Original

The Natural Resistance of Tropical Woods against Biodeterioration

Kunio TSUNODA*[1]

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Abstract——Forty-one tropical wood species (30 Brazilian and 11 Ghanaian species) were tested for their natural resistance against decay fungi using *Coriolus versicolor* and *Tyromyces palustris* according to JIS Z 2119, subterranean termites under choice situations using *Coptotermes formosanus* and wood-destroying borers in the marine environment.

Seventeen species of the test materials were resistant against both decay fungi and termites, sustaining less than 1% weight loss. Only 7 of them were also resistant against shipworm attack: *Swartzia aptera, Mezilaulus itauba, Dialium aubrevillei, Erytxrophleum ivorense, Ongokea gore, Manilkara multinervis* and *Chlorophora excelsa*. Further investigation on their extractive will be worthwhile to undurstand the factors involved in the high resistance against biodeterioration.

Key words: tropical wood, decay fungus, termite, marine borer, shipworm, natural resistance, extractives

1. Introduction

It is well known that a great deal of economic loss of wood is annually caused by decay fungi, wood-attacking insects including subterranean termites, and marine wood-boring animals. However, only limited amount of fundamental information on the natural durability of tropical woods has been available. Due to the scattered knowledge, therefore, most recommendations and guide lines of practical wood use have been dependent largely on the experience.

On the other hand, some early workers were deeply involved in the natural resistance of tropical hardwoods[1~5]. They tried to establish an estimate of the comparative resistance of woods against biological attacks in both laboratory and field tests. The data has been halpful for the selection of wood species for use in biologically hazardous situations. Based on the extensive screening trials, some extractives of certain wood species were proved to be effective in preventing biodegradation[6~8].

Apart from synthetic chemistry, naturally-existing chemicals seem more environmentally acceptable because governmental and public concern about the use of

*[1] Research Section of High Performance Wood Products.

man-made chemicals has been increasing and authoritative approval is becoming difficult to obtain.

The work reported here is the result of laboratory decay and termite bioassays, and marine exposure treals of some tropical hardwoods.

2. Materials and Methods

2.1 Wood samples

Thirty species of Brazilian woods were supplied by Serviço de Treinamento e Pesquisas Florestais, and 11 Ghanaian woods were obtained from Forest Products Research Institute (Ghana). Botanical and common names are given in Table 1 together with their air-dried specific gravities.

Cubic wood samples (2×2×2 cm) were prepared from each wood species for laboratory decay and termite tests. For marine exposure, a test board (5×2 cm in cross section and 10 cm in length) was cut from each timber block.

2.2 Decay test

Decay test was conducted according to JIS Z 2119-1977 using 6 replicates of each timber species. Sapwood specimens of *Fagus crenata* and *Cryptomeria japonica* were employed as references to determine the relative ratio of decay resistance of the tested materials. Details should be referred to the standard.

2.3 Termite test

Test samples were exposed to the laboratory colony of *Coptotermes formosanus* Shiraki at 28±2°C for 4 weeks. Five replicates of all the test wood species were randomly placed, 3 cm apart from each other on the surface of the soil in the concrete trough where the termite colony had been maintained. Sapwood specimens of *Pinus densiflora* were included for monitoring the activity of the termites during the test period.

Percentage weight loss of each specimen was calculated from the weights before and after laboratory choice test.

2.4 Marine exposure test

One panel each of the 41 tropical woods and *P densiflora* sapwood was exposed to marine borers' attack. The exposure was initiated on August 1, 1975 at Naruto (34° 12′30″N, 134°36′27″E), Tokushima Pref. Any replicate, unfortunately, could not be prepared due to the restricted size of wood blocks available for the present investigation.

Both cross ends of 4 boards were screwed to plastic battens taking 2 cm apart from neighbors, and the assembled boards were postitioned vertically between 80~100 cm below the water surface.

Table 1. Test tropical woods*.

