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Full Length Research Paper

Natural durability of heartwoods from European and tropical Africa trees exposed to marine conditions

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Marine durability of heartwoods obtained from tropical African and European species against marine borer attacks in underwater exposure in Turkish coasts was investigated. Test hangers including wood species of 18 European and 15 African wood species were fastened to test area and exposed at a depth of 6 m along the coasts of seas (East and West Black Sea, Marmara Sea, Aegean, East and West coasts of mediterranean in Turkey seashore). Most European wood samples suffered severe attacks from boring organisms. On the other hand, some tropical African species (*Lophira alata*, *Nauclea diderichii*, *Tieghemella heckelii*, *Chlorophora excelsa*, *Distemonanthus benthamianus*, *Pterocarpus soyauxii* and *Millettia laurentii*) showed high natural marine durability in all seas, while the rest of them were only slightly degraded by boring organisms. The test areas in Trabzon, Ereğli and İskenderun cities which are industrial harbours were shown to have the highest boring attacks. Other test areas, Bandırma, Alaçatı and Finike which are yacht marinas were shown to have little boring and fouling attacks.

Key words: Marine durability, tropical and European heartwoods, boring organisms.

INTRODUCTION

When wood products are used in marine environments, they are often attacked by marine organisms (Mouzouras et al., 1990; Johnson et al., 1992). Wood-boring marine animals belong to the families of Teredinidae and Pholadidae in the Mollusca and Limnoria, Sphaeromatidae and Cheluridae in the Crustacea. Boring organisms in the Teredinidae are dominant in most seas and cause damage deep inside of the wood, whereas species in the other families are less destructive, causing only superficial damage (Ryabchikov, 1957; Ryabchikov et al., 1963). Naturally durable heartwoods are generally used where potential for biological and physical degradation is high, whereas sapwoods are not preferred due to their low natural durability (Sivrikaya, 2003; Oliver, 1974; Plaster and Sawyer, 1998). Some tropical heartwoods with naturally marine durability have been used without treatment with wood preservative chemical for some using area like harbors, quays and decks and are replaced with new ones as necessary (Eaton, 1985). Destruction time and activity of marine borers in treated wood with chemical preservatives depend on the toxicity of the preservatives used and the leaching properties of the wood. The amount of degradation by marine borers depends on the properties of the tree species used in marine conditions (Berkel, 1970).

Little research has been conducted on wood-boring marine organisms in Turkey. Demir (1954) found *Teredo navalis* in deep waters of the Marmara sea. Berkel (1961) reported that several woods used in waters around İstanbul were rapidly destroyed by boring organisms. Sekendiz (1981) examined *T. navalis* in the East Black Sea region and found boring organisms in the Turkish waters (Sivrikaya, 2003). Pınar (1978) carried out ecological experiments on fouling and boring organisms and investigated the effectiveness of antifouling paints on wood, metal and glass panels in the harbors of the Turkish ports of Amasra, İstanbul, Çanakkale, İzmir and Mersin over 12 months. At these stations, *Teredo navalis*, *Limnoria tripunctata* and *Chelura terebrans* were identified in untreated black pine (*Pinus nigra*). The boring activity was severe in all harbors except İzmir. Bobat (1994) studied durability of treated wood species (Scots pine, fir, oak and beech) with creosote and chro-

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Table 1. Water salinity, average temperatures and coordinates of the test areas.

City ID	Test areas	Geographical latitude (North)	Geographical longitude (East)	Saltiness ratio (%)	Average temperatures low and high (yearly) (^{0}C)
61	Trabzon	41° 06'	39° 25'	0.18	7.9 - 24.4
67	Ereğli	41° 16'	31° 25'	0.19	8.4 - 25.3
10	Bandırma	40° 21'	27° 57'	0.22	9.4 - 26.5
35	Alaçatı	38° 15'	26° 23'	0.35	11.2 - 27. 5
07	Finike	36° 18'	30° 09'	0.37	16.1 - 29. 3
31	İskenderun	36° 35'	36° 11'	0.39	16.2 - 29.7

mated copper borate (CCB) over 14 months in the harbors of İzmir, Mersin and Trabzon. He found that samples exposed in the Marmara Sea were not degraded, whereas untreated samples, except for oak, were almost destroyed in the Mediterranean and Black Seas. Two mollusks were found in Scots pine and oak treated with CCB (chromated copper borate) and exposed in the mediterranean and Black Seas. Sivrikaya (2003) investigated marine borers in samples of both sapwood and heartwood of Scots pine, oak and chestnut in Amasra on the Black Sea coast. During the 12-month trial, only *T. navalis* was identified in the wood samples. In Scots pine samples, sapwood suffered slightly more attack than heartwood. Borer tunnels were found in oak and chestnut woods much fewer than in Scots pine.

