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Assessment of qualitative stem parameter in the Tangential Longitudinal Section (TLS) of *Artocarpus heterophyllus, Artocarpus altilis and Artocarpus camansi*

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Abstract

Taxonomy of the *genus Artocarpus* is sometimes difficult because of similar external morphology. While detailed internal anatomical profiling of secondary xylem tissues is needed to classify the wood correctly, detailed qualitative evaluations of the stem are still relevant for species-level ambiguities across regional species. The aim of this study is the assessment of the qualitative stem parameters of the tangential longitudinal section (TLS) of Artocarpus heterophyllus, *Artocarpus altilis* and *Artocarpus camansi*. The plant samples were collected from Aguluezechukwu, Anambra State, Nigeria and were identified by a plant taxonomist with voucher numbers NAUH-264A, NAUH-077B and NAUH-265A respectively. Microscopic analyses showed that the taxa exhibited different structural features. In particular, active vessels, nonstoried septate fibres and a wide range of parenchyma ray structures (uniseriate, biseriate, and prominent multiseriate) were found in A. heterophyllus and A. altilis. A. camansi on the other hand lacks vessels in the planes analyzed tangentially and has a simple ray profile with only uniseriate and biseriate rays and no multiseriate rays. Nonstoried septate fibres, on the other hand, are constant in the three species. Finally, the different micromorphological variations can be useful diagnostic criteria and taxonomic characters for proper species distinction and anatomical identification among the *genus Artocarpus*.

Keywords: *Artocarpus heterophyllus*; *Artocarpus altilis*; *Artocarpus camansi*; Tangential Longitudinal Section; Wood anatomy

INTRODUCTION

The Tangential Longitudinal Section (TLS) presents qualitative stem parameters which are important micromorphological diagnostic features for discriminating the closely related taxa in the *genus Artocarpus* (Moraceae). Three economically and ecologically prominent members of this genus, *Artocarpus heterophyllus* Lam. Subtle but distinct features of the secondary xylem and axial/radial vascular networks occur in jackfruit (Artocarpus odoratissimus L.), breadfruit (*Artocarpus altilis* (Parkinson) Fosberg) and breadnut (*Artocarpus camansi* Blanco). These features with TLS orientation reveal rays of differing ray parenchyma structure, ray width, occurrence of multiseriate and uniseriate rays, ray height features, vessel end-wall perforations and interfibre pitting mechanisms which serve as important criteria in comparative plant anatomy.

The configuration and number of rays is essential for systematic analyses of Artocarpus wood architecture. For TLS, the rays of *Artocarpus heterophyllus* are mostly heterocellular with square or upright marginal cells surrounding procumbent central cells. The rays are multiseriate and usually are relatively wide, 3-6 cells wide, and have distinct procumbent bodies, with margins that are uniseriate. Multiseriate framework with uniseriate rays scattered among it. However, in *Artocarpus altilis*, the rays are mostly multiseriate with lower height profiles and narrower width of cells, typically 2 – 4 cells wide. In A. altilis, the ray tissue appears to be more evenly distributed, comprising of more procumbent cells and with less distinct erect marginal extensions, suggesting different mechanical adaptations. *Artocarpus camansi* has ray structures with anatomical affinities to both congeners but with uniquely high multiseriate rays, many of which are

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multi-tiered uniseriate with extended uniseriate tails which extend in the vertical plane to a great extent.

In addition to the various types of ray parenchyma arrangement, tangential sections show important features of the vessel elements and axial parenchyma. In all three species the vessel elements have simple end walls that are transverse or slightly oblique. However, the distribution and crowding of alternate vestured to non-vestured interfibre and intervascular pits are very variable. *Artocarpus heterophyllus* has large, crowded, oval to polygonal intervascular pits, which have distinct lenticular apertures. *Artocarpus altilis* has slightly smaller, moderately spaced circular pit apertures while A. camansi has elongated, closely spaced pit fields. In tangential section, Axial parenchyma is paratracheal, mainly Vasicentric to Aliform, making supportive sheaths around the corridors of the vessels.

