NATURAL DURABILITY OF *Cupressus lusitanica*, *Cryptomeria japonica* AND *Pinus taeda* WOODS IN FIELD TRIAL

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Resumo

Durabilidade natural das madeiras de Cupressus lusitanica, Cryptomeria japonica e Pinus taeda em ensaio de campo. O objetivo do presente estudo foi avaliar a durabilidade natural das madeiras de *Cupressus lusitanica*, *Cryptomeria japonica* e *Pinus taeda* submetidas a ensaio de campo de apodrecimento, através da perda de massa e índice de deterioração. O experimento foi conduzido em campo aberto no município de Curitibanos/SC, por um período de 24 meses, com avaliações realizadas a cada 6 meses. Para condução do estudo utilizou-se as madeiras das espécies de *Cupressus lusitanica* (16 anos), *Cryptomeria japonica* (16 anos) e *Pinus taeda* (madeira juvenil=15 anos e adulta>30anos) das quais foram confeccionados corpos de prova com as dimensões de 2,5 x 5,0 x 50,0 cm, de espessura, largura e comprimento, respectivamente, seguindo o padrão sugerido pela IUFRO. Após 24 meses de exposição ao campo de apodrecimento à madeira das espécies *C. japonica* e *C. lusitanica* apresentaram índice de deterioração que refletiu ataque evidente, porém moderado de fungos e térmitas, enquanto as madeiras de *P. taeda* (juvenil) e *P. taeda* (adulta) apresentaram índice de deterioração que refletiu em apodrecimento intenso ou ataque intenso de térmitas. Em relação à perda de massa as madeiras de *C. japonica* e *C. lusitanica* foram classificadas como altamente resistentes, a madeira de *P. taeda* (juvenil) foi considerada resistente e a madeira de *P. taeda* (adulta) foi considerada como moderadamente resistente. De maneira geral, as madeiras de *C. lusitanica* e *C. japonica* apresentaram maior durabilidade natural quando utilizadas em contato com o solo.

Palavras-chave: Apodrecimento, biodeterioração, degradação natural.

Abstract

The purpose of this study was to evaluate the natural durability of *Cupressus lusitanica*, *Cryptomeria japonica* and *Pinus taeda* woods subjected to a rotting field trial, through mass loss and deterioration index. The trial was conducted in an open field in the city of Curitibanos, State of Santa Catarina, Brazil, for a 24-month period, with evaluations carried out every 6 months. For developing the study, we used the woods of *Cupressus lusitanica* (16 years), *Cryptomeria japonica* (16 years) and *Pinus taeda* (juvenile=15 years and mature wood>30 years) species, from which test specimens were made with the dimensions of 2.5 x 5.0 x 50.0 cm in thickness, width and length, respectively, following the standards suggested by IUFRO. After 24 months of exposure to the rotting field the woods of *C. japonica* and *C. lusitanica* species showed a deterioration index that reflected an evident but moderate attack of fungi and termites, while the woods of *P. taeda* (juvenile) and *P. taeda* (mature) showed deterioration index that reflected an intense rotting and intense attack of termites. Regarding the mass loss the woods of *C. japonica* and *C. lusitanica* were classified as highly resistant, while *P. taeda* (juvenile) was considered resistant and *P. taeda* (mature) was considered moderately resistant. In general, the woods of *C. lusitanica* and *C. japonica* showed greater natural durability when used in contact with the soil.

Keywords: rotting, biodeterioration, natural degradation.

INTRODUCTION

The Brazilian forestry sector contributes significantly to the country's economy, and generated a sectorial gross domestic product (GDP) of R$ 86.6 billion in 2018, with an increase of 13% over the previous year (IBÁ, 2019). The latest estimate indicates that the country has 7.83 million hectares of planted forests, which are responsible for supplying more than 90% of the wood intended to the various forest segments (IBÁ, 2019).

Wood is widely used because it has numerous interesting characteristics, such as easy handling, high mechanical strength, capacity to be a thermal and acoustic insulator, in addition to the most diverse aromas, colors and textures, which make it very desired by man since the beginnings of humanity (APRILE *et al.*, 1999).

