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STUDY ON BASIC WOOD PROPERTIES OF CRITICALLY ENDANGERED SPECIES *SYZYGIUM ALBUM*

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ABSTRACT

Syzygium album is a critically endangered species, and the wood basic properties haven't been reported. Therefore, this paper analyzes the wood from the anatomical characteristics, physical properties, and secondary components. The results showed that observed *S. album* wood of a 46-year-old tree is diffuse-porous to semi-diffuse-porous wood. The maximum vessel tangential diameter is 127.47 µm, which is found at the beginning of the earlywood. The wood rays are heteromorphic type I and II, and the multi-column part is mostly 3 cells wide. In physical properties, the air-dry density is classified as "heavy", whereas its air-dry and full-dry differential dry shrinkage are "small" and "medium", respectively. This indicates that the wood performs better when dried. The content of benzene-ethanol extract from *S. album* wood is 2.10%. The benzene-ethanol extracts were analyzed by GC-MS, and the main components are 2,6,11,15-tetramethylhexadecane (3.29%), eicosamethyl cyclodecasiloxane (10.02%), octadecamethyl cyclononasiloxane (7.43%), and tetracosamethyl cyclododeca- siloxane (3.60%), etc.

KEYWORDS: *Syzygium album*, anatomical features, physical properties, secondary components, GC-MS.

INTRODUCTION

Syzygium album Q.F. Zheng is an evergreen tree from the *Syzygium Gaertn* in the Myrtaceae family. It was discovered and named by Professor Zheng Qingfang of Fujian

Agriculture and Forestry University in the early 1990s. *S. album* can be used as a shade tree, street tree, embankment tree, or windbreak tree, and its wood can be used for high-value furniture and craft materials (Compiling Group of Flora of Fujian 1990, Cheng et al. 1992, Zheng 2014). At present, only one wild *S. album* has been found in Yunxiao County, Fujian Province, China, and it is listed as a very rare species in Fujian Province. According to the IUCN Red List of Threatened Levels (Version 3.1), *S. album* is a critically endangered species (Qin et al. 2017, Zheng et al. 2021).

To date, research on the *Myrtaceae* family has focused mainly on the chemical composition of leaves and stems; antibacterial components and activities; extraction and pharmacology of traditional Chinese medicinal components (Chandrasekaran and Venkatesalu 2004, Eganathan et al. 2012, Hanif et al. 2020); and observation of leaf characteristics (Huang and Liu 2003, Soh and Parnell 2011). Wood research has been reported in only a few papers (Chen 2006, Cheng 1980, 1985, Cheng et al. 1992, Schmid and Baas 1984, Tang 1975, Vliet and Baas 1987, Wei 1988, Zheng and Wu 2000), and there are no specific reports on *S. album* wood. A small number of references describe its morphological characteristics (Zheng 2014), phenological observations (Wu 2014), harvest technology (Liu et al. 2017), sterile sowing and tissue culture techniques (Chen 2021), habitat status, and protection evaluation (Zheng et al. 2021), as well as techniques for orchard establishment (Zhang 2021). Because *S. album* is a very rare species, anatomical characteristics, physical properties, and secondary components of its wood were investigated using a naturally broken branch of the wild *S. album* caused by severe weather. The findings fill gaps in our understanding of its basic wood properties, providing theoretical support for wood identification and the genetic breeding of *S. album*.

MATERIAL AND METHODS

Materials

A naturally broken side branch of a 46-year-old *S. album* tree was obtained from Xiahe Town, Yunxiao County, Fujian Province, China (24°00'56″N, 117°10'39″E, altitude 253 m). The wild *S. album* is located in a valley in the foothills of the northwest slope of low hills. The side branch was 46 years old, 21 cm in length, and 8.26 cm in diameter. One disc with a 10 mm thickness and two discs with a 40 mm thickness were sawn from the end of the side branch near the trunk, then air-dried for use.

Macrostructure observation

A 40 mm wood disc was cut into three sections and polished with 240 mesh, 400 mesh, 600 mesh, 800 mesh, and 1000 mesh abrasive belts. The macroscopic structures of the polished wood, such as the growth rings, pore, material color, and texture, were observed with the naked eye, a magnifying glass, and a stereomicroscope.

Microstructure observation and measurement

The 10 mm disc was cut into a 10 mm wide section that passed through the center. As the growth rings were very narrow, 10 × 10 × 10 mm cubes were obtained from the pith to the sapwood at distances of 1 cm, 2 cm, 3 cm, and 4 cm from the pith. They were made into three-dimensional permanent sections of 10 ~ 20 μm and 50 μm.

The remaining four small pieces were cut into several small wood strips as thick as a matchstick using a knife and digested using Franklin's solution to obtain temporary whitened sections after maceration for later use.

A microscopic image analysis system (Motic 3.0 software) was used to observe and measure microstructural features. The ratio of each tissue was measured in the transverse section, and vessel diameter was measured in the tangential direction. The height and width of the wood rays were measured in the tangential section. The temporary sections made of the isolate were used to measure fiber length, fiber width, fiber lumen diameter, and vessel length. The measurements were repeated 60 times, and scanning electron microscopy (SEM) was used to observe 50 μm thick slices.

Physical tests

According to China's national standards GB/T1932: 2009 and GB/T1933: 2009, the 40 mm disc was processed to the required size, and its basic density, air-dry density, absolute dry density, air-dry shrinkage rate, and full-dry shrinkage rate were measured.

Secondary component analysis

According to China's national standard GB/T35816: 2018, the remaining samples obtained from the above processing steps were ground into 40 ~ 60 mesh powder and placed in a jar with a frosted glass stopper. The content of benzene-alcohol extract was determined, and 10 ml of concentrated benzene-ethanol extract was used for gas chromatography-mass spectrometry (GC-MS) analysis (Xu et al. 2013).

The chromatographic test was performed by injecting 1 μL of sample under a high-purity helium environment with a flow rate of 1 $mL\cdot min^{-1}$ and a split ratio of 1:1. The injection port temperature was 250°C. The initial column temperature was 60°C; it was maintained for 4 min, increased at a rate of $5°C\cdot min^{-1}$ to 200°C for 5 min, then continuously increased at a rate of $4°C\cdot min^{-1}$ to 280°C for 20 min.

