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Anatomical study of *Shorea* species in Sri Lanka

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Abstract. The six *Shorea* species native to Sri Lanka Beraliya dun (*S. disticha*), Navada dun (*S. stipularis*), Dun (*S. zeylanica*), Yakahalu dun (*S. trapezifolia*), Yakal dun (*S. astylosa*), and Thiniya dun (*S. congestiflora*) are commercially valuable timbers within the Dipterocarpaceae family, yet their close morphological resemblance creates substantial difficulties in accurate species-level identification across field, trade, and processing contexts. This study aimed to establish reliable wood anatomical criteria for distinguishing these six *Shorea* species through microstructural analysis and its quantitative relationship with timber density. Permanent sections in transverse, radial, and tangential planes were prepared and examined under light microscopy, with vessel diameter and ray dimensions measured using Micrometrics SE Premium imaging software, while timber density was determined through the water displacement principle. All six species exhibited solitary and multiple vessel arrangements, with mean vessel diameters differing considerably across taxa, providing a primary basis for microscopic discrimination. Ray structure ranged from uniseriate to multiseriate configurations, with measurable variation in ray height and width offering additional diagnostic value. Axial parenchyma patterns including paratracheal and apotracheal forms differed consistently among species, reinforcing anatomical boundaries

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at the cellular level. A statistically significant negative correlation was identified between wood density and vessel diameter, indicating that species with greater density characteristically develop narrower conducting elements. By integrating vessel arrangement, ray morphology, parenchyma distribution, and density values, a dichotomous identification key was constructed that successfully and unambiguously separates all six taxa. The anatomical framework and dichotomous key developed in this study offer timber inspectors, foresters, and wood processing industries a scientifically grounded, practical tool for the accurate identification of Sri Lankan dun timbers in both raw and processed forms

Keywords: anatomical features; wood density; wood anatomy; timber identification; vessel characteristics; microscopic features; dichotomous key

Introduction

Timber remains a critical natural resource in sustainable construction due to its renewability, aesthetic value, and favourable mechanical properties. In many tropical countries, including Sri Lanka, it continues to play an essential role in both traditional and modern building practices. However, increasing pressure on natural forests and growing demand for high-quality timber have intensified concerns regarding species authentication and resource management. Nearly 300 local timber species are available in Sri Lanka, as reported by I.G. Chathushaki *et al*. (2025), but only 30 species are commonly available in the timber market. Timber has been a popular construction material in Sri Lanka since ancient times and, according to M.C. Anuruddha *et al*. (2025), it is considered one of the most valuable raw materials in the country because of its multipurpose usage. Though replacement for the wood which comes from steel and concreate doesn't bear the same structural properties, timber is a natural structural material whose strength properties and other characteristics vary considerably. These variations occur not only within the same family, species even from tree to tree it may occur. The strength of timber depends on its species and the effects of certain growth characteristics, as explained by J.P. Cabral *et al*. (2022).

Dipterocarpaceae is a taxonomically diverse family comprising 17 genera, including five monotypic genera. The genus *Shorea* is the largest, containing 186 species, of which 121 are threatened. The Sri Lankan endemic genus Stemonoporus has 26 species, all of which are assessed as threatened, as noted by K. Atapattu *et al*. (2022). In Sri Lanka, the genus *Shorea* is represented by 15 species, of which 13 are endemic to the country, with 10 species found specifically in the wet zone. However, the existence of different classification systems for this genus, proposed by several authors, has created some taxonomic complexity, as discussed by A. Musa *et al*. (2024).

In the Sri Lankan timber market, there are venders will sell low maturity products with low-grade timber species that considered as below the. Buyers who cannot identify the authenticity of timber species are easily misled by forged documents and misidentified timber. The authenticity percentage is very low for both local and imported timber species, although local timber species have a higher authenticity percentage compared to imported species, according to G.W.C. But *et al.* (2023). A study of Sri Lankan timber species, including *Shorea spp*., has linked properties to four categories: building construction, furniture/joinery, light construction, and miscellaneous, promoting evidence-based selection over traditional species-oriented practices, as reported by A.J. Duffy (2024). Previous research by P. Chalise *et al*. (2022) conducted a detailed anatomical investigation of *Shorea robusta*, commonly known as Sal, which P. Chalise *et al*. (2022) described as one of the major multipurpose timber trees in Nepal. The main objective of this study is to identify six *Shorea* species by anatomical features and prepare a dichotomous key.

