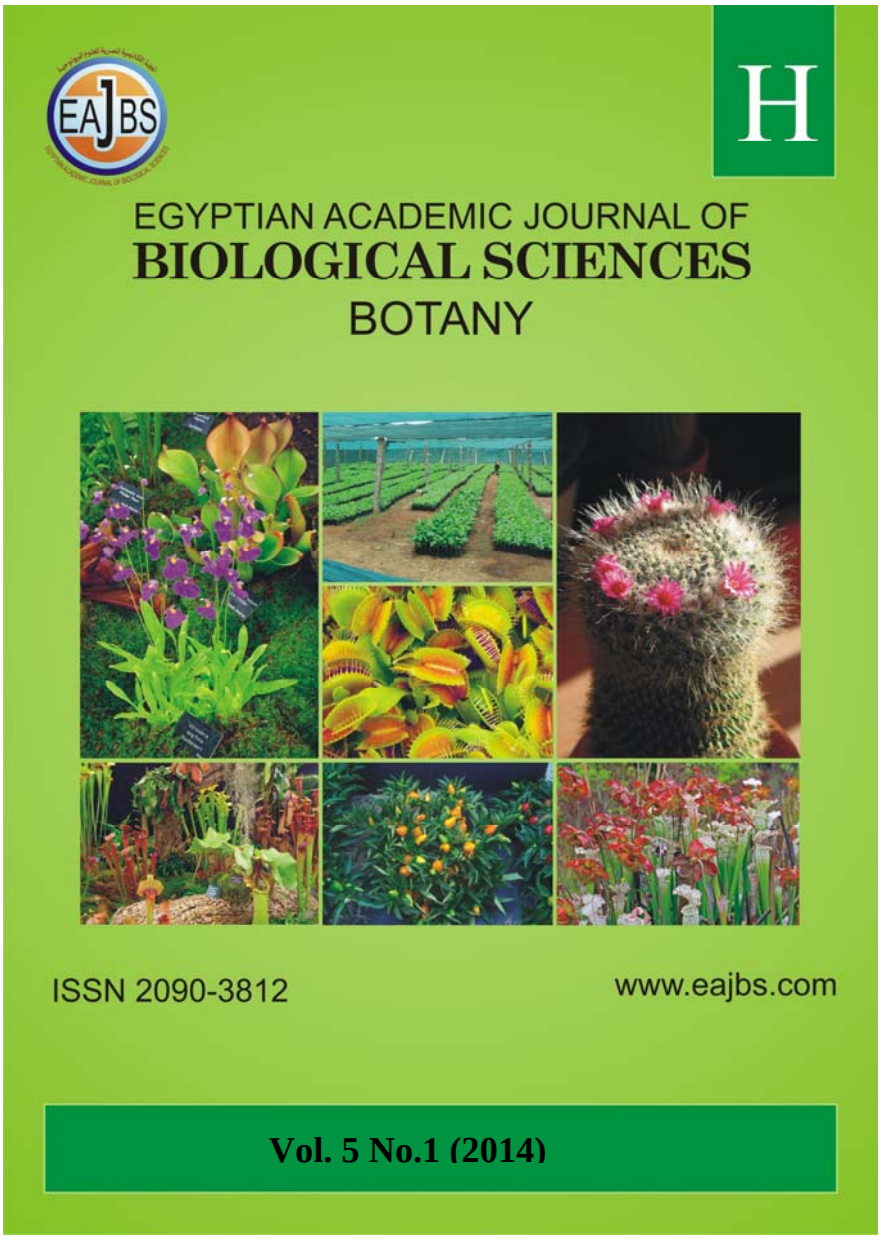

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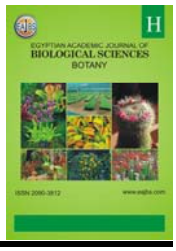

Preliminary assessment of the microanatomy of okra [Abelmoshcus (L.)] Wood

Osawaru, M. E.*; Ogwu, M. C. and Emokpare, A. A.
Plant Conservation Unit, Department of Plant Biology and Biotechnology, Faculty of Life Sciences, University of Benin, Benin City, Nigeria
*edwinosawaru@yahoo.com

ABSTRACT

Okra (*Abelmoschus esculentus* (L.) Moench and *Abelmoschus caillei* (A. Chev.) Stevel) belongs to the family Malvaceae. They are grown in many parts of the world, especially in tropical and subtropical countries where they provide income and food security. Three accessions of the two species of Okra were collected from the Nigerian Institute of Horticulture (NIHORT), Ibadan and cultivated in the University of Benin, Nigeria. The examination of sections obtained at the seventh node of each sample of *Abelmoschus esculentus* (Samples A and B) and *Abelmoschus caillei* (Sample C) was conducted at Forest Research Institute (FRIN), Ibadan. Results from the microanatomy analysis reveal average length of fibre for Sample A, B and C are 1118.5-1376.4 µm, 1376.4-1142.0-1131.0 µm and 1325-1363 µm respectively while average fiber diameter for Sample A, B and C are 28.8-31.0 µm, 22.3-27.7 µm and 24.3-24.9 µm respectively. The lumen diameter was 15.4-17.9 µm, 12.3-16.6 µm and 12.8-14.9 µm respectively for Sample A, B and C while 6.6-6.7 µm, 4.9-5.3 µm and 5.1-6.1 µm are the values obtained for cell wall thickness of sample A, B and C respectively. These values are comparable to those for flax (*Linum usitatissimum* L.), hemp (*Cannabis sativa* L.), ramie (*Boehmeria nivea* L.), jute (*Corchorus capsularis* L. and *Corchorus olitorius* L.), kenaf (*Hibiscus cannabinus* L.), sisal (*Agave sisalana* Perr.). Thus, it can be suggested that the fibre dimension indicates possible usefulness of these Okra species as alternative source of raw materials for several industrial process.

