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Original article

Influence of two xylophagous fungi on the natural durability of ten timber species in Ucayali, Peru

Influencia de dos hongos xilófagos sobre la durabilidad natural de diez especies maderables de Ucayali, Perú

Influência de dois fungos xilófagos na durabilidade natural de dez espécies madedeiras em Ucayali, Peru

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ABSTRACT

The objective of the research was to determine the natural durability in ten timber species from secondary and primary residual forests in the Ucayali region, Perú, from infection with two xylophagous fungi *Pycnoporus sanguineus* (which causes white-rot) and *Lenzytes erubencens* (causal agent of brown rot). The wood samples analyzed were: *Apeiba membranacea, Apuleia molaris, Brosimun utile, Croton matourensis, Jacaranda copaia, Matisia cordata, Septotheca tessmannii, Schizolobium amazonicum, Simauroma amara, Terminalia oblonga;* powered by two xylophagous fungi, which were treated at the carpentry of the National University of Ucayali. The analysis of the study was experimental, according to the guidelines of the ASTM D 2017-81 Standard, under *in vitro* conditions of the treated material. Once the range of the species rot index was achieved, the average per species of xylophagous fungus, the standard deviation, the coefficient of variation and the confidence parameters were calculated in accordance with COPANT 1974. The results established the relation among xylophagous fungi species and the height of the trunk, both as a function of natural durability. It was concluded, according to the type of risk, the management that could be given to the studied woods and the recommendations for the correct use of vulnerable woods.

Keywords: Tropical forest; Timber species; Xylophagous fungus; Durability.

RESUMEN

El objetivo de la investigación fue determinar la durabilidad natural en diez especies maderables procedentes de bosques secundarios y primarios residuales de la región de Ucayali, Perú, a partir de la infección con dos hongos xilófagos *Pycnoporus sanguineus* (que origina pudrición blanca) y *Lenzytes erubencens* (agente causal de pudrición parda). Las muestras de madera analizadas fueron: *Apeiba membranacea*, *Apuleia molaris*, *Brosimun utile*, *Croton matourensis*, *Jacaranda copaia*, *Matisia*

cordata, *Septotheca tessmannii*, *Schizolobium amazonicum*, *Simauroma amara*, *Terminalia oblonga*; accionado por dos hongos xilófagos, que fueron tratadas en la carpintería de la Universidad Nacional de Ucayali. El análisis del estudio fue de tipo experimental, según las pautas de la Norma ASTM D 2017-81, bajo condiciones *in vitro* del material tratado. Una vez conseguido el rango del índice de pudrición de las especies, se calculó el promedio por especie de hongo xilófago, la desviación estándar, el coeficiente de variación y los parámetros de confianza convenientemente a lo que establece COPANT 1974. Los resultados establecieron la relación entre la especie de hongo xilófago y los niveles de fuste, ambos en función de la durabilidad natural. Se concluyó, según tipo de riesgo, el manejo que se les podría dar a las maderas estudiadas y las recomendaciones para el correcto uso de maderas vulnerables.

Palabras clave: Bosque tropical; Especie maderable; Hongo xilófago; Durabilidad.

RESUMO

O objectivo da investigação era determinar a durabilidade natural em dez espécies madedeiras provenientes de florestas residuais secundárias e primárias na região de Ucayali, Peru, de infecção com dois fungos xilófagos Pycnoporus sanguineus (que causa a podridão branca) e Lenzytes erubencens (agente causal da podridão castanha). As amostras de madeira analisadas foram: Apeiba membranacea, Apuleia molaris, Brosimun utile, Croton matourensis, Jacaranda copaia, Matisia cordata, Septotheca tessmannii, Schizolobium amazonicum, Simauroma amara, Terminalia oblonga; alimentadas por dois fungos xilófagos, que foram tratados na carpintaria da Universidade Nacional de Ucayali. A análise do estudo foi experimental, de acordo com as diretrizes da Norma ASTM D 2017-81, em condições in vitro do material tratado. Uma vez atingido o intervalo do índice de apodrecimento das espécies, a média por espécie de fungo xilófago, o desvio padrão, o coeficiente de variação e os parâmetros de confiança foram calculados de acordo com a COPANT 1974. Os resultados estabeleceram a relação entre as espécies de fungos xilófagos e os níveis de caule, ambos em função da durabilidade natural. Concluiu-se, de acordo com o tipo de risco, a gestão que poderia ser dada às madeiras estudadas e as recomendações para o uso correto das madeiras vulneráveis.

