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Research Paper

WOOD ANATOMY OF *Kostermansia* AND *Durio* (MALVACEAE - HELICTEROIDEAE: DURIONEAE) IN MALAYSIA

Nordahlia A.S. [1], Noraini T. [2], Chung R.C.K. [1] & Lim S.C. [1]

[1] Forest Research Institute Malaysia, 52109 Kepong, Selangor Darul Ehsan, Malaysia
[2] School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor Darul Ehsan, Malaysia.

Abstract

Wood anatomy of the monotypic genus of *Kostermansia* and 13 species of *Durio* from Malaysia were studied. The results indicated that *Kostermansia* can be distinguished from *Durio* as opposed from the studies by other researchers who stated that *Kostermansia* is identical to *Durio*. Characters that can be used to separate these genera are wood density, vessel arrangement, ray height, ray width, the shape and size of intervessel pits, size of vessel-ray pits and mineral inclusion. The presence of prismatic crystals in chambered axial parenchyma and occasionally in tile cells was observed in *Kostermansia*. On the other hand, in *Durio* the presence of prismatic crystals in chambered and non-chambered axial parenchyma was observed in 10 species studied, whilst the silica was absent. However, in the other three species which were *D. griffithii, D. grandiflorus* and *D. excelsus* showed present of silica*,* whilst crystal was absent. The silica in these three species present in the axial parenchyma, occasionally in tile cells and procumbent ray cells.

Key words: Density-intervessel pits-vessel ray pits- silica-crystal.

INTRODUCTION

According to [1] and [2] the delimitation of families within the core Malvales is problematic, viz. Sterculiaceae, Tiliaceae, Bombacaceae and Malvaceae. The phylogenetic studies based on chloroplast and nuclear ribosomal DNA strongly suggested that they should be merged into expanded family Malvaceae with nine subfamilies which are Byttnerioideae, Grewioideae, Tilioideae, Helicteroideae, Sterculioideae, Brownlowioideae, Dombeyoideae, Bombacoideae and Malvoideae [3,4,5,6,7,8]. In Malaysia, the genera formerly included in the family Bombacaceae are now grouped in two subfamilies which are Bombacoideae (*Bombax* L.) and Helicteroideae (*Coelostegia* Benth., *Kostermansia* Soegeng, *Durio* Adans. and *Neesia* Blume).

Kostermansia is a monotypic genus with only one species namely *K. malayana*. This species is large trees to 50 m tall and 100 cm diameter and endemic to Peninsular Malaysia [9]. *Durio* is a genus of about 29 species which are confined to the tropics of Southeast Asia, distributed from Sri Lanka, India and Mynmmar through Thailand, Peninsular Malaysia, Borneo, Sumatra, the Phillipines to New Guinea [10]. Tree of *Durio* are medium to large trees to 60 m tall and 120-140 cm in diameter [11]. According to Salma [12], the present account recognises 24 species of *Durio* in Malaysia. There are 14 spesies of *Durio* in Peninsular Malaysia [13,12], 16 species in

Sarawak [14,15] and 12 species in Sabah [16]. [17] reported that wood of *Kostermansia* and *Durio* are suitable for light costruction indoors, door and window frames, flooring, planking, veneers and plywood, wooden sandals and coffins.

[9] first described the genus of *Kostermansia* and reported that the genus is closely related to *Durio* and *Coelostegia*. [18] studied the vegetative anatomy of *Kostermansia* and when compared with *Durio,* found that the leaf anatomy of *Durio* differs from *Kostermansia*, whereas the wood anatomy of *Durio* is identical to *Kostermansia*. The characters he used included ray width, ray height, vessel diameter, frequency of vessel multiples and degree of homogenus or heterogeneity of the rays. However, the study by [19] also reported the wood anatomy of *Kostermansia* is similar to that *Durio,* therefore both genera are difficult to differentiate. The wood anatomy of *Durio* is widely studied [20,18,21,22,23,24,25,19] whereas the anatomical study on the genus *Kostermansia* is rather limited. The objectives of this study are to investigate the variation in the macroscopic characteristics and microscopic wood anatomical characters of *Kostermansia* and *Durio* species in Malaysia, and to assess their taxonomic values for differentiating these two genera.

MATERIALS AND METHODS

A total of 53 authenticated wood samples were obtained from several institutional wood collections (Table 1) referred according to [26]. For macroscopic characteristics, observation were made on their physical features which include the direction of grain, texture and ripple marks (present or absent) using the 10x lens. The density was determined using oven-dry weight and green volume. Microscopic slides were prepared, according to[27,28,29] where wooden block of 1 x 1 x 1.5 cm was taken from each species studied and boiled in distilled water until they were well soaked and sank. A sledge microtome was used to cut thin sections of between 15 and 20 μm from the cross, radial and tangential surfaces of each block. The thin sections were immersed in 1% aqueous safranin-O for several minutes and dehydrated using alcohol series with increasing concentrations: 30%, 50%, 70%, 90% and 95% untill excess stains were removed. Clear the sections in clove oil and mount in Canada Balsam and left to dry in an oven at 60ºC for 48 hours. For maceration [30] wood samples were split into small matchstick size pieces and transferred into a test tube containing a mixture of 30% hydrogen peroxide:glacial acetic acid at a ratio of 1:1 The test tube was then heated in a water bath at 45°C until the sticks turned silvery white. Distilled water was used to wash the softened sticks in order to remove the excess acid. The cleaned sticks were then shaken in distilled water to break up fibres. One or two drops of safranin-O were added into the test tubes to stain the fibres for easy observation. Microscopic observations and measurement of the wood structure were carried out using a light microscope. Descriptive terminology and measurements follow the IAWA List of Microscopic Features for Hardwood Identification [30]. Statistical analysis was carried out using statistical analysis software package (SAS ver. 6.12, 1996).

