



Xylophagous fauna associated with timber and comparative efficacy of pyrethroid-based treatments and *Eucalyptus camaldulensis* essential oil in Korhogo, northern Côte d'Ivoire

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Abstract

Wood-boring insects constitute a major constraint to the conservation and durability of timber in tropical environments. The present study aimed to identify the main insects associated with timber in the municipality of Korhogo and to evaluate, under semi-controlled conditions, the efficacy of two synthetic insecticides, bifenthrin and cypermethrin, as well as the essential oil of *Eucalyptus camaldulensis*. An entomological survey was conducted at 40 sites, including carpentry workshops, sawmills, houses and public buildings. The observed insects were collected and identified in the laboratory. The efficacy of the treatments was then evaluated on the main species of each group, namely *Prostephanus truncatus* among Coleoptera and *Macrotermes subhyalinus* among termites. Six treatments were compared: control, bifenthrin at 0.1%, cypermethrin at 0.2%, and *E. camaldulensis* essential oil at 40, 60 and 80 µL. Repellent effects were monitored for 75 min, and mortality was assessed after 24, 48 and 72 h. The inventory recorded 12 species, including six termite species and six Coleoptera species. *M. subhyalinus* had the highest mean occurrence frequency among termites (52.50%), whereas *P. truncatus* was dominant among Coleoptera (35%). The essential oil showed dose-dependent repellent activity, with mean rates ranging from 76 to 92% in Coleoptera and from 83.84 to 96.96% in termites. Termite mortality reached 100% within 24 h with cypermethrin and the three essential oil doses, whereas among Coleoptera, mortality reached 100% after 48 h with 80 µL of essential oil. These results highlight the repellent and insecticidal potential of *E. camaldulensis* essential oil, while emphasizing the need to improve its formulation to limit the effects associated with its volatility.

Keywords: Insects, wood, essential oil, *Eucalyptus camaldulensis*, Korhogo

Introduction

The wood industry encompasses a range of activities related to the production and processing of wood and constitutes an important source of employment and income worldwide. It generates several thousand products and makes a significant contribution to national economies (Li *et al.*, 2022). In Africa, the forestry sector also contributes to economic activities and employment, particularly through formal and informal processing activities (FAO, 2015). In Côte d'Ivoire, wood production and processing occupy an important place in the national economy. Between 2018 and 2022, the wood sector reportedly generated approximately CFAF 800 billion per year, while the informal sector also represents an important economic activity (Kouadio, 2023; N'Guessan, 2019). Wood is also widely used in construction, furniture manufacturing, and various domestic applications (Doubmbia and Kra, 2009). However, because of its biological nature and physical properties, particularly its hygroscopicity, wood remains subject to various degrading agents. Among these, wood-boring insects constitute an important cause of deterioration of their quality and durability (Damay, 2014; Mouras *et al.*, 2007). Wood-boring insects comprise various species capable of using wood as a food resource or as a substrate during their development. Termites and several families of Coleoptera are particularly important in the degradation of fresh, dry, or processed wood. Their attacks can result in the formation of galleries, holes, cavities, and frass, progressively reducing the mechanical strength of the material (Beauchene, 2006;

Fraval, 2008). Termites constitute a major group of wood-degrading agents. Workers are responsible for searching for and exploiting food resources and account for most of the damage caused to woody materials. Some species of Macrotermitinae also use symbiotic fungi to efficiently exploit woody substrates (Mouras *et al.*, 2007). Among Coleoptera, several families include species associated with wood. Bostrichidae and Cerambycidae are among the groups frequently encountered on timber. The larvae of many species bore galleries inside the material, while adults contribute to population dispersal and the establishment of new infestations. Bostrichidae may be associated with dry wood and processed materials (Delobel and Tran, 1993). Wood protection generally relies on preventive or curative treatments based on insecticides. However, the use of plant protection products in Côte d'Ivoire is sometimes characterized by inadequate knowledge of the products, the use of unregistered formulations, and inappropriate application practices (FAO and CEDEAO, 2011; Samb, 2023). These practices may increase risks to the environment and human health and justify the search for solutions better adapted to local conditions. Synthetic insecticides, particularly pyrethroids, are widely used because of their effectiveness at low concentrations. Bifenthrin and cypermethrin exhibit insecticidal and repellent activity against various pests. At the same time, plant-derived biopesticides are attracting increasing interest because of the diversity of secondary metabolites they contain and their insecticidal or repellent properties (Isman,

