Schinopsis spp.
Family: Anacardiaceae
Quebracho

Other Common Names: Barauva, Brauna, Quebracho hembra (Brazil), Quebracho colorado, Q. chaqueno, Q. santiagueno (Argentina).

Distribution: Botanical range extends over northern Argentina, western Paraguay, a small portion of Bolivia, and to the interior of the state of Bahia in Brazil.

The Tree: Scrubby growth 30 to 50 ft high; 12 to 36 in. in diameter. Trunks are often bent and twisted and swollen at the base. *S. balansae* reported to reach a height of 80 ft. and a diameter of 60 in.

The Wood:
General Characteristics: Heartwood light red, deepening to brick red, uniform or with black streaks; distinct but not sharply demarcated from the yellowish sapwood. Luster low to medium; texture fine and uniform; grain irregular, often roey; odor not distinctive, taste astringent. Heartwood contains 20 to 30% tannin.

Weight: Basic specific gravity (ovendry weight/green volume) 1.00; air-dry density 75 pcf.

Mechanical Properties: (Standard not known)

Moisture content (%)	Bending strength (Psi)	Modulus of elasticity (1,000 psi)	Maximum crushing strength (Psi)
15% (69)	19,800	2,190	NA
15% (69)	13,800	1,950	8,900

Drying and Shrinkage: Reported to check and warp severely, particularly when cut into thin boards. A kiln schedule similar to T1 -B1 has been suggested. No data available on shrinkage values.

Working Properties: Very difficult to work, especially when dry, but takes a high natural polish.

Durability: Highly durable, though standing trees are often defective as a result of heart rot.

Preservation: No data available.

Uses: Tannin extraction, railroad crossties, heavy construction, fence posts, poles, fuel.

Additional Reading: (56), (69)

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CHARACTERISTICS OF TEN TROPICAL HARDWOODS FROM CERTIFIED FORESTS IN BOLIVIA
PART I WEATHERING CHARACTERISTICS AND DIMENSIONAL CHANGE

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ABSTRACT

Ten tropical hardwoods from Bolivia were evaluated for weathering performance (erosion rate, dimensional stability, warping, surface checking, and splitting). The wood species were *Amburana cearensis* (roble), *Anadenanthera macrocarpa* (curupau), *Aspidosperma cylindrocarpon* (jichituriqui), *Astronium urundeuva* (cuchi), *Caesalpinia* cf. *pluviosa* (momoqui), *Diplotropis purpurea* (sucupira), *Guibourtia chodatiana* (sirari), *Phyllostylon rhamnoides* (cuta), *Schinopsis* cf. *quebracho-colorado* (soto), and *Tabebuia* spp. (lapacho group) (tajibo or ipe). *Eucalyptus marginata* (jarrah) from Australia and *Tectona grandis* (teak), both naturally grown from Burma and plantation-grown from Central America, were included in the study for comparison. The dimensional change for the species from Bolivia, commensurate with a change in relative humidity (RH) from 30% to 90%, varied from about 1.6% and 2.0% (radial and tangential directions) for *Amburana cearensis* to 2.2% and 4.1% (radial and tangential) for *Anadenanthera macrocarpa.* The dimensional change for teak was 1.3% and 2.5% (radial and tangential) for the same change in relative humidity. None of the Bolivian species was completely free of *warp* or surface checks; however, *Anadenanthera macrocarpa, Aspidosperma cylindrocarpon,* and *Schinopsis* cf. *quebracho-colorado* performed almost as well as teak. The erosion rate of several of the wood species was considerably slower than that of teak, and there was little correlation between wood density and erosion rate. Part 2 of this report will include information on the decay resistance (natural durability) of these species.

Keywords: Wood properties, weathering, density, growth rate, erosion rate, flat-grain, vertical-grain, durability, natural durability.

INTRODUCTION

The objective of this research was to evaluate the weathering performance (erosion rate, dimensional stability, warping, and surface checking) of ten tropical hardwoods from Bolivia compared with jarrah and teak.

Some tropical hardwoods have good natural durability. These species are resistant to decay, insect attack, and weathering (photodegradation caused by the ultraviolet (UV) radiation in sunlight). Teak (*Tectona grandis* L.f.) has

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good natural durability, and it has traditionally been used in many outdoor applications including boats, decking, and outdoor furniture. It has been a commercial species since 2000 B.C. (Simatupang et al. 1996). The demand for wood that has good weathering properties and durability continues to increase, but the harvest, even from intensively managed teak plantations, cannot keep up with this demand. The objective of this study was to evaluate the weathering properties of ten tropical hardwoods from Bolivia to determine if some of them could provide performance similar to that of teak.[2] For comparison, teak harvested from natural forests in Burma, plantation-grown teak from Central America, and jarrah (Eucalyptus *marginata* Donn ex Sm.) from Australia were included. The study was also aimed at determining which species would be suitable for manufacturing products for outdoor use and which ones would be better suited for indoor use. General information, such as strength and stiffness, density, general appearance, and green to oven-dry shrinkage is available on some of these species (Chudnoff 1984). However, there is no information on their weathering characteristics, particularly their dimensional stability when exposed to cyclic wetting and drying or changes in relative humidity. Nor was there information on the erosion rate of the surface during weathering.

Several reports had information on the decay, weathering, and dimensional stability characteristics of teak. Teak was included in a study by the Working Group on Utilization of Tropical Woods (Forestry and Forest Products Research Institute 1998, pp. 23-84). This group evaluated the anatomical structure, mechanical properties, and decay resistance of 23 tropical woods from Papua, New Guinea. They ranked teak among the most durable species. Burmester (1972, 1975) and Burmester and Wille (1975) reported that there was considerable anisotropy in the swelling of teak with changes in relative humidity (RH); half of the total swelling took place in the range of 86% to 100% RH. They attributed the dimensional stability of teak to its low percentage of hydrolysable hemicellulose compared with other wood species. Bhat (1998) evaluated the properties of fast-grown teak from intensively managed plantations. He reported that strength, specific gravity, and percentage heartwood were not adversely affected. Teak was included in accelerated weathering studies of tropical wood species from Taiwan (Wang et al. 1980a, b; Wang 1981, 1990). These authors reported that teak was ranked with the group of wood species most resistant to surface checking and end-grain splitting. The vertical-grained pieces had less end-grain splitting than the flat-grained pieces.

