Tanzania and LSF's effort to promote sisal from nursery to industry including developing value chain.

Dr. Assad Farooq, Head, Department of Fiber Technology, UAF presented and discussed the research undertaken by him on characterization of Sisal fiber and development of decorticator. Head of Women Entrepreneur Centre at the Institute of Home Sciences, University of Agriculture Faisalabad, showed interest in sisal fiber and said that women engaged at the centre may also try making products of sisal.

The forum was concluded with a positive response from the participants that this has helped in creating interest in crop that is water efficient and can be source of income generating for many farmers in marginal areas.

Engaging Jute Industry

LSF's on-going effort to engage Jute industry had been quite encouraging for trying and developing locally available sisal fiber for producing product samples. The participation and interest shown by the representatives of private sector i.e. Pakistan Jute Mills Association (PJMA), textile, mills and other institutions in sisal development has been quite encouraging. Particularly the jute mills and PJMA showed interest in shifting their production to sisal fibre if it becomes available in the country.

Sisal Stakeholders Alliance Meeting

Lok Sanjh Foundation conducted Sisal Stake Holders Alliance Meeting, Subject Specialists, researchers and other active stakeholders from Department of Fiber and Textile Technology, University of Agriculture Faisalabad, Ayub Agriculture Research, Arid Agriculture University, University and Engineering and Technology Lahore, National textile University, Social Sector, Textile and Private Sector, farmers, Importer and Exporter and from Media participated in the Event. The objective of the meeting was to discuss the production technologies of Sisal Plant and discover different processing and marketing scenarios keeping in view the national and international market setups. Meeting ended with three Scenarios with participants; as continuing of work commenced by different Research and development establishments bring forward the technology/research and techniques from Lab to Farm and Public private partnership in sisal development. Lastly sisal-working group/committee was formed with its working body and agenda was finalized.

International Conference on Natural Fibers

LSF organized International Conference on Natural Fibers in January 2015 engaging stakeholders from cotton industry, National Agricultural Research and Academic Institutions, and Tanzania Sisal Industry. The conference was a great success to encourage all the stakeholders working on Cotton and Sisal crops. The Govt and research departments got fully convinced to support Lok Sanjh Foundation in all aspects of cotton/Sisal production. It emphasized that there is a need to cater growing needs for which cotton and sisal are the best options

Collaboration with Tanzania Sisal Board (TSB)

LSF had been able to develop good understanding with TSB through a visit to Tanzania and later participation of DG in conference on Natural Fibers held in Islamabad. The DG, TSB had assured to provide all technical assistance in developing Sisal planting and production process. In addition, one Pakistani scientist from PMAS-AAUR had spent two weeks at Tanzania's Malingano Research Institute (MRI) for gaining first hand knowledge of research and development which would help in replicating and up scaling the sisal production and processing in Pakistan.

Sisal Decortication

Development of Sisal Decorticator

The growing and dissemination of sisal crop in the country is associated with the development of fiber decortication, fiber characterization, fiber processing and value addition facilities. Since there were no sisal decorticators machines available in Pakistan , therefore, LSF engaged two institutions i.e. University of Agriculture, Faisalabad (UAF) and NARC for developing decortication machines.

As a result, the department of Fibre & Textile Technology, UAF had been able to design and develop the Sisal decorticator. The developed decorticator machine was smarter than the other internationally available machines. However, it was tested of its decortication function which was found more effective due to specially designed decorticating cylinder and the under knife. Hence, fibres came out clean and were almost free of green matter.

In spite of all these efforts, there is vast cushion of improvements in the existing design of decorticator. The department of Fibre & Textile Technology wanted to improve the design of sisal decorticator in terms of making it diesel operated mobile, so that it can work in the fields to avoid the deterioration in the quality of sisal leaves during transportation.

Moreover, the automation of the sisal decorticator was necessary to make it more practical. Automatic feeding and delivery instead of manual feeding could do this. Furthermore, Characterization of sisal fibres is of vital importance. The quality of fiber extracted from indigenous wild sisal plant was evaluated and the other parameters related to percentage of fibres in the leaves were also of vital importance. The process is on going and hope to get good results.

Similarly, Agricultural and Biological Engineering Institute (ABEI) formerly Farm Machinery Institute (FMI) of NARC had also successfully developed one decorticator machines which was tested for its operation. This machine designed and developed by ABEI was cost effective and was displayed during LSF's "Women's Mela" held on 9th April 2015 at NARC.

Testing Sisal Fiber and its Applications

LSF and University of Engineering and Technology (UET), Faisalabad Campus had agreed to sign MOU for collaboration between both the organizations. In this regard, UET had offered to test the quality of fiber, dyeing and various high-end applications of fiber. The UET argues that since in the beginning sisal production will be minimum, therefore, one may go into developing applications of fiber for better market return

Chapter 3: Learning from Tanzania

Linkages with Sisal Industry – LSF team Visit to Tanzania in 2014

Team of 4 persons (3 from LSF and Vice Chancellor Arid Agriculture University Rawalpindi) travelled to Tanzania with the following objectives;

- To assess feasibility of sisal production in dry and rainfed areas of Pakistan.
- Meetings with stakeholders of sisal industry in Tanzania.
- To study model of sisal industry in Tanzania.
- To identify opportunities for collaborative R & D on sisal.
- To look for possible collaborations for sisal cultivation in Pakistan.

The visit was hosted and facilitated by Katani Pvt. Ltd.Katani Ltd is a private company with its head office in Tanga City, Tanzania. Katani has five sisal estates in the Korogwe District (Tanga Region) where it operates sisal decortication factories. The company provides technical support and extension services to farmers in the estates through different schemes. The company is processing sisal from raw form to different products at estates and factories which are further marketed for sale in local and international markets. The team had meetings with Tanzania Sisal Board, Staff of agriculture research institute, Agricultural University and visited various sisal estates being run by Katani Ltd to see the process of decortication, drying, brushing and baling of sisal fibre. The team also had a meeting with members of sisal producers organization to learn their experiences of sisal cultivation.

Meeting with Tanzania Sisal Board

The LSF team met with the Director General (DG), TSB Mr. Hamisi Mapinda at Katani House in Tanga. The office of the TSB was housed in Katani House at the time of visit. Dr. Shahid Zia introduced his team and briefed the DG, TSB about the purpose of visit and learning from the Tanzania sisal experience and replicating in Pakistan. The DG, apprised the team about the short history of Sisal development in Tanzania, trends in its success, challenges and demand fluctuations in the global market, establishment of TSB and its role related to the promotion of sisal in the country. The TSB was established in 1997 by an Act of Parliament and is charged with the regulation and promotion of the sisal industry with the aim of making it sustainable through increased productivity and profitability. They connect all buyers of sisal fibre and sisal products from Tanzania.

He told that Tanzania is 2nd in production of Sisal to Brazil and it is a very important crop for small farmers in Tanzania and is a major foreign exchange earner . It survives drought and heavy rain and can be grown anywhere in Tanzania except sea , without pesticides , herbicides and fertilizers . It only requires soil and sun , has no seasonality , can be intercropped along with food crops and other cash crops . The Tanga region is one of the major sisal growing areas . He told that by -products of the Sisal are many i .e . Bio -gas from the waste of sisal can be used to generate energy and already UNIDO has supported one such plant . The bio -gas plants can locally be built in Tanga now . The Sisal Research Institute of Tanzania is already collaborating with other Universities of Brazil and The Netherland for further research on Sisal .

In addition he apprised the visiting team that talks between TSB and a US based firm which is leading importer and exporter of premium agave - based products are at advance stage to start producing agave Syrup and honey to be used by domestic consumers in beverage industry . He shared the samples of these by -products . As per DG the syrup and Honey produced seems to be the latest health food craze around the world and it is good for diabetics . This new trend in using sisal products would also help in encouraging sisal farming and improving the economy and increase employment .The matter related to cultivation methods of sisal , agronomic practices , multiplication of sisal through tissue culture and suckers were discussed . The visiting team expressed its interest in rapid multiplication of sisal in Pakistan where climatic conditions in some regions are almost similar to Tanga and abandoned land is present . The meeting was concluded with discussion on the possibility of signing Memorandum of Understanding (MoU) with the TSB and in this regard it was agreed:

- LSF will work out draft of MoU for cooperation in various areas between TSB and Pakistan which will be sent to DG , for review and changes , if required so .
- A tri -partite MoU will be signed among TSB , LSF and University of Arid Agriculture , Rawalpindi .
- The DG TSB will be invited to visit Pakistan for attending a conference during which MoU can be signed .

Visit to Katani Facilities in Tanga Region

Katani with its head office at Katani House located in Tanga City, Tanga Region in Tanzania, operates sisal decortication factories in five Estates namely Hale, Mwelya, Ngombezi, Magoma and Magunga Estate all located in the Korogwe District of Tanga Region.

