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NATURAL DURABILITY OF SEVEN TROPICAL TIMBER SPECIES IN GROUND CONTACT AT THREE SITES IN MÉXICO

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The interaction between wood and soil is one of the most hostile environment that a piece of wood can be exposed to. However, few field tests have been developed to determine its natural durability of Mexican timber species. In this study, the natural durability of seven tropical timber species was determined in Mexico, according to the European Standard EN 252. Test stakes were placed at three sites (Veracruz, Michoacán and Nuevo León) with different climatic, altitude, biodiversity and soil type conditions. After one year of exposure, statistical differences ($p < 0.001$) in decay level for sites and species were determined. The site with the most adverse environment was Veracruz followed by Michoacán and Nuevo León. *Dalbergia granadillo*, *Cordia elaeagnoides* and *Swietenia humillis* were classified according to the European Standard EN 350-1 as very durable (Class 1), while *Enterolobium cyclocarpum* and *Hura polyandra* were classified as durable (Class 4). *Tabebuia donell-smithii*, *Tabebuia rosea* and *Fagus sylvatica* (control) were classified as non-durable (Class 5).

Keywords: Field test, European Standard 252, level of decay, durability class, pick-test.

INTRODUCTION

Wood durability is the resistance of wood to deterioration caused by organisms and the environment. The natural durability of a timber species is related to its ability to maintain a low level of moisture content (Öqvist 1988, Flaete et al. 2008). The degradation process is a complex interaction between the wood and environmental factors, e.g., microorganisms, climate, moisture, solar radiation (mainly UV radiation), temperature and other factors including time of exposure and type of treatment. The degree of rot resistance of wood in contact with soil is the result of the relationship between the natural durability of the wood, climatic conditions and soil characteristics such as texture, amount of organic matter, pH, nutrients, microorganisms, moisture and degree of aeration (Schmidt 2006, Rahman & Chattopadhyay 2007).

Field tests are a practical and reliable way to formulate predictions of the service life of wood species. This type of test can be costly and requires long periods of time (Larsson-Brelidet et al. 2011). A gradual series of changes start when wood is in-ground, i.e. its color changes because of solar radiation, rain and soil humidity. Also, during exposure, durability decreases because extractives are leached, while the amount of water in the cell cavities increases. If moisture content exceeds 20%, an increment of microorganisms attack the structural component of wood (hemicellulose, cellulose and lignin) resulting in the wood being destroyed by fungi, the most important organisms in wood degradation. However, the rate at which wood decays may vary between sites (Wakeling 2006, Brischke and Rapp 2008a, Ali et al. 2011, Jebrane et al. 2014). To determine the level of durability, it is necessary to expose wood to environmental conditions at different sites, to increase the number of agents that impair the wood (Edlund et al. 2006). This

will facilitate finding sites with a high impact on treatments and wood durability, and aid the determination of durable wood species.

In the tropical forests of Mexico, as with other tropical areas around the world, lesser-known tropical timber species are grown with potential use in various applications. However, basic research to obtain information on natural durability of these lesser-known timber species is needed (Febrianto et al. 2015). The objectives of this study were to evaluate the natural durability of seven important tropical Mexican timber species: *Cordia elaeagnoides, Dalbergia granadillo, Enterolobium cyclocarpum, Hura polyandra, Swietenia humillis, Tabebuia donell-smithii, Tabebuia rosea* and *Fagus sylvatica* (the control) on three sites with different soil types and environmental conditions, and to classify the timber species according to durability.

MATERIALS AND METHODS

Timber species and preparation of test stakes

Heartwood free of defects or mechanical damage of *C. elaeagnoides, D. granadillo, E. cyclocarpum, H. polyandra, S. humillis, T. donell-smithii, T. rosea* and the control *F. sylvatica* were sawn into test stakes measuring 25 × 50 × 500 mm (radial × tangential × longitudinal). The total number of test stakes was 45 for each species. All test stakes were dried in a climate chamber at 65% relative humidity and 20 °C to a moisture content of about 12%.

