KFRI Research Report 35

NATURAL DURABILITY OF COMMERCIAL TIMBERS OF KERALA WITH REFERENCE TO DECAY

M.Balasundaran
Nazma
R.Gnanaharan

KERALA FOREST RESEARCH INSTITUTE
PEECHI, THRISSUR

December 1985 Pages: 15

CONTENTS

ABSTRACT

Natural durability of five timber species of Kerala, namely, *Mesua nagassarium, Hopea parviflora, Vateria indica, Vepris bilocularis* and *Vitex altissima,* was studied adopting accelerated laboratory soil-block test method. *Bombax ceiba* was used as reference timber. Test fungi included three brown rotters and six white rotters (two species were represented by two strains). Fungi were screened for their aggressiveness and the following aggressive ones, namely, *Lenzites trabea, Polyporus palustris* (brown rotters), *P. hirsutus, P. sanguineus* and *P. versicolor* (white rotters) were used in the further study.

Wood of *M. nagassarium, H. parviflora* and *V. altissima* lost less than 10 per cent weight when exposed to any test fungus and these timber species are grouped under 'highly resistant'. Wood of *V. indica* was 'resistant' against all the fungi, even though it was rated as non-durable by the graveyard stake test. *V. bilocularis* was highly resistant against *L. trabea* but in general, it is only moderately resistant.

Significant inverse correlation between density and percentage weight loss was found in the case of *H. parviflora* and *V. bilocularis.* However, this relationship was either poor or not consistent in the case of other timber species.

Among the brown-rot fungi, *P. palustris* was the most aggressive and among the white-rot fungi, *P. versicolor.* These two fungi could be used as representative test fungi.

Keywords: Accelerated laboratory test; Decay fungi; Natural durability Tropical timbers; Wood decay.

INTRODUCTION

Tropical forests are endowed with a high diversity of species. Generally only selected species are extracted for purposes like plywood, railway sleepers, construction, etc. Because of the increasing population, expansion of agricultural land and rapid industrialisation, the forest wealth is fast depleting and it has become imperative to make use of the less-known species also. To evaluate the utilisation potential of any species, besides knowing the anatomical, physical and mechanical properties, information on the resistance to insect and decay fungi is important. If the less-known species are not durable, then their treatability with preservative chemicals to improve the service life should be studied to be able to make use of the wood effectively.

Durability of wood is generally assessed by graveyard stake test in which wooden stakes are half-buried in soil and exposed to natural outdoor conditions. However, it takes several years to complete the test. In addition to decay causing microorganisms, several other biological and chemical agencies may be acting upon the wood. Hence it is not possible to assess the damages caused by any single agency. So accelerated laboratory tests have become necessary to determine the durability of wood against fungi, termites, etc. individually. Such tests are conducted under controlled conditions of temperature and humidity. In the test to determine the resistance of wood against decay fungi, the wood is exposed to maximum hazards against several decay causing organisms individually. The decay resistance is quantified by assessing the weight loss and arriving at the relative decay resistance. The two common test methods are (1) the agar-block method (Kolle flask) and (2) soil block method. In these methods agar and soil are used as media for fungal growth respectively. In the present study soil-block method was adopted.

Timber species occurring in tropical rain forests have been tested for decay resistance by several workers. Koning-Vrolijk *et al.* (1962) tested comparative decay resistance of seven species from the rain forests of New Guinea using agar-block method. Da Costa and Osborne (1967) tested 26 species from New Guinea using soil-block method against two brown-rot fungi and two white-rot fungi. Osborne (1967) tested 25 Fijian timber species against two white-rot and two brown-rot fungi using soil-block method. Six species from the Amazon Basin of Brazil were tested against one white-rot and one brown-rot fungi using the above method (Reis, 1972).

In India, Bakshi *et* al. (1967) tested natural resistance of 52 species against five brown-rot and five white-rot fungi. As many of the species commonly occurring in the rain forests of Kerala were not included in the above study, this study was taken up to assess the natural durability of timber species of Kerala adopting accelerated laboratory tests.

MATERIALS AND METHODS

Timber species

Five mature trees (girth of 150 cm and above at breast height (GBH)) of each of the following species except *Vepris bilocularis* for which there were only three trees, were identified from selection felling coupes in the semi-evergreen and evergreen forests of Thenmala, Trichur and Wynad Forest Divisions of Kerala (Table 1).

