Role of Anatomical Structure on Yield and Quality of Bast Fiber

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Abstract

Anatomical structure (cross-sectional area and surface structure of fiber bundle) greatly contributes to quality determination of fiber filaments. Fiber bundle with greater cross-sectional area produces coarse and strong fibers suitable for gunny bags, whereas fibers with low cross-sectional area produce fine fibers used in fabrics and finer textiles. Over-retting or under-retting will reduce fiber quality. It is difficult to assess the fiber quality if not retted properly and cannot be used in breeding process. Plant breeders may use this simple technique for genetic improvement in yield and quality of bast fiber crops (jute, kenaf, ramie and flax). The paper discusses about the anatomical techniques for use by the crop breeders for superior quality genotypes in bast fibers to help the farming community and jute industry get higher profit and superior quality fibers for various end uses.

1. Introduction

In fiber-yielding plants, fiber development is a determined and unidirectional biological process. A stem fiber is conditioned by anatomical structures present in the stem and derived mainly from the cambial activity, where fiber filaments grow in a protophloic origin. Fiber cells, after full development, become cemented at the ends by cementing materials like hemicellulose and pectin to form the fiber strands. The fiber strands make their way through the stem in a zigzag pattern becoming cemented here and there forming the meshy structure in jute and other bast fibers except ramie, flax and sunnhemp (*Crotalaria juncea*).

In ramie fiber, the filament is composed of one fiber cell starting from the base to the top of the plant. It is the strongest fiber of vegetable origin. The formation of a meshy network is the main characteristics of these bast fibers. The ultimate fiber cells derived from fusiform initials, which form the building skeleton of the fiber filament, are pointed at the apex with a lumen, the morphology of which varies in various fiber crop species. Large variation is observed in fiber bundle structure among crop species and among varieties of the same species for shape of fiber wedge, number of layers, number of fiber bundles and their structures. In general, the fiber wedge is tapering to blunt with gradual reduction of fiber bundles towards the tip. The inter-connection of fiber bundles forms the meshy structure. The structure of fiber bundles and their cross sectional area varies among the varieties of *Capsularis* jute. The general characteristics of fiber bundle structure and ultimate fiber cells are depicted in Figure 1. A crop breeder has to select a plant on the basis of its morphological structure, as fiber retting will destroy the crop without providing seed for progeny population. Moreover, during retting process, microbial organisms degenerate the parenchymatous tissue without affecting ligno-cellulosic fiber filaments, thereby liberating fiber strands after completing retting process and washing with water. Over-retting or under-retting will reduce fiber quality. Therefore, it is difficult to assess the fiber quality if not retted properly and cannot be used in breeding process. Considering these limitations, anatomy of fiber filament depicts clearly the genetic potential of fiber quality of crop plants as discussed herein. Large variability occurs among bast fiber crop species

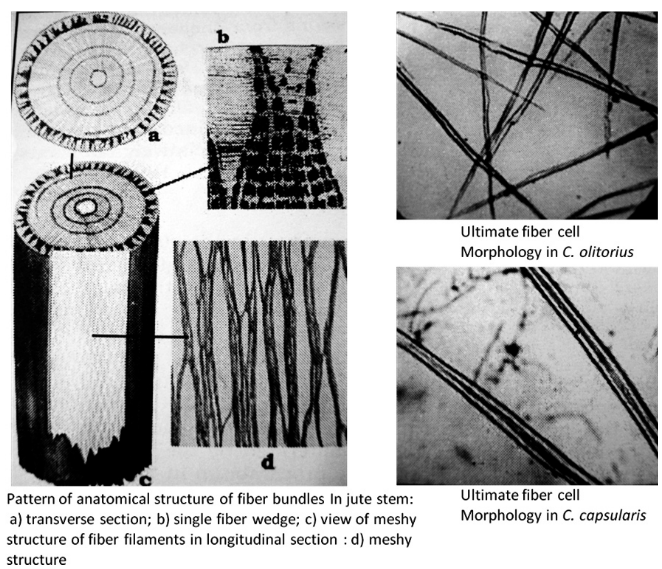
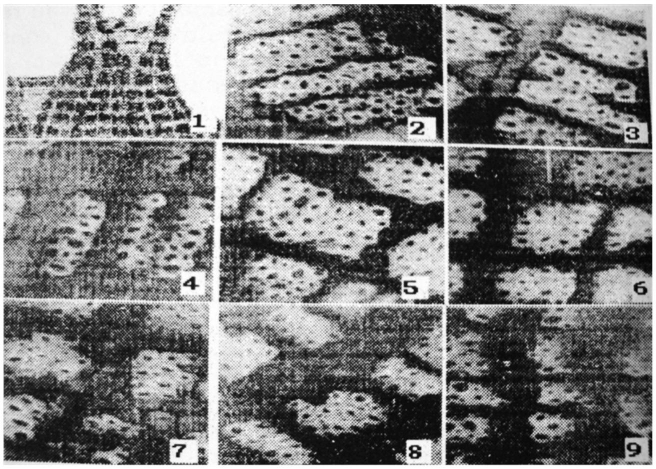


