

Assessment of Natural Durability and Biodeterioration Resistance in Two Fast-Growing Tropical Tree Species: A Comparative Study of *Acacia mangium* and *Leucaena leucocephala*

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Abstract

This study compared the natural durability and termite resistance of wild small-diameter *Acacia mangium* and *Leucaena leucocephala* wood under tropical field conditions. Specimens (30 cm × 2.5 cm) were exposed for 12 weeks in a graveyard test following ASTM D1758-06 standards at the Universiti Malaysia Kelantan (UMK) Jeli Campus. Decay and termite damage were assessed through visual ratings, weight loss analysis, and termite identification. Results showed that *A. mangium* exhibited significantly lower weight loss (30.54%) than *L. leucocephala* (51.95%) ($p < 0.05$), indicating higher natural resistance. The dominant termite species identified was *Coptotermes curvignathus* Holmgren. The superior durability of *A. mangium* is attributed to its higher content of extractives such as tannins and phenolics that inhibit fungal and termite activity. Findings classify *A. mangium* as moderately durable (Class II–III) and *L. leucocephala* as less durable (Class III–IV), emphasizing the need for preservative treatment in tropical applications.

Keywords: *Acacia mangium*; *Leucaena leucocephala*; natural durability; termite resistance; biodeterioration

1 Introduction

Acacia mangium and *Leucaena leucocephala* are exotic species that have become well established in Malaysia. Originally introduced for reforestation purposes, both species have demonstrated remarkable adaptability and resilience, leading to their classification as invasive species in certain regions (Rasat et al., 2016a; 2016b). *Acacia mangium* belongs to the subfamily Mimosoideae of the Fabaceae family and is native to Indonesia, Papua, Western Irian Jaya, the Maluku Islands, Papua New Guinea, and north-eastern Queensland in Australia (Pinyopusarerk, 1993). It is a fast-growing tropical species capable of reaching up to 30 m in height and 50 cm in diameter under optimal conditions.

Ecologically, *A. mangium* thrives at the margins of rainforests, open forests, and woodlands, particularly in areas affected by fire, where soils tend to be acidic and nutrient-poor. It also grows well on well-drained hillsides and lowlands, and even in moderately drained coastal plains (Krisnawati et al., 2011). Due to its wide adaptability to marginal soils,

approximately one-third of the world's land area is considered suitable for its cultivation. Southeast Asia hosts a large proportion of tropical acacia plantations, covering around 2 million hectares (Midgley & Turnbull, 2003).

The growing demand for *A. mangium* wood, driven by its multiple industrial applications, has stimulated large-scale plantation development in countries such as Indonesia and Malaysia, primarily for pulp and paper production. Its commercial planting is also expanding in China, the Philippines, Thailand, and Vietnam. The species has been introduced widely across Asia including Bangladesh, China, Taiwan, India, Laos, Sri Lanka, and Thailand as a plantation tree (Hegde et al., 2013). Its wood is valued for sawn timber, veneer, woodchips, fuelwood, pulp, and paper products. Anatomically, *A. mangium* exhibits non-septate fibers, vasicentric and aliform axial parenchyma, and predominantly uniseriate rays. The wood is diffuse-porous, with solitary or radially grouped vessels and prismatic crystals within the axial parenchyma. Although the wood contains relatively fewer vessels and thinner cell walls, these characteristics collectively indicate favorable wood quality. In general, many Australian *Acacia* species exhibit invasive traits, with at least 23 species identified as invasive worldwide (Gibson et al., 2011).

Conversely, *L. leucocephala* gained recognition during the 1970s and early 1980s as a “miracle tree” due to its high nutritional value as a forage tree and its broad range of applications (Brewbaker et al., 1989). Commonly known as the white lead tree or *ipil-ipil*, *L. leucocephala* is native to Central America and has naturalized across tropical and subtropical regions between 30°N and 30°S. It is frequently cultivated as a shade tree for coffee, cocoa, pepper, vanilla, and hemp plantations (De Angelis et al., 2021).

This hardy shrub or small deciduous tree thrives under humid tropical conditions and is distinguished by bipinnate leaves with numerous small grey-green leaflets (Amini et al., 2017a). Its fodder value was recognized more than 400 years ago in Central America and the Yucatan Peninsula, and it was subsequently introduced to the Philippines by Spanish explorers as livestock feed (Brewbaker et al., 1987). From there, it spread widely across tropical regions and was later introduced to Australia, where it became naturalized in parts of northern Australia by the early 20th century (Brewbaker, 2016).

