Termites Infestation on Different Eucalyptus Wood Species and Control Using Natural Oil from Plants

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Research Article

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Abstract

Termites are one of the major pests of wood and the use of synthetic insecticides in the control constitutes a major challenge to environmental health. This study assessed the level of damage on the wood of four *Eucalyptus* species on exposure to subterranean termites using preference and non preference tests in the field; and the efficacy of different plant oils to protect wood damage. Physical properties responsible for wood resistance were determined using standard procedures. Pearson correlation, Analysis of Variance (ANOVA) and Tukey's Honestly Significant Difference ($p < 0.05$) were used for data analysis. The results showed that the highest and lowest wood damages were recorded in *Eucalyptus tereticornis* and *Eucalyptus cloeziana*, respectively throughout the period of observation in Samaru-Zaria and Afaka, Kaduna. The results also showed that wood of *E. cloeziana* was harder than that of *E. tereticornis*; and correlated significantly with the percentage wood loss. Solignum, a synthetic wood protectant, reduced wood loss to termite infestation more than the plant oils. Oil extracts from neem seed, Jatropha seed and palm kernel significantly reduced wood loss than in the control treatment. However, the potency of these plant oils reduced with time. The wood of *E. cloeziana* demonstrated high level of resistance against termite infestation; and neem oil, Jatropha oil and palm kernel oils can be used as wood protectants as alternatives to synthetic wood preservatives.

Introduction

Eucalyptus tree commonly used as plantation species throughout Africa is one of the exotic tree species established for the implementation of trial afforestation project in the semi-arid region of Nigeria. It was first introduced to Nigeria in 1916; and has since been adapted and thrives well because its plantation requires non-expensive inputs for propagation (Onifade, 2001). They have been successful as exotics because of their capacity for fast growth and tolerance to harsh environments. *Eucalyptus* species possess other adaptive features which include intermediate growth, fast coppicing and tolerance to drought, fire, soil acidity and low soil fertility (Rockwood et al., 2008). In Africa, especially, the semid-arid region of Nigeria, *Eucalyptus* trees are essentially utilized as fuel wood, timber for building construction; and poles for electricity and telecommunication transmission lines. They have also been used commercially for production of essential oils and medicinal purposes (Adeniyi et al., 2006; Adeniyi and Ayepola, 2008; Gero et al., 2012; Abubakar and Mahdi, 2015).

Termites have been identified as one of the major pests that cause damage to wood and trees worldwide (Lee et al., 2003). *Eucalyptus* species are susceptible to termite damage during plantation establishment and also its wood and wood products in use (Nyeko and Nakabonge, 2008; Alamu et al., 2022). Bio-deterioration has been described as one of the major problems of wood in service and it is addressed mostly by impregnation with appropriate chemical preservatives (Owoyemi and Olaniran, 2014). The use of conventional wood impregnation methods are based primarily on the application of toxic chemicals (Papadopoulos, 2010). However, the use of conventional chemical treatments has been restricted as a result of their ill impacts on human and environmental health. Exploitation of the natural defense mechanisms of durable wood species has therefore been recommended for use by wood preservation industry (Rachael et al., 2006).

The plantation of forest species and the use of woods having natural resistance to termites offer an alternative for the use of chemicals products. This resistance is conferred by some physical and chemical properties of wood which include wood density, wood hardness and the presence of metabolites such as alkaloids, terpenoids, phenols, quinones and tannins (Gupta and Sen Sarma, 1978; Shanbhag and Sundararaj, 2013). Identification of *Eucalyptus* species with natural durability and resistance to termites will be of immense benefits to growers and end users and also reduce the application of synthetic insecticides to reduce or prevent termite infestation. The use of such species in plantation establishment will encourage environmentally saved forestry management. Therefore, this study examined the potential natural resistance in four *Eucalyptus* species on exposure to subterranean termites; and the use of natural oils against termite infestation.

Materials And Methods

Study area

The study was carried out in Afaka (Latitude 10.66697; Longitude 7.387451) and Samaru-Zaria (Latitude 11.166667; Longitude 7.633333), Kaduna State in the Northern Guinea Savanna vegetation zone of Nigeria. The climate is characterized by a clear distinction between dry and rainy seasons. The rainy season lasts from mid-April to early October with the months of August and March being the peak of the wet and dry seasons, respectively. The mean annual rainfall is 1266.0 mm based on annual rainfall record of forty three years (1969–2012) (NIMET 2012).

Temperatures are high throughout the year with the highest in March (about 38.6 °C) and the lowest in January (about 20.2 °C). Relative humidity in the dry season is below 10% in the afternoon and 90% at dawn. During the rainy season, the relative humidity can be over 70% in the midday and 95% at dawn.

