Resistance of Some Indigenous Tree Species to Termite Attack in Nigeria[1]

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ABSTRACT The resistance of some indigenous types of tree species to attack by termites (Blattodea: Termitidae) was investigated in Ondo State, Nigeria. Indigenous trees of different bulk densities used for this study were *Celtis zenkeri* Engl. (Cannabaceae), *Albizia lebbeck* (L.) Benth. (Fabaceae), *Terminalia superba* Engl. & Diels (Combretaceae), *Cola gigantia* A. Chev. (Malvaceae), and *Terminalia ivorensis* A. Chev. (Combretaceae). The three locations used for the study were Okitipupa, Akure, and Akungba-Akoko, representing lowland rainforest, tropical rainforest, and savannah regions, respectively. The primary termite species recovered were *Macrotermes bellicosus* (Smeathman), *Macrotermes sybhylinus* (Rambur), and *Odontotermes horni* (Wasmann) for Okitipupa, Akure, and Akungba-Akoko, respectively. Field-exposure tests for each of the locations suggested that density affected the resistance of the wood samples to termite attack. Wood in the high density class had a better resistance to attack by termites compared with low density wood. The severity of attack was highest in Akure and least in the Okitipupa location. Irrespective of wood density and location in Ondo State, Nigerian lumber should be treated before installation to ensure protection.

KEY WORDS durability, wood density, mound, visual rating, soil properties, lumber

Wood is readily degraded by bacteria, fungi, and termites (Schultz &Nicholas 2002). However, there is variability in resistance to these degrading agents across tree taxa (Kityo & Plumptre 1997). Insects represent a significant hazard to forest trees and commercial forestry in Nigeria, with termites (Blattodea: Termitidae) considered among the most serious pests (Verma et al. 2016). Chemical treatment of lumber is generally recommended to prevent activity of termites and other wood destroying insects, such as powder-post beetles and carpenter ants (Walters 1981). However, most lumber for construction in Ondo State, Nigeria is not chemically treated for rots or insects as relatively few people have knowledge regarding wood resistance, insect identification, or adequate precautionary measures (Owoyemi 2010). Precautions that should be taken to provide termite control include reducing moisture content of the lumber, and using naturally durable or

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pressure-treated wood (Zelinka 2013). Termites are widespread throughout tropical and subtropical countries, and their severity of attack make them a serious pest and economically significant. The severity of attack also varies according to the termite species and wood type (Arab & Costa-Leonardo 2005, Green et al. 2005).

Termites are present in different ecological regions and there are differences in the extent of termite infestations from different geographical locations (Ahmed 2000). Due to their cuticle structure, it has been proposed that moisture is probably the most important environmental requirement for termite survival (Collins 1969). Because of their susceptibility to desiccation, the relative humidity within places inhabited by subterranean termites is the primary determinant of their survival. Studies (Ahmed 2000, Arab & Costa-Leonardo 2005, Green et al. 2005) have reported higher foraging and tunneling activities of *Reticulitermes* spp., *Coptotermes* spp., and *Heterotermes* spp. occurring in sites of relatively higher soil moistures. Construction workers should be aware of the challenges encountered in combating the attack of termites from different ecological regions. Therefore, the objective of this study was to determine the resistance of selected wood types to natural termite damage at three locations in Ondo State, Nigeria.

Materials and Methods

Study area. Three locations were selected in Ondo State, Nigeria. They were a tropical rainforest site at the Federal University of Technology in Akure, a lowland rainforest site at Adekunle Ajasin University in Akungba-Akoko, and a savannah site at Ondo State University of Science and Technology in Okitipupa. Ondo State lies entirely in the tropics between latitudes 5°45′ and 8°15′ north and longitudes 4°45′ and 6°0′ east (Figure 1).