Timber remains one of Sri Lanka's most valued construction materials, yet the marketplace is increasingly vulnerable to misidentification and fraud. As emphasised by C.K. Muthumala *et al*. (2024; 2025), low-grade or immature timber is substituted for premium species under falsified documentation. Among the commercially traded species, the genus *Shorea* the largest within the Dipterocarpaceae family presents a particular identification challenge, as its 15 Sri Lankan representatives share strikingly similar external appearances, grain patterns, and colouration, making visual discrimination unreliable even for experienced traders. Despite the ecological and economic significance of these species, no dedicated anatomical identification framework exists for the six lesser-studied Sri Lankan *Shorea* timbers *S. disticha, S. stipularis, S. zeylanica, S. trapezifolia, S. astylosa,* and *S. congestiflora* leaving a critical gap in both taxonomic science and timber authentication practice. Although anatomical studies of *Shorea* robusta have previously been conducted in neighbouring regions by P. Chalise *et al*. (2022), systematic wood anatomical investigations targeting Sri Lanka's endemic *Shorea* species remain absent from the literature. Current identification methods rely predominantly on macroscopic traits and field expertise, neither of which provides reproducible or legally defensible results in market or forensic contexts. This underscores the urgent need for a scientifically robust, microscopy-based identification approach that can differentiate these species at the cellular level and support evidence-based timber authentication across trade, construction, and conservation sectors. This study sought to identify reliable wood anatomical features that can differentiate these six *Shorea* species by analysing their microstructure and examining its quantitative association with timber density.

Materials and Methods

This investigation was conducted from June to September 2025 in the lowland wet agro-ecological zone of Ratnapura District, Sri Lanka, where six *Shorea* species naturally occur. Three mature, healthy trees per species were randomly selected yielding 18 specimens in total using simple random sampling to ensure equal probability of inclusion and minimise selection bias. Selected trees were free from visible disease, mechanical damage, and abnormal growth deformities, and were positively identified at the species level by a qualified taxonomist prior to sampling, consistent with established practice in descriptive wood anatomy where three to five individuals per species are considered sufficient when intraspecific variation is low (Wheeler *et al*., 1989). Defect-free heartwood blocks of approximately 2 cm × 2 cm × 5 cm were extracted at breast height (1.3 m above ground level) and oriented for sectioning in the transverse, radial, and tangential planes to standardise the anatomical region examined and eliminate height-related structural variability. The six *Shorea* species selected for this study are presented in Table 1.

Table 1. Selected timber species for the study

Common name	Scientific name
Beraliya dun	*Shorea disticha*
Navade dun	*Shorea stiplaris*
Yakal dun	*Shorea astylosa*

Table 1, Continued

Common name	Scientific name
Dun	*Shorea zeylanica*
Yakahalu dun	*Shorea trapezifolia*
Thiniya dun	*Shorea congestiflora*

Source: compiled by authors

All anatomical examinations were carried out at the Wood Science Laboratory, State Timber Corporation, Battaramulla, Sri Lanka. All sampling procedures were conducted in accordance with the principles of the Convention on Biological Diversity (1992) to ensure ethical and sustainable utilisation of biological resources. The anatomical study of timber species followed standard protocols as outlined by E.A. Wheeler *et al*. (1989) and A. Laskowska *et al*. (2021). Preparation of wood samples for microscopic examination included sectioning of wood samples in transverse, radial, and tangential planes, followed by preparation of thin sections suitable for microscopic observation. Staining and mounting procedures were conducted according to established protocols, after which microscopic examination and documentation of anatomical features were performed. Anatomical characteristics evaluated included vessel arrangement and dimensions, parenchyma distribution, fiber characteristics, and ray structure, following standard wood anatomical terminology and measurement protocols.