Both *A. mangium* and *L. leucocephala* are economically and ecologically valuable due to their wide range of applications. *A. mangium* produces high-quality wood with a smooth and lustrous surface, suitable for premium flooring and furniture production (Sharma et al., 2011). It is also utilized in animal feed, fiber production, and tannin extraction (Orwa et al., 2015). Similarly, *L. leucocephala* is used for reforestation, animal fodder, construction poles, firewood, pulp production, and traditional medicine (Oliva et al., 2000).

Despite their versatility, the durability of wild small-diameter *A. mangium* and *L. leucocephala* wood has not been comprehensively evaluated. In humid tropical environments, unprotected wood is highly susceptible to degradation caused by fungal and bacterial activity under prolonged exposure to moisture and oxygen (Sell & Feist, 1986). Water plays a pivotal role in these deterioration processes through combined biological, chemical, and physical mechanisms. However, there remains a paucity of scientific data on the natural durability and termite resistance of these two species, particularly for small-diameter wild-grown wood.

This knowledge gap limits the effective utilization of *A. mangium* and *L. leucocephala* in industries such as construction, furniture manufacturing, and other wood-based sectors. A deeper understanding of their resistance to biological degradation, particularly termite attack, is essential to assess their suitability as sustainable alternatives to conventional wood species. Evaluating their comparative performance under natural exposure conditions will provide crucial insights for developing treatment methods, utilization standards, and best management practices for sustainable wood resource use.

Therefore, this study aims to evaluate and compare the durability properties of wild small-diameter *A. mangium* and *L. leucocephala* wood. The findings from this study are expected to contribute to improved understanding of the natural durability of these species, facilitate their optimal utilization, and promote sustainable forest resource management in tropical regions.

2 Materials & Methods

2.1 Sampling location and specimen collection

Wood samples of *A. mangium* and *L. leucocephala* were collected from natural stands located near the Faculty of Earth Science, Universiti Malaysia Kelantan (UMK) Jeli Campus, Kelantan, Malaysia (5°44'15"N, 101°51'47"E). Small-diameter logs with diameter at breast height (DBH) around 10–15 cm were harvested from healthy trees and processed into test specimens (30 cm × 2.5 cm). All samples (10 replicates) were air-dried to approximately 12% moisture content before testing, following ASTM D 143-94 (2000).

2.2 Field exposure (graveyard test)

The durability assessment was conducted through a graveyard test at an outdoor site within UMK Jeli Campus. Each specimen was buried vertically, with half of its length (15 cm) below ground and the remaining half above ground randomly. The soil was clay loam, moderately drained, with a pH of 5.0–6.0. Specimens were exposed for 12 weeks (March to May), consistent with ASTM D 2017-05 (2005) which is standards for evaluating the resistance of wood to subterranean termite attack under field conditions. The local tropical climate, characterized by temperature (24.7 – 25.5 °C), high humidity (81 – 85%) and rainfall (129 – 232 mm), provided optimal conditions for natural decay and termite activity.

2.3 Assessment of decay and termite attack

After 12 weeks, specimens were retrieved, cleaned, and visually rated for decay and termite damage using the ASTM D 1758-06 (2006) five-point scale as shown in Table 1.

Table 1: Class and visual rating for decay and termite damage by ASTM D 1758-06

Class	Rating	Condition	Description
I	10	Sound	No visible attack or decay
II	9 - 7	Slightly attacked	Superficial attack or minor surface degradation
III	6 - 4	Moderately attacked	Penetration or moderate decay in localized areas
IV	3 - 1	Severely attacked	Structural failure or heavy decay
V	0	Destroyed	Specimen completely decayed or disintegrated

The percentage of weight loss was calculated to quantify the degree of deterioration using Equation (1).

$$\text{Weight Loss, } WL (\%) = \frac{W1 - W2}{W1} \times 100 \quad (1)$$

Where,

W1 = conditioned weight before exposure to decay and termites (g)

W2 = conditioned weight after exposure to decay and termites (g)

2.4 Termite identification

Termites found during the test were collected, preserved in 70% ethanol, and identified using taxonomic keys (Tho & Kirton, 1992; Vellupillai & Ab Majid 2024). The dominant species were documented and photographed for verification.

2.5 Data analysis

Data were analysed using IBM SPSS Statistics (Version 27). A paired samples *t*-test was used to compare mean weight loss between species, with statistical significance set at $p < 0.05$.