Mass spectrometry was performed with an EI electron source, mass spectrometry bombardment voltage of 70 eV, ion source temperature of 230°C, scanning mass range of 50 ~ 550 amu, and solution delay time of 4 min.

RESULTS AND DISCUSSION

Macrostructural characteristics

The purple-red-brown wood has a fine structure with medium or heavy density and hard features, a smooth and glossy surface without a distinctive smell and taste, oblique grain, no clear sapwood and heartwood, and somewhat obvious growth rings with 11 rings per cm under a magnifying glass. The latter arise from a row of pores with slightly larger diameters at the earlywood position, which forms a light-colored band with vasicentric parenchyma. The small pores from diffuse-porous to semi-diffuse-porous wood are invisible to the naked eye but are slightly visible under a magnifying glass. The pores in the earlywood are slightly larger than those in the latewood and are mainly in a diameter column, often reducing at the end of the growth ring. Abundant white crystal fillings can be seen on the tangential section. The longitudinal parenchyma shows an vasicentric and paratubular banding. Compared with the pores, the slimmer wood rays are slightly visible as ray markings under a magnifying glass in the radial section (Fig. 1).

Fig. 1: Macrostructure of Syzygium album wood.

Vessels

In cross-section, the vessels have circular and oval openings; they are typically arranged in groups of two to three, with a small number of single pores and pore groups (Fig. 2a). The vessel element is spindle-shaped and cylindrical (Fig. 2b). The perforation plates between vessels are slanted with a single perforation (Fig. 2c). The pits between vessels are arranged alternately, i.e. appendage pits; the pit openings are included, and the pit ring is polygonal (Figs. 2d and e), similar to the inter-tubular pits of *S. samarangense (BI.) Merr. et Perry* described by Chen Shusi (2006). Ductal tracheids are occasionally seen (Fig. 2f).

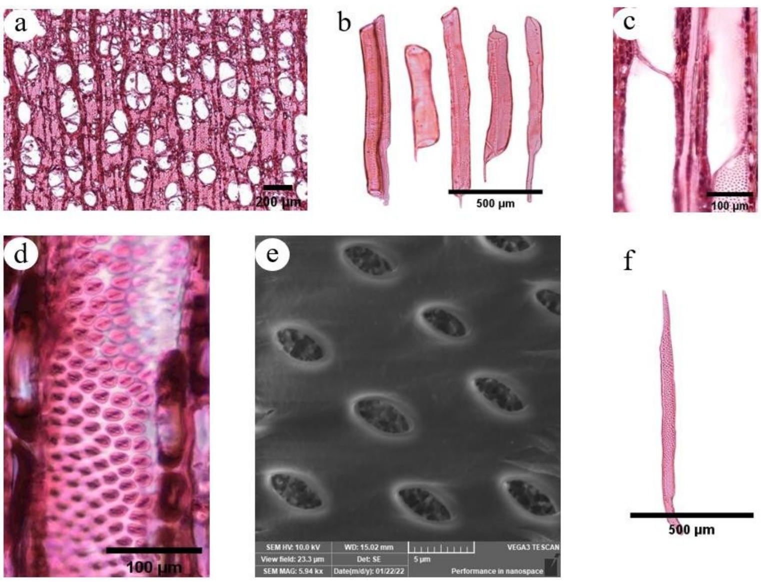

Fig. 2: Microstructure of the vessel elements of S. album wood: (a) The shape and arrangement of pores, (b) The morphology of the vessel element, (c) Simple perforation, (d) Ductal tracheid, (e) The shape and arrangement of pits on the vessel wall under light microscope, (f) The shape and arrangement of pits on the duct wall under SEM.

The vessel diameter is largest in the tangential direction at the beginning of the earlywood with a tissue ratio of 22.70%, and the tissue ratio greater than the average level of wood recorded in the literature. This indicates that the number of vessels is large (Tab. 1).

Tab. 1: Quantitative indicators of micro-characteristics of S. album wood.

Experimental project	Mean	Max	Min	CV	F value and significance
Vessel length (μm)	704.33	883.25	504.94	13.13	2.346
Vessel tangential diameter (μm)	79.72	127.47	43.27	20.40	3.649*
Fiber length (μm)	1577.78	1852.06	1247.22	7.81	6.777**
Fiber width (μm)	20.66	25.68	15.80	10.66	0.705
Fiber length to width ratio	76.37	-	-	-	-
Fiber lumen diameter (μm)	4.42	7.50	2.73	22.59	11.701**
Fiber double-wall thickness (μm)	16.19	21.09	12.52	11.38	5.924**
Fiber wall to lumen ratio	3.66	-	-	-	-
Uniseriate rays height (μm)	438.88	740.01	247.61	20.77	1.513
Uniseriate rays width (μm)	12.65	18.97	9.46	16.22	1.482
Fusiform rays height (μm)	551.92	900.10	309.04	22.39	1.404
Fusiform rays width (μm)	36.82	51.42	24.32	15.88	22.939**
Fiber ratio (%)	53.60	68	36	12.58	1.632
Vessel ratio (%)	22.70	36	23	22.88	2.228
Wood ray ratio (%)	20.30	32	12	23.75	0.530
Longitudinal parenchyma ratio (%)	3.44	12	0	19.86	0.432

Note: Significance: **, $P < 0.01$; *, $P < 0.05$.

Based on the classification of the International Association of Wood Anatomists, the average vessel length and the tangential diameter place *S. album* in the "medium" level (350–800 μm, 50–100 μm) (IAWA Committee 1989).

In the radial direction, with increasing distance from the pith, the vessel length first increases, then decreases, then increases again, although these variations are not significant (Fig. 3). Vessels at different positions show no clear differences in length. The tangential diameter is consistent with the length, and the increase becomes greater 3 to 4 cm away from the pith. One-way analysis of variance shows that the difference between the tangential vessel diameters at different positions is significant.