Palavras-chave: Floresta tropical; Espécie madeireira; Fungo xilófago; Durabilidade.

INTRODUCTION

The Amazon is known for its countless variety of timber species, especially in countries like Perú and Brazil, the largest nations. Secondary forests represent a large portion of the Amazon. The study of the biology of secondary forests focuses mainly on natural secondary forests, as the cause of the successions that rehabilitate a forest (Dourojeanni, 2016); differing from those originated by human activity, which currently represent a larger area than those caused by natural disturbances, in addition to having greater implications on land use, rural development and conservation of natural resources in general (Tuezta and Rodríguez, 2018).

The Peruvian Amazon possesses more than 50 % of the national territory, the usufructable and virtually commercial timber species fluctuate widely in their chemical, physical, mechanical properties and suitability for management. For this reason, the exploitation of the treated species is selective, generating pressure on a minority of the forest population. The demand for timber species in the national and international market is increasingly demanding, thus forcing research into potential

timber species that can satisfy the increase in market demand. For this reason, an inherent property of a natural and timber species is its capacity to resist (natural durability) to the attack of microorganisms, such as destructive agents (xylophagous fungi), which cause the species to rot.

Wood is, without a doubt, the product of greatest commercial demand provided by the forests, as well as one of the most important components of the complex forest resource in Peru. Wood is defined as an important group of soil organic carbon, whose structural components and cell walls include: cellulose, hemicellulose and lignin (Taylor *et al*., 2002). The lack of knowledge and understanding about the main characteristics of wood and its correct use causes a selective overexploitation of a certain species over others (González and Icochea, 1980).

According to MINAGRI's report (2017), in Perú the relationship between annual area of forest plantations for commercial purposes (timber) from 2011 to 2017, with respect to the total area with potential for commercial forest plantations, is at an average level of 0.23 %. The importance of natural durability lies in the length of time that the physical and chemical properties of the wood remain in effect, since the indication of its correct management depends on them. Likewise, it provides basic information to select and properly attribute the existing preservation and drying procedures, according to the final disposal of the material, thus achieving the correct and full benefit of the existing wood species (Taylor *et al.,* 2002).

According to Cartwright and Findlay (1958), the natural durability of species should be understood as the ability to resist attack by destructive factors (both biotic and abiotic), but considering the effect of fungi on other agents. Furthermore, it was internationally agreed to attribute the term "natural durability" to the causal effect of fungi, which are considered to be the major cause of rot in timber species. González and Icochea (1980) argue that the real importance of classifying woods according to their inherent natural durability is subject to the fact that this criterion allows proposing the state of preservation for which it is necessary, as well as the report of the probable toxicity levels of the recommended and used preservative. Likewise, Cruz *et al*., (2018) conclude that, in order to lay the foundations for an adequate use of wood, it is essential to know its natural durability under the effect of pernicious agents, both biotic and abiotic.

The current demand for timber species, places Perú as a preferential supplier, which generates the need for the product offered to meet the quality standards imposed by the market, but in turn without damaging the ecosystem where these forest species are located. For this reason, in the present investigation, the main objective is to determine the natural durability in 10 species that may be timber from secondary and primary residual forests in the region of Ucayalí, Perú, from infection with two xylophagous fungi *Pycnoporus sanguineus* (which causes white rot) and *Lenzytes erubencens* (causal agent of brown rot). According to the previous precept, Silva-Castro *et al.,* (2016) state that structural wood is highly sensitive to different models of biodegradation, mainly caused by fungi, bacteria and insects. What is determined below is the measurement of the level of rot of a wood to determine its use in industry. The tests are carried out following the experimental method established in the international standard ASTM D 2017-81, endorsed by the American Society of Wood Preservers (AWPA). The evaluation of the durability of the 10 wood species proposed above, are valued according to the loss of initial dry weight, measured in percentage, following the recommendations of Cartwright and Findlay (1958).

