





Articles

Use of boric compounds in the preservative treatment of *Pinus sp.* and *Eucalyptus urophylla*

Uso de compostos bóricos no tratamento preservativo de *Pinus sp.* e *Eucalyptus urophylla*

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ABSTRACT

This study aimed to assess the effectiveness of a solution based on boric acid and sodium tetraborate in the preservative treatment of *Pinus sp.* and *Eucalyptus urophylla* wood, as well as to determine the most efficient concentration. Samples measuring 2 × 2 × 5 cm (thickness × width × length) were exposed to a vacuum of 600 mmHg in two 30-minute stages, with a 40-minute interval between them to assist the impregnation of the solution at concentrations of 2%, 3%, 4%, 5%, and 6%. The samples were tested using a colorimetric method with curcumin and a salicylic acid solution to assess compound penetration. Two termite bioassays were conducted: a feeding preference test with *Constrictotermes cyphergaster*, in which mass loss was evaluated, and a forced-feeding test with *Cryptotermes brevis*, in which both mass loss and termite mortality rate were assessed. The results showed that all solution concentrations were effective; however, it was not feasible to determine an optimal concentration.

Keywords: Boron; Termites; Eucalyptus; Mass loss; *Pinus sp.*

RESUMO

Esta pesquisa teve o objetivo de avaliar a eficácia de uma solução a base de ácido bórico e tetraborato de sódio no tratamento preservativo da madeira de *Pinus* sp. e *Eucalyptus urophylla*, e também definir a concentração que se mostrou mais eficiente. Foram utilizadas amostras de 2 x 2 x 5 cm (espessura x largura x comprimento), submetidas a um vácuo de 600 mmHg em duas etapas de 30 min cada, com intervalo de 40min entre eles para auxiliar na impregnação da solução nas concentrações de 2%, 3%, 4%, 5% e 6%. As amostras foram submetidas a um teste de colorimetria utilizando curcumina e uma solução de ácido salicílico para avaliar a penetração do composto nas amostras. Dois ensaios com térmitas, um ensaio de preferência alimentar com a espécie *Constrictotermes cyphergaster* no qual foi avaliada a perda de massa das amostras, e um ensaio de alimentação forçada com a espécie *Cryptotermes brevis* onde foram avaliadas a perda de massa e a taxa mortalidade dos cupins. Os resultados mostraram que todas as concentrações da solução foram eficientes, porém não foi possível definir uma concentração ótima.

Palavras-chave: Boro; Cupins; Eucalipto; Perda de massa; *Pinus* sp.

1 INTRODUCTION

Wood is an organic material primarily composed of cellulose, hemicellulose, and lignin, with other chemical constituents classified as extractives, which vary among species both in composition (tannins, resins, sugars, among others) and in their quantity within the wood (PAES *et al.*, 2016; SANTOS *et al.*, 2016). Because it is an organic material, wood is susceptible to attack by external agents such as termites, fungi, and beetles.

Termites are insects of the order Blattodea: Termitoidea, previously classified as Isoptera. Occurring mainly in tropical regions, nearly 3,000 species have been identified, of which about 300 are found in Brazil (CIPRIANI *et al.*, 2019). While termites play an important ecological role in nutrient cycling (BEZERRA-GUSMÃO *et al.*, 2011), they are also responsible for significant financial losses in the global timber industry (NAJJARI *et al.*, 2023).

Cryptotermes brevis is considered an urban pest, primarily because of the difficulty in identifying colonies (PIERROT *et al.*, 2022), but also because of its capacity for rapid colony spread, as young individuals can differentiate into colony founders

(JUNIOR, 2015). *Constrictotermes cyphergaster*, in turn, is endemic to Caatinga and Cerrado regions and is an arboreal species, constructing its nests in the trunks of trees or shrubs (BARBOSA-SILVA *et al.*, 2019).

Some tree species possess wood with high natural resistance to these organisms, mainly associated with the presence of extractives acting either individually or synergistically (CARVALHO *et al.*, 2015). However, not all species with commercial importance, such as eucalyptus and pine, exhibit strong natural resistance against termites, being highly susceptible to their attack (LAZAROTTO *et al.*, 2016; MODES *et al.*, 2017).