Species	Family
Mesua nagassarium (Burm. f.) Kosterm. (= *M. ferrea* Auct, non Linn.)	Guttiferae
Hopea parviflora Bedd.	Dipterocarpaceae
Vateria indica Linn.	Dipterocarpaceae
Vepris bilocularis (Wt. & Arn.) Engl.	Rutaceae
Vitex altissima Linn.	Verbenaceae

Preparation of test blocks

Billets of 60 cm length (30 cm above and 30 cm below the GBH point of 1.37 m from ground level) were cut from the butt log of each tree. Planks of 2.5 cm thickness were sawn from the billets across the diameter. Blocks were prepared only from heartwood. In timbers without distinct heartwood and sapwood, battens of 5 cm width were removed from either side of planks. Test blocks of 2.5 x 2.5 x 1.0 cm with 1.0 cm in the grain direction were prepared. Six defect-free randomly selected blocks, from each tree were tested against each test fungus and four blocks were used as adjustment blocks. Reference blocks of the same size were prepared from mature trees of *Bombax ceiba* Linn. as described above. Highly perishable *B. ceiba* has been used earlier as a reference timber in natural durability studies in India (Bakshi *et* al., 1967). Twenty defect-free reference blocks, randomly collected, were used against each test fungus. Feeder strips of 3.0 x 3.0 x 0.3 cm were also obtained from *B. ceiba.*

Test fungi

The following brown-rot and white-rot fungi were used initially in the study. Among the white-rot fungi, two species were represented by two strains. The wood of *M. nagassarium* was tested against these nine fungi and the aggressive ones were selected.

Table **Place of collection and density (at 12 per cent moisture content) of timber species tested.**

Mesua nagassarium		*Hopea parviflora*		*Vateria indica*		*Vepris bilocularis*		*Vitex altissima*	
Tree No.	Density kg/m³	Tree No.	Density kg/m³	Tree No.	Density kg/m³	Tree No.	Density kg/m³	Tree No.	Density kg/m³
5907[a]	973	5910[a]	**929**	5913''	659	5904[a]	793	5901''	831
5908a	994	5911[a]	887	5914[a]	561	5905[a]	819	5902[a]	800
5909''	1000	5912[a]	809	5915[a]	670	5906[a]	875	5903[a]	764
5927[b]	1040	5924[b]	893	5920[b]	542			5918[c]	621
5928[b]	949	5925[b]	916	5921[b]	607			5923[c]	700
Mean	991		887		608		829		743

[a] **Thenmala Forest Division (Southern Circle)**
[b] **Trichur Forest Division (Central Circle)**
[c] **Forest Division (Northern Circle)**

Brown-rot fungi

Lenzites trabea Pers. ex Fries (= *Gloeophyllum trabeum* (Pers. ex Fries)' Murr. (FRI 635)

Polyporus meliae Underw (FRI 836)

P. palustris Berk. & Curt. (FRI 528)

White-rot fungi

Irpex flavus Klotzsch (FRI 73 (a))

Polyporus hirsutus Wulf. ex Fries (FRI 534)

P. sanguineus L. ex Fries (FRI 918)

P. sanguineus L. ex Fries (DMSRDE 720)

P. versicolor L. ex Fries (FRI 165)

P. versicolor L. ex Fries (DMSRDE 475)

The fungal cultures were obtained from the Forest Research Institute and Colleges, Dehra Dun (FRI) and the Defence Meterials and Stores Research and Development Establishment. Kanpur (DMSRDE). After the initial screening, *Z flavus* and the DMSRDE strains of *P.sanguineus* and *P. versicolor* were rejected. Also, *P. meliae* was utilised only against *M.nagassarium.*

Test methods

The procedure outlined in ASTM Standard (1981) for accelerated laboratory test was followed in the study. Test fungi were grown on 2 per cent malt agar in petri dishes and about 1 cm2 piece each was transferred aseptically on each feeder strip. When the fungus almost covered the feeder strips in about 2 to 3 weeks, the test blocks and reference blocks were transferred aseptically, two blocks into each bottle. The adjustment blocks were kept on the uninoculated feeder strips.