To be able to relate these internal wood features in a wider botanical context, they associate the internal wood variations with the macro-morphological, geographical and ecological features. Within the Moraceae family, taxonomic re-arrangements continually help to clarify the limits of species or subgeneric classification and offer a solid foundation for an anatomical study (Gardner & Zerega, 2021). In addition to the above, these three species show adaptive diversification, which is highlighted by ecological variations, geographical distribution and macro-vegetative characteristics observed throughout Southeast Asia and the Pacific (Yahya et al., 2024).

The morphology of Artocarpus stems directly affects their physiology including latex secretion and accumulation of secondary metabolites. The latex from *Artocarpus heterophyllus* and other species has been chemically and physically characterized to reveal specialized laticiferous tubes that extend vertically and radially in xylem tissue which assist in defensive secretion mechanisms (Nepacina et al., 2020). These tissues have secondary metabolic pathways that produce bioactive compounds of extraordinary biological activity. The antiviral properties of A. heterophyllus include its remarkable ability to inhibit the hepatitis C virus (Hafid et al., 2017). Additionally, crude extracts of A. heterophyllus, A. altilis and A. camansi are found to have significant antimalaria activities against the strains of Plasmodium species, thus indicating the pharmaceutical potential of the genus (Hafid et al., 2016). These secondary xylem and bark tissues contain complex flavonoids, prenylated stilbenes and chalcones, which can be responsible for the extensive medicinal uses of these plants (Krupa et al., 2020).

There are macro- and micro-morphological and reproductive differences between the three taxa which are paralleled by anatomical variants in stem TLS parameters. The epidermal analysis of leaves shows that their external characteristics, stomatal density and trichome structures are similar to the internal differences in evolution of wood architecture (Ikwuanusi et al., 2026c). Comparative studies on fruit development, post harvest quality parameters, and seed features of A. altilis and A. camansi also depict the correlation between resource allocation patterns and vegetative structural differences (Karunakaran et al., 2026). The physiological properties of A. camansi highlighted by post harvest evaluation serve to support the use of this species as a uniquely processed tissue, commercial product, and nutrient source compared to its seedless congener (Mohammed & Wickham, 2021).

These results are combined into diagnostic profiles in comparative taxonomic assessments that are performed across A. heterophyllus and A. altilis and A. camansi. Key external morphological features for field identification are leaf lobation pattern, stipule scars and branching habit (Ikwuanusi & Izundu, 2026b). Anatomical analysis of the internal tissues of stems is carried out in detail to define the structure parameters which resolve taxonic overlaps and they include xylem element dimensions, ray height and distribution of ray cells in TLS (Ikwuanusi & Izundu, 2026a). Finally, the qualitative

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TLS stem parameters give useful anatomical reference points for the species integrity and industrial value of *Artocarpus heterophyllus*, *Artocarpus altilis* and *Artocarpus camansi*.

METHOD

The test samples, (the leaves and stem of *Artocarpus heterophyllus, Artocarpus altilis and Artocarpus camansi*) were obtained from Aguluezechukwu, in Aguata Local Government Area of Anambra State, Nigeria. The town is known for agriculture and a strong community-driven development approach. It was founded by an individual from Uga who hunted an elephant in the forest ("Agụ"). The town, led by traditional ruler Igwe F.E. Ebelendu, faces erosion issues but is actively growing, developing infrastructure like roads, schools, and the Nkwo market. Chemicals and facilities used in the practical were obtained from Plant Science and Biotechnology Laboratory, University of Nigeria Nsukka, Nigeria. All plant materials for this study were identified by Prof. C. A. Ezeabara, a Plant Taxonomist in Botany Department, Nnamdi Azikiwe University, Awka and given herbarium numbers as NAUH - 264^{A} for *Artocarpus heterophyllus,* NAUH – 077^{B} for *Artocarpus altilis and* NAUH - 265^{A} for *Artocarpus camansi*,

