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Original Article

Wood resistance of *Magonia pubescens* (Sapindaceae), *Dalbergia nigra*, and *Machaerium amplum* (Fabaceae) to *Nasutitermes* sp. (Blattodea: Termitidae)

Resistência da madeira de *Magonia pubescens* (Sapindaceae), *Dalbergia nigra* e *Machaerium amplum* (Fabaceae) a *Nasutitermes* sp. (Blattodea: Termitidae)

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Abstract

Termites of the genus *Nasutitermes* sp. (Blattodea: Termitidae), which feed on cellulose, may cause wood to become brittle and fragile. This study aimed to evaluate the natural resistance of three native wood species: *Magonia pubescens* (Sapindaceae), *Dalbergia nigra* and *Machaerium amplum* (Fabaceae) to attack by *Nasutitermes* sp. termites and to investigate the relationship between resistance, extractive content, and oven-dry density. Samples of each wood species were subjected to a forced feeding process with *Nasutitermes* sp. termites for 30 days. Following the exposure, the oven-dry density, extractive content, percentage of wood loss, and termite mortality were determined for each sample. *Dalbergia nigra* exhibited resistance to termite attack and had the highest extractive content at 13.14%. Conversely, *M. amplum* had the highest wood loss at 5.37% and the lowest extractive content at 1.94%. Both species showed a negative correlation between wood loss and extractive content, but no correlation with wood density. *Magonia pubescens* had the highest density at 0.90 g/cm^3. *Macherium amplum* and *M. pubescens* caused 100% termite mortality, while *D. nigra* caused 40% mortality.

Keywords: oven-dry density, extractives, wood loss, termites, wood deterioration.

Resumo

Os cupins do gênero *Nasutitermes* sp. (Blattodea: Termitidae), que se alimentam de celulose, podem tornar a madeira quebradiça e frágil. Este estudo teve como objetivo avaliar a resistência natural de três espécies nativas de madeira: *Magonia pubescens* (Sapindaceae), *Dalbergia nigra* e *Machaerium amplum* (Fabaceae) ao ataque de cupins *Nasutitermes* sp. e investigar a relação entre resistência, teor de extrativos e densidade anidra. Amostras de cada espécie de madeira foram submetidas a um processo de alimentação forçada com cupins *Nasutitermes* sp. por 30 dias. Após a exposição, a densidade anidra, teor de extrativos, porcentagem de perda de massa e mortalidade de cupins foram determinados para cada amostra. *Dalbergia nigra* apresentou resistência ao ataque de cupins e teve o maior teor de extrativos, com 13,14%. Por outro lado, *M. amplum* teve a maior perda de massa, com 5,37%, e o menor teor de extrativos, com 1,94%. Ambas as espécies mostraram uma correlação negativa entre perda de massa e teor de extrativos, mas nenhuma correlação com a densidade da madeira. *Magonia pubescens* teve a maior densidade, com 0,90 g/cm^3. *Machaerium amplum* e *M. pubescens* causaram 100% de mortalidade de cupins, enquanto *D. nigra* causou 40% de mortalidade.

Palavras-chave: densidade anidra, extrativos, perda de massa, cupins, deterioração da madeira.

1. Introduction

The natural resistance of wood, which refers to its ability to withstand attack by biological, physical, and chemical agents, differs among species (Reis et al., 2019; Vivian et al., 2020). Deteriorating agents such as bacteria, fungi, and termites, play a crucial role in the environment by breaking down materials and releasing new nutrients into the soil. However, these agents also cause wood degradation, resulting in economic losses for both producers and consumers (Arif et al., 2019; Rasib et al., 2023).

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Termites, such as those of the genus *Nasutitermes* sp. (Blattodea: Termitidae), are insects that consume cellulose, causing wood deterioration by building galleries, rendering it fragile and brittle (Boulogne et al., 2017). These insects are responsible for damage to wood in both urban and rural areas, leading to volume and economic losses in wood products. Termites are considered one of the most destructive wood pests due to the extensive damage they cause (Ribeiro et al., 2014a; Batista et al., 2020; Boulogne et al., 2017). While termites pose a threat to wooden structures and products, certain tree species are known for their natural resistance to wood-boring insects.