Preparation of raw materials. Five indigenous tree species: *Celtis zenkeri* Engl. (Cannabaceae) (known locally as Ita), *Cola gigantia* A. Chev. (Malvaceae) (known locally as Oporoporo), *Terminalia superba* Engl. & Diels(Combretaceae) (known locally as Afara), *Terminalia ivorensis* A. Chev. (Combretaceae) (known locally as Idigbo), and *Albizia lebbek* (L.) Benth. (Fabaceae) (known locally as Ayinre) were selected. Freshly sawn boards of these tree species were obtained from a sawmill in Akure. Thirty samples (3.5 × 3.5 × 45 cm) were obtained from each tree species by cutting fifteen pieces of sapwood from the outer portion of a log, and fifteen pieces of heartwood from the inner portion of a log using a circular saw. A total of 150 samples for all tree species were divided into three groups for each location using five replicates per treatment. All samples were labeled and weighed (green weight). The samples were oven-dried at 103 ± 2°C for 24 h and re-weighed (dry weight). The dry-weight density of the samples was determined and classified as high (>550 kg/m^3), medium (450 to 550 kg/m^3), or low (<450 kg/m^3).

Field test. Field-exposure tests of the wood samples to termites were carried out at the Okitipupa, Akungba-Akoko, and Akure sites (Figure 2). The study sites were cleared and sprayed with wood shavings to induce termite activity. Samples for each of the five wood species were buried at a depth of 22.5 cm in a grid with a spacing of 100 by 100 cm. The exposure test ran from 8 September through 28 November 2015, which was a transition period from the rainy to the dry season. The samples were assessed weekly using a visual rating according to the American Society for Testing Materials Standard D-3345-74 (ASTM 1980), where

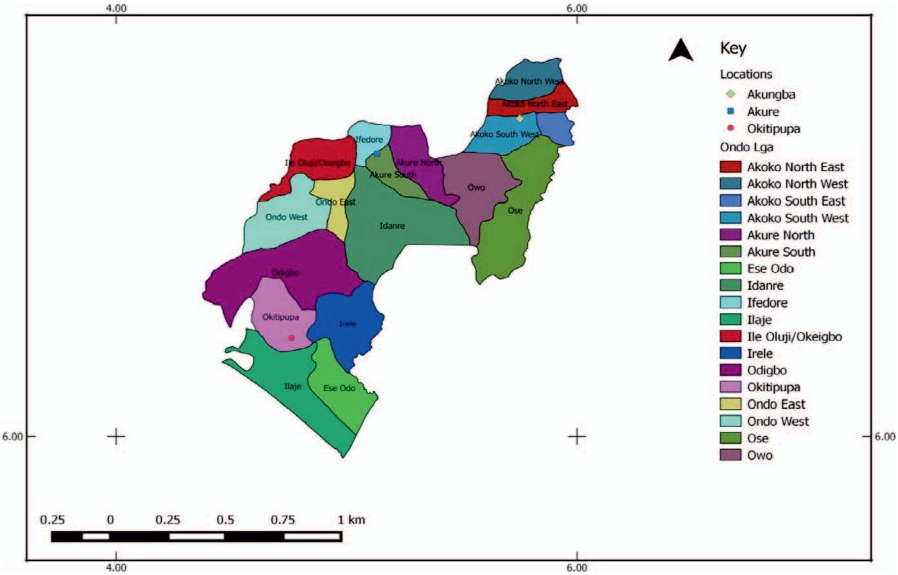

Fig. 1. Map of Ondo State, Nigeria showing study locations (between latitudes 5°45′ and 8°15′ north and longitudes 4°45′ and 6° east).

10 = sound, surface nibbles permitted, 9 = light attack (10% portion eaten), 7 = moderate attack (20% eaten), 4 = heavy attack (30 to 40% eaten), 0 = failure (over 50% eaten). The experiment was terminated after 12 weeks and the percentage weight loss was determined using the formula: weight loss = $((T1 - T2)/T1) \times 100$, where: T1 = weight before exposure to termites, T2 = weight after exposure to termite attack.

Termite identification was performed by collecting worker and soldier termites from the mud tube nest at three weekly intervals from each study area. The samples were placed in a conical flask with cotton wool and chloroform was added for preservation. Identifications of termite species were done under a digital microscope.