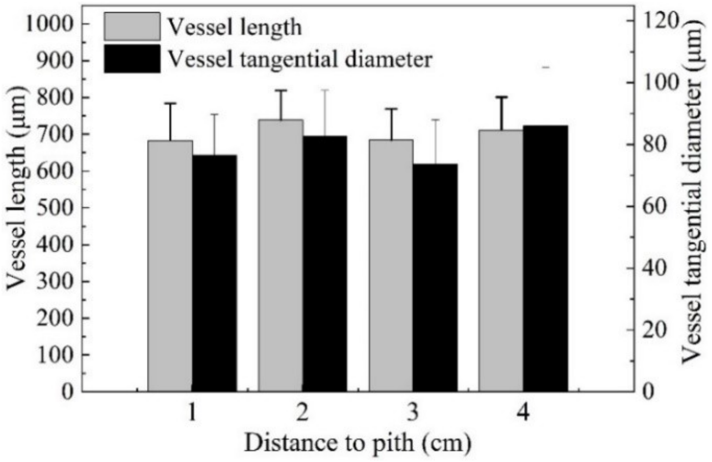

Fig. 3: Radial variation of the vessel length and tangential diameter of S. album wood.

Wood fiber

Wood fibers are an important tissue for mechanical support in hardwoods (Cheng 1985). The wood fibers of the *S. album* are spindle-shaped cells with sharp ends and a small lumen wall thickness (Fig. 4). The maximum double wall thickness of wood fibers is 21.09 μm, and the average fiber wall to lumen ratio is 3.66. Fibrous tissue accounts for 53.60% of *S. album* wood and has a medium fiber length (900 ~ 1600 μm) (Tab. 1). The fiber length changes slightly from 1 to 2 cm away from the pith and then remains constant (Fig. 5).

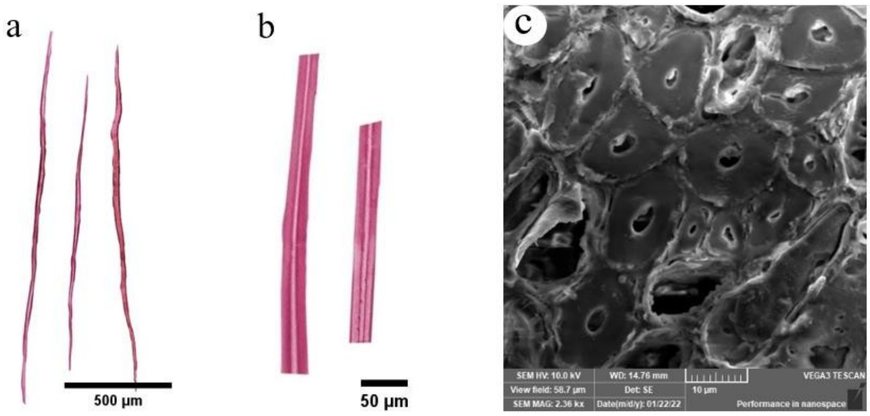

Fig. 4: Microstructure of the wood fibers of S. album wood: (a) Fiber morphology, (b,c) Fibers with small cavity wall thickness.

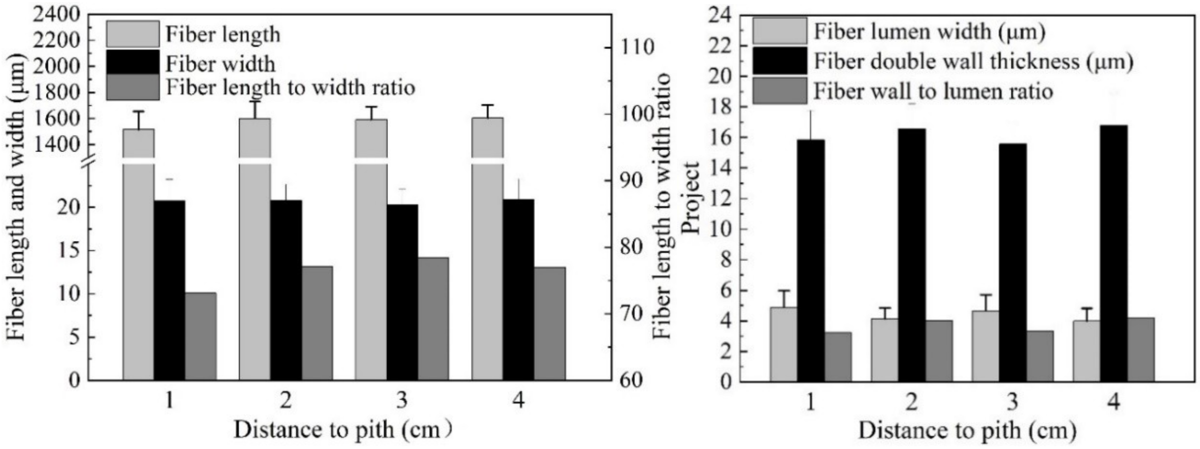

Fig. 5: Radial variation of the fiber morphology of S. album wood.

One-way analysis of variance showed that the samples 1 cm away from the pith differed significantly from those 2, 3, and 4 cm from the pith, and the latter three were similar, probably because of the young age of the wood. Fiber diameter showed little change, and differences between different positions were not significant. The change in fiber aspect ratio first increased greatly, and then decreased slightly, and the aspect ratio of the sample 1 cm from the pith center was the smallest due to the small fiber length. With increasing distance from the pith, fiber lumen diameter first decreased, then increased, then decreased again but did not show a high degree of variation. The largest lumen diameter was again 1 cm from the pith, and different positions showed extremely significant variations. The double-walled fibers are thick due to the nearly constant fiber diameter; opposite to the trend in fiber lumen diameter, their thickness first increased, then decreased, and then increased again. The maximum double wall thickness occurred 4 cm away from the pith at different positions. This difference reached a highly significant level; the change in fiber wall to lumen ratio was consistent with the trend in fiber double-wall thickness, but the amplitude was greater.

Wood rays

Wood rays are composed of parenchyma cells in hardwoods and function in the horizontal transport and storage of nutrients (Cheng 1985). *S. album* has non-superimposed rays of heteromorphic type I and II (Figs. 6a-c and 6f,g). The upright and square ray cells are higher than the procumbent ray cells (Figs. 6f,g). There are 2–3 multi-column part in the same wood ray (Figs. 6d,e). The wood rays are filled with rich brick-red inclusions without crystals, and there is obvious nodular thickening between ray parenchyma cells (Fig. 6h). The mainly large round pits are found between vessels and ray parenchyma cells, with occasional oblique notches (Figs. 6i,j), consistent with Zheng's results for the *Syzygium Gaertn* (2000). *S. album* wood contains 22.30% wood rays (Tab. 1).

