# Comparative Wood Anatomy of Four *Artocarpus* Species of North East India with Reference to Their Identification

**M.K. Singh, C.L. Sharma and M. Sharma**

**Abstract** The present study was carried out in four *Artocarpus* species namely *A. chaplasha*, *A. heterophyllus*, *A. lakoocha* and *A. nitidus* collected from the forests of Assam and Mizoram, NE India. The main objective of study was to evaluate variation in anatomical features among species both qualitatively and quantitatively. All selected species had diffuse-porous wood with indistinct rings, vessels solitary or in radial multiple of 2–3, simple perforation plate, intervessel pits alternate, laticifers in the form of black streaks among fibres and rays, vessel ray pits similar to intervessel pits, vasicentric and lozenge aliform parenchyma. In addition, presence of ray flecks and latex ducts in rays of *A. chaplasha,* gelatinous fibres in *A. chaplasha* and *A. nitidus*, sheath cells in *A. lakoocha* and *A. nitidus*, axial parenchyma confluent and winged aliform in *A. heterophyllus* were observed. Tissue proportions among species showed maximum percentage of fibres in *A. nitidus*, vessel and rays in *A. heterophyllus* and parenchyma in *A. nitidus*, respectively. Maximum vessel frequency was observed in *A. chaplasha*, while maximum rays were recorded in *A. nitidus* and *A. lakoocha*. Quantitative characters showed statistically non-significant differences within species, while these characters exhibited significant differences among species. Correlation for most of the anatomical characteristics was too weak to be significant, but the correlation of specific gravity was positively significant with ray width and negatively significant with fibre diameter.

**Keywords** *Artocarpus* · Anatomical characteristics · Diffuse-porous · Axial parenchyma · Tissue proportion

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## Introduction

The family Moraceae comprises of 37 genera and 1050 species (Berg et al. 2006) and has mostly trees or shrubs. It is widely distributed in tropical and sub-tropical regions of the world and a few in temperate regions (Raturi et al. 2001). It consists of five tribes namely Moreae, Artocarpeae, Dorstenieae, Castilleae and Ficeae (Berg 2001). Of these, Artocarpeae also known as breadfruit tribe, is characterised by inflorescence architecture (simple spike to complex globose heads), reduction of stamen number, peltate interfloral bracts, vitreous silica and straight filaments. *Artocarpus*, *Hullettia*, *Paratocarpus*, *Prainea*, *Batocarpus* and *Clarisia* are important genera of this tribe (Datwyler and Weiblen 2004; Clement and Weiblen 2009). *Artocarpus* J.R. Forst. is the largest genus in the tribe and third largest genus in the family Moraceae after *Ficus* and *Dorstenia*. It has about 45 species which are distributed in Indo-Malayan region of South-East Asia and about 7–8 species are known to occur in India (Raturi et al. 2001).

A limited information is available on anatomical studies of *Artocarpus* (Gamble 1922; Purkayastha 1996). Topper and Koek Noorman (1980) reported presence of laticifers in ray tissue and fibre tissue in number of *Artocarpus* species, while Anoop et al. (2011) carried out study on variation in bark thickness, heartwood content, fibre morphology, vessel and ray morphology in *A. heterophyllus* Lam. and *A. hirsutus* to understand radial variation in wood anatomical properties within trees. Raturi et al. (2001) described the gross structure of *A. chama*, *A. gomezianus*, *A. heterophyllus*, *A. hirsutus* and *A. lakoocha* collected from other parts of India, Bangladesh and Myanmar. There is no report on anatomy of *A. nitidus* in the available literature. The present study is an attempt to describe the wood anatomy of four species of *Artocarpus* of NE India with an aim to evaluate variation in anatomical characteristics within and among species both qualitatively and quantitatively.

## Materials and Methods

The samples of *A. chaplasha* Roxb., *A. heterophyllus* Lam., *A. lakoocha* Roxb. and *A. nitidus* Trec. were collected from forests of Assam and Mizoram as listed in Table 1. Eight trees with straight bole and uniform crown were selected for each species, and wood samples of size 5 $cm^3$ were taken at breast height. Each wooden block was cut into 2 $cm^3$ size and fixed in FAA for 24–48 h, after which they were preserved in 50% alcohol. Cross, radial longitudinal and tangential longitudinal sections were cut with the help of a sliding microtome. Permanent slides were prepared by following standard procedure. Small radial slivers of different *Artocarpus* species were treated with Franklin's solution for maceration to measure fibre and vessel length. Temporary slides were prepared by using 50% glycerol, and a random sample of 50 fibres and 50 vessels were measured from each sample with

