NATURAL DURABILITY OF EIGHT TROPICAL HARDWOODS FROM CAMEROON

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NZOKOU, P., WEHNER, K. & KAMDEM, D. P. 2005. **Natural durability of eight tropical hardwoods from Cameroon.** This study investigated the natural durability of eight tropical wood species which were commercial wood species *Triplochiton scleroxylon, Khaya ivorensis, Terminalia superba, Chlorophora excelsa* and *Pterocarpus soyauxii*, and secondary species, namely, *Microberllinia brazzavilensis, Pycnanthus angolensis* and *Musanga cecropioides* tested against brown rot (*Gloeophyllum trabeum* and *Poria placenta*) and white rot (*Irpex lacteus* and *Trametes versicolor*) decay fungi according to a laboratory soil block test conducted according to ASTM D2017-81 standard. Weight losses (WL) obtained after 16 weeks of exposure to decay fungi were used to calculate the decay index, classify and rank the natural fungal durability of these species. *Pterocarpus soyauxii* with a decay index of less than 0.15 was the only species resistant to both brown rot *G. trabeum* and white rot *T. versicolor*. It is suitable for above and ground contact applications. *Microberllinia brazzavilensis, T. superba, K. ivorensis, P. soyauxii* and *C. excelsa* showed potential for above ground applications with WL of less than 20% when exposed to brown rot *G. trabeum* as well as WL of more than 35% against *P. placenta* and the white rot decay fungi.

Key words: Decay – *Gloeophyllum trabeum* – *Poria placenta* – *Trametes versicolor* – *Irpex lacteus*

NZOKOU, P., WEHNER, K. & KAMDEM, D. P. 2005. **Ketahanan semula jadi lapan kayu keras tropika dari Cameroon.** Kajian ini menyiasat ketahanan semula jadi lapan spesies kayu tropika iaitu spesies komersial *Triplochiton scleroxylon, Khaya ivorensis, Terminalia superba, Chlorophora excelsa* dan *Pterocarpus soyauxii* serta spesies sekunder *Microberllinia brazzavilensis, Pycnanthus angolensis* dan *Musanga cecropioides.* Spesies kayu ini didedahkan kepada kulat reput perang (*Gloeophyllum trabeum* dan *Poria placenta*) serta kulat reput putih (*Irpex lacteus* dan *Trametes versicolor*) di makmal menggunakan ujian blok kayu–tanah selaras dengan piawai ASTM D 2017-81. Berat yang hilang (WL) selepas 16 minggu pendedahan kepada kulat reput diguna untuk mengira indeks pereputan serta mengelas dan menentukan tahap ketahanan semula jadi kayu-kayu ini. *Pterocarpus soyauxii* yang mempunyai indeks pereputan kurang daripada 0.15 merupakan satu-satunya spesies yang mempunyai kerintangan kepada kulat reput perang *G. trabeum* dan kulat reput putih *T. versicolor.* Kayu ini sesuai untuk penggunaan di atas tanah dan penggunaan bersentuhan dengan tanah. *Microberllinia brazzavilensis, T. superba, K. ivorensis, P. soyauxii* dan *C. excelsa* berpotensi untuk penggunaan bersentuhan dengan tanah. Kayu-kayu ini mempunyai WL kurang daripada 20% apabila didedah kepada kulat reput perang *G. trabeum* dan WL lebih daripada 35% apabila didedah kepada *P. placenta* dan kulat reput putih.

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Introduction

Tropical forests are known for their structurally complex diversity. Timber harvesting from tropical forests has been characterized by selective logging of a few major commercial species, leaving untapped or as waste a large group of commercially less acceptable species called lesser-known or secondary species (Freezaillah 1984). Pow and Babjide (1977) reported that of about 600 tree species, only 60 in Nigeria were being used commercially. A similar pattern is observed in Cameroon, where more than 300 species attain exploitable size, but only about 80 are commercially exploited, of which only five contribute more than half the total volume harvested (Nzokou 1996). These main species include ayous (*Triplochiton scleroxylon*), sapele (*Entandrophragmma cylindricum*), African mahogany (*Khaya ivorensis*), iroko (*Chlorophora excelsa*) and frake (*Terminalia superba*). Other species are considered secondary species and are, therefore, mostly used locally for firewood and other low value construction applications.