Sample No.	Botanical name	Family	Common name	Specific gravity in air dry
1	*Moronobea coccinea*	Guttiferae	Anani de terra firme	0.83
2	*Aspidosperma album*	Apocynaceae	Araracanga	1.01
3	*Saccoglottis guianensis*	Humiriaceae	Acuá	1.04
4	*Goupia glabra*	Celastraceae	Cupiuba	0.94
5	*Bertholletia excelsa*	Lecythidaceae	Castanheira do pará	0.82
6	*Lecythis paraensis*	Lecythidaceae	Castaheira sapucaia	1.13
7	*Terminaria* sp.	Combretaceae	Cuiarana	1.04
8	*Peltogyne paradoxa*	Leguminosae	Coataquiçaua	1.04
9	*Roupala montana*	Proteaceae	Faeira	0.97
10	*Swartzia aptera*	Leguminosae	Gombeira	1.20
11	*Mezilaurus itauba*	Lauraceae	Itauba preta	1.00
12	*Dalbergia spuruceana*	Leguminosae	Jacarandá do pará	1.06
13	*Holopyxidium jarana*	Lecythidaceae	Jarana	1.02
14	*Ocotea fragantissima*	Lauraceae	Louro canela	0.76
15	*Adenostephanus* sp.	Proteaceae	Louro faia	0.65
16	*Ocotea* sp.	Lauraceae	Louro vermelho	0.63
17	*Ocotea* sp.	Lauraceae	Louro branco	0.47
18	*Qualea* sp.	Vochysiaceae	Mandioqueira rosa	0.69
19	*Manilkara huberi*	Sapotaceae	Maçaranduba	1.07
20	*Manilkara amazonica*	Sapotaceae	Maparajuba	0.97
21	*Didymopanax morototoni*	Araliaceae	Morototó	0.63
22	*Astronium lecointei*	Anacardiaceae	Muiracatiara	0.91
23	*Euxylophora paraensis*	Rutaceae	Pau amarelo	0.79
24	*Cordia tectandra*	Boraginaceae	Parapará	0.43
25	*Tabebuia serratifolia*	Bignoniaceae	Pau d'arco	1.23
26	*Laetia procera*	Flacourtiaceae	Pau jacare	0.90
27	*Bowdichia* sp.	Leguminosae	Sucupira	0.98
28	*Couratari* sp.	Lecythidaceae	Tauari vermelho	0.61
29	*Tachigalia* sp.	Leguminosae	Tachi preto	0.75
30	*Bagassa guianensis*	Moraceae	Tatajuba	0.93
31	*Dialium aubrevillei*	Leguminosae	Duabankyu	1.00
32	*Erythrophleum ivorense*	Leguminosae	Potrodom	0.95
33	*Mitragyna stipulosa*	Rubiaceae	Subaha	0.58
34	*Ncsogordonia paraverifera*	Tiliaceae	Danta	0.75
35	*Ongokea gore*	Olacaceae	Dodwe	0.80
36	*Manilkara multinervis*	Sapotaceae	Berekankum	1.09
37	*Lophira alata*	Ochnaceae	Ekki	1.05
38	*Cylicodiscus gabunensis*	Leguminosae	Denya	1.03
39	*Parinari excelsa*	Rosaceae	Ofam	0.85
40	*Chlorophora excelsa*	Moraceae	Iroko	0.71
41	*Nauclea diderrichii*	Rubiaceae	Opepe	0.79

* Sample Nos. 1–30: Brazilian woods, Nos. 31–41: Ghanaian woods.

During the first 5 years, the boards were removed every three months to X-ray using Softex Type EMB (X-raying conditions: 40 KV-3 mA-18 sec) and Fuji Softex films. After the period, the boards were inspected yearly until the total length of immersion reached 9 years. When necessary, surface fouling organisms were scraped to facilitate the application of X-ray technique. The X-ray photographs were used to grade the shipworm attack of the test boards according to the following scales.