MATERIALS AND METHODS

The development of the research was in the carpentry of the National University of Ucayali. The range of the sample was constituted by pieces of wood of 10 species (*Simauroma amara, J. copaia, Schizolobium amazonicum, Apeiba membranacea, B. utile, M. cordata, Apuleia molaris, T. oblonga, C. matourensis, Septotheca tessmannii*), processed during three days. The samples were from five pieces per species, collected from the Centro de Investigación y Capacitación Forestal Macuya-CICFOR, located in the Federico Basadre Road km. 19, Coronel Portillo province, in the Ucayali Region. Specimens were circularly sectioned with diameters between 4 and 6" thick, delimiting each portion in a range of three levels: base, middle and apex. Sixteen specimens were extracted per level, using only eight specimens per level and multiplying by five sections of the treated material, which generated a total of 120 specimens for each treated species (free of cracks and crevices, healthy, without signs of insect infection, rot, mold or blue stain). At the end of the collection of the sample of each wood species and its subsequent transfer to the location of the investigation, the following parameters were taken into account.

Dendrological identification

The dendrological identification of the forest species, potentially timber, was developed in the establishments of the Regional Herbarium of the Tropical Diseases Research Institute and Altura-IVITA, belonging to the Universidad Nacional Mayor de San Marcos.

Method of investigation

For the development of this research analysis, the experimental method of ten forest species was carried out under *in vitro* conditions, following the indications of the international standard ASTM D: 2017-81. The indicators of the analysis were two types of xylophagous fungi (*P. sanguineus and L. eurebecens*), which were cultivated in a rotting chamber, contained in a sterilized standard artificial medium, in an environment adjusted to adequate conditions of temperature and relative humidity to support the rotting phenomenon on the treated material. For the accuracy of the initial dry weight, the wood samples were dried in a regulated oven at 30 ºC, until a constant dry weight was achieved, then the samples were sterilized in an autoclave with pressurized wet steam (120 ºC and 15 lb in^{-2}, for 20 min.) and placed inside the rotting chambers. The incubation stage lasted about 12 weeks, after which the previously used samples passed through the drying phase again in an oven until a constant weight was achieved and with this value the final weight of the samples was determined.

Data collection procedure. Preparation of test specimens

The specimens were processed on a diamond-tipped disc saw, then the remaining sawdust and chips were removed from the sample material with a 120 grit sandpaper. They were then dehumidified in a controlled oven at 100 ± 2 °C until the weight of the sample remained unchanged. After this process, they were placed for 20 minutes (according to Standard ASTM-1413) in a drying hood supplied with anhydrous $CaCl_2$ crystals and then weighted on a balance with 0.01 g accuracy, considering the original weight of the analysis.

Species of xylophagous fungi

The selected fungi were collected from the Macuya Forest Research Center, Faculty of Forestry and Environmental Sciences, National University of Ucayali. Later, they were classified at the Wood Preservation Laboratory of the National Agrarian University La Molina. The species used for the research are*: P. sanguineus* y *L. erubescens*.

Preparation of the culture medium

In parallel to the preparation of the standard culture medium (Table 1), the culture medium was prepared by dissolving it in hot distilled water and then standardizing it by manual stirring until it reached boiling point.

Table 1. - Composition of the standard culture medium

Compound	Quantity in grams
Agar agar	20 g
Malt extract	12 g
Dextrose	20 g
Peptone	1 g
Distilled water	1 000 g

Preparation of the rotting chambers

Transfer 20 ml of hot and liquid culture medium containing 0.5 g of disinfectant solution into each glass bottle and sterilize in an autoclave at 120 °C temperature and 15 lb/pg^2 pressure within 20 minutes. They were then left to cool and placed horizontally on a space previously sterilized with a 0.1 % mercury chloride II ($HgCl_2$) solution.