RESULTS

3.1 *Kostermansia* Soegeng

Macroscopic features

Growth rings present and distinct. Grain straight to interlocked. Texture coarse and uneven. Ripple marks absent. Density range from 818 to 866 kg/m^3 with average of 842 kg/m^3 at 15 % air dry (Table 2).

Microscopic features

Growth rings: Present and very distinct marked by differences in fibre wall thickness (Figure 1A).

Vessels: The distribution of vessel is typically diffuse. Arrange in radial and tending to form oblique pattern. Vessel grouping is 55% solitary, in radial multiples of 2−3(−6) and clusters of 3-5 occasionally present. Solitary vessels are mostly round, but oval vessels are occasionally present (Figure 1 A & B). Average tangential vessel diameter is 271 µm with a range of 251 µm to 291 µm. Average vessels frequency is 4 with a range of 4−5 vessels per mm^2. The average length of vessel element is 766 µm with a range of 646 to 886 µm. Perforation plates simple. Intervessel pits alternate and is loosely arranged ,circular to oval and polygonal with coalescent apertures, 2−4 pits per chambers (Figure 1C), medium in size and with a horizontal diameter average of 8.1 µm with a range of 7.1 to 9.1 µm, average vertical diameter of 7.8 µm with a range of 7.0 to 8.6 µm. Vessel-ray pits have distinct borders (Figure 1E), similar to the intervessel pits in arrangement and size where the pits are alternate, circular to oval and medium in size with an average horizontal diameter of 8.4 with a range of 7.4 to 9.4 µm. Tylosis and deposits absent.

Tracheids and Fibres: Vascular tracheids are absent. Fibres with simple to minutely bordered pits, less than 3 µm in diameter, mainly occurring on the radial walls and characterised as non-septate fibre (Figure 1F). Average fibre length is 1.7 mm with a range of 1.6 to 1.9 mm. Fibre diameter ranges from 25 to 30 µm with an average of 28 µm. The fibre wall thickness ranges from 4.0 to 6.0 µm with an average of 5.0 µm. The fibres wall is classified as thin to thicked wall.

Axial parenchyma: Axial parenchyma is abundant, predominantly apotracheal parenchyma with diffuse and diffuse in aggregates. Narrow bands of 1−3 cells wide present, forming reticulate with the rays (Figure 1B). Paratracheal parenchyma is predominantly scanty or occasionally vasicentric with narrow sheath around the vessel, 1−3 cells wide (Figure 1B). Axial parenchyma strands range from 7 to 10 cells per strand.

Rays: Multiseriate and uniseriate rays present, 6 to 9 rays per mm^2 (Figure 1D). Aggregate rays absent. The multiseriate ray with 3 to 4 cells width and height ranges from 0.9 to 1.5 mm with an average of 1.2 mm. There are three types of cell composition: homogenous rays with all ray cells procumbent, heterogenous ray type III with procumbent and one row of upright/square cells and heterogenous ray type II with procumbent and 2 rows of upright/square cells (Figure 1G). Tile cells of the *Durio*-type present, same height as the procumbent cells and alternating with the procumbent ray cells (Figure 1I). Dark-coloured gum-like contents were occasionally observed in the procumbent and upright/square cells. Sheath cells and storied structure absent.

Mineral inclusions: Prismatic crystal in chambered axial parenchyma, in short chain of 2−7 chambers, 1 crystal per cell or chamber (Figure 1H). Prismatic crystals occasionally present in the tile cells (Figure 1I). Silica bodies absent.

3.2 ***Durio*** Adans.

Macroscopic features

Growth rings in *Durio* present but vary from distinct to indistinct. Grain is straight to slightly interlocked. Texture is coarse and uneven. Ripple marks absent. Density ranges from 685 to 801 kg/m^3 with an average of 743 kg/m^3 at 15 % air dry (Table 2).

Microscopic features

Growth rings: Growth ring varies from distinct (*D. carinatus*, *D. graveolens*, *D. lowianus*, *D. macrophyllus*, *D. zibethinus*, *D. singaporensis, D. excelsus* and *D. griffithii*) to indistinct (*D. affinis*, *D. oxleyanus*, *D. grandiflorus*, and *D. oblongus*) marked by different in fibre wall thickness (Figure 2A-B).

Vessels: The distribution of vessel is typically diffuse. Arrange in radial pattern. Vessel grouping is 54% to 82% solitary, in radial multiples of 2−4(−9), clusters of 3-6 occasionally present (Figure 2A-B). *D. zibethinus* consists of the highest percentage of solitary vessels with 82% whereas *D.carinatus* has the lowest percentage with 56%. Solitary vessels are mostly round, but oval vessels are occasionally present (Figure 2A-B). Tangential vessel diameter ranges from 239 to 311 μm with an average of 275 μm. *D. oxleyanus* consists of significantly largest average vessel diameter of 316 μm (range: 284−348 μm), whereas the lowest average vessel diameter is found in *D. oblongus* with an average of 247 μm (range: 217−277 μm). Vessels frequency ranges from 2 to 4 with an average of 3 vessels per mm^2. Vessel element length ranges from 592 to 851 μm with an average of 722 μm. The longest vessel element length was found in *D. oxleyanus* with an average of 884 μm (range: 820−948 μm). Perforation plates simple. Intervessel pit is alternate and loosely arranged, circular to oval with coalescent apertures, 2−4 pits per chambers (Figure 2D), small in size with an average horizontal diameter of 6.2 μm (range: 5.3−7.0 μm), average vertical diameter of pits are 5.1 μm (range: 4.1−5.9 μm). Vessel-ray pits have distinct borders (Figure 2F), similar to the intervessel pits in arrangement, shape and size where the pits are alternate, circular to oval and small size with an average horizontal diameter of 6.6 (range: 5.2−7.1 μm). Tylosis and deposits absent.