Figure 1: General characteristics of fiber bundle structure and ultimate fiber cells

in the anatomical structure of fiber bundles and their orientation and intensity in the fiber wedge. General features of the anatomy of some of the bast fiber crops which are mainly of secondary origin from cambial activity as mentioned above are depicted in Figure 2.



Variability in fiber bundle structure among *C. olotorius* genotypes: 1- fiber wedge; 2-9 – fiber bundle morphology

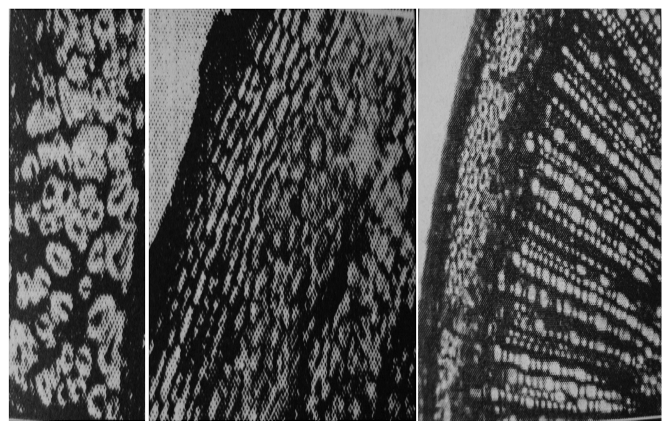
Figure 2: General features of anatomy of some bast fiber plants

The anatomical structure of fiber bundle predicts fiber quality parameters. From the fiber anatomy, it can be observed that the greater cross-sectional area of fiber bundle shown in Figure 2 produce coarse fiber, but has greater fiber tenacity originated from greater number of fiber cells. On the contrary, fibers having minimum cross-sectional area of fiber bundles produce finer fiber filaments of desirable spinning quality.

The irregular contour of fiber bundles produce fiber filament with irregular surface of poor fiber quality. The morphology of ultimate fiber cells, and their tip and size vary widely among crop species. It has been reported that longer fiber cells contribute to greater strength. Tossa jute (*Corchorus olitorius*) produces good quality fiber for desirable fiber bundle structure compared to white jute (*C. capsularis*), which has undesirable fiber bundle structure. In *C. olitorius* there are large variations in fiber bundle intensity and fiber bundle structure, thereby offering scope for selection of variety with high yield potential and high fiber quality. There is enough scope for selection of genotype for better quality such as fineness and bundle with uniform surface for application in genetic improvement of quality. The same is observed in *C. capsularis*. The main defects of this jute are the irregular fiber bundles and more meshy structure compared to that of *C. olitorius*. Therefore, emphasis should be given to improve fiber quality using anatomical traits. Besides, greater number and layers of fiber bundles fiber^{-1} wedge may also be considered for yield improvement.