The species *Machaerium amplum* Benth and *Dalbergia nigra* (Vell.) Allemão ex Bent (Fabaceae) are economically and ecologically important species that occur in various soil and climatic conditions across all Brazilian biomes and regions (Souza and Lorenzi, 2019; JBRJ, 2024). The species *Magonia pubescens* A. St.-Hil (Sapindaceae) is distributed throughout the country's biomes, with individuals found in different vegetations and climates, primarily in tropical and subtropical areas (Souza et al., 2020; JBRJ, 2024), occurring mainly in well-drained, high terrains with fertile sandy-silty soils, like the Brazilian Cerrado (Macedo et al., 2009). These three species are native to Brazil, non-endemic and environmentally important in the Brazilian Cerrado (JBRJ, 2024). Given their widespread distribution and ecological significance, understanding the natural resistance of these wood species to biological agents like termites is important for sustainable wood utilization.

The natural resistance of wood to biological agents is crucial in determining its suitability for specific applications, as it prevents economic losses and ensures longevity of wood products, particularly in regions with prevalent wood-destroying organisms like termites (Oliveira et al., 2017). This resistance depends on the wood's chemical and physical properties, including extractive content and density. Extractives, the non-structural components, play an important role in protecting wood from biological attack, while density is often associated with mechanical strength and stability (Silveira et al., 2019; Batista et al., 2020). Investigating the relationship between these properties and the natural resistance of various wood species is essential for determining the most suitable materials for specific applications.

The relationship between wood properties and the natural resistance of the wood species was investigated, contributing to the understanding of factors influencing timber's durability against termites and other biological agents. This study aimed to evaluate the natural resistance of wood from the Brazilian native species *D. nigra*, *M. amplum*, and *M. pubescens* against termite (*Nasutitermes* sp.) attack through a forced feeding process.

2. Material and Methods

2.1. Samples

Wood sample discs from the base of stems of *D. nigra*, *M. amplum*, and *M. pubescens* were collected from trees sourced from the North, Northwest, and Central regions of Minas Gerais, as part of the Forest Inventory of this state. The trees' ages could not be determined because of the lack of annual growth rings, their resprouting after fires that hides their true age, and/or irregular growth patterns due to climate fluctuations.

Five samples measuring 1.5 × 1.5 × 1.5 cm (longitudinal × radial × tangential) were prepared from each species, totaling 15 samples. These samples were collected along the radial axis, spanning from the central pith outward to the bark. Additionally, five *Pinus* wood samples were included for comparison, following the guidelines of the American Society for Testing and Materials (ASTM, 2005), with a modification to the sample size of the samples, with a total size of 3.38 cm^3. The mass and volume of each sample were measured to calculate the oven-dry density and analyze the wood loss caused by termites.

2.2. Termites

Termite were collected at the Federal University of Minas Gerais campus in Montes Claros, Minas Gerais, Brazil. Termites were captured using 20 × 20 cm cardboard squares placed in a moistened box, allowing them to migrate onto the cardboard. Then, the termites were transferred to a 10-liter bucket containing 20 sheets of paper towels, with 10 of them moistened with distilled water at the bottom and 10 dry towels as a cover (ASTM, 2005). After 6 h, the more vigorous termites had organized themselves in the dampest area, separating from the weaker ones on top. The most robust termites were then selected and used for the forced feeding test in the laboratory.

2.3. Forced feeding test

The experiment followed the ASTM D-3345 (ASTM, 2005) standard. Jars of 500 mL capacity were washed, sterilized with ethanol 70% and 1.0% sodium hypochlorite solution, and filled with 200 g of sterilized sand and distilled water to saturation point. After a 12-h rest period, a wood sample was partially inserted into the sand, with 50% of its length buried and the rest exposed. One gram (± 0.05 g) of *Nasutitermes* sp. workers were introduced into each jar. The jars were sealed with tulle fabric to allow oxygen intake while preventing termite escape.

The sealed jars were kept in an air-conditioned room at 27 °C ± 2 °C and 75% ± 5% relative humidity for 30 days, following ASTM D-3345 (ASTM, 2005) and Paes et al. (2010) recommendations. Samples were examined after the first and fourth weeks to check for tunnel formation. The natural wood resistance was assessed by measuring mass loss, termite-induced damage, termite mortality rate, and the time taken for complete termite mortality in each flask (ASTM, 2005).

2.4. Extractive content

Sawdust was produced by processing additional wood samples from *D. nigra*, *M. amplum*, and *M. pubescens* using a Wiley-type knife mill. The sawdust was sieved, with the portion retained on the 60-mesh sieve used for further analysis. The samples were weighed on a 0.001g precision balance (TAPPI, 1997).