In another previous work, Hernandez (1993) studied the moisture sorption properties of several Peruvian wood species. They included *Amburana* sp. [ishpingo negro (probably *A. cearensis* (Allemao) A.C. Sm.)], *Aspidosperma* sp. (Pumaquiro), and *Tabebuia serratifolia* (Vahl) G. Nicholson (tahuari or ipe). These species are in the same genera as *Amburana, Aspidosperma,* and *Tabebuia* used in our study and their densities were quite similar. Hernández focused on characterizing the hysteresis effect during shrinking and swelling, and he reported volumetric swelling for these species of between 7.5% (*Amburana* sp.) and 18.1% (*Tabebuia serratifolia*). Florsheim and Tormazello-Filho (1996) studied the dependence of anatomical characteristics on the location in the tree where the wood came from for several tropical wood species from Brazil. *Astronium urundeuva* (Allemao) Engl. was included in their study.

EXPERIMENTAL

Materials

Short lengths of lumber of the various species were obtained from a mill in Bolivia. The

[2]These species are harvested using environmentally sensitive techniques from sustainably managed forests in Bolivia that are certified by the Forest Stewardship Council (FSC). For information on FSC, see their web page at www.fscus.org and link to FSC in other parts of the world from there, These certified forests should ensure the continued existence of these ecosystems and give sustainable yields of forest products indefinitely.

species were *Amburana cearensis, Anadenanthera macrocarpa* (Benth.) Brenan, *Aspidosperma cylindrocarpon* Muell. Arg., *Astronium urundeuva, Caesalpinia* cf. *pluviosa* DC., *Diplotropis purpurea* (Rich.) Amshoff, *Guibourtia chodatiana* (Hassl.) J. Leonard, *Phyllostylon rhamnoides* (Poisson) Taubert, *Schinopsis* cf. *quebracho-colorado* (Schldl.) F. Barkley & T. Meyer, and *Tabebuia* spp. (lapacho group). Teak, both natively grown from Burma and plantation-grown from Central America, and *Eucalyptus marginata* were also included in this study for comparison.

Vertical- or flat-grained specimens 75 by 6 by 100 mm (radial, tangential, longitudinal or tangential, radial, longitudinal) were cut from the boards. These specimens were used to measure dimensional changes, density, warping, surface checking, and splitting after cyclic wetting and drying exposures. Specimens 25 by 6 by 25 mm (radial, tangential, longitudinal) were cut for determining wood loss from the surface (erosion) during weathering. Because some of the boards were cross-grain (neither radial nor tangential cut), it was not possible to get sufficient specimens for radial and tangential dimensional changes for all species. In some cases, only the volumetric change could be determined.

Methods

The densities were determined by weighing and measuring the specimens at approximately 6% and 12% moisture content (30% RH/27°C or 65% RH/27°C, respectively). The dimensional change in the radial, tangential, and longitudinal directions was determined by cycling specimens between environmental rooms that were at 30% RW27°C and 90% RH/27°C. It was found that approximately 2 weeks were required to reach constant weight for these species. Consequently, the specimens were conditioned for 3 weeks at each relative humidity. Volume change of the specimens was calculated from the change in length, width, and thickness with the change in RH. The weathering characteristics were determined from the erosion of wood from the surface during exposure in a xenon arc weathering apparatus (24 h of light and 4 h of water spray each day). The temperature in the weathering apparatus was maintained at 42°C to 45°C and the RH varied from 25% during the light only period (20 h per day) to 95+% during the water spray. The erosion was measured microscopically at 600-h intervals by the method reported by Black and Mraz (1974) and later by Feist and Mraz (1978). For each wood species, six measurements were made on each of three replicates to give eighteen observations for each erosion determination. To get an erosion measurement that was representative of the actual wood loss from the surface, the erosion measurements were made as far from the vessels as possible. A linear regression analysis of the erosion measurements was done to give erosion rates; the Y-intercept was not fixed to 0. The hardwood erosion values previously published by Sell and Feist (1986) were fit using a linear regression in the same way as the data obtained for this study. Specimens for determining warping and surface checking were also exposed to the same conditions as the erosion specimens. The warping and surface checking evaluations were given numerical evaluations according to the following: 10 = no change, 8 = slight change, 5 = moderate change, and 1 = severe change.

RESULTS AND DISCUSSION

The ten Bolivian species along with the teak are ranked for surface checking, warping, erosion rate, and volumetric swelling in Table I. The surface checking and warping ratings were obtained from cyclic wetting and drying during exposure to ultraviolet radiation. This exposure indicates how well a wood species will perform in outdoor exposure. Teak has the least surface checking and warping, which confirms its reputation for good weathering characteristics. Cyclic wetting and drying caused excessive warping and surface checking in *Phyllostylon rhamnoides, Guibourtia chodatiana,* and *Caesalpinia* cf. *pluviosa.* In

TABLE 1. *Ranking of cracking, warping, erosion rate, and volumetric swelling.*[a]

Cracking[b]		Warping[b]		Erosion raw (µm/1,000 h)		Swelling[c] (%)	
Burmese teak	10	Burmese teak	8	*Astronium*	14	*Amburana*	4.0
Plantation teak	10	Plantation teak	8	*Diplotropis*	18	Burmese teak	4.4
Anadenanthera	8	***Anadenanthera***	8	*Guibourtia*	21	Plantation teak	5.0
Aspidosperma	8	***Tabebuia***	8	***Anadenanthera***	24	***Aspidosperma***	5.7
Tabebuia	8	***Aspidosperma***	7	***Schinopsis***	26	*Guibourtia*	5.8
Diplotropis	8	***Schinopsis***	7	*Caesalpinia*	29	***Schinopsis***	6.6
Schinopsis	7	*Phyllostylon*	5	*Phyllostylon*	44	*Astronium*	6.9
Astronium	6	*Amburana*	4	*Amburana*	54	***Tabebuia***	7.1
Amburana	6	*Astronium*	3	***Tabebuia***	67	*Phyllostylon*	7.0
Caesalpinia	3	*Caesalpinia*	3	Burmese teak	71	***Anadenanthera***	7.3
Guibourtia	2	*Guibourtia*	2	Plantation teak	71	*Caesalpinia*	7.9
Phyllostylon	1	*Dipiotropis*	1	***Aspidosperma***	81	*Diplotropis*	7.0

