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Olfactory and Trail-Following Responses of *Coptotermes curvignathus* to Selected Plant Leaf Extracts

Niken Subekti[1]*, Sonika Maulana[2], Ahmad Naharuddin Ramadhan[1], Putri Nabila[3], Yusuf Sudo Hadi[4]

[1]Department of Biology, Faculty of Mathematics and Natural Science, Universitas Negeri Semarang, Semarang 50229, Central Java, Indonesia
[2] Department of Mechanical Engineering, Faculty of Engineering, Universitas Negeri Semarang, Semarang 50229, Central Java, Indonesia
[3]Undergraduate Program, Biology Department, Universitas Negeri Semarang, Semarang 50229, Central Java, Indonesia
[4]Papua New Guinea University of Technology, School of Forestry, Lae City 113, Papua New Guinea

*Corresponding author: nikensubekti@mail.unnes.ac.id

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Abstract. Subterranean termites, particularly *Coptotermes curvignathus*, are destructive pests that cause serious damage to wood, crops, plantation commodities, and building structures. The development of plant-based semiochemicals may provide an environmentally friendly alternative for termite management by utilizing natural compounds that influence termite orientation behavior. This study aimed to evaluate the olfactory and trail-following responses of *C. curvignathus* workers to selected plant leaf extracts and to identify their potential roles as attractants, repellents, or trail-disrupting agents. Leaves of cajuput, eucalyptus, citronella, pine, and tea tree were extracted using 70% ethanol, concentrated by rotary evaporation, and analyzed using gas chromatography-mass spectrometry (GC-MS). Olfactory responses were tested using a Y-tube olfactometer, while trail-following behavior was evaluated using a Y-shaped filter paper assay. Each treatment was replicated 15 times using different worker termites, and the data were analyzed using the chi-square test. The highest olfactory response was observed in cajuput extract (80.00%), followed by eucalyptus (60.00%), pine (53.33%), tea tree (40.00%), and citronella (33.33%). In the trail-following assay, cajuput produced the highest positive response (93.33%), followed by pine (80.00%), eucalyptus (53.33%), tea tree (33.33%), and citronella (26.66%). GC-MS analysis showed that cajuput was dominated by α-pinene and 1,8-cineole, while citronella contained geraniol and citronellol, compounds associated with repellent activity. These findings indicate that plant-derived volatile monoterpenes influence termite orientation and trail-following behavior. This research supports SDG 12 and SDG 15 by promoting plant-based termite management and reducing reliance on synthetic termiticides.

Keywords: Bioattractant; Coptotermes curvignathus; GC-MS; leaf extract; olfactory response; trail-following behavior

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INTRODUCTION

Coptotermes curvignathus is one of the most destructive subterranean termite species and is widely recognized as an economically important pest in agricultural systems, plantations, forestry, and building construction. Termite infestation may cause serious losses because subterranean termites feed on cellulose-based materials, damage wooden structures, and often remain undetected until the damage has reached an advanced stage. In Indonesia, *Coptotermes spp.* have long been reported as a major structural pest with substantial economic, social, and ecological impacts (Subekti, 2010). Another study also found *C. curvignathus* among termite species attacking residential buildings and reported that termite attack contributed substantially to building damage (Subekti et al., 2018). Abbas et al. (2024) reported that termite attacks can contribute to substantial agricultural losses, accounting for approximately 20% to 45% of crop yield reduction. In urban environments, termite infestation has also been reported to affect trees and built structures. Ul Abdin et al. (2024), for instance, found that 272 out of 1,363 examined urban trees were affected by termite attack. As a subterranean termite, *C. curvignathus* commonly constructs nests underground; however, this species is also able to establish supplementary or satellite nests above the soil surface, enabling it to attack elevated parts of buildings and other wooden materials (Nanda et al., 2018; Wikantyoso et al., 2024). This biological characteristic makes the detection and management of *C. curvignathus* particularly challenging.