RESULT AND DISCUSSION

4.1 Microgram of the Tangential Longitudinal Section of Stem of *Artocarpus heterophyllus*

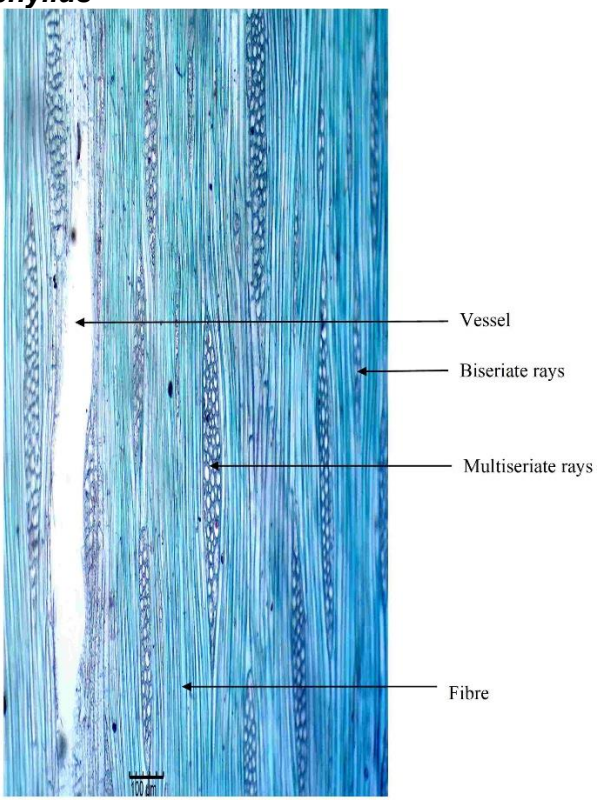


Plate 1: TLS of the stem of *A. heterophyllus showing* uniseriate, biseriate and multiseriate rays with multiseriate rays being prominent, large pitted vessel and abundant septate fibres

The tangential longitudinal section of the stem of *Artocarpus heterophyllus* shows the complex arrangement of plants parts in Plate 1. The prominent multi-seriate rays can be seen in the microscopic observation, as well as the narrower uniseriate and biseriate ray configuration which makes efficient lateral transport across the secondary xylem

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tissue. Large vessels with extensive pitting can clearly be seen parallel to a dense population of septate fibres which are important for mechanical support to the woody stem matrix. This special cell system of vascular elements and ray parenchyma emphasizes the important diagnostic features of the botanical species at the micro-morphological level.

4.2 Micrograph of the Tangential Longitudinal Section of Stem of *Artocarpus altilis*

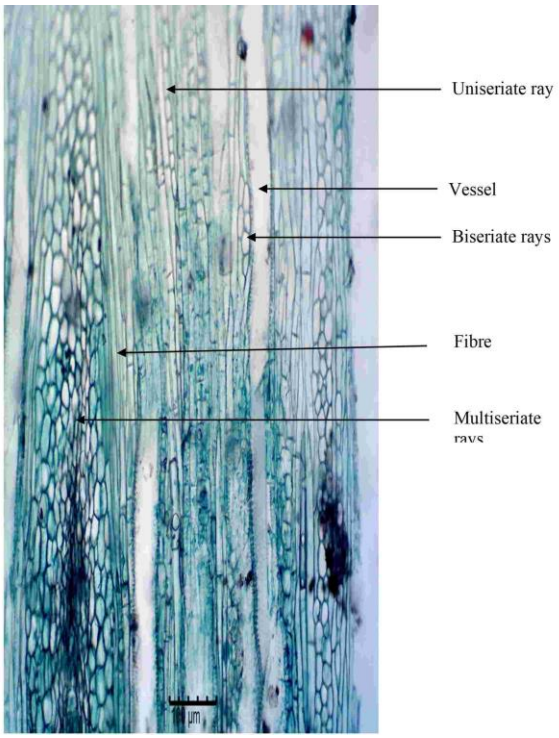


Plate 2: TLS of the stem of *A. altilis showing* uniseriate, biseriate and multiseriate rays with multiseriate rays being prominent, pitted vessel and septate fibres