Samples were collected from heartwood portion of wood. Wood block of 2 cm × 2 cm × 2 cm was taken for the slide preparation, representing Transverse, Tangential and Radial section of the wood. After taking the sample from the tree, it was socked in the water before preparation of the slides. Samples were prepared as blocks of approximately 8 mm × 8 min size with anatomical orientation for microtome sectioning.

Sliding microtome (Model LEICA SM 2000R-SCHITTEN MIKROTOM) was used to produce section cut from the wood species. This microtome has a wedge shape sharp blade. The piece of wood sample and the knife were flooded with 30% Ethanol during section cutting to facilitate fine sectioning. The wood specimens were taken from transverse, radial and tangential sections at the range of 10-15 mm thickness by using sliding microtome, in here mainly consider about transverse section cutting of the wood samples (Fig. 1).

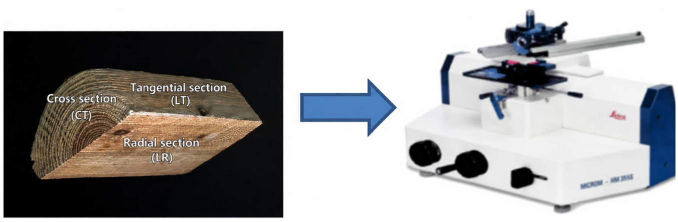

Figure 1. Section cutting and procedure of preparing slides (Model LEICA SM 2000R-SCHITTEN MIKROTOM)

Source: created by authors

Preparation of wood samples for microscopic examination included sectioning of wood samples in transverse, radial, and tangential planes, followed by preparation of thin sections suitable for microscopic observation. Sections were mounted permanently with Canada Balsam following a standardised dehydration and staining protocol. The procedure involved initial dehydration in 50% alcohol for 5 minutes, followed by staining with safranin in 50% alcohol for 15 minutes to remove moisture and impart colour to the sections. The stained sections were then washed in alcohol and subjected to a graded dehydration series: 70% alcohol for 5-10 minutes, 90% alcohol for 10 minutes, and absolute alcohol for 10 minutes with covers to prevent evaporation. The dehydrated sections were then transferred to an absolute alcohol and xylene mixture for 10 minutes, where the appearance of milkiness indicated incomplete dehydration, necessitating repetition of the previous stage. Finally, sections were cleared in xylene for 10 minutes under cover and permanently mounted in Canada Balsam. Transverse, tangential, and radial sections were prepared for comprehensive anatomical examination and documentation.

The light microscope was used to make anatomical observations on both qualitative and quantitative parameters at 4 × 10 magnifications. Micrometrics SE Premium 4 software and anatomical images were used to get measurements. Quantitative wood anatomical characteristics were measured, such as the mean tangential diameter of the vessel Lumina. Qualitative factors were found, including the vessel's morphology, the presence of deposits within it, and the organisation of the parenchyma. According to the 1989 IAWA list, slides were made and measurements were made for every sample. (Baas *et al.*, 2004). A handheld microscope Toontor TE013 was used to examine wood samples in order to see the vessel number and Ray number that fit in 25 mm^2. Within a 25 mm^2 area, anatomical observations were made at 20 magnifications.

Wood density was measured using Archimedes' principle. Wood samples were selected from each timber species and thoroughly cleaned to remove sawdust and other debris. Each sample was soaked in water for approximately three days to ensure complete saturation, with the assumption that all vessels and pores were filled with water within this period. A water-filled beaker was placed on an electrical balance and its initial weight (w_1) was recorded. The water-soaked wood sample was then submerged in the beaker to a constant depth using a thin stick attached to a stand, and the final weight of the beaker (w_2) was measured. Following this, the timber samples were placed in an oven at 103°C for 48 hours to remove all available moisture, with samples maintained in the oven until a constant weight was achieved. After 48 hours, the timber samples were transferred to a desiccator to cool down, and the oven-dry weight (g) of each sample was measured (checked it with the classification of density as in Table 2). This consistent procedure was maintained for all wood samples, and density was calculated using the following formulas. The wet weight of the timber sample was calculated by the following formula

$$x = w_1 - w_2, \tag{1}$$

where x represents timber weight, w_1 –internal beaker weight and w_2 –final beaker weight.