2006; Pavela, 2016). *Eucalyptus camaldulensis* is a species widely introduced into several dry regions of West Africa. Its leaves are rich in volatile compounds and essential oils that may have interesting biological properties (Florence, 1996; Jacobs, 1981; Coppen, 2002). Previous studies have demonstrated the insecticidal and repellent activity of *Eucalyptus* essential oils against various stored-product pests and termites (Togola *et al.*, 2014; Welle *et al.*, 2022; Bamba, 2025). *Eucalyptus* essential oils may also exhibit variable activity depending on insect species and exposure conditions (Cheng *et al.*, 2009; Siramon *et al.*, 2009). In the municipality of Korhogo, data on the diversity of insects responsible for the degradation of timber and on the comparative effectiveness of the treatments used remain limited. It is therefore relevant to identify the main wood-boring insects encountered in timber and to assess the activity of chemical treatments and a plant-derived essential oil.

The objective of this study was therefore to investigate the wood-boring insect fauna associated with timber in the municipality of Korhogo and to evaluate the repellent and insecticidal activity of bifenthrin, cypermethrin, and *E. camaldulensis* essential oil.

Material et methods

1. Study area

The study was conducted in the municipality of Korhogo (9°27'41'' N; 5°38'19'' W), located in northern Côte d'Ivoire, approximately 635 km from Abidjan (Figure 1). The municipality covers an area of 12,500 km² (CNRA, 2019). The climate is of the Sudanian-Guinean tropical type, with a rainy season from May to October and a dry season from November to April. Annual rainfall ranges from 1,200 to 1,400 mm. The vegetation mainly consists of wooded savanna (CNRA, 2019) [7, 2]