For many years, termite control has relied heavily on synthetic chemical termiticides. Active ingredients such as chlordane, chlorpyrifos, and imidacloprid have been used in different termite management practices, particularly for subterranean termites (Oi, 2022). Although synthetic termiticides can be effective, their long-term use raises environmental and health concerns, including soil and water contamination, toxicity to non-target organisms, human health risks, and the possible development of pest resistance. Some synthetic compounds are also persistent in the environment and may be difficult to degrade (Syahidah & Subekti, 2019). These concerns have encouraged the search for alternative termite management strategies that are more environmentally friendly, target-specific, and compatible with sustainable pest management. Previous studies using natural materials, such as gaharu leaf extracts and bamboo wulung smoke, have demonstrated that plant-derived materials may provide environmentally friendly alternatives for termite management (Subekti et al., 2019; Subekti & Yoshimura, 2020).

One promising approach in termite management is the use of baiting systems. Termite baiting exploits the social behavior of termites, especially trophallaxis, through which workers share food with nestmates and distribute active ingredients within the colony. This mechanism allows bait toxicants or behavior-modifying compounds to spread gradually and may eventually suppress or eliminate colonies (Chouvenc, 2025). However, the effectiveness of baiting systems depends strongly on the ability of termites to locate, recognize, and continuously interact with the bait material. Therefore, bait development requires not only suitable toxicants or active ingredients, but also attractant compounds that can stimulate termites to approach and follow chemical cues associated with food sources. In this context, the study of termite olfactory responses and trail-following behavior is important for improving semiochemical-based baiting strategies.

Termites are eusocial insects that rely strongly on chemical communication to regulate foraging, orientation, recruitment, and colony organization. Worker termites locate food sources through exploratory movement and subsequently deposit trail pheromones that guide other colony members to the food source (Lee et al., 2021; Mitaka & Akino, 2021). In addition to pheromonal cues, termites are able to detect volatile organic compounds released by wood, soil, decaying plant materials, and other environmental sources through their olfactory system (Sillam-Dusses et al., 2020). These volatile compounds may function as attractants, repellents, or disruptors of orientation behavior. Therefore, understanding how termites respond to plant-derived volatiles is essential for identifying natural compounds that can be used to manipulate termite movement and foraging behavior.

Plant leaf extracts contain various bioactive compounds, including monoterpenes, sesquiterpenes, alcohols, aldehydes, and other volatile organic compounds that may affect insect behavior and physiology. Several plant-derived compounds have been reported to act as attractants, repellents, antifeedants, toxicants, or semiochemical disruptors in insects (Lucia & Guzman, 2021; Masriany et al., 2020). In termite management, such compounds may be useful either to enhance bait attractiveness or to reduce termite activity in vulnerable areas. However, the behavioral effects of plant leaf extracts are highly dependent on their chemical composition, concentration, and target termite species. A plant extract that acts as an attractant in one behavioral context may not necessarily stimulate trail-following behavior, whereas another extract may interfere with termite orientation or produce repellent effects.

Previous studies have investigated the bioactivity of plant extracts against termites, including their toxic, repellent, or feeding-deterrent effects (Chen & Oi, 2020; Kasseney et al., 2016). Nevertheless, studies integrating olfactory preference, trail-following behavior, and chemical profiling of selected plant leaf extracts remain limited, particularly for *C. curvignathus*. Addressing this gap is important because termite movement and food-searching behavior are influenced by various environmental factors, including olfactory gradients (Su & Bardunias, 2005). Therefore, evaluating both olfactory and trail-following responses can provide a more comprehensive understanding of how plant-derived volatiles influence termite behavior. This study aimed to evaluate the olfactory and trail-following responses of *C. curvignathus* workers to selected plant leaf extracts and to identify their potential roles as attractants, repellents, or trail-disrupting agents based on behavioral bioassays and GC-MS profiles. The findings may support the development of environmentally friendly termite management strategies, especially semiochemical-based baiting or repellent systems that reduce reliance on synthetic termiticides.