However, one characteristic in particular will affect its use, its natural durability, especially in tropical countries, such as Brazil, with great climatic variation and xylophages among its regions. According to Jesus *et al.* (1988), the knowledge of this characteristic helps in the choice of timber species that can be used in environments where they will be subject to damages caused by climatic and abiotic factors and a diversity of xylophagous agents (biotics) present in the environment, especially in direct contact with the soil. Therefore, according to Melo *et al.* (2010), the knowledge of its natural durability, and also of the places where the wood can be used, will avoid wastes and expenses due to the pieces replacement.

In order to evaluate the wood natural durability, one of the most used tests are the "rotting fields", subjecting wood to external environments in direct contact with the soil, being exposed to irregular cycles of leaching, sun exposure, drying, chemicals and xylophages present in the soil, which can act together in the wood deterioration (COSTA *et al.*, 2005). In addition to field tests, there are laboratory tests, which allow greater control of the optimal development conditions of xylophages (temperature, humidity and photoperiod), therefore providing intense attacks, and consequently providing faster results.

According to Araújo *et al.* (2012) in view of the scarcity of high natural durability species supply from native forests, due to environmental issues, it is not possible to meet the demand for these woods, which are practically depleted. When they still can be extracted, respecting the supply and demand law, the commercial value of these species has been increasing, and their use is economically impracticable. Therefore, according to this perspective to meet the current and future demand for wood products, the only safe source is in planted forests, using fast-growing species that are managed for a self-sustainable production.

In this scenario, several species/genus with great potential for large-scale cultivation emerge, some are already a reality in the forestry industry, such as *Pinus* and *Eucalyptus* genus, which together represent 92% of the planted area in the country (IBÁ, 2019), and some others also deserve attention, such as *Cupressus* and *Cryptomeria* genus.

Today the Southern region has its forest base focused on the *Pinus* genus, which has rapid growth and resistance to the cold weather of this region. However, based on the studies reported in the literature (COSTA *et al.*, 2005; SCHEFFER & MORRELL, 1998), the wood of this genus has a low natural durability, especially when used in contact with the soil. And seeking to provide subsidies to new alternatives, the *Cupressus* and *Cryptomeria* genus arise, which like *Pinus*, are conifers and adapt very well to the region conditions.

In *Cupressus* genus the *Cupressus lusitanica* species stands out, which is popularly known as cypress, and in the *Cryptomeria* genus there is the *Cryptomeria japonica*, also called Japanese cedar. Both have a great potential for cultivation in the Southern region of Brazil, but the real quality of their wood is still unknown, especially concerning their natural durability. Carneiro *et al.* (2009) and Okino *et al.* (2010) mention the great adaptive and growing potential of *C. japonica* and *C. lusitanica* to the conditions of the Santa Catarina Plateau.

Therefore, with the scarcity of technical information on the natural resistance of these species wood, we sought to infer, based on field tests, which is the durability level of these species, in order to find new alternatives for more severe uses of wood, especially in contact with the soil. Consequently, the purpose of this study was to evaluate the natural durability of *C. lusitanica*, *C. japonica* and *P. taeda* woods subjected to a rotting field trial.

MATERIAL AND METHODS

Used species

In order to develop the study, the woods of *P. taeda*, with juvenile wood (up to 15 years) from a plantation located in the city of Campo Belo do Sul/SC, with spacing of 3.0 x 2.0 m (1,600 trees/ha), and the mature wood (with 43 years of age, using the wood portion above the 30th growth ring), obtained from a plantation in the city of Correia Pinto/SC, with spacing of 2.0 x 2.0 m (2,500 trees/ha) were used. And the *C. lusitanica* and *C. japonica*, both juvenile wood (16 years), were obtained from experimental forest stands from Florestal Gateados Ltda. implemented in the city of Campo Belo do Sul/SC, with spacing of 2.5 x 2.0 m (2,000 trees/ha).