To obtain extractives, two solvents were employed: toluene and ethanol 95% (2:1) (TAPPI, 1997). Before extraction, the samples were washed, placed in petri dishes, and oven-dried at 103 ± 2 °C for 24 h (Jankowsky, 1990). Afterwards, approximately 2 g of the samples were weighed on a precision scale.

The extraction was carried out in a Soxhlet apparatus, where the paper filter containing sawdust was placed in the extractor and washed with 170 mL of toluene-ethanol (2:1) at 60 °C to 100 °C for 6 to 8 h, respectively. The samples were then air-dried for 24 h at room temperature.

Following this, the samples underwent a second Soxhlet extraction, washed with 170 mL of distilled water for 6 to 8 h (TAPPI, 1997), with an adaptation involving the use of distilled water. After the extraction process, the extractive-free wood samples were air-dried for 24 h at room temperature. Subsequently, they were weighed on a 0.001g precision balance, and the extractive content was determined by mass difference.

The content of toluene-ethanol extractives was calculated using the following Equation 1:

$$TE(\%) = \left(\frac{(DW1 - DW2)}{DW1} \right) * 100 \quad (1)$$

where: TE% = toluene-ethanol extractives content, expressed as a percentage; DW1 = Absolute dry weight of wood with extractives, in grams; DW2 = Absolute dry weight of wood free of extractives, in grams.

2.5. Oven-dry wood density

Wood samples of the studied species underwent oven-drying for 48 h to determine the oven-dry density. The oven-dried samples were weighed on a 0.001g precision scale. Their dry volumes were measured using a precision caliper. With the dry mass and dry volume data for each sample, the oven-dry density was calculated (ASTM, 1994; ABNT, 2003; Marques et al., 2012).

Oven-dry wood density was calculated using the following Equation 2:

$$ODD = \frac{DW}{V} \quad (2)$$

where: ODD: oven-dry density; DW= dry weight (g); V= dry volume (cm^3).

2.6. Statistical analysis

The resistance of the wood was assessed by calculating wood loss and termite mortality at the experiment's conclusion. The experimental design was completely randomized, with five replicates per wood species. The obtained data underwent the Shapiro-Wilk normality test and Bartlett's homogeneity test using R software (R Core Team, 2020). Wood loss values were transformed into *arcsin* [square root (wood loss/100)] to improve homogeneity (Steel and Torrie, 1980). Subsequently, the data was subjected to ANOVA. When significant differences were detected, Tukey's test ($P \leq 0.05$) and Pearson's Correlation ($P \leq 0.05$) were applied (R Core Team, 2020).

3. Results

The wood loss, oven-dry density, and extractive content varied among the timber species. *Dalbergia nigra* had the lowest wood loss (1.92%), while *M. amplum* had the highest (5.37%). *Magonia pubescens* (2.26%) had a wood loss similar to the control *Pinus* (Table 1). *Magonia pubescens* had the highest oven-dry density (0.90 g/cm^3), followed by *M. amplum* at 0.81 g/cm^3, *D. nigra* at 0.7 g/cm^3, and *Pinus* sp. at 0.43 g/cm^3 (Table 1). *Dalbergia nigra* had the highest extractive content (13.14%), while *M. amplum* had the lowest (1.94%). *Magonia pubescens* and *Pinus* sp. had extractive contents of 6.09% and 4.79%, respectively (Table 1).

A negative correlation existed between wood loss and extractive content for *D. nigra*, *M. amplum*, and all species combined (Table 2). But no correlation was found between wood loss and density for any species.

There were differences in *Nasutitermes* sp. worker mortality among wood species (Figure 1). *Machaerium amplum* and *M. pubescens* caused complete mortality, the highest observed rates, while *Pinus* sp. exhibited the lowest mortality at 20%. *Dalbergia nigra* showed an intermediate mortality rate of 40%.

4. Discussion

Wood's natural resistance stems from its extractive content and density. Denser woods, harboring higher extractive quantities, demonstrate enhanced durability and insect resistance, exhibiting resilience against xylophagous insects (Stallbaun et al., 2016). Of the three species studied, *Dalbergia nigra* exhibited the lowest wood loss from termite attack despite its lower density. This suggests wood

Table 1. Mean values of wood loss (%), density (g/cm^3), and extractive content (%) for *D. nigra*, *M. amplume*, and *M. pubescens* wood subjected to *Nasutitermes* sp. feed.