Tracheids and Fibres: Vascular tracheids are absent. Fibres non-septate, with simple to minutely bordered pits less than 3 μm in diameter, mainly occurs on the radial walls (Figure 2G). Average fibre length is 1.7 mm (range: 1.4−2.0 mm). Among the *Durio* species examined, *D. lowianus* has the longest fibre with an average length of 1.9 mm (range: 1.8−2.2 mm), whereas *D. griffithii* has the shortest fibre with an average length of 1.5 mm (range: 1.3−1.6 mm). Fibre diameter ranges from 21 to 28 μm with an average of 25 μm. Fibre wall ranges from 3.6 to 5.9 μm in thickness with an average of 4.8 μm. The fibre wall is classified as thin to thicked wall.

Axial parenchyma: Axial parenchyma abundant in all *Durio* species studied predominantly apotracheal parenchyma with diffuse and diffuse in aggregates. Narrow bands of 1−3 cells wide present, forming reticulate with the rays (Figure 2C). Paratracheal parenchyma is predominantly scanty or occasionally vasicentric with narrow sheath around the vessel, 1−3 cells wide (Figure 2C). Axial parenchyma strands range from 7 to 10 cells.

Rays: Multiseriate and uniseriate rays present, 5−7 rays per mm^2 (Figure 2E). The height of multiseriate ray ranges from 1.2 to 2.4 mm with an average of 1.8 mm. The highest ray is found in *D. grandiflorus* with an average of 2.4 mm (range: 1.7−3.0 mm), whereas *D. lowianus* has the lowest ray with an average of 1.6 mm (range: 1.0−2.2 mm). Ray width in the genus *Durio* ranges from 4 to 10 cells. *D. singaporensis* has the largest ray with ranges 8-10 cells width. The smaller ray was found in *D. grandiflorus*, *D. oblongus*, *D. lowianus* and *D. carinatus* with ranges 4-6 cells width. There are three types of cell composition in the ray, they are homogenous ray with all ray cells procumbent, heterogenous ray type II with procumbent and one row of upright/square cells and heterogenous ray type III with procumbent and 2 rows of upright/square cells (Figure 3A). Tile cells of the *Durio*-type present and of the same height as the procumbent ray cells and alternating with the procumbent ray cells (Figure 3A). Dark-coloured gum-like contents were occasionally observed in the procumbent and upright/square cells. Sheath cells and storied structure absent.

Mineral inclusions: Prismatic crystals found in all species studied except *D. grifithii, D. excelsus* and *D. grandiflorus*. Prismatic crystals present in chambered axial parenchyma, in short chain of 2-8 chambers, 1 crystal per cell or chamber (Figure 3B) but can also present in non-chambered axial parenchyma with 1-2 crystal per strand (Figure 3C). Prismatic crystals were found in chambered axial parenchyma cells in most species studied except *D. macrophyllus*, *D. zibethinus* and *D. singaporensis* which contained prismatic crystals in both chambered and non-chambered axial parenchyma cells

Silica bodies present only in the species of *D. griffithii*, *D.excelsus* and *D. grandiflorus* and occur in axial parenchyma, occasionally found in tile cells and procumbent ray cells (Figure 3D).

DISCUSSION

According to [18] and [19], the wood anatomy of *Kostermansia* is identical with *Durio* and its wood shares many general similarities with *Durio*. The most important characteristic of both genera are the present of *Durio*-type tile cells which is restricted to tribe Durioneae of Bombacaceae [22], whereas the *Pterospermum*-type tile cells were found in the families of Sterculiaceae and Tiliaceae [31]. [32] reported that *Grewia* of the family Tiliaceae consists of *Pterospermum*-type tile cells whilst the intermediate *Durio*-type tile cells were observed in *Microcos*. The present of tile cells is the characteristics restricted to the most subfamilies of Malvaceae [31,22,33]. The other wood anatomy characters which are similar between these two genera are presented in Table 2. Based on this study, the percentage of solitary vessels is about 55-66 % which is higher than the findings by [34] who reported that the solitary vessel of tribe Durioneae is about 10% to less than 50%. These two genera have large vessel diameter up to 200 µm with *D. oxleyanus* being the largest. [35] reported that *D. oxleyanus* can absorb preservatives easily; it might be due to the presence of large vessel diameter in this species.
In this present findings have shown that there are significant differences in some macroscopic and microscopic wood anatomical characters between *Kostermansia* and *Durio* that can used to distinguish these two genera. However, these macroscopic and microscopic characters could not be used to distinguish *Durio* species in this study. A comparison on the macroscopic characters which is density and wood anatomy of *Kostermansia* and *Durio* are presented in Table 3. *Kostermansia* wood was found to have significantly higher density than *Durio* which were 842 kg/m3 and 740 kg/m^3 respectively. This present results shows lower value in density of *Kostermansia* compared to [17] and [19] which recorded the density of this species was 865 kg/m^3. On the other hand, [17] reported that *Durio* has the density of 545 to 800 kg/m3. The differences in the value of density between the present and previous studies might be due to the sample obtained from different trees, different localities and different parts of the trees. This fact is supported by [36] and [37], where the density varies along the tree height, along the wood disc and also from different localities.

Kostermansia and species belongs to the genus *Durio* showed vessels in radial pattern arrangement. However, the oblique arrangement of vessels was clearly observed in *Kostermansia*. [18] reported similar finding in *Kostermansia* which have radial and oblique arrangement of vessel. [38] reported radial arrangement of vessels in *Durio*. Intervessel pits shape of *Kostermansia* is circular to oval and also polygonal, however in *Durio* the shape of intervessel pits are circular to oval. On the other hand, size of intervessel pit and vessel ray pit are also significantly difference at $p \leq 0.05$ with *Kostermansia* categorised as medium size whilst *Durio* as small size (Table 3). These sizes and shape of intervessel and vessel ray pits are also reported by [18] and [39].