A wide variety of information is available on tropical species, often related to botanical characteristics as well as structural, anatomical and mechanical properties. Data on machining and finishing properties as well as durability and seasoning behaviour of wood are often limited or are of subjective quality (Collardet 1976). Several underutilized tropical timber species have been reported to possess good mechanical and physical properties, but their utilization is limited to outdoor applications where the biological and physical deterioration is a threat (Ofori 1985). A comprehensive literature review has shown that limited information is available on the natural durability of the so-called 'secondary species'.

Collardet (1976) reported that 80 to 85% of known tropical wood species are not durable. Consequently, problems associated with low durability of tropical timbers are one of the major deterrents to increased utilization of tropical wood species for outdoor applications.

Several reports described the durability of tropical woods in terms of durable and not durable (Sallenave 1955, Bolza & Keating 1972, Fortin & Poliquin 1976, Chudnoff 1980, Desch & Dinwoodie 1981, Patterson 1988). The description of the methodology used to classify species is limited. The objective of this study was to examine the classification of the durability of some Cameroonian tropical species using a well-established and accepted protocol.

A standard (ASTM D-2017-81), published by the American Society for Testing Materials (ASTM 1999), describing a relatively simple laboratory method was used to estimate the natural durability of fungi and to extrapolate their durability in relation to their end-use above ground or ground contact applications. This protocol, although designed for temperate species and in temperate environments, was used to estimate the durability of tropical species and to enable comparison of results with data available in the literature (Bolza & Keating 1972, Fortin & Poliquin 1976, Miller *et al.* 2003).

Eight species were selected and used in this study. Four major species known as commercial species—African mahogany (*K. ivorensis*), iroko (*C. excelsa*), African padauk (*Pterocarpus soyauxii*) and ayous (*T. scleroxylon*), and four others described as secondary species—frake (*T. superba*), ilomba (*Pycnanthus angolensis*), parassolier

(*Musanga cecropioides*) and amouk (*Microberllinia brazzavillensis*) were used. Among these species, only iroko is considered resistant to brown and white rot fungi (Chudnoff 1980, Fortin & Poliquin 1976), African mahogany and frake are both classified as susceptible to both brown and white rot fungi (Fortin & Poliquin 1976), while ayous, amouk, ilomba and parassolier are classified as very susceptible to brown and white rot fungi (Fortin & Poliquin 1976, Chudnoff 1980).

Materials and methods

Wood species

Eight tropical wood species, ayous (*T. scleroxylon*), frake (*T. superba*), amouk (*M. brazzavillensis*), ilomba (*P. angolensis*), iroko (*C. excelsa*), African mahogany (*K. ivorensis*), African padauk (*P. soyauxii*) and parassolier (*M. cecropioides*) were obtained from Cameroon. Southern yellow pine (*Pinus echinata*), red maple (*Acer rubrum*) and aspen (*Populus tremuloides*) were used as reference for comparison.

Sample preparation

Flat and quarter sawn air-dried boards measuring (50 × 50 × 500 mm) were obtained from a sawmill in Douala, Cameroon and shipped to the Michigan State University in East Lansing. Special care was taken to ensure that species were accurately identified using both macroscopic and microscopic anatomical features such as colour, density, rays, pores and parenchyma cells. Upon arrival, the boards were stored in a conditioning room maintained at 20 °C and 65% relative humidity until they reached equilibrium moisture content (EMC) of 12 ± 2%. The specific gravity (SG) of each species was determined on samples conditioned at 12% EMC by dividing the oven-dry weight by the volume at 12% EMC. Kiln-dried southern yellow pine, red maple and aspen used in this study were obtained from lumber yards located in Lansing Michigan.

Fifty sapwood cubes measuring 19 × 19 × 19 mm were cut from the boards for each species and conditioned at 20 °C and 65% relative humidity to EMC of 12 ± 2% before the decay test. Conditioned cubes with similar weights were chosen for further testing.

Soil block test

The decay test was conducted according to ASTM D-2017-81 procedures (ASTM 1999). Two brown rot fungi—*Gloeophyllum trabeum* (Madison 617 ATCC 11539), *Poria placenta* (Madison 698, ATCC 11538) and two white rot fungi—*Trametes versicolor* (R-105 from Jeff Morrell) and *Irpex lacteus* (FP-105915 from Jeff Morrell) were used in this study.