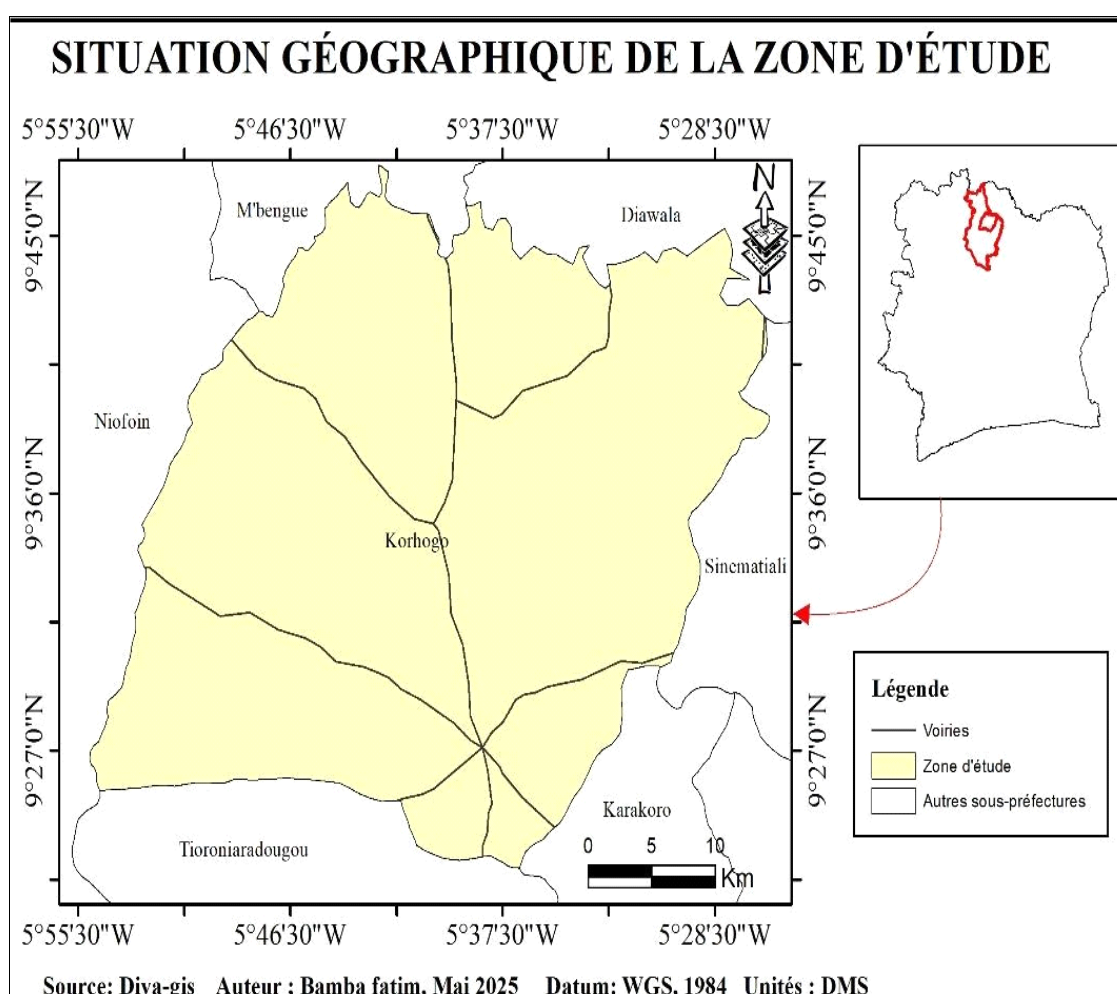


Fig 1: Location of study area (Bamba, 2025)

2. Preliminary Survey

A preliminary survey was conducted among stakeholders involved in wood protection and processing, particularly pesticide sellers, sawmill managers, and carpenters. The objective was to identify the insecticide products commonly used and the main wood species exploited. The products identified included formulations based on chlorpyrifos-ethyl, bifenthrin, and fipronil. According to the list of pesticides registered in Côte d'Ivoire as of June 11, 2025, the bifenthrin-based product identified for wood treatment

was registered, whereas several other products encountered were not included in this list.

3. Inventory of Wood-Boring Insects

Sampling was conducted at 40 sites distributed throughout the city of Korhogo along a transect covering the four cardinal directions. Inspections focused mainly on roofs, furniture, and unprocessed logs. Infestation sites were identified based on indicators such as the presence of galleries, holes, frass, or directly observable insects. The

collected insects were preserved in 70% alcohol and then transported to the laboratory for identification under a stereomicroscope. Beetles were identified using specialized identification keys and reference works, notably Delobel and Tran (1993) and Schäfer *et al.* (2000). Termites were identified based on the works of Sjöstedt (1926), Ahmad (1950), Bouillon and Mathot (1965), Roy-Noël (1966), and Sands (1998). The occurrence frequency of each species was determined based on its presence at the inspected sites. [2, 6, 12, 29, 31, 32, 34]

4. Extraction of the essential oil of *Eucalyptus camaldulensis*

The leaves of *E. camaldulensis* were collected from the botanical garden of University Peleforo GON COULIBALY. Young leaves were preferentially selected. After collection, they were dried for three weeks in the shade and protected from direct sunlight. Extraction was carried out by hydro distillation using a Clevenger-type apparatus. A mass of 600 g of dried leaves was used. The essential oil obtained was separated from the hydrosol and then stored in tightly closed amber glass bottles, protected from light, until use. The essential oil was used purely. Aliquots of 40, 60, and 80 µL were taken for the biological assays.

5. Preparation of Treatments and Contact Toxicity Test

The tests were conducted on *Tectona grandis* blocks measuring 2.5 × 5 × 5 cm. Six treatments were compared:

- T0: untreated control;
- T1: bifenthrin at 0.1%;
- T2: cypermethrin at 0.2%;
- T3: *E. camaldulensis* essential oil, 40 µL;
- T4: *E. camaldulensis* essential oil, 60 µL;
- T5: *E. camaldulensis* essential oil, 80 µL.