Physical properties of the soil from the study sites (bulk density, moisture content, and particle size) were determined in July 2014 by collecting three soil samples per study location. Samples were collected at a depth of 0 to 15 cm and

Fig. 2. Field plots (“timber graveyard”) in (A) Okitipupa, (B) Akungba-Akoko, and (C) Akure.

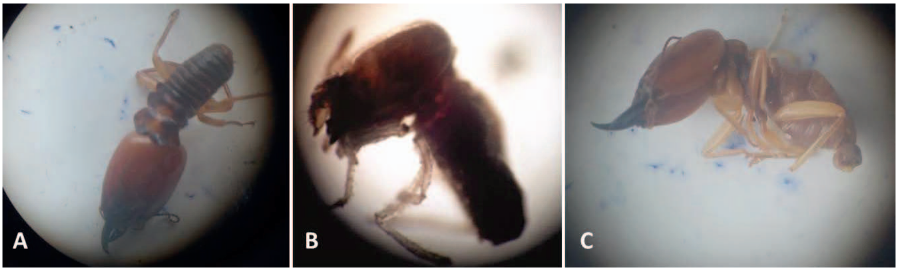

Fig. 3. (A) *Macrotermes subhyalinus* (soldier), (B) *Odontotermes horni* (Wasmann), and (C) *Macrotermes bellicosus* (soldier).

15 to 30 cm. The samples were dried for 24 h at 105°C and weighed. The percentage moisture content and bulk density were calculated using the formulae: % moisture content = $((W1 - W2)/W1) \times 100$ and bulk density = $(W1 - W2)/W1$, where W1 = dry weight, W2 = wet weight, and V = volume.

Statistical analysis. The experimental design was a $3 \times 5 \times 2$ factorial experiment in a Completely Randomized Design. Factor A was the three study locations (Akure, Akungba-Akoko, and Okitipupa), factor B was the five wood species (*Celtis zenkeri, Cola gigantia*, *Terminalia superba*, *T. ivorensis*, and *Albizia lebbek*), and factor C was the wood portion (sapwood or heartwood). The data obtained were subjected to Analysis of Variance (ANOVA), and Duncan Multiple Range Test was carried out to separate individual means when there were significant differences in the ANOVA (Steel & Torrie 1960).

Results and Discussion

Termites identified at study locations. *Macrotermes subhyalinus* (Rambur) was identified at Akure, *M. bellicosus* (Smeathman) was identified at Okitipupa, while *Odontotermes horni* (Wasmann) was identified at Akungba-Akoko (Figure 3). These results support the work of Harris (1971) and Akande (1992), who reported that termites are widely spread across vegetation zones of Nigeria, examples of which include *M. subhyalinus* (rainforest), *Odontotermes pauperism* (Sudan and Guinea Savannahs), and *M. crucifer* (rainforest). Our results confirm the work of Korb (2010) who reported that *M. bellicosus* and *M. subhyalinus* are large mound building termites dotting the landscape from rainforest to the savanna zones of Nigeria.

Soil properties at field locations. We found that the soil bulk densities for the study locations were higher for Akure, compared with Akungba-Akoko and Okitipupa (Table 1), and Akure had the highest termite attack rate. Okitipupa and Akungba-Akoko had similar soil bulk densities, but the termite attack rate was higher in Akungba-Akoko than Okitipupa, where the wood was rarely attacked (Table 7). Jurgenrius et al. (1999) reported that the bulk density of termite-modified soils was higher compared with surrounding soils. This increased density might be caused by increase compaction of the soil with termite saliva and

Table 1. Soil characteristics at three field sites in Ondo, Nigeria.