[a] Species in bold type are those best suited for outdoor use. The two types of teak are underlined for comparison. The replications are listed in Table 4.
[b] Average rating on a scale of 1 to 10 with 10 being the best condition.
[c] Volumetric swelling from 30% to 90% relative humidity.

contrast, *Anadenanthera macrocarpa, Aspidosperma cylindrocarpon, Tabebuia* spp., and *Schinopsis* cf. *quebracho-colorado* showed only minor warping and surface checking. (These species are in bold type in Table 1 to make it easier to compare their properties.) These four species should perform well in outdoor exposure but probably not as well as teak. The erosion rates are probably not a very good indication of how well a wood species will perform. Note that teak is near the bottom of the list for erosion rate in Table 1. Although the dense woods such as *Astronium urundeuva, Diplotropis purpurea,* and *Guibourtia chodatiana* weather very slowly, they are prone to warping and splitting.

Table 2 lists the erosion rates of each species along with some physical and anatomical properties that we suspect might influence weathering characteristics. The erosion rates were determined from a linear regression of the average erosion measurements. Several of

TABLE 2. *Physical properties.*

Species	Density[a] (kg/m³)	*Erosion* rate (µm/ 1,000 h)	Color (heartwood)	Anatomical properties[b]				
				I	II	III	IV	V
Amburana cearensis	640	54	Lt. brown	n	n	l	y	t-th
Anadenanthera macrocarpa	1,050	24	Dk. reddish brown	n	n	m	n	th-vt
Aspidosperma cylindrocarpon	730	81	Med. reddish tan	n	n	s	n	th
Astronium urundeuva	1,200	14	Dk. reddish brown	n	y	m	n	th-vt
Caesalpinia cf. *pluviosa*	980	29	Dk. brown	n	n	m	n	th
Diplotropis purpurea	910	18	Dk. brown	n	n	l	y	th
Guibourtia chodatiana	950	21	Med. reddish brown	n	n	m	n	th
Phyllostylon rhamnoides	990	44	Lt. yellowish tan	n	n	s	n	th
Schinopsis cf. *quebracho-colorado*	1,170	26	Dk. reddish brown	n	y	m	n	th-vt
Tabebuia	960	67	Dk. greenish brown	n	n	s	n	th-vt
Eucalyptus marginata	910	35	Dk. brownish red	n	y	1	n	th
Teak (native)	640	71	Lt. golden brown	y	y/n	m-l	n	t-th
Teak (plantation)	730	71	Lt. golden brown	y	y/n	m-l	n	t-th

[a]Volume and mass were measured at 65% RH (27°C), which corresponds to 12% EMC.
[b]Labels for columns are as follows:
I. Ring or semi-ring porous (n = no, y = yes)
II. Tyloses in vessels (n = no, y = yes)
III. Vessel size [s, small (>80 µm): m, medium (80-150 µm); l, large (>150 µm)]
IV Axial parenchyma abundant around vessels (n = no, y = yes)
V. Thickness of fiber walls (t, thin; th, thick; vt, very thick)

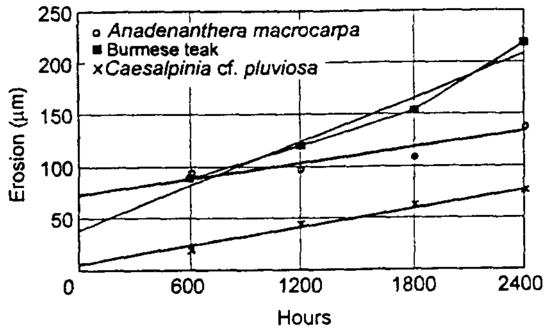

FIG. 1. Erosion of *Anadenanthera macrocarpa, Caesalpinia* cf. *pluviosa* (momoqui), and Burmese teak versus time of exposure in a weathering chamber (xenon arc radiation and periodic water spray). Each point is an average of 18 observations.

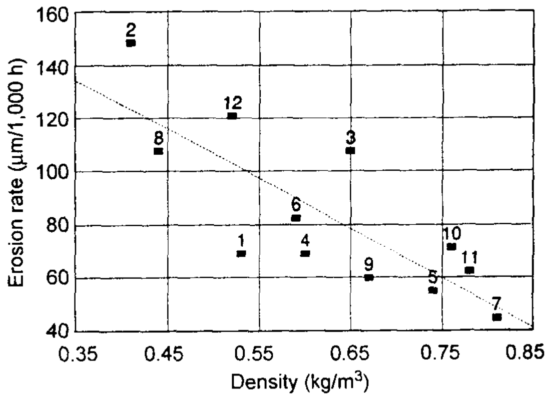

FIG. 2. Regression analysis of erosion rate versus density for temperate hardwoods determined from data by Sell and Feist (1986). R^2 = 0.64. 1. *Ulmus americana* (American elm), 2. *Tilia americana* (basswood), 3. *Betula alleghaniensis* (yellow birch). 4. *Prunus serotina* (black cherry), 5. *Fagus sylvatica* (European beech), 6. *Acer* sp. (maple), 7. *Carya* sp. (hickory). 8. *Alnus rubra* (red alder), 9. *Quercus rubra* (red oak), 10. *Fraxinus americana* (white ash), 11. *Quercus alba* (white oak), 12. *Liriodendron tulipifera* (yellow-poplar).

the erosion versus time plots are shown (Fig. 1). The Y-intercept was not fixed to 0 for the regression. During the first several hundred hours of exposure in the weathering chamber, the specimens undergo changes in the surface that seem to be unrelated to erosion (such as raised grain). Following this initial period, the erosion can be fit to a linear model if the time of weathering is not too long. In most cases, the R^2 values were above 0.90 for a regression of the average erosion.

