Floresta Ambient., Rio de Janeiro, 2024; 31(3): e20240011
https://doi.org/10.1590/2179-8087-FLORAM-2024-0011
ISSN 2179-8087 (online)

ORIGINAL ARTICLE – Forest Products Science and Technology

# Natural Durability of *Mimosa tenuiflora* and *Mimosa caesalpiniaefolia* Woods: Two Species from the Brazilian Dry Forest

Rodolpho Stephan Santos Braga[1]
Rafael Rodolfo de Melo[2]
Alexandre Santos Pimenta[1]
Alencar Garlet[3]
Juliana Lorensi do Canto[1]
Pedro Nicó de Medeiros Neto[4]

[1]Universidade Federal do Rio Grande do Norte (UFRN), Natal, RN, Brasil.
[2]Universidade Federal Rural do Semi-Árido (UFERSA), Mossoró, RN, Brasil.
[3]Serviço Florestal Brasileiro (SFB), Natal, RN, Brasil.
[4]Universidade Federal de Campina Grande (UFCG), Campina Grande, PB, Brasil.

## Abstract
Knowledge of the characteristics and durability of every wood species is essential so it can be better directed for the correct harnessing. In a wood rot field test, this work aimed to determine the natural durability of timber species from the Brazilian dry forest, *Mimosa tenuiflora* and *Mimosa caesalpiniaefolia*. The slats were buried in the ground up to half their length and distributed in the field according to a completely randomized experimental design. Annual assessments were performed to determine the deterioration rate. Furthermore, mass loss and condensed tannin content were quantified. The condensed tannin content found for the species was 4.40% for *M. caesalpiniaefolia* and 3.99% for *M. tenuiflora*. The results of 3 years of evaluation of the test make it possible to understand that both species presented durable wood, where *M. caesalpiniaefolia* presented a deterioration rate of 77.27%, while *M. tenuiflora* presented 66.27%, making them of high natural durability.

**Keywords:** Biodeterioration, field rot tests, mass loss, tannin content, semiarid climate.

## 1. INTRODUCTION AND OBJECTIVES

Although the wood found in the Brazilian dry forest (Caatinga biome) is socially and economically significant, its technological characteristics have been barely investigated. An example of this is the natural durability of wood, which plays a crucial role in determining its appropriate use (Paes et al. 2013). When used in internal and external environments without chemical treatment, wood is vulnerable to various biological agents that feed on it, such as insects, fungi, bacteria, and marine organisms. Rotting fungi, in particular, are mainly responsible for destroying various structural elements made from wood, which can cause significant economic damage through structural collapse and the need to replace damaged parts. Furthermore, they facilitate subsequent insect attacks, compromising the quality of wood products (Stangerlin et al. 2013).

The contact between wood and the soil is one aspect strictly related to its natural durability. It is essential to know the deteriorating agents and identify their main deterioration damages so that indications can be made regarding the best use of wood following its properties (Ribeiro et al. 2014; González-Laredo et al. 2015). However, the place where the wood will be employed is a factor to be considered when evaluating natural durability. That is because the wood from the same species in different environments can exhibit different behavior depending on different temperature conditions, humidity, aeration, insolation, and diversity of xylophages (Jacobs et al., 2019; Martín and López, 2023).

Furthermore, wood's natural resistance is associated with several biotic and abiotic factors, which can be physical, chemical, or mechanical (Stallbaun et al., 2017; Vivian et al., 2020). Also, several characteristics of wood play a role in its resistance, such as the quantity and composition of extractives present in the heartwood, its anatomical constitution, density, lignin content, and moisture content, which can influence the durability of wood in high, medium, or low resistance, which may indicate its use, especially in tropical countries (De Ligne et al., 2021; Martín and López, 2023).

From this perspective, in order to correctly use wood, it is necessary to evaluate the natural durability of the species through specific tests. There are two tests to assess the degree of natural durability of wood in relation to the action of deteriorating organisms: laboratory and field tests. Although laboratory tests provide results in a short time, field tests present more realistic and reliable results, as they are obtained under conditions similar to those in which the wood will be used, being the most used in the analysis and monitoring of the natural resistance of wood for different forest species (Romanini et al. 2014; Pilocelli et al. 2015).