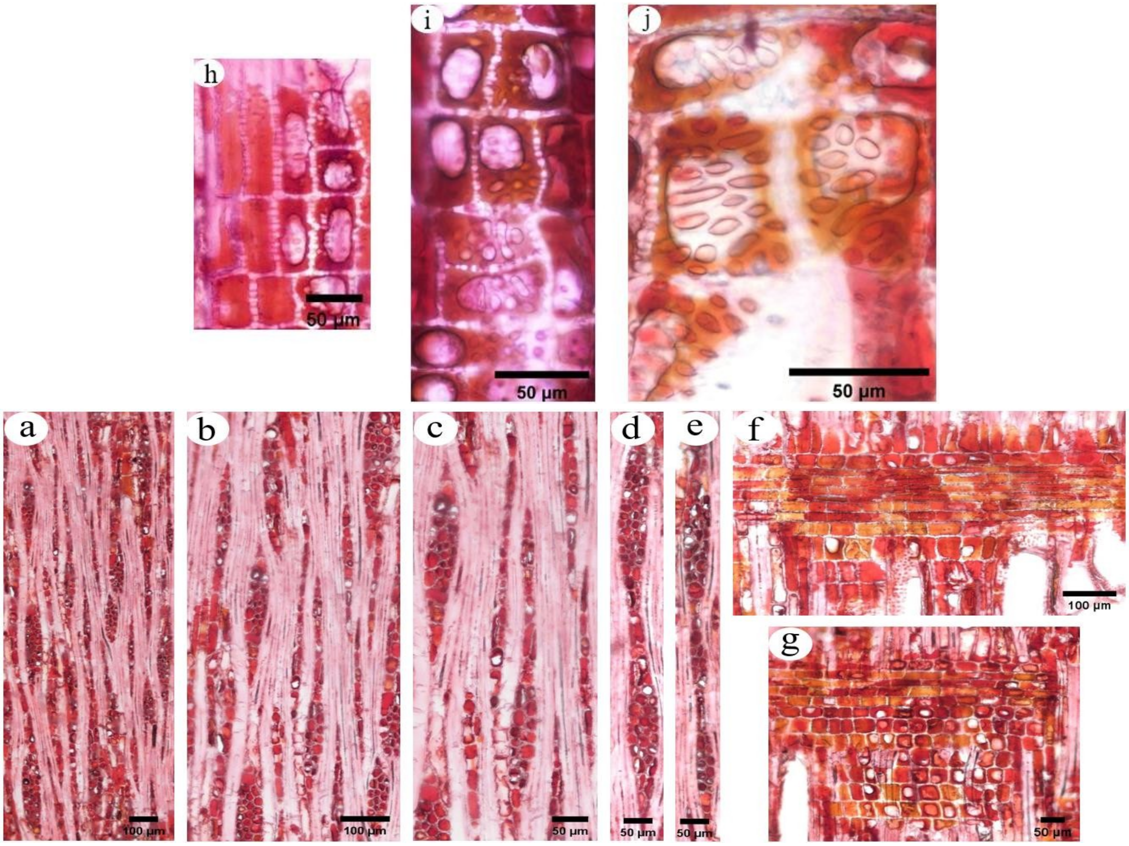

Fig. 6: Microstructure of the wood ray of S. album wood: (a-e) The expression of wood ray on the tangential section, (f,g) The expression of wood ray on the radial section, (h) Nodular thickening between ray parenchyma cells, (i,j) Between vessels and ray parenchyma cells pits arrangement.

Uniseriate rays and fusiform rays both decrease, increase, and decrease again in height, and fusiform rays are higher than uniseriate rays with slight variation (Fig. 7). However, this variation did not reach a significant level in a one-way analysis of variance. Uniseriate rays' width was almost unchanged in the radial direction, indicating that parenchyma cells in a single ray have a relatively constant width, and the one-way analysis of variance showed that differences in ray width were not significant. The Fusiform rays increased and then decreased in width, and this difference was highly significant.

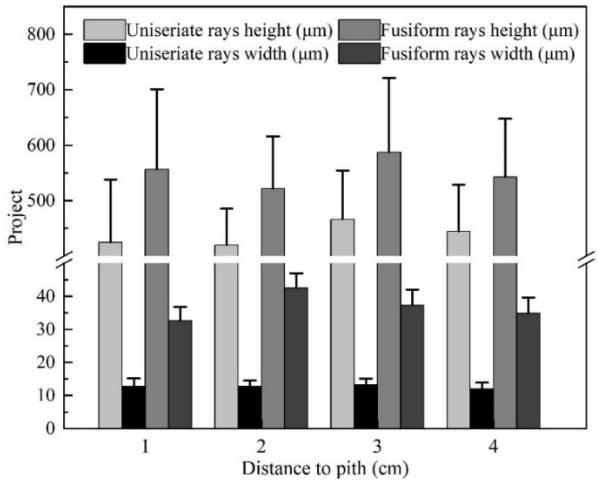

Fig. 7: Radial variation of the wood ray height and width of S. album wood.

Longitudinal parenchyma

Longitudinal parenchyma refers to a group of parenchyma cells formed by the division of spindle-shaped primitive cells, that is, a tissue composed of parenchyma cells arranged along the tree axis (Cheng 1985). *S. album* has many longitudinal parenchyma with ring-tube, ring-tube-band, scattered, and scattered-aggregate shapes, and the ring-tube-band appearing between earlywood and latewood with a width of 1–2 layers (Figs. 8a,b). The longitudinal parenchyma and cell morphology are clearly visible (Figs. 8c,d). The parenchyma shows somewhat obvious thick nodules (Fig. 8e); a portion of the parenchyma is filled with brick red inclusions, and compartmentalized crystal cells with rhombohedral crystals are common (Figs. 8f,g).

Retrieval code according to the IAWA hardwood identification system

The macroscopic and microscopic characteristics of *S. album* wood were written as 7p, 13p, 22p, 29p, 31p, 41p, 53p, 66p, 70p, 72p, 76p, 77p, 79p, 93p, 106p, 107p, 108p, 142p, 152p, and 155p according to the IAWA hardwood microscopic characteristics list, where p refers to present (IAWA Committee 1989, Brandes et al. 2020).