The bifenthrin and cypermethrin formulations were diluted in distilled water according to the selected concentrations. The essential oil was applied without dilution. The treatments were applied by manually brushing the different surfaces of the blocks. The insects used for the tests were collected from structures showing recent infestations. The individuals were divided into groups of 10 beetles and 50 termites. The most frequent species from each group was selected for the tests, namely *P. truncatus* among the beetles and *M. subhyalinus* among the termites. Each treatment was replicated five times.

The treated blocks were individually placed in ventilated containers containing the insects. For termites, a substrate collected from active termite mounds, sieved through a 2-mm mesh and maintained at approximately 90% humidity, was used. For beetles, ambient humidity was maintained using moistened paper. Mortality was recorded after 24, 48, and 72 h of exposure. The mortality rate was calculated and then corrected according to Abbott's formula (Abbott, 1925).^[1, 2]

$$\text{Mortality rate(TM)} = \frac{\text{Number of dead insects}}{\text{Total number of insects}} \times 100$$

$$\text{TM corrected} = \frac{M - M_{\text{control}}}{100 - M_{\text{control}}} \times 100$$

6. Evaluation of repellent activity

Repellent activity was assessed according to the zone preference method described by McDonald *et al.* (1970) and Obeng-Ofori and Reichmuth (2010). Whatman filter paper discs, 9 cm in diameter, were divided into two halves. One half received the corresponding treatment, while the other received distilled water. The two halves were then joined together to form a complete disc. For each replicate, 10 beetles or 50 termites were placed in the center of the Petri dish. The distribution of insects between the treated and untreated areas was observed after 15, 30, 45, 60, and 75 min. Each treatment was replicated five times.^[23]

7. Statistical analysis

The data were subjected to the Shapiro-Wilk normality test at the 5% significance level. When the assumptions of normality were not met, the Kruskal-Wallis test was used to compare the treatments. Multiple comparisons were performed using Dunn's test with a Bonferroni correction. The analyses were conducted using RStudio, version R 4.4.0.2, while Microsoft Excel was used for descriptive data processing.

Results

1. Insecticide products and wood species recorded

The survey revealed a diversity of products used for wood protection (Table 1). Formulations based on chlorpyrifos-ethyl were the most common among the products recorded. Only one bifenthrin-based product, Pyrical Super 100 EC, was listed as registered for wood protection in the consultation list. Several other products used by stakeholders were not included in this list.

Table 1: Insecticides Used by Wood Industry Stakeholders in Korhogo

Trade name	Type of insecticide	Active ingredients	Indicated use	Registered or not registered
Pyrical 480 EC	Curative and preventive	Chlorpyrifos-Ethyl	Termites, Wood-boring beetles, Lyctid beetles	NR
Xylimon	Curative and preventive	-	Termites and Wood-boring beetles	NR
SUPERPYROS plus	Curative and preventive	Chlorpyrifos-Ethyl	Versatile	NR
Pyrical super 100EC	Preventive	Bifenthrine	Wood	R
Capsidor 50 SC	Preventive	Fipronil	Termites	NR
PYRIBOIS 50EC	Curative and preventive	-	Termites, Wood-boring beetles, Ambrosia beetles, Bark beetles	NR
Pyrical bois 480	Curative	Chlorpyrifos-ethyl	Termites, Wood-boring beetles, Longhorn beetles	NR

EC				
Percal bois 720 EC	Curative	-	Termites and other wood-boring insects	NR
Percal bois 480 EC	Curative	-	Wood-boring insects	NR

The wood species most frequently cited by the stakeholders were teak (*Tectona grandis*), mahogany (*Khaya ivorensis*), saman (*Samanea saman*), dabema (*Piptadeniastrum*

africanum), framiré (*Terminalia ivorensis*), iroko (*Milicia excelsa*), fraké (*Terminalia superba*), and kapok (*Ceiba pentandra*) (Table 2).

