United States
Department of
Agriculture

Forest Service

Forest
Products
Laboratory

Research
Paper
FPL–RP–632

Separation of *Dalbergia nigra* from *Dalbergia spruceana*

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Abstract

The wood anatomical characteristics of *Dalbergia nigra* and *Dalbergia spruceana* are too similar to permit reliable species separation, which is sometimes important because *D. nigra* is a Convention on International Trade in Endangered Species-protected species whereas *D. spruceana* is not. However, the density, water fluorescence, and ethanol fluorescence of heartwood specimens are different between the species and these chracteristics permit the separation of the species. *Dalbergia spruceana* is denser (≥1.0 g/cm^3) than *D. nigra* (<1.0 g/cm^3), its water extract is fluorescent whereas that of *D. nigra* is not, and its ethanol extract fluorescence is blue whereas that of *D. nigra* is greenish-blue.

Keywords: *Dalbergia nigra, Dalbergia spruceana*, density, fluorescence

January 2006

Miller, Regis B.; Wiemann, Michael C. 2006. Separation of *Dalbergia nigra* from *Dalbergia spruceana*. Research Paper FPL-RP-632. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 5 p.

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Separation of *Dalbergia nigra* from *Dalbergia spruceana*

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Introduction

From time to time, the USDA Forest Products Laboratory Center for Wood Anatomy Research (CWAR) receives requests concerning the possible importation of wood species that are on the Convention on International Trade in Endangered Species (CITES) list of prohibited species (www.cites.org). Among the species of *Dalbergia*, only *Dalbergia nigra* (Vell.) Allem. ex Benth. is listed on CITES Appendix I: Species that are threatened with extinction (Environment Canada 2002). Its harvest is prohibited by CITES. *Dalbergia nigra* (Brazilian rosewood) has long been a timber of commerce. It is native to the Brazilian Atlantic Forest in the states of Bahia, Espiritu Santo, Minas Gerais, Paraná, Santa Catarina, and São Paulo (Alves Camargos et al. 2001) and is still harvested illegally.

Although there are many other tree species of *Dalbergia* in Brazil, most of them are not commercially valuable. Alves Camargos et al. (2001) list 15 species, and de Carvalho (1997) lists 13 tree species, plus 26 species that are lianas or shrubs. The ones that are commercially important include kingwood (*D. cearensis* Ducke), tulipwood (*D. decipularis* Rizzini & A. Mattos; syn. *D*. aff. *frutescens* (Vell.) Britton), and Amazon rosewood (*D. spruceana* Benth.) (Kribs 1968, Record and Hess 1943). Some are easily identified to species. *Dalbergia decipularis* is ring-porous and *D. cearensis* has numerous small (<100 µm) vessels, which make these species distinct from *D. nigra* and *D. spruceana*. However, *D. nigra* and *D. spruceana* cannot be easily separated on the basis of anatomy. They both have large (>200 µm) vessels, storied rays, and axial parenchyma that is both aliform and in apotracheal bands, as well as other similar macroscopic and microscopic anatomical features. The CITES Identification Guide (Environment Canada 2002) illustrates the wood anatomical features useful in distinguishing among these woods. The natural range of *D. spruceana* is the Amazon Basin, primarily the states of Amazonas and Pará (Alves Camargos et al. 2001), and it does not overlap that of *D. nigra*, endemic to the Atlantic Forest, so the two species can be distinguished if provenance is known.

We sought a simple method to separate *D. nigra* from *D. spruceana* on the basis of physical and chemical characteristics of the woods. An informal comparison of the specimens from the CWAR wood collections suggested that density might be a useful tool, and some specimens were annotated to show fluorescence under UV light. Therefore, we decided to conduct a more controlled study to determine if density and fluorescence could separate the species' woods.