Polycarbonate bottles of 400 ml were filled with 95 g of forest soil of about 70% MC. The forest soil was first screened for roots and other wood debris. Then the soil clumps were broken into particles and passed through No. 6 sieve and stored in plastic bags.

An aspen feeder strip measuring 3 × 25 × 30 mm was placed above the soil in each bottle and the bottles were autoclaved for one hour at 121 °C. The bottles were inoculated with agar plugs cut from the edge of an actively-growing colony of the test fungus. Culture bottles were incubated until the fungus covered the feeder strips. Bottles with vigorous fungus growth without contamination were selected for the soil block test.

Conditioned wood cubes were weighed prior to sterilization using autoclave for one hour at 121 °C. Sterilized cubes were aseptically placed on the feeder strip with end exposed to the feeder strips. Ten sterilized cubes from each wood species were used for each decay fungus. The cubes were incubated at 25 °C and 75% relative humidity for 16 weeks to obtain a weight loss (WL) of about 60% for the aspen reference cube samples (Jusoh & Kamdem 2001).

At the end of the 16-week incubation period, the wood blocks were removed from the culture bottles. Fungal mycelium were carefully and gently brushed off from the blocks with a sponge. Mycelium-free blocks were placed in the conditioning room maintained at 20 °C and 65% relative humidity until they reached a constant weight to the nearest 0.01g.

The weight loss percentage was calculated by using the weight of the conditioned cubes immediately before the sterilization by autoclave ($W1$) and the weight of the conditioned cubes after the16 week-incubation period and the removal of the fungal mycelium ($W2$) using the following equation:

$$WL\ (\%) = 100 \times \frac{WL - W2}{W1} \tag{1}$$

The decay index (*DI*) was calculated according to European standard E350-1 by dividing the *WL* of a species by that of the reference aspen when exposed to similar decay fungus for 16 weeks using the following equation:

$$DI = \frac{WL \text{ of a species}}{WL \text{ of aspen reference species}} \tag{2}$$

Data analysis

A non-parametric statistical analysis was performed to establish and to rank the durability of each species according to their WL against decay fungi. The Wilcoxon matched pairs signed-rank test was chosen because it can handle non-parametric data with large standard deviation and also to determine the direction and magnitude of the difference between pairs, and to rank the difference between groups using SAS Version 8 (SAS Institute 1999). This test performs a ranking of mean values by giving more weight to the data showing large variability and less weight to data with small differences. The group with a lower Wilcoxon score is the best performer and the group with the higher Wilcoxon score is the worst performer. The Krustal-Wallis test was also used to compare the difference between the WL of the species at a 5% significance level because it can handle non-parametric data.

Results and discussion

Table 1 shows specific gravity values of the timbers. The WL of reference southern yellow pine, aspen and maple samples challenged by pure cultures of brown rot and white rot fungi during the 16-week period averaged 44 to 61%. This level of WL for reference species confirms the validity of this soil block test.

After 16 weeks of exposure, the average WL of samples exposed to the brown rot fungus *G. trabeum* ranged from 0.3% for African padauk to 67.3% for ilomba (Table 2). Ayous samples had 24% WL, African mahogany and amouk samples had 9.4 and 9.0% WL respectively. Ayous (42%), amouk (37%), African mahogany (23%) and frake (37%) had higher WL when exposed to *P. placenta* compared with *G. trabeum*.

The WL of iroko samples exposed to both brown rot fungi was less than 7%: an average of 5% with *P. placenta* and 6.4% with *G. trabeum*. African padauk showed a good level of resistance against *G. trabeum* with a WL of less than 1%. Ilomba and parassolier samples were almost destroyed by *P. placenta*, losing 56 and 60% weight respectively. No significant difference was found between the WL values of ilomba, parassolier and aspen. From these results, it can be concluded that African padauk showed an acceptable level of resistance against *G. trabeum*. The same remarks can

Table 1 Average specific gravity of wood species

Species	Vernacular name	Specific gravity
Triplochiton scleroxylon	Ayous	0.36
Pycnanthus angolensis	Ilomba	0.70
Musanga cecropioides	Parassolier	0.23
Microberllinia brazzavillensis	Amouk	0.55
Terminalia superba	Frake	0.47
Khaya ivorensis	African mahogany	0.68
Pterocarpus soyauxii	African padauk	0.67
Chlorophora excelsa	Iroko	0.52

