International Scholars Journals

African Journal of Wood Science and Forestry ISSN 2375-0979 Vol. 4 (2), pp. 231-237, February, 2016. Available online at www.internationalscholarsjournals.org © International Scholars Journals

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Full Length Research Paper

Termite resistivity of the stem and branch woods of *Aningeria robusta* (A. Chev) and *Terminalia ivorensis* (A. Chev)

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Received 15 January, 2015; Accepted 22 February, 2016

Adequate information on stem wood and branch wood termite resistivity would enhance their efficient utilization, especially branch wood, whose use could widen the raw material base of the timber industry. Termite resistivity using field test method was determined for sapwoods and heartwoods along the stem and branch of *Terminalia ivorensis* and *Aningeria robusta. Ceiba pentandra* was the control. With slight attack and very durable wood, *T. ivorensis* heartwood at stem base was most resistant. Heartwood at middle of stem was durable and moderately attacked. *T. ivorensis* stem base sapwood, stem crown heartwood, branch base, middle and top heartwoods were comparable, having moderate durability (17 ± 1.9 - 24.5 ± 1.5% mass loss) or moderate attack. *T. ivorensis* sapwoods were less resistant to termite attack (mass loss: 19.2 ± 1.0 - 48.7 ± 2.5%) than their corresponding heartwoods (which lost between 4.3 ± 0.8 – 24.5 ± 1.5 %), but were more resistant than *C. pentandra*, the heartwoods and sapwoods along *A. robusta* stem and branch, were completely consumed (100% mass loss). With similar termite resistivity, *A. robusta* branch wood could suitably supplement its stem wood. *T. ivorensis* stem wood and branch wood termite resistivity also confirms that their branch wood could supplement the supply of wood from this timber.

Keywords: Axial stem position, bio-degrader, branch wood, heartwood, mass loss, natural durability, severe attack, visual durability rating,

INTRODUCTION

Branch wood represents an important secondary wood resource (Olarescu, 2009). Its use is of critical importance to the wood industry because it has the potential of ensuring regular supply of wood, while sustaining the wood industry and other related sectors (Okai et al., 2004; Gurau et al., 2008; Olarescu, 2009; Kiaei, 2011). Dadzie (2013) estimated that the utilization of 28.60% of the merchantable branchwood from the total extracted wood volume would translate into preserving or conserving about 6 ha of forest land area. However, for the performance of branchwood or wood from any tree part to meet timber users' expectations, ensure regular supply of wood and sustain the wood industry, adequate information of its termite resistivity is critical. Termite resistivity plays a critical role in the service life of wood (Cao et al., 2011), since termites are major decomposers of wood (Opoku-Kwarteng, 2014). In the tropics, termites pose greater threat to timbers than decay fungi (Wong et al, 1998). Their damage to wood is far more than other tropical insects (Tho and Kirton, 1990; Opoku-Kwarteng, 2014). Moreover, the natural resistance of wood against bio-degraders including termites vary widely (Ncube, 2010; Nascimento et al., 2013) between and within timber species and even within a single timber tree (Kandeel and Bensend, 1969; Panshin and de Zeeuw, 1980; Zobel and Van Buijtenen, 1989; Zhang et al., 1994; Sehlstedt-Persson and Olov, 2010). The resistance of wood to bio-degradation (and termite resistivity), differs between sapwoods and heartwoods (Taylor et al., 2002;

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CIRAD, 2011; Roszaini and Hale, 2011) and along tree height (Scheffer and Cowling, 1966). The stem and branchwoods of *Taxus canadensis* (Marshall) were found to be strongly resistant and resistant respectively to bio-degradation (Forest Products Laboratory, 1974; Richter et al*.,* 2012). This indicates variation of the natural resistance between the stemwood and branchwood of this timber. According to Opoku-Kwarteng (2014), the factors that influence natural durability variations of wood also influence its termite resistivity. Consequently, termite resistance is expected to vary between the stemwood and branchwood of trees.