Materials and Methods

We assembled all specimens of the two species from the FPL wood collection, which consists of two parts: the original Madison collection (MADw), which started in 1911, and the Samuel J. Record collection (SJRw), which started in 1905 and was donated by Yale University in 1970 (Stern 1988). Thirty-two of these were identified as *D. nigra* and six as *D. spruceana* (Table 1.) Some of the specimens were trade or non-vouchered specimens of unknown provenance, one was a branch covered by bark, some were veneer or too small to obtain accurate density measurements, some were duplicates, and some contained sapwood. The yellowish sapwood is often of lower density than the dark-colored heartwood and does not exhibit fluorescent properties. The collection numbers of the *D. nigra* and *D. spruceana* specimens of known origin that were 100% heartwood are listed in Table 2. The specimens were subdivided into three groups for analysis. Group 1 included the specimens that could reasonably be considered authentic and contained no sapwood. Group 2 included the specimens that contained sapwood. For this group, the percentage of sapwood was estimated visually for each specimen, and the extracts were taken from the heartwood portion when possible. Group 3 included heartwood specimens that may not have been correctly identified; for example, those labeled as trade specimens.

All the specimens were at the ambient equilibrium moisture content of the FPL wood collections, which is 6% to 7%. The density of each specimen (except the veneer, the bark-covered branch, and one of each of the duplicates) was measured using the water displacement method described by Heinrichs and Lassen (1970), which is as follows. The dry weight of each specimen was measured on a balance with a weighing range of 0 to 5000 g and a precision of 0.1 g. Each specimen was then placed in a weighted, tared, wire mesh cage suspended from the weighing pan of the same balance. Below the balance was a large (45-cm-diameter, 40-cm-deep) plastic tub that contained water to about two-thirds of its depth.

Table 1. Brazilian specimens identified as *Dalbergia nigra* or *Dalbergia spruceana*.

Xylarium	No.	Species	Location notes	Collector notes	Collection date	Voucher	Sample notes
MADw[a]	7017	*D. nigra*	Bahia	Curran, H.M., 6		MAD	Botanical material identified by Dr. Blake; SJRw 4146
MADw	10769	*D. nigra*	Collantina, Espirito Santo	Whitford, H.N., 76	July 1918	MAD	Received from Smithsonian Institute, 3/6/1928; SJRw 3273
MADw	13091	*D. nigra*	Espirito Santo	Brazilian Forest Service, 6	Nov. 1949	none	
MADw	21010	*D. nigra*				none	Received from National Rifle Association of America; USw 7343
MADw	23334	*D. nigra*		Instituto Florestal De Sao Paulo		none	Gift Set 57
MADw	31954	*D. nigra*		Columbian Exposition	1893	none	Received in 1971 from Field Museum; Fw 01050
MADw	31955	*D. nigra*		Columbian Exposition	1893	none	Received in 1971 from Field Museum; Fw 01132
MADw	31956	*D. nigra*		Columbian Exposition	1893	none	Received in 1971 from Field Museum; Fw 01133
MADw	31957	*D. nigra*		Hildebrand, 17			Received in 1971 from Field Museum
MADw	31958	*D. nigra*	Rio de Janeiro	Jardim Botânico, 19		F, RB	Received in 1971 from Field Museum
SJRw[b]	550	*D. nigra*				none	Veneer (1 mm)
SJRw	1442	*D. nigra*	Lower Amazon	Brewer Collection		none	Determined by S.J. Record
SJRw	3107	*D. nigra*	Rio de Janeiro	Whitford, H.N., 7	Aug. 1918	none	Trade sample
SJRw	3222	*D. nigra*	Espirito Santo	Whitford, H.N., 42	July 1918	none	Determined by S.J. Record
SJRw	3273	*D. nigra*	Collantina, Espirito Santo	Whitford, H.N., 76	July 1918	MAD	Received from Smithsonian Institute, 3/6/1928; MADw 10769
SJRw	3301	*D. nigra*	Escura, Minas Gerais	Whitford, H.N., 1	1918	none	Trade sample; determined by S.J. Record
SJRw	3302	*D. nigra*	Escura, Minas Gerais	Whitford, H.N., 2	1918	none	Trade sample; determined by S.J. Record
SJRw	3303	*D. nigra*	Minas Gerais	Whitford, H.N., 3	1918	none	Trade sample
SJRw	3509	*D. nigra*	Pedras Pretas, Bahia	Curran, H.M., 370A	1918	MAD	
SJRw	3525	*D. nigra*	Jequié, Bahia	Curran, H.M., 386	1918	MAD	Determined by S.J. Record
SJRw	4146	*D. nigra*	Rio Grongogy, Bahia	Curran, H.M., 6		MAD	Botanical material identified by Dr. Blake; MADw 7017
SJRw	4230	*D. nigra*			Aug. 1920	none	Donated to C.M. Richards by missionary; determined by S.J. Record
SJRw	4296	*D. nigra*	Cotete, Bahia	McCall, Henry J., 27	1920	none	Donated to C.M. Richards; determined by S.J.Record
SJRw	4452	*D. nigra*				none	From J.H. Monteath Co., NY
SJRw	5900	*D. nigra*				none	From C.H. Pearson, NY
SJRw	5990	*D. nigra*				none	From W.W. Rowlee, Cornell University
SJRw	6001	*D. nigra*				none	From W.W. Rowlee, Cornell University
SJRw	32586	*D. nigra*			June 13, 1936	none	From J.H. Monteath Co., NY
SJRw	36063	*D. nigra*	Espirito Santo		Dec. 9, 1938	none	From Paulo F. Souza
SJRw	38188	*D. nigra*			June 1, 1940	none	From W.J. Hutchinson
SJRw	38189	*D. nigra*			June 1, 1940	none	From W.J. Hutchinson
SJRw	53033	*D. nigra*	Minas Gerais	H.S. Irwin, 2025		MAD	4-cm-diameter branch with bark
MADw	18588	*D. spruceana*	Rio Juruá, Amazonas	Krukoff, B.A., 4921	1933	NY	Fourth Expedition to Brazil, received from Syracuse
MADw	31968	*D. spruceana*		Ducke 150		MAD	Received in 1971 from Field Museum; SJRw 22610
SJRw	1430	*D. spruceana*	Lower Amazon	Brewer Collection		none	Determined by S.J. Record
SJRw	4014	*D. spruceana*	Pará	Museu Goeldi			
SJRw	22610	*D. spruceana*	Brazilian Amazon	Ducke 150	Jan. 14, 1933	MAD	Received in 1971 from Field Museum; MADw 31968
SJRw	38248	*D. spruceana*	Pará		June 1, 1940	none	From W.J. Hutchinson