The company also owns a spinning and weaving mill the largest of its kind in Africa known as Tancord (1998) Ltd a subsidiary of Katani Ltd., the Central Workshop in Ngombezi, Korogwe District, and a sisal energy company with its facilities located at Hale Estate called Mkonge Energy Systems (MeS) Ltd- a subsidiary of Katani Ltd.

The company is vertically integrated in the sisal sector which is an emerging market posing opportunities for investment and development, Katani Ltd. is at the forefront in the exploration of new avenues for further utilization and commercialization of sisal. The activities range from primary processing, spinning, weaving, selling and marketing sisal products to developing projects related to best practices in sisal farming and new products, such as, renewable energy from sisal biomass. All the five estates are rented to Smallholders and Out Grower Scheme known as SISO. Katani Ltd. Started the SISO in 1999 in one of its estates called Mwelya/Usambara and then later to other estates. Under this arrangement, small-scale farmers, according to a contractual arrangement, are allocated farming plots ranging from minimum 6 hectares to 20 hectares where they grow sisal and sell sisal leaves to Katani Limited who are buyers of their products.

The operations of the company comprise of providing technical support and extension services to farmers in the estates through the SISO Scheme. The core activities of processing sisal and producing products at the estates and factory are coupled with marketing and sales of the products in the local and export market.

Following Katani facilities in Tanga region were visited:

Visit to Ngombezi Central Workshop

LSF team visited Ngombezi Central workshop in Korogwe district where it held meeting with its General Manager, Mr. Bakarai T. Omari and workshop Chief Engineer Mr. Julius. K. Nyogoto. The chief engineer of workshop explained the functioning of various machinery used in sisal cultivation, decortication and processing. He apprised the visiting team that initially decortication machinery was imported from the UK. However, with regular experiment to improve the designs and efficiency of different machines, now this workshop was producing local machines used in sisal production and processing. For example, Katani first introduced small size of Mobile decorticator.

operated with 16 HP peter diesel engine. But leaning from experience now large scale central decortication facilities have been established at different sisal estates where sisal leaves are transported on tractor trolley for processing. This reportedly has increased efficiency. And this has the potential to generate biogas to be used at the plant. The workshop has been working since 1970 and providing backstopping support to decortication facilities operating at 5 sisal estates owned by Katani. It was told that by 2020 with a processing of one million ton target 15 central decortication facilities will be established. At the time of visit 56 workers were working in a six days in a week in only one shift. The team was shown around the workshop where different machinery was being manufactured.

Visit to Sisal Decortication Facilities at Nogombezi and Hale Estates

The team also visited sisal decortication facility at Ngombezi estate in, Krogowe district to see the process of decortication, sun drying, and baling of sisal fibre for further processing. This plant had been established near the river Pangani for meeting water requirements during sisal decortication. It was observed that decortication requires plenty of water. The waste water from decortication was treated naturally storing and passing through three ponds before falling in the river again. Katani Ltd was planning to build small scale hydel facility for the decortication plant.

At this plant the team saw how the sisal leaves are transported, unloaded, fed into the plant, fiber extraction, sun drying and baling for taking it for further processing into products. One of the team members, Dr. Rai Niaz Ahmed who was an Agri-Engineer pointed out some improvements in collecting extra fiber which was flowing into the wastewater before falling in the first pond where it was collected manually by the labourers. The management of the decortication unit agreed with Dr. Rai Niaz's suggestion for improving the design. On the same day the team also had a chance to visit Hale Sisal Estate where Katani had decortication plant and Bio-Gas unit. At Hale the team had a meeting with male and female members of sisal producers organization working under SISO scheme to learn their experiences related to sisal cultivation.

The organization was headed by women named Zahoora Amiri. She told the team that sisal growers organization have 123 members who on an average grow sisal on 6 hectares of land contracted from Katani Ltd. As stated earlier, the estate is owned by Katani and sisal growers get land to grow sisal on contract and Katani provides all kinds of extension services including transportation of sisal leaves to decortication facility. After deduction of various kinds of expenses incurred by Katani on production and processing the growers are paid every 60 days.

When Zahoora was asked whether she gets enough income from sisal? she responded that "she likes growing sisal and also supplement her income through intercropping Maize (Mahind in Swahili) as staple , legumes, beans, sunflowers and sesame which she can sell in the market if surplus from her own household consumption".

The Team also visited and learnt different components of sisal energy production at Hale Estate where Katani had established sisal energy company called Mkonge Energy Systems Ltd. The Bio-Gas plant had installed capacity of 150 kw generates electricity through using Sisal waste material. It also generates compost. This plant, Katani Claims to be the first of its kind in the world was established with the cooperation of UNIDO. Here at the Bio-Gas plant the team was apprised about the plant by Mr. Gilead E. Kissaka, General Manager. He also demonstrated the operation and generation of electricity including available compost produced as by product. The electricity generated so was used mainly within the decortication plant and some excess was supplied to the domestic quarters within the estate.

Katani's Bio-Gas plant at Hale

Visit to Agriculture Research Institute (ARI), Mlingano, Tanga

The team visited ARI spread over 800 hectares of land and held meeting with its Director Mr. Shabani Hamisi who was assisted by an Agronomist and Head of Sisal Research Programme, Mr Josef Begani. It was apprised to the team that 'Mlingano Agriculture Research Institute was established during the British colonial regime in 1934 with the objective to conduct research for improvement of sisal yield. The Director, in his briefing, told that nearly all sisal varieties grown in Tanzania were developed at Mlingano. In the beginning when Sisal was introduced, Tanzania had only one variety. More hybrid varieties were developed and currently three varieties were grown in Tanznia. At the time of visit, Mlingano had a collection of over 120 varieties of sisal which they claim to be the largest collection in the world. Similarly, it was the only Sisal Research Institute dedicated to sisal Research in the world.

The team was told that 'main activities covered under sisal research were variety evaluation, agronomy, and plant protection. They also had the Meristematic Tissue Culture (MTC) laboratory established in 2000, financed by Common Funds for Commodities 34 (CFC) and United Nations Industrial and Development Organization (UNIDO). The laboratory was aimed at multiplying good sisal plants which are high yielding and uniform materials. The sisal materials multiplied by tissue culture will be established in estate nurseries which will serve as multiplication centers for planting materials. Mlingano is engaged in research related to natural resource management, soil and land resources and fertilizer use technology. Nearly all activities in the country related to land evaluation and land use planning, fertilizer recommendations, agro ecological zones and soil analysis have had a connection with the Mlingano.

The team discussed the possibility of any collaborative research with Arid University, Rawalpindi, Pakistan. In his regard Mr. Shaban Hamisi principally agreed to facilitate the research on sisal. He also agreed to host the research fellow from Pakistan and to initiate collaborative sisal research in Pakistan. In this regard Tripartite MoU among ARI, LSF and PMAS-AAUR may be signed through TSB.

Visit to Tancord Spinning Mill

The team after visiting Mlingano went to see the sisal spinning and weaving Mill at Ngomeni, known as Tanzania Cordage or Tancord (1998) Ltd- a subsidiary of Katani Ltd. Reportedly, with the closing of Usambara Spinning Mill, there were now four of the original five spinning mills still operating in Tanzania with only 35 percent installed capacity being utilized, and these were Tancord (1998) Ltd, Amboni Spinning Mill, 21st Century and Ubena Spinning Mill.

Most spinning/weaving mills were established in the 1960s and 1970s. However, some were complemented with newer machineries in the last decade. The spinning mills produce many products according to market demand. For example, twine, cordage for hay, packaging, baling, building and many other uses including carpets, wall covering, doormats, car mats, buffing cloth used for polishing of metal and furniture, fine yarn, bag cloth, padding, mattresses and handicrafts. All of these products have one thing in common, which is advantageous compared to synthetics: they are biodegradable, natural and safe.

During the visit Mr. Noah Komba, General Manager and Mr. William A. Mazigo, Production Manager of the Mill took the team around and showed spinning, brushing, weaving of carpets, making ropes and twine, and bailing of finished fiber for export etc. The general manager also told that “Tancord is largest spinning Mill in the country and it employs 300 people in two shifts”. He also showed various samples of various products particularly carpets and mats. It was already around sun set and team left for Tanga for overnight stay.

Visit to Sokoine University of Agriculture (SUA). Morogoro

Morogoro is a city with a population of over 315,866 in the southern highlands of Tanzania, located 169 km west of Dar es Salam and 335 km south of Tanga from where it was of 4 hours' drive. Morogoro is located and nesteled at the foot of the rugged Uluguru Mountains. It is a city of cultural mix with Muslims marked by the five time daily calls of prayer from the mosques. Asian community was also visibly present in various businesses among the presence of European and American tourists and development workers. Morogoro Region beside boasting Mikumi National Safari Park is Tanzania's second largest producer of coffee, cotton, sunflower oil, millet, maize and sisal.

