ISSN impresa 0717-3644
ISSN online 0718-221X

Maderas. Ciencia y tecnología 21(2): 231 - 238, 2019

DOI: 10.4067/S0718-221X2019005000210

ASSESSING THE NATURAL DURABILITY OF DIFFERENT TROPICAL TIMBERS IN SOIL-BED TESTS

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ABSTRACT

Ground contact speeds up timber decay because of the large number of microorganisms in soil. This study, we assessed the natural durability of seven tropical species using the European standard EN-807 (2001). We embedded samples of *Dalbergia granadillo*, *Cordia elaeagnoides*, *Swietenia humillis, Tabebuia donell-smithii*, *Hura polyandra*, *Enterolobium cyclocarpum* and *Tabebuia rosea* and temperate species *Fagus sylvatica* (as a control) in sandy, clay-sandy-loam and clay-loam for 8, 16, 24 and 32 weeks. We evaluated durability of the samples by determining the mass loss and modulus of elasticity (MOE) loss. The results varied significantly (p < 0,001) depending on timber species and soil type considered. The *D. granadillo* and *C. elaeagnoides* were the most durable, with mass losses of 4,5%; 6,5% and MOE losses of 4,5%; 20,5%; respectively. *F. sylvatica, T. rosea* and *E. cyclocarpum* samples were the least durable, with mass losses of 22,3-25% and MOE losses of 35,8-59,8% respectively. Decay was most aggressive in sandy-clay-loam soil followed by the clay-loam soil and finally the sandy soil.

Keywords: Decay, ground contact, mass loss, MOE loss, tropical wood.

INTRODUCTION

Tropical timber species vary in color, chemical composition, physical and mechanical properties and durability. Some woods are particularly attractive and is used to make furniture, musical instruments, car interior trims and various types of handicrafts. Worldwide trade in tropical timber products reached a global volume of 273,1 million m^3 in 2014 (OIMT 2015). According to the Statistical Yearbook of Forestry Production of 2015 (SEMARNAT 2016), 336064m^3 (Total Stem Volume, TSV) of common tropical timber species and 13378 m^3 TSV of precious tropical species were harvested in Mexico, represent 5,7% of the total production and with a value of US$ 24909087,1 (SEMARNAT 2016).

Technological characterization of lesser known tropical species (LKTS) have enabled replacement of over-harvested timber species with some of these other species in the furniture-making and musical instrument sectors. In addition to aesthetic criteria used for timber species selection, natural durability is one of the most important attributes.

Natural durability is defined as the resistance of the timber species to degradation by biotic and abiotic media (Eaton and Halle 1993). Durability can be evaluated using a variety of laboratory and field-based methods (Meyer *et al.* 2014). The most common method involves embedding the timber in soil, which after sea water, is one of the most aggressive types of environment to which timber is exposed. The wide variety of microorganisms in soil, such as soft rot fungi (Ascomycetes) guarantee the effectiveness of the test, because

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Received: 07.09.2017 Accepted: 12.11.2018

microorganisms are capable of adapting to different environmental conditions (soil) and to timber preservatives (Schmidt 2006). The rate of decay of timber varies according to the type of soil used. Factors such as soil type, moisture content, chemical properties and the microorganisms present influence the type of attack and level of degradation (Jebrane *et al.* 2014, De-Avila *et al.* 2016).

The main objective of this study was to evaluate the natural durability of samples of the tropical timber species *Cordia elaeagnoides, Dalbergia granadillo, Enterolobium cyclocarpum, Hura polyandra, Swietenia humillis, Tabebuia donell-smithii* and *Tabebuia rosea,* were loss of mass and modulus of elasticity caused by exposure of the timber samples to different types of soil under laboratory conditions.

MATERIALS AND METHODS

Timber species and sample preparation

Samples of undamaged, defect-free heartwood from *Cordia elaeagnoides* DC*, Dalbergia granadillo* Pittier*, Enterolobium cyclocarpum* (Jacq.) Griseb*, Hura polyandra* Baill*, Swietenia humillis* Zucc*, Tabebuia donell-smithii* Rose and *Tabebuia rosea* (Bertol) DC and of the temperate specie *Fagus sylvatica* L. (as a control) were obtained from the Faculty of Wood Technology, University of San Nicolás de Hidalgo (México). The wood was cut into 100 x 10 x 5 mm^3 (length x radial x tangential) specimens for testing.