This study was carried out in 6 test stations (the city harbour and marinas of the Trabzon, Ereğli, Bandırma, Alaçatı, Finike and İskenderun) in the 4 seas- Black Sea, Marmara Sea, Aegean and mediterranean Seas- that surround Turkey. The aim was to determine the natural marine durability of European and tropical African tree species' heartwoods, as well as to identify boring and fouling organisms in Turkish waters.

MATERIALS AND METHODS

Test samples prepared from heartwoods of 33 wood species (18 European and 15 tropical wood species) were cut according to standard TS 4176/1984. Four replicate wood samples at the measurements of 200 x 75 x 25 mm were prepared from each wood species for each test area according to standard TS EN 275/2000. Totally, 24 samples were tested from each wood species for 6 test areas. The European species were *Abies nordmanniana* (fir), *Carpinus betulus* (Hornbeam), *Castanea sativa* (chestnut), *Cedrus libani* (cedar), *Cupressus sempervirens* (cypress), *Fagus orientalis* (beech), *Fraxinus excelsior* (ash), *Juglans nigra* (Wallnut), *Juniperus foetidissima* (juniper), *Morus alba* (mulberry), *Olea europaea* (olive), *Pinus nigra* (Austrian pine), *Prunus avium* (cherry), *Quercus petraea* (oak) and *Ulmus minor* (elm). The tropical species were *Afzelia bipindensis* (dousse), *Chlorophora excelsa* (iroko), *D. benthamianus* (movingui), *Didelotia africana* (gombe), *E. cylindiricum* (sapelli), *Guibourtia ehie* (ovengkol), *Guibourtia tessmannii* (bubinga), *Khaya anthotheca* (akajou), *Lophira alata* (azobe), *Millettia laurentii* (wenge), *Nauclea diderichii* (bilinga), *Pericopsis elata* (afrormosia), *Pterocarpus soyauxii* (paduk), *Termination superba* (limba) and *Tieghemella heckelii* (douka).

Four replicate control samples were prepared from *P. sylvestris* at the same measurements and were treated with chromated copper arsenat (CCA) and chromated copper borate (CCB) at the maximum concentration for marine conditions (Sivrikaya, 2003) of 10% for each test area.

Fouling and boring organisms were extracted from the wood and identified under a stereomicroscope in the Faculty of Marine Sciences of the Aegean University. Boring organisms were identified according to Turner (1966), Schultz (1969), Parenzan (1974) and Cachia et al. (2004). Average low and high seawater temperature for each test area, water salinity and coordinates were shown in Table 1 and the map of test sites in Figure 1.

Control samples were included in the study for comparing resistance of tropical heartwoods with impregnated wood samples which have marine durability for chemicals. The standard is accepting a test period for short-term exposure of approximately 1 year in tropical and non-tropical regions. The test samples were placed at all stations at a depth of 6 m and exposed to marine conditions for 1 year. Evaluation of marine organism attack on treated and untreated wood samples was carried out by visual inspection following the instructions given by the standard, TS EN 275/2000. Table 2 shows the evaluation standards used for measuring the extent of hazards caused by marine organisms.

Statistical analysis

Destruction points were evaluated using a computerized SPSS 13.0 statistical program and tested with univariate analyses, followed by a Duncan test with a 95% confidence interval. Marine durability of the whole wood samples was determined for 6 test areas together with control samples, statistically.

RESULTS

Only one stand including heartwoods species was collected from each test station and brought to the Laboratory of Marine Science at the Aegean University where fouling and boring organisms were identified. The other three test stands were brought to the Faculty of Wood Science at Duzce University where the degree of marine organism attack was assessed.

Most of the European wood samples were damaged heavily by boring organisms at the İskenderun and Trabzon harbours. Five tropical woods in this study (*N. diderichii*, *T. heckelii*, *C. excelsa*, *P. soyauxii* and *M. laurentii*) were sound in all test areas, whereas degradation of the other tropical species (*P. elata*, *K. anthotheca*, *D. africana*, *T. superba* and *E. cylindiricum*) was damaged at

Figure 1. Map of the test areas.