The objective of the meeting was to discuss the research on sisal and possibility for any cooperation among LSF, PMAS- AAUR and SUA. The dean of the faculty of Agriculture, Prof. Bendantunguka Tiisekwa briefed the team that SUA was established in 1984 in Morogoro. The University was currently made up of four campuses and one constituent college. The campuses were: the Main Campus in Morogoro, the Olmotonyi Campus in Arusha, and the Mazumbai Campus in Lushoto. The constituent college, known as Moshi University College of Cooperative and Business Studies (MUCCoBS) is located in Moshi.The SUA University had 3 faculties (Agriculture, Forestry and Veterinary Medicine) and 2 institutes namely the Institute of Continuing Education and the Development Studies Institute. University's research programmes mainly included: Soil and water management for crop and livestock production, technology transfer, adoption and agricultural diversification, food crops improvement including promotion of underutilized indigenous crops, nutrition and family resources management, farming systems research, improvement and management of natural resources and plantation forests including economics, policy, harvesting and utilization.

During discussion it was felt that University may not have some specialized unit working exclusively on sisal research. Rai Niaz Ahmed, Vice Chancellor of the only Arid Agriculture University in Pakistan offered cooperation in Research to SUA in various areas related to such as, climate change, desert ecology and sisal. The Vice Chancellor invited all the Deans and the Vice chancellor of SUA to Pakistan and proposed to sign MOU focusing on research in various fields, faculty and student exchange. He said that PMAS –AAUR can offer many opportunities to SUA.

It was proposed that University should develop R & D programmes focusing on Sisalbeing an important cash crop for the country. University of Agriculture, Morogoro expressed its consent and interest for collaborative research on sisal with Pakistan.The meeting was concluded with a positive note to work out MOU for encouraging Public Private Partnership (PPP) and South-South collaboration.

Meeting with OXFAM GB

The team held meeting with Associate Country Director, Dr. Ralph Roothaert of OXFAM at dinner. The objective of the meeting was to know what OXFAM was doing in Sisal development and learn from its experience. Dr. Roothaert briefed about OXFAM's recent intervention related to sisal livelihood programme in Kishapu area where OXFAM was working with farmers and they were motivated to grow sisal as boundaries or hedge rows. In this regard 10,000 farmers were growing sisal on their field boundaries and, as reported, their income had been increased. This experience sharing was useful for the team as in the Pakistani context local farmers initially can opt for sisal boundaries like in Kishapu. OXFAM showed its willingness to share its experience with LSF and its team. This was the last leg of the visit to Tanzania.

Follow Ups:

Visit and Meetings:

- Katani Pvt Ltd hosted and facilitated the visit and meetings. They have agreed to collaborate with University of Arid Agriculture, Rawalpindi and Lok Sanjh to facilitate development of sisal industry in Pakistan.
- Katani also agreed to share the design of decorticator which they have manufactured. It was also identified that engineering department of UAAR may also work to improve the design of decorticator.
- Tanzania Sisal Board agreed for collaboration with Pakistan particularly for research.
- University of Agriculture, Morogoro is agreed for collaborative research on sisal with Pakistan.
- Mlingano Research Institute, Tanzania agreed to facilitate the research on sisal. They have also agreed to host the research fellow from Pakistan and also to initiate sisal research in Pakistan.

For Lok Sanjh:

- Sisal plantation as hedges or intercropping as a cash crop by smallholders.
- Nursery development in collaboration with university of arid agriculture.
- Establishment of decortication facility at local level.
- To build the knowledge base and technical capacity of stakeholders, especially farmers, in quality, marketing and standards with the aim of transforming them into entrepreneurs.
- To plan for value addition.
- Organization of farmers into groups and cooperatives to be empowered to engage and deal with other stakeholders in a sustainable way.
- R&D activities together with market studies in collaboration with other institutes.

Sisal Development Initiative – LSF team Visit to Tanzania in 2015

A combined team of Lok Sanjh Foundation, National Agricultural Research Center (NARC), and PMAS Arid Agriculture University visited Tanzania in the leadership of Dr. Shahid Zia, Managing Director, Rural Business Development Center (RBDC), Islamabad Pakistan.

The visit included meetings with Country Representative Oxfam Novib, Pakistan Embassy in Tanzania, Tanzania Sisal Board and extensive visits to the sisal production areas and related Industry.

Visit to Tanzania Sisal Board in Tanga

In this meeting with TSB, Director General of Tanzania Sisal Board provided overview of Tanzania Sisal Board (TSB) and its roles and responsibilities. Tanzania Sisal Board was established in 1997 to promote the development and improvement of the sisal industry, to make regulations for the control of pests and diseases, to finance and or conduct research directly or through agents in any matter related to the sisal industry, to issue export and import license upon such terms and conditions, to regulate and control the quality, marketing and export of sisal, to collect, refine and disseminate information concerning sisal and promote its use, to advise the government on all matters pertaining to the sisal industry, and to carry out such other functions in relation to the sisal industry as the Minister may direct from time to time.

Visit to Hale Estate at Korogwe District

The team afterwards moved to Hale estate at Korogwe District. Here General Manager, Gilead Kissaka welcomed the visiting team and initially showed the decortication process. The leaves were transported from fields through trollies, where the leaves were placed on conveyer belt pasing through large drum where with ample application of water the leaves were decorated, the biomass was collected in small flowing stream and fiber portion continuously moved on ropes where it was collected and bunched in a bundle. The bundles were then transported to another area where they were placed on wires to dry. The biomass was collected at large area to generate biogas. Again at bio mass collection area, the smaller fibers were collected again and remaining pulp was sent for gas production. The dried fiber was than brushed and further disseminated to another unit where standard bale was formed weighing 250 Kg.

Visit to Sisal Bio-Energy Plant

The team also visited Bio gas plant which is called Mkonge Energy Systems Company Limited (MeS) incorporated in January 2008. The company is a joint venture between Katani Limited of Tanzania with 80 percent of the shares and Chengdu DeTong Environmental Engineering Company of The People's Republic of China who have 20% shares. The company's focus is on the development of the renewable energy sector through creation and promotion of energy projects in Tanzania and other East and Central African countries.

The team was briefed that an appropriate training programs and study tours to biogas production facilities in China, were organized to enable staff at Katani Ltd. to gain valuable experience in the operation and maintenance of medium-scale biogas energy systems. The equipment suppliers have remained in close contact with staff at Katani Ltd in order to offer further support. The biogas is produced with the waste derived from the Sisal decortication plant. The stored biogas is then used to run two 150Kw electricity generators for a rated total electricity output of 300 Kw. The electricity is used mainly within the decortication plant and some of the excess can also be supplied to the domestic quarters within the estate. The excess biogas can also be distributed to surrounding communities to cover cooking and lighting requirements.

The project was a good example of how cleaner and renewable energy technologies can significantly reduce environmental pollution and degradation of the ecosystems while providing surplus energy for productive use. Soil fertility can also be improved by the biofertilizer by-products from the process. The project demonstrates the potential for significantly improving economic viability for the sisal processing industry through the provision of cheaper and cleaner energy generated from process waste and thus enhancing overall competitiveness in local and international markets. Excess energy produced in this manner can be potentially fed to the grid or distributed to surrounding rural populations.The concept on production of bio-energy from sisal waste was developed in 2005 within the context of the larger CFC - financed "Product and Market Development of Sisal and Henequen Products" project. Katani Ltd, are the main counterpart together with the Ministry of Agriculture and Food Security and Tanzania Sisal Board.

Visit to the Smallholder Sisal Grower

The delegation visited a village along with Mr. Hamisi, where small farmers were growing sisal. One of the farmers told that he had grown sisal on 4 acres of his land and had been cultivating for the last many years. Recently, he had established a cooperative and provided with small mobile decorticator. He demonstrated the cultivation technique, the cutting process, further handling and mainly decortication and drying. The decorticator was operated and leave were decorticated, it was small mobile decorticator machine with reasonably good efficiency. Farmers further stated that, the dried fibers were baled and transported to Tancord for further processing and product development.

Visit to the Sisal Industry

Team visited the factory, TANCORD to see sisal fibre processing and product development. The company manufactures various products such as twines, ropes and woven products.





Purchase of Sisal Decorticator

LSF signed a contract with Katani Ltd to import sisal decorticator in Pakistan. That will help processing of wild sisal available in Pakistan. That extracted fibre will be analysed by experts to determine its quality and market value. This imported decortcator will be used as a model to develop further units by ABEI department of NARC.