Soil origin, preparation and analysis

Clay-sandy-loam, clay-loam and sandy soils were collected from sites in the Mexican states of Veracruz, Nuevo León and Michoacán. The samples were placed in plastic containers (60 x 40 x 15 cm^3) for the test and maintained at 20±2 °C; humidity, 65% ±2; and soil moisture content, 95% of water holding capacity (WHC). The soil pH, electrical conductivity and texture were determined according to NOM-021-RECNAT (2000), and the organic matter content following Walkley and Black (1934). The site description and analytical results are summarized in Table 1.

Table 1: Characteristics of the clay-sandy-loam, sandy and clay-loam soils collected from Veracruz, Michoacán and Nuevo León (Mexico) used to determine the natural durability of samples of seven tropical timber species.

Site	Soil origin		
	Veracruz	Michoacán	Nuevo León
Geographical coordinates	19°30' N, 96°22' O	19°39' N, 11°13' O	24°47' N, 99°32' O
[1]Type of climate	Warm, subhumid (Aw1)	Temperate with moderate humidity, C(w1)	Semarid and subhumid AC (Wo)
Soil type	Clay-sandy-loam	Sandy	Clay-loam
[2]pH	7,8	5,3	7,8
Electric conductivity (µS/cm)	398,7	183,7	342,3
[3]Organic matter content (%)	3,4	2,6	3,3
[3]Organic carbon (%)	2,0	1,5113	1,9
[2]Texture Sand (%)	50,6	86,6	12,6
Loam (%)	26,4	8,4	40,4
Clay (%)	23,1	5,1	47,1

[1] García (1973), [2]NOM-021-RECNAT (2000), [3]Walkley and Black (1934).

Determination of natural durability of timber

Timber durability was determined on the basis of European standard EN-807 (2001). Twelve samples of each timber species were set aside as control (week zero). Another forty-eight samples of each species were partially buried in containers of each type of soil. The samples were embedded at random positions in the soil to 80% of their length. Each sample was separated by a space of 20 mm. Twelve samples of each timber species were extracted from each type of soil after 8, 16, 24 and 32 weeks. All samples were conditioned (20 °C and 65% relative humidity) to 12% moisture content, before the modulus of elasticity (MOE) test was applied.

Modulus of elasticity (MOE) testing

Modulus of elasticity (three point method) was assessed on samples exposed for 0, 8, 16, 24 and 32 weeks for each species in each type of soil, in an Instron testing system (Shimadzu SLFL-100KN). The load was applied at a speed of 2 mm/min, and the MOE was determined using Equation 1 (DIN-52 186 (1978)).

$$MOE = \frac{l^3}{4bh^3}\frac{\Delta F}{\Delta f} \qquad (1)$$

Where:

- **MOE** = Modulus of elasticity (MPa)
- ***ΔF*** = load (N)
- **l** = length between the points (mm)
- ***Δf*** = deflection (mm)
- **b** = sample width (mm)
- **h** = sample thickness (mm)

Mass loss

The mass loss was determined gravimetrically at the end of MOE test with Equation 2.

$$\mathrm{W}l = \frac{W_1 - W_2}{W_1}100 \qquad (2)$$

where:

- **Wl** = mass loss (%)
- $\mathbf{W_1}$ = mass at the beginning of the test (g)
- $\mathbf{W_2}$ = mass at the end of the test (g)

Statistical analysis

The mass and MOE loss data were subjected to analysis of variance (ANOVA) with a factorial arrangement of 8 x 3 x 5. The factors were wood species (eight), soil type (three) and exposure time (five), with twelve repetitions for each treatment. Tukey's test was applied when the ANOVA indicated a statistically significant difference between the factors. All statistical analyses were performed with SPSS version 20.

RESULTS AND DISCUSSION

Mass loss

The timber mass decreased from on average 22,9% to 4,1% after the samples had been in contact with the different types of soil for 32 weeks. The ANOVA revealed highly significant differences ($p < 0,0001$) for species, contact time and type of soil, and for the contact time x soil, species x soil, and species x contact time interactions (Table 2). Tukey tests for differences between species, soil type and contact time revealed statistically significant differences (Table 3, Table 4 and Table 5).

Table 2: Summary of the ANOVA results for mass loss and modulus of elasticity (MOE) loss in samples of seven tropical timber species embedded for 32 weeks in three different types of soil.