0: No attaack, 1: Trace attack, 2: Slight attack, 3: Moderate attack, 4: Heavy attack

After X-raying, the boards were immediately returned to the sea to permit continuous attack. Some boards were discarded when test boards were severely attacked or grading scale reached 2 or higher after 4 years' exposure, and the remains were reconstituted for the further exposure.

3. Results and Discussion

3.1 Resistance against decay fungi

Weight losses of *F crenata* caused by *Coriolus versicolor* (L. ex Fr.) Quélet and *Tyromyces palustris* (Ber. et Curt.) Murr. were 34.5% and 24.4%, respectively. Sapwood of *C. japonica* sustained less weight losses: 9.7% by *C versicolor* and 14.0% by *T. palustris*. Relative ratios of decay resistance of all the test wood species to both *C. japonica* and F. *crenata* are summarized in Table 2.

When the ratio of wood species is higher than 1.0, the species is more resistant to decay fungi than a reference wood species. As shown in Table 2, most of the test materials were more resistant than *F. crenata* with an exception of *Mitragyna stipulosa* (No. 33) against *C. versicolor*.

In comparison with *C. japonica,* 5 species were less resistant against *C versicolor*. Those were *Ocotea* sp. (No. 17), *Didymopanax morototoni* (No. 21), *Laetia procera* (No. 26), *Couratari* sp. (No. 28) and *M. stipulosa* (No. 33). Two of them (Nos. 26 and 33) were not resistant against *T. plustris,* either.

Based on the percent weight loss of the specimens after decay test, approximately a half of the species were considered as highly decay resistant woods: sample Nos. 1, 2, 7, 8, 9, 10, 11, 12, 14, 16, 27, 31, 32, 34, 36, 37, 38 and 40. It has been pointed out that high durability of a certain group of timbers to biodegradation is primarily dependent on their extractives[9~12]. That, therefore, supports the further efforts to examine the effect of extractives. Although some tropical woods of higher density tended to show better performance in the field stake test[13], the tendency was not always true for the present test species.

Table 2. Relative decay resistance and termite resistance of tropical woods.

Sample No.	Relative decay resistance				Weight loss (%) by termites*3		
	To *Cryptomiria japonica*		To *Fagus crenata*				
	COV*1	TYP*2	COV	TYP	min.	mean	max.
1	1. 11	1. 11	1. 53	1. 32	0	2. 4	6. 6
2	1. 11	1. 10	1. 53	1. 31	0	0	0
3	1. 02	1. 11	1. 39	1. 32	0	0	0
4	1. 08	1. 07	1. 49	1. 27	0	0. 5	1. 1
5	1. 09	1. 09	1. 50	1. 30	0	0	0
6	1. 09	1. 10	1. 50	1. 31	0	0	0
7	1. 11	1. 11	1. 53	1. 32	0	0	0
8	1. 11	1. 11	1. 53	1. 32	0	0	0
9	1. 11	1. 11	1. 53	1. 32	0	0	0
10	1. 11	1. 10	1. 52	1. 32	0	0	0
11	1. 11	1. 11	1. 53	1. 32	0	0	0
12	1. 11	1. 11	1. 53	1. 31	0	0	0
13	1. 10	1. 09	1. 51	1. 30	0	0	0
14	1. 10	1. 11	1. 52	1. 32	0	0	0
15	1. 05	1. 10	1. 45	1. 32	0	11. 9	25. 8
16	1. 10	1. 11	1. 52	1. 32	0	0	0. 2
17	0. 97	1. 10	1. 34	1. 31	0	0	0
18	1. 00	0. 95	1. 51	1. 14	0	1. 2	3. 7
19	1. 10	1. 09	1. 52	1. 31	0	0	0
20	1. 08	1. 09	1. 49	1. 30	0	0	0
21	0. 83	1. 01	1. 14	1. 21	90. 0	97. 7	100
22	1. 08	1. 10	1. 49	1. 32	0	0	0
23	1. 10	1. 09	1. 52	1. 30	0	0	0
24	0. 89	1. 03	1. 20	1. 23	0	52. 9	98. 3
25	1. 09	1. 09	1. 51	1. 31	0	0	0
26	0. 94	0. 93	1. 30	1. 12	0	1. 6	4. 0
27	1. 11	1. 11	1. 53	1. 32	0	0	0
28	0. 93	1. 04	1. 28	1. 24	26. 2	36. 3	47. 4
29	1. 04	1. 10	1. 43	1. 31	0	0. 2	0. 9
30	1. 10	1. 09	1. 51	1. 30	0	0	0
31	1. 10	1. 16	1. 51	1. 32	0	0	0
32	1. 11	1. 16	1. 53	1. 32	0	0	0
33	0. 68	0. 98	0. 94	1. 12	67. 5	73. 3	80. 0
34	1. 11	1. 16	1. 53	1. 32	0	41. 9	74. 5
35	1. 10	1. 14	1. 52	1. 29	0	0	0
36	1. 10	1. 16	1. 51	1. 31	0	0	0
37	1. 10	1. 16	1. 52	1. 32	0	0. 3	1. 2
38	1. 11	1. 16	1. 52	1. 32	0	0	0
39	1. 09	1. 15	1. 50	1. 31	0	2. 2	4. 2
40	1. 10	1. 16	1. 52	1. 32	0	0	0
41	1. 09	1. 16	1. 51	1. 31	0	0. 5	1. 7
Pinus densiflora (sapwood)					0	59. 1	85. 7