The density at 0% moisture level, was calculated by the following formula:

$$\rho = m \times \rho_w \text{ (1,000 kg/m}^2\text{)}, \tag{2}$$

where ρ represents density, m –oven dry weight of timber sample and ρ_w –density of water.

Table 2. Classification of density at 12% MC, kg/m^3

Density class	Density range
Very high	> 840
High	641-840
Medium	500-640
Low	500 <

Source: compiled by authors

Observations and measurements of anatomical features were systematically recorded for all six *Shorea* species. Using Micrometrics SE Premium 4 software, which is accessible at the State Timber Corporation's Research Division, the Mean Vessel Diameter (Tangential Diameter) of six timber species was measured in a 5 × 5 mm cross section. Number of vessels were measured in 5 mm × 5 mm cross section, of six *Shorea* timber species cross section number of Ray height was measured using Tangential section of 06 timber species using Micrometrics SE Premium 4 software available at Research Division of the State Timber Corporation. Number of rays were measured in 5mm × 5mm cross section, of six *Shorea* timber species cross section number of Ray height was measured using Tangential section of 06 timber species using Micrometrics SE Premium 4 software available at Research Division of the State Timber Corporation. Selected Six *Shorea* timber species were studied considering their anatomical features by microscope. Vessels, Rays, Parenchyma and other anatomical properties were used for construction of Identification keys in accordance with E.A. Wheeler *et al*. (1989).

Results

The wood anatomy of six *Shorea* species native to Sri Lanka *S. disticha* (Beraliya Dun), *S. stipularis* (Navada Dun), *S. zeylanica* (Dun), *S. trapezifolia* (Yakahalu Dun), *S. astylosa* (Yakal Dun), and *S. congestiflora* (Thiniya Dun) was systematically examined across transverse, radial, and tangential sections. Key qualitative and quantitative parameters vessel features, ray dimensions, axial parenchyma patterns, and intercellular canal distribution were assessed for their diagnostic value in species-level identification. Photographic representations of anatomical sections for all six species are presented in Figure 2.

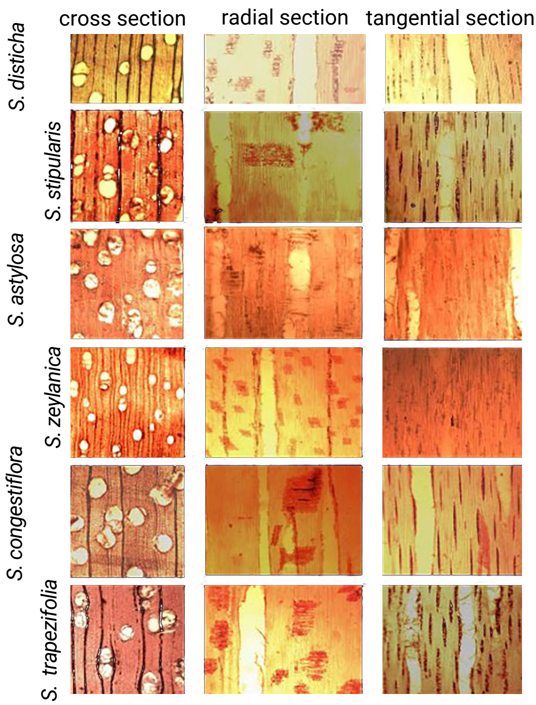

Figure 2. Tree section of anatomical slides photos

Source: created by authors

Macroscopic characteristics: heartwood colour. Heartwood colour provided an initial, macroscopic basis for preliminary distinction among the six species (Table 3). *S. zeylanica* (Dun) and *S. congestiflora* (Thiniya Dun) both exhibited red to reddish-brown heartwood, while *S. disticha* (Beraliya Dun) and *S. trapezifolia* (Yakahalu Dun) shared brown tones. *S. astylosa* (Yakal Dun) was distinctive with yellow heartwood, and *S. stipularis* (Navada Dun) was the only species to display white to grey colouration. However, given that some species share similar hues, colour alone was insufficient for reliable identification, and microscopic features were essential for unambiguous discrimination.