Inoculation of rot chambers

The previously sterilised chambers were infected with small portions (1 cm in diameter) of the xylophagous fungi chosen for the experiment, with the help of a punch, and were placed in the electrically controlled oven at 27 ± 1 °C and 70 ± 4 % relative humidity, until the mycelium covered at least half of the surface region of the culture medium. The rotting chambers were placed in the incubation room for a period of 90 days.

Conditioning of test specimens

The dry samples were sterilized in an autoclave at 120°C and 15 lb plg^{-2} in pressure for 20 minutes and allowed to cool to room temperature under sterile conditions in a microvoid device. One specimen was then introduced into each rot chamber, using disinfected surgical gloves and forceps. The lids were also partially screwed on to promote oxygen availability and gas exchange, which is essential for the correct metabolism in xylophagous fungi.

Determination of the final weight

Once the exposure stage of the handled material was completed, the test specimens were removed from each used rotting chamber and washed with acetone alcohol, then dried in an oven until a constant weight was obtained; cleaning the mycelium remains, a drying bell was placed, provided with calcium chloride, in a period of 20 min. Later, the material was weighed in a balance with 0.01 g. of precision, considering this result as the final weight of the experimental analysis. The loss of weight of the wood (material handled) was calculated with the following mathematical formula (Equation 1).

$$\text{Weight loss} = [(\text{Initial weight} - \text{Final weight}) / \text{Initial weight}] \times 100\ \% \quad (1)$$

Where:

i. The weight loss of the test specimens in the experiment was expressed as a percentage (%).
ii. The initial and final weight of the test specimens of the experiment is expressed in grams (g).

When the weight loss of each species was determined, following the above mathematical formula, four resistance groups of wood were differentiated, according to the proposed resistance grade, following the ASTM D: 2017-81 Standard (Table 2).

Table 2. - Wood grading according to ASTM Standard D-2017-81

% Weight loss	Degree of resistance to the test fungi	Group by resistance
0-10	Highly resistant	A
11 to 24	Resistant	B
25 to 44	Moderately resistant	C
+ 44	Non-resistant	D

Statistical processing of data

From the results obtained from the indices of rot, the average per species was computed in relation to the selected xylophagous fungus, the standard deviation, the coefficient of variation and the confidence limits, according to the COPANT standard (1974), Pan American Commission on Technical Standards. The randomized method was used to determine the resistance to rot under the action of each xylophagous fungus, with a factorial arrangement, considering in the development of the experiment samples from five trees, three longitudinal levels per tree and six treatments.

Random Complete Design (RCD), with a 2-factors factorial arrangement (Table 3):

F_1 Fungi = 2 (H_1 = *P. sanguineus*, H_2 = *L. erubescens*)

F_2 Levels = 3 (N_1 = Below, N_2 = Medium, N_3 = Apex)

Repetitions = 5 (trees)

Unidades experimentales = 2 x 3 x 5 = 30

For each level, eight test especimens were available, four of which were infected with *P. sanguineus* (fungus 1) and four with *L. erubescens* (fungus 2) (Table 3).

120 (test specimens) / 4 (inoculated test specimens) = 30 UE

Table 3. - Completely randomized 2-factors factorial design

1	**H_1 N_1**
2	H_2 N_1
3	H_1 N_2
4	H_2 N_2
5	H_1 N_3
6	H_2 N_3

It was worked with a level of significance equal to 5 %, through the ANOVA and Fisher's Multiple Range LSD tests, in relation to the level of rot caused by each species of fungus and its effect on tree species. For the analysis the ACD was used with a two-factor and five-factor factorial arrangement, having six treatments (two xylophagous fungi species, by three levels). Repetitions were performed at five different sites and, for each site, an average of the four test tubes was obtained, resulting in 30 experimental units (2 x 3 treatments and five repetitions); in addition, the rotting chambers were placed at random in the incubation chamber (Calzada, 1985).