Table 2. Evaluation system for measuring the extent of destructions by marine organisms (TS EN 275/2000).

Scale	Extent of destruction	Destruction points and appearance
0	No destruction	No visible tunnel or destruction by marine organisms
1	Little destruction	Tunnels are one or a few number and cover 15% of total sample area
2	Moderate destruction	Tunnels cover 25% of total sample area
3	Violent destruction	Tunnels covered at the rate (25 - 50) % of total sample area
4	Fully destruction	Tunnels covered at the rate of above 50% of total sample area

Table 3a. Analyses of variances (ANOVA) for the effects test area and European-Tropical and tree species on variables (destruction degree) (p < 0.001).

Source	Type III sum of squares	Df	Mean square	F	Sig.
Corrected model	1983.728	179	11.082	49.053	0.000
Intercept	4080.272	1	4080.272	18060.220	0.000
Test area	494.878	5	98.976	438.089	0.000
European-Tropical	435.556	1	435.556	1927.869	0.000
Tree species	527.922	28	18.854	83.454	0.000
Test Area * European* tropik	23.028	5	4.606	20.385	0.000
Test areas * tree species	502.344	140	3.588	15.882	0.000
European -tropic * Tree species	214.069	14	15.291	67.680	0.000
Test area * Europ-tropical * Trees	219.097	70	3.130	13.854	0.000
Error	122.000	540	0.226		
Total	6186.000	720			
Corrected total	2105.728	719			

Dependent Variable: destruction grade.
Dependent Variable: Destruction grade; a Adjusted R squared = 0.923.

moderate degree. All European and tropical wood species and test areas were compared individually by using univariate analysis. In addition, 2 and 3 way interactions were applied for the test sites and wood species. Treated wood samples (with CCA and CCB) at these 6 harbors had not been damaged for one year. Statistical ANOVA table and Duncan test, including all test samples were described in 5 categories and significant levels were shown in Tables 3a and 3b.

European and tropical species were compared in separate group with wood species and stations were compared, individually. In addition, 2 and 3 way interactions

Table 3b. Duncan test results of test areas (Alpha = 0.05).

Test areas	N	Subset (Destruction points)				
		1	2	3	4	5
Alaçatı	120	1.08				
Finike	120		1.52			
Ereğli	120			2.48		
Bandırma	120				2.68	
Trabzon	120					3.23
İskenderun	120					3.30
Significant		1.000	1.000	1.000	1.000	0.278

Means for groups in homogeneous subsets are displayed. Based on type III sum of squares, The error term is mean square (Error) = 0.226, uses harmonic mean sample size = 120.

were applied for the test sites and wood species. According to statistical tests, the highest destruction was shown in wood panels at İskenderun and Trabzon test areas, and there was no difference statistically between them. Degrees of destruction ranged from the highest to the lowest; İskenderun harbour showed the highest boring hazards with degree near Trabzon harbour, followed by Ereğli, Bandırma, Finike and Alaçatı.

Marine durability of the wood species

After the ratings were determined for the Duncan test, the 33 wood species were arranged in 9 natural durability categories in Table 4. The wood species with similar durability are indicated by the same letter in homogenous groups. None attack was observed in test samples in our controls. Table 4 also indicates the natural durability of the wood species from the highest to the lowest.

M. laurentii and *T. heckelii* showed the best performance followed by *L. alata*, *P. soyauxi* and *O. europaea*. Olivewood had surprisingly showed high durability in the range of 5. These five species were degraded less than other tropic species. Figure 2 shows İskenderun harbour, where an attack by marine borers was more severe than other harbours. *G. ehie* and *N. diderichii* (group 3), *D. benthamianus* and *C. excelsa* (group 4) and *A. Bipindensis*, *P. elata* and *E. cylindiricum* (group 5) showed slightly less durability. Of the European species *J. foetidissima* was the most resistant, with durability similar to *D. Africana* (group 6). *T. superba*, *G. tessmannii*, *C. sativa*, *J. nigra*, *R. pseudoacacia*, *C. sempervirens*, *M. alba* and *Q. petraea* had moderate durability against marine borers (group 7) with ratings of 2,58-3,17. *C. libani*, *C. betulus* and *K. anthotheca* showed high degradation (group 8), while *U. minor, P. nigra*, *P. sylvestris*, *F. excelsior, P. avium*, *F. orientalis, A. glutinosa* and *A. nordmanniana* had the highest degradation (group 9) (Figure 2).

