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Anatomical Features Affecting Safranine Solution Permeability in *Anthocephalus chinensis* (Lam.) Rich. ex Walp.[1]

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ABSTRACT

This report describes the wood anatomy and 1% safranine solution penetration depth in radial and longitudinal directions of *Anthocephalus chinensis* belonging to the family Rubiaceae native to Bangladesh. The wood of this species was mostly characterized by diffuse porous, vessel with simple perforation plate, vestured alternate intervessel pittings, relatively medium vessel elements and fiber, and nonseptate fiber with distinctly bordered pits at radial wall. The body ray cell was procumbent with 2 to over 4 rows of upright and square marginal cells. Sometimes, the rays with procumbent, square and upright cells were mixed. Latewood fiber was thin to thick walled while it was very thin walled in earlywood. Axial parenchyma was diffuse, vasicentric, 5-8 cells per parenchyma strand dominantly present. Liquid penetration depth was observed in radial and longitudinal directions at moisture level of 7.42%. Longitudinal penetration was found 6.3 times higher than radial penetration. The initial penetration rate of safranine solution was high, but gradually decreased during the course of time. Different anatomical features were found to be responsible for the variation of safranine solution penetration depth compared to *Gmelina arborea*.

Key words: Wood anatomy, Hardwood, Diffuse-porous wood, Safranine solution, Penetration depth.

INTRODUCTION

Rubiaceae is a family of flowering plants, variously called the madder, bedstraw, or coffee family. As now circumscribed, there are about 600 genera and more than 10,000 species in the family Rubiaceae. The genera are distributed into tribes and placed in one of the three recognized subfamilies 1. Rubioideae, 2. Cinchonoideae and 3. Ixoroideae.

The species is found from Nepal eastward to Bangladesh, India (Assam province and Chotanagpur district at Bihar Province, Myanmar (Burma), Sri Lanka, the Philippines, Indonesia, and Papua New Guinea (Whitmore 1984). *Anthocephalus chinensis* is a large, deciduous (or some-times evergreen), and fast-growing species with spreading branches (Troup 1921; Zabala 1990). The leaves are simple, opposite, 12 to 25 cm by 5 to 10 cm, ovate, elliptic-oblong, shining, coriaceous and glabrous above, and pubes-cent beneath (Brandis 1921; Zabala 1990). This tropical wood species is taken under consideration to know the permeability which can be compared to native Korean wood species. Also this paper describes different anatomical features to identify this species. Permeability of safranine solution in radial and longitudinal direction of *Anthocephalus chinensis* was also described and the penetration depth variations due to anatomical features are discussed briefly. This knowledge can be applied for wood treatment and drying.

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MATERIALS AND METHODS

Wood identification

Wood samples of *Anthocephalus chinensis* (Lam.) Rich. ex Walp. are obtained from different wood suppliers in Bangladesh. Microscopic slides and macerations were made according to standard techniques (Baas and Zhang 1986). Samples for FE-SEM (Field Emission Scanning Electron Microscope) were prepared as did in Exley et al. (1977). At different resolution and magnification, the samples were observed under FE-SEM, including macerated cells. The terminology and the method for determining quantitative features conform to the recommendations by the IAWA Feature List (IAWA Committee 1989).

Sample preparation

Only radial and longitudinal directions were considered. Samples of 6 cm (long) x 1 cm (radial) x 0.5 cm (tangential) were made from air-dried wood. As longitudinal penetration was observed on radial surface, the same sample was used for measuring the permeability in two directions. Samples were sealed with silicon resin except one radial and one tangential surface for the radial penetration experiment while in longitudinal penetration experiment; it was one radial and one cross section. This was done to prevent the leakage by other surfaces. Three replications were done for each direction and 7 measurements were performed in every replication.

Camscope observation

The safranine solution penetration behavior was observed by ***i***-camscope (SV32).

Preparation of 1% safranine solution

In 1L volumetric flask 10g of safranine powder was taken and 500ml of 50% ethyl alcohol was added. After mixing properly, distilled water was added upto the mark.