[a]MADw, the original Madison collection, which started in 1911.

[b]SJRw, the Samuel J. Record collection, which started in 1905 and was donated by Yale University in 1970 (Stern 1988).

Table 2. Weights, densities, and fluorescent properties of the two *Dalbergia* species whose origin is known, whose identification is reliable, and that do not contain sapwood (specimens arranged by ascending density for each species).

Specimen	Air-dry weight (g)	Density (g/cm^3)	Fluorescence		
			Surface	Water extract color	Ethanol extract color
Dalbergia nigra					
MADw[a] 13091	51.1	0.76	no	none	greenish blue
SJRw[b] 3525	100.3	0.79	no	none	greenish blue
SJRw 3303	104.8	0.80	no	none	greenish blue
SJRw 4296	49.1	0.81	no	none	greenish blue
SJRw 3222	66.2	0.82	no	none	weak greenish blue
SJRw 3301	27.2	0.84	no	none	greenish blue
SJRw 4146	286.2	0.90	no	none	greenish blue
SJRw 3302	128.8	0.93	no	none	greenish blue
SJRw 36063	83.2	0.93	no	none	greenish blue
MADw 7017	93.5	0.96	no	none	greenish blue
Species mean		0.85			
Species standard deviation		0.07			
Dalbergia spruceana					
SJRw 4014	3.0	1.00	no	blue	blue
SJRw 1430	48.2	1.00	no	weak blue	blue
SJRw 38248	80.5	1.05	no	blue	blue
Species mean		1.02			
Species standard deviation		0.026			

[a]MADw, the original Madison collection, which started in 1911.
[b]SJRw, the Samuel J. Record collection, which started in 1905 and was donated by Yale University in 1970 (Stern 1988).