Marine organisms

In this study, fouling organisms were identified on the wood samples as well as boring organisms. We observed 26 species of fouling organisms, mainly in the Porifera, Bryozoa, Polychaeta, Cirripedia, Mollusca and Tunicata. Mollusca were dominant, with 17 species, followed by Polychaeta with 4 species, Porifera with 2 species and Bryozoa, Cirripedia and Tunicata with one species each. For the diversity of organisms and distribution among the stations, İskenderun was richest with 18 species, 14 of which were Mollusca. This was followed by Alaçatı and Finike with 6 species, Bandırma with 5 and Trabzon and Ereğli with 4. Both *T. navalis* and *L. pedicellatus* (Mollusca) were found at all stations. *N. norvegica* (Mollusca) was found in Trabzon and İskenderun, while *B. carinata* was only found in İskenderun. In addition, *L. tripunctata* was the only crustacean species and was only found in Finike and İskenderun.

DISCUSSION

Tropic tree species used in this study have high specific gravity, extractive content and blunt effects. High blunt effects are explained by their high silica and calcium crystal contents of the wood species (Bozkurt and Erdin, 1989). The heartwood of these species resists against wood treatment processes. When marine durability of these species was arranged, it seems that several wood properties affect woods' marine preservation feature. The content silica and calcium as well as physical and chemical properties of woods affect woods' marine durability. In addition, it could be difficult for marine borers to file denser woods. Marine borers grind wood materials while using it for food (Berkel, 1970).

Some tree species of heartwoods consist of some toxic extractive materials, which improve the marine durability of them. Even *M. laurentii* does not include the highest silica and calcium oxalate contents. This study result indicated that it had the highest marine durability in all testing areas. The toxicity and additionally physical and chemical properties of *M. laurentii* might repel the marine borers. Within the wood species, *M. laurentii* is the only known one that causes stomach cramps and paralysis symp-

Table 4. Natural durability classification of European and tropical African tree species in view of destruction points obtained from Duncan test results.

Durability groups	Tree species used test		DP	HG
	Control	CCA treated control samples	0.00	s
	Control	CCB treated control samples	0.00	s
1	Wenge	*Millettia laurentii*	0.29	a
	Douka	*Tieghemella heckelii*	0.33	a
	Azobe	*Lophira alata*	0.58	b
2	Paduk	*Pterocarpus soyauxii*	0.71	b
	Olive	*Olea europaea*	0.79	b
3	Ovangkol	*Guibourtia ehie*	1.00	c
	Bilinga	*Nauclea diderichii*	1.00	c
4	Movingui	*D. benthamianus*	1.42	d
	Iroko	*Chlorophora excelsa*	1.75	d
	Dousse	*Afzelia bipindensis*	1.92	e
5	Afrormosia	*Pericopsis elata*	1.96	e
	Sapelli	*E. cylindiricum*	2.00	e
6	Juniper	*Juniperus foetidissima*	2.21	f
	Gombe	*Didelotia africana*	2.38	f
	Limba	*Terminalia superba*	2.58	g
	Bubinga	*Guibourtia tessmannii*	2.63	g
	Chestnut	*Castanea sativa*	2.67	g
7	Walnut	*Juglans nigra*	2.88	g
	Black locust	*R. pseudoacacia*	2.94	g
	Cypress	*Cupressus sempervirens*	3.04	g
	Mulberry	*Morus alba*	3.08	g
	Oak	*Quercus petraea*	3.17	g
	Cedar	*Cedrus libani*	3.29	h
8	Hornbeam	*Carpinus betulus*	3.46	h
	Akajou	*Khaya anthotheca*	3.50	h
	Elm	*Ulmus minor*	3.71	i
	Austrian pine	*Pinus nigra*	3.75	i
	Scots pine	*Pinus sylvestris*	3.75	i
9	Ash	*Fraxinus excelsior*	3.75	i
	Cherry	*Prunus avium*	3.75	i
	Beech	*Fagus orientalis*	3.88	i
	Alder	*Alnus glutinosa*	3.92	i
	Fir	*Abies nordmanniana*	3.96	i

HG: Homogeneous groups, DP: Destruction point.
Results is based on destruction degrades. A = 0.05.

toms on timber workers (Bozkurt and Erdin, 1989). More works need to be done to determine the exact extractive components of *M. laurentii* for explaining this effect. The second highest marine durability of *T. heckelii* observed in this study should be explained with its high silica content. In addition, the third highest marine durability of *L. alata* should be due to its highest wood density. *P. soyauxii* and *G. ehie* showed the fourth and fifth highest durability and the findings were explained with their higher extractive and calcium oxalate contents. The rest of the wood species examined showed marine durability regarding the amount of calcium crystals.

