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Evaluation of Naturally Grown Termite Resistant Tropical Wood Species

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Selecting termite resistant wood species for household and construction purposes can guarantee their durability and reduce the pressure on forest resources. The objective of this study was to evaluate the resistance of selected tropical wood species to termite attacks in a natural environment. For this evaluation, 100 wood specimens were cut to 20 cm length, 2.5 cm thickness, and 5 cm width and placed in an open field. Each wood sample was partially inserted into the ground to a depth of 10 cm, and the remaining part was kept above the ground for visibility and handling purposes during the sampling period. Wood density analyses were simultaneously carried out in the laboratory using wood specimens of equal length (2 cm), thickness (2 cm), and width (2 cm). The results indicated that species such as *Terminalia superba* and *Hallea ciliata* had the highest mean weight loss of 57.62% and 30.27%, respectively, and were highly susceptible to termite attacks compared to *Terminalia ivorensis*, *Lophira alata*, and *Heritiera utilis*, which were very resistant with only mean weight losses of 0.29%, 0.78%, and 0.81%, respectively. Some wood species, such as *Terminalia superba*, *Piptadeniastrum africanum, Terminalia ivorensis,* and *Hallea*

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ciliata exhibited low density, whereas *Lophira alata*, *Nauclea diderrichii*, and *Tetraberlinia tubmaniana* displayed high density. A significant correlation (r = -0.79, p < 0.001) was observed between the weight loss and the density of the selected wood species. It was noted that variations in termite resistance were primarily attributed to wood density.

Keywords: Density; resistance; species; termite; tropical; wood.

1. INTRODUCTION

Wood is among the most important and versatile natural resources, cherished for its distinctive qualities and widespread availability [1]. Its utility extends to countless everyday items, from solid wood structures to wood pulp and various wood-derived chemicals. Notably, wood remains a popular choice over competing materials such as steel, aluminum, brick, concrete, plastics, glass, and ceramics, owing to its numerous advantages. Moreover, it stands out as a renewable resource with environmental friendly properties, setting it apart from its rivals. However, wood faces a significant challenge known as bio-deterioration, which diminishes its lifespan [2].

Bio-deterioration represents a critical factor influencing consumers' preference for wood over alternatives like steel and concrete. Consequently, research has been spurred to explore the inherent resilience of various local commercial wood species [3]. Natural resistance, in this context, refers to a wood species' inherent ability to ward off bio-deterioration without the need for artificial preservatives. This resistance often arises from the presence of extractives in the heartwood region [4]. Notably, even among hardwood species, the sapwood of all known trees remains highly susceptible to decay unless thoroughly removed [5].

The natural durability of wood, which quantifies its ability to withstand the onslaught of biodegradation agents, is a dynamic characteristic that undergoes transformation as trees mature and their central wood cells evolve into heartwood [6]. Within this diverse spectrum of wood species, some display only mild resistance to insect attacks, making them vulnerable to the relentless appetite of termites, while others boast robust heartwood laden with potent natural compounds that act as an effective deterrent against termite infestations [7]. In this intricate dance of adaptation and evolution, the intricate interplay between tree species and the natural environment dictates the degree of protection that wood can offer against the relentless forces of bio-deterioration. These varying levels of resistance underscore the importance of exploring and identifying wood species with superior termite resistance, as they hold the key to enhancing the longevity and sustainability of wood-based products in an ever-growing world that relies on wood for diverse applications.

In tropical and subtropical regions, termites are the primary pests of wood and wood products [8]. Wood serves as their main source of sustenance, and the susceptibility of wood to termite infestation depends on several factors, including hardness, temperature [9], moisture content, wood decay from fungi, allelochemicals in the wood [10], and wood density [11]. Many wood species have evolved their own chemical defenses (extractives) to repel invaders, particularly in regions without a frost season to naturally control insect populations [12].

As the global population continues to grow, the demand for wood-based products rises exponentially [13]. Consequently, numerous tree species utilized for various purposes face increasing threats [14]. Liberia, for example, relies heavily on wood and wood products for applications like fencing, household furniture, and building and construction facilities. However, termite damage poses a substantial economic burden on the country. Despite the significance of termite resistance, information on termite-resistant wood species is lacking. Therefore, the objective of this study was to evaluate wood species with natural termite resistance, laying the foundation for quality grading options and sustainable forest management practices.