Meeting with Pakistan Embassy in Tanzania

A meeting was organized with Pakistan Embassy in Tanzania to introduce the team and purpose of visit. LSF work on sisal and its potential in Pakistan was shared with the Ambassador, Mr Muammad Iqbal, who appreciated the coordinated efforts of Lok Sanjh with stakeholders in Tanzania and assured his cooperation and facilitation required by Pakistani delegates.

Final Meeting with Tanzania Sisal Board

On last day, a meeting was held at Katani House to discuss visit findings; any challenges opportunities and futuristic collaboration and coordination. Dr. Shahid Zia indicated thatdelegate is seriously looking in the future collaboration.

Pakistan has vast barren areas in south Punjab, costal belt and in Baluchistan province that can be utilized for sisal cultivation. Both countries can easily utilize each other capabilities and can enhance collaboration, which we look forward to next level in coming years. We need to prioritize the resources, and workout the research agenda. We need to be more creative in product development and its commercialization. There is great room to work in collaboration and benefit both the countries through signing memorandum of understating and different other collaborative and coordination activities.

Concluding Session and Remarks

During this final meeting the officials of Tanzania Sisal Board and TSB emphasized on the following points in the best interest of Tanzania and Pakistan collaboration to introduce sisal crop in Pakistan:

I. It is necessary to have coordinated action on the part of Government of Pakistan and Tanzania Sisal Board with the mediation of Lok Sanjh Foundation, for the promotion of

sisal crop & industry in Pakistan. This South-South cooperation will provide conducive environment to various stakeholders to enable investment through financing institutions and other, resources and services to flow into the sisal sub-sector of agriculture in Pakistan to enable growth and development for economic development and significant contribution to national initiatives in Pakistan. It is also essential to intiate value chain entry points at the beginning without challenging community social norms, especially with regard to the participation of women and the youth.

II. There are a number of developmental and policy issues which are important to facilitate the integration of smallholders in the sisal value chain. Government of Pakistan should ensure that the sisal sub-sector significantly contributes to its agricultural sector policy objectives of improving food security; improving crop varieties; improving farming systems; improving production technologies and efficiencies; and crop diversification.

III. While introducing sisal in Pakistan, the improvement of food security, crop diversification and farming systems should be ensured through the development of smallholder schemes which see value in using the same land and labour to produce more than one crop by mixing sisal with food crop production. Better yields on food crops have been recorded in sisal fields than on pure crop land as there is always some moisture around sisal plants. Mixing sisal with food crop production reduces the investment costs aswell as those of maintaining the crops while at the same time giving higher returns.

IV. Efficiencies in fibre extraction and sisal growing should be improved through interventions at the time of planting sisal crop may lead to the development of high density planting, development of new processing methods using the mobile decorticators which have lower losses in fibre and utilize less water and less energy.

V. Women should be included in the value chain to start use of sisal fiber to make differents products, mats, bags etc. at local level and training arrangements in the real life skills development will be instrumental in the development and promotion of the use of sisal products.

VI. Fibre production is not profitable in the short term and incentives are needed to attractinvestments, as well as to organize growers and grower/processor/trader contractual arrangements to ensure that they are not marginalized in the chain. Before smallholders join any sisal schemes they must be assured that the business venture will be profitable.

VII. Smallholders may be assisted in forming their own organizations suited to their business needs in order to have self regulation. Producer groups have to be strengthened; they need to be involved in decision making, including price setting, to ensure fair dealings and transparency.

VIII. More serious challenge is the change of mindset. Farmers should not be given the hope for subsidies. Smallholder schemes should be market driven to ensure sustainability. Temporary assistance should only act as a building block for commercialization.

IX. Tanzania Sisal Board and Lok Sanjh Foundation's team leaders to continue exchange visits in future for mutual learning to introduce sisal crop production and introduction of related decortication and brushing machinery.

X. Tanzania Sisal Board signed an agreement for the sale of one decorticator to Lok Sanjh Foundation for the Farm Machinery Directorate of NARC to replicate the technology at local level.

Linking with Private Sector – Follow up Visit to Tanzania in 2015

A follow up visit of Tanzania along with private sector was organized and an MOU has been signed with Tanzanian Sisal Board for Future Knowledge sharing, Research and Technical Assistance.

Chapter 4: Research Efforts in Pakistan

1. Collaboration with University of Arid Agriculture for Research on "In Vitro Propagation of Sisal Plant"

LSF engaged Pir Mehr Ali Shah University of Arid Agriculture (PMAS-UAAR) for research and rapid propagation of sisal plant through tissue culture. Since most plants seldom set seeds; therefore sexual reproduction through true seeds is usually inconvenient. For the new planting of large areas, a large number of seed plant lets (4000 plants per ha) is needed, therefore the development of a new propagation technique using in vitro culture methods could be of practical value. In this regard University obtained small plant lets from Lok Sanjh Foundation which were used for propagation.

Expected results

A protocol for micro-propagation of Sisal plant will be optimised according to local conditions. Subsequently a large number of plants will be produced using this protocol, which will be distributed by appropriate agencies to resource-poor farmers of drought hit areas of Pakistan. In this way, tremendous acreage of land, which otherwise is not arable, will come under economic plant production. This will promote various allied enterprises like fibre extraction and textile industry, which in turn, is expected to revolutionize the income of farmers and the country.

Explant Preparation

Small plant let obtained from Lok Sanjh Foundation was used for in vitro culture. Plant materials were first cleaned carefully under running water. All the leaves of the plantlet were removed and only a segment of the basal part (a cylinder of approximately 1 cm in height) was used as explant. First it was washed with cefotexime (antibiotic) solution (250mg/l) for five minutes, then with 70% ethyl alcohol for 30sec, followed by sterilization with 20% clorox (commercial bleach containing 5.2% NaOCl) for 10 min and finally rinsed 5 times in autoclaved distilled water. The exposed surface of the tissue was removed with a razor blade under aseptic condition, leaving a cylinder of 2 mm in height. The cylinder was then divided in 8 sections by vertical cuts with the razor blade; each section was placed separately in a jar containing culture medium.

Culture medium and culture conditions

The culture medium consisted of Murashige & Skoog basal salts containing 2% (w/v) sucrose, 10% (v/v) coconut water and 0.8% (w/v) agar, and supplemented with different combinations of Naphthalenacetic acid (NAA), Indolylbutyric acid (IBA) and Kinetin (KIN). Cultures were incubated at a temperature of 25°C and illuminated for 16 h per day at 2000 lux. After two weeks, explants enlarged and started to gain chlorophyll.

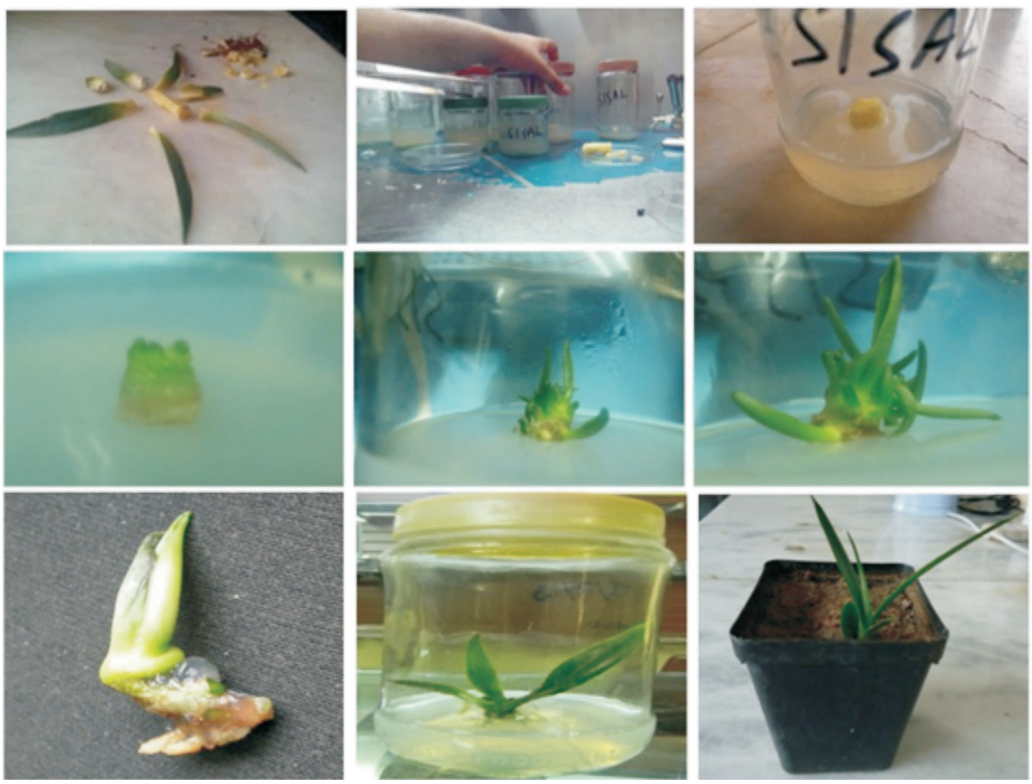
Regeneration and Rooting

Multiple shoot buds started to appear after four weeks of culture. After four more weeks, the explants were taken out of jars in laminar air flow, were separated by sterile scalpel blade and inoculated on rooting medium. Rooting medium was of two types; one having MS basal salts with 1mg/l NAA and the other devoid of any hormone. After four weeks on rooting medium, it was observed that 90% shoots showed root induction on hormone free medium while no rooting was observed on the medium with NAA.