Keywords: *Abelmoschus* (Okra), Microanatomy, Wood, Fibre, Economic plant

INTRODUCTION

Okra (*Abelmoschus* species) belongs to the family Malvaceae. Edwin *et al.* (2006) reported that the family has about 82 genera and more than 1,500 species. Most of them are economically important including *Corchorus* (Jute) and *Gosypium* (Cotton) while some are renowned for their aesthetic values for example *Rosa sinensis* (Hibiscus). The genus *Abelmoschus* originate from central Africa but is now cultivated in tropical and subtropical regions of the world (Schipper, 2000; Arapitsas, 2008). They may be annual

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herbs, perennial shrubs or trees and produce characteristic mucilaginous substance (Edwin *et al*., 2006). Okra is one of the most commonly grown vegetable crops in Nigeria (Mensah *et al.,* 2008) and is available almost throughout the year. Okra is known as 'ilasa' in Yoruba, 'kubewa' in Hausa, 'okwuru' in Ibo and 'ikhiavo' in Benin (Gill, 1988). They are used for different purpose most common been as soup or stew. They are present in most home gardens, distant farms and on the road side in Nigeria and can provide food and income security for the populace. This crop can be grown on a large commercial farm or as a garden crop (Aladele *et al.,* 2008).

There are various types of okra including *moshatus, manihot, esculentus, tuberculatus, ficulneus, crinitus, angulosus*and *caillei*. The focus of this study is on two species; *A. esculentus* (common Okra) and *A. caillei* (West African Okra). Osawaru *et al.* (2011) reported 25 quantitative and 16 qualitative characters used to analyze the genetic diversity in *A. caillei*. Although a great degree of similarity exists between *esculentus and caillei*, there are marked morphological differences such as plant size, pod shape, length and diameter between these two varieties. In relation to their zone of cultivation, *A. esculentus* is adapted to the "Sudano-Sahelian zone and *A. caillei* is referred to as "Guinean" type (Schipper, 2000). *Abelmoschus caillei* is found only in West Africa, where it originated as an allopolyploid hybrid between *Abelmoschus manihot and Abelmoschus esculentus* (Benchasri, 2012). A relatively higher chromosome number of between 185-199 have been reported for *A. caillei* with 194 as the most frequently reported (Siesmonsma and Hamon, 2002). The International Plant Genetic Resources Institute (IPGRI) germplasm database suggests more than 46 institutions in different countries worldwide possess about 11000 accessions of cultivated okra and wild related species (Aladele *et al*., 2008)

Their fruits bear numerous oval, smooth, dark green to dark brown seeds (Schippers, 2000; Omonhinmin and Osawaru, 2013). They grow best in warm climates with minimum temperature of 18°C (Nwachukwu and Mbagwu, 2008).The application of fertilizer or manure can help to enhance the growth, yield and quality of okra fruits (Vijaya and Seethalakshmi, 2011). Osawaru and Abioye (2012) reported that parts and products of okra constitute major economic activity in West Africa; although about 60 % of okra grown, is for the fresh vegetable market. In south western Nigeria, the cost of a bowl of fresh fruits sells at 300 naira per kilogram. According to Obire (2002) this price depends on the state of the fresh fruits. Large pods constitute greater weight but small immature pods of a low fruit weight command premium price (Schippers, 2000). The frequency of consumption from Edo state, Nigeria is 0.7% as compared to twenty-nine vegetables considered in a study by Mensah *et al*. (2008). The young pods contain protein of about 1.6-2.2 %, carbohydrate, vitamin A, B and C (Nonnecke, 1989). Rubbing of mucilage on the external reproductive organ and considerable consumption of the fruit aids easy and faster delivery (Obire, 2002). The fibre can be processed into drying agent by industries (Gogus *et al.,* 1999). The colour of okra fibre is quite variable, and they range from white to yellow, depending on the action of UV radiation (Lee *et al.,* 2008). Dehydrated okra is used as emulsifier for salad dressing (Nonnecke, 1989). Mishra and Pal (2007) reported the use of okra mucilage as a source of polyacrylonitrile, which can be used with suitable chemical graft for the synthesis of biodegradable polymers. The increasing demand of inulins, lignin, oxalic acids, saponins, tannins carotenoids, flavonoids, resins and other chemicals obtained from stem by pharmaceuticals has

implied scientists to search for plant species which could yield appreciable amount of these raw materials. (Udobi and Onaolapo, 2009; Askok *et al.,* 2012; Chumbhale and Upasani, 2012).

Microanatomy is the study of the microscopic anatomy of cells and tissues of plants and is commonly performed by examining cells and tissues by sectioning and staining, followed by examination under a light microscope or electron microscope (Carlquist, 2001). Different or similar plant parts can be examined. Sections are made based on the part been assessed. The sequence of features used by wood anatomists include: growth rings, vessel elements, imperforate tracheary elements (ITEs), axial parenchyma, rays and piths. Others may include idioblasts, secretory tissues, cambial variants (anomalous secondary growth), and cambial ontogeny products (Carlquist, 2001; Schweingruber *et al*., 2012). Growth rings represent layers of cells produced by vascular cambium and may reflect a full year's growth and are called annual rings (Worbes, 1992). Abrupt changes in the environment especially in the availability of water can cause a plant to produce more than one growth ring in a year (Carlquist, 2001; Worbes, 2002). Vessel element may then be described as dead cell formed from the fusiform initial, but still has functions and are still protected by surrounding living cells (Carlquist, 2001; Worbes, 2002).