Table 3. Colour of heartwood of the selected *Shorea* species

Species name	Colour of the heartwood
Beraliya Dun	Brown or shades of brown
Navanda Dun	White to grey
Yakal Dun	Yellow or shades of yellow
Dun	Red or shade of red
Yakahal Dun	Brown or shades of brown
Thiniya Dun	Red or shade of red

Source: compiled by authors

Vessel features. Vessel characteristics showed pronounced variation across the six species, providing the most discriminatory microscopic features for identification (Table 4). All species exhibited oval or round vessel shapes and predominantly solitary arrangement; however, *S. zeylanica*, *S. trapezifolia*, and *S. congestiflora* additionally formed radial vessel multiples of two to three, distinguishing them from the exclusively solitary arrangement observed in *S. disticha*, *S. stipularis*, and *S. astylosa*.

Table 4. Key anatomical features (Vessels) of selected *Shorea* species

Species	Vessels				
	Shape	Grouping	Tangential lumen diameter, mean (μm)	Vessels per 25 mm^2	Tyloses and deposits in vessels
Beraliya (Shorea disticha)	Oval	exclusively solitary	152	116	Absent
Nawadadun (Shorea stipularis)	Oval	exclusively solitary	156	99	Absent
Yakal (Shorea astylosa)	Round Oval	exclusively solitary	169	115	Present
Dun (Shorea ceylanica)	Oval	solitary and radial multiples of two to three	100	154	Present
Yakahaludun (Shorea trapezifolia)	Oval	solitary and radial multiples of two to three	172	187	Present
Thiniyadun (Shorea congistiflora)	Wood diffuse-porous	solitary or radial multiple of two	231	161	Present

Source: compiled by authors

Mean tangential lumen diameter differed substantially among species, ranging from 100 µm in *S. zeylanica* to 231 µm in *S. congestiflora* a more than twofold difference. *S. congestiflora* had the widest vessels and the second highest vessel frequency (161 per 25 mm²), while *S. zeylanica* had the narrowest vessels despite its relatively high vessel density (154 per 25 mm²). This inverse relationship between vessel diameter and vessel frequency reflects the established negative correlation between vessel size and wood density. *S. trapezifolia* had the highest vessel frequency (187 per 25 mm²) paired with a wide mean diameter (172 µm), indicating that vessel grouping into multiples may partially compensate for the density-diameter trade-off in this species. Tyloses and vessel deposits were absent in *S. disticha* and *S. stipularis* but consistently present in the remaining four species, providing an additional diagnostic character.

Ray structure. Ray dimensions and cellular composition varied consistently among species, offering additional reliable criteria for identification (Table 5). Ray frequency ranged from 27 per 5 mm in *S. trapezifolia* the species with the highest vessel density to 46 per 5 mm in *S. disticha*. This inverse relationship between ray frequency and vessel frequency is consistent with the structural trade-off between conducting and storage tissue in hardwoods. Ray width (seriation) ranged from 1-2 seriate in *S. disticha* to 1-4 seriate in *S. astylosa*, *S. zeylanica*, and *S. congestiflora*. Notably, ray cell type provided a clear binary distinction: *S. disticha* and *S. astylosa* possessed heterogeneous rays comprising both procumbent and upright/square cells whereas the remaining four species exhibited homogeneous rays composed exclusively of procumbent cells. This character aligned with intercellular canal distribution and was incorporated as a key discriminating feature in the dichotomous identification key.

Axial parenchyma and intercellular canals. Axial parenchyma patterns differed markedly among species and proved highly diagnostic (Table 5). *S. congestiflora* was immediately separable by the near absence of axial parenchyma a character unique among the six taxa. *S. stipularis* exhibited a combination of scanty paratracheal, vasicentric, and winged-aliform parenchyma; *S. astylosa* and *S. zeylanica* both displayed aliform and confluent forms, with *S. zeylanica* additionally showing aliform-confluent parenchyma. *S. disticha* and *S. trapezifolia* presented the more restricted scanty paratracheal and vasicentric patterns respectively, further differentiating them from species with more elaborate parenchyma configurations. Intercellular canals in long tangential lines were present in five of the six species and are characteristic of the Dipterocarpaceae family. The sole exception was *S. stipularis* (Navada Dun), in which intercellular canals were entirely absent. This single feature unambiguously separates *S. stipularis* from all other species examined and serves as the primary dichotomous branch point in the identification key.