Sites

Three different geographic sites, i.e. Veracruz, Nuevo León and Michoacán, were selected to expose wood specimens to a range of climates, soils and altitude to assess how these environmental conditions affected wood durability. The three sites (field tests) were those with no previous cultivation or agrochemical application. The test stakes were not disturbed during the study period. Veracruz (19° 35' N and 96° 22' W, 50 m asl) is located at Centro de Investigaciones Costeras la Mancha (CICOLMA) in the municipality of Actopan, Veracruz. The CICOLMA is managed by the National Institute of Ecology (INECOL). The local climate is type A (w1) (100%), that is warm sub-humid with an annual average temperature greater than 22 °C. The temperature of the coldest month is 18 °C, rainfall for the driest month is lower than 60 mm, the summer rains index (precipitation/temperature) is between 43.2 and 55.3, and the winter rain percentage is from 5.0–10.2%. Nuevo León (24° 47' N and 99° 32' W, 384 m asl) is located at Facultad de Ciencias Forestales of Universidad Autónoma de Nuevo León (FCF-UANL) in the municipality of Linares, Nuevo León. The local climate is classified as AC (Wo), that is semidry sub-humid with two rain seasons (summer and autumn). Michoacán (19° 38' N and 103°13' W, 1977 m asl) is located at Facultad of Biología of the Universidad Michoacana de San Nicolás de Hidalgo (FB-UMSNM) in Morelia, Michoacán. The local climate is type C (w1), with average humidity corresponding to average annual summer rains from 700 to 1000 mm, and annual winter rains of 5 mm. Weather conditions of the three sites is described in detail in García (1973).

Soils

The pH, electrical conductivity texture (NOM-021-RECNAT-2000), percentage of organic matter and organic carbon were determined for soil samples from the three sites, using the method adapted from Walkley & Black (1934). The results are shown in Table 1.

Installation of wooden stakes

Sites were fenced to prevent disturbance of the study plots. At each site, three plots measuring 210 cm × 90 cm were established, then five test stakes of each species were randomly installed in each plot. The test stakes were buried 250 mm vertically and spaced 300 mm apart. A total of 120 test stakes were installed in each site.

Decay classification

The effects of biotic (fungi and insects) and abiotic (soil and humidity) agents on the natural durability of test specimens buried were evaluated after 12 months. Test specimens were taken out of the soil and excess soil brushed off before assessing the level of deterioration using the pick-test. The pick-test analyses the way wood fibres break when a knife is inserted into the wood grain at a shallow angle to the surface, and then pried back to lever up a thin splinter. Decay level was classified according to the European Standard EN 252 (EN 1989) where 0 = no attack,

Table 1 Soil properties of the three study sites used to test the durability of seven tropical timber species in México

		Veracruz	Michoacán	Nuevo León
Soil type		Clay sandy loam	Sandy	Clay loam
pH		7.8	5.3	7.8
Electrical conductivity (μS cm^{-1})		398.7	183.7	342.3
Organic matter (%)		3.4381	2.6054	3.259
Organic carbon (%)		1.9942	1.5113	1.8904
Texture	Sand (%)	50.6	86.6	12.6
	Loam (%)	26.4	8.4	40.4
	Clay (%)	23.1	5.1	47.1

Organic matter and organic carbon data were obtained from Walkley-Black (1934)

1 = slight attack, 2 = moderate attack, 3 = severe attack and 4 = failure (Table 2).

Wood durability was determined according to the European Standard EN 350-1 (EN 1994), and uses the ratio (*x*-values) between the median service life of the stakes of the tested wood species and median service life of stakes of the reference species (*F. sylvatica*).

Wood durability:

$$x = \frac{\text{median service life of the tested timber}}{\text{median service life of the reference species } (F.\ sylvatica)} \quad (1)$$

Statistical analysis

Decay classification data for species and sites were compared using analysis of variance (ANOVA) followed by Tukey's multiple comparison test ($p \leq 0.05$). Statistical analyses were carried out with SPSS software program version 20.

RESULTS AND DISCUSSION

Mean decay rating according to EN 252

The pick-test for determining deterioration levels of in-ground test stakes was a reliable and sensitive way of measuring durability in early stages of rotting. Natural decay resistance values obtained by the pick-test method in the present study were similar to those reported by Wilcox (1983) and Morrell et al. (1986).

The natural decay resistance values from test stakes of the tropical timber species on ground contact after twelve months obtained by pick-test method are shown in Figure 1. The ANOVA test indicated that decay hazard and durability differed significantly among species and sites, with a significant interaction between the two factors (two-way ANOVA, $p < 0.001$; Table 4). The results of the Tukey tests among the sites showed three groups; while among species four statistical groups were found (Table 5 and Table 6). The decay hazard at Veracruz (2.0) was significantly higher than that at Michoacán (0.9), which in turn had a decay hazard that was significantly greater than that at Nuevo León (0.6; $p < 0.001$, Tukey's test). The establishment and evolution both on the surface of and within wood of wood destroying fungi is favored by the environment (rainfall, temperature and relative humidity) (Råberg et al. 2005). The level of decay was strongly influenced by moisture content and temperature (Brischke & Rapp, 2008b). Wood exposed to different environment is subject to different degrees of decomposition (Deacon 1997, Meyer et al. 2012 and Jebrane et al. 2014), and this was evident in three sites of the present study. Broadly, the rate of decay could be attributed to the effects of temperature, water availability, type of soil, vegetation and the type of organic matter on the surface (Wakeling 2006, Cuffre et al. 2010 and Brischke et al. 2011). In the present study, test stakes showed the greatest level of biodeterioration in Veracruz, which had the warmest and most humid climate (tropical) of the three sites. A warm and humid environment is associated with a high activity of wood decay microorganisms that may have contributed to