For each weighing, the empty cage was completely submerged, and the balance was tared to 100 g. The cage was then raised, a specimen was inserted, and the cage plus specimen were again completely submerged. The weight of the submerged specimen was recorded. The submersions were quick, and the specimens did not adsorb an appreciable amount of water because of their high density and low hygroscopicity caused by extractive content.

Specimen density was then calculated for each specimen using the following formula, where the weights are in grams and the density is in grams per cubic centimeter:

$$\text{Density} = \text{Dry Weight}/(\text{Dry Weight} + 100\text{ g} - \text{Submerged Weight})$$

The surface fluorescence of each specimen was observed by making a fresh cut and holding the specimen under a 2-A long-wave ultraviolet lamp. To determine water-extract fluorescence, we placed a few shavings of each specimen in a small vial of water, shook it vigorously, and observed the response to UV light. To determine alcohol extract fluorescence, we placed a few shavings of each specimen in a small vial of 95% ethanol, shook it vigorously, and again observed the response to UV light. Response to UV was recorded as positive (fluorescence) or negative (no fluorescence) for the bulk specimen, and as the color of the fluorescent extract or none (no fluorescence) for the water and ethanol extracts.

Results and Discussion

Ten specimens of *D. nigra* and three specimens of *D. spruceana* met the criteria for authenticity and absence of sapwood (Group 1). Table 2 gives the air-dry weight, density, and fluorescence response of each of these specimens.

The mean densities of the two species were different (0.85 g/cm^3 for *D. nigra*, 1.02 g/cm^3 for *D. spruceana*). More importantly, however, the two species had different density ranges. The range for *D. nigra* was 0.76 g/cm^3 to 0.96 g/cm^3, whereas the density range for *D. spruceana* was 1.00 g/cm^3 to 1.05 g/cm^3 (Table 2). Therefore, density alone is sufficient to separate these two species, based on heartwood samples.

None of the specimens exhibited surface fluorescence. Water extract exhibited a blue fluorescence for *D. spruceana* but no fluorescence for *D. nigra*. Ethanol extract was fluorescent for all specimens, but the color varied: blue for *D. spruceana* and greenish-blue for *D. nigra*. Thus extract fluorescence can serve as an additional aid for distinguishing between the heartwood of these two species, although samples of both species may be necessary for comparison of the "blue" versus "greenish-blue" fluorescence of the ethanol extracts.

Table 3. Weights, densities, and fluorescent properties of the *Dalbergia* specimens that contain sapwood (specimens arranged by ascending density for each species).

Specimen	Sapwood content (%)	Air-dry, weight (g)	Density, (g/cm³)	Fluorescence		
				Surface	Water extract color	Ethanol extract color
Labelled *Dalbergia nigra*						
SJRw[a] 3509	100	166.0	0.72	no	none	none
SJRw 3273	80	87.0	0.81	no	none	greenish blue
MADw[b] 31957	20	90.8	1.01	no	none	greenish blue
SJRw 5990	10	112.5	1.01	no	blue	blue
Species mean			0.89			
Species standard deviation			0.146			
Labelled *Dalbergia spruceana*						
MADw 18588	100	91.2	0.80	no	none	none
SJRw 22610	40	151.1	0.85	no	blue	blue
MADw 31968	30	95.3	0.86	no	blue	blue
Species mean			0.84			
Species standard deviation			0.032			

[a]SJRw, the Samuel J. Record collection, which started in 1905 and was donated by Yale University in 1970 (Stern 1988).
[b]MADw, the original Madison collection, which started in 1911.

For the rest of the specimens in our collection, the results were sometimes surprising. For those labeled *D. nigra*, only the specimen that was entirely sapwood had a density (0.72 g/cm³) lower than the lightest authentic heartwood specimen (0.76 g/cm³). Furthermore, the densest specimens that contained sapwood were heavier (1.01 g/cm³) than the heaviest authentic heartwood specimen (0.96 g/cm³). All the *D. spruceana* specimens containing sapwood were much lower in density than the specimens that were entirely heartwood; their densities (0.80–0.86 g/cm³) were approximately equal to the mean density of the authentic *D. nigra* specimens (0.85 g/cm³) and increased with decreasing percentage of sapwood (Table 3).