For this study, 10 trees of each species were used, from which the first log with 1.30 meters in length (between base and diameter at breast height) was removed to obtain a specimens. From each species, 55 defect-free test specimens were made, in the dimensions of 2.5 x 5.0 x 50.0 cm in thickness, width and length, according to the IUFRO (International Union for Forestry Research Organization) standards, as mentioned by Lepage (1970). Then they were dried in a commercial kiln in order to reduce the wood moisture (between 15 and 20%) so that the specimens could be sanded for a better finishing.

In order to obtain the initial mass (Mi) the test specimens were subjected to drying in a laboratory oven, with forced air circulation, at a temperature of 60 ºC until obtaining a constant weight. Subsequently, they were weighed on a precision scale, and their dimensions were measured using a ruler and a digital caliper to calculate the volume. With the mass and volume values, the wood density was calculated, after drying at 60 ºC, using Equation 1 to assist in the results discussion.

$$D = \frac{m}{v} \tag{1}$$

where: D is the density (g/cm³), m is the mass (g) and v is the volume (cm³).

The mass obtained from the weighing was called initial mass and served as the basis for calculating the mass loss after exposure to the rotting field.

Rotting field installation

The rotting field was installed in December 2015, in an open field in the Experimental Forest Area belonging to the Federal University of Santa Catarina (UFSC), in the city of Curitibanos, State of Santa Catarina, Brazil, at latitude and longitude of 27°18'52.11"S and 50°42'36.36"O, respectively, at an altitude of 835 meters. According to Köppen's classification, the region climate is Cfb - humid subtropical with mild summers (EMBRAPA, 2012). The rotting field was established in 73.5 m² (9.8 x 7.5 m) of total area, where cleaning and maintenance were performed periodically (monthly).

The experiment was conducted in a randomized block design (DBC), using plots subdivided in time, with 5 blocks with 10 test specimens of each species per block, as shown in the drawing of Figure 1. Test specimens were installed in the soil 30 cm equidistant between each other and 100 cm between the blocks, and were buried up to half their length (depth of 25 cm), the region known as outcrop zone, usually the most affected.

Figure 1. Sketch of rotting field.
Figura 1. Croqui do campo de apodrecimento.

Analysis of climatic conditions in the period and fungal attack potential

As they are variables that can influence the biodeterioration intensity, climatic data such as temperature, humidity and rainfall rates of Curitibanos region were collected during the experiment period, at the meteorological station located at UFSC campus, in the city of Curitibanos, at 1,097 meters of altitude.

Based on the meteorological data, the fungal attack potential (FAP) of the region was calculated, according to Equation 2, developed by Scheffer (1971) and adapted to the conditions in Brazil by Martins *et al.* (2003).

$$FAP = \sum_{january}^{december} \frac{[(T-2).(D-3)]}{16,7} \tag{2}$$

where: FAP is the fungal attack potential, T is the average temperature (ºC), D is the number of days in the month with rainfall equal to or greater than 0.30 mm.

Natural durability evaluation

The woods natural durability was evaluated by visual analysis (deterioration index), as proposed by Lepage (1970), and by the mass loss after exposure to the field. Periodically, every 6 months, in June and December, for 2 years after the experiment installation, 5 test specimens per species were evaluated, one per block as shown in Figure 1. They were systematically removed and over the course of the two years 20 test specimens were inspected per species.

The test specimen inspection began with the application of a slight impact with the hands on the exposed part of the stake while still in the ground. According to Lepage (1970) this procedure aims to find out if the loss of resistance was able to cause the stake breaking. Test specimens that showed no rupture were carefully removed.

After removal, samples were cleaned using a soft bristle brush to remove all adhered soil, a procedure necessary to facilitate its visual evaluation and not influence the mass loss results.

The deterioration index consisted of a visual analysis assigning scores to the test specimens from the field at each evaluation period, according to the classification shown in Table 1, as proposed by Lepage (1970).

Table 1. Classification of wood deterioration by visual index.
Tabela 1. Classificação da deterioração da madeira pelo índice visual.