A pit is a gap in the secondary wall of a plant cell with pit cavities, which are empty spaces connecting the lumen of each cell, and the pit membrane, which forms a partition between the adjacent pit cavities (Dickinson, 2000). Pits play an important role in the movement of sap in living trees and in the penetration of liquids or gasses into timber (Tsoumis, 1991). Sano and Jansen, (2006), reported that, it is likely that large pores or perforations in interfibre pit membranes are one of the factors that are involved in the dehydration of wood fibres.

The aim this present study is to investigate the fibre dimension of Okra stems, act as a model study for future research on stem anatomy, determine if okra is a cost efficient source of renewable fibre that can function in the manufacture of paper, pulp, fibre boards, ropes, fabrics, carpets and so on and to contribute to the data base of Okra stem microanatomy.

MATERIALS AND METHODS

Plant Material

Abelmoschus esculentus and *Abelmoschus caillei* seeds were obtained from the seed bank of Nigerian Institute of Horticulture (NIHORT), Ibadan.

Study Area

Abelmoschus esculentus and *Abelmoschus caillei* were cultivated beside the screen house of the Department of Plant Biology and Biotechnology, University of Benin. Sections were obtained at the seventh node of each plant, with length of about 30 cm. This was performed with the aid of a hand saw. Samples were then labelled, stored in polytene bags and transported to Plant Anatomy Department, Forest Research Institute of Nigeria (FRIN), Ibadan.

Maceration Preparation of Samples

Maceration solution was prepared by combining 1 part of a 30 % hydrogen peroxide solution, four parts of distilled water and five parts of glacial acetic acid. This preparation was performed in a fumed cupboard.

1- Transverse and tangential sections of about 100 mm x 1 mm, were prepared from each sample with the aid of a microtome.
2- The sections are then placed into vial containing the maceration fluid; the volume of the fluid required is approximately 10X the volume of the tissue.
3- The vials are capped tightly and placed in an oven for 2 days at a temperature of 56 ^{0}C.
4- The maceration is completed when the fluid becomes clear and tissues appear whitish to translucent.
5- The tissues were then rinsed gently in three changes of water (2 hours between each change) and left in water overnight. The samples were given final rinse in water and stored in 30 % glycerol solution.
6- The samples are transferred into vial and capped tightly, and shaken vigorously until the water becomes clouded with cells.
7- A small drop of the mixture is applied to a glass slide, and covered with a cover slip.

Stain Preparation

1- The stain was prepared by dissolving 100 ml of 0.1 M benzoate buffer, pH 4.4 in 0.1g of Toluidine Blue O (TBO).
2- The prepared macerated tissues were then placed on clean slides.
3- The tissues were then flooded with an aqueous solution of 0.1 % TBO solution for one minute.
4- The stains were gently removed using a piece of filter paper.
5- The tissues were then washed by flooding them in water, dried with filter paper; this was repeated until there was no excess stain around the samples.
6- A drop of clean water was then applied over the samples and a cover slip was then placed over the samples.

Microanatomy

Light microscope enabled the survey of variability and distribution of features in tissues. Prepared slides were placed on a stage and viewed under a magnification of 80X. At this magnification, the fibre dimensions and cell wall thickness are revealed and measured using a stage micrometer (Edward, 1998).

Statistical Analysis

Descriptive statistical analysis was used to determine their mean, variance and standard deviation as described by Ogbeibu (2005) using Microsoft excel 2003 to compute the data.

RESULTS

Results are presented in Tables 1-6, Figures 1-4 and Plates 1-9.

Table 1 shows result for the fibre length, fibre diameter, lumen diameter and cell wall thickness for sample 1 A. The result shows that the mean value for fibre length is 1188.5 µm, 28.8 µm for fibre diameter and 15.4 µm for lumen diameters. Fibre length has a high variance value of 108720.9 µm.

Table 1: Mean, variance, standard deviation and standard error of fibre dimension for sample 1A

S/N	FL(µm)	FD(µm)	LD(µm)	CT(µm)
□	1188.5	28.8	15.4	6.7
S^2	108720.9	33.6	17.1	1.9
S	329.7	5.8	4.1	1.4
S□	73.7	1.3	0.9	0.3

Key:
FL = Fibre length FD = Fibre diameter
LD = Lumen diameter of fibre CT = Cell wall thickness of fibre
µm = Micrometer □= Mean
S^2 = Variance S = Standard deviation
S□ = Standard Error.

Table 2 shows result for the fibre length, fibre diameter, lumen diameter and cell wall thickness for sample 1B. The result show that the mean value for fibre length of the sample is 1376.4 µm, 31.0 µm for fibre diameter, 17.9 µm for lumen diameter and 6.6 µm for cell wall thickness.

Table 2: Mean, variance, standard deviation and standard error of fibre dimension of sample 1B

S/N	FL(µm)	FD(µm)	LD(µm)	CT(µm)
□	1376.4	31.0	17.9	6.6
S^2	34636.5	36.9	19.6	2.7
S	186.1	6.1	4.4	1.6
S□	39.4	1.4	0.9	0.4

Key:
FL = Fibre length FD = Fibre diameter
LD = Lumen diameter of fibre CT = Cell wall thickness of fibre
µm = Micrometer □ = Mean
S^2 = Variance S = Standard deviation
S□ = Standard Error.

Table 3 shows result for the fibre length, fibre diameter, lumen diameter and cell wall thickness for sample 2A. The result show that the mean value for fibre length is 1142.0 µm, 27.7 µm for fibre diameter, 16.6 µm for lumen diameter and 5.3 for cell wall thickness. The variance of fibre length is 34845.3 µm, 25.7 µm for lumen diameter, 14.6 µm for fibre diameter and 0.9 µm for cell wall thickness.