Site	Sand (%)	Clay (%)	Silt (%)	Sand (%)	Clay (%)	Silt (%)	Bulk density (g/cm^3)	Textural Class
	0–15 cm soil Depth			15–30 cm Soil Depth				
Okitipupa	52.4	41.0	6.6	54.4	45.0	0.6	1.11	Clay
Akure	55.7	14.5	29.8	63.7	29.0	7.3	1.61	Sandy clay loam
Akungba-Akoko	69.7	21.0	9.3	71.4	21.0	7.6	1.10	Sandy clay loam

incorporation of organic matter into the soil. More silt and sand are added to the soils in areas where termites are present, and repacking of soil particles by termites minimizes soil pore spaces, which causes the soil bulk density to increase. Ackerman et al. (2007) determined that mounds of *Subulitermes mirosoma* (Silvestri) and *Anhangatermes macarthuri* (Constantino) contained higher proportions of sand and silt-sized particles when compared to surrounding soils. Jouquet et al. (2002) reported that *Odontotermes pauperans* select finer sized particles deep in the soil profile to construct their nests. Tunnelling also aerates the soil and redistributes materials within it (Eggleton & Taylor 2008). The USDA Textural Triangle was used to determine the texture class according to Shirazi & Boersma (1982). For the 0 to 15 cm depth, soil from Okitipupa was classified as clay, soil from Akure was classified as loam, and soil from Akungba-Akoko was classified as sandy clay loam (Table 1). For the 15 to 30 cm depth, soils were classified as clay, sandy clay loam, and sandy clay loam for Okitipupa, Akure, and Akungba-Akoko, respectively. The greatest termite attack was observed in Akure and the lowest in Okitipupa (Table 7). This rate of termite attack was consistent with decrease from loamy to clay (Table 1). This result agrees with Ab Majid & Ahmad (2013) who reported that *Coptotermes* species in Australia infest building structures located on sandy loam soils.

Field assessment of termite activity. ANOVAs for wood density, ASTM visual ratings, and weight loss assessment showed significant differences for location, tree species, and the wood portion (sapwood or heartwood) (Tables 2, 3, and 4). The tree species in this study were divided into three density classes (high, medium, and low). At the end of the field test at Akure, *C. zenkeri* and *A. lebbeck* in the high density class had the least termite damage, *T. ivorensis* and *Cola gigantia* in the medium density class had intermediate termite damage, and *T. superba* in the low density class had the most termite damage (Table 5). The medium and low density wood species also had the highest weight losses (>20%) compared with the high density wood (<1%). Our study corroborates findings of Owoyemi et al. (2013) who reported that wood in high density classes had higher resistance to termite attack compared with medium or low density classes. However, we note that the natural durability of wood is determined not only by its density, but also by its chemical composition that slows decomposition and deters insects (Slahor et al. 2001, Rowell et al. 2005).

Table 2. Analysis of variance for environmental variables on the density of wood.

Source of variation	Sum of squares	df	Mean squares	F	*P*
Location	866.6	2	433.3	0.2	0.01
Wood	3,003,161.6	4	75,0790.4	335.5	0.04
Portion	14,009.3	1	14,009.3	6.3	0.01
Location * Wood	46,344.9	8	5793.1	2.6	0.02
Location * Portion	11,500.6	2	5750.3	2.6	0.51
Wood * Portion	92,878.0	4	23,219.5	10.4	0.01
Location * Wood * Portion	14,257.2	8	1782.2	0.8	0.17
Error	537,080.1	240	2237.8		
Total	3,796597.9	269			

Our results showed that sapwoods were less resistant to termite attack than heartwood (Table 6). This is likely due to the starch deposits that are retained in sapwood after drying (Lebow 2010). Chemicals extracted from heartwood protect wood against decay organisms (Hinterstoisser et al. 2000, Schultz &Nicholas 2002). Natural durability of wood is complex and factors such as wood density, lignin content, and antioxidants may be involved (Schultz & Nicholas 2002).

The severity of termite attack was different at the three study locations that were in different climatic zones. The tropical rainforest at Akure had the highest termite damage at 30.5% weight loss; the savannah zone at Akungba-Akoko had medium termite severity at 17.9% weight loss; and the lowland rainforest at Okitipupa had the lowest termite severity at 0.05% weight loss (Table 7). However, our findings could be influenced by termite species and environmental influences. For example, heavy rainfall at Okitipupa, could disturb foraging activities of *M. bellicosus*. Furthermore, *M. subhyalinus* present at Akungba-Akoko is an aggressive forager that can leave their foraging holes nocturnally to locate food more quickly compared with *M. bellicosus* (Abe et al. 2014). Puche & Su (2001) and Grace et al. (2002) report that termite foraging patterns differ among species and are likely

Table 3. Analysis of variance for ATSM visual rating (ATSM 1980) of wood damage.