METHODS

This study used a quantitative experimental laboratory design to evaluate the behavioral responses of *Coptotermes curvignathus* Holmgren workers to selected plant leaf extracts. The research was conducted from February to June 2026 at the Biology Laboratory, Department of Biology, Faculty of Mathematics and Natural Science, Universitas Negeri Semarang, Indonesia. The experiment consisted of two behavioral bioassays, namely an olfactory response assay using a Y-tube olfactometer and a trail-following assay using a Y-shaped filter paper method. Chemical constituents of the leaf extracts were identified using gas chromatography-mass spectrometry (GC-MS). The observed behavioral responses were expressed as the number and percentage of termites choosing or following the treated and control arms. The use of *C. curvignathus* as the target termite species was supported by previous reports describing *Coptotermes spp.* as important structural pests in Indonesia and Semarang (Subekti, 2010; Subekti et al., 2018).

Termites

Worker termites of *C. curvignathus* were obtained from a laboratory colony maintained at the Biology Laboratory, Universitas Negeri Semarang, Indonesia, following termite maintenance and bioassay approaches used in previous termite studies with modifications (Subekti et al., 2019; Subekti & Yoshimura, 2020). The colony was maintained under dark and humid laboratory conditions to support termite survival and activity. Only healthy and active worker termites with relatively uniform body size were selected for the bioassays. Soldier termites and inactive or injured workers were excluded from the experiment.

A total of 150 worker termites were used in this study. Seventy-five workers were used for the olfactory response assay, consisting of five leaf extract treatments with 15 replicates each. Another 75 workers were used for the trail-following assay, also consisting of five leaf extract treatments with 15 replicates each. Each replicate used a different worker termite to avoid repeated behavioral responses from the same individual. The exact age of the termites was not determined because the workers were obtained from a laboratory colony; therefore, selection was based on caste, activity, and physical condition.

Leaf Extracts

Leaf extracts were prepared from five plant species, namely cajuput (*Melaleuca cajuputi* Powell), eucalyptus (*Eucalyptus globulus* Labill.), citronella (*Cymbopogon nardus* (L.) Rendle), pine (*Pinus merkusii* Jungh. & de Vriese), and tea tree (*Melaleuca alternifolia* (Maiden & Betche) Cheel). Fresh leaves were air-dried for three days at room temperature and cut into small pieces before extraction. The dried leaf materials were macerated using 70% ethanol for three consecutive 24-hour periods. The extract solution was then filtered and concentrated using a rotary evaporator at 60°C for two 24-hour periods until a concentrated gel-like extract was obtained. This solvent-extraction approach was adapted from previous plant-based termite control studies using plant extracts and from broader studies on plant-derived insect-control materials (Subekti et al., 2019; Syahidah & Subekti, 2019; Chen & Oi, 2020; Lucia & Guzman, 2021).

For the behavioral assays, each concentrated leaf extract was diluted using 70% ethanol. Ethanol was also used as the control treatment in both the olfactory response assay and the trail-following assay. The chemical constituents of each leaf extract were analyzed using GC-MS at the Organic Chemistry Laboratory, Universitas Negeri Semarang.

Olfactory Response Assay

The olfactory responses of *C. curvignathus* workers to the leaf extracts were evaluated using a Y-tube olfactometer modified from Wang et al. (2012), with adjustments for termite workers and plant leaf extracts. The olfactometer consisted of a distilled water chamber, molecular sieve chambers containing silica gel and zircon sand, an activated carbon chamber, a flow meter, an air pump, and a glass Y-tube. These components were connected using odor-free silicone tubing to supply clean and stable airflow as the odor carrier. The Y-tube consisted of one main arm measuring 3 cm in length and two lateral arms measuring 7 cm each, with an internal diameter of 1 cm.

A 25 µL aliquot of each leaf extract solution was applied to a paper disc and air-dried to allow the solvent to evaporate. The treated paper disc was then placed in one lateral arm of the Y-tube. Another paper disc treated with 70% ethanol alone was placed in the opposite lateral arm as the control. Both lateral arms were supplied with equal airflow at 0.6 L/min. The use of paired treated and control substrates followed the logic of choice bioassays commonly used to evaluate termite preference or repellency toward natural products (Hall & Traniello, 1985; Subekti & Yoshimura, 2020; Wang et al., 2012).