Shifting of Plants to Pots

On attaining the height of 5 inches, these rooted plants were shifted to autoclaved mixture (1:1:1) of sand, soil and farmyard manure in plastic cups. As in vitro grown plants lacked cuticle layer on their leaves, these cups were kept in shade and covered with transparent polythene bags to maximise humidity and avoid sudden shock of desiccation. Polythene bags were removed gradually in two weeks.

Different steps of procedure have been shown pictographically in following figure.



Rapid Propagation Through Tissue Culture

LSF with the collaboration of Pir Mehar Ali Shah Arid Agriculture University, Rawalpindi (PMAS-AAUR) under its Sisal Research Programme (SRP) had successfully undertaken research for in vitro rapid propagation of sisal through Tissue culture for nursery development of Sisal plant. Under this research a protocol for micro-propagation of Sisal plant was optimized according to local conditions. In addition, out of a total of 250 sisal bulbils imported from Tanzania, more 100 were given to PMAS-AAUR and National Agricultural Research Centre (NARC) for further research and propagation, while LSF also planted some sisal plants at its centre near Fateh Jang, District Attock.

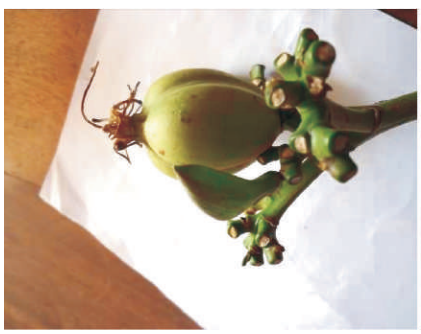
2. Research Activity at Agricultural Research Institute, Milingano

Dr. Mehmood ul Hassan spent 5 days at the Agricultural Research Institute, Milingano after the departure of other delegates of this visit from 10-15 February, 2015 staying at the Resaerch Institute. The main objective was to learn from the research experience of scientists of Sisal Research Institute and he recorded following observations:

- 80 genotypes of sisal were cultivated at this institute for their characterization and evaluation. As a plant breeder and geneticist, it was an amazing experience to note that how the traits of two infereior parents were combined together to develop excellent hybrid. It was a typical example of heterosis. The female parent (Agave amanuensis) had few but long, thin and papery leaves with higher susceptibility to Krogwe Leaf Spot disease while male parent (Agave angustifolia) possessed small leaves with abundant strong spines on leaf margins. However, it possessed strong resistance to Krogwe Leaf Spot and its leaves were thick, fibrous, fleshy and numourous in number. One of its hybrid offspring, namely 11648 had ideal combination of traits; disease resistance, more number of long, thick, fleshy, fibrous leaves without spines on margins.

- Although Agave Sislana has more resistance to Krogwe Leaf Spot disease but owing toits pentaploid genome, it could not be used in hybrid development.


- A hybrid plant growing in small space between two bigger plants developed spines on leaf margin due to stress; a phenomenon which was already observed by Dr. Mehood ul Hassan in previous experiments in Pakistan. This was reported by him in a paper presented in the international conference on Natural Fibres held on 6-7 January, 2015 in Islamabad, Pakistan which was organized by Lok Sanjh Foundation.




- Tissue Culture Laboratory of the Agricultural Research Institute, Milingano have very good facilities and staff was equipped with excellent expertise. It was a surprise for Dr. Mehmood that they were using almost the same protocol which is being used in laboratories of Pakistan during 2013-14, under a project funded by Lok Sanjh Foundation.
- Soil testing laboratory had state of the art equipment and it was facilitating the sisal farmers of Tanzia in a true sence.
- Visits were conducted to the small farmers which helped Dr. Mehmood in having indepth knowledge and understaning of the status, prospects and challenges of sisal cultivation in countries like Pakistan where most of the farming community is small holders.
- Although, Tanzania is extremely blessed country with respect to weather and soil conditions which are almost ideal for plant culture, it was noticed that there was a dire need of mechanization, upgrading and modernization of agricultural systems to further improve the efficiency.

3. Investigations Related to Fibre Characteristics of Different Indigenously Produced Sisal Fibres

Sisal fiber is extracted from the leaves of Agave sisalana that is the Mexican plant and is now mainly cultivated in Tanzania, Brazil, Indonesia and India. Due to its strength and durability, it is placed in the category of "hard fibers". The word sisal means cold water. Sisal fibre occupies 6th place among fibre plants, which represent 2% of the world's production of plant fibres (plant fibres provide 65% of the world's fibres). The sisal plant produces approximately 200 - 250 leaves throughout its productive period. The life span of sisal plant is 7-10 years. The shape of sisal leaves is like sword and is about 1.5 to 2 meters tall. Young leaves may have a few minute teeth along their margins, but lose them as they mature.

A good sisal plant yields about 200 commercial used leaves with each leaf having a mass composition of 4% fibre, 0.75% cuticle, 8% other dry matter and 87.25% moisture. Thus a normal sisal leaf weighing about 600g yields about 3% by weight of fibre with each leaf containing about 1000 fibres.

Figure 1 Sisal plant

Diameter of the fibre varies from 100mm to 300mm. The length of the sisal fibre varies between 0.6 and 1.5 m and its diameters range from 100 to 300 µm. Cellulose content in sisal fibres is about 70%. The fibre is composed of numerous elongated fibre cells that are narrowed towards both ends. Fibre cells are linked together by middle lamellae, which consist of hemicelluloses, lignin and pectin. A sisal fibre in cross-section is built up of about 100 fibre cells. The cross section of sisal fibres is neither circular nor fairly uniform in dimension. The lumen varies in size but is usually well defined. The longitudinal shape is approximately cylindrical.

Physically, each fibre cell is made up of four main parts, namely the primary wall, the thick secondary wall, the tertiary wall and the lumen. The fibrils are, in turn, built up of micro fibrils with a thickness of about 20 µm. The micro fibrils are composed of cellulose molecular chains with a thickness of 0.7 µm and a length of a few µm. Sisal fibre is fairly coarse and inflexible. The tensile properties of sisal fibres are not uniform along its length. The fibres extracted from the root or lower parts of the leaf have a lower tensile strength and modulus. The fibres become stronger and stiffer at midspan, and the fibres extracted from the tip have moderate properties. The lower grade fibre is processed by the paper industry because of its high content of cellulose and hemicelluloses.

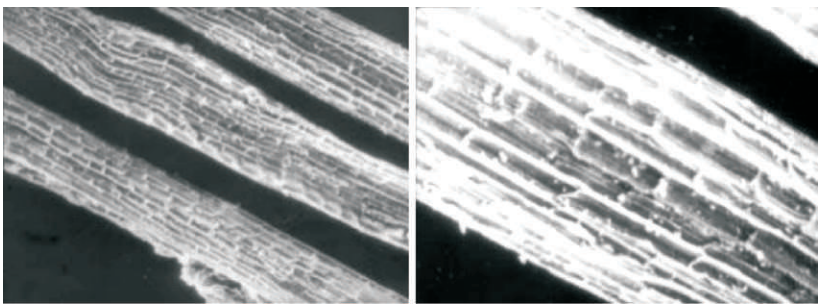


Figure 2 Longitudinal appearances of sisal fibre bundle

The medium grade fibre is used in the cordage industry for making ropes, baler and binders twine. Ropes and twines are widely employed for marine, agricultural, and general industrial use. The higher-grade fibre after treatment is converted into yarns and used by the carpet industry. Products made from sisal are being developed rapidly, such as furniture and wall tiles made of resonated sisal. The sisal reinforced composites are used in the internal linings of vehicles, the sides of car doors, package holders, panels, ceilings, wheel wells, consoles, skid plates etc. to reduce weight of vehicle to reduce fuel consumption. Recent year's sisal has been utilized as a strengthening agent to replace asbestos and fiberglass as well as an environmentally friendly component in the automobile industry.