Table 2: Wood species used in Korhogo

Trade name	Wood species	
	Family	Scientific name
Teck	Lamiaceae	<i>Tectona grandis</i>
Acajou	Meliaceae	<i>Khaya ivorensis</i>
Saman	Fabaceae	<i>Samanea saman</i>
Dabema	Fabaceae	<i>Piptadeniastrum africanum</i>
Framiré	Combretaceae	<i>Terminalia ivorensis</i>
Iroko	Moraceae	<i>Milicia excelsa</i>
Fraké	Combretaceae	<i>Terminalia superba</i>
Fromager	Malvaceae	<i>Ceiba pentandra</i>

2. Species richness of wood-boring insects

A total of 12 species of xylophagous insects belonging to two main groups were recorded: six termite species and six beetle species. The identified termites were *Amitermes guineensis*, *Trinervitermes trinervius*, *Odontotermes pauperans*, *Macrotermes*

subhyalinus, *Ancistrotermes* sp. and *Pseudacanthotermes militaris*. Among the beetles, the recorded species were *Neandra brunnea*, *Minthea obsita*, *Lyctus brunneus*, *Lyctus linearis*, *Prostephanus truncatus* and *Dinoderus minutus*. The beetles belonged mainly to the families Bostrichidae and Cerambycidae (Table 3).

Table 3: List of wood-boring insect and beetle species recorded at the sampling sites

Orders	Family	Subfamily	Species	Trophic groups	Inspected sites	
					Carpentry workshop / Sawmill	Houses/Public buildings
		Amitermitinae	<i>Amitermes guineensis</i>	Xylophages	*	*
		Nasutitermitinae	<i>Trinervitermes trinervius</i>	Fourrageurs		*
			<i>Odontotermes pauperans</i>			*
Blattoptera	Termitidae		<i>Macrotermes subhyalinus</i>		*	*
		Macrotermitinae	<i>Ancistrotermes</i> sp.	Champignonnistes	*	*
			<i>Pseudacanthotermes militaris</i>			*
	Cerambycidae	Prioninae	<i>Neandra brunnea</i>		*	
			<i>Minthea obsita</i>			*
		Lyctinae	<i>Lyctus brunneus</i>		*	*
Coleoptera			<i>Lyctus linearis</i>	Xylophages	*	*
	Bostrichidae		<i>Prostephanus truncatus</i>		*	*
		Dinoderinae	<i>Dinoderus minutus</i>			
Total	3	6	12	-	40	

3. Frequency of occurrence of species

Among beetles, *P. truncatus* had the highest mean occurrence frequency, with 35%, compared with 20% for *L. brunneus* and 17.50% for *L. linearis*. *N. brunnea* had a mean frequency of 10%, whereas *D. minutus* and *M. obsita* had frequencies of 10% and 7.50%, respectively. Among termites,

M. subhyalinus was the most frequently observed species, with a mean frequency of 52.50%. It was followed by *Ancistrotermes* sp. (15%), *O. pauperans* (10%), *P. militaris* (10%), *A. guineensis* (7.50%), and *T. trinervius* (5%). The results therefore show a predominance of *M. subhyalinus* among termites and *P. truncatus* among beetles (Table 4).

Table 4: Occurrence frequencies of the different species encountered

Species	Carpentry workshop / Sawmill (%)	Houses/Public buildings (%)	Mean Frequency (%)
<i>Neandra brunnea</i>	21.05	0	10
<i>Minthea obsita</i>	0	14.29	7.50
<i>Lyctus brunneus</i>	26.32	14.29	20
<i>Lyctus linearis</i>	21.05	14.29	17.50
<i>Prostephanus truncatus</i>	31.58	38.10	35
<i>Dinoderus minutus</i>	0	19.05	10

<i>Amitermes guineensis</i>	10.53	4.76	7.50
<i>Trinervitermes trinervus</i>	0	9.52	5
<i>Odontotermes pauperans</i>	0	19.05	10
<i>Macrotermes subhyalinus</i>	47.37	57.14	52.50
<i>Ancistrotermes</i> sp.	21.05	9.52	15
<i>Pseudacanthotermes militaris</i>	0	19.05	10

4. Symptoms and damage to wood

Inspections revealed significant damage attributable to termites and wood-boring beetles. In termites, attacks were mainly characterized by

the presence of internal galleries, cavities, and progressive deterioration of the wood structure. In some cases, the presence of earthen sheathing constituted a characteristic indication of termite activity (Figure 2).