Table 2 Percentage weight loss (WL) and moisture content (MC) of wood blocks after 16 weeks of laboratory soil block test

Wood	Fungus							
	P. placenta		*G. trabeum*		*I. lacteus*		*T. versicolor*	
	WL	MC%	WL	MC%	WL	MC%	WL	MC%
Ayous	42 (4)	84	24 (4)	52	56 (8)	77	61 (8)	56
Ilomba	56 (6)	91	67 (0.3)	49	56 (27)	52	64 (18)	87
Parassolier	60 (9)	87	64 (7)	86	NA	NA	NA	NA
Amouk	37 (8)	61	9 (2)	48	70 (8)	54	57 (7)	77
Frake	37 (8)	67	15 (5)	46	51 (8)	44	52 (5)	73
African mahogany	23 (14)	72	9.4 (3)	43	45 (7)	49	54 (5)	49
African padauk	ND	ND	0.3 (0.5)	65	ND	ND	0.2 (0.1)	79
Iroko	5 (1)	58	6.4 (2.5)	38	34 (10)	42	51 (10)	54
Aspen	57 (4)	90	50 (5)	84	60 (7)	87	49 (6)	69
Yellow pine [a]	49 (3)	NA	46 (4)	NA	44 (7)	NA	48 (7)	NA
Maple [a]	45 (7)	NA	61 (3)	47	60 (10)	NA	48 (10)	NA

ND = not done

Values in parentheses are standard deviations.

[a] Source = Kamdem *et al.* (1996)

be made for iroko affected by *G. trabeum* and *P. placenta*. Brown rot is known to degrade preferentially cellulose and it is more prevalent in softwood species.

The WL of African padauk after 16 weeks of exposure to white rot *T. versicolor* was less than 1%, confirming the high decay resistance of this species as reported (Nzokou & Kamdem 2003). WL of all other species challenged with white rot *I. lacteus* and *T. versicolor* were higher than 33% (Table 2). For *I. lacteus*, the lowest WL of 34% was obtained with iroko, followed by African mahogany 45%, frake 51%, ilomba and ayous, each 56% and amouk 70%. Samples exposed to *T. versicolor* had WL values ranging from 51% for iroko to 64% for ilomba. The WL values of iroko and African mahogany challenged by white rot fungi were statistically different from the WL of aspen reference specimens at 95% level of confidence. The high WL values obtained with white rot for seven of the tropical hardwood species can be explained by the fact that hardwoods are more susceptible to white rot decay fungi than softwood (Schultz & Nicholas 1997). White rot fungus is always included in the testing of the natural durability of hardwood species because it attacks all of the wood components, while brown rot fungi preferably attack the hemicellulose and cellulose, leaving the lignin undigested (Hickin 1971, Green & Highley 1997). Differences in the ability of brown and white rot fungi to use hemicelluloses are believed to be the main reason why brown rot fungi prefer softwoods to hardwoods (Winandy & Morell 1993, Nzokou & Kamdem 2003).

Several factors have been used to explain the durability of wood species. The factors are density, growth rate, nitrogen and mineral content, hemicellulose content as well as the type and amount of extractives compounds (Eaton & Hale 1993). Several tropical wood species contain extractives, inorganic and nitrogen compounds that can be related to durability. Iroko heartwood contains an alkaloid known as chlorophorin a stilbene with known antifungal activity (Padayachee & Odhav 2001, Shimizu *et al.* 2003). Padauk is also a well-known and very durable species. Its durability is likely attributed to its extractives rich in flavonoids.

According to ASTM standard, D2017-81, an average weight loss of 0 to 10% is considered as highly resistant, 11 to 24% is considered as resistant, 25 to 44% is classified as moderately resistant, and anything above 45% is considered as slightly resistant or non-resistant. Thus, from the weight loss values caused by the brown rot fungi *G. trabeum* and *P. placenta* and based on ASTM criteria using the most destructive fungus as the determinant of the resistance, parassolier and ilomba are classified as non-resistant, ayous, frake and amouk are moderately resistant, African mahogany is resistant and iroko is classified as highly resistant against brown rot fungi (Table 3). However, all seven species are classified as non-resistant against white rot fungi (Table 3). To compare with European standards, the decay index (x) calculated as the average corrected mass loss of test specimens divided by the average mass loss of reference specimens (aspen) is presented in Table 4 (EC 1993).