Table 5. Key anatomical features rays, parenchyma and intracellular canals of selected *Shorea species*

Species	Rays			Parenchyma	Intercellular canals
	Rays per 5 mm	Ray width	Type of ray cells		
Beraliya (*Shorea disticha*)	46	Ray width 1 to 2 seriate	Heterogeneous	Axial parenchyma scanty and paratracheal	Axial canals in long tangential lines
Nawadadun (*Shorea stipularis*)	35	Ray width 1 to 3 seriate	Homogeneous	Axial parenchyma scanty paratracheal Axial parenchyma vasicentric Axial parenchyma winged-aliform	Not present

Table 5, Continued

Species	Rays			Parenchyma	Intercellular canals
	Rays per 5 mm	Ray width	Type of ray cells		
Yakal (*Shorea astylosa*)	35	Ray width 1 to 4 seriate	Heterogeneous	Axial parenchyma Aliform Axial parenchyma confluent	Axial canals in long tangential lines
Dun (*Shorea ceylanica*)	37	Ray width 1 to 4 seriate	Homogeneous	Axial parenchyma confluent Axial parenchyma scanty and vasicentri Axial parenchyma aliform confluent	Axial canals in long tangential lines
Yakahaludun (*Shorea trapezifolia*)	27	Ray width 1 to 3 seriate	Homogeneous	Axial parenchyma scanty and vasicentric	Axial canals in long tangential lines
Thiniyadun (*Shorea congistiflora*)	33	Ray width 1 to 4 seriate	Homogeneous	Axial parenchyma absent or rare	Axial canals in long tangential lines

Source: compiled by authors

Relationship between vessel diameter and wood density. A statistically significant negative correlation was identified between mean vessel diameter and wood density across the six species. Species with narrower vessels notably *S. zeylanica* (100 µm) exhibited higher wood density, while *S. congestiflora* with the widest vessels (231 µm) showed comparatively lower density values. This pattern reflects the hydraulic-mechanical trade-off in wood structure: denser woods invest proportionally more in thick-walled fibres and smaller lumina, resulting in narrower conducting elements. This density-vessel diameter relationship reinforces the diagnostic utility of vessel diameter measurements, linking functional wood properties to species identity in a quantitatively verifiable manner.

Dichotomous identification key. The anatomical features selected for the dichotomous key axial parenchyma pattern, intercellular canal presence, vessel arrangement, and ray cell type were chosen because they showed the most consistent, qualitatively clear, and species-exclusive variation across all six taxa (Dormontt *et al.*, 2015). Quantitative characters such as vessel diameter and ray frequency, while diagnostically informative, were used as supporting evidence rather than primary key characters due to overlapping ranges. The resulting key successfully and unambiguously separates all six Shorea species and is presented below. It is designed for practical use with light microscopy and does not require specialised equipment beyond standard anatomical slide preparation, making it directly applicable to timber inspection, forensic identification, and trade verification contexts.

Dichotomous key to six Sri Lankan Shorea species based on wood anatomical features:

1a. Axial parenchyma absent or rare – Thiniya Dun (*S. congestiflora*)

1b. Axial parenchyma present → (2)

2a. Intercellular canals absent – Navada Dun (*S. stipularis*)

2b. Intercellular canals present (tangential lines) → (3)

3a. Axial parenchyma aliform or confluent → (4)

3b. Axial parenchyma not aliform or confluent → (5)

4a. Vessels exclusively solitary; ray cells heterogeneous – Yakal Dun (*S. astylosa*)

4b. Vessels in radial multiples; ray cells homogeneous – Dun (*S. zeylanica*)

5a. Ray cells heterogeneous; rays 1-2 seriate – Beraliya Dun *(S. disticha*)

5b. Ray cells homogeneous; rays 1-3 seriate – Yakahalu Dun (*S. trapezifolia*)