For each replicate, a single worker termite was introduced into the main arm of the Y-tube and allowed to move freely toward one of the lateral arms. The termite choice was recorded when the worker entered one of the lateral arms and remained there for more than 30 seconds. A positive olfactory response was recorded when the termite remained in the arm containing the leaf extract-treated paper disc, whereas a control response was recorded when it remained in the ethanol-treated arm. Termites that did not make a clear choice were recorded as no response and excluded from the choice analysis. Each treatment was replicated 15 times using different worker termites. To minimize positional bias, the position of the treated and control arms was alternated between replicates. The Y-tube was cleaned and dried between treatments to prevent residual odor contamination (Bakaruddin & Ab Majid, 2019; Lee & Phelan, 2025).

Trail-Following Assay

The trail-following assay was conducted based on the method of Hall and Traniello (1985), with modifications to the dimensions of the Y-shaped trail and the use of leaf extracts as tested cues. A Y-shaped line was drawn on filter paper measuring 12.5 cm in diameter. The main line was 3 cm long, while each lateral line was 7 cm long. One lateral line was treated with 75 mm³ of leaf extract solution, whereas the opposite lateral line was treated with 70% ethanol as the control. The treated filter paper was air-dried for 2 min before the assay. The design of the Y-shaped filter paper used in this assay is shown in Figure 1.

A single worker termite was placed at the base of the main line and confined using a plastic cylinder measuring 1 cm in diameter for 1 min before release. The test unit was covered with a Petri dish measuring 12.5 cm in diameter and lined with transparent red plastic to reduce disturbance from external light. After release, the termite was allowed to move along the Y-shaped trail. A positive response was recorded when the termite followed the line treated with leaf extract solution, whereas a control response was recorded when the termite followed the ethanol-treated line. Termites that did not follow either line or did not show a clear response were recorded as no response. Each leaf extract treatment was replicated 15 times using different worker termites. The filter paper was replaced after each replicate to avoid contamination from termite pheromones or residual extract compounds.

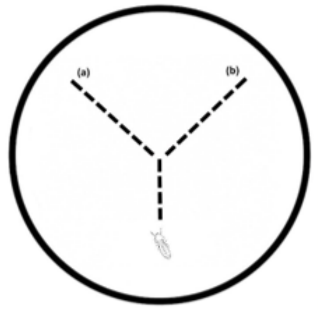

Figure 1. Schematic illustration of the Y-shaped trail-following assay used to evaluate the response of *C. curvignathus* workers to selected leaf extracts.

Note: One lateral line was treated with leaf extract solution, while the opposite lateral line was treated with 70% ethanol as the control. A single worker termite was released from the base of the main line, and its response was recorded based on the trail followed.

Data Analysis

The olfactory response rate was calculated as the percentage of termites choosing the leaf extract-treated arm relative to the total number of termites showing a clear choice. The repellency level was calculated as the percentage of termites choosing the control arm relative to the total number of termites showing a clear choice. The trail-following response rate was calculated as the percentage of termites following the leaf extract-treated line relative to the total number of termites showing a clear response. Frequency-based choice data are commonly used in insect behavioral bioassays to evaluate preference, repellency, or trail-following responses (Hall & Traniello, 1985; Wang et al., 2012).

The observed frequencies of termites choosing the treated and control arms were analyzed using the chi-square goodness-of-fit test for each leaf extract, with an expected ratio of 1:1. The same analysis was applied to the trail-following assay to determine whether the number of termites following the treated line differed significantly from the number following the control line. A result was considered statistically significant when the P value was lower than 0.05, indicating that the observed distribution of termite responses differed from the expected 1:1 distribution between the treatment and control choices. The results were presented as frequencies, percentages, and significance values.