3 Results and Discussion

3.1 Visual assessment and decay classification

Both species exhibited degradation after 12 weeks of field exposure (Figure 1). *Acacia mangium* specimens showed minor surface decay, while *L. leucocephala* suffered moderate to severe deterioration, including termite tunnelling. Based on visual ratings, *A. mangium* averaged 7.8 (slightly attacked), while *L. leucocephala* averaged 5.2 (moderately attacked). The superior performance of *A. mangium* may be attributed to the presence of extractives and polyphenolic compounds that confer antifungal and antitermitic properties (Olaga et al., 2024).



Figure 1: Wood condition after undergoing 12 weeks of graveyard test

The classification of natural durability for tropical species generally places *A. mangium* within the moderately durable category, consistent with previous reports (Krisnawati et al., 2011; Yahya et al., 2023). In contrast, *L. leucocephala* tends to fall within the less durable range, making it more vulnerable to biological deterioration under humid tropical conditions.

3.2 Weight loss and durability performance

Weight loss analysis revealed significant differences in the durability performance between *A. mangium* and *L. leucocephala* following exposure to fungal and termite degradation. *Acacia mangium* exhibited an average weight reduction of 30.54%, whereas *L. leucocephala* experienced a markedly higher loss of 51.95% (Figure 2). These results indicate that *A. mangium* possesses greater natural resistance to biodeterioration, consistent with its moderate durability classification reported in earlier studies (Wong et al. 2005).

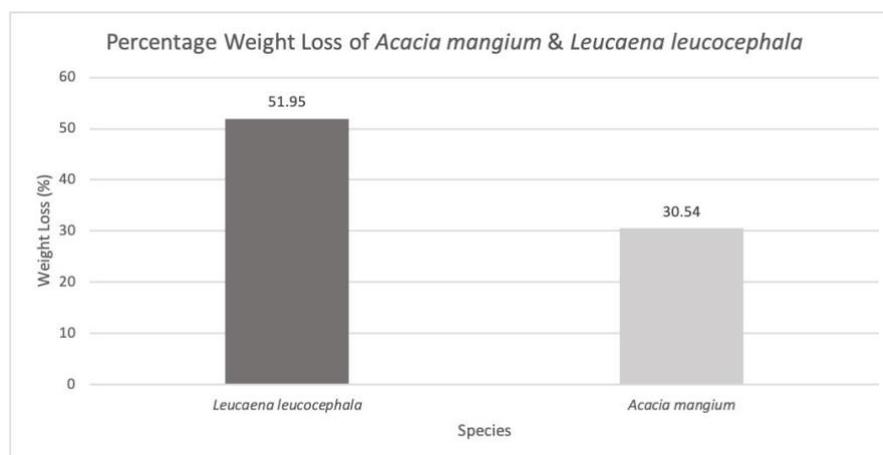


Figure 2: Percentage weight loss of *A. mangium* and *L. leucocephala*

The lower weight loss observed in *A. mangium* compared to *L. leucocephala* may be attributed to its presence of heartwood extractives such as tannins, lignin, and phenolic compounds likely contribute to its inhibitory effect against fungal and termite activity (Wong et al. 2005; Amini et al., 2017b). In contrast, the lack of strong natural protective chemicals of *L. leucocephala* facilitates rapid colonization by decay organisms, leading to accelerated decomposition and higher mass loss (Oliva et al. 2000; Amini et al., 2017a). These findings corroborate previous observations by Wong et al. (2005) and Kim & Singh (2016), who reported comparable patterns of deterioration among fast-growing tropical hardwoods under natural field exposure.

Statistical analysis using a paired t-test confirmed that the difference in mean weight loss between the two species was significant ($t = 2.413$, $p = 0.002$) (Table 2). This finding further supports the conclusion that *A. mangium* exhibits superior durability and structural stability compared to *L. leucocephala* when exposed to biodeterioration conditions.

Table 2: Paired t-test results comparing weigh loss between *A. mangium* and *L. leucocephala*

Source	Mean difference	Std. deviation	t	p-value
Species	21.408	0.01	2.413	0.002*

Note: * = significant at 95% confidence level.

3.3 Termite and Fungal Resistance

The natural durability of *A. mangium* and *L. leucocephala* exhibited clear variation in resistance to termite and fungal degradation. *Acacia mangium* demonstrated moderate natural resistance to termite attack, commonly classified within durability class II–III under tropical timber standards (Koutika & Richardson, 2019). The moderate resistance of *A. mangium* is primarily attributed to the presence of extractive compounds, particularly tannins and phenolics, which can inhibit termite feeding activity and reduce fungal colonization (Yahya et al., 2023). The higher lignin content further enhances dimensional stability and reduces water permeability, indirectly minimizing fungal colonization.