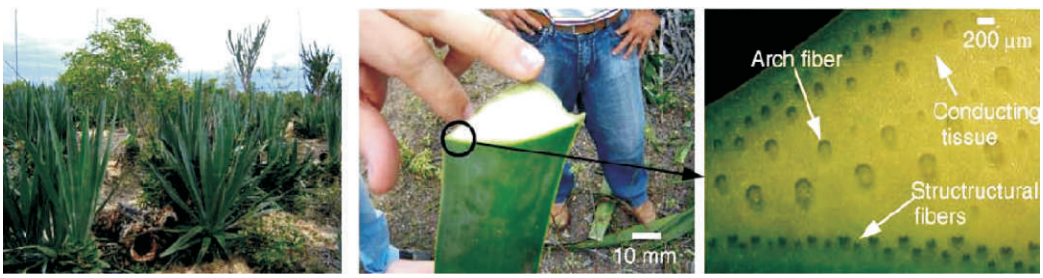


Figure 3 Fibre location in plant leaves

Well, a big constraint in getting benefit from properties of sisal fibre is extracting it from the leaves safely. Various methods have been adopted to extract the sisal fibre from the leaves since ancient times. The fibre is extracted from the leaf either by retting, by scraping or by retting followed by scraping or by mechanical means using decorticators.

Sisal fibre made from the process of decortication, leaves are crushed and beaten by a rotating wheel set with blunt knives, so that only fibres remain. The other parts of the leaf are washed away by water. Decorticated fibres are washed before drying the sun or by hot air. The fibre quality depends upon moisture content so proper drying is important. To get better grades of fibre artificial drying has been found in place of sun drying. Dry fibres are machine combed and sorted into various grades, largely on the basis of the previous in-field separation of leaves into size groups.

Today, lots of natural fibres are being used in making textile products such as cotton, jute, hemp etc. However, still there are such natural fibres that need utmost attention of researchers for being having great potential of fulfilling needs of modern world both in terms of comfort and versatility thanks to their eco-friendly, non-toxic and user-friendly behavior. Sisal fibre is the big example of such neglected natural fibres and it has great potential of generating powerful revenue for the country for being using as s substitute of jute fibre. Today, jute industry in Pakistan is facing severe decline and 7 out of 11 jute industries in Pakistan has been shut down due to trading constraints of jute fibre during its import from Bangladesh. The new applications for sisal fibre reinforced composites are making the fancy articles, mats, carpets, fancy articles and many others.

It is an established fact the quality of the fabric is always strongly associated with that of fibres. Therefore, the knowledge of quality of the sisal fibres will play a vital role for determining the quality of the products manufactured from them. In this backdrop the present investigations are being planned to characterize the various varieties of sisal fibres for determining their potential for further processing. Moreover, the quality of the indigenously produced sisal fibres will be compared with international sisal fibre quality characteristics.

Scope of Work

The specific scope of study

- Determination of fibre quality characteristics
- Fibre Length
- Fibre Fineness
- Fibre strength
- Fibre stiffness
- Moisture percentage
- Comparison of the indigenously produced sisal fibres with international sisal fibre quality characteristics

Experimental / Methodology

The study was conducted in the Department of Fibre & Textile Technology, Universityof Agriculture Faisalabad. The following procedures were adopted to achieve the specific research objectives.

Materials

The following material was provided by provided from Lok Sanjh Foundation.

i. Indigenous Sisal Leaves

ii. Sisal fibre samples imported from Tanzania

Figure 4 Indigenous sisal leaves

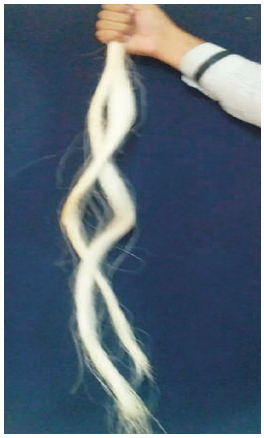


Figure 5 Sisal fibre samples imported from Tanzania

Methods

The selected sisal leaves were decorticated using decortication machine in the department of Fiber & Textile Technology, University of Agriculture, Faisalabad.

Decortication Procedure

Decortication is done by hand feeding single leaves halfway into the decortication machine between the rotating drum and a plate with sharp edges, while grasping one end of the leaves. The leaf is then withdrawn from the unit and reversed to clean the second half, while the feeder holds the clean cleaned fibre portion. The waste is taken away from the machine after regular intervals. Being portable, such type of decorticators can easily perform in the fields where the sisal is grown. After that, the extracted fibre is given a quick wash and hangs out to dry. In this type of extraction, each leaf being processed separately.

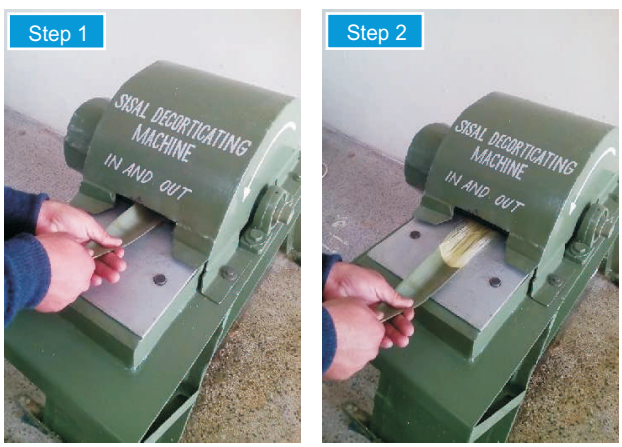


Figure 6 Sisal decorticating machine

Figure 7 Sisal fibres after decortication

Sisal Fibre Testing

Following physical characteristics of sisal fibres will be determined using standard procedures.

- Fibre Length
- Fibre Fineness
- Fibre Strength
- Fibre Stiffness
- Moisture Percentage

Fibre Length

The length of sisal fibre is the length of leaf. The fibre can be extracted from the leaves almost equal to the length of leaf. There is simple method of fibre length determination. The length of the leaf is measured manually by means of measuring tape and ultimately the length of extracted sisal fibre is also measured by the same procedure. This standard method was also adopted in this research work to measure the length of sisal fibre.

Figure 8 Indigenous sisal leaf

Fibre Fineness

Fibre fineness is the measure of diameter of individual fibre strands. There are two methods of measurement of sisal fibre fineness.

Measurement of Fibre Fineness in terms of "Tex"

The standard international method of measurement of sisal fibre fineness in the laboratory is determining the linear density by weighing a specific length. This way of measuring linear density is called Tex. Tex is defined as "The weight in grams of one kilometer of fibers". In the present research work, the forty (40) sisal fibers having equal length i.e., 500 mm were taken and weighed. Then after calculation, the weight of 1000 m fibers was calculated for measurement of Tex.

Figure 9 weighing sisal fibres

Measurement of Fibre Fineness by Microscope

Microscope allows the physical measurement of sisal fibre diameter in terms of mm. In the present research work, the fibre fineness was determined by taking microscopic views of individual fibers and then drawing the line across the diameter of sisal fibre. Straight line along the diameter shows the fibre diameter and this is the fineness of sisal fibre.

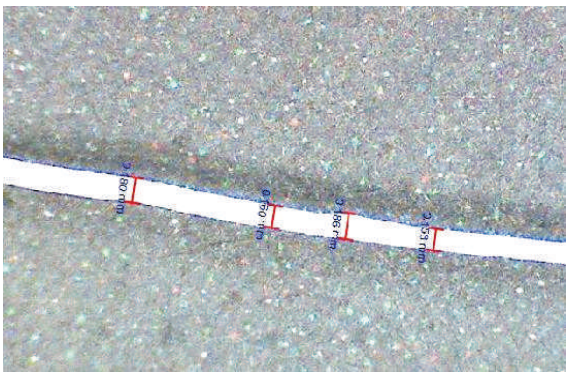


Figure 10 Microscopic image of sisal fibre

Fibre Strength

Fibre strength in cN of individual sisal fibers was determined by means of Electronic Single End Strength Tester in the Department of Fibre & Textile Technology. Moreover, the elongation in mm and tenacity in cN/dtex of individual sisal fibres was also measured by means of Electronic Single End Strength Tester.The single sisal fibre was clamped between two jaws of Electronic Single End Strength Tester having displacement 30 mm and 500 mm respectively. Pre-tension was kept 5 cN. After the gauge adjustment, the instrument was operated with the help of software for strength testing of individual fibre.

Figure 11 Electronic single end strength tester

Fibre Stiffness

As sisal fibers are straight and having no twist, so by twisting the sisal fibers in one direction, we can check the ultimate bearing capacity of sisal fibre before breakage by imparting maximum number of twists. The maximum of number of twist that a single sisal fibre can withstand before breakage is the stiffness of fibre.