Table 3: Mean, variance, standard deviation and standard error of fibre dimension of sample 2A

S/N	FL(µm)	FD(µm)	LD(µm)	CT(µm)
□	1142.0	27.7	16.6	5.3
S^2	34845.3	14.6	25.7	0.9
S	186.7	3.8	5.1	1.0
S□	41.7	0.8	1.1	0.2

Key:
FL = Fibre length FD = Fibre diameter
LD = Lumen diameter of fibre CT= Cell wall thickness of fibre
µm = Micrometer □ = Mean
S^2 = Variance S = Standard deviation
S□ = Standard Error.

Table 4 shows result for the fibre length, fibre diameter, lumen diameter and cell wall thickness for sample 2B. The result show that the mean value for fibre length is

1131.0 µm, 22.3 µm for fibre diameter, 12.3 µm for lumen diameter and 4.9 µm for cell wall thickness.

Table 4: Mean, variance, standard deviation and standard error of fibre dimension of sample 2B

S/N	FL(µm)	FD(µm)	LD(µm)	CT(µm)
□	1131.0	22.3	12.3	4.9
S^2	103177.4	23.2	12.6	1.4
S	321.2	4.8	3.6	1.2
S□	71.8	1.1	0.8	0.3

Key:
FL = Fibre length FD = Fibre diameter
LD = Lumen diameter of fibre CT = Cell wall thickness of fibre
µm = Micrometer □ = Mean
S^2 = Variance S = Standard deviation
S□ = Standard Error.

Table 5 shows result for the fibre length, fibre diameter, lumen diameter and cell wall thickness for sample 3A. the result show that the mean value for fibre length is 1325.1 µm, 24.9 µm for fibre diameter, 12.8 µm for lumen diameter and 6.1 µm for cell wall thickness. The standard deviation for fibre length was 203.3 µm, 2.2 µm for fibre diameter, 2.1 µm for lumen diameter and 1.5 µm for cell wall thickness.

Table 5: Mean, variance, standard deviation and standard error of fibre dimension of sample 3A

S/N	FL(µm)	FD(µm)	LD(µm)	CT(µm)
□	1325.1	24.9	12.8	6.1
S^2	41337.1	4.7	4.4	2.3
S	203.3	2.2	2.1	1.5
S□	45.5	0.5	0.5	0.3

Key:
FL = Fibre length FD = Fibre diameter
LD = Lumen diameter of fibre CT = Cell wall thickness of fibre
µm = Micrometer □ = Mean
S^2 = Variance S = Standard deviation
S□ = Standard Error.

Table 6 shows result for the fibre length, fibre diameter, lumen diameter and cell wall thickness for sample 3B. The result show that the mean value for fibre length is 1363.4 µm, 24.3 µm for fibre diameter, 14.9 µm for lumen diameter and 5.1 µm for cell wall thickness. The standard deviation for cell wall thickness is 0.9 µm, 3.5 µm for lumen diameter, 4.1 µm for fibre diameter and 295.9 µm for fibre length.

Table 6: Mean, variance, standard deviation and standard error of fibre dimension of sample 3B

S/N	FL(µm)	FD(µm)	LD(µm)	CT(µm)
□	1363.4	24.3	14.9	5.1
S^2	87586.1	16.6	12.0	0.9
S	295.9	4.1	3.5	0.9
S□	66.1	0.9	0.8	0.2

Key:

FL = Fibre length
FD = Fibre diameter
LD = Lumen diameter of fibre
CT = Cell wall thickness of fibre
µm = Micrometer
□= Mean
S^2 = Variance
S = Standard deviation
S□ = Standard Error.

Fig.1 show the average fibre length of the two Okra accessions. The highest length was recorded by sample 1B followed by sample 3B. More so, the lowest fibre length was obtained from sample 2A and 2B respectively.

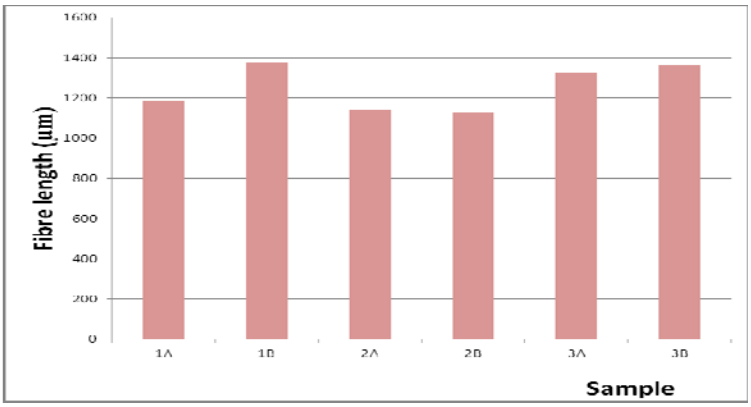

Fig. 1: Average length of Okra (*Abelmoschus*) fibre

Fig. 2 show the average fibre diameter of the two Okra accessions. The highest fibre diameter was obtained from sample 1B while the lowest fibre diameter is recorded from sample 2B

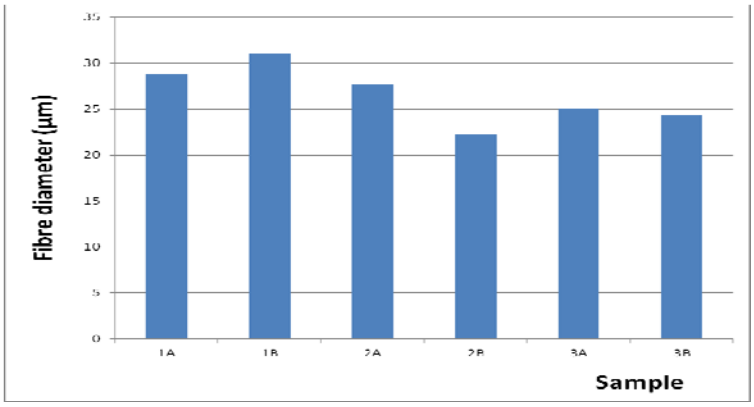

Fig. 2: Average diameter of Okra (*Abelmoschus*) fibre

The average lumen diameter is represented below. Sample 1B had the highest value followed by sample 2A and 1A respectively. The lowest lumen diameter was recorded from sample 2B and 3A respectively (Fig. 3).