RESULTS AND DISCUSSION

Olfactory responses of C. *curvignathus* to selected leaf extracts

The olfactory response assay showed that *C. curvignathus* workers responded differently to the five tested leaf extracts. The highest proportion of termites choosing the extract-treated arm was observed in the cajuput treatment, with 80.00% of workers responding to the treated paper disc, followed by eucalyptus at 60.00%, pine at 53.33%, tea tree at 40.00%, and citronella at 33.33% (Figure 2). Based on the chi-square goodness-of-fit test, only cajuput extract produced a significantly higher response than the control ($P < 0.05$), whereas eucalyptus, pine, tea tree, and citronella did not show statistically significant differences from their respective controls ($P > 0.05$).

These results indicate that cajuput leaf extract had the strongest olfactory attraction to *C. curvignathus* workers among the tested extracts. The high response to cajuput suggests that its volatile compounds may function as odor cues that stimulate termite orientation. Termites rely strongly on their olfactory system to detect food-related volatiles, colony-related cues, and other semiochemicals associated with their surrounding environment (Xu et al., 2024). Therefore, plant-derived volatile compounds may influence termite movement either by attracting workers toward a potential resource or by interfering with their normal orientation behavior. This interpretation is consistent with previous studies demonstrating that cajuput extracts can exhibit attractant effects on *C. curvignathus*, suggesting that their volatile constituents may function as chemical attractants for subterranean termites (Arinana et al., 2024; Arinana et al., 2025).

The moderate response to eucalyptus and pine suggests that these extracts may contain compounds detectable by termites, although their attractiveness was not strong enough to produce a statistically significant preference in the olfactory assay. Plant volatile organic compounds (VOCs) are known to exhibit different behavioral effects depending on their chemical composition, concentration, and interactions with the insect olfactory system, resulting in attractive, neutral, or repellent responses (Bedini et al., 2024; Escobar-Bravo et al., 2023). By contrast, the lower responses observed in citronella and tea tree may indicate that these extracts contain volatile compounds with repellent or disruptive effects, as essential-oil constituents can produce concentration-dependent repellency (Heinbockel & Shields, 2026; Wu et al., 2022). However, because citronella and tea tree responses were not statistically significant in this assay, their repellent potential should be interpreted cautiously and supported by further dose-response or compound-specific tests.

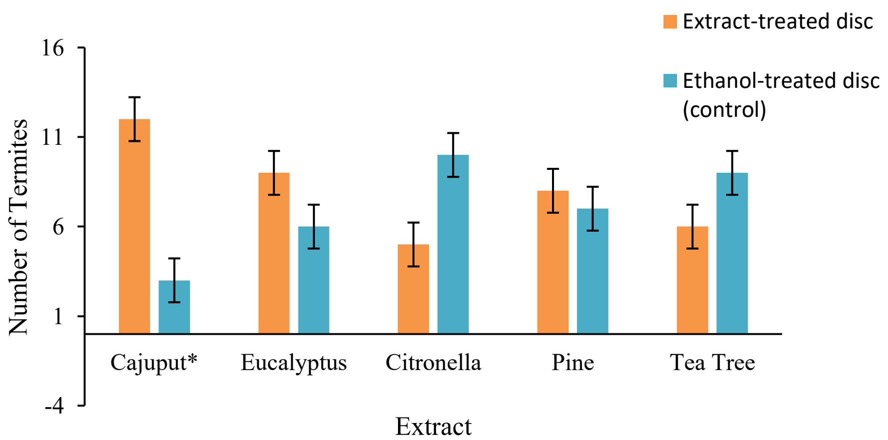

Figure 2. Olfactory responses of *C. curvignathus* workers to selected leaf extracts. For each extract, the left bar represents the number of termites choosing the extract-treated disc, whereas the right bar represents the number choosing the ethanol-treated disc (control). Asterisks (*) indicate significant differences between treatment and control choices based on the chi-square goodness-of-fit test ($P < 0.05$); ns indicates non-significant differences.

Trail-following responses of *C. curvignathus* to selected leaf extracts

The trail-following assay also showed different behavioral responses of *C. curvignathus* workers to the tested leaf extracts. Cajuput produced the highest positive trail-following response, with 93.33% of workers following the extract-treated trail, followed by pine at 80.00%, eucalyptus at 53.33%, tea tree at 33.33%, and citronella at 26.66% (Figure 3). Based on the chi-square goodness-of-fit test, cajuput and pine produced significantly higher trail-following responses than their controls ($P < 0.05$). In contrast, eucalyptus, tea tree, and citronella did not significantly stimulate trail-following behavior ($P > 0.05$).