After about six weeks of exposure to the test fungi, two reference blocks were taken out, the fungal mycelium removed, oven dried and weighed to find out the weight loss. This was continued every week until 60 per cent weight loss was reached in the reference blocks. At that stage, test blocks and adjustment blocks were taken out and their oven-dry weight determined. If the adjustment blocks had any weight loss due to any other causes, necessary corrections were made in the oven-dry weight of test blocks. The weight loss in test blocks due to decay was calculated and the decay resistance graded. Analysis of variance test was carried out on the weight loss data.

The density of wood samples from all the trees was determined by water displacement method. The relationship between percentage weight loss and density was investigated using simple linear regression analysis.

RESULTS

Screening for aggressive decay fungi

The weight loss data of test blocks of *M. nagassarium* exposed to different fungi and the time taken (in weeks) for the reference blocks to attain 60 percent weight loss are recorded in Table 2. The test commenced with blocks from three trees (No. 5907, 5908, 5909) and after screening the .fungi for their aggressiveness, blocks from the remaining two trees were exposed to the selected aggressive fungi.

Though *L. trabea* caused a low weight loss in the test blocks from the above three trees, it was highly aggressive. It took only 14 weeks to cause 60 per cent weight loss in the reference blocks. *P. versicolor* (FRI 165) caused an average weight loss of 0.70 per cent in the test blocks compared to 0.53 per cent by *P. versicolor* (DMSRDE 475). The former took only 15weeks to cause 60 per cent weight loss in reference blocks, whereas the latter took 21 weeks. *P. sanguineus* (FRI 918) caused an average weight loss of 0.81 per cent in the test blocks and the reference blocks lost 60 per cent weight in 14 weeks. The weight loss of test blocks caused by *P. sanguineus* (DMSRDE 720) was only 0.50per cent and it took 21 weeks for the reference blocks to attain 60 per cent weight loss.

I. flavus was found to be least aggressive. The weight loss for the test blocks ranged from 0.03 to 0.15per cent. This fungus took the maximum time of 26 weeks to cause 60 per cent weight loss in the reference blocks. It was decided to eliminate the less aggressive strains of *P. versicolor* (DMSRDE.475), *P sanguineus* (DMSRDE 720) and *I.flavus* from further test. Thus, there were six fungi left for testing blocks from the remaining two trees (5927 and 5928) of *M. nagassarium.* In order of their aggressiveness they were *P. palustris* (FRI 528), *P. sanguineus* (FRI 918), *L. trabea* (FRI 635), *P. versicolor* (FRI 165), *P. hirsutus* (FRI 534) and *P. meliae* (FRI 836).

Weight loss

Mesua nagassariurn

The average weight loss of wood of *M. nagassarium* exposed to the six fungi ranged between 0.22 and 5.17 per cent (Table 2). Statistical analysis of the data showed significant difference at p =0.01 level among the test fungi and among the trees tested. The interaction between these two factors was also highly significant. Among the fungi, the white rotter *P.versicolor* caused the maximum weight loss in the test blocks and the brown rotter *L. trabea* caused the minimum. The density of wood samples at 12 per cent moisture content varied from 949 to 1040 kg/ms (Table 1).

Table 2. Weight loss in test blocks of ***Mesua nagassarium*** exposed to different fungi.

S. No.	Test fungus	Weight loss (%) * Tree number 5907	5908	5909	5927	5928	Mean	Weeks taken to attain 60 % weight loss in reference blocks
	Brown-rot fungi							
	Lenzires trabea (FRI 635)	0.25	0.19	0.07	0.19	0.39	0.22	14
2.	***Polyporus meliae*** (FRI 836)	0.44	0.17	0.15	2.97	2.19	18	16
3.	***P. palustris*** (FRI 529)	0.31	0.96	0.13	8.51	0.85	2.15	12
	White-rot fungi							
4.	***Irpex flavus*** (FRI 73 (a)	0.03	0.09	0.15	**		0.09	26
5.	***P. hirsutus*** (FRI 534)	0.35	0.45	0.79	2.51	35	07	16
6.	***P. sanguineus*** (FRI 918)	0.72	0.94	0.77	32	2.31		14
7.	***P. sanguineus*** (DMSRDE 720)	0.45	0.54	0.52	**		0.50	21
8.	***P. versicolor*** (FRI 165)	0.60	0.70	0.81	12.64	11.19	5.17	15
9.	***P. versicolor*** (DMSRDE 475)	0.66	0.38	0.54	**		0.53	21
	Average of S. Nos. 1, 2, 3, 5, 6 and 8	0.44	0.57	0.45	4.69	3.04		