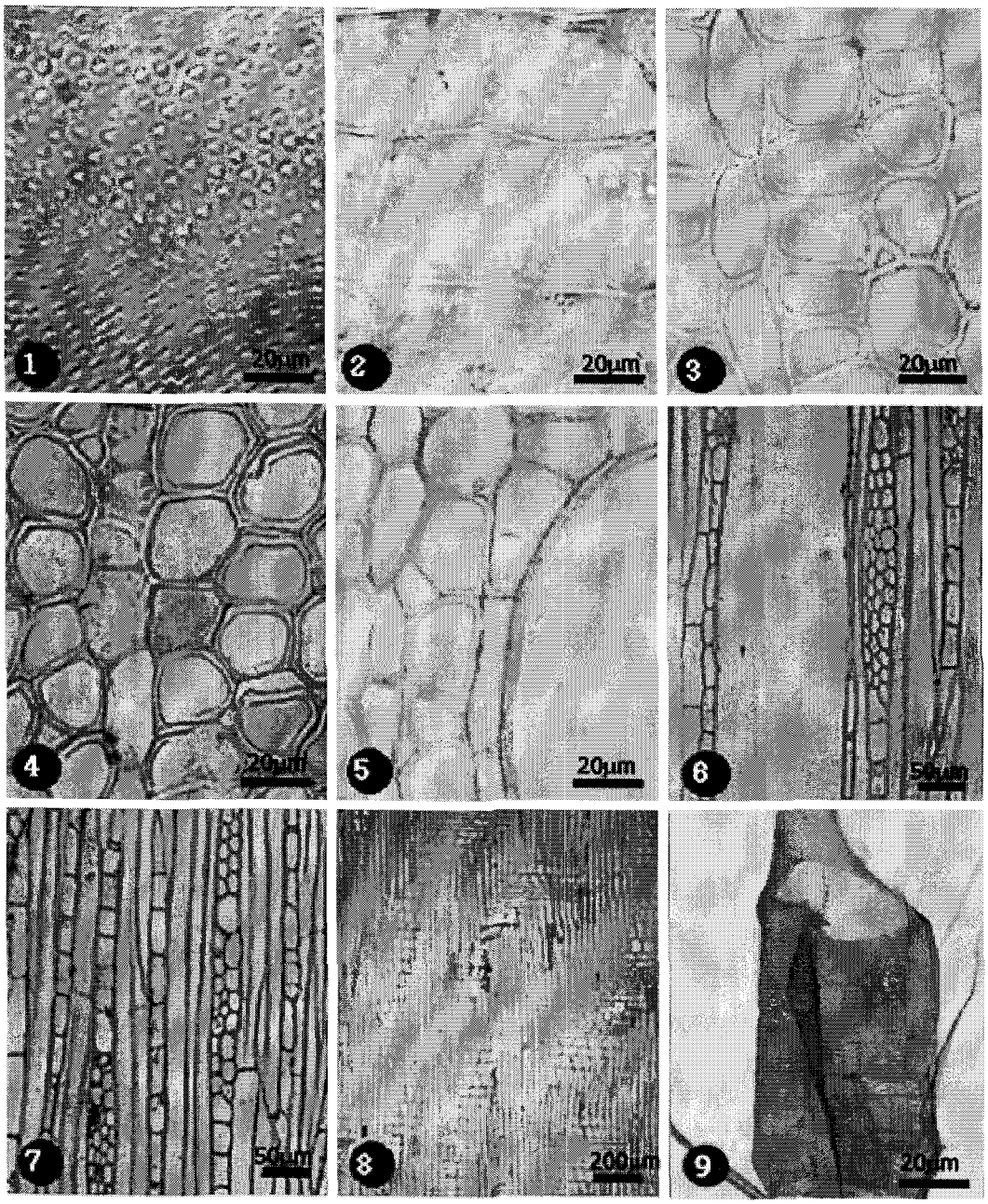
Observation

Moisture content in wet weight basis was recorded just before the safranine solution permeability test. While observing the safranine solution penetration, the room temperature was 24°C and the wind speed was 0m/s. The coated sample was fixed on a petridish and the safranine solution was poured on it. Safranine solution penetration was observed by ***i***-camscope (SV32). With ***i***-Solution software, the safranine solution impregnation video file was captured for 5-minutes. This 5 minutes video file consisted of 300 frames. Specific frames were selected at 1, 2, 3, 4 and 5 minutes by VitrualDub-MPEG2 software.