Preparation of wood samples

The preparation of wood samples for the experiments was carried out by felling one stand each of *E. camaldulensis*, *E. citriodora*, *E. cleoziana* and *E. tereticornis* from plantations established in 1988 at Buruku experimental site of Trial Afforestation Station, Afaka, Kaduna State, Nigeria (10.6196° N, 7.2316° E). The trees were cross cut into three portions of 4 m each representing the bottom, middle and top parts. The middle portion was further cross cut into two billets of 2 m out of which 20×50×2000 mm boards were produced. Thereafter, each board was sliced into 20× 20 × 2000 mm scantlings. Wood block samples of 20× 20 × 200 mm were prepared from the scantlings and air-seasoned for two weeks before it was used for the study. The wood blocks were oven-dried at 100°C until constant weight and weighed prior to field trials.

Feeding deterrence

Feeding deterrence was carried out using wood preference and non-preference tests in a timber grave yard at Trial Afforestation Research Station premises in Afaka, Kaduna and replicated at Savanna Forestry Research Station premises, Samaru, Zaria, Nigeria (11.1667^{o}N, 7.6333^{o}E). For preference test, a wood block each from the four *Eucalyptus* species was tied together in a group representing an experimental unit. Each group was replicated ten times as a set and three separate sets were prepared for wood damage assessment at 3, 6 and 9 months. The wood blocks were arranged in a Randomized Complete Block Design, buried in the soil at 20 cm depth and at a distance of 2 m apart. Wood damage was assessed at 3, 6 and 9 months after being buried in the soil. At each assessment, the wood blocks were removed from the soil, cleaned and oven-dried at 100^{o}C until constant weight and re-weighed to determine the weight loss. The percentage weight loss was calculated and used as the percentage of wood eaten by termites.

For non-preference field trials, the wood blocks were prepared as in preference test except that the wood block of different *Eucalyptus* species was buried in the soil individually at a distance of 2 m apart in the field. Each *Eucalyptus* species was replicated 10 times and arranged in a Randomized Complete Block Design. The experiment was replicated three times for damage assessment at 3, 6 and 9 months. The wood blocks were removed at 3, 6 and 9 months and assessed for damage as in the preference test. Data on percentage wood damage in preference and non-preference tests were transformed using arcsine before being analyzed using ANOVA and means were separated using Tukey's HSD test ($p \leq 0.05$). Results of preference and non-preference tests were subjected to a t-test analysis for the comparison of wood damage under the two tests.

Determination of wood density

Ten wood sample specimens were prepared from each *Eucalyptus* species in the Department of Forest Resources Management, University of Ibadan, Ibadan, Nigeria. The wood samples were oven-dried at 103^{o}C until constant weight was achieved. The masses (*m*) of the wood samples were determined accurately to the nearest 0.001g using Analytical weighing balance. The volume (*v*) of each wood sample was calculated by the product of the average length, average breadth and average thickness of the wood sample. A vernier caliper with the accuracy of 0.02mm was used to take the individual linear dimensions of the wood sample. The density for each wood species was calculated using the formula:

$\rho = m/v$

Where,

ρ = wood density

m = mass of the wood sample (g)

v = volume of the wood specimen (cm^3)

Determination of wood hardness

The wood hardness of different *Eucalyptus* species was carried out at the Department of Metallurgical and Material Engineering, Ahmadu Bello University, Zaria, Nigeria according to the provisions in ASTM-E18-79 using Rockwell hardness tester on “F” scale (Indentec Rockwell Hardness Tester) with 1.588mm (1/16 inch) steel ball indenter, minor load of 10kg, and major load of 60kg. Before the test, the mating surface of the indenter, plunger rod and test samples were thoroughly cleaned by removing dirt, scratches and oil. The minor load of 10kg was applied to the sample in a controlled manner without inducing impact or vibration and zero reading position was established. Then the major load of 60kg was applied and the reading was taken when the large pointer came to rest. The load was removed by returning the crank handle to the latched position and the hardness value read directly from the semi-automatic digital scale (Idris *et al*., 2012). Hardness values were reported by writing the number followed by the letters HR for Hardness Rockwell and affixing the name of the scale (F) used (Idris *et al*., 2012).