Discussion

The findings of this study demonstrate that microscopic wood anatomy provides a reliable and practical basis for distinguishing six *Shorea* species native to Sri Lanka that are otherwise difficult to separate by external morphology alone. This outcome is consistent with established practice in tropical timber identification, where vessel arrangement, ray structure, and axial parenchyma patterns form the core of species-level diagnostic frameworks (Wheeler & Baas, 1988; Wheeler *et al*., 1999). The qualitative stability and consistency of these cellular characters across individuals makes them particularly well-suited for discrimination within genera characterised by close morphological affinity, such as *Shorea* (Helmling, 2020).

Vessel features proved to be the most discriminatory category of characters examined. The mean tangential lumen diameter ranged from 100 μm in *S. zeylanica* to 231 μm in *S. congestiflora*, a range consistent with values reported for other *Shorea* species across Southeast Asia, where vessel diameters of 81-270 μm have been documented within the white meranti group (Helmling, 2020). The exclusively solitary vessel arrangement observed in *S. disticha*, *S. stipularis*, and *S. astylosa* contrasts with the radial multiples found in *S. zeylanica*, *S. trapezifolia*, and *S. congestiflora*, providing a clear binary character at the microscopic level. These grouping patterns are broadly analogous to those described in related dipterocarp genera, where radial vessel multiples are associated with species of higher vessel frequency (Ohashi *et al*., 2014). The presence of tyloses and vessel deposits in four of the six species absent only in *S. disticha* and *S. stipularis* further extended the suite of vessel-based criteria available for identification.

The statistically significant negative correlation identified between vessel diameter and wood density supports a widely documented functional trade-off in angiosperm wood anatomy. Wood density correlates negatively with vessel diameter and positively with vessel packing density across tropical tree species (Fajardo *et al*., 2022), reflecting the hydraulic efficiency–mechanical safety trade-off whereby denser woods invest proportionally more in thick-walled fibres and correspondingly narrower lumina. Within the Dipterocarpaceae specifically, N. Malik *et al*. (2025) reported that wood density was negatively correlated with axial parenchyma abundance across five dipterocarp species, consistent with the pattern observed here in *S. congestiflora*, which combined the widest vessels with near-absent parenchyma. The density-vessel diameter relationship identified in this study thus has both practical and functional significance: it provides a quantitative parameter that reinforces the qualitative anatomical distinctions and links species identity to measurable differences in timber mechanical properties relevant to end-use classification.

Ray and axial parenchyma characters provided complementary discrimination at finer taxonomic resolution. The distinction between heterogeneous rays found in *S. disticha* and *S.astylosa* and the homogeneous rays present in the remaining four species constitutes a reliable qualitative character that is consistent with broader patterns in *Shorea* systematics (Musa *et al*., 2024). Axial parenchyma patterns, ranging from scanty paratracheal in *S. disticha* to the near-complete absence in *S. congestiflora*, showed species-specific consistency throughout the sampled material and matched configurations documented for the genus in the

Dipterocarpaceae wood anatomy literature (Erwin *et al*., 2025). The complete absence of intercellular canals in *S. stipularis* is particularly noteworthy, given that axial intercellular canals in long tangential lines are regarded as a diagnostic feature of the family Dipterocarpaceae (Erwin *et al*., 2025). This absence represents a taxonomically informative deviation that is immediately detectable under light microscopy and serves as the most decisive branch point in the constructed dichotomous key.

The dichotomous key constructed from these combined anatomical criteria successfully and unambiguously separates all six *Shorea* species. By prioritising qualitative characters axial parenchyma pattern, presence of intercellular canals, vessel arrangement, and ray cell type the key minimises the dependence on quantitative measurements that may exhibit intraspecific variability. This approach mirrors that taken in identification keys for other morphologically similar tropical genera, where stable structural characters are preferred over metric thresholds (Wheeler & Baas, 1998). The key is operable using standard light microscopy on permanent anatomical sections, without recourse to molecular or chemical methods, making it directly applicable in field laboratories, timber yards, and customs inspection settings. Given the commercial importance of Sri Lankan dun timbers and the ongoing risk of misidentification in the regional timber trade, the availability of a verified anatomical key represents a tangible contribution to sustainable forest resource management and timber trade governance.