Fig 2: Damage caused by termites

In beetles, the damage was mainly characterized by circular perforations and the presence of sawdust or fine frass. These attacks were likely to result in a progressive decrease in the

mechanical strength of the material. The intensity of the damage varied according to the storage conditions observed in sawmills, carpentry workshops, and dwellings (Figure 3).



Fig 3: Damage caused by beetles

5. Repellent activity against beetles

All treatments exhibited a repellent activity higher than 50% throughout the observations, except for the control (Table 5). Bifenthrin at 0.1% showed a mean repellency of 57.60%, whereas cypermethrin at 0.2% reached 60.00%. The essential oil

exhibited higher activity, with mean repellency rates of 76.00% at 40 μ L, 83.20% at 60 μ L, and 92.00% at 80 μ L. Differences among treatments were significant at several observation times, particularly at 30, 45, 60, and 75 min. The 80 μ L doses of essential oil were notably different from bifenthrin.

Table 5: Repellency rate of beetles as a function of time
The values followed by different letters in the same column differ significantly at the 5% level.

Treatments	Concentration	15 min	30 min	45 min	60 min	75 min	Mean repellency rate
Bifenthrine	0.10%	60 ± 12.24	48 ± 8.36 b	52 ± 10.95 b	64 ± 8.94 b	64 ± 8.94 b	57.6 ± 9.89
Cyperméthrine	0.20%	52 ± 8.36	64 ± 8.94 ab	60 ± 12.24 ab	64 ± 8.94 b	60 ± 12.24 ab	60 ± 10.15
HE Eucalyptus	40 µl	72 ± 10.95	72 ± 10.95 ab	80 ± 14.14 ab	76 ± 8.94 ab	80 ± 14.14 ab	76 ± 11.82
HE Eucalyptus	60 µl	56 ± 13.41	88 ± 10.95 ab	80 ± 0.00 ab	96 ± 8.94 a	96 ± 8.94 ab	83.2 ± 8.45
HE Eucalyptus	80 µl	80 ± 14.14	92 ± 10.95 a	92 ± 10.95 a	96 ± 8.94 a	100 ± 0.00 a	92 ± 8.99
Control	0	4 ± 8.94	4 ± 8.94 c	4 ± 8.94 c	4 ± 8.94 c	4 ± 8.94 c	4 ± 8.94
p-value	—	0.126	0.005	0.002	0.008	0.001	—

6. Repellent activity against termites

The repellent activity was higher in termites than in beetles. Bifenthrin showed a mean repellency rate of 67.68%, compared with 74.08% for cypermethrin. The essential oil showed a clear increase

with dose: 83.84% at 40 µL, 91.52% at 60 µL, and 96.96% at 80 µL. The differences between treatments were significant at the different observation times. The repellent effect of the essential oil increased with concentration (Table 6).

Table 6: Termite repellency rate as a function of time
The values followed by different letters in the same column differ significantly at the 5% level.

Treatments	Concentration	Mean repellency rate by time interval					Repellency rate
		15 min	30 min	45 min	60 min	75 min	
Bifenthrine	0.10%	60±5.65b	62.4±4.56b	64±8.94b	76±7.48ab	76±10.19ab	67.6±7.36
Cyperméthrine	0.20%	58.4±8.29b	82.4±10.43ab	76.8±6.92ab	74.4±9.63ab	78.4±7.26ab	74.08±8.51
HE Eucalyptus	40 µl	66.4±7.26ab	86.4±8.29ab	85.6±7.79ab	84±10.80ab	96.8±3.34a	83.84±7.50
HE Eucalyptus	60 µl	81.6±9.20ab	88.8±3.34ab	92±8.48ab	97.6±2.19a	97.6±3.57a	91.52±5.36
HE Eucalyptus	80 µl	96±4.00a	94.4±4.56a	98.4±2.19a	98.4±2.19a	97.6±3.57a	96.96±3.30
Control	0	8±0.00c	8±0.00c	8±0.00c	12±0.00c	12±0.00c	9.6±0.00
p-value		< 0.001	0.03	0.01	0.02	0.04	-