*1: *Coriolus versicolor*, *2: *Tyromyces palustris* *3: *Coptotermes formosanus*

3. 2 Resistance against subterranean termites

Most of the species tested in the present investigation were proven to be termite resistant as shown in Table 2. Among Brazilian timbers, 23 of them sustained less than 1% weight loss during the test period. Carter and De Camargo found that *Reticulitermes flavipes* (Kollar) and *C. formosanus* did little damage to heartwood specimens of 9 Brazilian timber species including *Mezilaurus itauba* in no-choice bioassay[14]. When exposed to drywood termites, *Cryptotermes brevis* (Walker), several Brazilian timber species performed well[15,16]. Those were *Vouacapoua americana, Dinizia excelsa, Goupia glabra* (No. 4), *Bowdichia nitida, Bagassa guianensis* (No. 30), *Platymiscium ulei* and *Carapa guianensis*. The data obtained on the natural termite resistance of tropical woods from other origins also revealed that some timber species were naturally resistant against termite attacks[17,18].

Bultman and others who evaluated the natural resistance of Ghanaian woods to *C. formosanus* in a force-feeding situation demonstrated that 7 species of the present test materials (sample Nos. 31, 32, 35, 36, 37, 40 and 41) were highly resistant to termite attacks[5]. Among those wood species, *Lophira alata* (No. 37) and *Nauclea diderrichii* (No. 41) were slightly attacked this time. *M. stipulosa* (No. 33) and *Nesogordonia paraverifera* (No. 34) were attacked very severely, sustaining seight losses of over 40% on average.

As the portion from which specimens were obtained (*e.g.* sapwood or heratwood) was not definite in the present investigation, exact causes could not be thoroughly discussed. However, some extracatives undoubtedly could play an important role to resist against termites as well as decay fungi[9,19~23].

3. 3 Resistance against shipworms

There are some reports available regading marine borer resistance of untreated woods in various parts of the world. Review of the reports showed that the natural marine borer resistance of the same timber species was variable even at the same test locality if the time of survey was different[24,25].

On the basis of the inspection results given in Table 3, only one Brazilian timber (No. 6) was completely free from shipworm attack after 5 years' marine exposure. A few more timber species such as sample Nos. 10, 11, and 19 were highly resistant. Nineteen species (Nos. 1, 2, 4, 5, 7, 8, 13, 15, 17, 18, 20, 21, 22, 23, 24, 26, 27, 29 and 30) were heavily attacked within 2 years. In most cases of these species, shipworms could increase in not only length but also number penetrating into test boards with the period of submergence as shown in Fig. 1.