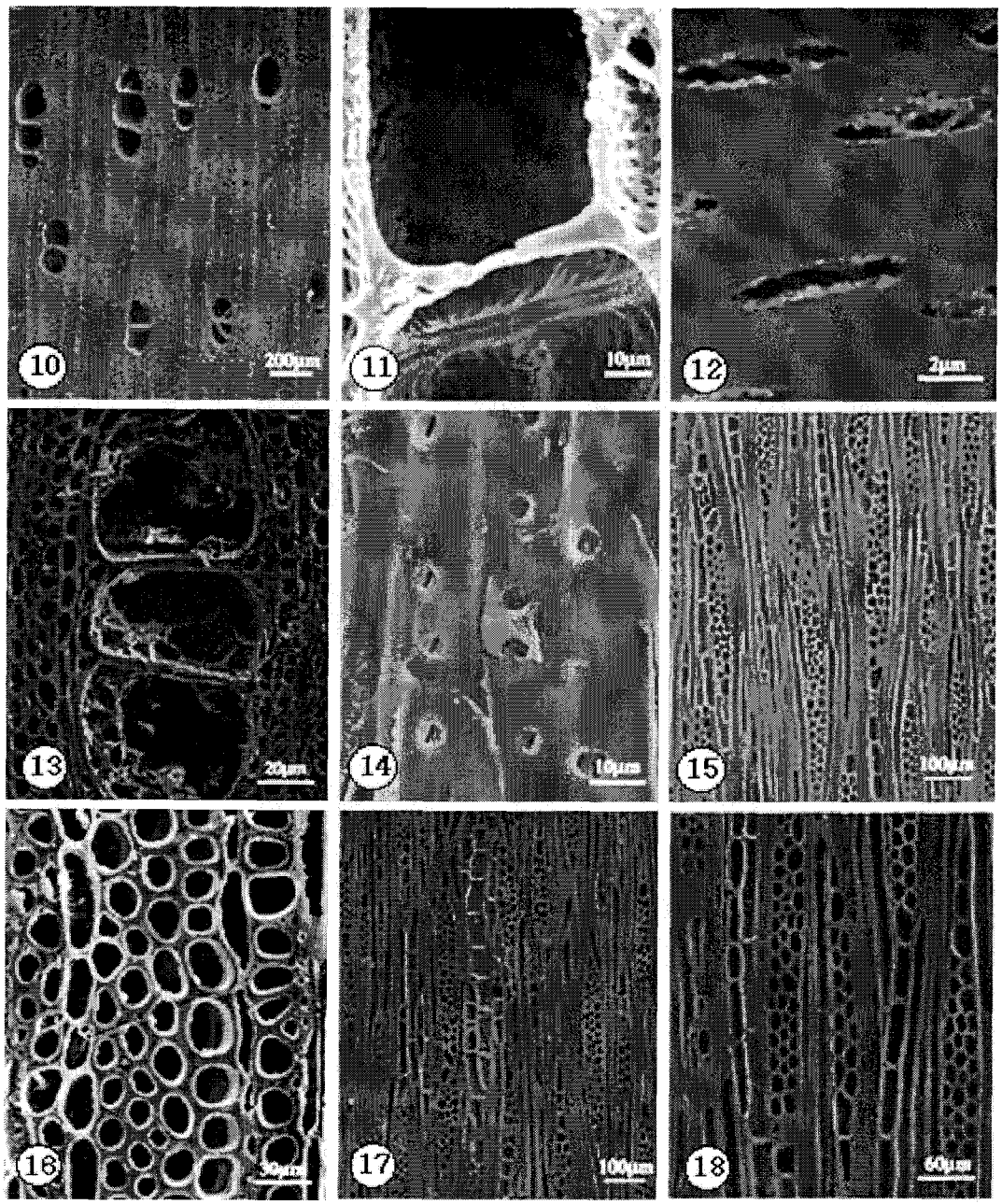
RESULTS AND DISCUSSION

Wood anatomical features

This tropical wood species was characterized with diffuse porous; indistinct growth ring boundaries (Fig.10); simple perforated vessels (Fig. 11) arranged in multiples (2–4 vessels) and in radial rows (Fig.10); 4-10 vessels per sq. mm; vessel with vestured (Fig. 12) polygonal alternate intervessel pits (Fig. 1); vessel-ray pits with distinct borders similar to intervessel pits in size and shape throughout the ray cell (Fig. 2); tyloses present in vessels (Fig. 13); non-septate (Fig. 15) fibers with distinctly bordered pits (Fig. 14); apotracheal axial parenchyma diffuse (Fig. 4) while paratracheal axial parenchyma vasicentric (Fig. 5); axial parenchyma present as strands and average 2-8 cells per axial parenchyma strand (Fig. 17).