Examples of such timber species from the Caatinga include *Mimosa tenuiflora* (Willd.) Poir. (Marques et al. 2021), and *Mimosa caesalpiniifolia* Benth. (Pareyen et al. 2018), which are indigenous to Brazil and belong to the Fabaceae family. Thus, considering the importance of the rational and sustainable use of wood from the Caatinga biome as a renewable resource, widely used for producing stakes and posts in Northeastern Brazil, little is known about the potential use of this raw material and its natural durability. The main hypothesis raised in this study is that wood from these species has high natural durability and can be used in direct contact with the ground.

Therefore, it is essential to develop research aimed at evaluating natural durability. These species generate potential information for appropriate use based on their technological characteristics, providing predictions of the useful life of products from these species. This way, the present work aims to determine the natural durability of two wood species from the Brazilian dry forest (locally called Caatinga), *M. tenuiflora* and *M. caesalpiniaefolia,* and compare with the tannin content of the wood.

## 2. MATERIALS AND METHODS

### 2.1. Rot field and local characterization

*M. tenuiflora* and *M. caesalpiniaefolia* logs were acquired from commercial forest plantations. The wood rotting field was implemented in Macaíba-RN, Brazil (5° 54' 03" S and 35° 21' 31" W) at an altitude of 55 m (Figure 1). This region is located between the coast and the interior of Rio Grande do Norte in the Brazilian Northeast. According to the Köppen and Geiger classification, the local climate is Aw type, a rainy tropical climate with a dry summer and rainy season. The season with the highest rainfall covers the months of February to July, with normal annual rainfall exceeding 1,200 mm, an average yearly temperature of approximately 25 °C, with a maximum of 28 °C and a minimum of 23°C (FUNCERN 2019).

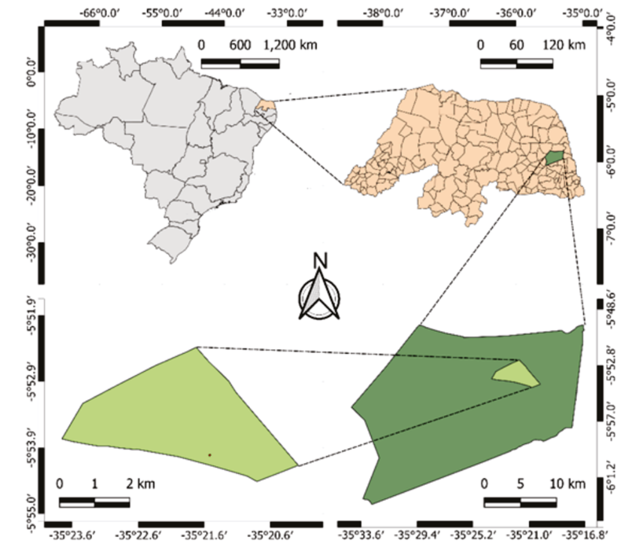


**Figure 1.** Location of the wood rotting field test – Brazil > Rio Grande do Norte State > city of Macaíba > field test area.

### 2.2. Sample preparation and sampling

Logs that were 2 m long were purchased and sawn into boards. A total of 30 slats were made from each wood species, according to the methodology established by IUFRO (International Union of Forest Research Organization) and described by Lepage (1970). The slats measured 5.0 cm in width x 2.5 cm in thickness x 50.0 cm in length. They were cut from the heartwood of the forest species, exposing the wood's radial, tangential, and longitudinal sections accurately. The slats were longitudinally buried in the ground, so 50% of the specimen became aboveground and the other 50% underground (Figure 2). As shown in Figure 3, the slats were distributed in the field following an entirely randomized block design with a space of 50 cm between the slats and 1 m between the rows, as described by Lepage (1970).