Ray characteristics also could be useful as diagnostic values in distinguish these two genera. *Kostermansia* showed significantly (at $p \leq 0.05$) lower value in ray height as compared to *Durio*. In this present study, *Durio* shows ray height to 2 mm which is similar to the findings by [22] who also observed higher ray with some of the species reaching 3 mm. *Durio* was found to have rays of 10 cells wide whereas *Kostermansia* has 1 to 4 cells which was also reported by [18]. [39] and [35] also reported *Durio* has wider ray which were ranges from 3 to 6 cells and 3 to 8 cells respectively. Ray cells of *Durio* and *Kostermansia* consist of one or two upright/square cells and this feature was also reported by [25]. However, [35] reported that the species of *Durio* have more than 4 rows of upright/square cells.

Mineral inclusion (crystal, druses and silica) are also one of the wood anatomical characteristics that have diagnostic values in differentiating wood up to species, genera or family level [40,30].

In this present study, prismatic crystals were found in *Kostermansia* in chambered axial parenchyma and occasionally in tile cells. However, silica bodies was absent in *Kostermansia*. [18] also recorded the absent of silica bodies and present of prismatic crystals in chambered axial parenchyma but not in tile cells. There were three types of mineral inclusion in *Durio*, where prismatic crystals were only found in chambered axial parenchyma which was observed in all species study, except *D. macrophyllus*, *D. zibethinus* and *D. singaporensis* where the prismatic crystals were found in both chambered and non-chambered axial parenchyma. According to [25] and [39] prismatic crystals in chambered axial parenchyma are common in most species of *Durio*. While, [35] stated that, prismatic crystals were observed in both chambered and non-chambered axial parenchyma cells in the species of *Durio*. Prismatic crystals were absent but silica bodies were present numerously in the axial parenchyma and occasionally in procumbent cells and tile cells, in three species studied (*D. griffithii*, *D. excelsus* and *D. grandiflorus*). [25] reported that *D. griffithii* was observed to have silica bodies in axial parenchyma but he does not record any silica bodies found in the procumbent and tile cells. [23] also reported presence of silica bodies in *D. grandiflorus*.

In the molecular study of [7] and [8], they proposed the segregation of the genera *Boschia* and *Durio* based on the samples of *Boschia griffithii* and three species of *Durio* (*D.oblongus*, *D.testudinarium* and *D.zibethinus*). In Malaysia, *Durio griffithii, D. grandiflorus* and *D. excelsus* are those species previously belonged to the genus *Durio*, subgenus *Boschia* while the other species of *Durio* are belonged to the subgenus *Durio* [41]. In this study, these three species shows the present of silica in the axial parenchyma, occasionally in tile cells and procumbent ray cells with the absence of crystals.

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Table 1. List of materials studied.

Genus/Species	Location	Collection number, wood number (Xylarium)
Kostermansia		
K. malayana Soegeng	Pahang, Rompin, Kelantan, Baling	KEP 31606, wt2528 (KEPw); KEP 10007, wt4400 (KEPw); KEP 50651, wt5691(KEPw); KEP 61080, wt8231 (KEPw)
Durio		
D. affinis Becc.	Bukit Rotan, Brunei, Simujan, Sarawak	FMS34468,wt4222 (KEPw); S15203 (SARFw)
D. carinatus Mast.	Kuantan, Pekan, Mersing, Sibu	KEP6653, wt179 (KEPw); KEP 43201, wt3490 (KEPw); KEP 70105, wt6816 (KEPw); S23109 (SARFw)
D. excelsus Bakh.	Sarawak, Belaga	S43565 (SARFw); S80134 (SARFw)
D. grandiflorus Mast.	Kinabatangan, Sabah	SAN138994, wt4743 (SANw)
D. graveolens Becc.	Sg. Siput, Ulu Gombak, Kuala Pilah, Sik,Lundu, Bintulu	KEP 8832,wt666 (KEPw); KEP 24970, wt4753 (KEPw); KEP 62973,wt6418(KEPw); KEP 73820,wt8237 (KEPw); S9621 (SARFw); S15129 (SARFw)
D. griffithii (Mast.) Bakh.	Plus FR Perak,Sugai Buluh FR, Senawang, Tatau Sarawak	FMS39052, wt2947 (KEPw); FMS45003, wt3846 (KEPw); FMS1978,wt4383 (KEPw); S22134 (SARFw)
D. kutejensis Becc.	Lundu, Sarawak, Marudi Sarawak	S15682 (SARFw); S22848 (SARFw)
D. lowianus Scort. ex King	Lenggong,Sg Buloh FR, Rompin, Kuala Muda, Enggang FR, Muar	KEP 10421,wt669 (KEPw); FMS44943,wt3816 (KEPw);KEP 31700,wt4843 (KEPw); KEP 59642, wt8193 (KEPw);KEP 74989,wt8194 (KEPw); KEP 70153,wt8238 (KEPw)
D. macrophyllus(King) Ridl.	Sg Siput, Kuala Kangsar, Kapit Sarawak	KEP 8836,wt668 (KEPw); KEP 127, wt125 (KEPw); S22284 (SARFw);
D. oblongus Mast.	Bau, Sarawak	S28996 (SARFw)
D. oxleyanus Griff.	Sg Siput,Senawang FR,Gading FR, Behrang FR,Sik,Batu Pahat.	KEP 8836,wt668 (KEPw); FMS541,wt664 (KEPw); KEP 66179,wt7345 (KEPw); KEP 61148, wt8195 (KEPw); KEP 73842,wt8198 (KEPw); KEP 79409, wt8241 (KEPw)
D. singaporensis Ridl.	Temerloh,Genting Sempah, Panti FR, Dungun	FMS10573,wt248 (KEPw); KEP 34258,wt3731 (KEPw); KEP 70188,wt8223 (KEPw); KEP 93681, wt9978 (KEPw); KEP 57405,wt6362 (KEPw)
D. zibethinus Murray	Kinta, Batang Kali FR,Chemor Kinta, Sg Lalang FR, FRIM Kepong, Sepilok FR, LungManis Beluran	KEP 65948,wt8122 (KEPw); KEP 64204,wt8221 (KEPw); KEP 65944,wt8235 (KEPw); KEP 72158,wt8236 (KEPw); FRI21831,wt9961 (KEPw); A2879, wt6149 (KEPw); SAN65612,wt2106 (SANw)