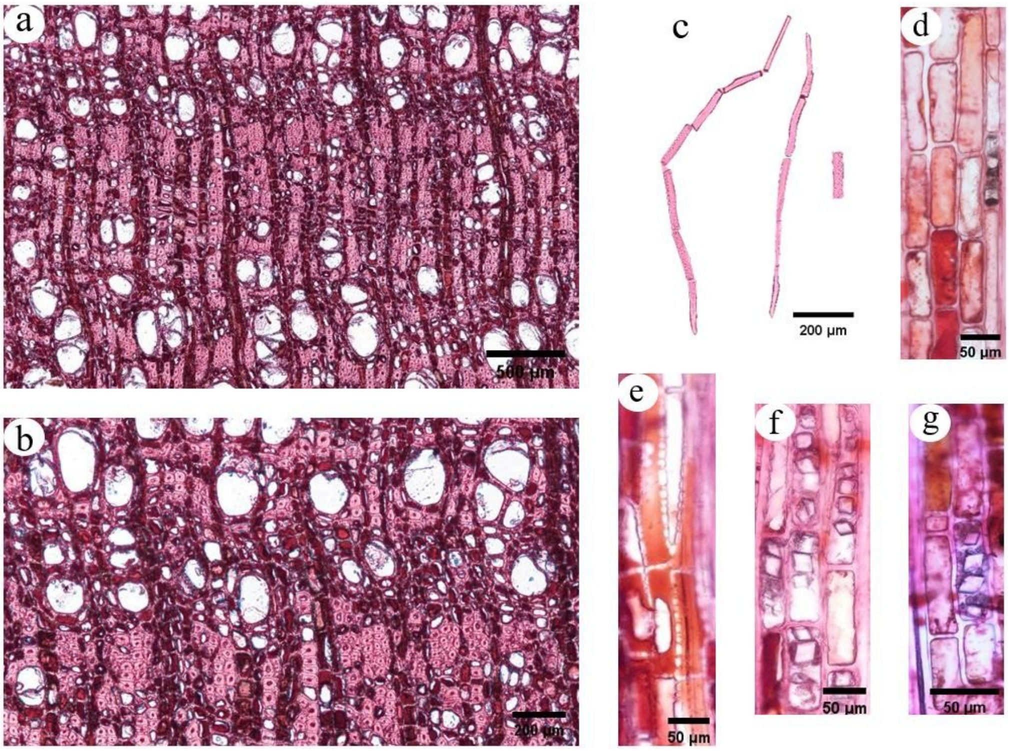

Fig. 8: Microstructure of the longitudinal parenchyma of S. album wood: (a,b) Longitudinal parenchyma arrangement, (c) Longitudinal parenchyma morphology, (d) Longitudinal parenchyma cells morphology, (e) Longitudinal parenchyma intercellular nodular thickening, (f,g) Compartmentalized crystal cells.

Density

S. album wood has a basic density of 0.62 $g{\cdot}cm^{-3}$, an air-dry density of 0.78 $g{\cdot}cm^{-3}$, and an absolute dry density of 0.72 $g{\cdot}cm^{-3}$, all with small standard deviations (Fig. 9a). According to China's wood air-dry density and wood property grading standard, *S. album* wood belongs to the "heavy" grade (0.75–0.95 $g{\cdot}cm^{-3}$) of air-dry density. Referring to the research of Cheng (1980, 1985) and Cheng et al. (1992), the wood properties and utilization of *S. globiflorum (Craib) Chantar. et J. Parnell*, *S. levinei Merr. et Perry*, and *S. szemaoense Merr. et Perry* in the same genus are similar to those of *S. araiocladum Merr. et Perry*, and their basic density (0.68 $g{\cdot}cm^{-3}$) and air-dry density (0.92 $g{\cdot}cm^{-3}$) are both higher than those of *S. album*. *S. tetragonum* Wall. has a higher basic density (0.67 $g{\cdot}cm^{-3}$) than that of *S. album* but a slightly lower air-dry density (0.76 $g{\cdot}cm^{-3}$). *S. cumini (L.) Skeels* has a very slightly lower basic density (0.61 $g{\cdot}cm^{-3}$) and air-dry density (0.76 $g{\cdot}cm^{-3}$). Therefore, *S. album* and *S. cumini (L.) Skeels* appear to have similar physical properties.

Shrinkage characteristics

The cell wall and the entire wood shrinks in size and volume after the wood moisture evaporates, and the rate of change in size and volume is called the shrinkage rate. *S. album* wood exhibits a small standard deviation in wood shrinkage rate, and the total drying shrinkage rate is greater than the air drying shrinkage rate (Fig. 9b), consistent with the results of Zhang et al. (2020). The air-drying differential shrinkage and the full-drying differential shrinkage were 1.41

and 1.65, respectively. According to China's classification standard for differential drying shrinkage of wood, the air-drying differential drying shrinkage of *S. album* wood is "small"(1.21 ~ 1.60), meaning that it shows little warping and cracking when drying and has good dimensional stability. Its dry shrinkage reaches a "medium" grade (Fig. 9a).

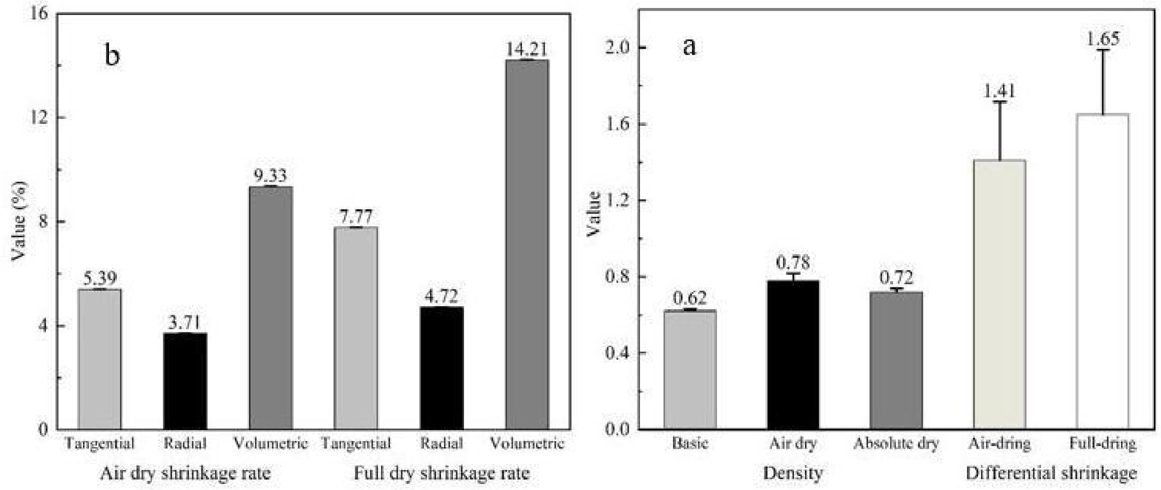

Fig. 9: The main physical properties of S. album wood.