Horn listed the following 7 timbers of the Amazon valley as Teredo resistant species: *Licania macrophylla, Carapa guianensis, Mezilaurus itauba, Licaria manhuba, Eschweilera odora, Parinarium rodolphi* and *Dicorynia ingens*[26]. He specially emphasized the

Table 3. Progressive shipworm attack on tropical woods:

Sample No.	6	12	18	24	30	36	42	48	54	60	72	84	96	108
	Period of submergence (month)													
1	4	4*												
2	3	4	4	4*										
3	2	2	3	3	4	4	4	4*						
4	2	4	4	4*										
5	3	4	4	4*										
6	0	0	0	0	0	0	0	0	0	0	0	Lost		
7	2	3	4	4*										
8	4	4*												
9	1	2	3	3	3	3	4	4*						
10	0	0	0	0	0	0	1	1	1	1	1	Lost		
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	2	2	2	2	2	2	2	2*						
13	3	4	4	4*										
14	2	2	2	2	2	2	2	2*						
15	3	4*												
16	2	2	2	2	2	3	3	3*						
17	4	4*												
18	2	3	3	4*										
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	3	3	3	4*										
21	4	4*												
22	4	4*												
23	2	3	4	4*										
24	4	4*												
25	0	1	1	1	1	1	1	1	1	1	1	1	2	2
26	4	4*												
27	3	4	4	4*										
28	1	1	1	1	1	1	1	1	1	1	1	1	2	2
29	4	4	4	4*										
30	3	4*												
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	1	1	1	1	1	1	1	1	1	1	1	1	1
33	2	3	3	4*										
34	4	4	4	4*										
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	1	1	1	1	1	1	1	1	1
37	2	2	2	2	3	3	3	3*						
38	2	2	3	3	3	3	3	3*						
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	1	1	1	1	1	1	1	1	1	1	1	1	1
41	1	1	1	1	1	1	2	2*						

*: Discarded when test boards were heavily attacked or grading scale reached 2 or higher after 4 years' exposure.

Grade of shipworm qttack

0: No attack, 1: Trace attack, 2: Slight attack, 3: Moderate attack, 4: Heavy attack

A sapwood specimen of *Pinus densiflora* was heavily attacked within three months' marine exposure.