Plate 2 shows the anatomical setup of tangential longitudinal section of stem of *Artocarpus altilis*. Prominent multiseriate rays with distinct uniseriate and biseriate rays forming a well-developed radial system for lateral translocation is displayed in the micrograph. Pitted vessels are well oriented vertically through the secondary xylem for water movement. In addition, there are a large number of septate fibres throughout the matrix which provide significant structural support. The stern anatomical structure of A. altilis can be diagnosed by the morphological combination of these features, at the micro scale.

4.3 Micrograph of the Tangential Longitudinal Section of Stem of *Artocarpus camansi*

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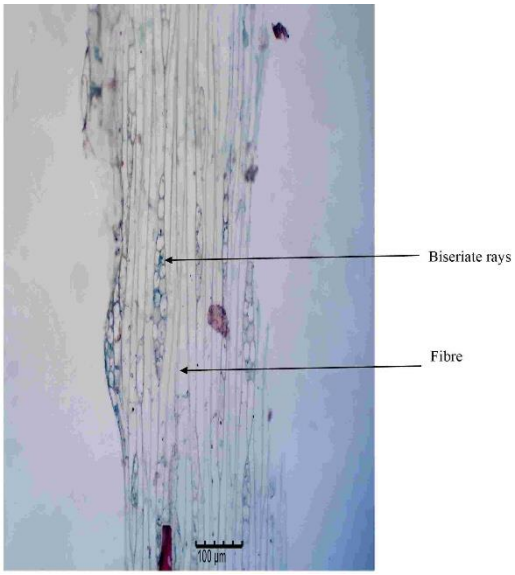


Plate 3: TLS of the stem of *A. camansi showing* uniseriate and biseriate rays, and abundant septate fibres

A microanatomical structure of the tangential longitudinal section of *Artocarpus camansi* stem is shown in Plate 3. The microgram shows clearly the uniseriate and biseriate rays, which are laterally disposed and arranged vertically across the section, which serves for lateral conduction. The secondary xylem is rich in septate fibres which are arranged in vertical rows to give important structural strength and stability to the stem tissue. The ray profile in this view is mainly differentiated by narrower uniseriate and biseriate profiles as compared to A. heterophyllus and A. altilis. The following micromorphological characteristics of these cells are important for the diagnosis of A. camansi.

4.4 Comparison of Anatomical Parameters in the Tangential Longitudinal Section of Mature Stem of *A. heterophyllus, A. altilis and A. camansi*

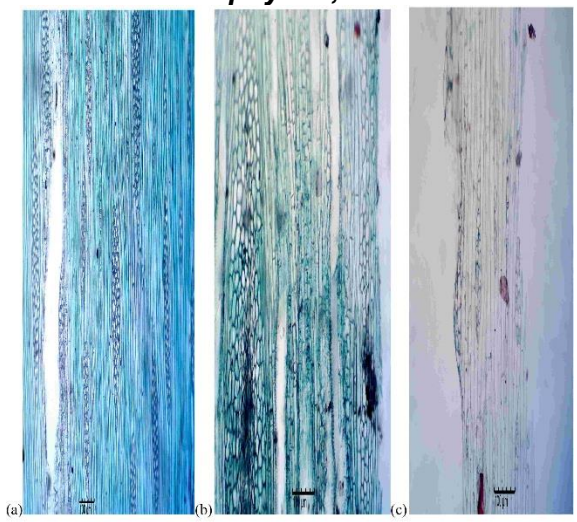


Plate 4 (a-c): Comparism of the TLS of the stem of *A. heterophyllus, A. altilis and A. camansi*