Table 2 Decay classification of test stakes in ground contact according to European Standard EN 252

Rating		Description (mm)	Maximun depth of decay (mm^2)	Minimum transversal section (%)	
0	No attack	No evidence of decay, softening or weakening caused by micro-organisms	0	1250	100
1	Slight attack	Limited evidence of decay, no significant softening or weakening up to certain depth	1	1104	88
2	Moderate attack	Significant evidence of decay, with areas of decay (softened or weakened wood) up to certain depth	3	836	67
3	Severe attack	Strong evidence of decay, extensive softening and weakening, typical fungal decay at large areas up to certain depth	5	600	48
4	Failure	Sample breaks	50	0	0

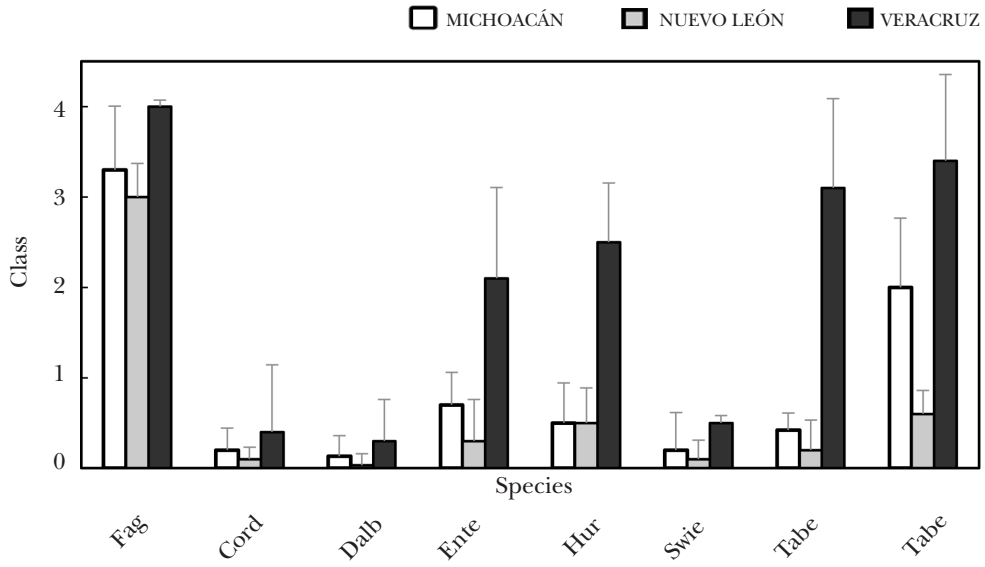

Figure 1 Mean durability (± standard deviation) according to EN 252 for seven tropical timber species and a reference species, at three sites in México; Fag = *Fagus sylvatica*, Cord = *Cordia elaeagnoides*, Dalb = *Dalbergia granadillo*, Ente = *Enterolobium cyclocarpum*, Hur = *Hura polyandra*, Swie = *Swietenia humillis*, Tabe = *Tabebuia rosea*

Table 3 Durability classification index according European Standard EN 350-1

Durability classification index	Description	*x*-value
1	Very durable	$x > 5$
2	Durable	$3 < x \leq 5$
3	Moderately durable	$2 < x \leq 3$
4	Slightly durable	$1.2 < x \leq 2$
5	Not durable	$x \leq 1.2$

the results observed at Veracruz. The difference between selected sites could be due to the high capacity of water retention of the soil, a nearly neutral pH and the presence of fungi of soft rot and bacteria (Ali et al. 2011, Cuffre et al. 2010, Jebrane et al. 2014). Dry (low moisture) sites usually have a low index of biodeterioration (Wakeling 2006), and the results for Nuevo León attest to that.

