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Assessing the Efficacy of Some Botanicals for the Control of Subterranean Termites in Nasarawa State, Nigeria

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Abstract

This study evaluated aqueous leaf extracts of *Plumeria rubra*, *Tephrosia candida* and *Anogeissus leiocarpus* for toxicity and repellency against the subterranean termite *Macrotermes subhyalinus* in laboratory bioassays. Crude extracts were prepared and applied at 10, 20, 30 and 40% w/v to filter papers; twenty worker termites per Petri dish (three replicates) were exposed, and mortality was recorded at 24 and 48 hours. All extracts produced dose-dependent mortality; at 40% w/v, *A. leiocarpus* caused 75.0% mortality at 24 h, while *P. rubra* and *T. candida* produced 71.7% and 71.7%, respectively; all extracts attained 100% mortality by 48 h (the diazinon positive control achieved 100% at 24 h; distilled water had no effect). In repellency assays (30 min exposure), extracts showed 50–71% repellence at the highest dose. Phytochemical screening indicated the presence of alkaloids, flavonoids, tannins and eugenol-related compounds that likely contribute to activity. These results indicate that the tested botanicals have potential as locally available termite control agents; further work is recommended to standardise extraction, determine LC50/LT50 values, evaluate field efficacy and develop safe formulations.

Keywords: Botanical termiticides, Macrotermes subhyalinus, Pest management, Phytochemical screening

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INTRODUCTION

Termites are important components of tropical and subtropical ecosystems. They are a group of social insects belonging to the order *Isoptera* and the family *Termitidae* (Bignell & Eggleton, 2000; Mitchel, 2002). Ecologically, they play an integral role in soil fertilisation, humus formation, decomposition of organic matter, and nutrient cycling, thereby supporting vegetation growth (Freymann et al., 2008; Jouquet et al., 2011; Garba et al., 2011). Their activities are not only crucial for ecosystem functioning but also for maintaining the productivity of agricultural systems in tropical regions. Recent studies have further emphasised their role as ecosystem engineers, influencing soil structure, microbial diversity, and plant performance (Chouvenc et al., 2021; Hinze et al., 2023).

Globally, termites constitute nearly 10% of annual animal biomass and are predominantly distributed in tropical and subtropical regions (Van Huis, 2017; Bonachela et al., 2015; Brune, 2014). Their evolutionary history traces their origin to sub-Saharan Africa, with species diversity being highest in rainforest habitats (Poulsen et al., 2014). Depending on their ecological niches, termites are broadly categorised into subterranean termites, which nest and forage belowground; dry wood termites, which spend their life cycles within dry timber; and damp wood termites, which thrive in moist wood environments (Govorushko, 2019). Of these, subterranean termites are the most destructive because of their soil-nesting habits and ability to feed on a wide range of cellulose-based materials, including structural timber, agricultural crops, and stored products. Their highly organised caste system—comprising workers, soldiers, and reproductive castes—enables efficient foraging, nest maintenance, and colony survival. Workers rely on symbiotic gut protists and bacteria to digest cellulose, making them uniquely adapted to degrading lignocellulosic materials (Schultz et al., 2021).

In natural ecosystems, termites survive by feeding primarily on detritus, wood, and other cellulose-rich substrates, and they have been reported in high abundance across agroecosystems (Bruno et al., 2001; Robert, 2007). Presently, nearly 3,000 species in 282 genera have been described worldwide (Kambhampati & Eggleton, 2000). In West Africa, the genera *Ancistrotermes*, *Macrotermes*, *Amitermes*, *Odontotermes*, *Microtermes*, and *Cubitermes* are among the most frequently encountered (Mitchell, 2002). *Macrotermes subhyalinus*, one of the most common species, is of particular concern due to its extensive damage to agricultural crops, wood, and infrastructure (Loko et al., 2017).

Despite their ecological importance, termites are best recognised as destructive pests with economic significance. They cause substantial losses to agricultural fields and human settlements by infesting food and cash crops, agroforestry plantations, and structural timbers in buildings, especially in warm tropical climates where their populations thrive (Rashmi & Sundararaj, 2013). The economic costs of termite infestation are significant, with estimates in Africa indicating millions of dollars in annual crop and structural damage (Nkunika et al., 2021). Moreover, in the context of climate change, termite activity and distribution patterns are expected to intensify, thereby amplifying their pest status (Ayuke et al., 2020).