Wood aspect	Deterioration index
Strong, no attack	100
Slight or superficial attack of fungi and termites	90
Evident but moderate attack of fungi and termites	70
Intense decay or intense termite attack	40
Break, almost total loss of resistance	0

Fonte: Adapted by Lepage (1970).

Two independent evaluators (in order to reduce the error given that it is a subjective analysis) made the analysis of the five samples collected from each species per period (one test specimen per species, of each of the five blocks), and from the results the deterioration index mean was obtained.

In order to determine the mass loss, after each period the removed samples were subjected to storage using a laboratory oven with forced circulation at 60 ºC until obtaining constant mass. Then the stacks were weighed on a precision scale, obtaining the final mass (Mf). Based on the samples initial and final mass, the mass loss was calculated using Equation 3, in order to classify the resistance class, according to ASTM D 2017-05 standard (2005). This standard refers to accelerated rotting tests in the laboratory, but as there are no standards for field tests it was decided to use it to have a basis for comparing the woods resistance.

$$ML(\%)=\frac{Mi-Mf}{Mi}x100 \quad (3)$$

where: ML is the mass loss (%), Mi é is the initial mass (g) and Mf is the final mass (g).

Statistical analysis

The data obtained from the experiment were tabulated and processed using Microsoft Office Excel 2010. For statistical analysis, the R studio software was used. To perform the density statistical analysis, a completely randomized design (DIC) was used. The rotting field was installed with a randomized block design (DBC), with plots subdivided over time, which was evaluated by analysis of variance (ANOVA) and Tukey mean test, with 95% of confidence probability.

RESULTS

Density

The wood density of *C. japonica*, *C. lusitanica* and *P. taeda* (juvenile and mature) can be observed in Table 2.

Table 2. Density of wood used.
Tabela 2. Densidade das madeiras utilizadas.

Species	Density (g/cm³)
C. lusitanica	0.429 ^{B}
C. japonica	0.328 ^{D}
P. taeda (Juvenile)	0.399 ^{C}
P. taeda (Mature)	0.553 ^{A}

Averages followed by the same letter, do not present a statistically significant difference by means test (Tukey, p> 0.05).

The density of the woods used varied significantly between the species and type of wood as it can be seen in Table 2. These values served to compare the species. The wood of *P. taeda* (mature) was the one that showed the significantly higher value, followed by *C. lusitanica*, *P taeda* (juvenile) and *C. japonica*.

Climatic conditions and fungal attack potential

Figure 2 shows the average fungal attack potential (FAP) of the field test run period.