RESULTS AND DISCUSSION

The exposure phase of the specimens of *Apeiba membranacea, J. copaia, C. matourensis, Schizolobium amazonicum, M. cordata, Simauroma amara, B. utile, Septotheca. tessmannii, Apuleia molaris, T. oblonga,* for the assessment of natural durability under the effect of two xylophagous fungi: *P. sanguineus* and *L. erubescens*, the average weight loss of the wood (%) was developed in an inverse relationship to the classification of the resistance of the wood to the phenomenon of rot (Table 4).

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Table 4. - Results of the rot resistance test after 90 days of experimentation

N.º	Species	Level	Weight Loss/Fungus		Average Weight/Species Loss (%)	Grading of wood by strength
			P. sanguineus	*L. eurebencens*		
1	*A. membranacea*	Base	51.24	53.67	54.21 %	Slightly resistant to the non-resistant
		Medium	52.06	57.05		
		Apex	53.89	57.33		
	Average		52.4	56.02		
2	*J. copaia*	Base	48.76	50.96	52.12 %	Slightly resistant to the non-resistant
		Medium	50.78	54.67		
		Apex	50.73	56.82		
	Average		50.09	54.15		
3	*C. matourensis*	Base	44.17	49.64	49.63 %	Slightly resistant to the non-resistant
		Medium	48.95	51.65		
		Apex	50.16	53.21		
	Average		47.76	51.5		
4	*S. amazonicum*	Base	44.01	45.83	46.11 %	Slightly resistant to the resistant
		Medium	44.87	46.78		
		Apex	45.78	49.37		
	Average		44.89	47.33		
5	*M. cordata*	Base	24.26	29.82	29.16 %	Moderately resistant
		Medium	26.86	32.02		
		Apex	28.28	33.7		
	Average		26.47	31.85		
6	*S. amara*	Base	24.12	25.05	28.03 %	Moderately resistant
		Medium	25.3	30.85		
		Apex	29.66	33.23		
	Average		26.36	29.71		
7	*B. utile*	Base	22.4	25.66	25.33 %	Moderately resistant
		Medium	24.23	26.39		
		Apex	25.61	27.66		
	Average		24.08	26.57		
8	*S. tessmannii*	Base	15.21	12.63	15.52 %	Resisteant
		Medium	16.32	14.63		
		Apex	18.3	16.03		
	Average		16.61	14.43		
9	*A. molaris*	Base	11.66	11.02	12.92 %	Resistant
		Medium	14.00	11.97		
		Apex	15.7	13.16		
	Average		13.68	12.05		
10	*T. oblonga*	Base	10.7	7.89	10.26 %	Highly resistant
		Medium	11.49	8.53		
		Apex	12.7	10.24		
	Average		11.63	8.89		

According to the results obtained in the interpretation of the wood resistance indexes, *Apeiba membranacea, J. copaia, C. matourensis and Schizolobium amazonicum* were found to be little or slightly resistant, with averages of 54.21 %; 52.12 %; 49.63 %

and 46.11 %, respectively. On the other hand, the resistant species with averages of 15.52 % and 12.92 % are *Septotheca tessmannii* and *Apuleia molaris*, while *T. oblonga* proved to be highly resistant with an average weight loss of 10.26 %.

In the species manipulated, relevant differences were observed between the values of percentages of rot, depending on the level of the shaft: in all cases the apical level represented the factor of greatest vulnerability, while the average level presented intermediate values and the base of the wood showed minimum values (Table 5).