Chemical termiticides, though widely used, present challenges such as high cost, environmental contamination, development of resistance, and risks to non-target organisms, including humans (Verma et al., 2022). This has renewed interest in eco-friendly alternatives such as botanicals and plant-derived bioactive compounds, which are generally biodegradable, locally available, and safer for the environment (Isman, 2020; Pavela & Benelli, 2021).

Among the botanicals of interest are *Plumeria rubra* (DC.) W.T. Aiton, *Tephrosia candida* (DC.) Pinsa, and *Anogeissus leiocarpus* (DC.) Guill. & Perr.—plants with traditional ethnobotanical uses but underexplored for termiticidal activity. *P. rubra* (family Apocynaceae) is a shrub or small tree reaching 2–8 m, commonly used in folk medicine. *T. candida* (family Fabaceae) is an erect shrub up to 1.5 m tall, valued for its insecticidal properties due to its high content of rotenoids and flavonoids. *A. leiocarpus* (family Combretaceae) is a slow-growing tree attaining 15–30 m in height, widely used in African traditional medicine and known for tannins and phenolic compounds with pesticidal properties. Previous studies have shown that plant extracts, including essential oils and secondary metabolites, can exhibit toxicity, repellence, or growth inhibition against a variety of insect pests, including termites (Ahmed et al., 2016; Rajashekar et al., 2021; Kéita et al., 2022). However, comprehensive evaluation of these three plants against *M. subhyalinus* is limited.

Therefore, this study was undertaken to investigate the termiticidal and repellent potentials of aqueous leaf extracts of *P. rubra*, *T. candida*, and *A. leiocarpus* against *M. subhyalinus* in Nasarawa State, Nigeria. By combining bioassays and phytochemical screening, the research aims to provide scientific evidence supporting the use of these botanicals in sustainable termite management strategies.

MATERIALS AND METHODS

Source and Preparation of Termite Feed

The stem of Plumeria rubra W.T. Aiton, used as termite feed in this study, was obtained from the College of Agriculture, Science and Technology research farm, Lafia, Nasarawa State, Nigeria. The choice of wood was based on previous records of high susceptibility to insect pests (Li et al., 2001).The stem was cut into pieces and preserved for use.

Preparation of Plant Materials and Extracts

The leaves of P. rubra were sourced from the College of Agriculture, Science and Technology research farm, while leaves of T. candida and *A. leiocapus* were sourced from Nasarawa State University, Keffi, Faculty of Agriculture. The three plant leaves were collected separately inside bagco bags in the month of March, 2025. The leaves were properly washed in clean water and left to dry at a room temperature of 30 ± 0°C in the entomology laboratory, Department of Pest Management Technology, for 30 days; thereafter, they were sun-dried for 10 days.

Termite Collections and Establishment for Test:

Adult worker termites (*Macrotermes subhyalinus* (Rambur)) were collected from two Local Government Areas from each of the three Senatorial Zones of Nasarawa State, namely Akwanga and Nasarawa Eggon LGAs (Northern Zone), Lafia and Doma LGAs (Southern Zone) and Keffi and Karu LGAs (Western Zone). Termite mounds were dug out using a hand drill, spade and digger. Soil containing termites was put on plastic sheets. Adult worker termites were collected from the plastic sheets using a camel hair brush and placed in plastic boxes (polyethylene plastic box).

Soft, small pieces from *P. rubra stem were added to the plastic boxes as feed for the termites.* The top parts of the plastic boxes were covered with muslin cloth that allows for air ventilation but prevents the escape of the termites. A moistened wad of cotton was placed inside the plastic boxes to maintain the required moisture level of 70-75% for the survival of termites. The boxes carrying the termites were transported to the entomology laboratory, where collected termites from the different areas were mixed into a single box of termite population and placed in a cool and dark area until needed for the experiment. The termite feed was continuously replenished, and humidity was kept at ± 72% in the plastic box.

Extraction and Isolation of the Botanicals:

The dried leaves of the botanicals were ground with a microplant grinding machine and sieved through a 0.25 mm pore-size mesh sieve to obtain uniform fine powders (Jembere et al., 2005). The resulting powders were kept separately in glass containers with screw caps and stored at room temperature in the dark prior to use. Portions from each powder container were separately concentrated using a Soxhlet extractor to obtain concentrated crude extracts.The amount of concentrated extract mixed with 100 ml of water was calculated on a weight-by-volume basis; that is, weight of extract/volume of water.Then, 10, 20, 30 and 40 g of each extract were soaked in 100 ml of water for 24 hrs to obtain concentration levels of 10, 20, 30 and 40 ml (w/v). Each mixture was filtered with clean cheesecloth and applied topically on worker termites.