The fiber filaments with more meshy structure offer obstacles during carding process, while fiber filaments with minimum meshy structure is easier to handle during carding process. A good example of better fiber type is *Malachra capitata*, which produces ideal fiber bundles for spinning process. The fiber bundles of this plant are more or less rectangular with uniform surface structure and are scarcely meshy revealing good fiber quality. Its fiber filament tenacity is also high. *Hibiscus cannabinus* produces better quality fiber compared to that of *H. sabdariffa*. Different species of minor *Hibiscus sp*. produce poor quality fibers with irregular fiber bundles and highly meshy fiber strands such as *Hibiscus panduraeformis*. On the contrary, *H. suratensis* produces uniform fiber bundles with less meshy structure. Similarly, *Sida rhombifolia* produces strong and good quality fiber. *Hibiscus vitifolius* produces uniform rectangular fiber bundle with good quality fiber of high strength. The fiber bundles of *Abutilon indicum* are united laterally producing flat ribbon-like fiber filaments after retting. Therefore, the anatomical structures contribute greatly to quality determination of fiber filaments.

In some stem fibers such as ramie, flax and sunnhemp, which are mainly of primary origin derived from procambium fiber, anatomy is quite different compared to those of other bast fibers of secondary origin mentioned above. The fiber cells are oval and grouped in the cortical regions. These are cellulosic in nature. The fibers cannot be extracted by biological retting process because the bacteria responsible for retting directly feed on cellulosic fiber unlike ligno-cellulosic fiber of other bast fibers such as jute and kenaf. Ramie fiber is extracted by chemical retting methods using specific chemicals. The anatomical structure of ramie and flax fibers are shown in Figure 3.



Transverse section of ramie stem showing the distribution of fiber cells in the cortex

A transverse section of flax stem showing orientation of fiber cells in the cortex

Figure 3: Anatomical structure of ramie and flax fiber

In the case of ramie (*Boehmeria nivea*), which produces strongest unicellular fiber filaments, fiber cells which are oval or egg-shaped are derived from procambial activity and are arranged in groups in the cortical regions. The intensity and cross sectional area of fiber cells vary greatly among varieties. Single fiber cell produces fiber filament unlike that of other bast fibers in which the fiber filament is composed of many ultimate fiber cells cemented at the tips. Therefore, there is a great scope in the selection of variety with higher yield potential and better fiber quality (Figure 3).

Flax (*Linum usitatissimum*) fibers are similar to ramie fiber cells being ovoidal and are present in patches in the cortical regions. Sunnhemp (*Crotalaria juncea*) also produces fiber cells in the cortex in similar manner. There are variations among varieties in the size and abundance of fiber cells, thereby giving scope for selection of varieties for high yield and fiber quality.

2. Parameters for Selection

2.1. For yield improvement

2.1.1. For long fibers of secondary origin (jute, kenaf, other *Hibiscus sp*.): Greater number of fiber bundles in fiber wedge unit^{-1} area, fiber bundle area is associated with greater plant height and basal diameter.

2.1.2. Fibers of primary origin (ramie, flax, sunnhemp): Greater number of fiber cells in transverse section of stem, greater number of fiber cell layers in fiber patch.

2.2. For fiber quality improvement

2.2.1. Bast fibers of secondary origin

Cross-sectional area

Fiber bundle with greater cross-sectional area produces coarse and strong fibers suitable for gunny bags whereas fibers with low cross-sectional area produce fine fibers used in fabrics and finer textiles.

Surface structure

Fiber bundle with irregular surface is not desirable which produces bad quality fabric, on the contrary, fiber bundle with uniform surface produces uniform filament for the fabrication of good quality textile.

Ultimate fiber cells

Long ultimate fiber cells with uniformity in surface and fiber cell tips confer higher fiber strength or tenacity.

2.2.2. Fibers of primary origin

Low cross-sectional area of fiber cells and uniformity in cell surface produce finer textile.