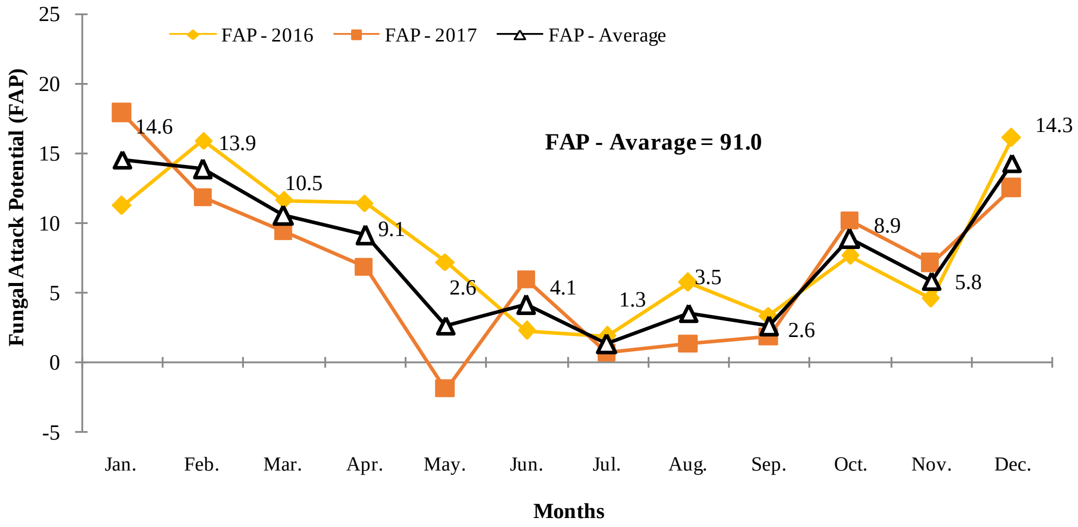

Figure 2. Fungal Attack Potential (FAP) during the evaluated period.
Figura 2. Potencial de Ataque Fúngico (PAF) durante o período avaliado.

The rainfall days counting in 2016 and 2017, considering a precipitation level equal to or greater than 0.30 mm, was 149 and 129, respectively. And the annual accumulated rainfall was 1,894.6 mm in 2016, and 1,025.8 mm in 2017. The average temperatures calculated in 2016 and 2017 were 16.7 and 16.4 ºC, respectively.

The accumulated FAP based on the measurements performed in the trial period for the years 2016 and 2017 were 98.7 and 83.3, respectively. Therefore, the average for Curitibanos region in the trial period was 91.0.

Natural durability evaluation

The deterioration index of the woods exposed to the rotting field can be observed in Figure 3, which exposes how much each species showed wear over the exposure time. Over time we can observe that there was a reduction in the index for all species, indicating that wood wear was occurring, as it can be seen in Figure 4.

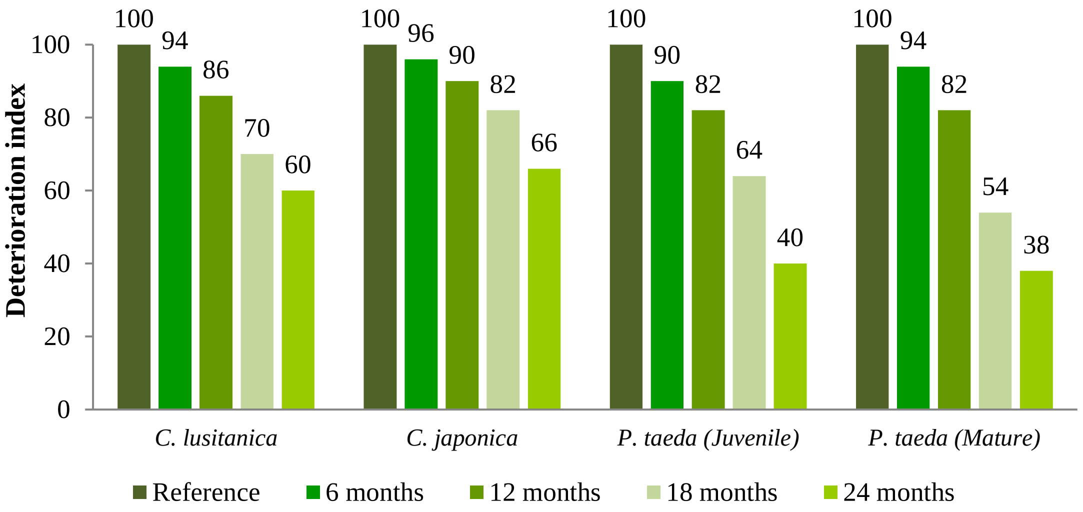

Figure 3. Deterioration index of the specimens submitted to the rotting field.
Figura 3. Índice de deterioração dos corpos de prova submetidos ao campo de apodrecimento.

According to Table 3, during the first 12 months of the experiment, the results obtained in the species deterioration index did not differ statistically from each other, indicating in this period that the woods suffered light or superficial attacks of fungi and termites. Even though there was no statistical difference between species, *C. japonica* was the species that showed the lowest surface degradation, slightly changing its appearance, followed by *C. lusitanica* species. On the other hand, juvenile and mature *P. taeda* species showed a greater surface wear, resulting in a lower index value.