2. MATERIALS AND METHODS

2.1 Wood Species Selection and Preparation

Ten potential wood species (*Tetraberlinia tubmaniana, Petersianthus macrocarpus, Terminalia superba, Piptadeniastrum africanum, Nauclea diderrichii, Lophira alata, Terminalia* *ivorensis, Hallea ciliata, Heritiera utilis,* and *Milicia regia*), commonly used in Liberia for fencing, household furniture, and building and construction, were selected for this study. A total of one hundred wood samples (10 from each species) were collected from representative sawmills and wood workshops throughout the country Liberia. During data collection, samples were properly labeled for identification purposes. Following Hadi et al. [15], samples were cut to 20 cm in length, 2.5 cm in thickness, and 5 cm in width to get similar sizes and labeled accordingly. The initial weight of the samples was then recorded using a precision electronic balance (0.00 g) in the laboratory.

2.2 Termite Resistance Test

The field experiment was conducted at the College of Agriculture and Sustainable Development, Cuttington University, Liberia, field experiment site. It was laid out on a plot of 16 m^2. Wood samples with the stated dimensions were installed at a 30 x 30 cm interval. Each wood sample was partially inserted into the ground to a depth of 10 cm, and the remaining part was kept above the ground for visibility and handling purposes during the sampling period. In every two-month interval, the wood specimens were taken out, carefully cleaned, air dried overnight, and weighed and recorded before they were taken back to the field. This procedure was repeated for a total of eight months.

2.3 Wood Density Test

Wood specimens of equal length (2 cm), thickness (2 cm), and width (2 cm) were cut from each of the selected wood species (100 samples) used in the termite resistance test. The initial weight of each sample was recorded before it was placed in an oven. Then, in order to remove the moisture content present within the wood, samples were placed in an oven at 105 °C until their weight became constant. Finally, the oven dry weight of each wood sample was determined by dividing the dry weight of the sample by its initial volume.

2.4 Data Analysis

Weight loss was computed as follows:

Weight loss = $(W_1\text{-}W_2)/(W_1)$ *100 Equation (1)

Where W_1 = weight of sample prior to the test (g) and W_2 = weight of sample after the test (g) following Hadi et al. [15] procedures. An analysis of variance (ANOVA) was conducted to determine if significant differences existed among the wood species in terms of their density and weight. Means were separated using the Tukey-Kramer HSD test at a significance level of 5% alpha. Resistance to termites was assessed using the standard model (resistance class against subterranean termites) developed by Tsunoda et al. [16] (Table 1). Pairwise correlation analysis was conducted using Pearson's product-moment correlation coefficient to examine potential relationships between the laboratory density test outcomes and the field termite resistance test results. All the statistical analyses were performed using SAS JMP Pro 14 software.

3. RESULTS

3.1 Termite Resistance Test

While wood is known to be susceptible to termite degradation, this study revealed notable variations in termite resistance among different wood species. For instance, *Terminalia superba* and *Hallea ciliata* displayed high susceptibility to termite attacks, resulting in the highest mean weight losses of 57.62% and 30.27%, respectively. In contrast, *Terminalia ivorensis*, *Lophira alata*, and *Heritiera utilis* exhibited remarkable resistance, falling into class I (very resistant) with mean weight losses of only 0.29%, 0.78%, and 0.81%, respectively (as shown in Table 2). The overall ranking of termite resistance among the selected wood species was as follows: *Terminalia ivorensis* > *Lophira alata* > *Heritiera utilis* > *Petersianthus macrocarpus* > *Nauclea diderrichii* > *Piptadeniastrum africanum* > *Milicia regia* > *Tetraberlinia tubmaniana* > *Hallea ciliata* > *Terminalia superba*.

Table 1. Resistance class against subterranean termites

Resistance class	Classification	Mass loss (%)
I	Very resistant	<3.52
II	Resistant	3.52 – 7.50
III	Moderate	7.50 – 10.96
IV	Poor	10.96 – 18.94
V	Very poor	> 18.94

Table 2. Weight loss and resistance class of the selected wood species

Wood species	Weight loss (g)	Weight loss (%)	Resistance class
Hallea ciliata	30.27^{b*}	23.37	V
Heritiera utilis	1.17^{d}	0.81	I
Lophira alata	1.82^{d}	0.78	I
Milicia regia	5.56^{cd}	3.35	I
Nauclea diderrichii	3.94^{cd}	2.72	I
Petersianthus macrocarpus	3.04^{cd}	1.80	I
Piptadeniastrum africanum	5.14^{cd}	3.32	I
Terminalia superba	58.86^{a}	57.62	V
Terminalia ivorensis	0.41^{d}	0.29	I
Tetraberlinia tubmaniana	8.44^{c}	4.87	II