The average density (12% equilibrium moisture content (EMC)) for the wood used in this study is listed in Table 2. Most of the species had densities ranging from 900 to slightly more than 1,000 kg/m^3. The exceptions to this were *Amburana cearensis* and *Aspidosperma cylindrocarpon,* which had a density similar to teak. At a specific moisture content, the density is determined primarily by the cell-wall thickness. High-density woods have thick-walled fibers and low-density woods have thin-walled fibers. The lowest density woods tested were teak, *Amburana cerarensis,* and *Aspidosperma cylindrocarpon.* Compared with species from the United States, these species are about the same density as northern red oak (*Quercus rubra* L.) and sugar maple (*Acer saccharum* Marsh.), which are some of the higher density woods in the United States. The erosion rates of teak, *Amburana cerarensis,* and *Aspidosperma cylindrocarpon* are among the highest rates for the species tested. For temperate hardwoods, the erosion rate has been shown to be related to wood density (Sell and Feist 1986). The data reported by Sell and Feist for 12 temperate hardwoods, with specific gravities in the range of 0.41 to 0.81, were replotted (Fig. 2). Using the erosion measurement reported by Sell and Feist, we found the R^2 for the linear regression analyses of erosion rate versus density to be only 0.64 (Fig. 2). In the work reported here, the plot of erosion rate versus density gave an even poorer correlation (Fig. 3; R^2 = *0.57).* In an effort to explain these poor correlations, several anatomical characteristics were evaluated for their effect on the erosion rate. In many temperate species like oak, elm, and ash, the wood is distinctly ring-porous and these vessels tend to increase the erosion rate of the earlywood, particularly if they have large diameters (Williams et al. 2001).

As with most tropical species, all the species are diffuse-porous, except teak, which is ring- to semi-ring porous. The pore (vessel) diameter is directly related to grain coarse-

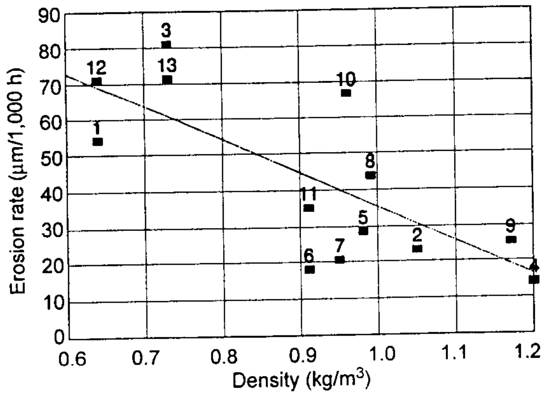

FIG. 3. Regression analysis of erosion rate versus density. R^2 = 0.57. 1. *Amburana cearensis,* 2. *Anadenanthera macrocarpa,* 3. *Aspidosperma cylindrocarpon,* 4. *Astronium urundeuva,* 5. *Caesalpinia* cf. *pluviosa,* 6. *Diplotropis purpurea,* 7. *Guibourtia chodatiana,* 8. *Phyllostylon rhamnoides,* 9. *Schinopsis* cf. *quebracho-colorado,* 10. *Tabebuia* spp., 11. *Eucalyptus marginata,* 12. *Tectona grandis* (teak, natively grown from Burma), 13. *Tectona grandis* (teak, plantation-grown from Central America).

ness—the smaller the vessel diameter, the finer the texture. Since the vessel is largely air space, wood with larger vessel diameters might be expected to erode faster than wood with smaller vessel diameters. We grouped vessel diameters into three classes, small (<80 µm), medium (80-150 µm), and large (>150 µm), which more or less correlates with fine, medium, and coarse texture. By comparing the pore sizes with the position of each species in Fig. 3, it appears that the species that have the largest vessel diameters (*Eucalyptus marginata, Diplotropis purpurea,* and *Amburana cerarensis*) lie below the average density/erosion rate line. Woods with small vessel diameters (*Phyllostylon rhamnoides, Aspidosperma cylindrocarpon,* and *Tabebuia* spp.) lie above this line. Thus, it appears that vessel diameter may have some effect on erosion rate for these species.

Axial parenchyma cells are very thin-walled cells that occur in various patterns in wood. Since these cells are thin-walled, the abundance of axial parenchyma surrounding the vessels might affect the erosion rate. *Diplotropis purpurea* and *Amburana cearensis* have an abundance of axial parenchyma surrounding their vessels, and both lie below the line in Fig. 3. This would indicate that the erosion is slower for those species, which is the opposite of what was expected. As mentioned previously, the erosion measurements were made as far from the vessels as possible. Since the axial parenchyma cells are found close to the vessels, their presence is probably not reflected in the measurements. This might explain the apparent inconsistency.

The occurrence of tyloses in the vessels appears to have no effect on the erosion rate (Table 2). Thus, the deviation from a linear relationship between density and erosion rate appears to be related to the pore size in these dense diffuse-porous species. The evidence for this is rather tenuous, and additional studies are planned to investigate this further.

Color of heartwood and extractives content had no noticeable effect on the erosion rate. All species lost almost all color (surface extractives) within 1,200 h of weathering (Table 3). The shades of gray differed among the species. In the absence of mildew growth in the xenon arc weathering chamber, the color of several of the wood species was an attractive silver gray (Figs. 4-8).