Table 3. Deterioration index of the specimens submitted to the rotting field.
Tabela 3. Índice de deterioração dos corpos de prova submetidos ao campo de apodrecimento.

Evaluations		**Species**			
Nº	Months	*C. lusitanica*	*C. japonica*	*P. taeda* (Juvenile)	*P. taeda* (Mature)
1	6	94^{Aa}	96^{Aa}	90^{Aa}	94^{Aa}
2	12	86^{Aab}	90^{Aa}	82^{Aab}	82^{Aab}
3	18	70^{Aab}	82^{Aab}	64^{Ab}	54^{Abc}
4	24	60^{Ab}	66^{Ab}	40^{Ac}	38^{Ac}

Averages followed by the same letter, lower case in the column or upper case in the line, do not show statistically significant variation by means test (Tukey, $p > 0.05$).

In the 24-month exposure evaluations, the visual index for the *C. japonica* and *C. lusitanica* species indicated an evident, but moderate attack of fungi and termites, while the woods of *P. taeda* (juvenile) and *P. taeda* (mature) indicated an intense rotting or intense attack of termites, as it can be seen in Figure 4. This can be justified by the presence of soil termites in the surrounding area.

What was also possible to observe is that after the field exposure, test specimens underwent a very noticeable change in natural color, and the wood was becoming with an aged aspect, with shades of gray. All species showed the same darkening pattern, but it was more marked in *P. taeda* wood (both juvenile and mature).

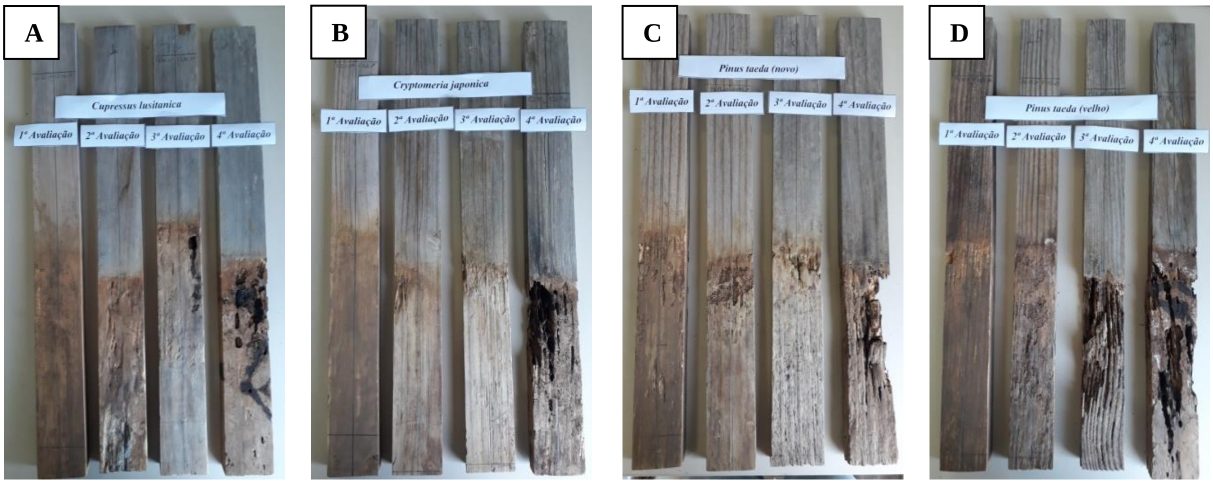

Figure 4. Wood of *C. lusitanica* (A), *C. japonica* (B), *P. taeda* (juvenile) (C), *P. taeda* (mature) (D) after exposure to field.
Figura 4. Madeira de *C. lusitanica* (A), *C. japonica* (B), *P. taeda* (juvenil) (C), *P. taeda* (adulto) (D) após exposição a campo.

The wood mass loss after exposure to the rotting field can be seen in Table 4.

Table 4. Mass loss (%) of the specimens submitted to the rotting field.
Tabela 4. Perda de massa (%) dos corpos de prova submetidos ao campo de apodrecimento.