Content of secondary chemical compositions

Secondary components make up a small but versatile fraction of wood, and there is remarkable variation in their identities and locations. They have a very important role and determine the smell, taste, and color of wood, especially for species in subtropical regions (Cheng 1985, Xu et al. 2013). The contents of secondary components are usually measured by extraction in benzene-ethanol mixture, ethanol, ether, acetone, dichloromethane, and water. After benzene-ethanol extraction, *S. album* wood contained 2.10% secondary components.

GC-MS analysis

The GC-MS total ion chromatogram of benzene-ethanol extracts of *S. album* wood is shown in Fig. 10.

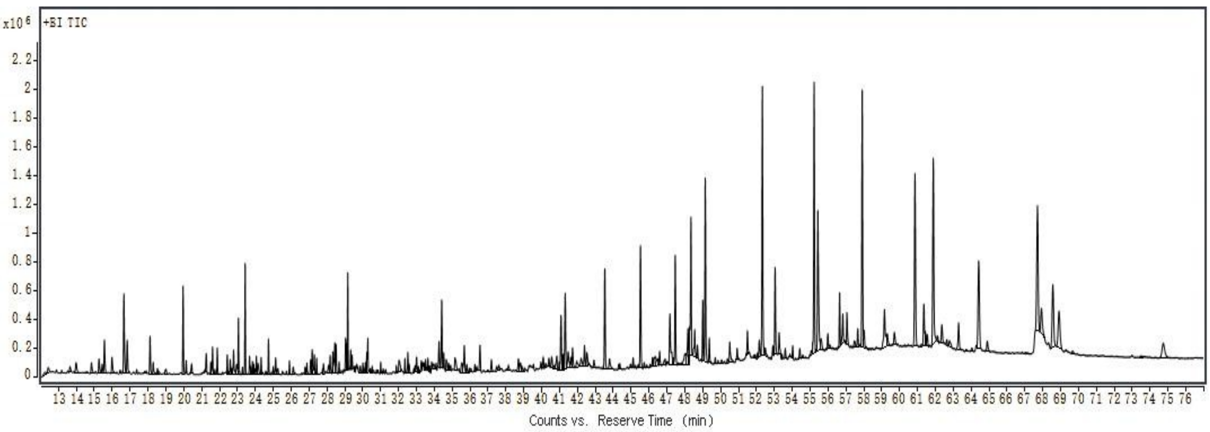

Fig. 10: The GC-MS total ion chromatogram of benzene-ethanol extracts of S. album wood.

According to the NIST11.L mass spectral library, 293 peaks were identified in the GC-MS analysis, and 82 peaks showed a matching degree ≥80%. Forty-six compounds were identified, and the peak areas of them accounted for 47.17% of the total peak area.

The extract contained numerous alkane compounds (28 types) with a relative content of 14.64%; siloxanes had the highest relative content (22.23%) and comprised only four compounds; there were also a small number of olefins (2 compounds), aromatic hydrocarbons (1 compound), amides (1 compound), and esters (10 compounds), the latter with a relative content of 7.79% (Fig. 11).

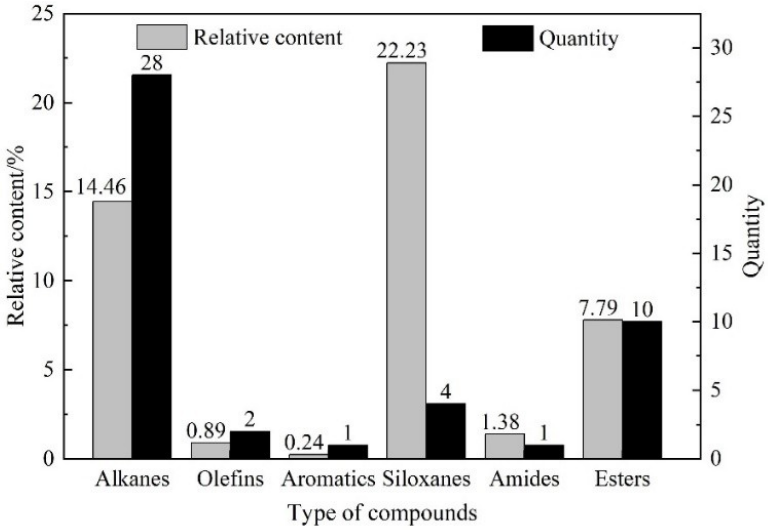

Fig. 11: The type of compounds of benzene-ethanol extracts of S. album wood.

Among compounds with relative peak areas (relative contents) ≥1% (Xu et al. 2015) were 2.92% 4,5-dimethylnonane, 1.18% cyclohexyldimethoxymethyl silane, 1.03% 4,6-dimethyldodecane, 3.29% 2,6,11,15-tetramethylhexadecane, 1.68% hexadecanoic acid ethyl ester, 2.20% oleate ethyl, 10.02% eicosamethyl cyclodecasiloxane, 1.38% oleic acid amide, 7.43% octadecamethyl cyclononasiloxane, and 3.60% tetracosamethyl cyclodode- casiloxane (Fig. 12).