The strong trail-following response to cajuput is consistent with the olfactory assay, indicating that cajuput extract may contain volatile compounds that stimulate both odor-mediated orientation and movement along a treated trail. This dual response is important because potential bait attractants should not only be detectable from a distance but should also be able to maintain termite movement toward or along the treated substrate. Therefore, cajuput extract may be considered the most promising candidate for further development as a plant-based bioattractant in semiochemical-based termite management (Arinana et al., 2025; Oladipupo et al., 2022). This result also complements previous Indonesian termite studies that emphasized the need for effective and environmentally friendly termite control strategies in response to building damage and pest pressure (Subekti, 2010; Subekti et al., 2018).

Pine extract showed a different response pattern. Although it did not produce a strong olfactory response in the Y-tube assay, it elicited a high trail-following response. This suggests that pine extract may be more effective as a contact or short-range orientation cue than as a long-range olfactory attractant. Such a response may reflect the ability of its chemical components to stimulate termite movement following direct contact with the treated substrate, rather than through airborne volatile signals. This is consistent with current understanding of termite orientation, which combines contact-based chemosensory signals and trail-pheromone-mediated navigation (Diallo et al., 2025). This finding indicates that different behavioral assays may reveal different functional roles of plant extracts in termite orientation.

Eucalyptus produced a moderate response in both assays, but the response was not statistically significant. This suggests that eucalyptus extract may be detected by termites but may not provide a sufficiently strong or stable cue to induce consistent trail-following behavior. Meanwhile, tea tree and citronella showed low positive responses in the trail-following assay. These results suggest that both extracts may reduce termite tendency to follow treated trails, possibly through repellent or trail-disrupting effects. Terpenoid compounds in essential oils are known to influence semiochemical perception and disrupt the orientation responses of insects, although their effectiveness depends on the type of compound and its concentration (Heinbockel & Shields, 2026). Nevertheless, further studies using different concentrations and isolated compounds are needed to confirm whether these extracts act primarily as repellents or as disruptors of pheromone-guided orientation.

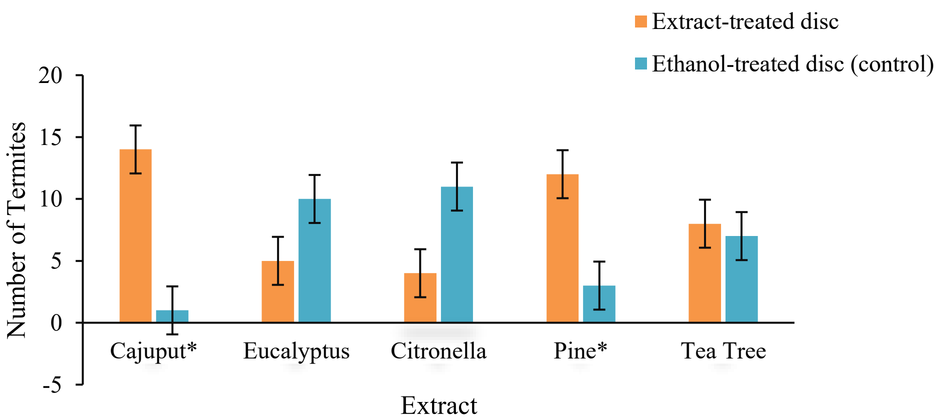

Figure 3. Trail-following responses of *C. curvignathus* workers to selected leaf extracts. For each extract, the left bar represents the number of termites following the extract-treated trail, whereas the right bar represents the number following the ethanol-treated trail (control). Asterisks (*) indicate significant differences between treatment and control choices based on the chi-square goodness-of-fit test ($P < 0.05$); ns indicates non-significant differences.