Source of variation	Sum of squares	df	Mean squares	F	*P*
Location	71.9	2	35.9	77.6	0.00
Wood	51.4	4	12.9	27.8	0.00
Portion	8.2	1	8.2	17.8	0.01
Location * Wood	56.8	8	7.1	15.3	0.02
Location * Portion	7.6	2	3.8	8.2	0.00
Wood * Portion	6.0	4	1.5	3.3	0.01
Location * Wood * Portion	14.3	8	1.8	3.9	0.00
Error	111.1	240	0.5		
Total	592.1	269			

Table 4. Analysis of variance for the percentage weight loss of five tree species after termite attack in Ondo State, Nigeria.

Source of variation	Sum of squares	df	Mean squares	F	*P*
Location	12,249.3	2	6124.7	37.2	0.03
Wood	14,118.2	4	3529.6	21.4	0.01
Portion	491.8	1	491.8	3.0	0.00
Location * Wood	12,760.2	8	1595.0	9.7	0.01
Location * Portion	478.2	2	239.1	1.5	0.09
Wood * Portion	1951.9	4	487.1	3.0	0.01
Location * Wood * Portion	5123.4	8	640.4	3.9	0.04
Error	39,563.6	240	164.9		
Total	150,243.0	269			

Table 5. Termite attacks on five tree species as influenced by wood density.

Treespecies	ASTM visual rating (0–10)[a]	Weight loss (%)	Wood density (kg/m^3)	Density classification
Celtis zenkeri	9.8 a[b]	0.9 c[b]	675.3 a[b]	High
Albizia lebbeck	9.9 a	0.3 c	577.5 b	High
Terminalia ivorensis	8.5 b	21.3 b	515.4 c	Medium
Cola gigantia	8.6 b	22.4 b	466.7 d	Medium
Terminalia superba	7.8 c	36.1 a	383.6 e	Low

[a]Standard D-3345–74 (ASTM 1980); higher rating indicates less termite damage.
[b]Means with the same letter are not significantly different ($P < 0.05$ in Duncan Multiple Range Test).

Table 6. Severities of termite attack on sapwood and heartwood of five tree species.

Wood sample	ASTM visual rating (0–10)[a]	Weight loss (%)
Celtis zenkeri sapwood	9.7 a[b]	1.3 c[b]
Celtis zenkeri heartwood	10.0 a	0.4 c
Terminalia ivorensis sapwood	7.7 c	33.1 a
Terminalia ivorensis heartwood	9.3 ab	9.5 bc
Albizia lebbeck sapwood	9.8 a	0.5 c
Albizia lebbeck heartwood	10.0 a	0.03 c
Cola gigantia sapwood	8.3 bc	23.7 ab
Cola gigantia heartwood	8.9 abc	21.0 abc
Terminalia superb sapwood	7.6 c	33.9 a
Terminalia superb heartwood	8.0 c	38.3 a

[a]Standard D-3345–74 (ASTM 1980); higher rating indicates less termite damage.
[b]Means with the same letter are not significantly different ($P < 0.05$ in Duncan Multiple Range Test).

Table 7. Severity of termite attacks at three study locations in Ondo, Nigeria.

Location	ASTM visual rating (0–10)[a]	Weight loss (%)
Akure	7.7 c[b]	30.5 a[b]
Akungba-Akoko	9.1 b	19.0 b
Okitipupa	10.0 a	0.1 c

[a]Standard D-3345–74 (ASTM 1980); higher rating indicates less termite damage.
[b]Means with the same letter are not significantly different ($P < 0.05$ in Duncan Multiple Range Test).

influenced by their ancestral habitat and the distribution of woody resources. In conclusion, we report variable distribution and activity of several termite species and highlight several environmental influences for their activity. Information concerning treatment of lumber for construction is important to prolong its longevity in these environments.

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