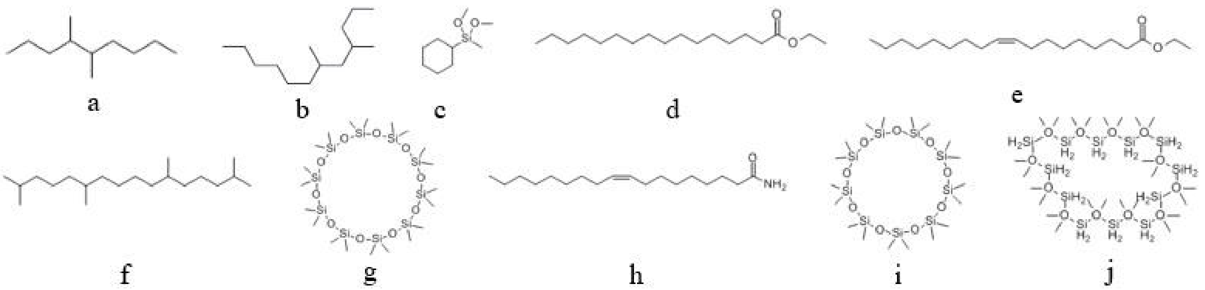

Fig. 12: Chemical structural formulas of substances with relatively high content levels in the benzene-ethanol extracts from S. album wood: (a) 4,5-dimethylnonane, (b) 4,6-dimethyldodecane, (c) Cyclohexyldimethoxymethyl silane, (d) Hexadecanoic acid ethyl ester, (e) Oleate ethyl, (f) 2,6,11,15-tetramethylhexadecane, (g) Eicosamethyl

cyclodecasiloxane, (h) Oleic acid amide, (i) Octadecamethyl cyclononasiloxane, (j) Tetracosamethyl cyclododecasiloxane.

Construction of fingerprint spectrum

The peaks of the main chemical components were taken as the characteristic peaks of the samples based on GC-MS analysis. Without considering the influence of peak height and peak width, a columnar fingerprint was drawn with retention time as the abscissa and the relative content of characteristic peaks as the ordinate. It clearly and intuitively shows the relative contents of the characteristic peaks corresponding to different retention times (i.e. relative peak areas) (Fig. 13) (Xu et al. 2015).

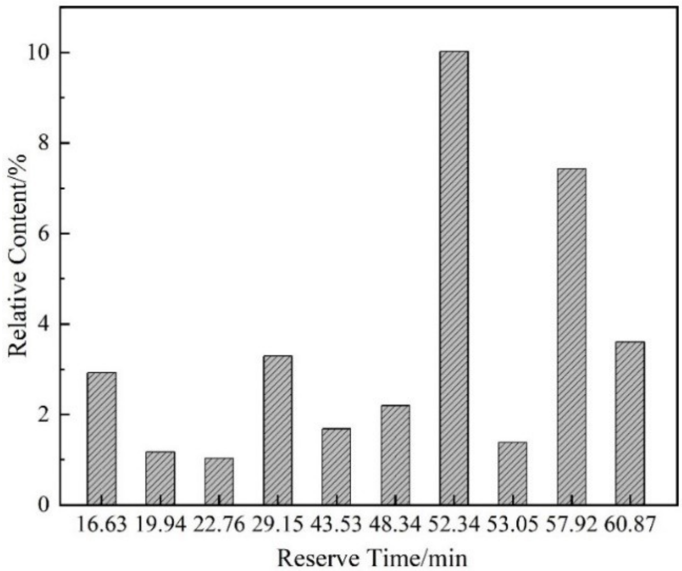

Fig. 13: Fingerprint of S. album wood.

When a sample is suspected to be *S. album*, it can be identified by matching the main compounds and comparing the fingerprints, as too many factors affect the secondary components, leading to differences in the characteristic peaks. As a result, this fingerprint only provides a reference for *S. album* identification based on the GC-MS method.

CONCLUSIONS

The macroscopic and microstructural characteristics of *S. album* were systematically described and quantitatively measured in this study, and a retrieval code was written based on the IAWA list of microscopic characteristics of hardwoods.

The significant features of *S. album* wood are hard with a fine, dense structure. *S. album* wood are the small pores and short-diameter multi-pores (2 ~ 3 pores) in diffuse-porous to semi-diffuse-porous wood and the abundant white crystals in the vessel groove. The wood vessel elements are spindle-shaped and cylindrical. The perforation plates between vessels are slanted with a single perforation. The pits between vessels are arranged alternately, i.e. appendage pits. The vessels account for a large proportion of the wood volume, and the average length and tangential direction diameter reach the "medium" level.

The wood rays are mainly heteromorphic type II, and fusiform rays have a width of 2 to 4 cells (usually 3 cells). There are obvious nodular thickenings between ray parenchyma cells, and filled with rich-brick-red inclusions without crystals. The pits between the vessels and wood ray parenchyma cells are mainly large and round in shape, with occasional oblique row nicks. *S. album* has abundant longitudinal parenchyma with ring-tube, ring-tube-band, scattered, and scattered-aggregate shapes appearing between earlywood and latewood. The parenchyma presents somewhat obvious thick nodules; portions of the parenchyma are filled with brick red inclusions, and compartmentalized crystal cells with rhombohedral crystals are common. The results of anatomical properties are of great significance for the identification and identification of this tree species.

The air-dry density of *S. album* is classified as "heavy" (0.75–0.95 $g \cdot cm^{-3}$), whereas its air-dry and full-dry differential dry shrinkage are "small" (1.21–1.60) and "medium", respectively. The wood physical properties of *S. album* are similar to those of *Syzygium cumini (L.) Skeels* in the same genus. Its high density shows that the mechanical strength is also high, and it has theoretical guiding value for the utilization of wood.

Benzene-alcohol extracts account for 2.10% of *S. album* wood, and 46 compounds were identified by GC-MS, including 14.64% alkanes, 0.89% olefins, 0.24% aromatic hydrocarbons, 22.23% siloxanes, 1.38% amides, and 7.79 % ester compounds. The rich content of its extracts indirectly indicates that the anti-corrosion and antibacterial properties are good. The more silicon-containing compounds may be the result of the trees absorbing minerals from the ground, and existing in the wood in the form of spar will increase the difficulty of wood cutting. The fingerprint established based on the main compounds can provide a reference for wood identification.

This study supplies missing data on the basic wood properties of *S. album*. However, due to the scarcity of samples, the evaluation of some wood properties cannot be completed directly. It will be supplemented when it is widely planted and grown into wood. Nonetheless, it is hoped that these results will provide sufficient theoretical guidance for the use of *S. album* in actual production and processing.