Timber species	Wood loss (%)	Oven-dry density (g/cm^3)	Extractive content (%)
Dalbergia nigra (Vell.) Allemão ex Bent	1.92 c	0.7 c	13.14 a
Machaerium amplum Benth	5.37 a	0.81 b	1.94 c
Magonia pubescens A. St.-Hil	2.26 b	0.90 a	6.09 b
Pinus sp.	2.55 b	0.43 d	4.79 bc

Means within a column followed by the same letter are not different according to Tukey's test (P = 0.05).

Table 2. Correlation coefficients between wood loss (%), density (g/cm³), and extractive content (%) for *D. nigra*, *M. amplume*, and *M. pubescens* wood subjected to *Nasutitermes* sp. feed.

Timber species	Wood loss vs. extractive (%)	Wood loss (%) vs. density (g/cm³)
Dalbergia nigra (Vell.) Allemão ex Bent	-0.93*	0.11ns
Machaerium amplum Benth	-0.89*	0.15ns
Magonia pubescens A. St.-Hil	-0.65ns	-0.38ns
Between species	-0.94*	0.22ns

*Significant at $P < 0.05$); nsNot significant at $P < 0.05$.

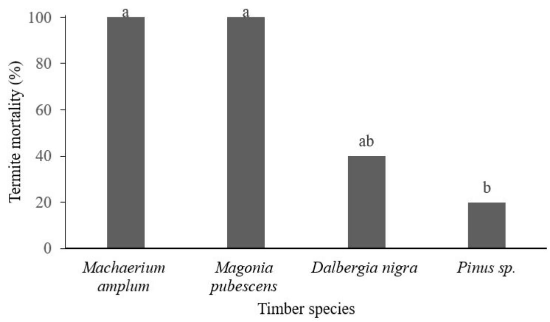

Figure 1. Mean mortality of *Nasutitermes* sp. workers feeding on *D. nigra, M. amplume*, and *M. pubescens* wood. Means followed by the same letter are not different according to Tukey's test ($p < 0.05$).

resistance does not solely depend on density, but also factors like ash, extractive, and lignin contents (Zulfiqar et al., 2020; Souza et al., 2022). Phenolic compounds in wood may confer toxicity, repellency, and anti-feeding effects against xylophagous insects, thereby reducing wood loss (Hassan et al., 2019; Anggraini et al., 2021).

Wood loss exhibited a negative correlation with extractive content for *D. nigra* and *M. amplum*. This negative correlation may potentially result from the anti-feedant or deterrent capacity of phenolic compounds, which could confer repellency and toxicity capable of causing termite mortality, thereby potentially influencing wood loss (Hassan et al., 2019; Elaieb et al., 2020; N'Guessan et al., 2023). Similar findings occurred with *Tectona grandis* L. fil. (Lamiaceae) after *Reticulitermes speratus* (Kolbe, 1885) (Blattodea: Rhinotermitidae) attack (Lukmandaru and Takahashi, 2008; Lukmandaru, 2013). *Juniperus occidentalis* Hook. var. *occidentalis* (Cupressaceae) also showed a negative correlation between wood loss and extractive yield after *Reticulitermes flavipes* (Kollar, 1837) (Blattodea: Rhinotermitidae) attack (Lipeh et al., 2020). *Magonia pubescens* showed no significant correlation between wood loss and extractive content. The lack of correlation suggests considering not just extractive amount, but also the specific compounds present, their type, and localization, as these factors impact termites without necessarily correlating (Paes et al., 2016; Medeiros Neto et al., 2022).

Dense woods tend to negatively impact termites' ability to mechanically fragment and consume the material (Stallbaun et al., 2016; Campos Carlos et al., 2021). However, no correlation existed between wood loss and density for the studied species. No significant correlation between wood loss and wood density were also observed after *Nasutitermes corniger* (Motschulsky, 1855) attack on Brazilian native species like *Croton sonderianus* Müll. Arg. (Euphorbiaceae), *Mimosa caesalpiniifolia* Benth., and *Mimosa tenuiflora* (Willd.) Poir. (Fabaceae) (Paes et al., 2007). Wood density alone does not determine termite resistance (Souza et al., 2022; Farias et al., 2023). Other physicochemical properties and interactions may act conferring resistance against termite attack (Qureshi et al., 2012; Souza et al., 2022).