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Phytochemical Analysis

The stored leaf powders of the botanicals (*P. rubra, T. candida and A. leiocapus*) were measured (100 g each) into beakers and soaked in water for a period of 24 hrs. The beakers were allowed to shake rigorously on a flask shaker to ensure proper dissolution of compounds.The dissolved solids were separated from their liquid components using a centrifuge.The solvents were evaporated using a rotary evaporator to concentrate the extracts.A quantitative analysis was conducted to determine the exact concentration of specific compounds in the extracts using light chromatography.

Bioassay Procedures for Toxicity of Botanicals

Flasks containing the four concentrations (40, 30, 20 and 10 ml) of the botanical extracts were shaken thoroughly for about 5 minutes to ensure uniform distribution of the solutes.What, man? No. Whatman filter papers, each 9 cm in diameter, were placed in Petri dishes and treated separately with 2 ml of the water extract from each of the four concentrations. Twenty adult worker termites were randomly selected from the stock population and transferred into the Petri dishes containing the treated filter papers. A 0.2% solution of Diazinon EC 60% served as the standard check, while water acted as the negative control.

All treated Petri dishes were covered with a double ring of black plastic sheet to simulate the dark galleries of termites. The treatments (four concentrations for each botanical) were replicated three times. Mortality of termites was recorded every 24 hours for three days following the application of the treatment.periment was conducted under laboratory conditions (30 ± 2ºC and 70-80% relative humidity).

Mortality with Botanical Extracts

For the assessment of mortality of worker termites, the botanical extracts were incorporated into the treated filter paper at a concentration of 10, 20, 30, and 40 % for each extracts with two controls; a negative (sterile water) and a commercial insecticide (Diazinon). The petri dishes having treated filter papers were held at temperature of 30 ± 2 ºC and relative humidity of 70 - 80 % for three days. Mortality was recorded at a 24 hr interval. The number of dead worker termites was recorded and the percentage mortality was calculated using Abbott equation of 1925 as described by Erturk (2007) shown below;

$$\text{Percent mortality} \quad \frac{number\ of\ dead\ termites}{total\ number\ of\ termites} \text{ X } 100$$

Termite Repellent Test due to Botanical Extracts.

Four experimental concentrations (10, 20, 30 and 40 ml w/v) of each botanical were tested separately. What, man? No. A filter paper (9 cm diameter) was cut into two equal parts; one part was treated with botanical extract, while the other half was doused with distilled water (untreated control). Both halves were placed 2 cm apart in a Petri dish. Twenty adult worker termites were introduced at the centre of the Petri dish, and the dish was placed in darkness in order to minimise the effect of light on the termites. Three replications were carried out for each concentration of botanical extract. The number of termites on both treated and untreated filter papers was recorded from each Petri dish 30 minutes after treatment application. The termite repellent level was determined based on the number of termites which remained on the extract-treated filter paper. The percentage repellent was calculated by Erturk's (2007) equation:

Repellence (%) $= \frac{C-T}{c} X\ 100$

Where:

C = Number of termites collected from untreated filter paper

T = Number of termites collected from treated filter paper

Experimental Designs and Treatment Details

All the experiments were laid out under Completely Randomised Design (CRD) with three replications. In all cases, 0.2 ml of diazinon was used as a standard check and distilled water as a control for comparison. Each treatment was tested at four concentrations (10, 20, 30 and 40 ml (w/v)). The data recorded for different response variables in the study were subjected to Analysis of Variance (ANOVA) using SAS version 9.2 software.

RESULTS

Percentage Termite Mortality Test

The results of this experiment, as shown in figure 1, revealed that aqueous extracts of P. rubra, T. candida and *A. leiocapus* leaves caused high mortality in the worker termites, which was significantly different among the extracts at varying concentrations and with the controls (diazinon and distilled water). Mortality rates at the lowest concentration (10 ml) were 27, 12 and 42% for P. rubra, T. candida and *A. leiocapus, respectively, after* 24 hrs of treatment.Percentage mortality increased with increasi ng extract concentrations.This was revealed by the increased mortality of 28, 15 and 45% at 20 ml and 71.65%, 55.00% and 68.35% at 30 ml for P. rubra, T. candida and *A. leiocapus, respectively, after* 24 hrs of treatment.Higher extract concentrations of 40 ml showed the highest mortality percentages of 75.00, 71.65 and 71.65% for *A. leiocapus, P. rubra* and *T. candida after* 24 hrs of treatment.100% termite mortality was observed for all tested extracts at 30 and 40 ml after 48 hrs of treatment, while positive control (Diazinon) showed 100% mortality after 24 hrs of treatment, and negative control (water) had no effect on termite mortality.