In the present research work, the above mentioned procedure was adopted to test the stiffness of sisal fibers. The counter meter of twist tester indicates the number of twists that a single sisal fibre can withstand and that count is the stiffness of concerned sisal fibre.

Figure 12 Digital twist tester

Moisture Percentage

The protocol for testing the moisture percentage of sisal fibres by oven-dry method is as follows;

i. 10 g of sisal fibres were taken and placed it in the oven to obtain the temperature range 120 -140°C.

ii. The sisal fibres samples were weighed again after taking it from the oven after 20 sec. The successive readings were taking after 5-10 minutes. The samples were confirmed oven-dried when the weight difference between successive readings became less than 0.05%.

iii. The successive readings for oven-dry weight of sisal fibres were again noted. When the samples became completely oven dried and the weight difference between successive readings became less than 0.05%, all the samples were finally weighed. This weight was considered as “Over-dry Weight”.

iv. Moisture percentage was calculated by using the following mathematical formula.

$$\text{Moisture (\%)} = \frac{\text{Total Weight} - \text{Oven-Dry Weight} \times 100}{\text{Total Weight}}$$

Results

The present study "Investigations Related to Fibre Characteristics of different indigenously produced Sisal Fibres" was conducted in the Department of Fibre & Textile Technology, University of Agriculture, Faisalabad. The results of the present research work given in tables are presented here under.

Fibre Length:

The length of sisal fibre is the length of leaf. The fibre can be extracted from the leaves almost equal to the length of leaf. Within the leaf, there are three basic types of fibers: structural, arch, and xylem fibers. The structural fibers give the sisal leaf its stiffness and are found in the periphery of the leaf. However, the fiber length can be damaged due to faulty decortications process. In order to measure the fibre length firstly, the leaf weight and leaf length was measured which is presented in the following

Table 1 Length and weight of leaves

Leaf No.	Length (In)	Weight (Kg)
1	51	1.5
2	53	1.3
3	51	1.4
4	52	0.75
5	52	1.6
6	51	1.6
7	43	1.05
8	52	1.05
9	53	1.2
10	53	1.9
	51.1	1.335

The average fibre length extracted from the indigenous leaves is 48 inches. While that of Tanzanian leaves is 32 inches. This might be due to the fact that indigenous plants are wild growing plants and the leaves were very big. So by comparing the length of both varieties of sisal leaves, it can be concluded that average length of indigenous sisal leaves is more as compared to Tanzanian leaves

Fibre Fineness:

The results obtained for fibre fineness of the indigenous grown and imported from Tanzania sisal fibres are given in the following table.

Fives Indigenous grown sisal fibers were selected randomly and their diameter was measured using the microscope and image analysis. Each fibre was measured at five different places. The mean values for five leaves are 0.1676, 0.192, 0.2292 , 0.185 and 0.1348. The overall mean of the diameter is 0.1817.

On the other hand, fives Tanzanian sisal fibers selected randomly diameter mean values are 0.2326, 0.1662, 0.2114, 0.2408 and 0.2818. The overall mean of the diameter is 0.2265.

Table 2 Fibre diameter of indigenous sisal fibres

Leaf No.	Fibre Diameter (mm)				
	1	2	3	4	5
1	0.163	0.171	0.244	0.185	0.129
2	0.155	0.171	0.231	0.172	0.133
3	0.156	0.184	0.204	0.191	0.184
4	0.168	0.21	0.243	0.178	0.114
5	0.196	0.224	0.224	0.199	0.114
Mean	0.1676	0.192	0.2292	0.185	0.1348

Table 3 Fibre diameter of Tanzanian sisal fibres

Leaf No.	Fibre Dia (mm)				
	1	2	3	4	5
1	0.221	0.18	0.238	0.259	0.281
2	0.238	0.186	0.219	0.251	0.318
3	0.265	0.16	0.217	0.233	0.26
4	0.224	0.153	0.198	0.22	0.263
5	0.215	0.152	0.185	0.241	0.287
Mean	0.2326	0.1662	0.2114	0.2408	0.282

The results showed that the fibres imported from Tanzania are thicker in diameter than the indigenous fibers. The overall difference in the diameter is also clear from the following microscopic images and their analysis.

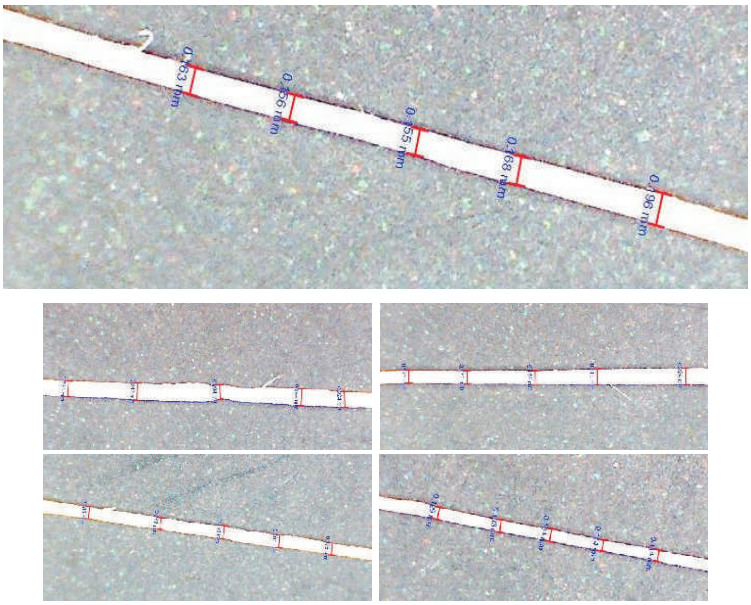


Figure 13 Microscopic images of indigenous sisal fibres

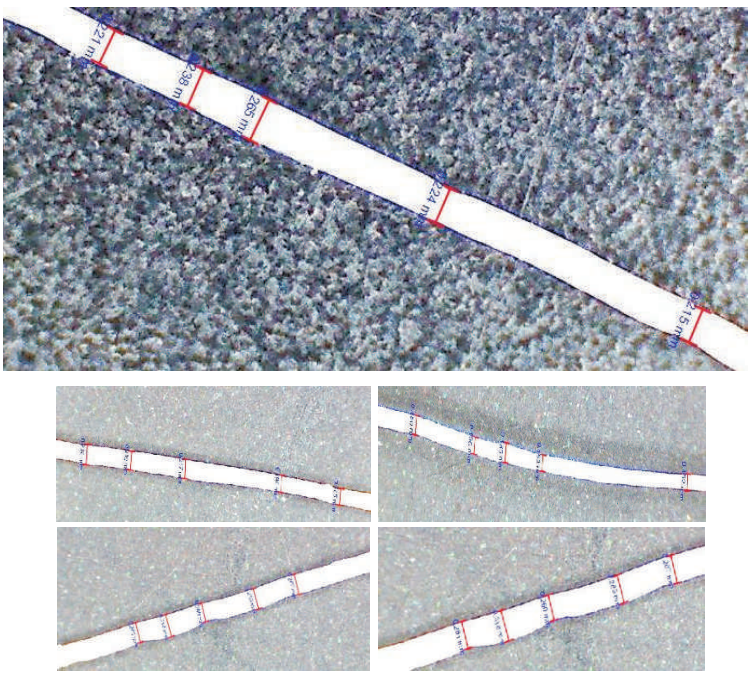


Figure 14 Microscopic images of Tanzanian sisal fibres

Figure 13 Microscopic images of indigenous sisal fibres
Figure 14 Microscopic images of Tanzanian sisal fibres

The results showed that the fibres imported from Tanzania are thicker in diameter (almost double) than the indigenous fibers. The other method to determine the fibre fineness is the gravimetric method. Defined fibre lengths were measured and their weight was determined. On the basis of gravimetric method the fibre fineness was determined in tex.

Tabel 4 Fibe fineness of Sisal fibres

Origin	Fibre Fineness in Tex
Indigenous	16 tex
Tanzaniz	30 tex
Reported Values	16 - 35 tex

As shown in the table, the indigenous fibres have fibre fineness of 16 tex while that of Tanzanian fibers is 30 tex. It is also reported in the literature, the sisal fibres may have fibre fineness ranging from 16-35 tex. Tex is unit for the measurement of linear density of fibres. Tex is defined as “The weight in grams of one kilometer of fibers”. Here we can conclude that Tanzanian fibre for being having more tex are thicker in diameter as compared to indigenous fibers.

Fiber Stiffness:

Compression property tests show that sisal fibres have the highest stiffness (measured by the twist method ± Appendix B) and therefore the lowest compressibility when compared to other fibres. This is 30% lower than that of jute and 50±60% lower than that of acrylics and wool. Sisal's recovery from compression is lower than that of jute by about 15%, and is only about one- third that of acrylic and wool fibres.