Table 5. - Descriptive statistics in relation to the average percentage of weight loss

	SPECIES	N	Mediuma	Desv.	Desv. Error	95 % of the confidence interval for the medium		Mínimum	Maximum
						Lower limit	**Upper limit**		
FUNGUS 1 (*P. sanguineus*)	*T. oblonga*	1	11.63	15.87	5.02	20.04	42.75	11.63	11.63
	A. molaris	1	13.68					13.68	13.68
	S. tesmannii	1	16.61					16.61	16.61
	B. utile	1	24.08					24.08	24.08
	S. amara	1	26.36					26.36	26.36
	M. cordata	1	26.47					26.47	26.47
	S. amazonicum	1	44.89					44.89	44.89
	C. matourensis	1	47.76					47.76	47.76
	J. copaia	1	50.09					50.09	50.09
	A. membranacea	1	52.40					52.40	52.40
	Total	**10**	**31.40**					**11.63**	**52.40**
FUNGUS 2 (*L. eurebecens*)	*T. oblonga*	1	8.89	18.08	5.72	20.31	46.19	8.89	8.89
	A. molaris	1	12.05					12.05	12.05
	S. tesmannii	1	14.43					14.43	14.43
	B. utile	1	26.57					26.57	26.57
	S. amara	1	29.71					29.71	29.71
	M. cordata	1	31.85					31.85	31.85
	S. amazonicum	1	47.33					47.33	47.33
	C. matourensis	1	51.50					51.50	51.50
	J. copaia	1	54.15					54.15	54.15
	A. membranacea	1	56.02					56.02	56.02
	Total	**10**	**33.25**					**8.89**	**56.02**

According to the analysis of variance, the rot factor originating from the applied xylophagous fungus had a statistically different effect among tree species (Table 6). It was observed that $P < 0.05$; this factor has a statistically significant effect on weight loss due to rot with a 95 % confidence level, indicating that weight loss is dependent on the type of tree species analyzed. While in the case of the fungal type factor, $P > 0.05$ indicates that there is no significant influence of the factor, which means that the two types of fungi used affected the tree species in the same way.

Table 6. - Analysis of variance for weight loss due to rot

Source	Sum of Squares	gl	Medium Square	F	P
MAJOR EFFECTS					
A:species	5280.26	9	586.696	111.54	0.0000
B: Fungus Type	22.472	1	22.472	4.27	0.0687
RESIDUES	47.3392	9	5.25991		
TOTAL (CORRECTED)	5350.07	19			

As for the tree species, when applying Fisher's Multiple Range LSD analysis, five homogeneous groups were observed with respect to the percentage of wood loss by rot (A, B, C, D and E) inter-group, there is no significant difference *P > 0.05* and extra-group, there are significant differences P < 0.05. In this sense, group C is separated from the rest and it is formed by B. utile, *Simauroma amara* and *M. cordata*, without differences between them, but different from the rest of the woods, which, according to the resistance classification mentioned in Table 4, represent moderately resistant woods (Table 7).

On the other hand, it can be considered that group E, with *C. matourensis, J. copaia* and *A. membranácea*, is different from group C, and in this case, these species were classified as slightly or not very resistant woods. Likewise, the species of this group presented significant differences in the percentage of rot with the species, *T. oblonga, Apuleia molaris* and *Septotheca tessmannii*, which were classified as resistant and highly resistant woods.

Table 7. - Fisher LSD Multiple Range Tests for Weight Loss from Rotting by Species

Species	Cases	Medium LS	Sigma LS	Homogeneous Groups				
T. oblonga	2	10.26	1.62171	A				
A. molaris	2	12.865	1.62171	A	B			
S. tessmannii	2	15.52	1.62171		B			
B. utile	2	25.325	1.62171			C		
S. amara	2	28.035	1.62171			C		
M. cordata	2	29.16	1.62171			C		
S. amazonicum	2	46.11	1.62171				D	
C. matourensis	2	49.63	1.62171				D	E
J. copaia	2	53.455	1.62171					E
A. membranacea	2	54.21	1.62171					E

A photochemical examination revealed the presence of compounds such as flavonoids, terpenoids and steroids in the extracts used, in hot water and alcohol. This experiment also determined the appropriate use of extracts in the samples handled and the approach of a relationship with the effect of resistance to the phenomenon of rotting caused by xylophagous fungi. Habboo *et al*., (2018) proposed that the cold water extractive has two additional components: saponin and alkaloid, which can be destroyed by heat exposure. This added to the information obtained parameters of the influence of the environment on the treated species.