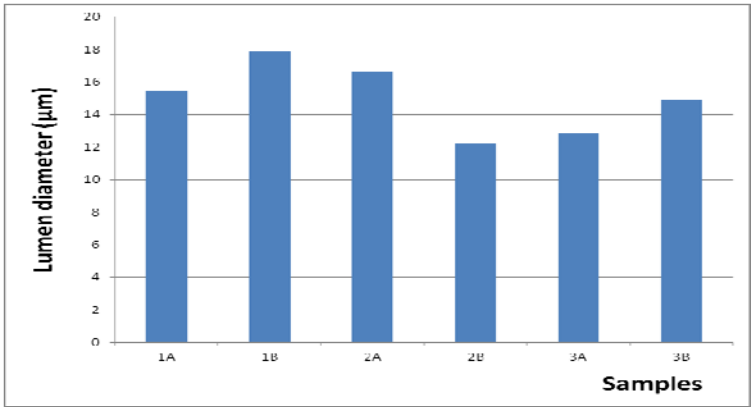

Fig. 3: Average lumen diameter of Okra (*Abelmoschus*) fibres

The average cell wall thickness is represented in Fig. 4. The result show that sample 1A had the thickest cell wall diameter followed by sample 1B and 3A respectively. The lowest value for cell wall diameter was obtained from sample 2B

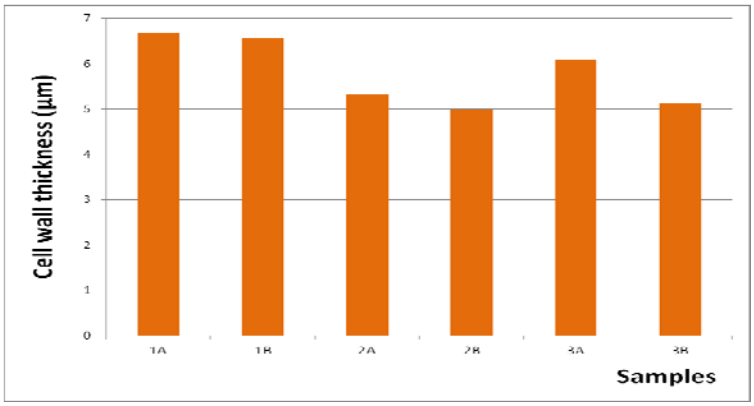

Fig. 4: Average cell wall thickness of Okra (*Abelmoschus*) fibre.

DISCUSSION

In the list of highly sought-after goals for a sustainable exploitation of natural resources, the use of plant-based material to replace fossil carbon-derived products ranks undoubtedly among the top. The increase in the world population, together with rapid industrial development, push towards the depletion of petrochemicals and subsequent need of finding sustainable sources of raw materials. Plant-sourced raw materials, such as fibre, are a renewable resource that can reduce our dependence on fossil carbon and synthetics. The food-oriented agricultural industry is progressively being redirected towards one ensuring also raw material for pulp and paper, textiles, construction and bio-fuels (Marques et al, 2010). This aspect is particularly important, as it offers an alternative to forest-sourced biomass. In view of the foreseen deficit in wood caused by the decreasing capacity of the world's forest to supply woody biomass, much effort is

devoted towards finding other sources of renewable raw material (Reddy and Yang, 2005).

In the last 20 years there has been tremendous interest in the use of natural fibres as reinforcement for polymeric materials (Chand *et al,* 1998). This has been stimulated by the increasing cost of manufacturing energy-intensive, synthetic fibres such as glass, carbon and Kevlar. Two well established products are Tufnol 6F/45 which is an epoxy-cotton composite and the Tespa which is a phenol wood fibre composite (Gupta, 1996). However, the poor strength properties of these two materials necessitated the need for further product optimisation. Fibre crops comprise flax (*Linum usitatissimum* L.), hemp (*Cannabis sativa* L.), ramie (*Boehmeria nivea* L.), jute (*Corchorus capsularis* L. and *Corchorus olitorius* L.), kenaf (*Hibiscus cannabinus* L.), sisal (*Agave sisalana* Perr.). Other plants that are of much less importance on a global scale, but are nonetheless cultivated for their fibres, include nettle (*Urtica* spp.) (Davies and Bruce, 1998), okra (*Abelmoschus esculentus*), banana (*Musa textilis*). The most important fibre crop, when looking at global annual production, is without any doubt cotton (*Gossypium spp*).

Mwaikambo (2006) simplified fibres into three main classes based on their morphological structure, namely: (a) stem fibres – those produced from plant stems, (b) leaf fibres-those produced from the leaf of plants, and (c) seed hair/- fruit fibres. Seed fibres, especially cotton, are separated from the seed by ginning while a technique called decortication is usually employed in separating fibre bundles form the leaf and stem of fibre plants. This technique is performed by a decorticator a machine used to strip fibre bundles from the stem or leaf. Fibres obtained from the stem of various dicotyledonous plants are referred to as 'bast' fibres to distinguish them from leaf fibres (Mwaikambo, 2006). It is also used to denote fibres obtained from the cortex and pericycle in addition to the vascular tissues. Stem fibre bundles are composed of elongated thick-walled cells joined together both end to end and side by side and arranged in bundles along the length of stem.

In *Abelmoschus* species, transverse section of stem shows three regions which includes: the outer epidermal region, cortex region and vascular bundle region. The vascular bundles are circularly arranged in the cortex. It consists of xylem, cambium and phloem. Phloem schelerenchyma cells of stem forms the fibre bundle. This makes fibers of *Abelmoschus* bast as they are sourced from phloem.