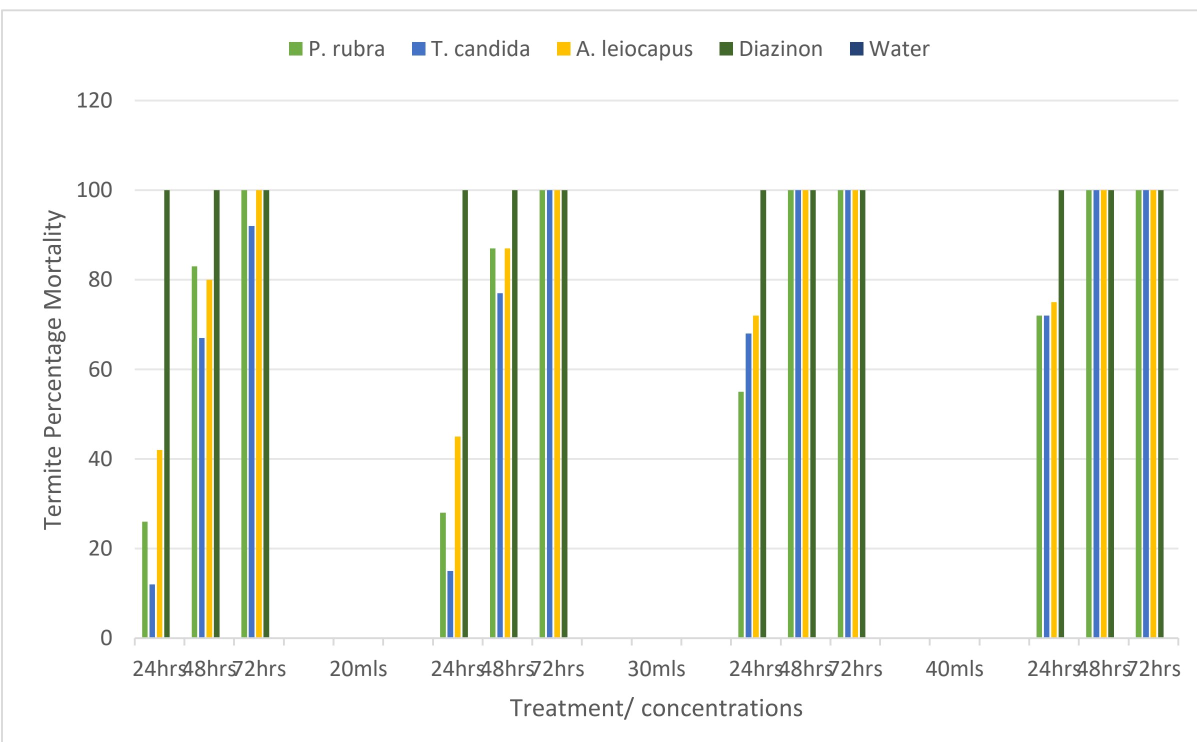

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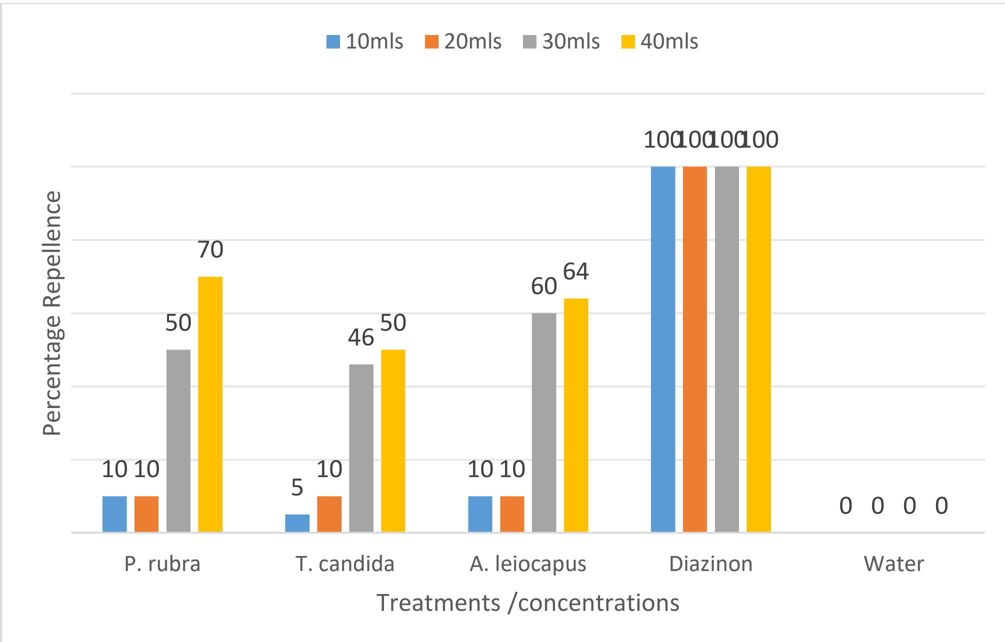
Fig.1: Percentage termites mortality of leaf extracts at various concentrations

Repellent Test

Results from the repellent test, as shown in figure 2, revealed that all tested leaf extracts had a repellent effect against termites at all the experimented concentrations within a period of 30 min. The most effective was *P. rubra* with 70% repellent at the highest extract concentration of 40 ml, followed very closely by *A. leiocapus* with 64%, while *T. candida* showed the lowest repellent rate of 50% at 40 ml.The termite percentage repellent rate decreased with lower leaf extract concentrations, with the least concentration of 10 ml showing 10, 5 and 10% repellent rates for *P. rubra, T. candida and A. leiocapus, respectively.* However, the standard check (diazinon) at a concentration of 0.2 ml repelled worker termites by 100%, while no repellent effect was observed in the control (water) experiment.



Fig, 2: Termite percentage repellent test of leaf extracts at various concentrations.

Phytochemical Analysis

The phytochemical analysis results in table 1 revealed alkaloid, flavonoid, tannins and eugenols as the most active ingredients. It was shown that none of the tested extracts contained phytate while eucalyptil was present only in *A. leiocapus*.

Table 1: Quantitative phytochemical analysis of leaf extracts.

	Plumeria rubra	***Tephrosia candida***	***Anogeisus leiocapus***
Tanins	18.9 mm/100g	14.80 mm/100g	-
Saponins	12.83 mm/100g	10.20 mm/100g	8.20 mm/100g
Flavonoids	17.00 mm/100g	14.64 mm/100g	14.01 mm/100g