Due to the susceptibility of wood to deterioration by termite attack, protective treatments are commonly applied (BARAÚNA *et al.*, 2017). Mechanical treatment employs high temperatures to enhance material resistance (CARVALHO *et al.*, 2019), and in some cases, thermal and chemical treatments are combined, as reported by Martha *et al.* (2024).

Chromated Copper Arsenate (CCA) and Chromated Copper Borate (CCB) are traditional chemical treatments used for wood preservation (FERRO *et al.*, 2016). However, these formulations contain heavy metals such as arsenic and chromium, which are harmful to human health and the environment (ELOY *et al.*, 2025).

Therefore, the objective of this study was to evaluate the efficacy of a boron-based compound as a low-toxicity alternative treatment to increase the resistance of *Eucalyptus urophylla* and *Pinus* sp. wood against *Constrictotermes cyphergaster* and *Cryptotermes brevis* in both feeding preference and no-choice feeding assays.

2 MATERIALS AND METHODS

2.1 Chemical treatment

The material was treated with a mixture of boric acid (P.A.) and sodium tetraborate (P.A.) in a 1:1 ratio, diluted in distilled water to achieve concentrations of 2%, 3%, 4%, 5%, and 6%, where 10 g of each compound diluted in 1000 mL corresponds to 1%.

After solution preparation, each wood species was subjected to a vacuum of 600 mmHg in two 30-minute cycles, with a 40-minute interval between them. Following removal from the solution, excess liquid was wiped off the surface with paper towels, and the samples were wrapped in plastic film, remaining at rest for 15 days to facilitate boron impregnation.

2.2 Samples and Statistical Analysis

Samples measuring 2 × 2 × 5 cm (thickness × width × length) from two distinct species—*Pinus* sp. and the eucalyptus clone MN463 (*Eucalyptus urophylla*)—were employed. For each species, the solution was applied at five concentrations, with four replicates per concentration, plus a control treatment for each species, also with four replicates, totaling 48 specimens per test.

The experiment followed a completely randomized design (CRD) in a two-way factorial arrangement, with species as the first factor and solution concentration as the second, where controls were considered as 0%. Statistical analyses were performed in R® software, and significance was assessed using the F-test at the 5% level.

2.3 Colorimetry

To visually assess the efficiency of solution impregnation, the specimens were exposed to a colorimetry test, which consists of applying a salicylic acid solution (6 g salicylic acid P.A., 20 mL hydrochloric acid, and 80 mL ethanol), followed by application of a curcumin solution ($[\text{HOC}_6\text{H}_3(\text{OCH}_3)\text{CH}=\text{CHCO}]_2\text{CH}_2$) diluted according to the manufacturer's instructions. The specimens were sawn in half for the application of the solutions to the inner part.

The interaction of curcumin with boron and the salicylic acid solution gives the specimens a pinkish-red coloration, as shown in Figure 1. The specimens were then subjected to visual evaluation according to the classification used by Baraúna *et al.* (2017) and Vivian *et al.* (2020), represented in Figure 2: 1 – null penetration (no

solution penetration in the specimen); 2 – vascular penetration (solution penetrates only into the wood vessels); 3 – irregular partial penetration (only part of the specimen is penetrated); 4 – peripheral partial penetration (the entire peripheral region of the specimen is penetrated); 5 – total penetration (the entire specimen is penetrated by the solution).

Figure 1 – Specimens treated for the colorimetry test



Source: Authors (2024)

In where: Specimens after the application of the salicylic acid and curcumin solutions.

Figure 2 – Classification of specimens according to treatment penetration



Source: VIVIAN *et al.* (2020)

In where: Most common penetration patterns in wood treatability tests.

2.4 Forced-Feeding Test

For the forced-feeding test, the procedure of the Institute for Technological Research/Wood Division (IPT/DIMAD D-2, 1980) for drywood termites was adopted, with an adaptation regarding the size of the specimens used. The material was exposed during the test to the species *Cryptotermes brevis*.