**Levels not connected by the same letters are significantly different.*

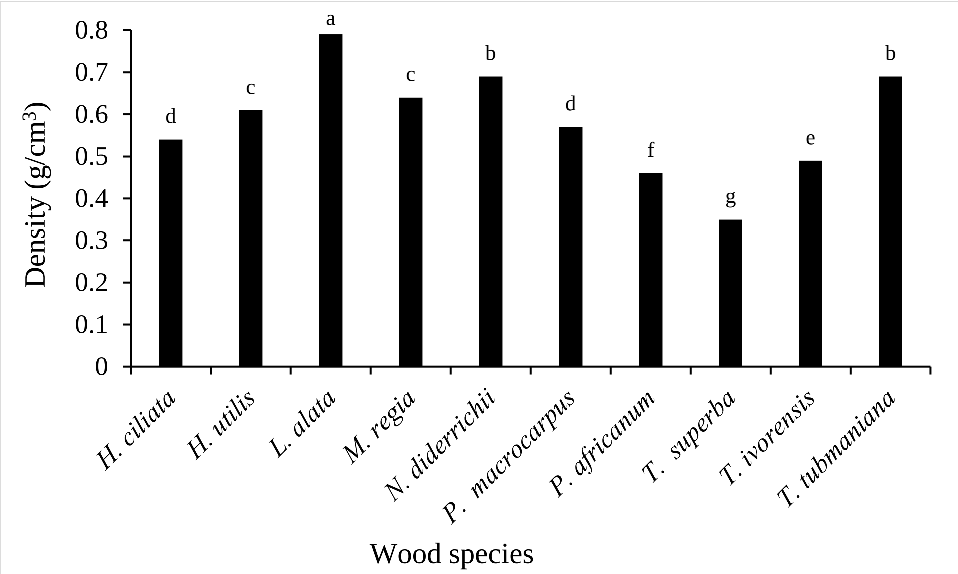

Fig. 1. Wood density (g/cm^3) comparative analysis of the selected ten wood species

3.2 Wood Density Test

The density analysis for the selected species was conducted separately in the laboratory, yielding results that revealed variations in wood density. Notably, wood species such as *Terminalia superba* (0.3 g/cm^3), *Piptadeniastrum africanum* (0.46 g/cm^3), *Terminalia ivorensis* (0.49 g/cm^3), and *Hallea ciliata* (0.54 g/cm^3) exhibited lower density in comparison to *Lophira alata* (0.79 g/cm^3), *Nauclea diderrichii* (0.69 g/cm^3), and *Tetraberlinia tubmaniana* (0.69 g/cm^3), which displayed higher density levels (as illustrated in Fig. 1).

3.3 Correlation between Wood Density and Termite Resistance

A correlation analysis was conducted to investigate the presence of any significant relationship between the weight loss and the density of the selected wood species. The results from the field were found to be consistent with the laboratory findings, indicating a significant negative correlation (r = -0.79, $p < 0.001$). The variations in termite resistance properties among the selected wood species were directly associated with the laboratory results, revealing that the sensitivity of the wood species to termite attacks decreased as density increased. This phenomenon was particularly evident in species such as *Terminalia superba* and *Lophira alata*.

4. DISCUSSION

4.1 Termite Resistance Test

As illustrated in Table 2, wood species such as *Hallea ciliata* and *Terminalia superba* proved to be significantly more susceptible to termite attacks than the others. Within the initial two months of the study, these two wood species had already incurred considerable termite damage, particularly to the portion that had been pegged into the soil. This outcome can be attributed to the fact that termites exhibit selective feeding habits and tend to target species they have more frequent contact with. This finding aligns with the results of Costa et al. [17], who noted similar preferences among termites for specific wood types.

In a study conducted by Lopez et al. in [18], the researchers explored the feeding patterns of termites and their implications for the evolutionary trajectories of different species. Termites are known for their diverse feeding habits, and these patterns can vary not only within a particular group of termites but also across different groups. Understanding these feeding patterns is crucial for comprehending how termites interact with various types of wood and how this interaction can impact the evolution of both termites and the wood species they consume.