**Figure 2.** Distribution of the wood slats in the rot test field.

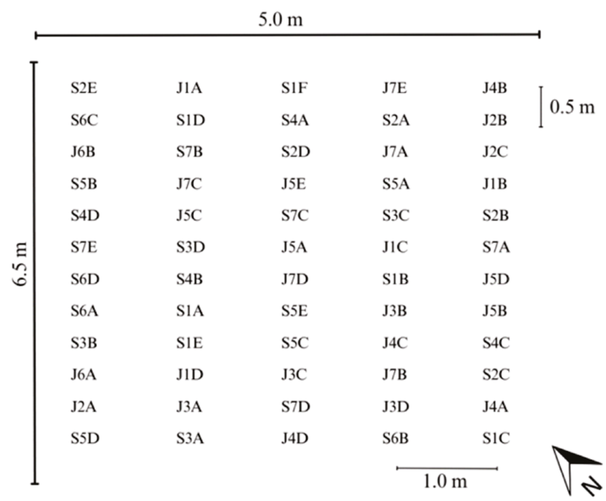


**Figure 3.** Sketch of the distribution of wooden slats in the rot test field

*First acronym (letters): J = *Mimosa tenuiflora* and S = *Mimosa caesalpiniaefolia*. Second acronym (number): This corresponds to each log from which the specimens were taken (1, 2, 3, 4, 5, 6 and 7). Third acronym (letter): This comprises the total sub-samples obtained from that log (A, B, C, D, E, and F).

## 2.3. Field deterioration test evaluation

The time-lapse of deterioration was three years (September 2020 to August 2023), with annual assessments to determine the deterioration rate and susceptibility index. Each year, the inspections were carried out in August, coinciding with the end of rainfall. The data collection started by removing the slats from the ground and cleaning them. Then, the deterioration index was determined following the criteria described by Becker (1972), cited in Table 1, where the rot state is established by attributing grades. Since the criteria are subjective, three different people attributed grades, and a mean value was calculated from the results.

**Table 1.** Deterioration level of wood in contact with soil.

| Sanity State | Grade | Deterioration Index (%) |
|---|---|---|
| Sound, no attacks detected | 0 | 100 |
| Light or superficial attack by fungi or termites | 1 | 90 |
| Evident but moderate fungal or termite attack | 2 | 70 |
| Intense rot or intense termite attack | 3 | 40 |
| Breakage, almost total loss of resistance | 4 | 0 |

Source: Becker (1972)

The samples were dried and weighed on a precision scale to determine the percentage of mass loss before being placed in the rotting field, obtaining the initial mass. After removing the soil samples, in their last evaluation, they were taken to the laboratory for surface cleaning and drying. For the initial drying of the specimens, the samples remained at room temperature for approximately three days; after this period, the samples were cleaned using a soft bristle brush and brushes of different sizes to remove all soil residue present in the sample. After cleaning, the drying process was carried out in an oven, which lasted around three days (72 hours) at 70 °C or until its mass stabilized. Soon after, they were weighed again on a precision scale to obtain the final mass and calculate the mass loss (Equation 1).

$$Pmt\ (\%) = \frac{(Mi - Mf)}{Mi} * 100 \qquad \text{Equation 1}$$

Where: *Pmt* (%) = total mass loss (g); Mi = initial mass (g); Mf = final mass (g)

## 2.4. Extraction and quantification of tannins

To analyze the condensed tannin content of the wood heartwood, the remaining samples of each species were transformed into sticks and later into sawdust in a Willey-type mill to obtain a material with smaller grain sizes. The sawdust used passed through the 32 “mesh” sieve and was retained in the 60 “mesh” sieve. The sawdust was homogenized, and the moisture content was determined dryly from the tannin content present in each sample. Three 25-g dry samples were used for the extraction and quantification of tannins. The samples were transferred to flat-bottom flasks with a capacity of 500 mL, to which 250 mL of distilled water (ratio 1:10) was added and boiled under reflux for 2 hours. Each sample was subjected to two sequences of extractions to remove the maximum amount of extractives present; thus, the material ratio of the solution was 1:20.

After each extraction, the material was passed through a 150 mesh (0.105 mm) sieve and a flannel cloth to retain fine particles. The extract was homogenized and filtered in a sintered glass funnel with porosity 2. Then, it was concentrated to 250 mL by evaporating the water in a Soxhlet-type apparatus. After concentration, three aliquots of 50 mL were removed from each extract, two were used to determine the condensed tannin content (TTC), and one was evaporated in an oven at 103 ± 2 °C for 48 hours to determine the percentage of total solids content (TST) (Equation 2).

$$TST\ (\%) = \frac{Mi - Mf}{Mi} * 100 \qquad \text{Equation 2}$$

Where: TST (%) = total solids content (%); Mi = dry mass of the sample (g); Mf = extract mass after drying (g).