Weight loss figures in Tables 2 to 6 are mean of six replicates. ** Not determined

The average weight loss of test blocks from *H. parviflora* against the five test fungi ranged between 0.70 and 1.74 per cent (Table 3). The data showed highly significant difference among the fungi and among the trees at p = 0.01 level. The interaction between these factors was also highly significant. The density ranged from 809 to 929 kg/m3 and the average density was 887 kg/m3 at 12 per cent moisture content (Table 1). The correlation coefficient (r) of linear regression data of density and weight loss was -0.78. The r^2 value of 0.60 shows that 60 per cent of the variation in weight loss is accounted by the variation in density.

Table 3 Weight loss in test blocks of *Hopea parviflora* exposed to different fungi.

Fungus	Weight loss (%)					Mean
	Tree Number					
	5910	**591**	**5912**	**5924**	**5925**	
Lenzites trabea	**0.99**	**0.32**	**1.51**	**0.61**	**70**	**1.03**
Polyporus palustris	**2.04**	**0.52**	**3.53**	**82**	**0.81**	**1.74**
P. hirsutus	**1.72**	**51**	**2.62**	**0.80**	**0.62**	**1.45**
P. sanguineus	**0.62**	**0.34**	**3**	**0.80**	**0.63**	**0.70**
P. versicolor	**0.45**	**0.36**	**2.48**	**0.40**	**1.17**	**0.97**
Mean	**16**	**0.61**	**2.25**	**0.89**	**0.99**	

Vateria indica

It can be seen from Table 4, that the average weight loss in test blocks caused by different fungi varied from 13.47 *(P. hirsutus)* to 18.02 per cent *(P. sanguineus).* Statistical analysis of the data showed highly significant difference among the test fungi and among the trees at p = 0.01 level. The interaction between these factors was also highly significant. The density of wood varied from 542 to 670 kg/m3 (Table 1). The correlation between density and weight loss due to fungal decay was poor, with only 26 per cent of the variation in weight loss being explained by variation in the density.

Table 4. Weight loss in test blocks of *Vateria indica* exposed to different fungi.

Fungus	Weight loss (%) Tree Number					Mean
	5913	5914	5915	5920	5921	
Lenzites trabea	15.04	10.21	12.60	18.61	12.02	13.70
Polyporus palustris	15.56	. 13.72	16.28	20.34	18.74	16.93
P. hirsutus	12.36	13.38	13.63	12.51	15.49	13.47
P. sanguineus	15.73	16.59	9.22	28.45	20.12	18.02
P. versicolor	14.95	9.04	14.62	22.57	19.40	16.12
Mean	14.73	12.59	13.27	20.50	17.15	

Vepris bilocularis

The average weight loss of test blocks caused by different fungi varied from 6.43 to 34.31 per cent (Table 5). The data showed highly significant difference between the test fungi and between the trees at $p = 0.01$ level. The interaction between these factors was also significant. The density of wood at 12 per cent moisture content ranged from 793 to 875 kg/m^3 and the average density was 829 kg/m^3 (Table 1). The correlation between density and weight loss was highly significant with $r = -0.99$.

Table 5. Weight loss in test blocks of *Vepris bilocularis* exposed to different fungi

Fungus	Weight loss (%) Tree number			Mean
	5904	59.05	5906	
Lenzites trabea	9.06	5.86	4.38	6.43
Polyporus palustris	39.74	37.	25.74	34.31
P. hirsutus	32.68	24.	21.62	26.24
P. sanguineus	19.42	22.	21.02	21.13
p. versicolor	32.23	31.	25.05	29.62
Mean	26.64	24.44	19.56	

Vitex altissima

The average loss of weight of wood caused by different fungi varied from 1.09 to 6.87 per cent (Table 6). There was highly significant difference among the test fungi at p = 0.01 level. Highly significant difference in weight loss among the trees tested and large variation in their response to different fungi resulted in the interaction between two factors, fungi and trees, also to be highly significant. The density of *V. altissima* at 12 per cent moisture content varied widely from 621 to 831 kg/m^3 with the average value as 743 kg/m^3 (Table 1). Only in the case of *P.sanguineus* there was significant negative correlation between density and weight loss. But this trend was not seen in the case of other fungi.

Table 6. Weight loss in test blocks of ***Vitex altissima*** exposed to different fungi.