All *Nasutitermes* sp. workers succumbed when exposed to *M. amplum* and *M. pubescens*, whereas worker mortality rates were lower at 40% and 20% for *D. nigra* and *Pinus* sp. Higher *Cryptotermes brevis* (Walker, 1853) (Blattodea: Kalotermitidae) mortality rates were found for *on Anadenanthera peregrina* (L.) Speg. (91%), *Anadenanthera columbrina var. cebil* (Griseb.) Altschul (78%), *Peltogine nitens* Tul. (76.5%), *Eucalyptus cloeziana* F. Muell. (75%), *Manilkara longifolia* (A.DC.) Dubard (73%), *Corymbia torelliana* (F. Muell.) K. D. Hill & L. A. S. Johnson (70%), *Maclura tinctoria* (L.) D. Don ex Steud. (68.5%), *Paubrasilia echinata* (Lam.) Gagnon, H.C. Lima & G.P. Lewis (65.5%), *Hymenolobium petraeum* Ducke (54.5%), and *D. nigra* (49.5%) when compared to *Pinus caribaea* Morelet (43%) (Gonçalves et al., 2013).

The high *Nasutitermes* sp. mortality with *M. amplum* and *M. pubescens* may result from extractives directly impeding consumption (Ribeiro et al., 2014b; Cosme Junior et al., 2020). These species' extractives may contain tannins, aromatic compounds, steroids, waxes, terpenes, and terpenoids with termite toxicity (Gonçalves et al., 2013; Bessike et al., 2023). Additionally, high mortality could be associate with extractive-caused symbiont imbalance (Stallbaun et al., 2016). Extractives may reduce microorganisms on the gut that are required for cellulose digestion, causing termite starvation (Costa et al., 2019; Eller et al., 2020). Further studies should identify the extractive present and their potential applications. Extractives have the capacity to protect against biological agents and can be used based on their characteristics and composition.

Wood resistance to termite attack is complex, influenced by factors beyond density. While denser woods exhibit higher resistance due to mechanical challenges for termites, density alone is insufficient for predicting resistance. This study underscores wood chemistry's crucial role, particularly extractive content and composition. Extractives can confer toxicity, repellency, and anti-feedant effects against xylophagous insects, reducing wood loss and increasing termite mortality. But, the extractive-resistance correlation varies across species, highlighting the importance of considering not just extractive quantity but also their qualitative nature, type, and localization within wood. Understanding the interplay between wood's physical and chemical properties is key to elucidating natural termite resistance mechanisms and developing wood protection strategies.

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References

AMERICAN SOCIETY FOR TESTING AND MATERIALS – ASTM, 1994. *ASTM D 1413: standard test method for wood preservatives by laboratory soil-block culture*s. Philadelphia: ASTM, vol. 410, pp. 119-121.

AMERICAN SOCIETY FOR TESTING AND MATERIALS – ASTM, 2005. *ASTM D-3345: standard test method for laboratory evaluation of wood and other cellulosic materials for resistance to termites*. West Conshohocken: ASTM.

ANGGRAINI, R., KHABIBI, J. and RIDHO, M.R., 2021. Utilization of wood vinegar as a natural preservative for sengon wood (*Falcataria moluccana* Miq.) against fungal attack (*Schizophyllum commune* Fries). *Jurnal Sylva Lestari*, vol. 9, no. 2, pp. 302-313. http://doi.org/10.23960/jsl29302-313.

ARIF, A., PUTRI, G. and MUIN, M., 2019. Hazard mapping of subterranean termite attacks in Makassar City, South Sulawesi, Indonesia. *Insects*, vol. 11, no. 1, pp. 31. http://doi.org/10.3390/insects11010031. PMid:31906069.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS – ABNT, 2003. *ABNT NBR 11941: densidade básica da madeira*. Rio de Janeiro: ABNT, 6 p.

BATISTA, F.G., MELO, R.R., CALEGARI, L., MEDEIROS, D.T. and LOPES, P.J.G., 2020. Resistência natural da madeira de seis espécies à *Nasutitermes corniger* Motsch em condição de campo. *Madera y Bosques*, vol. 26, no. 2, e2622017. http://doi.org/10.21829/myb.2020.2622017.

BESSIKE, J.G., NDIWE, B., FONGNZOSSIE, E.F., PIZZI, A., MFOMO, J.Z., BIWOLE, A.B., TOUNKAM, M.N., BIWÔLÉ, J.J.E., BITONDO, D., KEKEUNOU, S. and AKONO, P.N., 2023. Evaluation of the potentials of *Jatropha curcas* seed oil and in combination with leaf extracts of *Cymbopogon citratus, Ocimum basilicum*, and *Eucalyptus globulus* as wood preservatives against *Macrotermes bellicosus* termites. *Industrial Crops and Products*, vol. 195, pp. 116205. http://doi.org/10.1016/j.indcrop.2022.116205.