The Stiasny method, described by Guangcheng et al., was used to determine each sample's condensed tannin content (TTC). (1991). Therefore, to 50 mL of crude extract, 4 mL of formaldehyde (37% m/m) and 1 mL of concentrated hydrochloric acid were added. Each mixture was boiled under reflux for 30 minutes. In this way, tannins form insoluble complexes that can be separated by simple filtration. For this purpose, a paper filter was placed in a Büchner funnel with a diameter of 10 cm and a depth of 4 cm. The material retained in the filter was dried in an oven at 103 ± 2 °C for 24 hours, then the Stiasny index was calculated (Equation 3). The condensed tannins in each sample were obtained by multiplying the Stiasny index by the total solids content (Equation 4).

$$I(\%) = \frac{M2}{M1} * 100 \qquad \text{Equation 3}$$

Where: I (%) = Stiasny index (%); M1 = mass of solids in 50 mL of extract (g); M2 = mass of tannin-formaldehyde precipitate (g)

$$TTC(\%) = \frac{TST * I}{100} \qquad \text{Equation 4}$$

Where: TTC (%) = condensed tannins content (%); TST = total solids content (Equation 2); I = Stiasny index (Equation 3).

### 2.5. Analysis of results

The research was conducted under a completely randomized design, where all experimental data were previously subjected to a normality analysis. As long as the data followed the normal distribution, they were subjected to analysis of variance. When significant statistical differences were established, the means were compared using the Tukey test with a probability of 95%. The percentage values of TST, I, and TTC were transformed into arcsen [square root (values in percentage/100)], a transformation suggested by Steel and Torrie (1980), to homogenize the variances and allow data analysis. The data were tabulated in a Microsoft Excel® spreadsheet and analyzed using the BioEstat 5.0 software (AYRES et al., 2007).

## 3. RESULTS AND DISCUSSION

### 3.1. Natural durability

Analyzing the deterioration level of the wood slats from both forest species after three years of exposure, a conspicuous material degradation could be observed (Figure 4). Even after one year of exposure, the *M. caesalpiniaefolia* wood presented higher resistance than the *M. tenuiflora*. Such a trend was kept unaltered until the end of the experiment, three years after it was implemented. This good deterioration resistance of *M. caesalpiniaefolia* wood corroborates the information cited by Moura et al. (2006), Gonçalves et al. (2010), Alencar et al. (2011), and Batista et al. (2022), who highlighted this species as having a high density and remarkable natural durability. These characteristics make its use possible for several applications, mainly for fence poles.

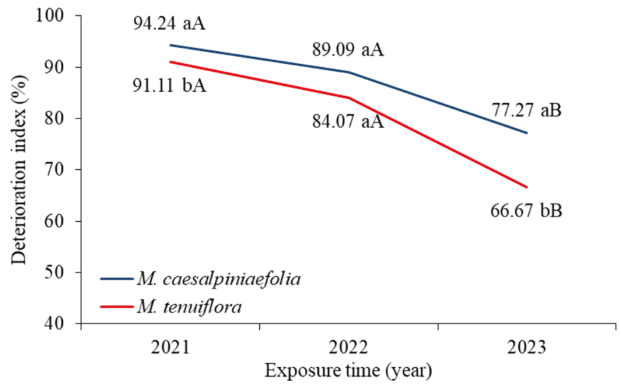


**Figure 4.** Deterioration index obtained for *M. tenuiflora* and *M. caesalpiniaefolia* woods as a function of exposure time.

*Means followed by the same lowercase letter (between species) and capital letters (same species) do not differ significantly from each other at 5% significance.

Considering the final exposure time, at the end of the third year of exposure, a significant difference was identified between the evaluated forest species, with *M. tenuiflora* showing more intense wear than *M. caesalpiniaefolia* wood (Figure 4). Similar results were also observed by Batista et al. (2022) in studies evaluating the performance of these species when exposed to rotting fields. However, it is important to highlight that although *M. tenuiflora* wood presents a lower performance than that observed, the results obtained for this species were also acceptable, especially if long-term exposure is considered. Paes et al. (2013) also highlight that *M. tenuiflora* wood can have considerable natural durability.

To better exemplify the appropriate distribution levels observed in the field at the time of evaluation, Figures 5A and 5B make it possible to observe the visible wear on the wood due to biotic and edaphoclimatic factors throughout the study period. Related grades were given according to the methodology proposed by Becker (1972).