Evaluations		**Species**			
Nº	Months	*C. lusitanica*	*C. japonica*	*P. taeda* (Juvenile)	*P. taeda* (Mature)
1	6	1.84^{Aa}	1.33^{Aa}	2.87^{Aa}	4.25^{Aa}
2	12	3.69^{Aa}	3.80^{Aa}	4.92^{Aab}	9.05^{Aa}
3	18	4.89^{Aa}	4.58^{Aa}	8.55^{Ab}	22.30^{Bb}
4	24	7.42^{Aa}	7.57^{Aa}	14.94^{Bb}	26.42^{Cb}

Averages followed by the same letter, lower case in the column or upper case in the line, do not show statistically significant variation by means test (Tukey, $p > 0.05$).

Although the woods of *C. japonica* and *C. lusitanica* showed densities with statistical differences (Table 2), regarding the mass loss there was no difference between them, and both obtained a lower mass loss. On the other hand, *P. taeda* (mature) wood showed the highest density among the species, and also the highest mass loss, surpassing the same species with juvenile wood.

It was observed that the woods performance in the first 12 months of the experiment showed no statistical difference between the species/wood, but from the third evaluation (18 months) the wood of *P. taeda* (mature) showed greater mass loss, with significant differences compared to the others. After the 24-months exposure the mass loss of *P. taeda* (mature) was intensified, followed by *P. taeda* (juvenile), *C. japonica* and *C. lusitanica,* and the latter two showed no significant difference between each other.

After two years (24 months) of field exposure, the woods could be classified, based on the resistance class of ASTM D 2017-5 (2005) standard, as follows: *P. taeda* (mature) = moderately resistant (ML=26.42%); *P. taeda* (juvenile) = resistant (ML=14.94%); *C. lusitanica* = highly resistant (ML=7.42%); *C. japonica* = highly resistant (ML=7.57%).

DISCUSSION

Climatic conditions and fungal attack potential

The mean FAP observed during the experiment (91.0) is within the range mentioned by Martins *et al.* (2003), which established FAP values in the range of 70.00 to 120.00 for most of the territory of Santa Catarina.

We observed that the months with the lowest FAP were between May and September, because in addition to little rainfall, the average temperature in these months decreased, so it is evident that there is a lower probability of attacks by xylophagous agents in periods with lower rainfall rates and lower temperatures. In the months from December to February, due to high temperatures and rainfall level, the highest values for the FAP were observed, indicating that in this period there is a higher risk of fungal attacks in woods.

Casavecchia *et al.* (2016) mention that the highest probability of fungal attack is in the rainy season, and in this period more attention should be given to the drying and storage of wood. The same authors also mention that the highest and lowest FAP for the state of Mato Grosso are in January and July, respectively. This same trend was observed for the state of Santa Catarina (in the city of Curitibanos), according to Figure 2.

When it is said that wood is susceptible to xylophages attack, that does not mean that in all uses it will be at risk, the susceptibility of the wood is influenced by other factors, such as the moisture content which the wood is exposed to, the use period (and also the use situation, such as internal or external, with or without contact with soil, etc.), in addition to the use region, because the presence of xylophages is influenced by environmental variables, such as temperature and rainfall.

Natural durability evaluation

In a study conducted by Costa *et al.* (2005), the fence posts of *Pinus elliottii*, after 3 years of the rotting field implementation, showed a deterioration index equal to zero, indicating that the natural durability of the species is approximately 3 years in the Cerrado region.

In the case of the wood color change, according to Ritter & Morrell (1990) this effect occurs due to the photochemical degradation that is promoted by the action of ultraviolet rays, which act mainly on lignin, on the outside of the wood, causing the tissue discoloration, and providing a grayish aspect. Due to the change in humidity (rain and sun) these woods also suffered surface cracks that facilitate the entry of xylophages, such as fungi and termites, which are naturally present in the soil.

This change in color was also observed in a trial conducted by Vivian *et al.* (2014) with *Eucalyptus grandis* and *Eucalyptus cloeziana* woods exposed to open field, which showed aging, while the samples that were exposed in the forest the aspect was normal, and can evidence that direct radiation causes photochemical degradation, causing aging.