BOULOGNE, I., CONSTANTINO, R., AMUSANT, N., FALKOWSKI, M., RODRIGUES, A.M.S. and HOUEL, E., 2017. Ecology of termites from the genus *Nasutitermes* (Termitidae: Nasutitermitinae) and potential for science-based development of sustainable pest management programs. *Journal of Pest Science*, vol. 90, no. 1, pp. 19-37. http://doi.org/10.1007/s10340-016-0796-x.

CAMPOS CARLOS, L.K., DIODATO, M.A. and CASTRO, V.G., 2021. Durabilidade natural de cinco espécies madeireiras da Caatinga em ensaio de deterioração em campo aberto e natural. *Advances in Forestry Science*, vol. 8, no. 3, pp. 1527-1534. http://doi.org/10.34062/afs.v8i3.12631.

COSME JUNIOR, L., TURCHEN, L.M. and GUEDES, R.N.C., 2020. Chemical constituents of tropical woods and resistance to the invasive drywood termite *Cryptotermes brevis. Journal of Applied Entomology*, vol. 144, no. 4, pp. 270-277. http://doi.org/10.1111/jen.12729.

COSTA, F.N., CARDOSO, R.P., MENDES, C.S., RODRIGUES, P.R.G. and REIS, A.R.S., 2019. Natural resistance of seven amazon woods to xylophagous termite *Nasutitermes octopilis* (Banks). *Floresta e Ambiente*, vol. 26, no. 3, e20170145. http://doi.org/10.1590/2179-8087.014517.

ELAIEB, M.T., AYED, S.B., DUMARÇAY, S., FARIA, B.F.H., THÉVENON, M.F., GÉRARDIN, P. and CANDELIER, K., 2020. Natural durability of four Tunisian *Eucalyptus* spp. and their respective compositions in extractives. *Holzforschung*, vol. 74, no. 3, pp. 260-274. http://doi.org/10.1515/hf-2019-0090.

ELLER, F.J., KIRKER, G.T., MANKOWSKI, M.E., HAY, W.T. and PALMQUIST, D.E., 2020. Effect of burgundy solid extracted from Eastern Red Cedar heartwood on subterranean termites and Wood-decay fungi. *Industrial Crops and Products*, vol. 144, pp. 112023. http://doi.org/10.1016/j.indcrop.2019.112023.

FARIAS, S.M.A.P., SIVIERO, A., PEREIRA, K.R.M., MACEDO, P.E.F., SANTOS, R.S., PASSOS, J.R.S. and FURTADO, E.L., 2023. Degradação biológica e a durabilidade natural de espécies florestais da Amazônia em campo de apodrecimento no Acre. *Research, Society and Development*, vol. 12, no. 4, e10112440990. http://doi.org/10.33448/rsd-v12i4.40990.

GONÇALVES, F.G., PINHEIRO, D.T.C., PAES, J.B., CARVALHO, A.G. and OLIVEIRA, G.L., 2013. Durabilidade natural de espécies florestais madeireiras ao ataque de cupim de madeira seca. *Floresta e Ambiente*, vol. 20, no. 1, pp. 110-116. http://doi.org/10.4322/floram.2012.063.

HASSAN, B., AHMED, S., MEHMOOD, N., MANKOWSKI, M.E. and MISBAH-UL-HAQ, M., 2019. Toxicity potential of heartwood extractives from two mulberry species against *Heterotermes indicola. Maderas. Ciencia y Tecnología*, vol. 21, no. 2, pp. 153-162. http://doi.org/10.4067/S0718-221X2019005000203.

JANKOWSKY, I.P., 1990 [viewed 20 March 2024]. *Fundamentos de secagem das madeiras* [online]. Piracicaba: ESALQ/USP. Documentos Florestais. Available from: http://www.ipef.br/publicacoes/docflorestais/cap10.pdf

JARDIM BOTÂNICO DO RIO DE JANEIRO – JBRJ, 2024 [viewed 20 March 2024]. *Flora e funga do Brasil* [online]. Rio de Janeiro: JBRJ. Available from: https://floradobrasil.jbrj.gov.br/FB216.

LIPEH, S., SCHIMLECK, L.R., MANKOWSKI, M.E., MCDONALD, A.G. and MORRELL, J.J., 2020. Relationship between attenuated total reflectance Fourier transform infrared spectroscopy of western juniper and natural resistance to fungal and termite attack. *Holzforschung*, vol. 74, no. 3, pp. 246-259. http://doi.org/10.1515/hf-2019-0096.