This test method is used for testing the rigidity of jute and kenaf fibres. A given amount of fibre of appropriate length is placed in the clips at the two ends of the twist testing machine. The fibres are twisted until they break. The higher the twist inserted the softer the fibre.

The results of the indigenous fibres are presented in the following table.

Tabel 5 Stiffness of indigenous Sisal fibres

Leaf No.	Stiffness (Number of Turns/foot)
1	712
2	806
3	756
4	850
5	890
6	942
7	776
8	898
9	982
10	846
Mean	845.8

The same test was applied to Tanzanian fibres which have revealed the stiffness of 350 turns/ foot. The fact is explained with the fineness of the Tanzanian fibers, as they are thicker in diameter, therefore they are more stiffer and break after fewer turns. The fact is explained with the fineness of the Tanzanian fibers, as they are thicker in diameter, therefore they stiffer and break after fewer turns.

Fibre Strength:

Fibre strength is the most important property of the sisal fiber because of its end uses. The most of the applications of the sisal fibers are related to the load bearing and composites. The fibre strength of the single filament was measured and the results are being presented in the following tables. The fibre strength was measured at 30 mm gauge and 500mm gauge, as these both gauges are reported in the literature. At 30 mm gauge, the maximum strength of the fibre was reported as 676 cN, while minimum was 546cN. Similarly, the elongation ranges from 10.67% to 21% while tenacity ranges from 3.7cN/dtex to 7.2cN/dtex. The mean values for single fibre strength, elongation at break and tenacity are 610 cN, 16.30% and 5.28 cN/dtex respectively.

Table 6 Fibre strength of sisal fibres at 30 mm gauge length

Sr #	At 30 mm Gauge Length		
	Strength (cN)	Elongation (mm)	Tanacity (cN/dtex)
1	614	10.67	6.80
2	643	14.67	3.90
3	636	15.33	5.30
4	676	21.00	4.40
5	591	19.33	6.10
6	632	12.33	5.50
7	611	19.67	3.70
8	575	19.00	4.60
9	546	14.33	7.20
10	576	16.67	5.30
Mean	610	16.30	5.28

At 500 mm gauge, the strength of the fibre was reported as 267 cN, while minimum was 153cN. Similarly, the elongation ranges from 6.8% to 11.2% while tenacity ranges from 0.7cN/dtex to 2.3cN/dtex. The mean values for single fibre strength, elongation at break and tenacity are 208.9 cN, 8.82% and 1.48 cN/dtex respectively.

Table 7 Fibre strength of sisal fibres at 500 mm gauge length

Sr #	At 500 mm Gauge Length		
	Strength (cN)	Elongation (mm)	Tanacity (cN/dtex)
1	197	6.8	1.40
2	240	8.2	0.70
3	264	7.4	2.30
4	174	11.2	1.10
5	199	9.4	0.90
6	213	7.6	1.30
7	267	10	1.10
8	153	10.8	1.90
9	179	7	2.00
10	203	9.8	2.00
Mean	208.9	8.82	1.48

The difference in the values of tensile parameters between 30 mm gauge and 500 mm gauge due to the fact that in case of 500 mm gauge, there is more possibility of having weaker places than in case of 30 mm. Therefore the strength values achieved at 300 mm gauge is always higher than 500 mm gauge.

The tensile strength and elongation of Tanzanian fibres was also determined. The strength at 30 mm gauge is 1610 cN while the elongation is 4.33 %. Similarly, strength and elongation values at 500 mm gauge are 950 cN and 2.73% respectively.

There is remarkable difference of tensile strength parameters between indigenous and Tanzanian fibre. Tanzanian fibres are stronger and stiffer in comparison with Pakistani indigenous fibres. One of the reasons is that Tanzanian fibres are almost double in thickness as compare to indigenous fibres; however, their strength is 3-4 times higher. Tanzanian fibres being stronger and stiffer in comparison with Pakistani indigenous fibres. One of the reasons is that Tanzanian fibres are almost double in thickness as compare to indigenous fibres; however, their strength is 3-4 times higher.

Moisture Regain Percentage:

The moisture regain percentage for indigenous fibres and Tanzanian fibres were measured by using oven dry method. Following results were obtained.

Tabel 8 Moisture regain of Sisal fibers

Origin	Moisture Regain
Indigenous	10.1%
Tanzaniz	10.6%
Reported Values	10.7%

As the moisture regain percentage for Indigenous fibres was measured as 10.1% and for the Tanzanian fibres as 190.6%, so these calculated values are found very close to the reported values of moisture regain percentage. Moreover, there is no remarkable difference between the moisture regain percentage of Indigenous fibres and Tanzanian fibres.

Conclusions

Conclusions drawn from the presented work along with the recommendation for improvement are being presented hereunder :

- The average fibre length extracted from the indigenous leaves is 48 inches . While that of Tanzanian leaves is 32 inches .
- Tanzanian fibre is almost double in diameter with respect to indigenous fibre . Moreover , the indigenous fibres have fibre fineness of 16 tex while that of
- Tanzanian fibers is 30 tex .
- The stiffness of indigenous sisal fibre is 84 turns / foot while that of Tanzanian Fibres is 350 turns / foot .
- At 300 mm gauge , the mean values for single fibre strength , elongation at break and tenacity are 61 cN , 16 . 3 % and 25 . 2 cN / dtex respectively . At 500 mm gauge , the mean values for single fibre strength , elongation at break and tenacity are 208 cN , 8 . 8 % and 21 . 4 cN / dtex respectively .
- The tensile strength and elongation of Tanzanian fibres was also determined . The strength at 300 mm gauge is 161 cN while the elongation is 4 . 33 %. Similarly , strength and elongation values at 500 mm gauge are 95 cN and 2 . 73 % respectively .
- The calculated value of moisture regain percentage for Indigenous fibers and Tanzanian fibres are 10 . 1 % and 10 . 6 % respectively .
- From all above results , it is concluded that Tanzanian fibres are much coarser and stiffer than Pakistani indigenous sisal fibres but they are 3 - 4 times stronger than the indigenous ones .

Overall Conclusion

Various tests i.e. tensile strength at different jaw spacing, moisture percentage, stiffness, length and fineness and image analysis of sisal fibres were performed. It can be inferred from the tested results that Tanzanian fibres are much coarser (double in diameter) and stiffer than Pakistani indigenous sisal fibres but they are 3-4 times stronger than the indigenous ones.

Recommendation

- As indigenous sisal fibres are less stiffer , softer and pliable , so their application in composites is not as good as of Tanzanian sisal fibres having stiffer nature and high tensile strength . Nevertheless the application of such softer fibres is found good in home textile industry .
- The women entrepreneurs can be established by the development of various handmade sisal products . However , in order to convert the sisal fibres to the handmade products , softening of fibres will be of vital importance . A research project in the direction of softening of sisal fibre must be carried out in future .
- The knowledge regarding sisal processing machinery is limited to the fibre decorticator .However , in order to process the sisal fibres a small scale fibre combing machine is also necessary after washing and drawing of the fibres . The research and development work for the sisal fibre combing should be accomplished before using it as a substitute of jute fibres .

References

1) Yu, C. and Zhang, Y. (1993), `The properties of sisal fibre and the effect of alkali treatment', Journal of China Textile University, Vol. 19, No. 5.
2) Das, P. K., Nag, D., Debnath, S., & Nayak, L. K. (2010). Machinery for extraction and traditional spinning of plant fibres. Indian Journal of Traditional Knowledge, 9(2), 386-393.
3) Franck, R. R. (Ed.). (2005). Bast and other plant fibres (Vol. 39). CRC Press.
4) de Andrade Silva, F., Chawla, N., & de Toledo Filho, R. D. (2008). Tensile behavior of high performance natural (sisal) fibers. Composites Science and Technology, 68(15), 3438-3443.
5) Kirby, R. H. (1963), Vegetable Fibres, Leonard Hill (Books) Ltd, London.
6) Gordon Cook, J., Handbook of Textile Fibres, Merrow Publishing Co. Ltd, Shilton, UK.
7) Catling, D. & Grayson, J. (1998), The Identification of Vegetable Fibres, Archetype Publications, London.
8) Fanchang, J. and Yu, C. et al. (1997), `Research on the spinnability of sisal fibre', Bast Fiber Technology, No. 3.
9) Mackie, G. (2004) 228 Ballylesson Rd. Drumbo, Lisburn, UK BT27 5TS. Private communication.
10) Donghong, C. (1999), `History review and looking ahead on the sisal production of worldwide and China', Fujian Science & Technology of Tropical Crops, Vol. 24, No. 1.

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