Table 3 Natural fungal durability classification according to ASTM 2017-81

Wood	Fungus type	Durability classification
Ayous	Brown rot	Moderately resistant
	White rot	Non-resistant
Ilomba	Brown rot	Non-resistant
	White rot	Non-resistant
Parassolier	Brown rot	Non-resistant
	White rot	Non-resistant
Amouk	Brown rot	Moderately resistant
	White rot	Non-resistant
Frake	Brown rot	Resistant
	White rot	Non-resistant
African mahogany	Brown rot	Resistant
	White rot	Non-resistant
African padauk	Brown rot	Highly resistant
	White rot	Highly resistant
Iroko	Brown rot	Highly resistant
	White rot	Non-resistant

According to the standard, specimens are classified as very durable (class 1, x < 0.15), durable (class 2, 0.15 < x < 0.30), moderately durable (class 3, 0.30 < x < 0.60), slightly durable (class 4, 0.60 < x < 0.90), and not durable (class 5, x > 0.90). Classification of the fungal durability according to EN 350-1 presented in Table 5 confirmed iroko and padauk as durable species. Except padauk, all species used in this study showed considerable susceptibility to white rot fungi, especially *T. versicolor.*

These classifications are similar to previously published results by Fortin and Poliquin (1976) as well as Chudnoff (1980). Chudnoff (1980) considered iroko as highly decay and termite resistant. However, this study suggests that iroko is decay resistant against brown rot but not against white rot fungi. It must be emphasized that the durability classification may also vary with the geographic origin and the specific conditions of the test (Fortin & Poliquin 1976, Zabel & Morrell 1992). For instance, Fortin and Poliquin (1974) reported contradictory results, i.e. iroko as

Table 4 Decay index of wood samples according to EN 350-1

	Fungus			
Wood	*P. placenta*	*G. trabeum*	*I. lacteus*	*T. versicolor*
Ayous	0.74	0.5	0.93	1.24
Ilomba	0.98	1.3	0.98	1.31
Parassolier	1.05	1.3	ND	ND
Frake	0.65	0.3	0.85	1.06
Amouk	0.65	0.2	1.17	1.16
African mahogany	0.4	0.2	0.75	1.1
African padauk	ND	0.01	ND	0.004
Iroko	0.09	0.1	0.57	1.04

Table 5 Durability classification according to EN 350-1

	Fungus			
Wood	*P. placenta*	*G. trabeum*	*I. lacteus*	*T. versicolor*
Ayous	4	3	5	5
Ilomba	5	5	5	5
Parassolier	5	5	ND	ND
Frake	4	3	4	5
Amouk	4	2	5	5
African mahogany	3	2	4	5
African padauk	ND	1	ND	1
Iroko	1	1	3	5

highly resistant, moderately resistant and non-resistant depending on the sample provenance.

Wood does not exhibit the same durability in all applications. The durability of a wood species used in ground contact exterior application is different from that for above ground interior or exterior applications. A wood species may be durable if used for shingle, window or door frames but not resistant for farm posts or piling. Several standards list the durability of a species or products in terms of hazard class and use category (AWPA 2002).

The ASTM standard D2017-81 (ASTM 1999) recognizes the susceptibility to *P. placenta* and *T. versicolor* when wood is used in ground contact. Therefore, these two fungi can be used as screening fungi for durability of wood used in such conditions. *Gloephlleum trabeum* is a better index for the durability of wood in above ground conditions (ASTM 1999).

Data for the ground contact durability index fungi (*P. placenta* and *T. versicolor*) and above ground fungus (*G. trabeum*) presented in Table 2 indicated that ilomba and parassolier were non-resistant for above and ground contact applications, ayous and frake were respectively moderately resistant and resistant to above ground conditions but non-resistant in ground contact applications. African mahogany was resistant to ground contact and highly resistant to above ground applications. Amouk was highly resistant in above ground applications and moderately resistant in ground contact as well as iroko and African padauk were both resistant in ground contact and above ground conditions.