The cell walls of fibres may be characterized as a non-protoplasmic component of the cell because after it is formed it is removed from metabolic activities (Mwaikambo, 2006). The cell wall determines the shape of the cell and the texture of the tissue (Chand *et al.,* 1998). On the basis of development and structure, four parts are commonly recognized in plant cell walls: the intercellular substance or middle lamella, the primary wall and the secondary wall. The intercellular substance occurs between the primary walls of two contiguous cells, and the secondary wall is laid over the primary, that is, next to the lumen (Mwaikambo, 2006).

The average lengths of okra fibre from least to highest were recorded in this order: sample 2B (1131.0 µm), 2A (1142.0µm), 1A (1188.5µm), 3A (1325.0µm), 3B (1363.4 µm) and 1B (1376.4µm) as shown in Fig. 1. These values are comparable to those for Jute (*Corchorus capsularis*) with length of 1900 µm and Kenaf (*Hibiscus cannabinus*) with length of 2000 µm as reported by Gassan *et al,* (2001). In contrast the value for cotton (*Gossypium spp.*) which was significantly greater with 20000 µm (Mwaikambo,

2006). Jute geotextile is one of the most important diversified jute products with a potentially large-scale application. It can have several applications such as: soil erosion control, vegetation consolidation, agro-mulching, reinforcement and protection of riverbanks and embankments, land reclamation and in road pavement construction. Jute fibres and wood are combined with thermoplastic materials for making semi-rigid as well as rigid boards. From the results obtained for *Abelmoschus esculentus*, it is important to consider okra as an alternative raw material.

The average diameters of okra fibre from least to highest were record in this order: sample 2B (22.3 µm), 3B (24.3µm), 3A (24.9 µm), 2A (27.7µm), 1A (28.8 µm) and 1B (31.0 µm) as shown in Fig. 2. These values are comparable to those of Ramie (*Boehmeria nivea*) with diameter of (28.1 µm). In contrast, Cotton (*Gossypium* spp.) and Bamboo (*Bambusa arundinacea*) had a smaller diameter with values 11.5 µm and 10.0 µm respectively (Mwaikambo, 2006). Ramie is used to make such products as industrial sewing thread, packing materials, fishing nets, and filter cloths. It is also made into fabrics for household furnishings (upholstery, canvas) and clothing, frequently in blends with other textile fibres (for instance when used in mixture with wool, shrinkage is reported to be greatly reduced when compared with pure wool.) Shorter fibres and waste are used in paper manufacture. Ramie ribbon is used in fine bookbinding as a substitute for traditional linen tape. Despite its strength, ramie has had limited acceptance for textile use. The fibre's extraction and cleaning are expensive, chiefly because of the several steps-involving scraping, pounding, heating, washing, or exposure to chemicals. Some or all are needed to separate the raw fibre from the adhesive gums or resins in which it is unsheathed. However, okra is yet to be explored in this areas; fibre extraction is relatively cheaper compared to ramie.

The average lumen diameters of okra fibre from least to highest were record in this order: sample 2B (12.276 µm), 3A (12.834 µm), 3B (14.880 µm), 1A (15.438 µm), 2A (16.64211 µm) and 1B (17.856 µm) as shown in Fig 3. These values are compared with those reported by Mwaikambo, (2006) for kapok was 2 µm in diameter.

The average cell wall diameters of okra fibre from least to highest were record in this order: sample 2B (4.991 µm), 3B (5.115 µm), 2A (5.332 µm), 3A (6.076 µm), 1B (6.572 µm) and 1A (6.665 µm) as shown in Fig. 4.

CONCLUSION

The stem of fibre crops represents one of the best examples in nature of contrasting lignifications pattern existing within the same plant. This heterogeneous secondary cell wall composition allows the use of fibre crops for different industrial sectors and provision of great value both for the environment and the economy, as they favour the shift towards a bio-based economy. The result from this investigation on the fibre dimension of Okra stems suggests the existence of similar diversity within *Abelmoschus* species. In addition to its importance on the data base of stem microanatomy, it also acts as a model study for future research on stem anatomy. It is of essence to note that okra is cost efficient, almost readily available and a source of renewable fibre that can be used in the manufacture of paper, pulp, fibre boards, ropes, fabrics, carpets, hence providing an alternative to synthetic polymers and giving us one less reason to pollute the world.

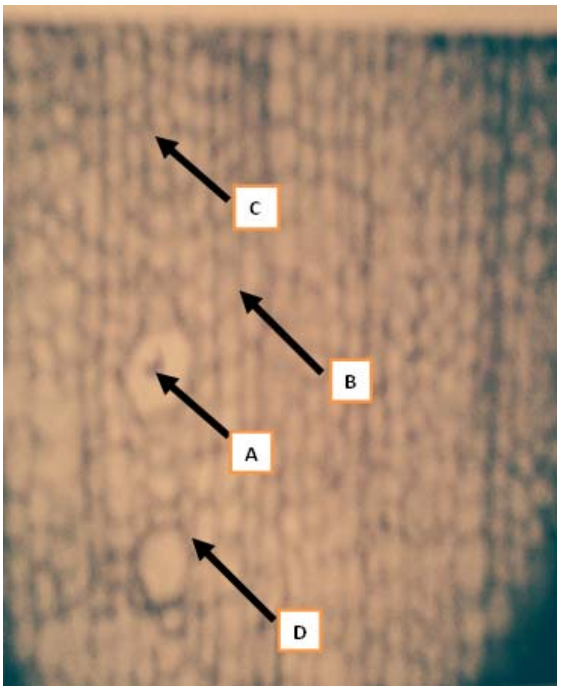

Plate 1: Transverse section of light photomicrograph of sample 1A stem
A = Vessels
B = Tracheid
C = Parenchyma
D = Vessel membrane