Furthermore, using naturally resistant wood reduces the handling of chemical products used in the wood treatment process, as is the case with treated eucalyptus, widely used in property fences, such as stakes and posts. Furthermore, it can encourage studies on forestry, reforestation, and sustainable forest management of native species. Therefore, new work analyzing wood degradation in the field is increasingly necessary to elucidate such meaningful relationships since no research guarantees an estimate in years of the durability of wood from these species studied. According to Melo et al. (2010), the subjective analysis attributed to grades is the main parameter for evaluating the durability of wood in field rot tests. However, Lopez and Milano (1986) pointed out that in addition to visual assessments of the deterioration index, a second parameter, mechanical testing or mass loss (residual dry mass), should be used better to characterize the natural resistance of wood under test. Field, as was carried out in the present study for the specimens of the two indigenous species.

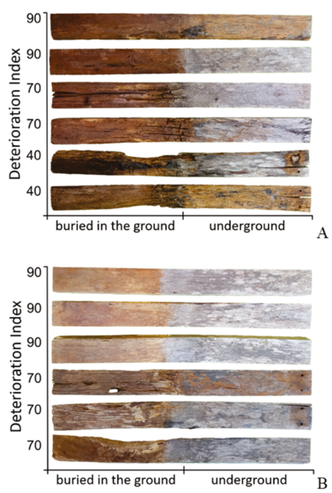


**Figure 5.** Levels of wear observed in the wood of *Mimosa tenuiflora* (Willd.) Poir. A) and *Mimosa caesalpiniaefolia* Benth. B) at the end of the third year of evaluation of the rotting field installed in Macaíba, Rio Grande do Norte, Brazil.

According to Figure 6, it is possible to observe the average mass loss of the samples at the end of the third year of evaluation in the rot field test. It is noted that the mass loss of *M. tenuiflora* was significantly higher than that observed for *M. caesalpiniaefolia*, with a difference of 9.06% loss. It is worth mentioning that *M. caesalpiniaefolia* showed a lower rate of deterioration of samples over the exposure time than *M. tenuiflora*. Therefore, the natural durability exhibited by *M. caesalpiniaefolia* wood in this test is higher than that observed for *M. tenuiflora*. Goes et al. (2023) remark that the market for wood preservative treatments carried out in autoclaves using vacuum pressure processes guarantees the durability of wood for an average of 15 years of service. However, it should be noted that in addition to being costly, these treatments use toxic chemicals, which are not environmentally friendly. Thus, species with regional availability and high resistance to the biotic agents and weathering emerge as an essential alternative with economic and environmental advantages.

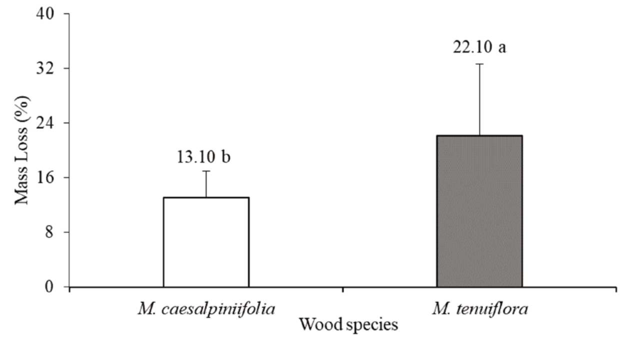


**Figure 6.** Mass loss after three years for *M. caesalpiniaefolia* and *M. tenuiflora*

*Means followed by the same letters are statistically equal at a 95% probability

In a similar study, Batista et al. (2022) also evaluated the mass loss of the two species under analysis for one year. They found results that align with what was observed in the study, of 10.89% for *M. tenuiflora* and 8.06% % for *M. caesalpiniaefolia*. However, Batista et al. (2022) report both species as highly resistant. Nogueira (2020) noted in his study with *M. tenuiflora* in a test of natural resistance to white rot with Ganoderma sp. that based on the mass loss values depending on different heights, the mass loss was higher in samples taken from the top, compared to the base and breast height diameter, which coincided with the high content of total extractives at 100% of the height at which the sample was taken. However, this relationship was not significant. Therefore, the species could be considered high resistance.