**Table 1** List of selected *Artocarpus* species

| Species name | Average height (m) | Average diameter at breast height (cm) | Coordinates | Locality |
|---|---|---|---|---|
| *A. chaplasha* | 14 | 43 | 27° 23′N, 95° 36′E<br>24° 01′N, 92° 54′E | Digboi reserve, Assam, Darlawn, Mizoram |
| *A. heterophyllus* | 13 | 33 | 27° 21′N, 95° 50′E<br>24° 01′N, 92° 54′E | Kothabasti reserve, Assam, Darlawn, Mizoram |
| *A. lakoocha* | 14 | 39 | 27° 36′N, 94° 35′E<br>24° 01′N, 92° 54′E | Poba reserve, Assam, Darlawn, Mizoram |
| *A. nitidus* | 15 | 36 | 24° 01′N, 92° 54′E | Dampui, Mizoram |

the help of an ocular micrometre at 40×. Twenty-five counts were taken for parameters like vessel diameter, fibre diameter, fibre wall thickness, ray height, and ray width, and 10 fields were selected on cross section to determine tissue proportion, vessel frequency and number of rays per mm. The data was analysed by software SPSS 16 and Microsoft excel 2007. The terminology and measurements were taken according to IAWA Committee (1989). Wood specific gravity was determined by water displacement method.

## Results and Discussion

Growth ring boundaries indistinct with diffuse porous wood. Vessels circular or oval in outline, solitary or in radial multiple of 2–3, simple perforation plate, intervessel pits alternate and vessel ray pits similar to intervessel pits in size and shape (Fig. 1a–e). Quantitative anatomical features are summarised in Table 2. Mean vessel length, vessel diameter and vessel frequency vary from 284.4 ± 82.61 µm (*A. nitidus*) to 350.5 ± 102.75 µm (*A. chaplasha*), 213 ± 76.80 µm (*A. chaplasha*) to 277.92 ± 93.82 µm (*A. nitidus*). Range of vessel frequency is 4–5 per $mm^2$ (Table 2). Vessel percentage varies from 12% (*A. nitidus*) to 26% (*A. heterophyllus*) (Fig. 2).

Fibres are square or polygonal in outline and constitute the ground tissue. Mean fibre length, fibre diameter and fibre wall thickness range from 1193.73 ± 326.71 µm (*A. heterophyllus*) to 1425.0 ± 338.70 µm (*A. lakoocha*), 165.57 ± 70.11 µm (*A. nitidus*) to 209.3 ± 59.92 µm (*A. chaplasha*) and 3.21 ± 2.34 µm (*A. heterophyllus*) to 4.90 ± 2.43 µm (*A. nitidus*) respectively. Septate fibres present except in *A. heterophyllus*. Fibre percentage varies from 44% (*A. chaplasha*) to 50% (*A. lakoocha*) (Fig. 2). Laticifers in the form of black streaks present among fibres in *A. heterophyllus* and *A. nitidus* (Fig. 1n).