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Table 2. Wood anatomical characteristics and density of *Kostermansia malayana* and *Durio* species.

SP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
K1	+VO	55	271(251-291)	4-5	766(646-886)	G	8.1(7.1-9.1)	7.8(7.0-8.6)	R,8.4(7.4-9.4)	F	5.0(4.0-6.0)	1.7(1.6-1.9)	+	1.2(0.9-1.5)	3-4	6-9	C	842(818-866)
D1	PVR	68	260(244-276)	2-4	731(646-816)	S	5.7(4.9-6.5)	4.4(4.1-5.3)	R,6.6(5.4-7.8)	F	4.4(3.6-5.1)	1.7(1.5-1.8)	+	1.8(1.3-2.2)	7-10	4-6	C	673(662-683)
D2	+VR	54	286(254-318)	2-4	827(772-882)	S	5.9(5.0-6.8)	5.3(4.3-6.3)	R,5.8(4.9-6.7)	F	5.0(3.8-6.1)	1.7(1.6-1.8)	+	1.6(1.0-2.2)	4-6	6-8	C	641(631-651)
D3	PVR	75	301(261-340)	1-2	785(677-892)	S	6.2(5.3-7.0)	6.2(5.3-7.0)	R,6.2(5.4-7.0)	F	4.5(3.8-5.2)	1.7(1.5-1.8)	+	2.4(1.7-3.0)	4-6	7-9	S	704(694-714)
D4	+VR	75	270(251-289)	3-5	726(627-825)	S	6.1(5.2-6.9)	5.3(4.5-6.1)	R,6.0(5.1-6.9)	F	4.7(3.7-5.6)	1.8(1.6-2.0)	+	1.7(1.3-2.1)	6-8	5-7	C	778(763-793)
D5	+VR	62	267(228-306)	3-4	580(476-684)	S	6.2(5.3-7.0)	6.2(5.3-7.0)	R,6.4(5.5-7.3)	F	4.7(3.4-5.9)	1.5(1.3-1.6)	+	1.7(1.3-2.1)	5-7	6-7	S	850(840-860)
D6	+VR	55	252(224-280)	2-5	734(588-881)	S	6.1(5.1-7.0)	6.1(5.1-7.0)	R,6.1(5.2-7.0)	F	4.5(3.3-5.7)	1.9(1.7-2.1)	+	2.2(1.6-2.8)	4-6	6-8	C	776(764-788)
D7	+VR	58	276(232-320)	2-4	662(583-741)	S	6.2(5.3-7.0)	5.4(4.5-6.3)	R,6.0(5.1-6.9)	F	5.0(3.9-6.1)	1.9(1.8-2.2)	+	1.6(1.0-2.2)	4-6	6-8	C	764(755-773)
D8	+VR	76	268(251-285)	2-3	644(559-729)	S	6.3(5.5-7.0)	5.1(4.1-6.4)	R,6.3(5.4-7.2)	F	4.6(3.3-5.8)	1.5(1.3-1.6)	+	2.0(1.4-2.6)	5-7	5-7	B	715(705-725)
D9	PVR	65	247(217-277)	2-5	707(597-817)	S	6.3(5.5-7.0)	6.3(5.5-7.0)	R,6.3(5.6-7.0)	F	4.3(3.5-5.1)	1.8(1.6-2.0)	+	2.1(1.4-2.9)	4-6	7-9	C	732(724-740)
D10	PVR	72	316(284-348)	1-2	884(820-948)	S	6.2(5.2-7.1)	5.1(4.1-6.1)	R,5.8(4.7-6.9)	F	5.5(4.3-6.7)	1.5(1.4-1.7)	+	1.7(1.3-2.2)	5-7	5-7	C	717(707-727)
D11	+VR	60	263(241-285)	3-5	759(649-869)	S	6.1(5.2-7.0)	5.2(4.8-5.6)	R,6.1(5.1-7.1)	F	4.2(3.3-5.0)	1.7(1.6-1.9)	+	1.7(1.1-2.3)	8-10	4-6	B	782(770-794)
D12	+VR	82	305(263-347)	1-3	693(547-839)	S	6.0(5.0-7.0)	4.8(4.1-5.6)	R,6.4(5.5-7.2)	F	5.7(4.5-6.8)	1.6(1.4-1.8)	+	1.8(1.3-2.2)	7-9	4-6	B	706(698-714)
D13	+VR	56	270(237-303)	2-4	692(574-810)	S	6.2(5.3-7.0)	5.0(4.2-5.8)	R,6.3(5.5-7.0)	F	4.7(4.0-5.5)	1.5(1.3-1.6)	+	1.7(1.4-2.1)	4-6	7-9	S	827(812-842)

Note:

SP=Species — 1.Growth rings; Vessel distribution, arrangement, grouping, outline (+= Growth rings present and distinct; P=Growth ring present but indistinct; V=vessel diffuse, vessel solitary, in radial multiples and in cluster R=radial pattern arrangement, O=Radial pattern or oblique arrangement)

K1=*K. malayana* — 2.Solitary vessel percentage %

D1=*D. affinis* — 3.Vessel diameter (µm); 4.Vessel per mm^2; 5.Vessel element length (µm)

D2=*D. carinatus* D3=*D. grandiflorus* D4=*D. graveolens* — 6.Perforation plate; intervessel pit arrangement, shape and size : *Durio* (S= Perforation plate simple, alternate, loosely arrange, circular to oval with coalescent apertures and small); *Kostermansia* (G=Perforation plate simple, alternate, loosely arrange, circular to oval and polygonal with coalescent apertures and medium)

D5=*D. griffithii* — 7. Diameter intervessel pit (horizontal) (µm); 8. Diameter intervessel pit (vertical) (µm)

D6=*D. kutejensis* — 9. Vessel ray-pit shape, size (R= Vessel ray-pit similar to the intervessel pits in shape and size); Diameter vessel-ray pit (horizontal)

D7=*D. lowianus* 10. Fibre pits and septate fibres (Fibres with simple to minutely borderd pits less than 3 μm in diameter, non-septate)
D8=*D. macrophyllus* 11.Fibre wall thickness (μm); characterized as thin to thicked wall 12. Fibre length (mm)
D9=*D. oblongus* 13.Axial parenchyma, ray and tile cells (+=Present of apotraheal, paratracheal, banded parenchyma, uniseriate ray, multiseriat ray, homogenus and hetrogenus ray, durio-type tile cells)
D10=*D. oxleyanus*
D11=*D. singaporensis* 14.Ray height (mm); 15. Ray width; 16. Ray per mm
D12=*D. zibethinus* 17.Mineral inclusion (C=Crystal present in chambered axial parenchyma, B=Crystal present in chambered and non-chambered axial parenchyma S=Silica present
D13=*D. excelsus*
18. Density (kg/m^3)

Table 3. Main differences of wood anatomical characteristics and density between *Kostermansia* and *Durio*

Character	**Genus**	
	Kostermansia	***Durio***
Density (kg/m^3)	842±24(818-866)^a	740±53(687-793)^b
Vessel		
Vessel arrangement	Radial pattern and oblique	Radial pattern
Intervessel pit shape	Circular to oval and polygonal	Circular to oval
Intervessel pits size (μm) (horizontal)	8.1±0.96 (7.1-9.1)^a Medium	6.2±0.89 (5.3-7.0)^b small
Vessel-ray pit size (μm)	8.4±1.0 (7.4-9.4)^a medium	6.0±1.0 (5.0-7.0)^b small
Ray		
Ray height (mm)	1.2±0.3(0.9-1.5)^b	1.8±0.6(1.2-2.4)^a
Ray width	3±0.5(3-4)^b	6±1.5(5-10)^a
Mineral inclusion		
Crystal	Prismatic crystals present in chambered axial parenchyma and occasionally in tile cells	Prismatic crystals present in the chambered axial parenchyma or in both chambered and non-chambered axial parenchyma or absence in *D. griffithii*, *D. grandiflorus* and *D. excelsus*
Silica	Absent	present in *D. griffithii* , *D. grandiflorus* and *D. excelsus* in the axial parenchyma, occasionally in tile cells and procumbent ray cells

Note: Number in the bracket ( ) is a value in ranges
Means followed by the different letter in the same rows are significantly different at p≤0.05.