The microanatomical overview of the tangential longitudinal sections (TLS) of the stem tissues of *Artocarpus heterophyllus*, *Artocarpus altilis* and *Artocarpus camansi* are shown in comparative manner in plate 4 (a-c). The large vessels with distinct pits and

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the septate fibres abundant in A. heterophyllus are well marked in Plate 4a together with the well-defined and prominent multiseriate rays. The structural variation of A. altilis is illustrated with multiple examples in Plate 4b, including multiseriate or biseriate and uniseriate ray types. The predominant character of A. camansi, noted in Plate 4c, is the narrower uniseriate and biseriate ray configuration, which is distributed between parallel septate fibres. These comparative diagnostic features are useful in outlining their anatomical differences.

Table 1: ***Comparative Anatomical Parameters in the Tangential Longitudinal Section of Mature Stem of A. heterophyllus, A. altilis and A. camansi***

Parameter	***Artocarpus heterophyllus***	***A. altilis***	***A. camansi***
Vessels	Present	Present	Absent
Rays	Uni-seriate, bi-seriate and multi-seriate rays present	Uni-seriate, bi-seriate and multi-seriate rays present	Uni-seriate and bi-seriate rays present.
Fibres	Non storied	Non storied	Non storied

The main anatomical traits of mature stems of *Artocarpus heterophyllus*, *Artocarpus altilis* and *Artocarpus camansi* are compared in table 1, which shows the results of observation made in tangential longitudinal sections (TLS). Fiber arrangements are completely uniform while there are observable differences in the configuration of vessel elements and the type of ray. For A. heterophyllus and A. altilis, vessels are clearly present in the mature stem structures and they are active in the longitudinal direction; however, for A. camansi, they are recorded as absent in the specific tangential planes evaluated and are not active in this direction. As to ray parenchyma architecture, both A. heterophyllus and A. altilis exhibit a great variety and complexity of cellular range of uni-seriate, bi-seriate, and prominent multi-seriate rays, a fact that favors efficient lateral translocation. In contrast, A. camansi has a simpler ray profile without multi-seriate rays, only Uni-seriate and Bi-seriate rays. In addition, the structure of fibres shows absolute uniformity throughout the group, both the three taxa and the entire secondary xylem matrix are consistently fibrous that is without any storie. The clear qualitative micromorphological differences make it possible to obtain reliable diagnostic criteria that can be used to distinguish the stem anatomy, to verify cell adaptation and to assign reliable taxonomic classification, within the *genus Artocarpus*.

Discussion

Comparative anatomical description of the secondary xylem architecture in the *Artocarpus heterophyllus*, *Artocarpus altilis*, and *Artocarpus camansi* shows that there are differences in the microstructural features along the tangential longitudinal sections of the xylem. As far as the distribution of the vascular elements are concerned, the vessels are clearly seen in the mature stem structures of *Artocarpus heterophyllus* and *Artocarpus altilis* while in the *Artocarpus camansi* they are found lacking within the evaluated tangential planes. With respect to the anatomical composition of these three species, Ikwuanusi and Izundu (2026a) reported similar trends in respect of the special cellular anatomy of the vascular tissues of the genus. The result was consistent with previous taxonomic studies by Gardner and Zerega (2021) who highlighted the close relationship between secondary xylem adaptations and certain subgeneric groupings and ecological distributions among Moraceae.

The architecture of the ray parenchyma also shows diagnostic differences between the taxa. The *Artocarpus heterophyllus* and *Artocarpus altilis* both have a wide range of cells with the presence of uniseriate, biseriate and well-developed multiseriate

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rays which allow efficient lateral translocation and nutrient storage through the secondary xylem tissue. *Artocarpus camansi*, on the other hand, displays a simpler ray system with only uniseriate and biseriate rays but lacks multiseriate rays, indicating significant divergence in radial transport mechanisms. The structural observation is corroborated by the works of Yahya et al. (2024) which examined vegetative characters and concluded that structural variations of ray width can be used as reliable field guide development and taxonomic characters. In addition, this result was in line with the general morphological evaluations that were carried out by Ikwuanusi and Izundu (2026b) which established that the arrangement of internal tissues of the stem is similar to the external vegetative characters among these closely related species.