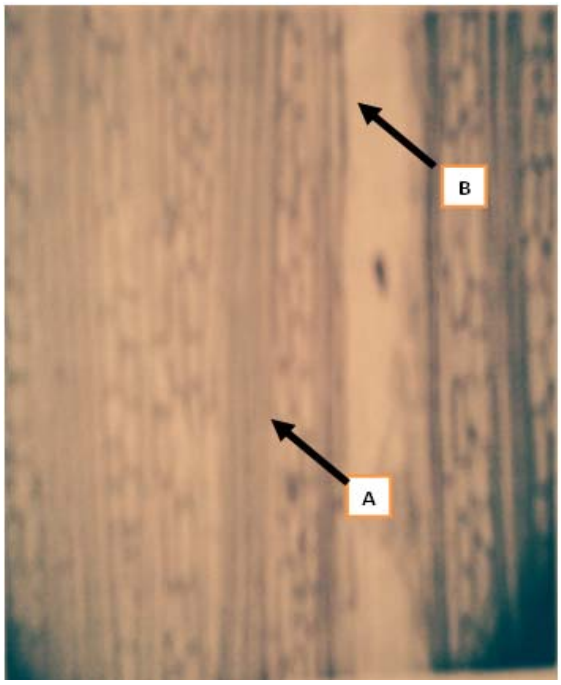

Plate 2: Tangential longitudinal section of photomicrograph of sample 1A
A = Tracheids
B = Vessels

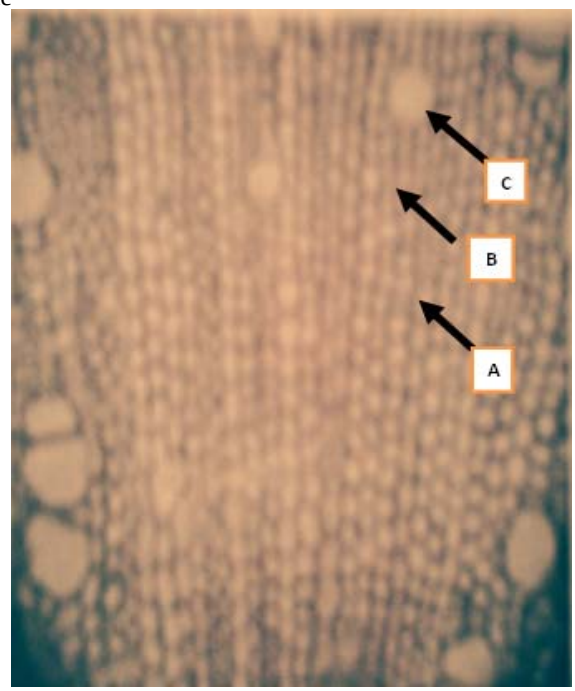

Plate 3: Transverse section of photomicrograph of sample 2A
A = parenchyma
B = Tracheid
C = pith

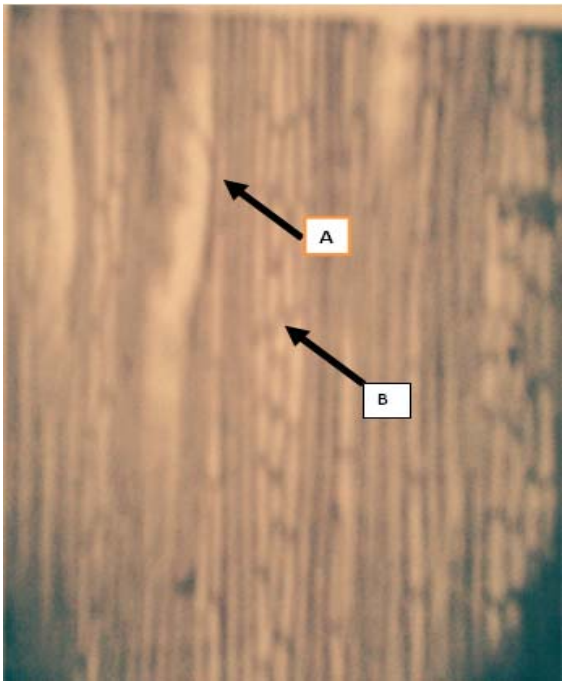

Plate 4: Longitudinal section of photomicrograph of sample 2B
A= Vessels
B= Ray cells

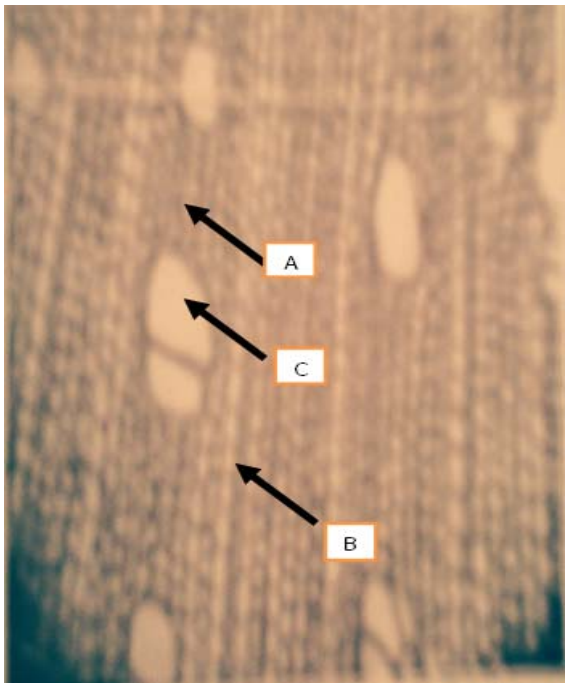

Plate 5: Transverse section of photomicrograph of sample 3A
A = Parenchyma
B = Tracheid
C = pith