Some chemical, physical and mechanical properties of durable tropical tree species were investigated. It could not be found any positive relation between properties and destruction points. On the other hand, all durable species do not contain calcium oxalate and silica minerals (Bozkurt at al., 1989). In this study, the marine durability

Figure 2. The samples from İskenderun harbour where the highest degradation after exposure time for 1 year.

of resistant species (wenge, douka, azobe, paduk) could be explained by their some properties. Wenge contains a toxic chemical material named 2.6-dimethoxybenzoquinone (Schulz at al., 1978) and high extractive amount (8.44%); paduk contains an irritative, dermatitis chemical named napthoquinones (Anon, 2008). Azobe, douka, ovangkol and paduk have high Brinell hardness and specific gravity. Hardwood species are durable in marine environment compared with soft wood species, because they resist against boring organisms filed.

The African wood samples, *L. alata*, *M. laurentii*, *P. soyauxii* and *T. heckelii* had limited tunnel formation caused by boring organisms (between 1-3 tunnels per specimen). The number of tunnels was very much in the European species because of their low natural durability. It was possible to break these specimens by hand due to the loss of mechanical strength in the honeycombed wood. In the naturally durable species, the structure of the material was not deformed. No trace of attack was evident in the tropical species at Eregli, Bandirma, Alacati and Finike, where low to moderate boring attacks occurred.

The European woods were heavily damaged by borer attacks in the harbors of Trabzon and İskenderun. Such damage is inevitable unless the wood is treated with preservatives. There was only moderate borer damage in Ereğli and Bandırma harbors and even less in Alaçatı and Finike. African wood samples of *L. alata*, *M. laurentii*, *P. soyauxii* and *T. heckelii* had low counts of tunnel-causing boring organisms of 1 to 3. On the other hand, the number of borer tunnels in European species of low durability was high and it was possible to break these samples by hand because they had become honey-combed and had lost their mechanical strength. For naturally durable species, which contained fewer tunnels, the structure of the material was not damaged. There were few or no traces of attack in the tropical species at the Ereğli, Bandırma, Alaçatı and Finike stations. However, signs of attack by *T. navalis*, *N. norvegica* and *L. pedicallatus* were observed, even in samples with natural durability, which contain high quantities of chemicals and minerals such as silica and calcium oxalate.

Regarding the water temperature and salinity, the damage on test samples was observed almost equal when comparing the Trabzon, which was coldest and less salty with İskenderun, which was hottest and much salty port. Temperature and salinity might affect the damage on wood samples. In this study, it is observed that İskenderun port had both marine borers and fouling organisms. On the other hand, Trabzon port has only 3 types of marine borers. Test samples from both industrial ports, Iskenderun and Trabzon had almost equal damage and this finding is mainly explained by the populations of almost equal marine borers. It is interesting that test samples compared from Finike and Iskenderun ports which are in Mediterranean coasts showed that test samples in Finike port having clean sea water had lower damage.

Conclusions

The existence of boring organisms in marine environments plays a large role in selection of woods for use in contact with seawater. The selection of tree species for marine use is important because many chemical wood preservatives leach out and pose a threat to marine ecosystems. Most European wood species need to be treated with chemical preservatives for use in marine construction, whereas most tropical tree species could be used in marine applications without chemical treatments.

The results of this study will be useful in the production of yachts, small boats, and port constructions that are in contact with seawater. If untreated wood is used in marine environments, species with natural resistance should be selected. Otherwise, wood should be treated with environmentally friendly preservatives that do not leach. If wood is used without treatment in harbors that are known to suffer severe attacks from boring organisms, round and thick wood is preferred for long service life.

Degradation of woody material by marine borers is inevitable unless the wood is treated with preservatives. Attack of *T. navalis*, *N. norvagica* and *L. pedicallatus* was observed even in the naturally durable samples with rich extractives and minerals such as silica and calcium cyrstals. Naturally durable species should be selected if wood is utilized in marine environment without treatment. Non-durable wood species should be treated with preservatives that are environmentally friendly as well as resistant to leaching. If wood is used without treatment in harbors that have severe attacks of boring organisms, thick and round structures are preferred for longer service life.