Conclusions

The six Sri Lankan *Shorea* species *S. disticha, S. stipularis, S. zeylanica, S. trapezifolia, S. astylosa,* and *S. congestiflora* although morphologically similar, exhibit sufficiently distinct wood anatomical characteristics to permit reliable species-level identification. Variation in vessel diameter, ray dimensions, and axial parenchyma patterning across transverse, radial, and tangential sections provided clear microstructural boundaries among taxa. The statistically significant negative correlation between vessel diameter and wood density further strengthened the discriminatory framework, linking functional wood properties to anatomical organisation. The dichotomous identification key constructed from these integrated criteria successfully and unambiguously separates all six species, offering a practical and scientifically grounded tool applicable across field, trade, and processing contexts. These findings address a longstanding challenge in the accurate identification of commercially important dun timbers in Sri Lanka, where visual similarity frequently leads to misidentification. The anatomical reference criteria and key established in this study provide timber inspectors, foresters, and wood processing industries with a reliable resource for species verification in both raw and processed timber forms, ultimately supporting sustainable timber trade, forest resource management, and conservation of native Dipterocarpaceae in Sri Lanka. The prospects for future research include expanding the anatomical database to additional Sri Lankan *Shorea* species, integrating molecular and chemical identification techniques with wood anatomy, and evaluating the influence of environmental and ecological factors on anatomical variation and timber properties to strengthen forensic timber identification and sustainable forest management practices.

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Conflict of Interest

None.

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Анатомічне дослідження видів *Shorea* у Шрі-Ланці

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Анотація. Шість видів роду Shorea, ендемічних для Шрі-Ланки – Beraliya dun (*S. disticha*), Navada dun (*S. stipularis*), Dun (*S. zeylanica*), Yakahalu dun (*S. trapezifolia*), Yakal dun (*S. astylosa*) та Thiniya dun (*S. congestiflora*) – є комерційно цінними породами деревини родини Dipterocarpaceae. Водночас їхня близька морфологічна подібність створює значні труднощі для точного визначення виду на рівні виду в польових умовах, торгівлі та під час переробки. Метою цього дослідження було встановити надійні анатомічні критерії деревини для розрізнення цих шести видів Shorea шляхом мікроструктурного аналізу та оцінки його кількісного зв'язку з щільністю деревини. Постійні зрізи в поперечній, радіальній та тангенціальній площинах були підготовлені та досліджені за допомогою світлової мікроскопії, при цьому діаметр судин і розміри променів вимірювалися за допомогою програмного забезпечення Micrometrics SE Premium, а щільність деревини визначалася методом витіснення води. Усі шість видів демонстрували як одиночне, так і групове розташування судин, при цьому середні діаметри судин суттєво відрізнялися між таксонами, що стало основною основою для мікроскопічного розрізнення. Будова променів варіювала від однорядної до багаторядної, а вимірювані відмінності у висоті та ширині променів мали додаткову діагностичну цінність. Патерни осьової паренхіми, включаючи паратрахеальні та апотрахеальні форми, послідовно відрізнялися між видами, підсилюючи анатомічні межі на клітинному рівні. Було виявлено статистично значущу негативну кореляцію між щільністю деревини та діаметром судин, що свідчить про те, що види з більшою щільністю характеризуються формуванням вужчих провідних елементів. Шляхом інтеграції розташування судин, морфології променів, розподілу паренхіми та значень щільності було побудовано дихотомічний визначальний ключ, який успішно та однозначно розрізняє всі шість таксонів. Розроблена в цьому дослідженні анатомічна структура та дихотомічний ключ пропонують інспекторам деревини, лісівникам і деревообробній промисловості науково обґрунтований практичний інструмент для точного визначення деревини дунових порід Шрі-Ланки як у необробленому, так і в обробленому вигляді

Ключові слова: анатомічні особливості; щільність деревини; анатомія деревини; ідентифікація деревини; характеристики судин; мікроскопічні особливості; дихотомічний ключ