Source of variation	Mass loss			MOE loss		
	*MS**	*F*	*p*	*MS**	*F*	*p*
Species (Spp.)	48714	288	<0,0001	164789	95	<0,0001
Contact time (T)	11894	164	<0,0001	53926	73	<0,0001
Soil (S)	12162	252	<0,0001	25911	52	<0,0001
Interaction (Spp. x T)	4216	8	<0,0001	11505	2	<0,0001
Interaction (Spp. x S)	14134	42	<0,0001	39723	11	<0,0001
Interaction (T x S)	494	3	0,002	3257	2	0,41
Interaction (Spp. x T x S)	1595	2	0,012	14753	1	0,41
Error	27628			282986		

*Mean square.

Table 3: Mean mass and modulus of elasticity (MOE) loss in seven tropical timber embedded for 32 weeks in three soil types. Significant difference in the mean values in relation to tree species are indicated by different lower case letters (Tukey test P<0,05).

Wood species	% Mass loss	%MOE loss
C. elaeagnoides	4,1a	21,0b
D. granadillo	4,3a	9,4a
E. cyclocarpum	21,6de	56,7f
F. sylvatica	22,9e	32,5c
H. polyandra	9,9c	36,0c
S. humillis	7,9b	19,0b
T. donell-smithii	6,2b	19,5b
T. rosea	20,6d	17,3b

Table 4: Mean values of mass and modulus of elasticity (MOE) loss in samples of seven tropical timber species embedded for 32 weeks in three different types of soil. Significant differences in relation to soil type are indicated by different lower case letters.

Soil type	% Mass loss	%MOE loss
Sandy (Michoacán)	9,8a	22,47a
Clay-loam (Nuevo León)	12,3b	29,7b
Clay-sandy-loam (Veracruz)	17,6c	33,9c

Table 5: Mean mass and modulus of elasticity (MOE) losses in samples of tropical timbers exposed for different times in three different soils. Significant differences in relation to time of exposure are indicated by different lower case letters (Tukey test, p<0,05).

Time (weeks)	% Mass loss	% MOE loss
8	8,6a	19,8a
16	12,1b	25,5b
24	15,1c	31,0c
32	17,1d	48,3d

MOE loss

Average MOE values decreased between 9,4% and 56,7% after the samples were embedded in soil for 32 weeks. ANOVA of the MOE loss data revealed highly statistically significant differences (p < 0,0001) for species, contact time and type of soil, as well as for the species x contact time and species x soil type interactions (Table 2). Tukey tests for species, soil type and contact time revealed significant differences (Table 3, Table 4 and Table 5).

The mean MOE loss was lowest (9,4%) in *D. granadillo*). The mean MOE loss in the *T. rosea, S humillis, T donell-smithii* and *C. elaeagnoides* samples ranged from 17,3% to 21%. The mean MOE loss in the *F. sylvatica* and *H. polyandra* samples was 32,5% and 36,0%, respectively. The mean MOE loss was highest (56,7%) in the *E. cyclocarpum* samples (Table 7).

Table 6: Mean mass loss in samples of seven tropical timber species and the control species *Fagus sylvatica* embedded for 8, 16, 24 and 32 weeks in three different types of soil.

Wood species	Sandy soil (weeks)				Clay-loam soil (weeks)				Clay-sandy-loam soil (weeks)			
	8	16	24	32	8	16	24	32	8	16	24	32
C. elaeagnoides	3,0	3,6	4,3	5,3	2,4	4,2	4,0	7,1	3,2	5,0	5,5	6,4
D. granadillo	2,9	3,0	4,9	6,3	5,4	4,1	3,2	4,8	2,8	4,0	5,3	6,8
E. cyclocarpum	12,1	20,9	19,4	25,8	12,4	19,6	28,9	27,4	21,4	25,3	31,2	37,9
F. sylvatica	5,7	9,1	12,6	13,7	16,2	22,4	26,2	30,8	31,0	38,9	44,2	48,6
H. polyandra	5,3	7,4	11,5	11,5	4,7	7,8	11,5	12,8	7,7	10,6	19,5	20,8
S. humillis	5,5	8,2	9,0	10,2	5,2	7,1	8,4	9,0	6,2	8,9	11,8	11,4
T. donell-smithii	1,6	4,3	5,1	6,8	2,0	4,8	6,8	9,2	4,9	8,3	12,4	15,1
T. rosea	12,3	15,8	20,7	20,1	11,9	16,7	26,9	30,9	17,8	26,6	31,0	36,8

Table 7: Mean MOE loss in samples of seven tropical timber species and the control species *Fagus sylvatica* embedded for 8, 16, 24 and 32 weeks in three different types of soil.