In contrast, *L. leucocephala* exhibited lower durability (class III–IV) and was more susceptible to termite infestation despite its higher wood density (Brischke et al., 2013; Kadir & Hale, 2019). This higher susceptibility is likely associated with its relatively high starch content and limited concentration of defensive secondary metabolites, which attract xylophagous organisms. Similarly, *L. leucocephala* presented low resistance to fungal decay, especially under conditions of high humidity or soil contact. The species' limited amount of decay-inhibiting extractives and higher nutrient content in the heartwood accelerate biodeterioration processes. Consequently, the wood's physical and chemical characteristics make it inherently less durable under prolonged field exposure.

In comparison, *A. mangium* exhibited greater resistance to brown-rot and white-rot fungi, attributed to its higher phenolic and flavonoid content that can inhibit fungal enzymatic degradation of lignocellulosic components (Koutika & Richardson, 2019). Although *A. mangium* performed better overall, both species cannot be considered highly durable under tropical exposure conditions. Hence, preservative treatments such as boron or copper–chrome–arsenate (CCA) impregnation are recommended to enhance service life and structural reliability, particularly for outdoor and ground-contact applications. The degradation patterns observed in this study reaffirm that durability is species-specific, governed by the unique anatomical and chemical composition of each species rather than environmental factors alone (Hillis, 2012).

3.4 Termite Species and Infestation Patterns

The primary termite species identified from the site belonged to the genus *Coptotermes* (Family Rhinotermitidae) (Figure 3), known for their aggressive subterranean foraging and high destructive potential on wood materials. *Coptotermes curvignathus* Holmgren was the most frequently encountered species, consistent with previous observations in Peninsular Malaysia (Tho & Kirton, 1992). Figure 4 shows the condition of the wood stakes after 12 weeks attacked by *Coptotermes curvignathus*.



Figure 3: *Coptotermes curvignathus* Holmgren



Figure 4: Condition of the wood stakes after 12 weeks attacked by *Coptotermes curvignathus*

The attack patterns indicated that *Coptotermes* species preferred the softer and more permeable *L. leucocephala* wood, leading to deep tunnelling and complete destruction in several specimens. Conversely, termite penetration in *A. mangium* was largely confined to the outer sapwood layers, with the core remaining intact. This suggests that the chemical resistance of *A. mangium* reduce termite feeding preference, aligning with findings by Wong et al. (1998) and Grace et al. (1998).

4 Conclusion

This study provides a comparative evaluation of the natural durability and termite resistance of wild small-diameter *A. mangium* and *L. leucocephala* wood under tropical field conditions. Both species were susceptible to biodeterioration; however, *A. mangium* exhibited superior resistance to fungal decay and termite attack compared with *L. leucocephala*. The mean weight loss of *A. mangium* (30.54%) was significantly lower than that of *L. leucocephala* (51.95%) ($p < 0.05$), indicating greater structural stability and slower degradation. The predominant termite species identified was *Coptotermes curvignathus* Holmgren, a highly destructive subterranean termite common in Malaysian soils.

The enhanced durability of *A. mangium* is attributed to its higher content of protective extractives, particularly tannins, phenolics, and lignin that inhibit microbial and termite activity. In contrast, the higher starch content and limited defensive compounds in *L. leucocephala* increase its susceptibility to biodeterioration. Accordingly, *A. mangium* is categorized within durability classes II–III (moderately durable), while *L. leucocephala* falls within classes III–IV (less durable). These findings emphasize the potential of *A. mangium* as a more sustainable raw material for tropical wood-based industries, provided that appropriate preservative treatments are applied to enhance service life and reliability.

Looking forward, extended exposure trials are recommended to assess long-term degradation dynamics under different environmental conditions. Future work should also focus on chemical profiling of extractives, microscopic characterization of decay mechanisms, and the evaluation of eco-friendly preservation or modification treatments. Integrating life-cycle and carbon stock analyses will further clarify the sustainability potential of these fast-growing species as renewable resources for tropical wood utilization and forest management.

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Conflict of interest

“The authors declare no conflict of interest”.

Authors' contribution

Corresponding authors are required to acknowledge co-author contributions using the Contributor Roles Taxonomy. The taxonomy includes the following roles: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, and Writing – review and editing.

NAB: Conceptualization, Methodology, Writing- Original draft preparation. **NT:** Data curation. **YJL:** Visualization, Investigation. **RPDW:** Supervision, Writing- Reviewing and Editing,

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