GC–MS profiles and possible roles of major compounds in termite behavioral responses

GC–MS analysis was conducted to identify the dominant volatile compounds present in each leaf extract. The major compounds detected in the extracts are presented in Table 1 and were used to interpret the behavioral responses observed in the olfactory and trail-following assays.

Table 1. Major compounds identified by GC–MS analysis of selected leaf extracts

Leaf extract	Major compounds identified	Relative abundance (%)
Cajuput	α-Pinene	32.59
	1,8-Cineole	22.02
	2-Methyl-2,4-pentanediol	23.02
	3-Carene	9.53
Eucalyptus	1,8-Cineole	81.26
	p-Cymene	8.45
	α-Pinene	6.45
	γ-Terpinene	2.13
Citronella	Geraniol	34.41
	Citronellal/Citronella compounds	15.33
	β-Citronellol	10.12
	α-Pinene	23.48
Tea tree	Terpinen-4-ol	37.47
	p-Cymene	33.04
	1,8-Cineole	6.88
	α-Pinene	6.31
Pine	α-Pinene	5.13
	1,8-Cineole	6.11
	α-Terpinolene	4.02
	p-Menth-3-en-1-ol	14.06
	Terpinen-4-ol–related compound	19.17

The behavioral responses observed in this study appear to be associated with the volatile profiles of the tested extracts. Cajuput, which produced the strongest responses in both the olfactory and trail-following assays, contained α-pinene, 1,8-cineole, 2-methyl-2,4-pentanediol, and 3-carene as major compounds. Recent studies indicate that termite chemoreceptor proteins can specifically interact with plant volatile compounds, including terpenoids such as α-pinene and 3-carene, suggesting that plant volatile compounds may play a role in termite environmental recognition (Yang et al., 2025). Their presence may contribute to the ability of termites to detect and orient toward cajuput-treated substrates. The combination of several volatile compounds in cajuput may also produce a more complex odor profile than a single dominant compound, thereby enhancing its attractiveness to termites (Bedini et al., 2024).

Pine extract also contained several terpene-related compounds, including α-pinene, 1,8-cineole, α-terpinolene, p-menth-3-en-1-ol, and terpinen-4-ol-related compounds. The high trail-following response to pine may be associated with this mixture of volatile and contact-active compounds. Monoterpenes commonly occurring in coniferous wood, particularly α-pinene and β-pinene, may modulate termite locomotory behavior and influence movement toward treated substrates, thereby increasing the likelihood of contact with these compounds (Poulos et al., 2024). Although pine did not show the strongest olfactory attraction, its chemical profile may stimulate termite movement after contact with the treated trail. This suggests that pine extract may function more as a short-range orientation cue than as a strong airborne attractant.

Eucalyptus extract was highly dominated by 1,8-cineole, with a relative abundance of 81.26%. Although 1,8-cineole is a volatile compound that can influence insect orientation, the dominance of a single compound may have produced a less complex chemical stimulus than the profiles found in cajuput and pine. This may explain why eucalyptus showed only a moderate response and did not significantly stimulate trail-following behavior. Therefore, eucalyptus may have limited potential as an attractant under the conditions of this study.

Citronella was characterized by high levels of geraniol, citronella-related compounds, β-citronellol, and α-pinene. The low responses to citronella in both assays suggest that geraniol and citronellol may be associated with repellent or orientation-disrupting effects. These compounds are commonly recognized as volatile terpenoids with strong odor activity and may interfere with insect olfactory reception (Lopez et al., 2025). In the context of termite behavior, such compounds may reduce the tendency of workers to approach or follow treated substrates; geraniol has also shown repellent activity in controlled insect assays (Lopez et al., 2025).

Terpinen-4-ol and p-cymene dominated the tea tree extract. The low trail-following response to tea tree suggests that these compounds may interfere with termite orientation or reduce the attractiveness of the treated trail. Terpinen-4-ol, in particular, may contribute to behavioral disruption because of its bioactivity against insects (Guo et al., 2016; Wu et al., 2022). However, because this study used crude extracts rather than purified compounds, researchers cannot determine the specific role of each compound with certainty. Further research using isolated compounds and controlled concentrations is needed to confirm their individual effects on termite behavior.