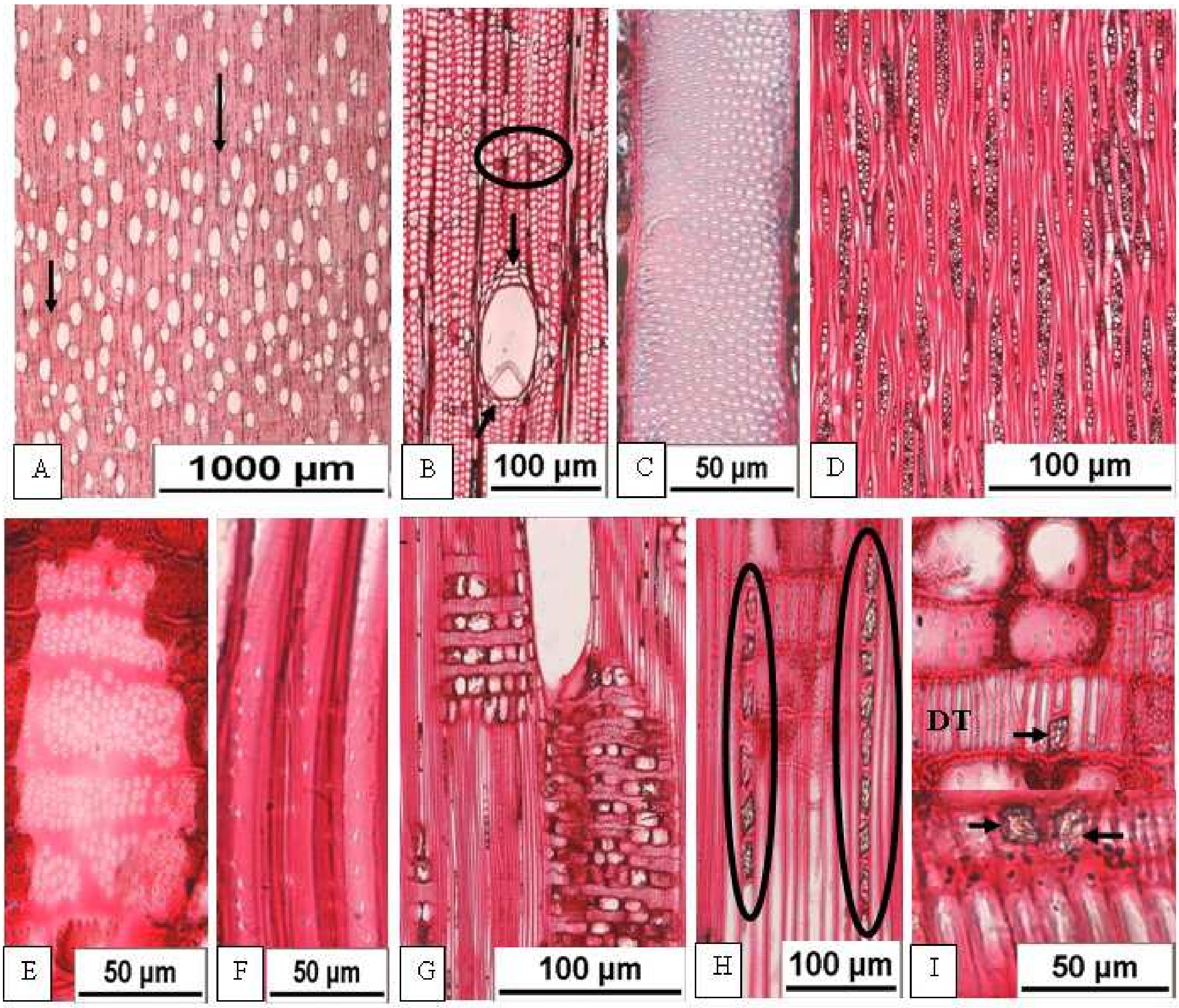

Figure 1 *Kostermansia malayana*: Transverse sections (A & B) A: Growth rings boundaries marked by differences in fibre wall thickness (arrow), vessel is diffuse, arrange in radial and oblique pattern, vessel solitary, in radial multiples and vessel in cluster. B: Apotracheal diffuse and diffuse in aggregates parenchyma, narrow bands (circle), paratracheal parenchyma (arrow). Tangential sections (C&D) C: Intervessel pit. D: Uniseriate and multiseriate rays. Radial sections (E-I) E: Vessel-ray pits. F: Fibres with simple to minutely borderd pits (arrow), fibre non-septate. G: Ray heterogenus. H: Crystal in chambered axial-parenchyma (circle). I: Tile cells of *Durio*-type (DT), crystal in tile cells (arrow).

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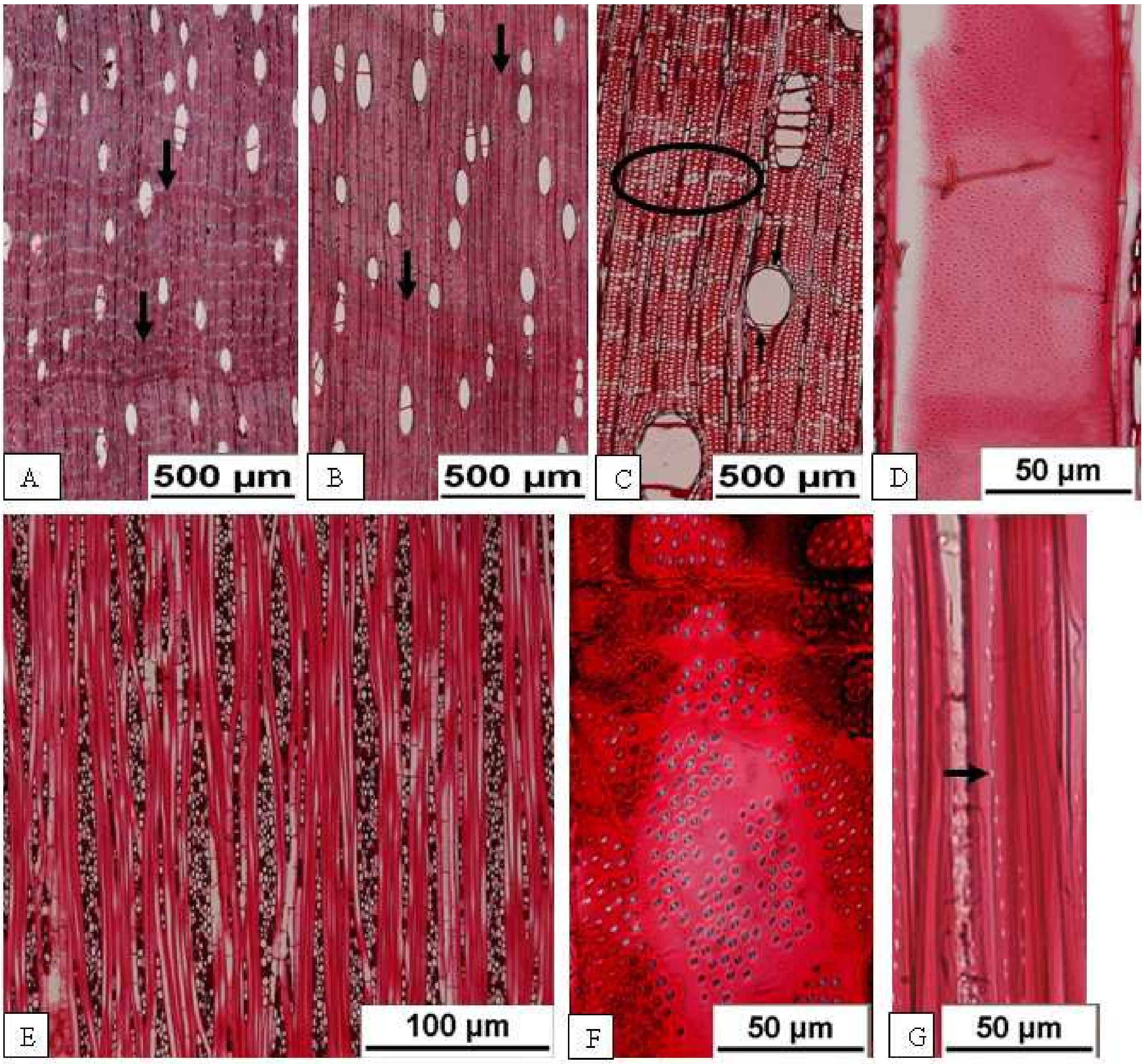