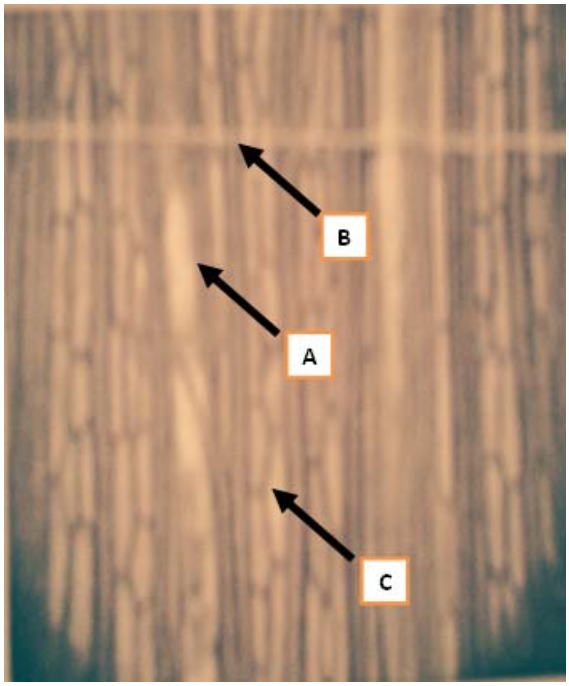

Plate 6: Tangential longitudinal section of photomicrograph of sample 3A
A= Vessels
B= Tracheid
C= Ray cells

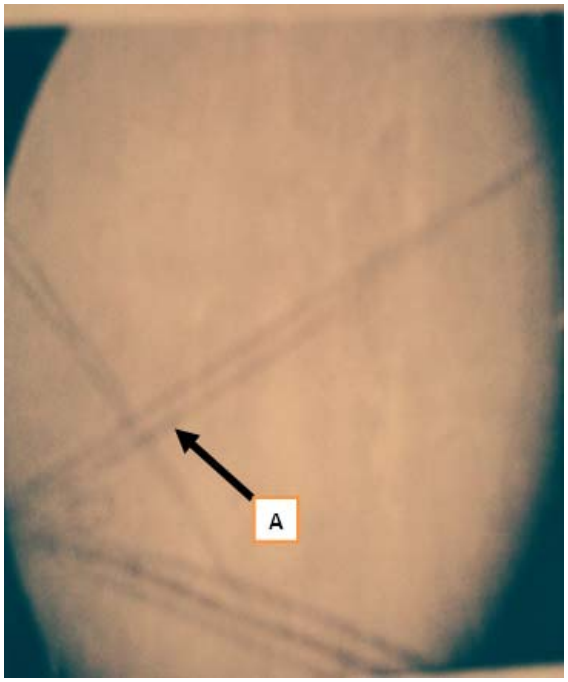

Plate 8: Photomicrograph of fibres of sample 2A
A= Fibres

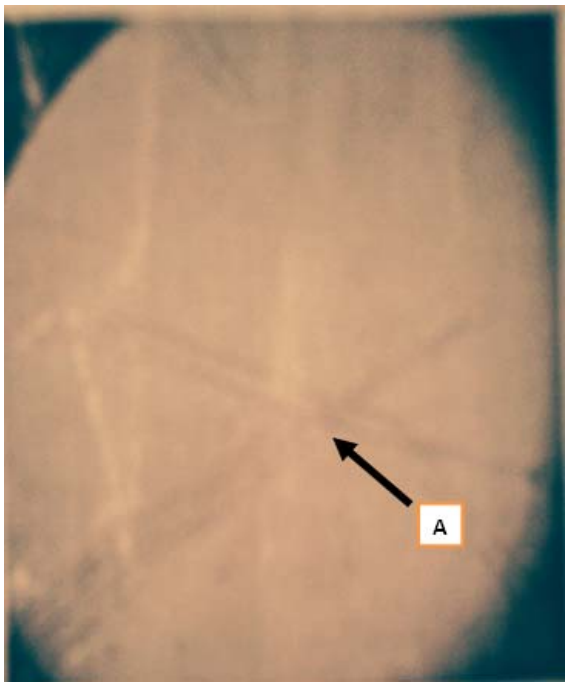

Plate 7: Photomicrograph of fibre of sample 1A
A= Fibres

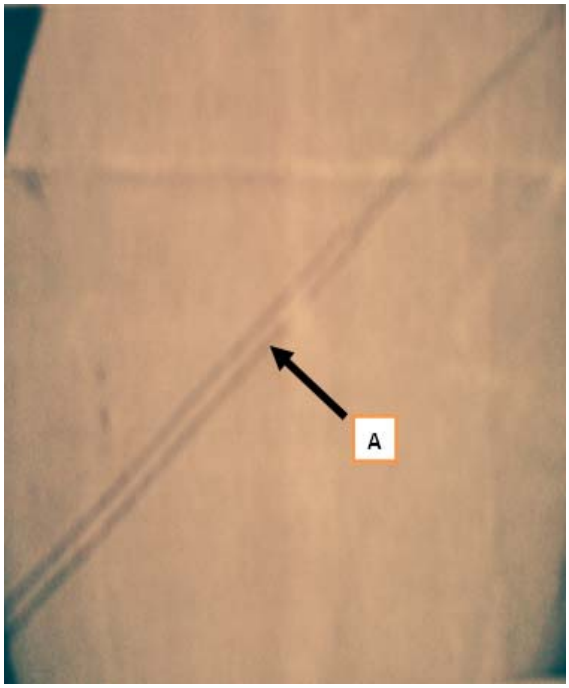

Plate 9: Photomicrograph of fibre of sample 3A
A = Fibres

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