## *3.2. Quantification of tannins*

Figure 7 shows the results obtained from the extraction and quantification of tannins present in *M. caesalpiniaefolia* and *M. tenuiflora* wood. These results agree with the deterioration rates and mass losses of the samples, so it is possible to observe that the higher levels of condensed tannins for *M. caesalpiniaefolia* may be related to the lesser deterioration of its wood, in addition to its lower loss of mass, giving this species better resistance due to extractives of phenolic origin.

In a study where the tannic substances present in different parts of the *M. caesalpiniaefolia* plant were quantified, an average content of 4.58% of condensed tannins was found for the thin branches, a result that is close to that found for the heartwood of the same species in this study (Azevêdo et al., 2017). It is worth mentioning that the heartwood is the portion of the wood most resistant to attack by xylophagous organisms (Melo, 2010). This is regarded as the fact that when the heartwood cells lose their physiological function, many extractives are deposited inside them. Such extractives of phenolic origin, such as tannins, can be toxic to xylophagous organisms and hinder the development of hyphae and the action of fungal decomposing enzymes (Paes et al., 2007; Olaga et al. 2024).

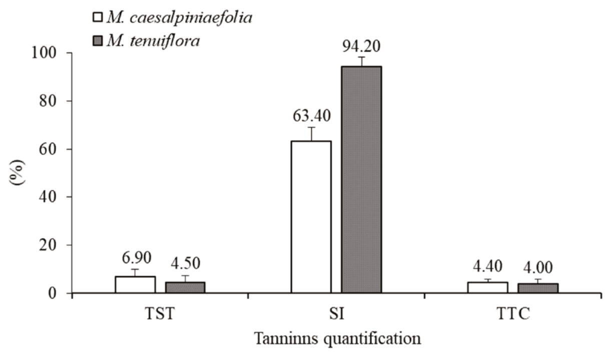


**Figure 7.** Total solids content (%), Stiasny index (%), and total condensed tannins content (%) determined for *M. caesalpiniaefolia*) and *M. tenuiflora*

*Means followed by the same letters are statistically equal at a 95% probability

Therefore, it can be concluded that a higher amount of tannins present in wood is strictly correlated with its more excellent natural durability. Sehlstedt-Persson and Karlsson (2010) remarked that the variability in the amount of extractives present in species can cause significant differences in the natural durability of wood species to xylophagous agents. On the other hand, the absence of extractives provides less natural durability of the wood to these agents (PALA, 2007). Thus, it is possible to note that comparing all the indices evaluated in this study, *M. tenuiflora* and *M. caesalpiniaefolia* have similar natural resistance. This information may contribute to the use and destination of these woods for a wide range of purposes, stating that both are durable woods by their natural properties, allowing them to be used as posts and stakes for uses that are already currently designated.

In general, to classify their durability, it is necessary to evaluate the species for a more extended period in the rotting field, making it possible to understand their natural resistance so that it is possible to designate other possible uses suitable for the wood of these species. Therefore, the species evaluated confirm the hypothesis initially raised, proving to be highly durable. Even when subjected to external use, in direct contact with the soil and exposed to environmental variations in weathering for a long period, the species performed well, with better acting observed for *M. caesalpiniaefolia*.

## 4. CONCLUSIONS

The resistance of these woods to biological deterioration and mass loss was demonstrated, with *M. caesalpiniaefolia* showing more excellent resistance compared to *M. tenuiflora*. These discrepancies may be directly related to the levels of condensed tannins, highlighting the crucial role of these compounds in protecting against xylophagous organisms. Finally, it is essential to highlight the need for continuous studies to evaluate the durability of these woods over time. This would allow a more comprehensive understanding of their performance in different environments and specific applications. Furthermore, the results corroborate the feasibility of using these woods, promoting more sustainable and environmentally respectful practices. They can guide the rational and sustainable use of Caatinga forest resources.

## ACKNOWLEDGEMENTS

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brazil (CAPES) – Finance Code 001 and the Brazilian National Council for Scientific and Technological Development (CNPq) for giving researcher scholarships.