Three species (*D. granadillo, C. elaeagnoides and S. humilis*), which fell within the low decay rating class, were significantly more resistant to decay than *T. donell-smithii, E. cyclocarpum* and *H. polyandra* (medium decay class rating), which in turn were more resistant to decay than *T. rosea* (high decay class rating). All test species including *T. rosea* were more resistant to decay

Table 4 Analysis of variance for the durability test including species and site

Souce of variation	df	Sum of squares	Mean squares	F value	p-value
Interaction	1	878.834	878.834	82864112.021	<0.001
Species	7	0.010	0.001	135.364	<0.001
Site	2	0.003	0.002	160.669	<0.001
Species × site	14	0.001	0.000	9.839	<0.001
Error	336	0.004	1.061E-005		
Total	360	879.197			

df = degree of freedom

Table 5 Tukey test of mean decay rating according to EN 252 for the seven tropical timber species

Sites	Mean decay rating	
Veracruz	2.0	a
Michoacán	0.9	b
Nuevo León	0.6	c

Different letters indicate significant differences with a 95% confidence level

Table 6 Mean decay rating according to EN 252 for the seven tropical timber species and a reference species, *Fagus sylvatica*

Species	Mean decay rating	
Fagus sylvatica	3.4	a
Tabebuia rosea	1.5	b
Hura polyandra	1.1	c
Tabebuia donell-smithii	1.2	c
Enterolobium cyclocarpum	1.0	c
Swietenia humillis	0.3	d
Cordia elaeagnoides	0.2	d
Dalbergia granadillo	0.1	d

Different letters indicate significant differences between species in the Tukey test at 5% significance level

than the reference, *F. sylvatica*, which received a high decay class rating.

Damage class

The test stakes in all sites exhibited superficial galleries of ten percent while insect damage was found only in Veracruz. The wide variety of soft rot fungi (Ascomycetes and Deuteromycetes) that inhabit the soil are noted for their adaptability to a range of soil and moisture levels, and preservatives (Schmidt 2006). The loss of strength of the fibres is caused by perforations or erosion in the secondary wall (Eriksson et al. 1990). Soft rot is more common in hardwood than in softwood. The samples in the present study showed soft rot deterioration caused by fungal attack, as was observed in previous studies (Brischke & Rapp 2008b, Brischke et al. 2013, Brischke et al. 2014, Jebrane et al. 2014).

Durability class

Table 7 shows the durability of the tested species in relation to test site, based on EN 350-1. The species, *C. elaeagnoides*, *D. granadillo* and *S. humilis* were classified as very durable in all three sites. Non-durable species were found only in Veracruz. All species studied were classified as very durable in Nuevo León. The study demonstrate the effect of site on timber durability, with the degree of decay related to site.

Table 7 Durability class of seven tropical timber species exposed at three sites in Mexico according to EN 350-1 (in parentheses)

Species	Michoacán		Nuevo León		Veracruz	
	x-valor		*x*-valor		*x*-valor	
Cordia elaeagnoides	19.3	(1)	86.0	(1)	10.8	(1)
Dalbergia granadillo	24.1	(1)	86.0	(1)	14.9	(1)
Enterolobium cyclocarpum	4.8	(2)	10.8	(1)	1.9	(4)
Hura polyandra	7	(1)	5.7	(1)	1.6	(4)
Swietenia humillis	13.8	(1)	28.7	(1)	7.9	(1)
Tabebuia donell-smithii	7.5	(1)	18.7	(1)	1.3	(5)
Tabebuia rosea	1.9	(4)	5.1	(1)	1.2	(5)

The description of durability according to EN 350-1 is shown in Table 3

CONCLUSIONS

The test site significantly influenced the level of deterioration of timber species, thus site characteristics should be considered when estimating the service life of certain timber species. The natural durability of the seven tropical timber species exposed to the three sites was different between sites and species. The site with a high decay hazard, Veracruz, had the highest degradation of test stakes. After twelve months in-ground, the timber species, *D. granadillo*, *C. elaeagnoides* and *S. humillis* were classified as very durable (Level 1), *E. cyclocarpum,* and H. polyandra were slightly durable (Level 4), and *T. donell-smithii* and *T. rosea* were classified as not durable (Level 5), following the European standard EN 252.

REFERENCES

Ali AC, Uetimane-Júnior E, Råberg U & Terziev N. 2011. Comparative natural durability of five wood species from Mozambique. *International Biodeterioration and Biodegradation* 65: 768–776.

Brischke C, Meyer L & Olberding S. 2014. Durability of wood exposed in ground comparative field trials with different soil substrates. *International Biodeterioration and Biodegradation* 86: 108–114.

Brischke C, Olberding S, Meyer L, Bornemann T & Welzbacher CR. 2013. Intrasite variability of fungal decay on wood exposed in ground contact. *International Journal of Wood Products* 4: 37–44.