Figs.1-9. Observed by optical microscope. -Fig.1. Intervessel pit alternate and polygonal. -Fig.2. Vessel-ray parenchyma pits. -Fig.3. Very thin walled fibers. -Fig. 4. Axial parenchyma diffuse. -Fig.5. Vasicentric axial parenchyma. -Fig.6. Larger rays commonly 3 to 4 seriate. -Fig.7. Rays with multiseriate portions as wide as uniseriate portions. –Fig.8. Procumbent body ray cells with over 4 rows of upright and/or square marginal cells. -Fig.9. Macerated vessel.



Figs.10-18. Observed by FE-SEM. -Fig.10. Distinct growth ring boundaries. wood diffuse-porous. vessels in short radial multiples. -Fig.11. Simple perforation plate. -Fig.12. Vestured pit. -Fig.13. Tyloses. -Fig.14. Fiber with bordered pit. -Fig. 15. Non-septate fiber. -Fig.16. Thin to thick walled fibers. -Fig.17. Two-eight cells per parenchyma strand. -Fig.18. Ray width 1 to 3 cells.

Number of ray cells per millimeter were 9 (sd=1.96, range 5-13). Ray width was1-3 cells (Fig. 18) which was dominantly present. Larger rays were commonly 3-4 seriate (Figs. 6, 18). Rays with multiseriate portions were as wide as uniseriate portions (Fig. 7). Multiseriate rays were composed of procumbent rays with 2 to over 4 rows of square/upright (Fig. 8) or procumbent rays. Square and upright cells were mixed throughout the rays (Fig. 8). Ray height and number of ray cells were varied due to uniseriate and multiseriate rays. Ray cell lumen diameters were varied from body ray cells to marginal ray cells.

Wood of this species has commercial importance. The basic specific gravity was as low as ≤0.40. The color of heartwood was basically yellow or the shade of yellow. It had no distinctive odor. The water extract was basically yellow or the shade of yellow. The ethanol extract was basically colorless to yellow or the shade of yellow. Negative responses were reported for the Froth and Chrome Azurol-S tests. The splinter burned to a full ash, and the color of ash was white.

Safranine solution penetration observed by Camscope

The moisture content of this species was found 7.42%. It is known that moisture content plays an important role for the impregnation of liquid in wood. And the permeability of some wood species decreases with increased moisture content (Comstock 1968). Above the fiber saturation point, wood can still take up water by absorption or capillary action until the cell cavities are filled with liquid water (Browning 1963). In this experiment, different moisture content effect on the safranine solution penetration depth was not considered.

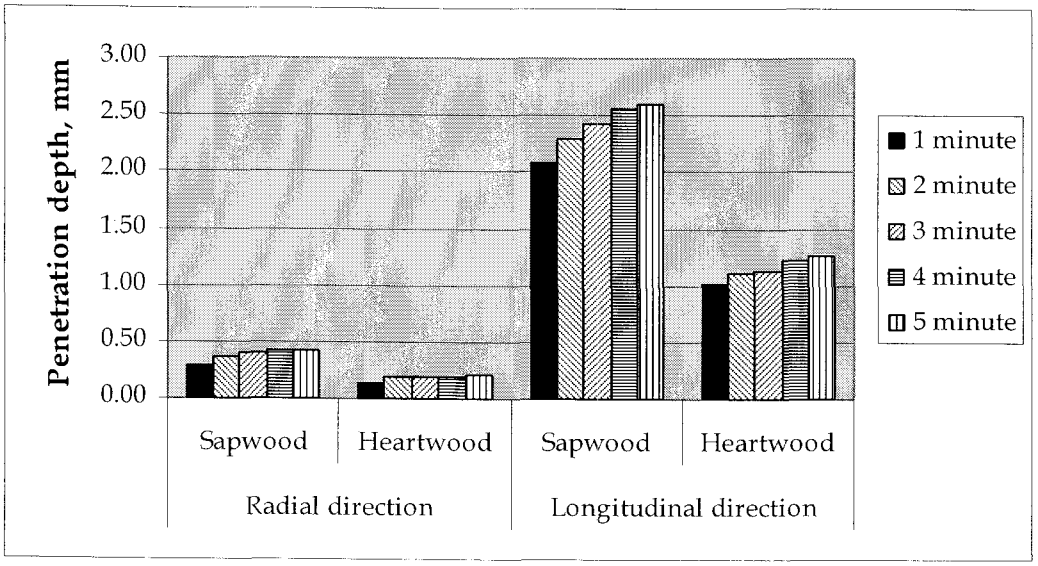


Fig.19. Bar graph showing longitudinal and radial penetrations of safranine solution.