A summary of the surface checking and warping observations is given in Table 3. *Anadenanthera macrocarpa, Aspidosperma cylindrocarpon, Schinopsis* cf. *quebracho-colorado,* and *Tabebuia* spp. were reasonably stable through numerous wetting and drying cycles. However, none of the specimens was as stable as the Burmese and plantation-grown teak. Because the cycling was done in a weathering device, we could also evaluate the specimens for surface roughness. Many of the wood species performed similarly to the teak. Figures 4 to 8 show the warping, splitting, checking, and surface changes of the specimens caused by cyclic weathering. *Anadenanthera macrocarpa* (Fig. 4) is an example of the species that had properties similar to teak (Fig. 5). Warping was rather severe with some species as shown by *Astronium urundeuva* (Fig. 6). Examples of severe surface checking

TABLE 3. *Color change, surface roughness, warping, and cracking of 75- by 10- by 6-mm specimens exposed to xenon arc UV radiation and intermittent water spray for 2,400 h.*[a,b]

Species	Color change				Surface roughness				Warping				Surface checking			
	600 h[c]	1,200 h	1,800 h	2,400 h	600 h	1,200 h	1,800 h	2,400 h	600 h	1,200 h	1,800 h	2,400 h	600 h	1,200 h	1,800 h	2,400 h
Amburana cearensis	5	1	1	1	5	5	5	1-5-1	5-8-1	1-8-1	5-8-1	1-8-1	5-10-8	5-8-8	5-8-5	5-8-5
Anadenanthera macrocarpa	5	1	1	1	5-5-8	5	5	5	8	8	8	8	10	8	8	8
Aspidosperma cylindrocarpon	1	1	1	1	8	8	8	8	5-8	5-8	8	5-8	8-10	8	8	8
Astronium urundeuva	1	1	1	1	5	5	5	5	5-1-5	1-1-5	5-1-5	1-1-5	8	8	5-8-8	5-8-5
Caesalpinia cf. *pluviosa*	5	1	1	1	8	8	8	5	1-5	1-5	1-5	1-5	5-8	5-8	5-8	5-8
Diplotropis purpurea	5	1	1	1	1	1	1	1	5	1	1	1	8	8	8	8
Guibourtia chodatiana	5	1	1	1	8	8	8	8	5-5-1	5-5-1	5-5-1	1-5-1	5-1-5	5-1-5	1-1-5	1-1-5
Phyllostylon rhamnoides	5	1	1	1	8	8	8	8	5	5	5	5	5	5-1	1	1
Schinopsis cf. *quebracho-colorado*	1	1	1	1	8-5	8-5	8-5	8-5	5-8	5-8	5-8	5-8	8-10	8-10	8-10	5-8
Tabebuia	5	1	1	1	5-8-5	5-8-5	5	5	8-8-5	8-8-5	8	8	10	10-8-8	8	8
Teak (native)	5	1	1	1	5	5	5	5-1-1	8	8	8	8	10	10	10	10
Teak (plantation)	1	1	1	1	8	8	8-5	8-5	10-8	8	8	8	10	10	10	10

[a] 10 = no change, 8 = slight change, 5 = moderate change, 1 = severe change.
[b] One number implies that all specimens were the same (two or three replicas per species).
[c] Hours of exposure.

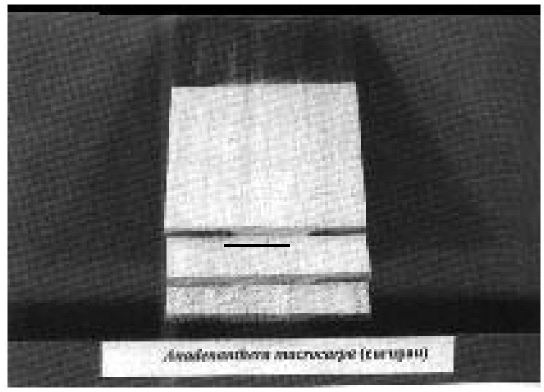

FIG. 4. *Anadenanthera macrocarpa* after 2,400 h exposure to accelerated weathering.

and cracking are also shown for *Amburana cearensis* and *Guibourtia chodatiana* (Figs. 7 and 8).

The ranking of volumetric swelling in Table 1 probably gives a good indication of performance indoors. Note that teak is near the top of the list. Although *Amburana cearensis* and *Guibourtia chodatiana* probably would not perform very well outdoors, they have good dimensional stability in the range of 30% to 90% RH and probably would perform well indoors. The longitudinal swelling of *Aspidosperma cylindrocarpon* was rather high (0.31%), and this may cause problems if long pieces are used (Table 4). The longitudinal swelling was high for some of the other species (*Astronium urundeuva* (0.20%), *Guibour-*

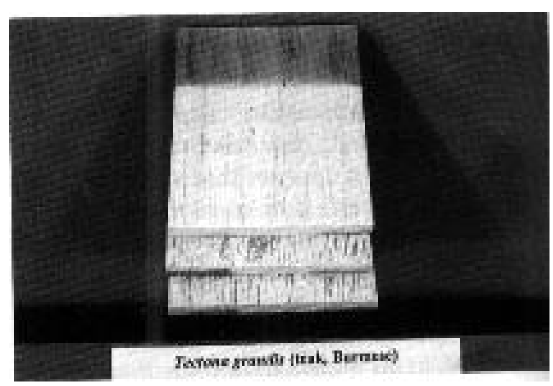

FIG. 5. *Tectona grandis* (teak) after 2.400 h exposure to accelerated weathering.

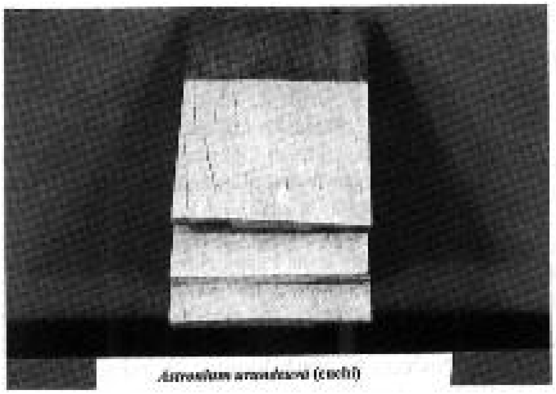

FIG. 6. *Astronium urundeuva* after 2,400 h exposure to accelerated weathering.

tia chodatiana (0.21%), and *Phyllostylon rhamnoides* (0.23%)), including plantation-grown teak (0.23%).