Wood treatment of *E. tereticornis* with natural oil

Eucalyptus tereticornis has been confirmed as the most susceptible species to termite attack in preference and non-preference tests. The wood blocks were prepared as described under preparation of wood samples above. Wood blocks of *E. tereticornis* were oven-dried at 100^{o}C until constant weight and weighed to determine the initial weights. After drying, the wood blocks were re-weighed; and the weights were recorded. The wood blocks were treated by submerging them separately in Solignum solution, Neem Seed oil, *Jatropha* Seed oil and Palm kernel oil in 2-L plastic buckets for 12 hours. The wood blocks were air-dried in the laboratory for 72 hours and re-weighed. Three sets of 10 wood blocks were treated with each preservative to be exposed to termites in the field for 6, 12 and 18 months. The treatments were arranged in a Randomized Complete Block Design in a timber graveyard. The experiment was carried out in Afaka, Kaduna and replicated in Samaru, Zaria.

At the end of each exposure periods, the wood blocks were removed and inspected for termite attack. The wood blocks were cleaned and oven-dried at 100^{o}C until constant weight in the laboratory. They were re-weighed to determine the final weight and the percentage of wood consumed by termites was calculated. Data collected on wood damage were transformed using arcsine before analyzed ANOVA. Significant differences in wood damage were separated using Tukey’s HSD test ($p \leq 0.05$).

Results

Wood infestation of termite on four *Eucalyptus* species

In wood preference experiment at Samaru, Zaria, the mean percentage of wood loss to termite at 3 months in *E. camaldulensis*, *E. citriodora* and *E. cloeziana* were not significantly different but significantly higher in *E. tereticornis* (Table 1). The mean wood losses of 8.71% and 11.58% recorded in *E. cloeziana* at 6 and 9 months respectively were significantly lower than wood losses in *E. tereticornis* but not significantly different from wood losses in *E. camaldulensis* and *E. citriodora*. In non-preference experiment, *E. tereticornis* recorded the highest percentage of wood loss to termite at 3, 6 and 9 months of wood exposure. These wood losses were significantly higher ($p \leq 0.05$) than in *E. cloeziana* but not significantly different from wood losses in *E. camaldulensis* and *E. citriodora.*

Table 1. Termite's wood damage (% ±S.E) on four *Eucalyptus* species in preference and non-preference tests in Samaru-Zaria, Nigeria

Wood species	Preference test			Non-preference test		
	Period of infestation in months					
	3	6	9	3	6	9
E. camaldulensis	8.82±0.87b	12.04±0.78ab	13.80±0.96b	7.49±0.94b	13.03±0.45b	15.23±0.44b
E. citriodora	7.78±1.18b	15.60±0.75ab	16.50±0.22ab	7.54±1.15ab	15.61±0.72ab	18.10±0.80ab
E. cloeziana	7.08±0.60b	8.71±1.18b	11.58±0.75b	7.33±0.87b	11.27±0.66b	12.30±0.79b
E. tereticornis	16.83±1.33a	17.16±4.36a	20.56±3.30a	14.27±3.09a	21.13±3.11a	24.46±3.46a

Means followed with the same letter in the column are not significantly different.

Table 2 showed the effect of termite infestation on different *Eucalyptus* wood species under non-preference and preference experiments in Afaka, Kaduna. The wood losses due to termites on the four *Eucalyptus* species in preference test at 3 months after wood exposure were not significantly different ($p \leq 0.05$). At 6 and 9 months, the wood losses in *E. tereticornis* were significantly higher than in *E. cloeziana* but not significantly different from losses inflicted on *E. camaldulensis* and *E. citriodora*. The result also showed that wood losses obtained in *E. cloeziana* were not significantly different from the percentage of wood losses obtained in *E. camaldulensis* and *E. citriodora*. In non-preference test, the percentage of wood loss in *E.cloeziana* was not significantly different from *E. camaldulensis* and *E. citriodora* but significantly lower than in *E. tereticornis*. The wood losses at 6 and 9 months were not significantly different in *E. camaldulensis*, *E. citriodora* and *E. tereticornis*; however, it was significantly low in *E. cloeziana*. A t-test analysis of the percentage of wood loss due to termites attack on the four *Eucalyptus* species in preference and non-preference experiments in Afaka, Kaduna and Samaru, Zaria showed that there was no significant difference between the two trial methods ($t(cal)<t(tab)$; df = 3; $p \leq 0.05$).

Relationship between Physical properties of Eucalyptus and termite infestation

The highest wood density (906 kg/m^3) was recorded in *E. camaldulensis* while *E. tereticornis* had the lowest density (795 kg/m^3) (Table 4). In addition, the highest wood hardness (7.78 HRF) was recorded in *E. cloeziana* and the least (5.48 HRF) was obtained in *E. tereticornis*. A regression analysis showed a negative significant relationship (R^2 = 0.94, p = 0.03) between wood hardness and the percentage of wood loss due to termite infestation on *Eucalyptus* species, while the relationship between the percentage of wood density and wood loss was not significant (R^2 = 0.17, p = 0.59) (Table 5).