One significant finding of their experiment was related to the resistance of different types of wood to termite attacks. The researchers assessed the mass loss of various wood specimens subjected to termite feeding. The results indicated that majority of the woods tested naturally exhibited a high level of resistance (classified as class I) against termite attacks. This suggests that many wood species have developed defenses or characteristics that make them less susceptible to termite damage.

However, the study also highlighted some exceptions to this trend. Specifically, two wood species, *Hallea ciliata* and *Terminalia superba*, stood out as being particularly vulnerable to termite attacks. These woods exhibited the highest percentage of mass loss when exposed to termites. This finding underscores the variability in termite-wood interactions, with some woods proving to be more susceptible to termite damage than others. Such insights are valuable for understanding the complex ecological relationships between termites and the plant species they feed on, shedding light to the broader evolutionary dynamics within ecosystems.

4.2 Wood Density Test

In this specific study, we measured the density values of the selected wood species, which ranged from 0.3 g/cm³ to 0.79 g/cm³. A similar density value (0.79 g/cm³) was reported by Pereira et al. [12], who stated this value as resistant to termite attacks. This measurement is crucial because wood density plays a vital role in determining its resistance to termite attacks. This finding aligns with the idea that wood properties, including dimensional stability, strength, and durability, are significantly affected by wood density, as highlighted by Costa et al. [17].

Furthermore, Stallbaun et al. [7] proposed that high-density wood tends to impede termites' ability to splinter the wood, making it more challenging for them to consume. This observation underscores the role of wood density as a critical factor in determining termite resistance. However, it's essential to recognize that assessing natural resistance involves considering not only wood density and the quantity of chemical extractives but also their chemical composition and their effects on various wood-consuming species, as emphasized by Marcondes et al. [19]. This indicates that while wood density is a significant factor, a comprehensive evaluation of termite resistance must also take the specific chemical attributes of the wood and how they interact with various termite species into account [20,21].

4.3 Correlation between Wood Density and Termite Resistance

The laboratory results, which demonstrated that the susceptibility of wood species to termite attacks decreased with increasing density, directly correlated with variations in the termite resistance abilities of the selected wood species. This observation aligns with the findings of Oberst et al. [22], who emphasized that wood's susceptibility to termite attacks diminishes as density rises, with natural durability being a pivotal factor contributing to wood quality and being partly linked to density. Similar results were corroborated by Owoyemi et al. [5], and Roszaini et al. [10], all of whom underscored that higher wood density leads to greater resistance against termite attacks.

In specific wood species like *Hallea ciliata* and *Terminalia ivorensis*, the study found no significant correlation between wood density and weight loss when exposed to termite attacks. Surprisingly, the results displayed random variations, indicating that, wood density did not seem to be a reliable indicator of termite resistance in these particular cases. This observation aligns with the findings of a study conducted by Alencar et al. [20], which reported a similar lack of correlation between mass loss and wood density in Sabiá (*Mimosa caesalpiniifolia*) wood. Interestingly, the study by Alencar and colleagues did differentiate between different phenotypes of Sabiá wood, considering the presence or absence of aculei, as well as the wood's position along the pith-to-bark direction, which may have contributed to the variable results.

Another study by Peralta et al. [21] also failed to establish a significant relationship between wood density and termite resistance in their investigation of termite consumption rates among various forest species' wood under field conditions. While these studies suggest that wood density alone cannot be considered the sole determinant of termite resistance, they did acknowledge the importance of wood hardness as a potential deterrent to termite damage. This highlights the complexity of factors that influence termite-wood interactions, indicating that while wood density plays a role, other characteristics such as wood hardness should also be taken into account when assessing termite resistance in different wood species.

5. CONCLUSION

Termites inflicted severe damage on wood species such as *Terminalia superba* and *Hallea ciliata*, while *Terminalia ivorensis*, *Lophira alata*, and *Heritiera utilis* exhibited strong resistance to termite attacks. A robust negative correlation (r = -0.79) was evident, underscoring that the susceptibility of wood species to termite attacks decreased with increasing density. Wood species that demonstrate resistance to termite attacks hold significant potential for outdoor applications in harsh environmental conditions and regions prone to various fungi or termite infestations. Considering the aforementioned points, this study has emphasized the importance of wood species' resistance to bio-deterioration and degradation. This knowledge is invaluable for informed decision-making among consumers, suppliers, and policymakers involved in reforestation efforts and the overall maintenance of a sustainable environment.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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