CONCLUSIONS

The weathering characteristics and dimensional stability of the ten species varied considerably. None of the Bolivian wood species was as resistant to surface checks and warping as teak; however, *Anadenanthera macrocarpa, Aspidosperma cylindrocarpon*, *Schinopsis* cf. *quebracho-colorado*, and *Tabebuia* spp. were next best. Of these four species, *Anadenanthera macrocarpa* and *Schinopsis* cf. *quebracho-colorado* were much more resistant to erosion than teak, probably because of their

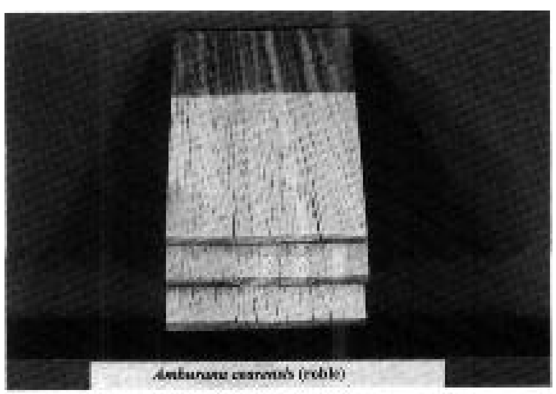

FIG. 7. *Amburana cearensis* after 2,400 h exposure to accelerated weathering.

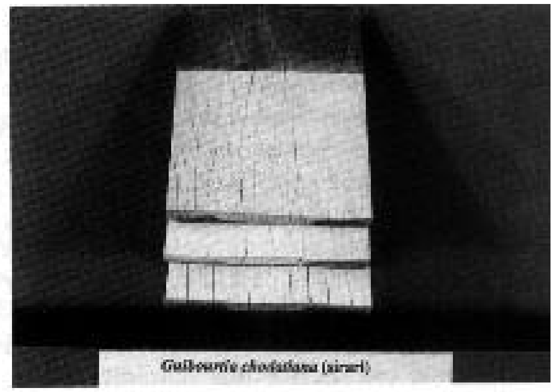

FIG. 8. *Guibourtia chodatiana* after 2,400 h exposure to accelerated weathering.

high density. The dimensional stability for *Amburana cearensis* and *Guibourtia chodatiana* was about the same as teak, but they warped and checked. On the basis of the limited number of samples of each species, it appears that *Anadenanthera macrocarpa*, *Aspidosperma cylindrocarpon, Schinopsis* cf. *quebracho-colorado,* and *Tabebuia* spp. could be used to manufacture furniture and similar items for use outdoors. However, this study did not address the machining characteristics of these species, and the more dense species may be difficult to machine. Durability with regard to the decay or insect attack was not

TABLE 4. *Average dimensional change (30% to 90% RH).*[a]

Species	Dimensional change (%) Longitudinal	Volume
Amburana cearensis	0.06 (4)	4.0 (4)
Anadenanthera macrocarpa	0.16 (4)	7.3 (4)
Aspidosperma cylindrocarpon	0.31 (2)	5.7 (2)
Astronium urundeuva	0.20 (4)	6.9 (4)
Caesalpinia cf. *pluviosa*	0.17 (4)	7.9 (4)
Diplotropis purpurea	0.09 (3)	7.0 (3)
Guibourtia chodatiana	0.21 (4)	5.8 (4)
Phyllostylon rhamnoides	0.23 (4)	7.0 (4)
Schinopsis cf. *quebracho-colorado*	0.16 (4)	6.6 (4)
Tubebuia	0.13 (4)	7.0 (4)
Eucalyptus marginata	0.09 (6)	7.7 (6)
Teak (native)	0.09 (3)	4.4 (3)
Teak (plantation)	0.23 (2)	5.0 (2)

[a]The number in parentheses is the number of specimens used to obtain the average value.

determined but will be reported in part 2. *Astronium urundeuva, Diplotropis purpurea,* and *Amburana cearensis* showed considerable warp. *Phyllostylon rhamnoides, Caesalpinia* cf. *pluviosa,* and *Guibourtia chodatiana* were badly checked and split. With changes in relative humidity in the range of 30% to 90%, all species showed good dimensional stability. They all seem to have excellent properties for manufacturing products for indoor use. However, some species had fairly high longitudinal dimensional change for this humidity range. These may not be suitable for flooring, unless short lengths are used.

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CHARACTERISTICS OF TEN TROPICAL HARDWOODS FROM CERTIFIED FORESTS IN BOLIVIA. PART II NATURAL DURABILITY TO DECAY FUNGI

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ABSTRACT

The natural durability of 10 lesser known, commercially available Bolivian hardwoods to decay fungi was evaluated using a modified ASTM soil-block analysis for 12 weeks. The blocks were then retested for an additional 12 weeks to determine their level of decay resistance, as determined by percentage of weight loss. *Astronium urundeuva, Caesalpinia* cf. *pluviosa, Schinopsis quebracho-colorado,* and *Tabebuia* sp. (lapacho group) were found to be highly resistant to decay; *Amburana cearensis, Anadenanthera colubrina* (syn: *A. macrocarpa), Aspidosperma cylindrocarpon, Diplotropis purpurea,* and *Guibourtia chodatiana,* resistant to decay; and *Phyllostylon rhamnoides,* moderately resistant to decay. We conclude that an extended soil-bottle test is an effective tool for assessing the level of natural durability of these and other tropical species.

Keywords: Natural durability, soil-block test, tropical hardwoods.

INTRODUCTION

Natural durability, weathering characteristics, and dimensional changes are important properties of wood for outdoor use. Much is known about some woods, like teak *(Tectona grandis L.)* and Honduras mahogany *(Swietenia macrophylla* King), but there are many gaps in our knowledge about some lesser known or lesser used species. This is especially true for woods from Bolivia, a country that has a large forest resource. Within the last 10 years, the development of this forest resource has expanded. The initial focus on harvesting mahogany *(S. macrophylla)* has shifted to the utilization of many species. To provide local land owners and operators of certified forests with information on weathering characteristics and decay resistance, we initiated a two-part project focused on 10

Bolivian hardwoods. In Part I, we studied weathering characteristics and dimensional changes (Williams et al. 2001). The work reported here describes Part II, tests on decay resistance using a modified ASTM soil-block analysis (ASTM 1994).

Information on the properties and characteristics of Bolivian hardwoods, including natural resistance to decay fungi, is found in several publications. Chudnoff (1984), Berni et al. (1979), and Chichignoud et al. (1990) compiled data on Latin American species; Teixeira et al. (1988), IBDF (1981, 1988), and Mainieri and Chimelo (1989) focused on Brazilian species; and Gérard et al. (1996) studied timbers of Guyana. These reports provide data on some Bolivian species, but most often present data on other species in the same genera. In most cases, it is not possible to determine if the data on decay resistance were derived from soil-block or long-term stake tests.