7. Toxicity against beetles

The treatments resulted in progressive mortality of *P. truncatus*. After 72 h, bifenthrin and cypermethrin each reached 90% mortality. With the essential oil, mortality was strongly dose dependent. At 40 µL, mortality remained

limited to 28% after 72 h. At 60 µL, it reached 72%. At 80 µL, it reached 100% as early as 48 h and remained at this level after 72 h. Statistical analyses showed significant differences among treatments at each exposure time ($p < 0.001$) (Table 7).

Table 7: Mortality rate of beetles as a function of time
The values followed by different letters in the same column differ significantly at the 5% level.

Treatments	Concentration	Corrected mortality rate (%) by exposure time		
		24h	48h	72h
Bifenthrine	0.10%	30 ± 12.24abc	62 ± 8.36b	90±7.07b
Cyperméthrine	0.20%	44 ± 8.94abc	86 ± 5.47ab	90±10b
HE Eucalyptus	40 µl	18 ± 8.36ac	28 ± 10.95bc	28±10.95bc
HE Eucalyptus	60 µl	54 ± 5.47a	68 ± 8.36b	72±8.36a
HE Eucalyptus	80 µl	98 ± 4.47a	100a	100a
Control	0	0d	0d	0d
p-value		< 0.001	< 0.001	< 0.001

8. Toxicity against termites

Termites showed high sensitivity to all treatments. Bifenthrin caused 99.59 ± 0.89% mortality after 24 h and 100% mortality after 48 h.

Cypermethrin and all three doses of essential oil resulted in 100% mortality as early as 24 h. Differences among treatments were highly significant at all three exposure times ($p < 0.001$) (Table 8).

Table 8: Termite mortality rate by time interval
The values followed by different letters in the same column differ significantly at the 5% level.

Treatments	Concentration	Corrected mortality rate (%) according to exposure time		
		24h	48h	72h
Bifenthrine	0.10%	99.59±0.89b	100b	100b
Cyperméthrine	0.20%	100b	100b	100b
HE Eucalyptus	40 µl	100b	100b	100b
HE Eucalyptus	60 µl	100b	100b	100b
HE Eucalyptus	80 µl	100b	100b	100b
Control	0	2±2a	5.6±3.57a	6.4±4.33a
p-value		< 0.001	< 0.001	< 0.001