## SUBMISSION STATUS

Received: 05 Mar. 2024
Accepted: 05 Aug. 2024
Associate editor: Fernando Gomes

## CORRESPONDENCE TO

**Rafael Rodolfo de Melo**
Avenida Francisco Mota, 572, 59.625-000, Mossoró, RN, Brasil.
e-mail: rafael.melo@ufersa.edu.br

## AUTHORS' CONTRIBUTIONS

Rodolpho Stephan Santos Braga: Formal analysis (Equal), Investigation (Equal), Methodology (Equal), Writing – original draft (Equal), Writing – review & editing (Equal).
Rafael Rodolfo Melo: Conceptualization (Equal), Project administration (Equal), Supervision (Equal), Writing – original draft (Equal), Writing – review & editing (Equal).
Alexandre Santos Pimneta: Conceptualization (Equal), Supervision (Equal), Validation (Equal), Writing – original draft (Equal), Writing – review & editing (Equal).
Alencar Garlet: Conceptualization (Equal), Data curation (Equal), Investigation (Equal), Project administration (Equal), Supervision (Equal), Validation (Equal), Writing – original draft (Equal), Writing – review & editing (Equal).
Juliana Lorensi do Canto: Conceptualization (Equal), Investigation (Equal), Project administration (Equal), Supervision (Equal), Validation (Equal), Writing – original draft – (Equal), Writing – review & editing (Equal).
Pedro Nicó de Medeiros Neto: Data curation (Equal), Formal analysis (Equal), Validation (Equal), Visualization (Equal), Writing – original draft (Equal), Writing – review & editing (Equal).

## REFERENCES


Alencar FHH, Paes JB, Bakke AO, Silva GLS. Resistência natural da madeira de sabiá (*Mimosa caesalpiniifolia* Benth.) a cupins subterrâneos. *Revista Caatinga* 2011; 24(1): 57-64.

Ayres M, Ayres Júnior M, Ayres DL, Santos AA. *BIOESTAT – Aplicações estatísticas nas áreas das ciências biomédicas*. ONG Mamirauá. Belém, PA. 2007. 380p.

Azevêdo TKB, Cardoso MGA, Campos DBP, Souza DG, Nunes LJ, Gomes JPS, Silva GGC. Substâncias tânicas presents em partes da árvore de sabia (Mimosa caesalpiniifolia Benth.) em plantio commercial de 5 anos. *Revista Agroecossistemas* 2017; 9(2): 263-274.

Batista FG, Melo RR, Medeiros DT, Lopes PJG, Gatto DA. Natural durability of five tropical wood species in field decay tests. *Maderas, Ciencia y Tecnologia* 2022; 24(51): 1-10.

Becker G. Suggested Standard Method for Field Tests with Wooden Stakes. *PANS Pest Articles & News Summaries* 1972; 18(1): 137-142.

De Ligne L, Van Den Bulcke J, Baetens JM, De Baets B, Wang G, De Windt I, Beeckman H, Van Acker J. Unraveling the Natural Durability of Wood: Revealing the Impact of Decay-Influencing Characteristics Other than Fungicidal Components. *Holzforschung* 2021; 75: 368-378.

Fundação de Apoio à Educação e ao Desenvolvimento Tecnológico do Rio Grande do Norte. *Resumo do diagnóstico do processo de revisão do plano diretor de Macaíba*. FUNCERN, 2019.

Guangcheng Z, Yunlu L, Yazaki Y. Extractive yields, Stiasny values and polyflavonoid contents in barks form six acacia species in Australia. *Australian Forestry* 1991; 554(2): 154-156.

Goes MB, Vale CM, Paula GD. A madeira roliça de eucalipto como solução estrutural e construtiva. *Revista Científica Multidisciplinar* 2023; 4(4): e443006.

Gonçalves CA, Lelis RCC, Abreu HS. Caracterização físico-química da madeira de sabiá (*Mimosa caesalpiniaefolia* Benth.). *Revista Caatinga* 2010; 23(1): 54-62.

González-Laredo RF, Rosales-Castro M, Rocha-Guzmán NE, Gallegos-Infante JA, MorenoJimenez MR, Karchesy J. Wood preservation using natural products. *Madera y Bosques* 2015; 21(especial): 63-76.

Jacobs K, Plaschkies K, Scheiding W, Weib B, Melcher E, Conti E, Le Bayon I. Natural durability of important European wood species against wood decay fungi. Part 2: Field tests and fungal community. *International Biodeterioration & Biodegradation* 2019; 137: 118-126.

Lepage, ES. Método padrão sugerido pela IUFRO para ensaios de campo com estacas de madeira. *Preservação de Madeiras*, 1970; 1(4): 205-216.