The specimens were paired and joined with adhesive tape, then sealed with paraffin, and placed in polyvinyl chloride (PVC) containers with a diameter of 3.5 cm and a height of 4.0 cm. Each container contained 40 termites (39 workers and 1 soldier) arranged on a Petri dish, a device used to prevent termite escape. The specimen sets were kept in a climate-controlled room (27 ± 2 °C and $65 \pm 5\%$ relative humidity) for 45 days.

After the test, the termites were removed from the containers to count survivors and determine mortality percentage, as well as to evaluate wear using scores ranging from zero to four: 0 (no wear), 1 (superficial wear), 2 (moderate wear), 3 (severe wear), 4 (deep wear), according to the classification established by IPT/DIMAD D-2 (1980).

2.5 Feeding Preference Test

For the feeding preference test, an adaptation of the methodology used by Brocco (2019) was adopted. The specimens were oven-dried at 50 °C until reaching constant mass and then randomly arranged in a completely randomized design on an aluminum grid just below the location where the termites would be placed.

A termite colony of the species *Constrictotermes cyphergaster* was collected and transferred to a 1000 L container that already contained the previously arranged specimens (Figure 3). The container had been pre-filled with a sufficient amount of water to keep the sand moist, which was replenished daily to maintain water level and prevent termite escape.

Figure 3 – Feeding preference test



Source: Authors (2024)

In where: *Constrictotermes cyphergaster* colony in the feeding preference test.

The test was observed for 40 days until termite activity completely ceased. After removal from the container, the specimens were washed under running water to remove any residues that could affect the material's weight. Subsequently, all specimens were oven-dried again at 50°C until reaching constant mass to assess mass loss.

3 RESULTS AND DISCUSSIONS

Table 1 presents the scores assigned in the colorimetry test following the standard of Figure 1, with observed results ranging from 3 – Irregular partial penetration to 5 – Total penetration, indicating good solution penetration in the specimens after vacuum treatment. However, it is important to emphasize that the colorimetry test is a visual assessment, and solution retention by the specimen may vary, as reported by Amaral *et al.* (2014).

Table 1 – Colorimetry evaluation scores

	AV.1	AV.2	AV.3	AV.4	AV.5	AV.6	MEAN	O. MEAN
MN1	3	5	4	4	4	5	4,2	4,1
MN2	4	5	3	4	3	5	4,00	
PN1	3	4	4	3	3	5	3,7	3,75
PN2	3	4	4	3	4	5	3,8	

Source: Authors (2025)

In where: Evaluators' scores for colorimetry efficiency according to the ratings in Figure 2. MN – *Eucalyptus urophylla*, PN – *Pinus* sp., AV – Evaluator, MEAN – Mean, O. MEAN – Overall mean.

Table 2 shows the mass loss values, expressed as percentages, for the species subjected to the forced-feeding test. Overall, the treatments exhibited very low mass loss percentages, ranging from 0% to 0.2% when considering individual specimens of each species, and from 0.06% to 0.13% when considering the mean values of specimens from both species.

Table 2 – Mass loss in percentage

Species	2%	3%	4%	5%	6%	Control
MN	0,20a	0,11a	0,11a	0,18a	0,17a	0,42a
PN	0,07a	0,05a	0,03a	0,09a	0a	0,26a
Mean	0,13a	0,07a	0,06a	0,13a	0,08a	0,34a

Source: Authors (2025)

In where: Mass loss of specimens in percentage after the forced-feeding test. Identical letters indicate statistically similar results, while different letters indicate statistically distinct results. MN – *Eucalyptus urophylla*, PN – *Pinus* sp.

However, the controls also exhibited low mass loss at the end of the test, with a mean percentage of 0.34%, not differing statistically from the mean values of the treated specimens. Since no statistical variation was observed, it was not feasible to attribute the low mass loss to the treatments, thus preventing the determination of an ideal solution concentration for specimen treatment.

Table 3 presents the termite mortality results expressed as percentages. It can be observed that all specimens subjected to any of the boron-based solution treatments

exhibited a high termite mortality rate, with the mean percentages for all treatments exceeding 90% mortality.