Soil-block tests or other accelerated laboratory tests have been done on some Bolivian species growing in Peru and Paraguay. Highley and Scheffer (1970) evaluated 30 Peruvian species, and Greenwood and Tainter (1980) evaluated 16 Paraguayan species. Others (Monteiro and de Freitas 1977; Cavalcante et al. 1978; Silverborg et al. 1970) evaluated closely related South American species, i.e., species in the same genus. In the absence of other critical data, results from species in the same genus may suggest similar decay resistance if the woods are similar in other respects.

EXPERIMENTAL

Materials

Heartwood from one tree of each of 10 species was obtained from a certified forest in Bolivia. The species were *Amburana cearensis* (Allemao) A. C. Smith (roble or ishpingo in Peru), *Anadenanthera colubrina* (Vell.) Brenan (syn: *A. macrocarpa* (Benth.) Brenan) (curupau or curupay), *Aspidosperma cylindrocarpon* Muell. Arg. (jichituriqui), *Astronium urundeuva* Engl. (cuchi), *Caesalpinia* cf. *pluviosa* DC. (momoqui), *Diplotropis purpurea* (Rich.) Amsh. (sucupira), *Guibourtia chodatiana* (Hassl.) J. Leonard (sirari), *Phyllostylon rhamnoides* (Poisson) Taubert (cuta), *Schinopsis quebracho-colorado* (Schidl.) F. Barkley and T. Meyer (soto or quebracho), and *Tubebuia* sp. (lapacho group, tajibo or ipe). Red pine *(Pinus resinosa* Ait.) and yellow birch *(Betula alleghaniensis* Britt.) were used for sapwood control samples.

The fungi used in the tests were pure cultures of two brown-rot fungi *(Tyromyces palustris* (Berk. and M.A. Curtis) Murrill, MAD 6 137) and *Gloeophyllum trabeum* (Pers.:Fr.) Murrill, MAD 617) and one white-rot fungus *(Trametes versicolor* (L.:Fr.) Pilat, MAD 697).

METHODS

We used a modified ASTM D-2017 soil-block experimental method (ASTM 1994). Two matched sets of the Bolivian heartwood samples (19- by 19- by 19-mm blocks) and control sapwood samples were prepared. Each set contained four replicates for a total of eight samples per species. Both sets were placed in standard soil-block bottles (two blocks per bottle) in a decay chamber (27°C and 80% relative humidity) and exposed for 12 weeks to pure cultures of the decay fungi. After 12 weeks, one set of samples was removed, oven-dried at 80°C to a constant weight, and weighed to determine weight loss. The oven-dried samples were then steam-sterilized and transferred to freshly prepared soil-block bottles. The other set of samples was not oven-dried; these samples were steam-sterilized and transferred to freshly prepared soil-block bottles to extend the test period to 24 weeks. Both sets were then exposed for a second 12-week period, after which they were oven-dried and weighed.

RESULTS AND DISCUSSION

The average percentages of weight loss and standard deviation for each species and fungus after 12 and 24 weeks of exposure are shown in Table 1 and Figs. 1 to 3. Following the ex-

TABLE 1. *Percentage of weight loss for wood species after 12 and 24 weeks of exposure to decay fungi in soil-block tests.*[a]

Species	*G. trabeum* MAD-617		*T. palustris* TYP-6137		*T. versicolor* MAD-697	
	12 wk	24 wk	12 wk	24 wk	12 wk	24 wk
Pinus resinosa (control)	58.4	—	31.4	—	9.5	—
	(9.3)		(7.5)		(1.4)	
Betula alleghaniensis (control)	40.6	—	34.8	—	38.6	—
	(4.0)		(6.1)		(3.0)	
Amburana caerensis	1.9	2.4	13.4	21.3	12.2	21.6
	(0.6)	(1.0)	(3.2)	(5.2)	(6.0)	(8.4)
Anadenanthera colubrina	2.3	2.2	10.7	23.1	1.9	2.2
	(1.4)	(2.0)	(4.9)	(7.4)	(0.3)	(7.0)
Aspidosperma cylindrocarpon	6.9	9.6	16.8	33.0	1.0	3.2
	(1.6)	(1.8)	(1.6)	(3.6)	(0.2)	(1.1)
Astronium urundeuva	0.2	−1.2	0.1	−0.5	1.5	0.6
	(0.1)	(1.5)	(0.2)	(0.4)	(1.3)	(1.4)
Caesalpinia cf. *pluviosa*	2.8	3.1	4.5	7.7	4.0	6.5
	(0.3)	(0.3)	(0.7)	(1.2)	(0.7)	(0.8)
Diplotropis purpurea	1.8	2.3	13.9	21.3	3.0	3.9
	(0.0)	(0.5)	(1.3)	(1.8)	(0.2)	(0.9)
Guibourtia chodatiana	7.9	25.3	17.1	37.0	6.8	16.6
	(1.1)	(6.1)	(1.0)	(3.6)	(3.8)	(7.1)
Phyllostylon rhamnoides	29.9	38.5	32.5	35.6	5.7	12.41
	(5.3)	(2.7)	(2.2)	(3.6)	(1.9)	(2.6)
Schinopsis quebracho-colorado	1.2	0.7	0.6	4.3	1.2	0.6
	(0.4)	(0.7)	(0.4)	(5.4)	(0.3)	(0.3)
Tabebuia sp. (lapacho group)	1.6	1.6	3.8	5.2	1.9	2.2
	(0.2)	(0.3)	(3.8)	(5.9)	(0.4)	(0.7)

[a] Values in parentheses are standard deviation. n = 8 for each fungus-wood pairing.

ample of Highley and Scheffer (1970), we separated the species into four decay resistance classes: highly resistant, 0–10% weight loss; resistant, 11%–24%; moderately resistant, 25%–44%; and nonresistant, 245%. This arbitrary decay resistance classification is suggested in the ASTM standards (ASTM 1994) and has also been used by Clark (1969) and others. For each species, we used the most destructive fungus as the determinant of resistance (Highley and Scheffer 1970).