Table 6 summarized the suitability for ground contact and above ground applications for the wood species used in this study. This classification, although slightly different from the traditional system, shows better potential for species previously classified as non-resistant or moderately resistant to decay fungi to be used for above ground applications. Ayous, frake and amouk, previously classified as non-durable, could be recommended for above ground specific end-uses with limited concern for their susceptibility to decay fungi.

Table 6 Natural decay classification based on above ground and ground contact (ASTM D 2017-81)

Wood species		Application	
Scientific name	Common name	Above ground	Ground contact
Triplochiton scleroxylon	Ayous	Moderately resistant	Non-resistant
Pycnanthus angolensis	Ilomba	Non-resistant	Non-resistant
Musanga cecropoides	Parassolier	Non-resistant	Non-resistant
Terminalia superba	Frake	Resistant	Non-resistant
Microberllinia brazzavilensis	Amouk	Highly resistant	Non-resistant
Khaya ivorensis	African mahogany	Highly resistant	Non-resistant
Pterocarpus soyauxii	African padauk	Highly resistant	Highly resistant
Chlorophora excelsa	Iroko	Highly resistant	Non-resistant

The Wilcoxon ranking of the performance of the seven species when exposed to four fungal species is presented in Table 7. This statistical test takes into account the average performance of each species and the range of values to assign a rank

Table 7 Classification of the decay susceptibility of tropical wood using the Wilcoxon ranking system

Timber	WL (%)		Wilcoxon score	Ranking
	Average	Range		
		T. versicolor		
Ayous	61 (8)	50 - 72	37.06	6
Ilomba	64 (17)	38 - 84	38.12	7
Frake	51 (5)	43 - 60	21.62	2
Amouk	57 (7)	46 - 67	32.37	5
African mahogany	53 (5)	45 - 59	25.12	4
African padauk	0.24 (0.15)	0 - 0.4	3	1
Iroko	51 (10)	37 - 69	22.68	3
		P. placenta		
Ayous	42 (4)	35 - 46	28	5
Ilomba	56 (6)	46 - 62	39.25	6
Frake	37 (8)	21 - 43	24.07	4
Amouk	37 (9)	15 - 42	22.87	3
African mahogany	23 (15)	8 - 48	16	2
Iroko	5 (1)	4 - 7	4.5	1
		I. lacteus		
Ayous	56 (8)	41 - 63	29.81	5
Ilomba	56 (28)	31 - 90	23.75	3
Frake	51 (9)	39 - 62	25.56	4
Amouk	70 (9)	54 - 82	40.18	6
African mahogany	45 (7)	32 - 52	18.62	2
Iroko	34 (10)	22 - 55	9.06	1
		G. trabeum		
Ayous	24 (5)	20 - 27	34	6
Ilomba	68 (1)	67 - 68	36.5	7
Frake	15 (5)	11 - 22	29.62	5
Amouk	9 (1)	7 - 11	20.56	4
African mahogany	10 (3)	7 - 15	21.5	3
African padauk	0.6 (0.5)	0 - 1	3	1
Iroko	6 (3)	5 - 13	11.5	2

to each species in relation to others within the same treatment. For *T. versicolor*, African padauk (used only with *T. versicolor* and *G. trabeum*) was ranked first, followed by frake, iroko, African mahogany, amouk, ayous and ilomba. For *P. placenta*, iroko was ranked first, followed by African mahogany, amouk, frake, ayous and ilomba. Very similar ranking was obtained for *I. lacteus*, the only difference being that ilomba was classified third. For *G. trabeum*, African padauk was the best performer, followed by iroko, African mahogany, amouk, frake, ayous and ilomba. Despite a few unexpected results such as the high ranking of ilomba with *I. lacteus*, the Wilcoxon rankings were consistent with the average values and suitable to compare and classify the natural durability of wood species. Overall, the durability classification obtained in this study was in agreement with data available in the literature. However, this study makes a step further by separating and classifying species for their durability in above and ground contact applications.

Conclusions

The natural durability of tropical hardwoods was evaluated based on weight loss and the decay index obtained from laboratory soil block test. Ayous, iroko, frake, parassolier, ilomba, African mahogany and amouk were all susceptible to white rot decay fungi. Iroko and African padauk were highly resistant to brown rot fungi. Based on ASTM suggestion screening for above and ground contact, frake, amouk, African mahogany, iroko and African padauk all showed good potential for above ground applications. African padauk was most suitable for both above and ground contact applications.

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