Effect of natural oils on wood damage of *E. tereticornis*

There was a significant reduction (p≤0.05) in the percentage of wood consumed by termites on wood treated with Solignum, NSO, JSO and PKO compared to untreated woods at all periods of wood exposure in Samaru, Zaria (Table 6). However, at 18 months there was no significant difference in the percentage of wood consumed between untreated woods and woods treated with PKO. In addition, the percentage of wood consumed by termites on woods treated with Solignum, NSO, JSO and PKO were not significantly different at 6 months of exposure; but at 12 and 18 months, wood losses recorded from woods treated with Solignum were significantly lower than wood losses recorded in woods treated with NSO and JSO. It was observed in Kaduna that, at 6 months the percentages of damage inflicted on untreated wood and woods treated with NSO, JSO and PKO were not significantly different but significantly (p≤0.05) higher than the percentage of wood loss in woods treated with Solignum. With an average of 27.61%, the wood consumed by termites in untreated wood at 12 months was significantly higher than the percentage of wood consumed by termites on wood samples treated with Solignum, NSO, JSO and PKO. The mean percentages of wood damaged by termites in untreated wood and wood treated with JSO and PKO at 18 months were not significantly different significantly (p≤0.05) higher than the percentage of wood consumed by termites on

Table 2. Termite's wood damage (% ± S.E) on four *Eucalyptus* species in preference and non-preference tests in Afaka, Nigeria

Wood species	Preference test			Non-preference test		
	Period of infestation in months					
	3	6	9	3	6	9
E. camaldulensis	11.60±2.58a	17.72±2.22ab	28.13±4.66a	13.42±ab	21.06±4.80a	25.23±5.52a
E. citriodora	12.45±1.22a	20.95±2.34a	26.39±4.87a	13.17±1.99ab	22.97±4.44a	28.04±4.21a
E. cloeziana	11.01±1.29a	13.35±1.17b	18.01±2.14b	9.48±1.43b	13.46±1.79b	16.28±1.81b
E. tereticornis	10.66±1.88a	23.02±4.83a	28.44±5.94a	17.72±4.78a	25.19±4.86a	29.36±4.26a

Means followed with the same letter in the column are not significantly different.

Table 4. Wood density and wood hardness of four *Eucalyptus* species.

Eucalyptus wood species	Wood density (kg/m^3)	Wood hardness (HRF*)
E. camaldulensis	906	7.07
E. citriodora	842	6.62
E. cloeziana	853	7.78
E. tereticornis	795	5.48

* Hardness Rockwell on scale F

Table 5: Relationship between physical properties of Eucalyptus wood and percentage wood loss

Parameters	Regression equation	R^2	Probability
Wood hardness and wood loss	y = -3.92x + 36.33	0.94	0.03
Wood density and wood loss	y = -3.99x +927.3	0.17	0.59

Table 6. Mean wood damage (%) of termites on *E. tereticornis* treated with Solignum and oil extracts from Neem, *Jatropha*

and Palm kernel seeds.

Treatment	Samaru, Zaria			Afaka, Kaduna		
	Period of exposure (Month)					
	6	12	18	6	12	18
Control	22.29 ± 5.10a	26.38 ± 4.12a	33.50 ± 2.66a	19.02 ± 3.49a	27.61 ± 4.79a	39.21 ± 6.92a
Solignum	7.26 ± 1.18b	10.19 ± 1.01c	16.79 ± 1.47c	9.82 ± 1.26b	15.75 ± 0.98b	21.29 ± 1.04c
Neem seed oil	11.31 ± 1.09b	16.56 ± 2.15b	24.09 ± 2.88b	15.32 ± 1.05a	19.16 ± 1.07b	29.71 ± 2.08b
Jatropha seed oil	9.42 ± 1.26b	18.02 ± 2.80b	21.36 ± 1.30b	18.02 ± 1.48a	21.59 ± 2.29b	35.68 ± 3.79a
Palm kernel oil	9.46 ± 1.91b	19.21 ± 2.33b	32.07 ± 5.26a	17.62 ± 2.09a	19.46 ± 1.90b	34.23 ± 2.78a

Means followed with the same letter in the column are not significantly different from each other, Tukey's HSD ($p \leq 0.05$)

woods treated with Solignum and NSO. The wood loss of 21.29% recorded on wood treated with Solignum was significantly lower than 29.71% recorded on wood treated with NSO.