3. Technique for Rapid Screening of Breeding Material

The technique mentioned above is suitable for main bast fiber crops such as jute, kenaf, ramie and flax. A small quadrant (piece) of bark is cut at the base of the stem of respective species at flowering stage. Then transverse section of the bark is cut with a sharp razor blade and seen under microscope by adding a drop of safranin in case of jute and kenaf for distinguishing ligno-cellulosic fiber strands and by adding bismark brown or light green in the case of ramie and flax for observing cellulose fiber cells in transverse section. Thus a large number of plants can be screened and selected within short time for desirable yield and quality contributing traits. This technique gives an opportunity to utilize the selected plants in the crossing programme for possible genetic improvement of yield and quality. The genetics of these traits need to be investigated for understanding the inheritance of the traits.

Taking a small portion of bark at the base of stem will not affect the plant growth but gives opportunity to the breeder to utilize selected plant in crossing with another desirable selection. The selection procedure will continue in F_1, F_2 to F_7 to obtain homozygous plants for combination of desirable yield and quality parameters. There is a need to improve the quality of white jute (*C. capsularis*) owing to irregular fiber bundle and highly meshy structure. Large variability in the fiber bundle structure exists among *Capsularis* varieties. Sudan is finer in bundle which could be utilized in improving the fineness of the fiber filament in *Capsularis*. The same technique needs to be adopted in the case of *H. sabdariffa* for improving fiber quality. The plant breeders may use this simple technique in genetic improvement of yield and quality of bast fiber crops following the schematic program as shown in Figure 4.

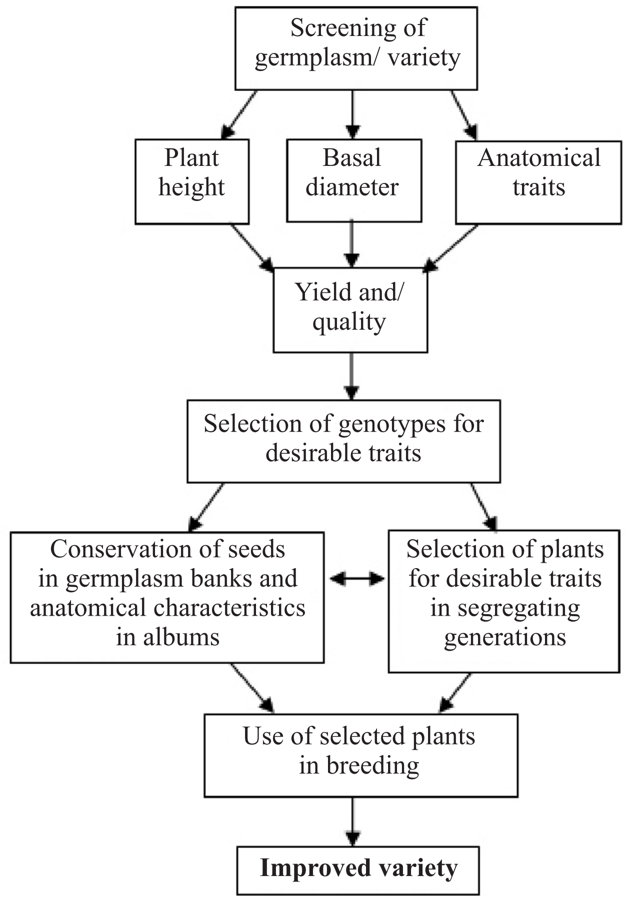


Figure 4: Schematic diagram for possible genetic improvement in yield and quality

4. Conclusion

The paper brings out the anatomical techniques which can be advantageously adopted by the crop breeders for superior quality genotypes in bast fibers to help the farming community and jute industry get higher profit potential and also superior quality fibers for various end uses. Geneticists have great scope to study the inheritance of various anatomical components of integrated fiber quality by experimenting the various bast fiber crops, their germplasm and breeding lines under optimum growing conditions. It emphasizes a necessity of inter-disciplinary research on quality and yield improvement of vegetable fibers.