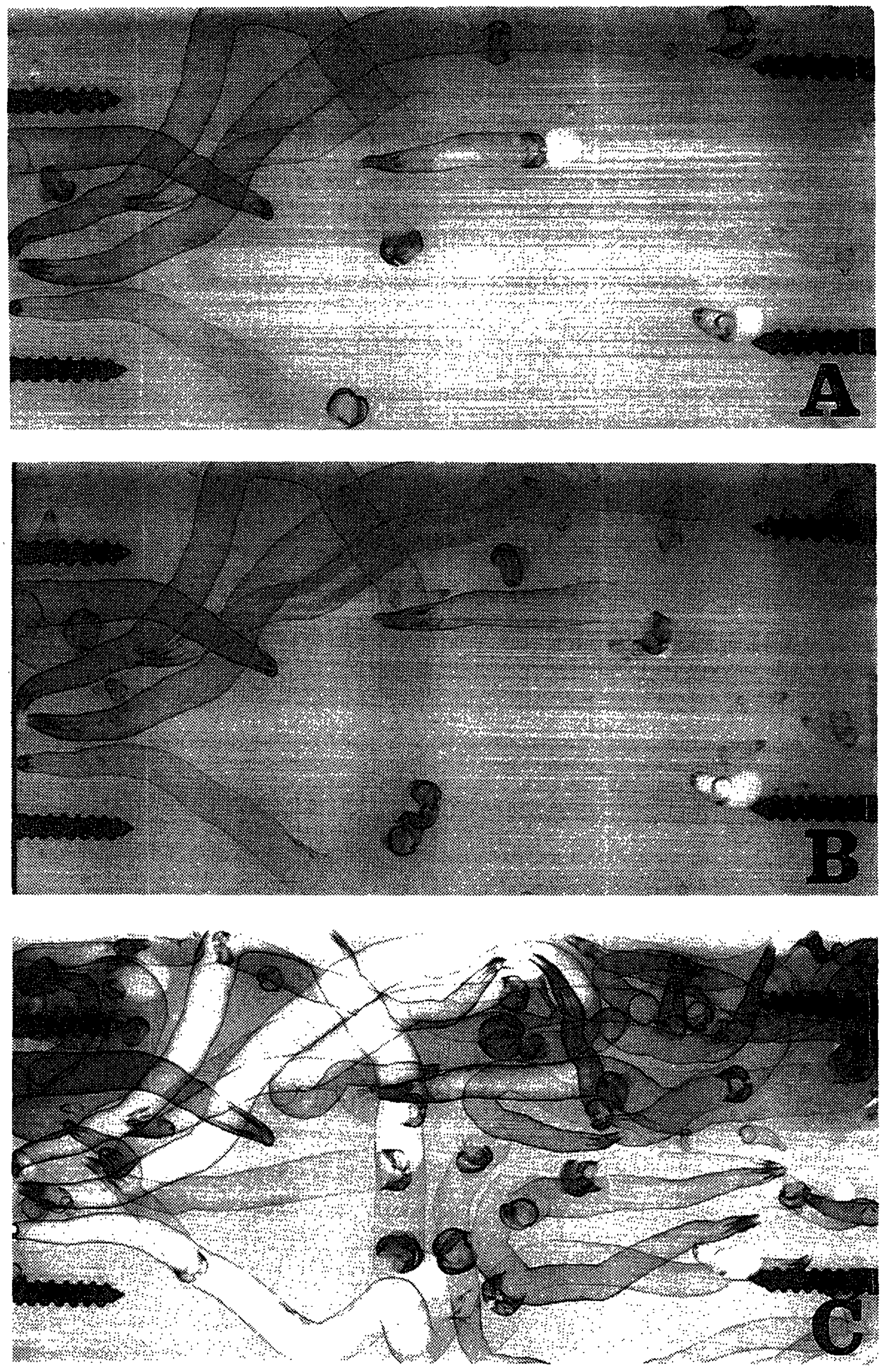

Fig. 1. Prograssive shipworm attack on a susceptible timber (sample No. 4 in Table 1).
Marine trial started on August 1, 1975 in Naruto.
A: 6 months' exposure, B: 9 months' exposure C: 12 months, exposure

significance of silica content as a factor of high marine borer resistance. Only *M. itauba* (No. 11) was included in the present investigation so that any further comparison was not made. More recently, two of the present test materials (Nos. 11 and 30) were tested by Lopez[27] in São Paulo State, Brazil. He concluded that both were moderately attacked, whereas in the present investigaton trace and severe attacks were recorded for *M. itauba* (No. 11) and *Bagassa guianensis* (No. 30), respectively.

Among 11 Ghanaian timbers (Nos. 31~41), 6 species performed well against shipworm attacks: *Dialium aubrevillei* (No. 31), *Erythrophleum ivorense* (No. 32), *Ongokea gore* (No. 35), *Manilkara multinervis* (No. 36), *Parinari excelsa* (No. 39) and *Chlorophora excelsa* (No. 40). Except *P. excelsa* (No. 39), all these species were very durable against biological attacks including decay fungi and termites.

Similarly as the cases against decay fungi and termites, the effect of position-in-tree seemed very important in preventing marine borer attack[28] in addition to the silica content as a physical barrier.

Present results indicated that over two-fifths of the test species (Nos. 2, 7, 8, 9, 10, 11, 12, 14, 16, 27, 31, 32, 35, 36, 37, 38 and 40) were highly resisant against terrestial decay fungi and termites, sustaining less than 1% weight loss. Seven of those (Nos. 10, 11, 31, 32, 35, 36 and 40) were also resistant against shipworms (no attack or trace attack after 5 years' marine exposure). Further research on their extractives will be worthwhile to account for the high resistance of them against biodeterioration.

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