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REFERENCES

Anon (2008). Information Sheet: Toxic Woods, http://www. hse.gov.uk, Woodworking Sheet No. 30 (http://www.hse.gov.uk/ pubns/wis30.pdf)

Berkel A (1961). Investigations of using wood material in sea constructions at İstanbul and around, Istanbul University, Forest Faculty B, 1(11): 45-54

Berkel A (1970). Wood Material Technology, Istanbul University, Forest Faculty Publication, IU Public No: 1448, İstanbul, p. 592.

Bobat A (1994). Utilizatin and resistant period of treated wood material in mine and undersea. Ph Thesis, Black Sea Technical University, Graduate School of Natural and Applied Sciences, Department of Forest Industrial Engineering, Trabzon, p. 166.

Bozkurt Y, Erdin N (1989). Commercially Important Exotic Trees, Istanbul University, Natural and Applied Sciences Publications, Public No: 3572-4, Istanbul-Turkey, p. 382.

Cachia C, Mifsud C, Sammut PM (2004). Caudofoveata, Solenogastres, Bivalvia, Scaphopoda and Cephalopoda. Backhuys Publishers, Leiden, p. 269.

Demir M (1954). Invertabrate deep animals of Bosphorus and Ada Shores, IU, Science Faculty, Hydrobiology Research Institute, Pub No: 3, İstanbul.

Eaton RA (1985). Preservation of marine timbers. In: Findley WPK Preservation of Timbers in the Tropics, Adam and Charles Black, London, pp. 157-188.

Johnson BR, Ibach RE, Baker AJ (1992). Effect of salt water evaporation on tracheid separation from wood surfaces. Forest Products J. 42: 57-59.

Mouzouras R, Jones AM, Jones EBG, Rule MM (1990). Non-destructive evaluation of hull and stored timbers from the Tudor ship Mary Rose. Studies in Conservation, 35: 173-188.

Oliver AC (1974). Timber for Marine and Freshwater Construction. Timber Research and Development Association, High Wycombe, UK, p. 65.

Parenzan P (1974). Carta d'Identità delle Conchiglie del Mediterraneo. Vol. 2. Bios Taras, Taranto, pp. 283-544.

Pınar E (1978). Fouling and Boring Organisms in Turkey harbours, The effects of antifouling-antiboring paints on these organisms. DKK Hidrography publication, DH-1049/DEBSS, Çubuklu-İstanbul.

Plaster SEM, Sawyer GS (1998). A survey to assess the current and future usage of timber in British port structures. Inst. Wood Sci. 146: 287-293.

Ryabchikov PI (1957). Distribution of Wood Borers in the Seas of the USSR. Moscow: Akaddemia Nauk. SSSR. Inst. Okean. p. 229.

Ryabchikov PI, Soldatova IN, Yesakova SE, Petukhova TA (1963). The Beginning of colonization of the sea Azov by several species of marine borers of the family Teredinidae, Trudy Inst. Okena, In: Scheer BT (1945). Development of Marine Fouling Communities, Biol. Bull. 89: 103-121.

Schultz GA (1969). How to know the marine Isopod Crustaceans. Wm. C. Brown Company Publishers, Iowa, p. 359.

Schulz KH, Garbe I, Hausen BM, Simatupang MH (1978). Sensitizing capacity of naturally occurring quinones. V. 2,6-Dimethoxy-p-benzoquinone: occurrence and significance as a contact allergen. Contact Dermatitis, Vol. 4: 204-213, and Arch. Dermatol. Res. 264(3), 1979: 275-286.

Sekendiz OA (1981). The investigations on harmful animals technically from division of East Black Sea. The University of Black Sea Technical. Forest Faculty Publications, Trabzon, pp. 127-212.

Sivrikaya H (2003). The impregnability and durability characteristics of sapwood and heartwood, Ph. D. Thesis, ZK University, Graduate School of Natural and Applied Sciences, Department of Forest Industrial Engineering, Bartın-Turkey, p. 187.

TS (4176/1984). Turkish Standard Institution. Wood-Sampling Sample Trees and Long for Determination of Physical and Mechanical Properties of Wood in Homogeneous Stands, Ankara, Turkey

TS EN 275/2000. Turkish Standard Institution. Wood Preservatives-Determination of preservative effects against to marine borers, Turkish Standards Institute, Ankara, Turkey.

Turner R (1966). A survey and illustrated catalogue of the Teredinidae (Mollusca: Bivalvia). Museum of Comparative Zoology, Harvard University, Cambridge, Mass. p. 265.