The harmful action of xylophagous fungi for these 10 potentially timber-yielding species is the phenomenon of rot, which is considered a negative factor on forest species with commercial demand, which are strongly affected by this phenomenon. In this study it was observed that brown rot started and progressed more rapidly compared to white and soft rot, thus coinciding with Brischke and Meyer-Veltrup (2016); however, it did not represent statistically significant differences (Table 8).

Table 8. - Fisher LSD Multiple Range Testing for Weight Loss from Rotting by Species

Fungus	Cases	Medium LS	Sigma LS	Homogeneous Groups
P. sanguineus	10	31.397	0.725252	A
L. eurebencens	10	33.517	0.725252	A

In this study, three forest species were highlighted as potentially timber species: *Septotheca tessmannii, Apuleia molaris* and *T. oblonga*; where, the variance factor established notable statistical differences in relation to the rest of the timber species, in terms of resistance to the fungi *P. sanguineus* and *L. erubescens*. In contrast to the parameters of rot caused by *P. sanguineus,* responsible for white rot, with respect to the rot generated by *L. erubescens*, which, although some differences in the percentages of weight loss can be seen, were not statistically significant.

The results obtained are contradictory to those obtained by other authors: González and Icochea (1980) and Ahn *et al.,* (2005), who point out that the specific quality of

the bioenzymatic action of xylophagous fungi, give way to logs in which different species of this class of fungi are distributed homogeneously in the substrate, stimulating mixed rotting.

Lehnebach *et al.,* (2017) indicated that the origin of the sapwood, the configuration of preservative substances of a phenolic nature and physical mechanisms (tyloses), produced the species' own heartwood. The assessment of the radial increase and the sapwood region of the trunk was governed by a single model at breast height, with an initial development and a continuous consecutive value, as a result of the ability to grow towards the crown instead of the reduction of the tree. The heartwood region and trunk volume increased more rapidly after this change was made.

The natural durability is associated with the high content of phenolic antioxidant compounds, especially tannins and flavonoids, combined with the presence of fungistatic alkaloids, increased according to natural preservation classes, from durable wood to moderately durable wood and correlated with antioxidant capacity (Anouhe *et al.,* 2018). The deterioration behaviour observed could be due to the fact that the heartwood of the species presented a higher quantity of extractive agents in relation to the sapwood, cooperating with a better preservation of the heartwood, the humidity index, the low penetrability and the blocking of the cellular cavities by gums, resins and tylosis.

Likewise, when evaluating the antioxidant activity of extracts with bark tannins, including isolated fractions and compounds, in thin layer chromatography, at the same time, these extracts were considered as inhibitors of fungal growth; all isolated fractions and compounds showed antioxidant activity. The antifungal activity was calculated by means of the Minimum Inhibitory Concentration (MIC) and the Minimum Fungicidal Concentration (MFC), according to Sanches *et al*., (2005).

CONCLUSIONS

After the evaluation of natural durability in 10 forest species, they were classified according to their rot percentages in the following categories: slightly resistant, *Apeiba membranacea, J. copaia, C. matourensis* and *Schizolobium amazonicum;* moderately resistant; resistant*, M. cordata, Simauroma amara* and *B. utile;* and the resistant and highly resistant species*, Septotheca tessmannii, Apuleia molaris* and *T. oblonga*.

L. erubescens was the causal agent of brown rot and was more aggressive, leading to greater weight loss in test containers than *P. sanguineus*, which stimulates the white rot phenomenon; but this was not statistically significant.

Therefore, it is concluded that the tree species *Septotheca tessmannii, Apuleia molaris* and *T. oblonga* can be used in conditions of exposure to xylophagous fungi, in direct contact with the soil and outside, provided that there is no risk of thermithicidal insects or that they are prevented and/or purged by physical means.

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The authors have participated in the writing of the work and analysis of the documents.