Wood species	Sandy soil (weeks)				Clay-loam soil (weeks)				Clay-sandy-loam soil (weeks)			
	8	16	24	32	8	16	24	32	8	16	24	32
C. elaeagnoides	14,4	9,4	18,6	32,2	19,7	17,8	16,3	23,73	8,9	20,6	20,2	32,2
D. granadillo	2,8	3,8	6,4	12,1	0,2	6,1	11,6	14,1	1,0	3,6	9,2	7,2
E. cyclocarpum	52,7	54,8	55,9	75,5	37,2	59,2	63,7	72,7	50,5	59,5	60,8	74,8
F. sylvatica	4,8	6,2	7,6	13,0	33,9	38,4	43,2	51,7	31,1	60,4	68,2	70,8
H. polyandra	27,9	34,2	35,7	46,5	21,3	37,4	38,2	49,3	29,5	37,2	41,8	61,9
S. humillis	0,2	3,8	17,9	28,1	12,9	15,9	18,8	21,7	9,1	19,4	21,6	34,7
T. donell-smithii	4,6	9,1	12,2	18,1	0,3	23,1	27,7	40,4	7,6	22,5	36,4	42,0
T. rosea	0,7	0,3	31,5	35,2	9,8	12,6	40,2	47,2	14,0	29,1	43,8	57,5

Durability of timber

The most durable timbers were *C. elaeagnoides* and *D. granadillo*, with mean values of mass loss in the different types of soil ranging from 4,1% to 4,3% (Table 3 and Table 6). The natural durability of both timbers were similar to that of *Tectona grandis* reported as highly durable after application of a similar test (Machek *et al*. 2001). Tests of tropical and European timber species also revealed some highly durable types of timber, with mean mass loss of 3% in *Acacia nigrescens, Pericopsis angolensis, Icuria dunensis* and *Pseudolachnostylis maprounaefolia*, and some species with low durability, with mean mass loss between 40% and 48% (Ali *et al*. 2011). The latter values are similar to those obtained in the present study for the non-durable timbers species. High durability is attributed to the effect of extractives Hillis (1972), Tsoumis (1991), Taylor (2004), Syofuna *et al.* (2012), Kadir (2017), as well as to the high density that causes reduction of microbial growth due to lack of oxygen (Tsoumis 1991). The *T. donell-smithii, S. humillis* and *H. polyandra* samples were of moderate durability (Table 3), with mass loss values ranging from 6,2% to 9,9% (Table 6). The *T. rosea, E. cy-*

clocarpum and *F. sylvatica* (control) timber samples were the least durable, with mass losses of 20,6%; 21,6% and 22,9% respectively (Table 6). The low durability of these timbers is attributed to low amounts of extracts (Taylor 2004).

Effect of soil type

The mass loss and MOE loss of the timber samples differed significantly depending on soil type (Table 4, Table 6 and Table 7). The sandy-clay-loam soil from Veracruz yielded the highest mass and MOE losses: mean values of 17,6% and 33,9% respectively. The sandy-loam soil from Nuevo León state yielded mean mass and MOE losses of 12,3% and 29,7% respectively. The sandy soil from Michoacán state produced mean mass and MOE losses of 9,8% and 22,5% respectively. The high mass and MOE losses caused by the loam-clay-sandy soil are due to the high pH (7,8) and high organic matter content (3,4) (Table 1).

In tests carried out with timber of low durability (*F. sylvatica*, *Populus* spp. and *Ulmus* spp.) mass losses values ranged between 35% and 40%, and MOE losses as well between 77% and 86% (Machek *et al*. 2001); similar values were obtained in the present test for *F. sylvatica*, *E. cyclocarpum* and *T. rosea* (Table 6 and Table 7).

Differences in mass loss in relation to soil type were also observed by Nami *et al*. (2006), Brischke *et al.* (2009) and by De-Avila *et al.* (2016) who concluded that mass losses, even from impregnated timber, are related to the type of soil used for the test. The sandy-clay-loam soil from Veracruz with pH 7,8 and an organic matter content of 3,4 % caused the highest level of deterioration in the samples of tropical timber tested. The maximum degradation of timber reported by Gersonde and Kerner (1984) was yielded by soil of pH 5,5-5,8 and organic matter content of between 5,8%-10%.