Alkaloids	18.96 mm/100g	-	17.00 mm/100g
Phytate	-		-
Eugenol	16.25 mm/100g	15.00 mm/100g	18.96 mm/100g
linalol	18.18 mm/100g	14.00 mm/100g	-
Eucalyptil	-	-	25.96 mm/100g
Rotenoids	-	10.00 mm/100g	18.24 mm/100g

DISCUSSION

The control of termites has been highly dependent on chemical application for many years.Though the use of chemical insecticides for control of termites has been effective, it is costly and generates detrimental effects on the environment and other biological systems. This study was carried out to examine the possibilities of aqueous leaf extracts of *P. rubra, T. candida and A. leiocapus* for their termiticidal efficacy.

Aqueous leaf extract of Plumeria *rubra* W.T. Aiton was tested against worker termites in this study. After only 48 hrs, 100% mortality occurred using this treatment. This greatly coincides with results from Aguoru et al. (2016), who tested *P. rubra* against Anopheles mosquitoes and bean weevils that showed 88.75% mosquito mortality and 90% bean weevil mortality after 48 hrs of treatment.In this study, the repellent property of P. *rubra* against worker termites was also examined. The repellent percentage of *P. rubra* on worker termites was tested for just 30 min, and the result showed a high repellent rate of 70%. This looks similar to the report of Ichsan et al. (2020), who examined the repellent properties of leaf extracts of P. rubra on rice-field rats, which caused metabolic disorder, significantly indicated by the decrease in its average consumption of food by 2.28 g and excretion of faeces by 0.34 g, and also the increase of average consumption of beverage by 3.89 ml, excretion of urine by 3.15 ml and body weight by 6.67 g.