LUKMANDARU, G., 2013. The natural termite resistance of teak wood grown in community forest. *Jurnal Ilmu dan Teknologi Kayu Tropis*, vol. 11, no. 2, pp. 131-139.

LUKMANDARU, G. and TAKAHASHI, K., 2008. Variation in the natural termite resistance of teak (*Tectona grandis* Linn. fil.) wood as a function of tree age. *Annals of Forest Science*, vol. 65, no. 7, pp. 708. http://doi.org/10.1051/forest:2008047.

MACEDO, M.C., SCALON, S.P.Q., SARI, A.P., SCALON FILHO, H., ROSA, Y.B.C.J. and ROBAINA, A.D., 2009. Biometria de frutos e sementes e germinação de Magonia pubescens St. Hil (Sapindaceae). *Revista Brasileira de Sementes*, vol. 31, no. 2, pp. 202-211.

MARQUES, S.S., PAES, J.B., ALVES, E.S., SILVA, A.G. and FIEDLER, N.C., 2012. Estudo comparativo da massa específica aparente e retrabilidade da madeira de pau-brasil (*Caesalpiniae chinata*

Lam.) nativa e de reflorestamento. *Revista Árvore*, vol. 36, no. 2, pp. 373-380. http://doi.org/10.1590/S0100-67622012000200019.

MEDEIROS NETO, P.N., PAES, J.B., GONÇALVES, F.G., LÓPEZ, Y.M., BARAÚNA, E.E.P. and RIBEIRO, L.S., 2022. Relation of physicochemical characteristics on biological resistance of eucalypts woods to xylophagous termites. *Journal of Building Engineering*, vol. 52, no. 15, pp. 104462. http://doi.org/10.1016/j.jobe.2022.104462.

N'GUESSAN, J.L.L., NIAMKÉ, B.F., YAO, N.J.C. and AMUSANT, N., 2023. Wood extractives: main families, functional properties, fields of application and interest of wood waste. *Forest Products Journal*, vol. 73, no. 3, pp. 194-208. http://doi.org/10.13073/FPJ-D-23-00015.

OLIVEIRA, J.T.S., PAES, J.B. and VIDAURRE, G.B., 2017. Biological resistance of eucalypt wood species to dry wood termites. *Scientia Forestalis*, vol. 45, no. 113, pp. 145-150. http://doi.org/10.18671/scifor.v45n113.14.

PAES, J.B., MELO, R.R., LIMA, C.R. and OLIVEIRA, E., 2007. Resistência natural de sete madeiras ao cupim subterrâneo (*Nasutitermes corniger* Motsch.) em ensaio de preferência alimentar. *Agrária*, vol. 2, no. 1, pp. 57-62. http://doi.org/10.5039/agraria.v2i1a1885.

PAES, J.B., SOUZA, A.D., LIMA, C.R. and MEDEIROS-NETO, P.N., 2010. Eficiência dos óleos de nim e mamona contra cupins xilófagos em ensaio de alimentação forçada. *Cerne*, vol. 16, no. 1, pp. 105-113. http://doi.org/10.1590/S0104-77602010000100012.

PAES, J.B., GUERRA, S.A.S., SILVA, L.F., OLIVEIRA, J.G.L. and SÃO TEAGO, G.B., 2016. Efeito do teor de extrativos na resistência natural de cinco madeiras ao ataque de cupins xilófagos. *Ciência Florestal*, vol. 26, no. 4, pp. 1259-1269. http://doi.org/10.5902/1980509825137.

QURESHI, N.A., QURESHI, M.Z., ALI, N., ATHAR, M. and ULLAH, A., 2012. Protozoidal activities of *Eucalyptus camaldulensis, Dalbergia sissoo* and *Acacia arabica* woods and their different parts on the entozoic flagellates of *Heterotermes indicola* and *Coptotermes heimi. African Journal of Biotechnology*, vol. 11, no. 57. http://doi.org/10.5897/AJB12.375.

R CORE TEAM, 2020 [viewed 20 March 2024]. *R: a language and environment for statistical computing* [online]. Vienna: R Foundation for Statistical Computing. Available from: https://www.R-project.org/

RASIB, K.Z., SHEHZAD, K. and TARIQ, H.M., 2023. Feeding preferences and responses of subterranean termite on different commercial timbers. *Journal of Dairy, Veterinary & Animal Research*, vol. 12, no. 1, pp. 13-17. http://doi.org/10.15406/jdvar.2023.12.00316.