Discussion

The survey conducted in the municipality of Korhogo identified 12 xylophagous species belonging mainly to termites and beetles. This diversity confirms the importance of these two groups in the degradation of timber. The predominance of *M. subhyalinus* among termites, with a mean frequency of 52.50%, indicates its importance at the study sites. The high occurrence of this species is consistent with previous observations made in the Korhogo region, particularly those reported by Coulibaly (2014) and Bamba (2025). The relatively high frequency of *P. truncatus* among beetles is also noteworthy. This species is known to be associated with dry plant materials and wood products. Its frequency of 35% at the surveyed sites confirms its importance in anthropogenic environments where wood is stored, processed, or used. The other Bostrichidae and Lyctinae species recorded are also known for their ability to colonize various woody substrates (Delobel and Tran, 1993; Schäfer *et al.*, 2000). The symptoms observed correspond to the classical forms of degradation associated with termites and beetles. The galleries and cavities observed in termite-infested wood, as well as the perforations and frass associated with beetles, may progressively affect the mechanical properties of the material. Similar observations have been reported for insects associated with processed wood, particularly Bostrichidae (Fraval, 2008). The preliminary survey also revealed relatively poorly regulated use of insecticides in the local wood sector. The presence of several products that were not included in the consulted list of registered pesticides is an important factor to consider in wood protection. This situation is consistent with general observations concerning difficulties in implementing plant protection recommendations and the circulation of unregistered products reported in West Africa (FAO and CEDEAO, 2011; Samb, 2023). The biological assays showed different responses between termites and beetles. Termites were highly sensitive to all treatments, with mortality close to or equal to 100% as early as 24 h. The high mortality obtained with *E. camaldulensis* essential oil confirms the results of Bamba (2025), who also observed complete termite mortality following exposure to this plant species. The insecticidal properties of *Eucalyptus* essential oils may be associated with their volatile constituents, as several studies have demonstrated their biological activity against different insects (Cheng *et al.*, 2009; Togola *et al.*, 2014). Among beetles, the effect of the essential oil was much more dependent on concentration and exposure time. The 40 μ L doses resulted in only 28% mortality after 72 h, whereas the 80 μ L doses reached 100% mortality as early as 48 h. This dose-response relationship is consistent with general observations reported for essential oils, whose insecticidal activity frequently increases with concentration and exposure duration (Nerio *et al.*, 2010). Belkacem and Melal (2021) also reported biological activity of *E. camaldulensis* essential oil against different beetle species. The difference in sensitivity between the two groups could be related to their biological and morphological characteristics. Termites are highly sensitive to several volatile substances, whereas some beetles may exhibit a more gradual response to planting secondary compounds. Siramon *et al.* (2009) notably showed that sensitivity to *Eucalyptus* essential oils may vary according to termite species and exposure conditions. The repellent activity observed further supports the potential of the essential oil as

a means of wood protection. In terms of the termites, the mean repellency rate reached 96.96% with 80 μ L, compared with 67.68% for bifenthrin and 74.08% for cypermethrin. An increase in repellency with concentration was also observed in beetles. This response is consistent with the recognized role of plant volatile compounds in insect defense mechanisms (Isman, 2006; Nerio *et al.*, 2010). Synthetic insecticides nevertheless showed substantial activity. Bifenthrin and cypermethrin caused high mortality in both groups, and cypermethrin reached 90% mortality in *P. truncatus* after 72 h. These observations are consistent with studies demonstrating the efficacy of pyrethroids against various insect pests. The interest in the essential oil therefore lies mainly in its repellent activity and its insecticidal potential at high concentrations. However, the results should be interpreted with caution. The experiments were conducted under semi-controlled conditions and involved only one beetle species and one termite species. In addition, the essential oil was used in its pure form, and neither its extraction yield nor its chemical composition was determined in this study. Its high volatility may also limit its persistence on treated surfaces. This constraint represents one of the main limitations of botanical insecticides and justifies further research on their formulation and stability (Isman, 2020; Coulibaly, 2014). Thus, *E. camaldulensis* essential oil appears to be a promising plant resource for the protection of woody materials, but its practical use requires further investigations focusing particularly on persistence, effective doses, formulation, and efficacy against different xylophagous species. [3, 2, 5, 8, 10, 2, 12, 15, 17, 18, 19, 26, 2, 30, 32, 33, 35]

Conclusion

This study characterized part of the wood-boring insect fauna associated with timber in the municipality of Korhogo and evaluated the efficacy of two synthetic insecticides and the essential oil of *Eucalyptus camaldulensis*. Twelve species were recorded, including six termite species and six beetle species. *Macrotermes subhyalinus* was the most frequent species among termites, whereas *Prostephanus truncatus* was dominant among beetles. Biological assays showed a high sensitivity of termites to the different treatments, with complete mortality obtained after 24 h with cypermethrin and the different doses of essential oil. In beetles, efficacy was more gradual and strongly dependent on concentration. The 80 μ L doses of essential oil achieved 100% mortality after 48 h. The essential oil of *E. camaldulensis* also exhibited significant repellent activity, particularly against termites. These results highlight its potential as a botanical resource for protecting wood against wood-boring insects. However, the volatility of the essential oil and the use of a limited number of species in the assays are limitations that should be taken into consideration. Further studies should focus on the chemical characterization of the oil, improvement of its formulation, its persistence on wood, its efficacy against different termite and beetle species, as well as its performance under real-world conditions of use.

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