Fungus	Weight loss (%) Tree number					Mean
	5 9 0 1	5902	5903	5918	5923	
Lenzites rrabea	1.40	2.48	0.66	0.47	0.46	1.09
Polyporus palustris	0.74	4.67	9.44	5.57	4.97	5.28
P. hirsutus	3.30	3.12	.66	3.70	2.07	2.77
P. sanguineus	0.34	.99	4.48	19.90	7.33	6.81
P. versicolor	4.71	4.89	9.48	5.56	9.74	6.87
Mean	2.30	3.43	5.14	7.04	4.91	

DISCUSSION

Among the six fungi used in this study to test the resistance of wood against decay, *P.versicolor* and *L. trabea* are suggested by the ASTM Standard as test fungi (ASTM, 1981). All the six test fungi were also used by Bakshi *et* al. (1967) against hardwoods.

The average weight loss of test blocks of M. nagassariurn, *H parviflora* and *V. altissima* exposed to any fungus was less than 10 per cent. According to the classi– fication of ASTM (1981) and Bakshi *et al.* (1967), all the above three species fall in the resistance Class I (highly resistant) against all the test fungi. *P. versicolor* brought about the maximum weight loss in *M. nagassarium* and *V. altissima; P. palustris,* in *H parviflora* and *V.bilocularis; P. sanguineus,* in *V. indica.* The brown rotter *L. trabeu* produced the minimum weight loss in *M. nagassarium, V. bilocularis* and *V. altissima.* Whereas all the fungi caused a weight loss of 21 to 34 per cent in *V. bilocularis, L. trabea* caused only about 6 per cent.

M. nagassarium, H. parviflora and *V. altissima* are large hardwood trees occurring generally in the west coast tropical evergreen and west coast semi-evergreen forests of Western Ghats in southern India. Purushotham et al. (1953) found that wood of *M. nagassarium* grown in Assam gave an average life of more than 20 years in the graveyard test, while that of Madras Province (probably from the northern part of Kerala) gave an average life of about 12 years. The former was included in durability Class I (average life, 15 years and above) and the latter in Class II (average life, 10 to 15 years). In the accelerated laboratory study, Bakshi *et al.* (1967) found that wood of Bengal-grown *M. nagassarium* was highly resistant against all the test fungi as obtained in the present study for Kerala-grown *M. nagassarium.*

In the graveyard stake test, wood of *H. parviflora* from the Madras Province and *V. altissima* from Kanara, now in Karnataka State, were found to be highly durable and included in the natural durability Class I. In the present study, wood of *V. altissima* though coming under Class I, showed less resistance than *M. nagassarium* and *H. parviflora* against the various decay fungi.

V. indica and *V. bilocularis* are also large trees endemic to tropical evergreen and semi-evergreen forests of Western Ghats. *V. indica* was resistant against all the test fungi. In the graveyard stake test, wood of *V. indica* collected from the then Madras State showed poor durability and was included in Class V (average life, 2 to 5 years). Findings of the present study are not in agreement with the results of the graveyard test. Other organisms besides decay fungi would have been involved in the graveyard test. Higher decay resistance of wood in laboratory tests than in field tests was observed by Da Costa and Osborne (1967), and, Osborne (1967) in the case of a few New Guinea and Fijian timber species respectively. Cavalcante *et al.* (1985) also reported no agreement between results from laboratory and field tests. Apart from the artificiality of the laboratory tests, a possible cause of the discrepancies can be due to the different performances of the same wood in different test sites.

V. bilocularis is a less-known species and the wood is usually mistaken for that of *Dysoxylum malabaricum* due to the similarity in colour though these species differ morphologically very much. *V. bilocularis* was highly resistant against *P. sanguineus* and moderately resistant against *P. palustris, P. hirsutus* and *P. versicolor.* We can classify the wood, in general, as moderately resistant (Class 111). The natural durability of this wood by graveyard test has not been reported so far.

Variation within timber species with respect to decay

Significant difference in weight loss among the trees of each species and among the test fungi was observed. The interaction between these two factors was also significant. This is to be expected as the variation in response of test blocks from different trees to any fungus as seen from the data (Tables 2 to 6) is large. Even though all the trees had a girth above 150 cm, rate of growth could have been different due to various factors contributing to the variation in decay resistance. Variations in, decay resistance among individual trees within a species and also radially are reported by Bakshi *et al.* (1967), Da Costa and Osborne (1967), and, Osborne (1967). The outer heartwood is generally more resistant than the heartwood close to pith. However, Koning-Vrolijk *et al.* (1962), and Scheffer and Duncan (1947) did not find such indication in all rain forest trees. Timber properties in general may vary to a rather high extent not only between different regions of growth but also between different trees and even within one tree (Willeitner, 1984).