As far as mechanical support elements are concerned, the arrangement of fibres is absolutely uniform in the whole group, and in all three taxa, there were no storied fibres in the secondary xylem matrices. In each species the woody stem matrix is composed of a lot of parallel fibres with septa which give it the structural strength, elasticity and stability. The qualitative micromorphological differences offer reliable diagnostic criteria for distinguishing stem anatomy and for determining a reliable taxonomic classification in the *genus Artocarpus*. This structural uniformity with a high degree of fibre orientation and a large range of vessel density and ray widths highlights the complex adaptive evolution that is going on in tropical woody plants.

The educational implications of the qualitative assessment of the stem parameters of the Tangential Longitudinal Section (TLS) of *Artocarpus heterophyllus*, *Artocarpus altilis*, and *Artocarpus camansi* are not just in curriculum design, pedagogical innovation, and institutional capacity building. Integrating microscopic wood anatomy into secondary and tertiary science curricula aligns with broader educational efforts to establish practical learning pathways (Morah et al., 2022) and foster value reorientation in STEM discipline delivery (Morah et al., 2024). Adopting experiential learning strategies in plant histology significantly enhances students' conceptual understanding and academic achievement, shifting instruction from abstract theory to hands-on investigation (Muogbo et al., 2025). Incorporating technological gamification (Enem et al., 2025) and Doodly-produced multimedia instruction (Johnson et al., 2026) can spark academic interest when visualizing complex cellular structures like ray parenchyma and vessel pitting. Furthermore, leveraging digital microscopy resources, open-access archives, and e-library systems demystifies complex biological concepts (Ogechukwu et al., 2023) and addresses student motivation and self-esteem as key predictors of achievement in biology (Ezeanyagu et al., 2023).

For effective implementation, science educators must possess adequate digital competence. Addressing variations in teacher computer literacy and usage ensures instructors can effectively integrate ICT into biology and chemistry instruction (Nneka & Okafor, 2013; Nnoli & Muogbo, 2025), mirroring foundational digital literacy needs observed across secondary school subjects (Enemuo et al., 2025). Moreover, providing explicit scaffolded instruction helps learners overcome technical analytical hurdles, similar to mathematical difficulties encountered in physics problem-solving (Ugonwa, 2015). Beyond classroom instruction, linking plant anatomical research to eco-tourism development and local natural resource management (Offiong et al., 2026) empowers students to recognize the practical relevance of science. Ultimately, equipping youth with rigorous scientific skills cultivates their intellectual potential for national development, academic excellence, and sustainable innovation (Mezieobi et al., 2022).

CONCLUSION

Qualitative stem parameters investigated in tangential longitudinal sections of the three Artocarpus species (*Artocarpus heterophyllus*, *Artocarpus altilis* and *Artocarpus camansi*) provide definite anatomical base for species identification. Microscopic

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examination shows significant differences in the structure of the vascular elements and ray parenchyma pattern among the three taxa. *Artocarpus heterophyllus* and *Artocarpus altilis* are characterized by complex rays, both uniseriate and biseriate as well as multiseriate, and the presence of vessels, whereas *Artocarpus camansi* has simpler rays, uniseriate, biseriate and multiseriate, and no vessels were found in the rays of the planes studied. In contrast, nonstoried septate fibres are completely uniform in all the species assessed and offer uniform mechanical support. Finally, the distinctive micromorphological differences are reliable diagnostic features that help clarify the taxonomy and could facilitate evolutionary studies in the *genus Artocarpus*.

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