Table 3 – Termite mortality in percentage

Species	2%	3%	4%	5%	6%	Control
MN	91,25b	88,75b	97,50a	97,50ab	97,50ab	40,00c
PN	90,00ab	95,00ab	91,25ab	86,25ab	95,00a	65,00b
Mean	90,63a	91,88a	94,38a	91,88a	96,25a	52,50b

Source: Authors (2025)

In where: Termite mortality rate in the forced-feeding test. Identical letters indicate statistically similar results, while different letters indicate statistically distinct results. MN – *Eucalyptus urophylla*, PN – *Pinus* sp.

Statistically, the means of the different solution concentrations did not differ from each other, with only the controls showing a difference compared to the treated specimens, exhibiting a mortality rate of 52.5%. This represents a difference of nearly 40% compared to the lowest mean among the treatments, which was 90.6% for the 2% solution treatment.

Table 4 presents the mass loss values, expressed as percentages, for the species subjected to the feeding preference test. It can be observed that the treatment using the 2% concentration was statistically similar to the other treatments and the control, differing only from the 6% treatment, which was also statistically similar to the remaining treatments and the controls.

Table 4 – Mass loss in percentage

Species	2%	3%	4%	5%	6%	Control
MN	1,34a	1,54a	1,61a	1,50a	1,96a	1,77a
PN	1,40b	1,74ab	1,50ab	1,78c	1,81c	1,05a
Mean	1,37b	1,64ab	1,55ab	1,64ab	1,88a	1,41ab

Source: Authors (2025)

In where: Mass loss of specimens in percentage after the feeding preference test. Identical letters indicate statistically similar results, while different letters indicate statistically distinct results. MN – *Eucalyptus urophylla*, PN – *Pinus* sp.

However, the mass variation observed throughout the experiment cannot be attributed to the treatments. There is an apparent tendency for the controls to exhibit higher mass loss in the forced-feeding test, but no statistical variation was observed among the means in this test, as well as in the feeding preference test, where no variation was detected either.

Regarding the feeding preference test, the probable reason for the lack of variation was the drying of the specimens at 50 °C, following the adaptation of Brocco (2019). Since the specimens failed to reach a fully dry mass during the drying period, i.e., they did not lose all their water, they may have been more easily influenced by ambient humidity.

This differs from the preparation for the forced-feeding test, where the methodology involved drying at temperatures above 100 °C, thus removing all water from the specimens in both drying steps (before and after the test) and consequently eliminating the influence of humidity on mass loss.

This hypothesis is supported by the results of Brocco (2019), in which an untreated material also showed a tendency for higher mass loss, with some controls being completely consumed by termites.

The results presented in Table 5, regarding wear scores for specimens in both the feeding preference and forced-feeding tests, further reinforce that the treatments did not influence mass differences. A higher mean wear score can be observed in the controls of the forced-feeding test, whereas in the feeding preference test, almost no wear was observed in either treated specimens or controls.

Table 5 – Evaluation of specimen wear

Test	Species	2%	3%	4%	5%	6%	Control
Feeding preference	MN	0,6	0,8	0,6	0,4	0,4	0,2
	PN	0,2	0,4	0,4	0,6	0,2	0,4
Forced-feeding	MN	1,1	1,0	1,1	1,3	1,1	3,1
	PN	1,2	1,1	1,1	1,0	0,8	2,4

Source: Authors (2025)

In where: Wear scores for the specimens after both tests. MN – *Eucalyptus urophylla*, PN – *Pinus* sp.

4 CONCLUSIONS

The colorimetry test showed that the vacuum treatment was effective in impregnating the preservative solution. From the evaluation of termite mortality in the forced-feeding test, it was statistically confirmed that the use of the solution increased termite mortality rates.

Although the feeding preference test indicated that the ideal treatment concentration is 6%, with the other concentrations showing results similar to the control, it is not possible to directly attribute mass loss to the treatments because to the different drying temperatures used.

Therefore, the results demonstrate the overall effectiveness of the treatment; however, it was not feasible to define the optimal solution concentration. For future studies, it is recommended to use more replicates per treatment, include a field-based feeding preference test, and evaluate other commercially important species to observe the behavior of the boron compound in conferring resistance against termites.

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