A justification for mature wood (*P. taeda* mature) having presented a greater mass loss can be due to the lower amount of extractives. A study conducted by Yeh *et al.* (2006) showed that the amount of extractives present in the juvenile wood of *P. taeda* was 3.3% and in mature wood 2.5%.

British Standard (1994) classifies the heartwood (physiologically inactive portion of the trunk, which usually shows extractive deposition, and makes it more resistant to biodegradation) of *P. taeda* as non-durable to the attack of fungi and as susceptible to the attack of termites and coleoptera of *Hylotrupes bajulus* and *Anobium punctatum* species. Gomes *et al.* (2005) mention that the natural durability of the species of *Pinus cariebea* var. *hondurensis,* evaluated in the field in the city of Belém/PA, was little durable, since it did not resist 12 months in contact with the soil.

The results obtained for the *C. lusitanica* wood, which was considered highly resistant, are consistent with those found by Jones *et al.* (2013), which after performing laboratory tests concluded that *C. lusitanica* wood was resistant to the *Gloephyllum trabeum* and *Trametes versicolor* fungi, but was less resistant to the *Coniophora puteana* fungi. However, the mass loss in none of the cases exceeded 6%, and was classified as very durable or highly resistant.

After 12 weeks in a laboratory trial conducted by Mohareb *et al.* (2010) the test specimens of *C. lusitanica* showed a mass loss of 2%, and in the same trial they also concluded that the extractives present in the heartwood of *C. lusitanica* are responsible for the wood resistance to biodegradation, because by performing the removal of extractives from the heartwood, the material was greatly degraded by the *Postia placenta* fungi, so concluding that these extractives act as natural biocides.

In an accelerated rotting trial conducted by Okino *et al.* (2009) the *Cupressus* sp. and *C. glauca* species with 25 and 17 years, respectively, were resistant to *Phanerochaete chrysosporium* e and *Gloephyllum striatum* fungi. The same authors mention that due to the presence of tropolone compounds in extractives, the woods of the Cupressaceae family are protected from rotting insects and fungi. Therefore, according to Low *et al.* (2005), the heartwood of *C. lusitanica* when used above ground is quite durable, resisting the attack of insects and fungi, while the sapwood, according to Shimizu *et al.* (2006) is quite susceptible to xylophagous attack and rotting. We point out that to use the sapwood more effectively, where it is desired that the wood is durable for longer, it is necessary to perform preserving treatments.

Scheffer & Morrell (1998) describe conflicts concerning the durability of *C. lusitanica* wood in the literature, because some mention it as resistant, while others mention it as very resistant. This fact may be due to the weathering and drying process of the wood, which can affect the extractive content due to the evaporation of volatile compounds, which can cause changes in its natural durability (MOHAREB *et al.*, 2010).

Regarding *C. japonica* wood, which was classified as highly resistant in this study, BIS-401 (2001) mentions that this wood is resistant in contact with the soil for a period of up to 60 months of exposure.

CONCLUSIONS

Based on the observed results, we conclude that:

- According to the FAP of the region obtained during the exposure period, the months of May to September are less conducive to biological deterioration, and the months of December to February are the most conducive to biological deterioration.
- Based on the mass loss, after the 24-month exposure to the rotting field, *C. japonica* and *C. lusitanica* woods are classified as highly resistant, *P. taeda* (juvenile) wood is considered resistant, and *P. taeda* (mature) wood is considered moderately resistant.
- After the 24-month exposure to the rotting field, *C. japonica* and *C. lusitanica* species showed index that reflect in moderate biological deterioration, while *P. taeda* (juvenile) and *P. taeda* (mature) woods showed rates that reflect an intense deterioration.
- *C. lusitanica* and *C. japonica* woods have greater natural durability in contact with the soil and in open environment, and therefore they can be used outdoors with greater safety when compared to *P. taeda* wood.

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