Relation between density and decay resistance

Wide variation in basic density among the five species and also within each species were observed (Table 1). The difference in density in the different trees of the same species indicates that the amount of extractives present might have been different. Da Costa and Osborne (1967), and, Osborne (1967) found negative relationship between density and percentage weight loss. In the present study also, significant inverse correlation between density and percentage weight loss was found in the case of *H. parviflora* and *V. bilocularis,* indicating that percentage weight loss decreased (or durability increased) with increase in density. However, this relationship was poor in the case of *V. indica*. There was no consistent correlation in the case of

M. nagassarium and *V. altissima*. However, in the case of V. altissima, there was significant negative correlation between density and weight loss caused by *P. sanguineus.* Generally the data indicated that there is a tendeney for the denser timbers to be more resistant to decay. Though *V. bilocularis* is a heavy timber, it is not durable. Wood of *M. nagassarium* and *H. parviflora* falls in the class of very heavy and highly durable.

In general, white rotters have caused greater weight loss than brown rotters. Among the white-rot fungi, *P. versicolor* is the most aggressive and among the brown-rot fungi, *P. palustris.* As the performance of a wood in service is likely to be determined by those fungi to which it is particularly susceptible, wood should be tested against the most destructive fungi (Moses, 1955; Da Costa and Aplin, 1959). Hence if the most destructive white-rot and brown-rot fungi are to be selected out of the fungi used in the present study, *P. versicolor* and *P. palustris* respectively will be the most suitable.

REFERENCES

American Society for Testing and Materials (ASTM). 1981. Standard method of accelerated laboratory test of natural decay resistance of woods. ASTM D 2017-71 (Reapproved 1978). Annual Book of ASTM Standards, Part 22, Philadelphia: 639-645.

Bakshi, B. K., Puri. Y. N. and Khan, S. N. 1967. Accelerated laboratory investigation on durability of wood. Final Technical Report. Forest Research Institute and Colleges, Dehra Dun. 57p.

Cavalcante, M.S., Lopez, G.A.C., Montagna, R.G. and Fosco Mucer, M.E.S. 1985. Natural durability of wood in ground contact - A correlation between field and laboratory tests. International Research Group on Wood Preservation Document No. IRG/WP/2182. 9p.

Da Costa, E.W.B. and Aplin, T.E.H. 1959. The resistance to decay in laboratory tests of 23 durable or moderately durable Australian timbers - Progress Report No. 2, Div. For. Prod., Sub-Project P. 13-15, CSIRO, Australia (Cited from Da Costa and Osborne,1967).

Da Costa, E. W. B. and Osborne, L. D.1967. Comparative decay resistance of twenty six New Guinea timber species in accelerated laboratory tests, Common. For. Rev. 46: 63-74.

Koning-Vrolijk, G. M.C., Jutte, S.M and Hof, T. 1962. Nova Guinea (N.S) 10, Botany 137-175 (Cited from Da Costa and Osborne, 1967).

Moses, C. S. 1955. Laboratory decay of some commercial species of Mahogany, For. Prod. J. 5:149-152.

Osborne, L. D. 1967. Comparative decay resistance of twenty five Fijian timber species in accelerated laboratory tests. Pacific Sci. 21: 539-549.

Purushotham, A., Pandey, J.N. and Jadav, Y. G. 1953. Wood preservation in India--Past, Present, and Future Indian Forest Bulletin (New Series) No. 168, Wood Preservation Series, Forest Research Institute and Colleges, Dehra Dun, 73 p.

Reis, M. S. 1972. Decay resistance of six wood species from the Amazon Basin of Brazil. Phytopathology 62.784 (Abstract).

Scheffer, T. G. and Duncan, C.G.1947. The decay resistance of certain Central American and Ecuadorian woods. Trop. Woods 92: 1-24.

Willeitner, H. 1984. Laboratory tests on the natural durability of timber - Methods and problems. International Research Group on Wood Preservation Document No. IRG/WP/2217. 11p.