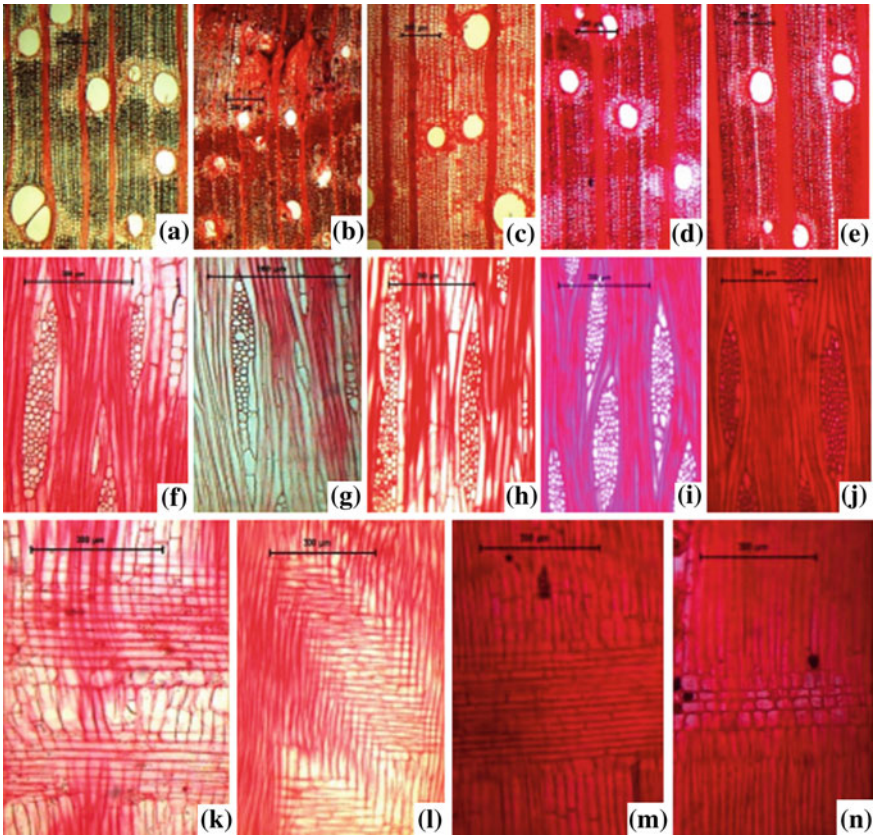


**Fig. 1** **a–e** Cross sections: diffuse-porous wood; vessels mostly solitary and in radial multiple of 2 in *A. chaplasha* (**a**) and *A. nitidus* (**e**); lozenge aliform and confluent parenchyma in *A. chaplasha* (**a**, **b**); lozenge aliform and vasicentric parenchyma in *A. heterophyllus* (**c**); lozenge aliform parenchyma in *A. lakoocha* and *A. nitidus* (**d**, **e**); ray flecks in *A. chaplasha* (**b**). **f–j** Tangential longitudinal sections: Biseriate, multiseriate rays and radial latex ducts in *A. chaplasha* (**f**, **g**); multiseriate rays and parenchyma strand in *A. heterophyllus* (**h**); multiseriate rays and sheath cells in *A. lakoocha* and *A. nitidus* (**i**, **j**). **k–n** Radial longitudinal sections: heterocellular rays comprising of body ray cells procumbent with marginal rows of square/upright cells in *A. chaplasha* (**k**), *A. lakoocha* and *A. nitidus* (**m**, **n**); homocellular rays comprising of procumbent cells in *A. heterophyllus* (**l**); laticifers in the form of dark streaks present among fibres in *A. lakoocha* (**m**) and in square/upright cells in *A. nitidus* (**n**)

Lozenge aliform parenchyma is present in all selected species. In addition, vasicentric parenchyma in *A. lakoocha* and *A. heterophyllus* and confluent parenchyma in *A. chaplasha* and *A. lakoocha* are observed (Fig. 1a, d). Parenchyma strands are 2–4 celled. Parenchyma percentage varies from 13% (*A. chaplasha*) to 21% (*A. lakoocha*) (Fig. 2).

Rays are uniseriate, biseriate and multiseriate in all species (Fig. 1f–j). Rays are heterocellular and composed of procumbent body cells with mostly two rows of

**Table 2** Dimensions of xylem elements in *Artocarpus* species

| Features | *A. chaplasha* range (µm) (Mean ± SD) | *A. heterophyllus* range (µm) (Mean ± SD) | *A. lakoocha* range (µm) (Mean ± SD) | *A. nitidus* range (µm) (Mean ± SD) |
|---|---|---|---|---|
| Vessel length | 128.2–641 (350.5 ± 102.7) | 128.2–615.3 (318.9 ± 92.0) | 153.8–666.6 (345.1 ± 102.7) | 128.2–512.8 (284.4 ± 82.6) |
| Vessel diameter | 78.1–448.0 (213 ± 76.8) | 46.8–797.1 (215.3 ± 163.9) | 78.1–396 (213.7 ± 66.5) | 151.0–609.5 (277.7 ± 93.8) |
| Vessel frequency | 2–21 (5.3 ± 3.6) | 2–16 (4.7 ± 2.5) | 2–12 (4.0 ± 1.8) | 2–7 (4.2 ± 1.3) |
| Intervessel pits | 5.2–18.2 (9.8 ± 2.3) | 5.2–18.2 (10.0 ± 2.5) | 5.2–20.8 (9.9 ± 2.5) | 5.2 ± 13 (8.5 ± 1.8) |
| Fibre length | 538.4–2487.1 (1390.7 ± 342.) | 461.5–2051.2 (1193.7 ± 326.7) | 589.7–2538 (1425 ± 338.7) | 641–2564 (1321.3 ± 347.5) |
| Fibre diameter | 105.2–368.3 (209.3 ± 59.9) | 105.2–394.6 (204.9 ± 184.1) | 52.6–394.7 (186.9 ± 68.3) | 52.6–420.9 (165.5 ± 70.1) |
| Fibre wall thickness | 1.3–10.4 (3.8 ± 2.0) | 1.3–11.7 (3.2 ± 2.3) | 1.3–11.7 (4.5 ± 2.2) | 1.3–11.7 (4.9 ± 2.4) |
| Ray height | 166.7–104.2 (496.8 ± 171.7) | 270.9–1000.3 (570.1 ± 152.4) | 156.3–1407 (583.4 ± 204) | 197.9–937.8 (599.0 ± 144.0) |
| Ray width | 31.2–114.6 (58.8 ± 14.0) | 41.6–135.4 (67.4 ± 15.5) | 20.8–114.6 (60.6 ± 19.6) | 41.6–93.7 (70.9 ± 13.2) |