Brischke C & Rapp AO. 2008a. Dose-response relationships between wood moisture content, wood temperature and fungal decay determined for 23 European field test sites. *Wood Science and Technology* 42: 507–518.

Brischke C & Rapp AO. 2008b. Influence of wood moisture content and wood temperature on fungal decay in the field: observations in different micro-climates. *Wood Science and Technology* 42: 663–677.

Brischke C, Welzbacher CR, Meyer L et al. 2011. Service life prediction of wooden components — Part 3: approaching a comprehensive test methodology. Pp 1–26 in Joran Jermer (ed) *Proceedings of the 42nd Annual Meeting of the International Research Group on Wood Protection* 8–12 May 2011, Queenstown.

En 1989. EN-252. *Field Test Method for Determining the Relative Protective Effectiveness of a Wood Preservative in Ground Contact.* European Committee for Standardization, Brussels.

En 1994. EN-350-1. *Durability of Wood and Wood-based Products–Natural Durability of Solid Wood. Part 1: Guide to the Principles of Testing and Classification of the Natural Durability of Wood.* European Committee for Standardization, Brussels.

Cuffré AG, Calvo CF, Genovese FV, Dorado ML & Piter JC. 2010. Caracterización de la durabilidad natural de la madera de *Eucalyptus grandis* de Argentina para su utilización en construcciones. Pp 74 in edUTecNe (editorial). *Proceedings of the VI Congreso Internacional sobre Patología y Recuperación de Estructuras,* 2–4 Jun 2010, Cordoba.

Deacon JW. 1997. *Modern Mycology.* Blackwell, Oxford.

Edlund ML, Evans FG, Henriksen K & Nilsson T. 2006. *Testing Durability of Treated Wood According to EN 252 Interpretation of Data From Nordic Test Fields. IRG/WP/06-20341.* The International Research Group on Wood Protection, Stockholm.

Eriksson KE, Blanchette RA & Ander P. 1990. *Microbial and Enzymatic Degradation of Wood and Wood Components.* Springer Verlag, Berlin.

Febrianto F, Pranata AZ, Septiana D et al. 2015. Termite resistance of the less known tropical woods species grown in West Java, Indonesia. *Journal of The Korean Wood Science and Technology* 43: 248–257.

Flæte PO, Alfredsen G & Evans FG. 2008. Comparison of four methods for natural durability classification after 2.5 years. *Pro Ligno* 4: 15–24.

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.

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.

Larsson-Brelid P, Brischke C, Rapp AO et al. 2011. Methods of field data evaluation - time versus reliability. Pp 1–18 in Joran Jermer (ed). *Proceedings of the 42nd Annual Meeting of the International Research Group on Wood Protection* 8–12 May 2011, Queenstown.

Meyer L, Brischke C & Pilgård A. 2012. Moisture performance based wood durability testing, Pp 1–26 in Joran Jermer (ed). *Proceedings of the 43rd Annual Meeting* of the *International Research Group on Wood Protection,* 6–10 May 2012, Kuala Lumpur.

Morrell J, Smith SM, Newbill MA & Graham RD. 1986. Reducing internal and external decay of untreated Douglas-fir poles a field test. *Forest Products Journal* 36: 47–52.

Öqvist H. 1988. *The Durability of Outdoor Wood. Field Test: Wood Panels Exposure Out of Ground Contact. Report No 204.* The Swedish University of Agricultural Sciences, Department of Forest Products, Uppsala.

Råberg U, Edlund ML, Terziev N & Land CJ. 2005. Testing and evaluation of natural durability of wood in above ground conditions in European overview. *Journal of Wood Science* 51: 429–440.

Rahman A & Chattopadhyay G. 2007. Soil factors behind inground decay of timber poles: Testing and interpretation of results. *IEEE Transactions on Power Delivery* 22: 1897–1903.

Schmidt O. 2006. *Wood and Tree Fungi: Biology, Damage, Protection and Use.* Springer Verlag, Berlin.

Semarnat. 2002. NOM-021-RECNAT-2000. *Establece las Especificaciones de Fertilidad, Salinidad y Clasificación de Suelos, Estudio Muestro y Análisis.* Norma Oficial Mexicana Secretaria De Medio Ambiente Y Recursos Naturales, México.

Wakeling RN. 2006. *Is Field Test Data From 20 × 20 mm Stakes Reliable? Effects of Decay Hazard, Decay Type and Preservative Depletion Hazard. IRG/WP 06-20327.* The International Research Group on Wood Protection, Stockholm.

Walkley A & Black IA. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* 37: 29–37.

Wilcox W. 1983. Sensitivity of the 'pick test' for field detection of early wood decay. *Forest Products Journal* 33: 29–30.