The speed of timber species degradation in terrestrial microcosm systems is related to the soil physical and chemical characteristics (Bravery 1975, Gersonde and Kerner 1984, Leightley and Russell 1980). However, these authors did not observe any correlation between the organic matter content and pH. They also reported that as a medium for timber degradation experiments, soil represents a complex system in which it is difficult to consider all variables involved, as the characteristics of different types of soil act and react in many different ways during the rotting process. The fungi and bacteria in the soil substrate is the dominating factor that influences the decay potential of the soil (Brischke *et al*. 2013) as well as the higher water holding capacity (Jebrane *et al.* 2014) while low oxygen availability is likely to reduce decay hazard (Wakeling 2006). Thus, while Savory (1955) noted a direct relationship between the soil organic matter content and timber rotting, in which mass loss is directly proportional to the organic matter content, the nitrogen content and aeration also affected the level of degradation of soil.

Effect of contact time

The timber durability, as indicated by both mass loss and MOE loss, varied in relation to exposure time (Table 5). The mean values of mass loss and MOE loss after the samples had been embedded in the soil for 32 weeks were 17,1% and 48,3% respectively. The MOE loss was the best indicator of the durability of timber species tested, as it was observed at early stages of decay, even when mass loss was low (Liese 1955, Hardie 1980, Ross and Pellerin 1994, Machek *et al*. 1997). Intensive degradation of carbohydrates by soft rot fungi produces MOE loss of 50% and only 5% of mass loss, thus causing the wood to crack as a result of reduced dimensional stability (Schmidt 2006). This was also observed in the samples of tropical timbers tested in the present study.

CONCLUSIONS

The mass loss and MOE loss differed in relation to timber species, type of soil and contact time. The timber samples that were most resistant to soil microorganisms were those from *Dalbergia granadillo* (mass loss of 4,3% and MOE loss of 11,1%) and *Cordia elaeagnoides* (4,1%; 21,0%). The timber samples of intermediate durability were those from *Swietenia humillis* (7,9%; 19,0%), *Tabebuia donell-smithii* (6,2%; 19,5%) and *Hura polyandra* (9,9%; 36,0%). The least durable samples were those from *Enterolobium cyclocarpum* (21,6%; 56,7%), *Fagus sylvatica* (22,9%; 32,5%) and *Tabebuia rosea* (20,6%; 17,3%). The soil from Veracruz (sandy-clay-loam soil) caused the highest level of degradation in the timber samples, followed by the soil from Nuevo León (sandy-loam soil), and the soil from Michoacán (sandy soil).

REFERENCES

Ali, A.C.; Uetimane, E.; Råberg, U.; Terziev, N. 2011. Comparative natural durability of five wood species from Mozambique. *International Biodeterioration & Biodegradation* 65(6):768-776.

Bravery, A.F. 1975. Micromorphology of decay in preservative treated wood. In Liese, W. (Ed.), *Biological Transformation of Wood by Microorganisms*. Springer: Berlin.

Brischke, C.; Welzbacher, C.R.; Rapp, A.O.; Augusta, U.; Brandt, K. 2009. Comparative studies on the in-ground and above-ground durability of European oak heartwood (*Quercus petraea* Liebl. and *Quercus robur* L.). *European Journal of Wood and Wood Products* 67(3):329-338.

Brischke, C.; Olberding, S.; Meyer, L.; Bornemann, T.; Welzbacher, C.R. 2013. Intrasite variability of fungal decay on wood exposed in ground contact. *International Wood Products Journal* 4(1):37-45.

Deutsches Institut für Normung. DIN. 1978. Prüfung von Holz DIN EN-52 186. 1978. Biegeversuch.

De-Avila, R.; Gonzales, P.H; Luiz, A.; Alberto, D. 2016. Decay resistance of four fast-growing eucalypts wood exposed to three types of fields. *Maderas-Cienc Tecnol* 18(1):33-42.

Eaton, R.A.; Halle, M.D.C. 1993. *Wood: decay, pests and protection.* Chapman & Hall: London.

European standard. EN. 2001. Wood preservatives. Determination of the effectiveness against soft rotting micro-fungi and other soil in-habiting micro-organisms. EN-807. 2001.