Anogeisus leiocarpus Guill. and Perr. leaf extract was also examined in this study for its termiticidal mortality and repellent efficacy. Results showed a 100% termite mortality within a short period of 48 hrs at 40 ml of extract concentration.This is in agreement with the results of Uwemedimo et al. (2025), who reported that extracts of *A. leiocarpus* greatly reduced the deterioration of selected timbers in a graveyard experiment after 12 days of treatment. The results of the aqueous leaf extract of Tephrosia *candida* D.C. Pinsa in this study were similar to Becker and Gencer (2024), who reported that extracts of aqueous leaf extracts of Tephrosia *spp*. efficiently repelled termites when applied around termite mounds.

Results from this study, as shown in Fig. 1, confirm that the examined plant extracts have substantive termiticidal efficacy, which can be attributed to the occurrence of large amounts of active ingredients (secondary metabolites) in individual plant extracts, as presented in Table 1. This claim agrees with the findings of Kim et al. (2000), who reported that flavonoids inhibited the activities of insects by preventing certain insect metabolism. Also, tannins retard the survivorship, growth and development of herbivore insects by their ability to bind to insect proteins. Moreover, Funk et al. (2009) revealed that certain plants with high deposits of alkaloids proved toxic to termites and other herbivorous insects by the disruption of protein metabolism, which affects ionic pathways, neurotransmission, reception, transport and enzyme synthesis, thereby causing severe changes in insect physiology and behaviour. Other metabolites present in the analysed extracts are eugenols and saponins, which have been discovered to have a disruptive effect on the nervous system of insects.

This study recorded a significant termite repellent efficacy for all tested extracts, as shown in Fig. 2. It can be argued that the high repellent rates of these extracts may be due to the pungent or offensive smell they possess. These strong scents may have caused the termites to move away from the respective treated papers to the untreated ones. This suggestion agrees with Kim et al. (2006), who reported that essential oils of terpenoids like eucalyptol, linalool and several other volatile oils were able to repel insects at low concentrations that were less harmful to mammals.Also, termicidal activity occurred in cajuput oil (Melaleuca cajuputi) against *Coptotermes formosanus due to the presence of* monoterpenes, diterpenes, sesquiterpenes and hydrocarbons.

CONCLUSION

The present study has demonstrated that aqueous extracts of *Plumeria rubra*, *Tephrosia candida*, and *Anogeissus leiocarpus* exhibit promising termiticidal and repellent effects against *Macrotermes subhyalinus*. Mortality rates increased with concentration and exposure time, while repellence assays revealed significant avoidance behaviour by worker termites. These results affirm that locally available plant species can serve as viable alternatives to synthetic termiticides, particularly in regions such as Nasarawa State, Nigeria, where termite infestations threaten agricultural productivity and structural integrity. By linking phytochemical composition to observed bioactivity, this research provides mechanistic insights that enrich the scientific discourse on botanical pest management.

Beyond their direct bioactivity, the use of botanicals for termite control carries broader ecological and socio-economic significance. Synthetic chemicals, though effective, are often costly, environmentally persistent, and hazardous to non-target organisms, including humans. In contrast, plant-based formulations offer biodegradability, accessibility, and cultural acceptance, making them attractive within integrated pest management (IPM) frameworks. Importantly, this study aligns with global calls for sustainable agricultural practices that reduce dependency on synthetic pesticides, thereby contributing to environmental conservation and public health (Isman, 2020; Pavela & Benelli, 2021).

Nevertheless, it is crucial to recognise the limitations of laboratory bioassays, which may not fully replicate field conditions where temperature, humidity, soil composition, and termite colony dynamics vary considerably. While the extracts showed high efficacy under controlled conditions, field trials are necessary to validate their performance and persistence in natural settings. Furthermore, the variability in phytochemical content due to factors such as plant age, harvesting season, and extraction method warrants additional standardisation. Advanced analyses, such as LC–MS or GC–MS, could further identify and quantify the active compounds responsible for termiticidal action, paving the way for bioactive-guided formulation.

In conclusion, this study underscores the potential of *P. rubra*, *T. candida*, and *A. leiocarpus* as eco-friendly alternatives for termite control, thereby offering new directions for sustainable pest management in sub-Saharan Africa. The findings provide a scientific basis for further research, development, and eventual adoption of botanical-based termiticides. With appropriate policy support, farmer education, and interdisciplinary collaboration, these botanicals could be integrated into broader pest management programmes, contributing not only to crop and structural protection but also to the promotion of biodiversity and environmental resilience.

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