Figure 2: Transverse sections of *Durio* woods (A-C) A-B: Growth rings boundaries marked by differences in fibre wall thickness (arrow), vessel is diffuse, arrange in radial, vessel solitary, in radial multiples and in cluster. C: Apotracheal diffuse and diffuse in aggregates parenchyma, narrow bands (circle), paratracheal parenchyma (arrow). Tangential sections of *Durio* woods (D&E) D: Intervessel pit E: Uniseriate and multiseriate rays. Radial sections of *Durio* woods (F&G) F: Vessel-ray pits G: Fibres with simple to minutely borderd pits (arrow), fibre non-septate.

A: *D. singaporensis*, B: *D.carinatus*, C: *D.lowianus*, D: *D.zibethinus*, E: *D.graveolens*, F: *D.kutejensis*, G: *D. grandiflorus*

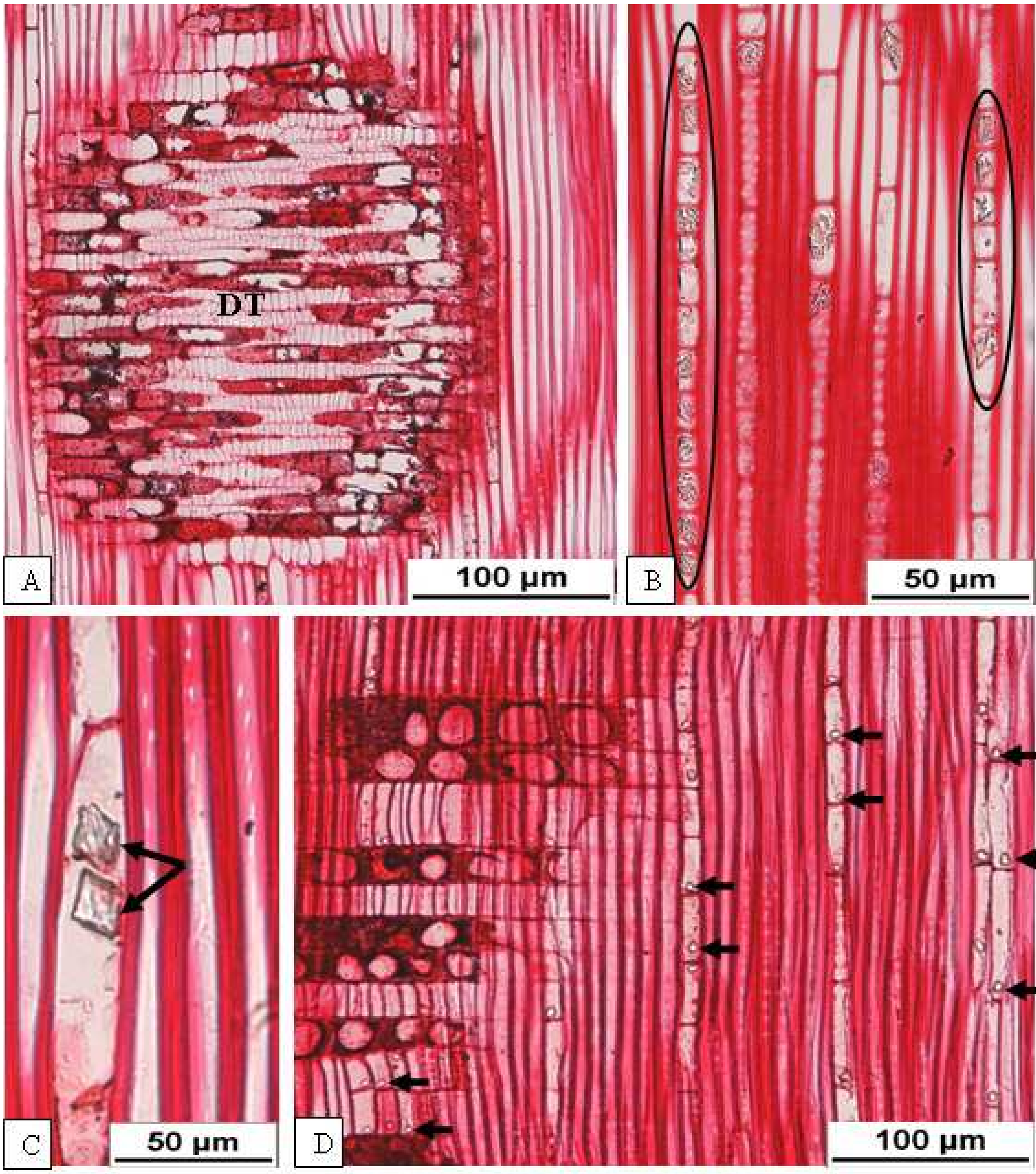

Figure 3: Radial sections of *Durio* woods (A-D) A: Ray heterogenus, tile cells of Durio-type (DT). B: Crystal in chambered axial-parenchyma (circle). C: Crystal in non-chambered axial-parenchyma (arrow). D: Silica in axial parenchyma and tile cells (arrow).

A: *D. oblongus,* B: *D. macrophyllus,* C: *D. zibethinus* D: *D. griffithii*