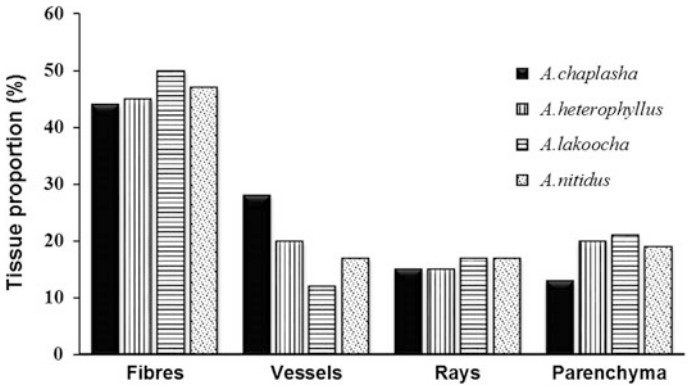


**Fig. 2** Tissue proportion of selected species of *Artocarpus*

upright/square marginal cells. Homocellular rays are recorded in few samples of *A. heterophyllus* (Fig. 2k–n). Ray height and ray width vary from 496.83 ± 171.75 µm to 58.87 ± 14.04 µm (*A. chaplasha*) to 599.08 ± 144.02 µm and 70.99 ± 13.23 µm (*A. nitidus*) respectively. Rays per mm are 4 (*A. chaplasha*) to 6 (*A. heterophyllus*). Rays percentage is recorded 15% in *A. chaplasha* and *A.*

*heterophyllus*, while *A. lakoocha* and *A. nitidus* show 17%. Ray flecks and radial latex ducts in rays of *A. chaplasha* (Fig. 1b, g), sheath cells in rays of *A. lakoocha* and *A. nitidus* (Fig. 1j) are recorded. Also laticifers in the form of black streaks are recorded in square/upright cells of *A. lakoocha*.

The present study shows that the wood of all selected species have common qualitative characters like indistinct growth rings, diffuse-porous wood, solitary vessel, simple perforation plate, vessel ray pitting, heterocellular ray and lozenge aliform parenchyma. These features are in agreement with the findings of Raturi et al. (2001) and Purkayastha (1996). Since these features are present in all species, therefore, these can be considered as characteristics of genus *Artocarpus*. Despite these, other features like presence of vasicentric parenchyma in *A. lakoocha* and *A. heterophyllus*, confluent parenchyma in *A. chaplasha* and *A. lakoocha*, absence of septate fibres in *A. heterophyllus*, radial latex ducts and ray flecks in *A. chaplasha*, sheath cells in *A. lakoocha* and *A. nitidus* have been reported first time and can be

**Table 3** Analysis of variance for selected parameters among selected species of *Artocarpus*

| Source | Dependent variable | Type III sum of squares | df | Mean square | F |
|---|---|---|---|---|---|
| Species | Fibre length | 4.203E7 | 3 | 1.401E7 | 38.197** |
| | Fibre wall thickness | 25.924 | 3 | 8.641 | 15.056** |
| | Fibre diameter | 31,912.233 | 3 | 10,637.411 | 31.169** |
| | Ray height | 6,815,036.196 | 3 | 2,271,678.732 | 34.411** |
| | Ray width | 7.218 | 3 | 2.406 | 5.443** |
| | Vessel length | 898,130.850 | 3 | 299,376.950 | 36.579** |
| | Vessel diameter | 8731.198 | 3 | 2910.399 | 40.126** |
| Replication | Fibre length | 5,390,032.479 | 7 | 77,0004.640 | $2.099^{ns}$ |
| | Fibre wall thickness | 3.186 | 7 | 0.455 | $0.793^{ns}$ |
| | Fibre diameter | 5132.835 | 7 | 733.262 | $2.149^{ns}$ |
| | Ray height | 1,004,294.230 | 7 | 143,470.604 | $2.173^{ns}$ |
| | Ray width | 1.011 | 7 | 0.144 | $0.327^{ns}$ |
| | Vessel length | 115,648.175 | 7 | 16,521.168 | $2.019^{ns}$ |
| | Vessel diameter | 685.082 | 7 | 97.869 | $1.349^{ns}$ |
| Error | Fibre length | 7,702,659.011 | 21 | 366,793.286 | |
| | Fibre wall thickness | 12.053 | 21 | 0.574 | |
| | Fibre diameter | 7166.906 | 21 | 341.281 | |
| | Ray height | 1,386,355.631 | 21 | 66,016.935 | |
| | Ray width | 9.282 | 21 | 0.442 | |
| | Vessel length | 171,872.492 | 21 | 8184.404 | |
| | Vessel diameter | 1523.143 | 21 | 72.531 | |