After 12 weeks of exposure, all Bolivian species had less than 13% weight loss and

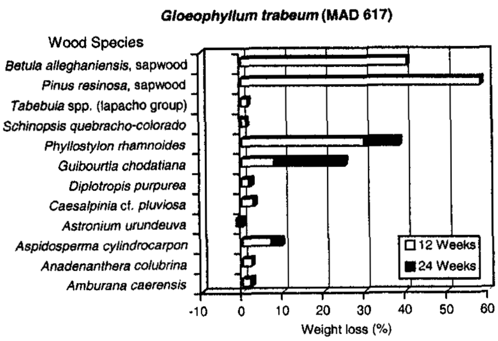

FIG. 1. Weight loss after 12 and 24 weeks of exposure to *Gloeophyllum trabeum* (MAD 617).

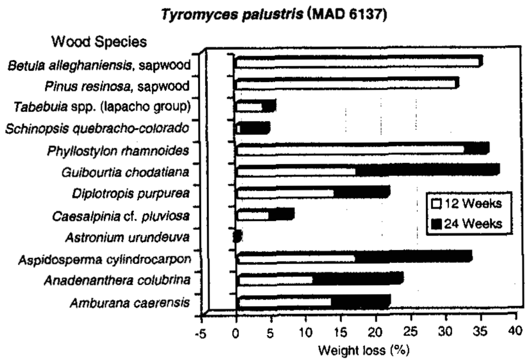

FIG. 2. Weight loss after 12 and 24 weeks of exposure to *Tyromyces palustris* (MAD 6 137).

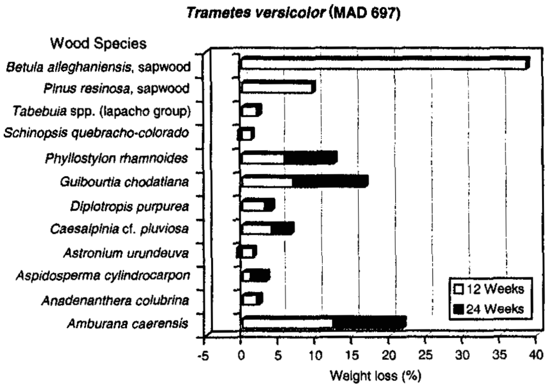

FIG. 3. Weight loss after 12 and 24 weeks of exposure to Trametes versicolor (MAD 697).

most had less than 10% weight loss as a result of decay by the white-rot fungus *Trametes versicolor.* For both brown-rot fungi, the controls and *Phyllostylon rhamnoides* had at least 30% weight loss. For all other Bolivian species, *Tyromyces palustris* caused less than 18% weight loss and *Gloeophyllum trabeum* less than 10% weight loss. Table 2 lists the decay resistance ratings of the Bolivian species after 12 weeks of exposure.

Because some species were suspected to be very resistant to decay, we designed the study to continue for more than the standard 12 weeks. If soil-block bottles are incubated for 24 weeks, they lose moisture, rendering the fungi less active. To make the test as severe as possible, we used two back-to-back 12-week tests. The two sets of samples for the 24-week test—one set oven-dried, weighed, and steam-sterilized; the other set only-steam-sterilized — showed similar weight losses. However, the oven-dried samples cracked, checked, and in some cases fell apart during drying. For future 24-week studies, we recommend that samples be transferred from 12-week-old bottles to fresh bottles without oven-drying. The sapwood control blocks were too decayed to be replaced into bottles for the second 12-week period.

Only two species showed a difference in decay resistance after 24 weeks compared with that after 12 weeks. *Guibortia chodatiana* and *Aspidosperma cylindrocarpon* shifted from the resistant to the moderately resistant category.

We compared our soil-block test results to reports in the literature. In some cases, results from laboratory, graveyard, or stake tests are reported; more often, the only sources of information are general observations and experience in service. Very little information was available for *Caesalpinia pluviosa, Guibourtia chodatiana,* and *Phyllostylon rhamnoides.* For *Aspidosperma cylindrocarpon,* we compared our results with results from a soil-block test (Highley and Scheffer 1970). In both studies, the white-rot fungus *T. versicolor,* MAD 697, and the brown-rot fungus *G. trabeum,* MAD 617, caused less than 10% weight loss. In our study, however, the very aggressive brown-rot fungus *T. palustris*, MAD 6137, caused 17% weight loss. In contrast, in the 1970 study, *Po-*

TABLE 2. *Decay resistance of wood species after 12 weeks of fungal exposure.*[a]

Species	Decay resistance class[b]
Amburana caerensis	Resistant
Anadenanthera colubrina	Resistant
Aspidosperma cylindrocarpon	Resistant
Astronium urundeuva	Highly resistant
Caesalpinia cf. *pluviosa*	Highly resistant
Diplotropis purpurea	Resistant
Guibourtia chodatiana	Resistant
Phyllostylon rhamnoides	Moderately resistant
Schinopsis quebracho-colorado	Highly resistant
Tabebuia sp. (lapacho group)	Highly resistant

[a] For each species, the most destructive fungus was used as the determinant of resistance (Highly and Scheffer 1970).
[b] Highly resistant, 0–10% weight loss; resistant, 11%–24%; moderately resistant, 25%–44%; and nonresistant, ≥45%.

ria monticola (syn. *Postia placenta)* (MAD 698) caused only 8% weight loss. In a similar study, Monteiro and de Freitas (1997) found that *Aspidosperma polyneuron* Mull. Arg. and an unidentified species of *Astronium* from Brazil were very decay resistant. Greenwood and Tainter (1980) evaluated the decay resistance of 16 species from Paraguay using soil-block tests. They also found that species of *Astronium, Anadenanthera, Aspidosperma,* and *Tabebuia* (lapacho group) were highly resistant to decay.

The use of a second 12-week period of exposure to decay fungi in soil-block bottles is an effective method of separating the decay-resistance ratings of durable tropical timbers. Species that show virtually no weight loss after 12 weeks do not change decay resistance categories. Those species that border between two categories can be more accurately classified after a second 12-week exposure period.

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