Lopez GAC, Milano S. Avaliação da durabilidade natural da madeira e de produtos usados na sua preservação. In: Lepage, ES. et al. *Manual de preservação de madeiras.* São Paulo: IPT – Divisão de Madeiras 1986; 2: 473-521.

Marques SRR, Azevêdo TKB, Castilho ARF, Braga RM, Pimenta AS. Extraction, quantification, and FTIR characterization of bark tannins of four forest species grown in northeast Brazil. *Revista Árvore* 2021; 45: e4541.

Martín JÁ, López R. Biological Deterioration and Natural Durability of Wood in Europe. *Forests* 2023; 14(2): 283.

Melo RR, Stangerlin DM, Santini EJ, Haselein CR, Gatto DA, Susin F. Durabilidade da madeira de três espécies florestais em ensaios de campo. *Ciência Florestal* 2010; 20(2): 357-365.

Moura ON, Passos MAA, Ferreira RLC, Molica SG, Lira Jr MA, Lira MA, Santos VF. Distribuição de Biomassa e nutrientes na parte aérea de *Mimosa caesalpiniaefolia* Benth. *Revista Árvore* 2006; 30(6): 877-884.

Nogueira SS, Castro VG. Variações longitudinais nas propriedades físicas da madeira de *Mimosa tenuiflora*. *Revista do Instituto Florestal* 2021; 33(2): 150-155.

Olaga TT, Antwi K, Bih FK, Donkor MB. Natural durability of *Acacia mangium* wood. *Nativa* 2024; 12(1): 179-83.

Paes JB, Lima CR, Oliveira E, Medeiros Neto PN. Características físico-química, energética e dimensões das fibras de três espécies florestais do semiárido brasileiro. *Floresta e Ambiente* 2013; 20(4): 550-555.

Paes JB, Melo RR, Lima CR. Resistência natural de sete madeiras a fungos e cupins xilófagos em condições de laboratório. *Cerne* 2007; 13(2): 160-169.

Pala H. Constituição e mecanismos de degradação biológica de um material orgânico: a madeira. *Construção Magazine* 2007; (20): 54-62.

Pareyn FGC, Araújo EDL, Drumond MA. *Mimosa caesalpiniifolia*: sabiá. Embrapa Semiárido, 2018.

Pilocelli ADM, Stangerlin DM, Pereira RL, Gatto DA, Calegari L, Pariz E, Susin F. Resistência natural das madeiras de cumaru, cedrinho e paricá submetidas a ensaios de deterioração de campo. *Ciência da Madeira* 2015; 6(1): 1-10.

Ribeiro MA, Stangerlin DM, Souza AP, Cardoso GV, Calegari L, Gatto GA. Durabilidade natural da madeira de jequitibá em ensaios de deterioração em campo aberto e floresta durante as estações de seca e chuva. *Comunicata Scientiae* 2014; 5(4): 402-411.

Romanini A, Stangerlin DM, Pariz E, de Souza AP, Gatto DA, Calegari L. Durabilidade natural da madeira de quatro espécies amazônicas em ensaios de deterioração de campo. *Nativa* 2014; 2(1): 13-21.

Sehlstedt-Persson M, Karlsson O. Natural durability and phenolic contente in dried scots pine heartwood. *BioResources* 2010; 5(2): 1126-1142.

Stallbaun PH, Barauna EEP, Paes JB, Ribeiro NC, Monteiro TC, Arantes MDC. Resistência natural da madeira de *Sclerolobium paniculatum* Vogel a cupins em condições de laboratório. *Floresta e Ambiente*, 2017; 24: e20160013.

Stangerlin DM, Costa AF, Garlet A, Pastore TCM. Resistência natural da madeira de três espécies amazônicas submetidas ao ataque de fungos apodrecedores. *Ciência da Madeira* 2013; 4(1): 15-32.

Steel RGD, Torrie JH. *Principles and procedures of statistic: a biometrical approach*. 2.ed. New York: Mc-Graw Hill, 1980. 633p.

Vivian MA, Grosskopf ÉJ, Nunes GC, Itako AT, Modes KS. Qualidade e eficiência de produtos naturais no tratamento preservativo das madeiras de *Araucaria angustifolia*, *Eucalyptus viminalis* e *Pinus taeda*. *Revista de Ciências Agroveterinárias*, 2020; 19(1): 35-47.