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REFERENCES

1. Brandes, A.F.D.N., Novello, B.Q., Lemos, D.N.D., Nascimento, L.B.D., Albuquerque, R.P., Tamaio, N., Barros, C.F., 2020: Wood anatomy of endangered Brazilian tree species. IAWA Journal 41(4): 510-576.
2. Chandrasekaran, M., Venkatesalu, V., 2004: Antibacterial and antifungal activity of *Syzygium jambolanum* seeds. Journal of Ethnopharmacology 91(01): 105-108.

3. Chen, C., 2021: Tissue culture technique of *Syzygium album*. (In Chinese). Subtropical Agriculture Research 17(03): 200-204.
4. Chen, S.S., 2006: Anatomy of vessel elements in the secondary xylem of *Syzygium samarangense*. (In Chinese). Chinese Bulletin of Botany 23(06): 677-683.
5. Cheng, J.Q., 1980: China tropical and subtropical wood. China Science Press. Beijing, Pp 450-454.
6. Cheng, J.Q., 1985: Wood science. China Forestry Press. Beijing, Pp 1029-1030.
7. Cheng, J.Q., Yang, J.J., Liu, P., 1992: China wood chronicles. China Forestry Press. Beijing, Pp 465-469.
8. Compiling Group of Flora of Fujian., 1990: Flora of Fujian (Volume IV). Fujian Science and Technology Press. Fuzhou, Pp 101-102.
9. Eganathan, P., Saranya, J., Sujanapal, P., Parida, A., 2012: Essential oil composition of leaves of *Syzygium makul* Gaertn. Journal of Essential Oil Bearing Plants 15(05): 827-831.
10. GB/T 1932, 2009: Method for determination of the shrinkage of wood.
11. GB/T 1933, 2009: Method for determination of the density of wood.
12. GB/T 35816, 2018: Standard method for analysis of forestry biomass Determination of extractives content.
13. Hanif, M.U., Hussain, A.I., Aslam, N., Kamal, G.M., Chatha, S.A.S., Shahida, S., Khalid, M., Hussain, R., 2020: Chemical composition and bioactivities of essential oil from leaves of *Syzygium cumini (L.) Skeels* Native to Punjab, Pakistan. Chemistry Biodiversity 17(08): e1900733.
14. Huang, X.D., Liu, J.Q., 2003: Characters of leaf epidermis seven species of *Syzygium* in Fujian. (In Chinese). Life Science Research 7(04): 329-335.
15. IAWA Committee., 1989: IAWA list of microscopic features for hardwood identification. IAWA Journal 10(03): 219-332.
16. Liu, D.C., Jiang, R.R., Chen, X.C., Fang, Z.F., 2017: Rapid propagation technology of *Syzygium album* cuttage. (In Chinese). Protection Forest Science and Technology (08): 30-34.
17. Qin, H.N., Zhao, L.N., Yu, S.X., Liu, H.Y., Liu, B., Xia, L.H., Peng, H., Li, Z.Y., Zhang, Z.X., Ying, L.K., Lin, Y.L., Liu, Q.R., Hou, Y.T., Liu, Y., Liu, Q.X., Cao, W., Li, J.Q., Chen, S.L., Jin, X.H., Gao, T.G., Chen, W.L., Ma, H.Y., Geng, Y.Y., Jin, X.F., Chang, Z.Y., Jiang, H., Cai, L., Zang, C.X., Wu, J.Y., Ye, J.F., Lai, Y.J., Liu, B., Lin, Q.W., Xue, N.X., 2017: Evaluating the endangerment status of China's angiosperms through the red list assessment. (In Chinese). Biodiversity Science 25(07): 745-757.
18. Schmid, R., Baas, P., 1984: The occurrence of scalariform perforation plates and helical vessel wall thickenings in wood of Myrtaceae. IAWA Journal 5(03): 197-215.
19. Soh, W.K., Parnell, J., 2011: Comparative leaf anatomy and phylogeny of *Syzygium Gaertn*. Plant Systematics and Evolution 297(1-2): 1-32.
20. Tang, Y., 1975: Yunnan tropical wood. China Science Press. Beijing, Pp 31-32.
21. Vliet, G.J.C.M., Baas, P., 1987: Wood anatomy and classification of the Myrtales. Missouri Botanical Garden 71(03): 783-800.

22. Wei, G.Y., 1988: Southeast Asian wood. Anhui Science and Technology Press. Hefei, Pp 177-180.
23. Wu, D.Q., 2014: Phenological observation of *Syzygium album*. (In Chinese). Land Greening (09): 38-39.
24. Xu, B., Zhu, T., Li, J.Y., Liu, S., 2013: Identification of wood between *Phoebe zhennan* and *Machilus pingii* using the gas chromatography-mass spectrometry direct injection technique. European Journal of Mass Spectrometry 19(03): 187-193.
25. Xu, B., Zhu, T., Liu, S., Zhang, H., 2015: Comparison between different sampling methods on gas chromatography–mass spectrometry analysis of *Pterocarpus santalinus*. Forest Products Journal 65(5-6): 226-231.
26. Zhang, P.J., Shang, X.H., Wu, Z.H., 2020: Difference in wood physical and mechanical properties of five kinds of *Eucalyptus*. (In Chinese). Journal of Northwest Forestry University 35(04): 184-190.
27. Zhang, Y.Z., 2021: Establishment of cuttings orchards for *Syzygium album*. (In Chinese). Chinese Journal of Tropical Agriculture 41(09): 33-36.
28. Zheng, Q.F., 2014: Endemic tree species in Fujian. Xiamen University Press. Xiamen, Pp 45-46.
29. Zheng, S.Q., Yang, W.Q., Fang, Z.F., Zheng, N., Liu, J.F., Lin, K.Q., Xiao, L.F., Li, L., 2021: Population status and protection evaluation of *Syzygium album*,a species with extremely small population. (In Chinese). Chinese Journal of Applied Ecology 32(01): 103-112.
30. Zheng, X.F., Wu, S.M., 2000: Studies on comparative wood anatomy of twenty-one species in nine genera of *Myrtaceae*. (In Chinese). Acta Scientiaum Naturalium Universitatis Nankaiensis (Natural Science Edition) 33(01): 23-28

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