*ns* Non-significant

**Significant at $P < 0.01$ level

used to differentiate these four species. Ray flecks were observed in few samples of *A. chaplasha*. The formation of ray flecks may be attributed to localised injury of cambium (Carlquist 2001) and was also reported by Purkayastha (1996) in the same species. Topper and Koek-Noorman (1980) reported radial latex ducts in *A. lakoocha* and *A. nitidus*. On the other hand, the laticifers in the form of dark streaks among fibres in *A. heterophyllus* and *A. nitidus* and radial latex ducts only in *A. chaplasha* are reported in the present study.

Analysis of variance was carried out in quantitative anatomical characters to see the variation within and among species. The results, presented in Table 3, indicate statistically non-significant differences within species and statistically significant differences among species. It indicates that selected wood element dimensions do not have any variation within species. But *Artocarpus* species can be differentiated on the basis of significant quantitative variation in wood element dimensions.

Correlation among different dimensions of wood elements and their relationship with specific gravity is presented in Table 4. The relationship among most of the parameters was too weak to be significant. Fibre length exhibited positive and significant correlation with fibre diameter and vessel length. Specific gravity was positively and significantly correlated with ray width, but negatively and significantly correlated with fibre diameter. It indicates that most of the anatomical parameters do not influence each other, but some fibre characteristics affect specific gravity. The present results corroborate the findings of other workers (Pande et al. 2005; Sharma et al. 2011a, b, 2014; Singh et al. 2013) in other hardwood species.

**Table 4** Pearson correlation among parameters of wood elements among selected species of *Artocarpus*

| Parameters | FL | FD | FWT | VL | VD | RH | RW | SG |
|---|---|---|---|---|---|---|---|---|
| Fibre length (FL) | 1 | 0.514* | 0.306 | 0.516* | 0.104 | −0.204 | −0.487* | −0.460 |
| Fibre diameter (FD) | | 1 | 0.434 | 0.383 | −0.154 | 0.135 | −0.252 | −0.629** |
| Fibre wall thickness (FWT) | | | 1 | 0.155 | 0.570* | 0.284 | 0.113 | 0.030 |
| Vessel length (VL) | | | | 1 | −0.201 | −0.095 | −0.443 | −0.315 |
| Vessel diameter (VD) | | | | | 1 | 0.192 | 0.078 | 0.214 |
| Ray height (RH) | | | | | | 1 | 0.094 | 0.128 |
| Ray width (RW) | | | | | | | 1 | 0.508* |
| Specific gravity (SG) | | | | | | | | 1 |

*Significant at 0.05 level
**Significant at the 0.01 level

**Key for identification of *Artocarpus* species is given below**:

1. Heterocellular rays and septate fibre present————————2
   Heterocellular rays and septate fibre absent————————*A. heterophyllus*
2. Laticifers in the form of dark streaks among fibres present————————*A. nitidus*
   Laticifers in the form of dark streaks among fibres absent————————3
3. Sheath cells present, both ray flecks and radial latex duct absent————————*A. lakoocha*
   Sheath cells present, both ray flecks and radial latex duct present————————*A. chaplasha.*

## Conclusions

All the *Artocarpus* species have common features like diffuse-porous wood, vessel solitary or in radial multiple of 2–3, simple perforation plate, alternate intervessel pits, vessel ray pits similar to intervessel pits in shape and size, heterocellular ray and lozenge aliform parenchyma. Septate fibres are present in all selected species except *A. heterophyllus*. Ray flecks and radial latex ducts are present only in *A. chaplasha*, while, in other species, laticifers in the form of black streaks among fibres (*A. heterophyllus* and *A. nitidus*) and in upright/square cells of rays (*A. lakoocha*) are present. Quantitative anatomical characters like fibre length, fibre diameter, fibre wall thickness, vessel length, vessel diameter, ray height, ray width show statistically non-significant variation within species and statistically significant variation among species. Wood specific gravity is positively and significantly correlated with ray width. Identification key is prepared on the basis of qualitative anatomical features for separation of species.

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