Overall, the results indicate that cajuput extract had the strongest potential as a bioattractant because it stimulated both olfactory orientation and trail-following behavior. Pine extract also showed potential as a trail-following stimulant, although its olfactory attractiveness was weaker. In contrast, citronella and tea tree may have potential as biorepellent or trail-disrupting agents because they produced low positive responses in both assays. These findings support the idea that plant-derived volatile compounds can influence termite orientation and may be used as a basis for developing semiochemical-based termite management strategies.

The novelty of this study lies in the integrated evaluation of olfactory response, trail-following behavior, and GC-MS profiles of selected plant leaf extracts against *C. curvignathus*. Previous studies have reported the bioactivity of plant extracts or natural products against termites (Lima et al., 2015; Subekti et al., 2019; Subekti & Yoshimura, 2020), but information on how these extracts influence both odor-mediated orientation and trail-following behavior in *C. curvignathus* remains limited (Thomas et al., 2023). By combining behavioral bioassays with chemical profiling, this study provides a more comprehensive understanding of how plant-derived volatile compounds may function as attractants, repellents, or trail-disrupting agents.

Scientifically, this study contributes to termite chemical ecology by showing that different plant extracts produce different behavioral responses depending on their volatile compound profiles and the type of behavioral assay used. Practically, the findings may support the development of environmentally friendly termite management strategies, particularly bioattractants for baiting systems and biorepellents for reducing termite activity in vulnerable areas. Cajuput and pine extracts may be further explored as attractants or trail-following stimulants, whereas citronella and tea tree extracts may be further tested as repellent or orientation-disrupting agents. These applications are relevant to the need for improved termite management in urban and residential environments, as indicated by previous Biosaintifika reports on termite population characteristics and building damage (Subekti, 2010; Subekti et al., 2018).

This research supports SDG 12, Responsible Consumption and Production, by promoting the use of plant-based materials as alternatives to synthetic termiticides. It also supports SDG 15, Life on Land, by contributing to pest management strategies that may reduce chemical contamination and help protect terrestrial ecosystems from the excessive use of persistent synthetic pesticides.

CONCLUSION

The selected plant leaf extracts elicited different olfactory and trail-following responses in *C. curvignathus* workers. Cajuput showed the strongest response in both assays, with the highest olfactory attraction and trail-following activity, indicating its potential as a plant-based bioattractant for semiochemical-based termite management. Pine also showed strong trail-following activity, although its olfactory attraction was lower than that of cajuput, suggesting that pine extract may function more effectively as a short-range orientation or trail-following stimulant. Eucalyptus produced a moderate response but did not consistently stimulate termite preference. In contrast, citronella and tea tree showed low responses in both assays, indicating their potential roles as repellents or trail-disrupting agents. The GC-MS profiles suggest that α-pinene and 1,8-cineole may be associated with attraction and orientation responses, whereas geraniol, citronellol, and terpinen-4-ol may contribute to repellent or disruptive effects. However, because this study used crude extracts, the specific role of each compound requires further confirmation. Future studies should evaluate dose-dependent responses, purified compounds, long-term behavioral effects, and field-scale applications to determine the practical effectiveness of these extracts in termite baiting or repellent systems.

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AUTHOR CONTRIBUTION STATEMENT

NS conceptualization, methodology, supervision, funding acquisition, and manuscript review. SM research apparatus preparation, methodological support, data collection, and formal analysis. ANR data interpretation, manuscript writing, editing, revision, and final proofreading. PN laboratory work, fieldwork support, data collection, and visualization. YSH conceptual input, validation, and manuscript review.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest regarding the publication of this paper.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors used AI-assisted technology solely for initial structural editing and language refinement under strict author supervision. Subsequent comprehensive proofreading and final language polishing were fully conducted by a professional English language specialist. No AI tools were used to generate research data, perform statistical analysis, fabricate references, or draw scientific conclusions. All scientific content, data interpretation, citations, and final manuscript decisions were verified and approved by the authors.

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