The fluorescence tests were also inconsistent. As expected, the two specimens that were entirely sapwood showed no fluorescence. Specimen SJRw 5990, with a sapwood content of 10% and a density of 1.01 g/cm³, had blue water extract and blue ethanol extract fluorescence. Therefore, we conclude that this specimen has probably been misidentified, and is, in fact, *D. spruceana*. The other dense specimen, MADw 31957, with a sapwood content of 20% and a density of 1.01 g/cm³ (typical of *D. spruceana*) showed no water extract fluorescence but had the ethanol-extract fluorescence characteristic of *D. nigra*. We conclude that this specimen is probably *D. spruceana*, with the fluorescence tests confounded by the fact that the heartwood was newly formed and had not yet developed the chemical character of old heartwood.

Table 4 shows the results of the tests on the remaining specimens, all of which were labeled as *D. nigra*. Of the remaining specimens, clearly ten were correctly identified, but the two densest specimens, SJRw 6001 and SJRw 1442, are in fact *D. spruceana*, as indicated by both their high densities (1.06 and 1.11) and their fluorescence colors in water and ethanol extracts. Why this might have occurred is unclear, because both species were validly published in 1860 (Oxford 1895). Perhaps *D. nigra* was the first species to be commercially harvested, and similar wood of *D. spruceana* was simply assigned the same trade name. The sheet of veneer showed the fluorescence reactions corresponding to *D. nigra*, indicating that this veneer was correctly identified. Many of the specimens sent to the CWAR from U.S. Customs for identification are in the form of plywood or veneer. The fluorescence test provides a means of separating *D. nigra* from non-CITES species even if density measurements are not practicable.

Conclusions

For woods from Brazilian trees, the CITES-protected species, *D. nigra*, can be reliably distinguished from the unprotected congener, *D. spruceana*, by means of density, water fluorescence, and ethanol fluorescence. For the tests to be reliable, however, heartwood specimens are necessary because the tests rely on extractives to achieve non-overlapping densities and to give the correct color responses of the extracts. For an inspector who wishes to determine if an unknown specimen from Brazil is the CITES-prohibited species, the density measure is the most practical as it requires only accurate weight and volume measures. However, any sapwood must be removed, the specimen must be conditioned to a uniform moisture content (although we used 6% to 7%, any moisture content below the fiber saturation point can be used if an adjustment for moisture is made), and if water immersion apparatus is unavailable, the specimen must be machined to a size and shape so that volume can be easily and accurately measured. As a practical matter, a

Table 4. Weights, densities, and fluorescent properties of other heartwood specimens labelled *Dalbergia nigra* but whose identification is not reliable (specimens arranged by ascending density).

			Fluorescence		
	Air-dry weight (g)	Density (g/cm^3)	Surface	Water extract color	Ethanol extract color
MADw[a] 31958	40.5	0.66	no	none	greenish-blue
MADw 31954	112.5	0.82	no	none	greenish-blue
SJRw[b] 3107	218.1	0.84	no	none	greenish-blue
SJRw 5900	83.1	0.85	no	none	greenish-blue
MADw 31955	46.8	0.86	no	none	greenish-blue
MADw 31956	74.4	0.88	no	none	greenish-blue
SJRw 4230	67.3	0.88	no	none	greenish-blue
SJRw 38189	175.0	0.92	no	none	greenish-blue
MADw 23334	27.0	0.97	no	none	greenish-blue
SJRw 4452	63.1	0.98	no	none	greenish-blue
SJRw 6001	124.3	1.06	no	blue	blue
SJRw 1442	40.0	1.11	no	blue	blue
SJRw 550 (veneer)	—	—	no	none	greenish-blue

[a]MADw, the original Madison collection, which started in 1911.
[b]SJRw, the Samuel J. Record collection, which started in 1905 and was donated by Yale University in 1970 (Stern 1988).

simple flotation test would probably serve because air-dry *D. nigra* floats whereas air-dry *D. spruceana* sinks. Water and ethanol extract fluorescence reactions are good back-ups (or sometimes the only possible means of separation), but they work only on heartwood. Surface fluorescence cannot be used to separate the species.

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