Discussion

The results of this study showed variations in the percentage losses of wood to termite attack among the different *Eucalyptus* species. A higher percentage of wood loss was recorded in *E. tereticornis* and the least in *E. cloeziana*. These variations might be due to genetic differences among the species. Such variations have also been recorded for wood traits such as wood basic density and lignin content in *Eucalyptus* populations (Chen et al., 2018). This study also confirmed a previous study that *E. tereticornis* is more susceptible to termite attack than *E. cloeziana* (Oliveira, 2017). The relatively low and high wood losses recorded on *E. cloeziana* and *E. tereticornis*, respectively may not be unconnected to softness and hardness of the species. Furthermore, wood density and wood hardness were negatively correlated with wood losses indicating that increase in these physical properties of *Eucalyptus* wood enhances resistance to termite damage. Shanbhag and Sundararaj (2013) had also reported a negative correlation between wood density and quantity of wood degraded by termites. Other research findings have revealed that wood density (Sornnuwat et al., 1995), wood hardness (Behr, 1972), wood moisture (Delaplane and La Fage, 1989) and wood extractives (Sornnuwat et al., 1995; Waller, 1989; Su and Tamashiro, 1986; Carter et al., 1983) influenced feeding activities of termites. Other studies have also reported that less dense *Eucalyptus* were more consumed by termites than those of higher density which however, may not be unconnected to the type and quantity of extractives in such woods (Paes and Vital, 2000). The presence of some phytochemicals was reported to confer resistance to termite attack on wood (Dungani et al., 2012; Santana et al., 2010). Termite-resistant woods are said to contain allelochemicals such as quinones that possess natural repellent and toxic properties (Dungani et al., 2012: Ganapaty et al., 2004). The natural durability of wood is often related to its toxic extractive components (Santana et al., 2010: Taylor et al., 2006).

In this study, results showed that weight loss increased with increase in the wood exposure period to termites. This is also in line with the observation of Nakabonge and Matovu, 2021 when exposed some *Eucalyptus* wood species to termite infestation in Uganda. Such increase in consumption has been attributed to termites' feeding habit where construction of tunnels that connect the nests to the sources of food preceded infestation (Peralta et al., 2004; Sim and Lee, 2012).

There was no significant difference in the percentage of wood losses between preference and non preference tests indicating that methods used for testing the susceptibility or resistance of *Eucalyptus* to termite damage in this study did not influence the result. However, the results at different locations showed that the percentage of wood damage was higher in Kaduna than in Zaria in the four *Eucalyptus* species. The difference in wood consumption between the two locations could be due to differences in termite diversity, their abundance and environmental factors.

The application of Solignum, NSO, JSO and PKO on the wood of *E. tereticornis* reduced wood damage by termites beyond 12 months after application. In addition, it was noted that after Solignum, NSO and JSO offered better wood protection than PKO. Several other studies have reported the efficacy and eco-friendly nature of *Jatropha* oil and neem oil in the management of termites (Alamu et al., 2018; Idoko and Gordon, 2021; Okwete *et al.*, 2021; Ahmed et al., 2020; Sotande *et al.*, 2011). Jatropha oil was reported to exhibit a synergestic effect on wood damaging fungi when used in the combination of Sodium tetraborate as wood preservative of *Triplochiton scleroxylon* (Georges *et al.*, 2022). The insecticidal efficacy of PKO have been reported on insects such as *Callosobrochus maculatus* on cowpea seeds and *Sitophilus zeamais* on maize in storage (Udin II and Sanusi, 2013; Babarinde et al., 2015; Law-Ogbomo and Enobakhare, 2006; Oladipo et al., 2022). However, the anti-termitic strengths of PKO, JSO and NSO reduced faster than Solignum with increase in the period of wood exposure to termite. This clearly confirmed that botanical pesticides are easily degradable and not persistent in the environment (Ahmad et al., 2011; Sarwar, 2012). The use of NSO, JSO and PKO therefore requires periodic re-applications and could be incorporated into the IPM component of termites for sustainable termite management.

Conclusion

This study compared the impacts of subterranean termites on the wood of four *Eucalyptus* species; and the efficacy of natural plant oils as wood protectants against termites attack. The results showed that wood of *E. cloeziana* exhibited the highest resistance against termite attack while the wood of *E. tereticornis* was the highly degraded. Application of NSO, JSO and PKO was highly encouraging as wood protectants against termites' infestation and could serve as alternatives to synthetic wood protectant. However, periodic application of these natural oils will be required for sustainable termite control.

Declarations

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Author contributions

OTA and FKE contributed to the conception, experimental work and interpretation of the analyzed data, writing and reviewing of the manuscript. The two authors read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

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