García, E. 1973. Modificación al sistema de clasificación climática de Köppen (para adaptarlo a las condiciones de la República Mexicana). Instituto de Geografía, Universidad Nacional Autónoma de México, Dirección General de Publicaciones: México.

Gersonde, M.; Kerner, W. 1984. Soft rot test with soils of different origins. In Proceedings IRG Annual Meeting, IRG/WP/2226. The International Research Group on Wood Protection: Stockholm, Sweden.

Hardie, K. 1980. A review of strength testing as a measure of biodeterioration of wood and wood based materials. *Int Biodet Bull* 16(1):1-8.

Hillis, W.E. 1972. Formation and properties of some wood extractives. *Phytochemistry* 11(4):1207-1218.

Jebrane, M.; Pockrandt, M.; Terziev, N. 2014. Natural durability of selected larch and Scots pine heartwoods in laboratory and field tests. *International Biodeterioration and Biodegradation* 91:88-96.

Kadir, R. 2017. Toxic effects of three selected Malaysian timbers plant extracts against subterranean termites. *Maderas-Cienc Tecnol* 19(4):417-432.

Leightley, L.E.; Russell, W.I. 1980. Soft rot decay of *Eucalytus maculata* Hook in different soils from Queensland, Autralia. In Proceedings IRG Annual Meeting, IRG/WP/1113. The International Research Group on Wood Protection: Stockholm, Swedem.

Liese, W. 1955. On the decomposition of the cell wall by micro-organisms. In: Record of the annual British wood preserving association.

Machek, L.; Derksen, A.M.; Sierra-Alvarez, R. 1997. Assessment of wood decay in small-scalle unsterile soil-bed tests. In Proceedings IRG Annual Meeting, IRG/WP 97-20111. The International Research Group on Wood Protection: Vancouver, Canada.

Machek, L.; Militz, H.; Sierra-Alvarez, R. 2001. The use of an acoustic technique to assess wood decay in laboratory soil-bed test. *Wood Science and Technology* 34(6):467-472.

Meyer, L.; Brischke, C.; Melcher, E.; Brandt, K.; Lenz, M.T.; Soetbeer, A. 2014. Durability of English oak (*Quercus robur L.)* comparison of decay progress and resistance under various laboratory and field conditions. *International Biodeterioration & Biodegradation* 86:79-85.

Nami, S.; Brischke, C.; Rapp, A.O.; Imamura, Y. 2006. Biological effectiveness of didecyl dimethyl ammonium tetrafluoroborate (DBF) against basidiomycetes following preconditioning in soil bed tests. *Wood Science and Technology* 40(1):63-71.

Norma Oficial Mexicana. 2000. NOM-021-RECNAT-2000. Secretaría de Medio Ambiente y Recursos Naturales.

Organización Internacional de las maderas tropicales. OIMT. 2015. Reseña anual y evaluación de la situación mundial de las maderas 2013-2014. Yokohama, Japón.

Ross, R.J.; Pellerin, R.F. 1994. Non-Destructive Testing for Assessing Wood Members in Structure. *Forest Products Laboratory.* General technical report: FPL-GTR 70.

Savory, J.G. 1955. The role of microfungi in the decomposition of wood. In: Record of the annual British wood preserving association.

Schmidt, O. 2006. *Wood and tree fungi*. *Biology, damage, protection and use.* Springer, Berlin.

Syofuna, A.; Banana, A.; Nakabonge, G. 2012. Efficiency of natural Wood extractives as Wood preservatives against termite attack. *Madera-Cienc Tecnol* 14(2):155-163.

SEMARNAT. 2016. Anuario Estadístico de la Producción Forestal 2015. Secretaría del Medio Ambiente y Recursos Naturales: México.

Taylor, A.M. 2004. Environmental effects on heartwood extractive content and their consequences for natural durability in Douglas-fir and Western Redcedar. Ph D. Thesis, Oregon State University, Oregon, USA. Available<https://ir.library.oregonstate.edu/downloads/h702q922s> (access date:12/03/2018).

Tsoumis, G. 1991. *Science and technology of wood: Structure, properties, utilization.* Chapman & Hall: New York.

Wakeling, R. 2006. Is field test data from 20 x 20mm stakes reliable? Effects of decay hazard, decay type and preservative depletion hazard. In Proceedings IRG Annual Meeting, IRG/WP 06-20327. The International Research Group on Wood Protection: Tromsø, Norway.

Walkley, A.; Black, I.A. 1934. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci* 37(1):29-37.