From the Figure 19, it is clear that sapwood penetration was higher than that of heartwood. In radial direction, ray cells are joined together to form a capillary structure which allows a pathway for safranine solution impregnation. It has been reported that ray parenchyma cells are important channels for radial flow in some species (Chong et al. 2007). Safranine solution input may vary due

to the ray parenchyma's diameter, length, endwall pitting and lateral wall pitting. Following same methodology, safranine solution impregnation depth was reported in *Gmelina arborea*, a diffuse porous wood species by Ahmed and Chun (2007). They reported that the radial conduction of safranine solution after 5 minutes of treatment was about 0.27 mm by ray parenchyma at 8.59% wood moisture level. But in this experiment we found the safranine solution penetration depth about 0.32mm. This variation can be explained by the wood moisture content, ray cell lumen diameter, endwall pit number, endwall pit diameter and ray cell length difference between two species. We found the ray cell lumen diameter of *Gmelina arborea* and *Anthocephalus chinensis* about 11.87 and 17.75μm, endwall pit number 18 and 26, endwall pit diameter 1.15 and 1.69μm, ray cell length 58.44 and 46.22μm respectively. In sapwood and heartwood, ray with higher number of endwall pit and larger diameter of endwall pits increased the penetration depth, because safranine solution is thought to be faced fewer obstacles to pass trough. In case of heartwood, the formation of deposits subsequently reduces the permeability of heartwood (Kumar and Dobriyal 1993). As a result, heartwood penetration was found lower than sapwood.

In longitudinal direction, the size, distribution and condition of the vessels are an important factor for the treatment of hardwood (Wang and DeGroot 1996). Longitudinal penetration was found 6.3 times higher than radial penetration. Because the fluid flowing longitudinally does not need to pass through the pits but in transverse flow between the vessels and other conducting cells, fluid has to pass through pits (Bao 1999). Though the same kinds of anatomical features were present in sapwood and heartwood, the heartwood penetration was found to be generally poor. Various gummy, resinous and chalky exudates often form in vessel lumens with the heartwood (Hillis 1987). We measured the anatomical features of *Gmelina arborea* which was used by Ahmed and Chun (2007) to compare the safranine solution penetration depth differences. We found the vessel tangential diameter of *Gmelina arborea* and *Anthocephalus chinensis* 156.26 and 154.09μm, vessel length 294.82 and 614.21μm, fiber tangential diameter 14.05 and 16.29μm, fiber length 987.57 and 1105.82μm respectively. Also in *Gmelina arborea*, fiber is septate with simple to minutely bordered pit. It is reported that the capillary pressure is high in narrow cell lumen compared with wider one (Chun and Ahmed 2006). Long vessel, fiber and narrow vessel made *Anthocephalus chinensis* more permeable than *Gmelina arborea*. Also the septate fiber in *Gmelina arborea* is thought to be another reason for its lower permeability.

During first minute, safranine solution penetration was found high and penetration speed was gradually declined. After 1 minute of penetration in radial direction, the speed of safranine solution impregnation was reduced to 77% at 2 minute, 93% at 3 minute, 97% at 4 minute and 96% at 5 minute of penetration. While in longitudinal direction, it reduced upto 91% at 2 minute, 95% at 3 minute, 94% at 4 minute and 98% at 5 minute of penetration. It means that penetration speed did not reduce following a specific pattern. Sometimes the penetration declination speed became low and sometimes it was little bit high. But it is obvious that safranine solution or any liquid penetration depth in wood can be increased by prolonging the treatment time.

CONCLUSIONS

The wood anatomy of *Anthocephalus chinensis* was characterized by indistinct growth ring boundaries, diffuse-porous, vessel arranged multiples and in radial rows, vessel with simple perforation plates, intervessel pits alternate, vestured and polygonal, vessel-ray pits with distinct borders similar to intervessel pits in size and shape throughout the ray cell. Tyloses were present in heartwood vessel, fiber with distinctly bordered pits, non-septate, diffuse apotracheal axial parenchyma. Paratracheal axial parenchymas were vasicentric. Multiseriate rays were composed of

procumbent ray with 2 to over 4 rows of square/upright or procumbent, square and upright cells were mixed throughout the ray. On the other hand, the penetration rate of safranine solution was found highest at 1 minute, but gradually decreased during the course of time. A higher penetration depth was observed in longitudinal direction. Heartwood was found to be difficult for safranine solution impregnation compared with sapwood. Different anatomical features like ray parenchyma lumen diameter, endwall pit number and diameter, vessel length and diameter, fiber length were found responsible for the variation of safranine solution penetration depth.

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