REIS, A.R.S., LOCH, A.G., MOREIRA, S.M.C.O., GONDIM, M.C., SILVA, M.R.D. and SANTOS, P.S.B., 2019. Natural resistance of wood from three forest species exposed to *Pycnoporus sanguineus* xylophagous fungus. *Advances in Forestry Science*, vol. 6, no. 4, pp. 839. http://doi.org/10.34062/afs.v6i4.9492.

RIBEIRO, M.A., STANGERLIN, D.M., SOUZA, A.P., CARDOGO, G.V., CALEGARI, L. and GATTO, D.A., 2014a. Durabilidade natural da madeira de jequitibá em ensaios de deterioração em campo aberto e floresta durante as estações de seca e chuva. *Comunicata Scientiae*, vol. 5, no. 1, pp. 402-411. http://doi.org/10.14295/cs.v5i4.262.

RIBEIRO, M.X., BUFALINO, L., MENDES, L.M., SÁ, V.A., SANTOS, A. and TONOLI, G.H.D., 2014b. Resistência das madeiras de pinus, cedro australiano e seus produtos derivados ao ataque de *Cryptotermes brevis. Cerne*, vol. 20, no. 3, pp. 433-439. http://doi.org/10.1590/01047760201420031277.

SILVEIRA, M.F., GOUVEIA, F.N., MOREIRA, A.C.O., OLIVEIRA, J.R.V., SILVA, A.S.V.S., ALMEIDA, G.F. and COSTA, A.F., 2019. Natural resistance of eight Brazilian wood species from the region Caatinga determined by an accelerated laboratory decay test against four fungi. *Holzforschung*, vol. 73, no. 2, pp. 151-154. http://doi.org/10.1515/hf-2018-0051.

SOUZA, D.A.T., VASCONCELOS, R.G., MOURA-NETO, L. and BUSTAMANTE, N.C.R., 2022. Resistência natural de três espécies de madeiras comerciais ao ataque de térmitas (Insecta, Blattodea) em Fragmento Florestal Urbano de Manaus, Amazonas. *Research, Society and Development*, vol. 11, no. 11, e365111133602. http://doi.org/10.33448/rsd-v11i11.33602.

SOUZA, M.J., MERCADANTE-SIMÕES, M.O. and RIBEIRO, L.M., 2020. Secondary-cell-wall release: a particular pattern of secretion in the mucilaginous seed coat of *Magonia pubescens. American Journal of Botany*, vol. 107, no. 1, pp. 31-44. http://doi.org/10.1002/ajb2.1415. PMid:31916253.

SOUZA, V.C. and LORENZI, H., 2019. *Botânica sistemática: guia ilustrado para identificação das famílias de angiospermas da flora brasileira, baseado em APG II.* 4ª ed. Nova Odessa: Instituto Plantarum.

STALLBAUN, P.H., BARAUNA, E.E.P., PAES, J.B., RIBEIRO, N.C., MONTEIRO, T.C. and ARANTES, M.D.C., 2016. Resistência natural da madeira de *Sclerolobium paniculatum* Vogel a cupins em condições de laboratório. *Floresta e Ambiente*, vol. 24, e20160013. http://doi.org/10.1590/2179-8087.001316.

STEEL, R.G.D. and TORRIE, J.H., 1980. *Principles and procedures of statistic: a biometrical approach*. 2nd ed. New York: McGraw Hill.

TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY – TAPPI, 1997. *TAPPI T 204 cm-97: solvent extractives of wood and pulp*. Atlanta: TAPPI Press.

VIVIAN, M.A., CORRÊA, R., MODES, K.S., CAETANO, A.C., PEDRAZZI, C. and DOBNER-JÚNIOR, M., 2020. Caracterização tecnológica da madeira de *Cupressus lusitanica* visando à produção de polpa celulósica. *Pesquisa Florestal Brasileira*, vol. 40, e201901894. http://doi.org/10.4336/2020.pfb.40e201901894.

ZULFIQAR, S., AHMED, S., SUFYAN, M., ARSHAD, M., NAWAZ, A. and HASSAN, B., 2020. Termiticide activities of wood extractives of *Ziziphus mauritiana* (Rhamnaceae) against subterranean termites under field conditions. *Revista Brasileira de Entomologia*, vol. 64, no. 1, e201998. http://doi.org/10.1590/1806-9665-rbent-2019-98.