Different boards from the same tree may thus exhibit different degrees of resistance to bio-degraders including termites (NCDOI OSFM Evaluation Services, 2012) and thus require specific termite resistivity examinations prior to their utilization in the industry (State Forest Technical Publication, 1995). *Terminalia ivorensis* (A. Chev) and *Aningeria robusta* (A. Chev) are important commercial timbers, whose stem heartwoods are moderately resistant and susceptible respectively to termites (Usher and Ocloo, 1980; Chudnoff, 1984; USDA Forest Product Laboratory, 2009; CIRAD, 2011). Even though their branchwoods have been recommended and accepted for commercial utilization in the wood industry, based on their comparable strength properties with the stemwoods (Yeboah, 2001; Okai et al*.,* 2004), information on their durability and termite resistivity is lacking. Besides, the field performance of the sapwoods and heartwoods at the different axial positions and within the stems and branches of *T. ivorensis* and *A. robusta* is expected to vary. This study, thus, sought to compare the termite resistivity along the stemwood and branchwood of *A. robusta* and *T. ivorensis*, including their sapwoods and heartwoods in the field using the graveyard test. The findings would aid the efficient utilization of wood from these two commercially important timbers, especially their branchwoods, which are being under-utilized. This would in turn reduce wastage and pressure on them, ensure total and sustainable utilization of their trees and increase raw material supply to the timber industry.

MATERIALS AND METHODS

(1) Preparation of wood samples

Mature trees (about 60 years) of two timber species (*A. robusta* and *T. ivorensis*) with heights of 14 to 15m and diameters ranging from 38.5 to 61.5cm for the stems were sampled from the Fum Headwater Forest in the Adansi North District of Ghana. Diameters of the branches sampled ranged from 18 to 34 cm. Billets (1m) were removed from the base (1m from the ground), the middle (50% stem height) and the crown (1m to branch attachment) of each stem, as well as from the base, middle (50% branch height) and top (15cm from branch tip) of the branches of each timber. Radial slabs were sampled from each billet and sections removed from the heartwood (5cm from the pith) and sapwood (5cm below the bark) regions. Ten replicates of defect-free sapwood and heartwood (12.5 x 25 x 250 mm) from the base, middle and crown of the stem and branch were used for the natural durability test. Ten replicates from *C. pentandra* (L.) Gaertn. served as the control. The samples were air-dried to 12% moisture content (mc) and their initial masses taken.

Field test

All the wood stakes from each timber and the control were randomly inserted vertically in the soil to half their length. Stakes were spaced 30 cm apart on a demarcated termite-prone site (50 × 50 m) at the Faculty of Renewable Natural Resources Demonstration Farm, Kumasi, Ghana. The accelerated field test lasted for 52 weeks (beginning from early April, 2010). The state of the stakes were inspected monthly for any alterations.

Determination of visual durability rating and mass loss

Visual durability rating codes used to grade the wood samples were according to EN 252 (1989): 0 – No attack, 1 = Slight attack, 2 = Moderate attack, 3 = Severe attack, 4 = Failed.
After final withdrawal from the field, the stakes were weighed and their percentage mass losses determined as an indication of their natural durability using the formula:

$$\text{Mass loss (\%)} = \frac{\text{Initial mass} - \text{Final mass}}{\text{Initial mass}} \times 100$$

The ratings for the percentage mass loss: 0-5% = Very durable, 6-10% = Durable, 11-40% = Moderately durable, 41-100% = Non-durable were according to Eaton and Hale (1993).

DATA ANALYSIS

ANOVA and Duncan's Multiple Range Test (DMRT) at 95 % Confidence level were used to test for variations in the percentage mass losses between the control (*C. pentandra*), sapwoods and heartwoods along the stems and branches of the two timbers.

RESULTS

The field termite resistance assessment of wood stakes in the form of visual durability ratings and percentage mass losses are presented in Table 2. Figures 2-5 display stakes of *T. ivorensis* with visible signs of termite attack after field exposure. Stakes of *C. pentandra*¸ the sapwood and heartwood along *A. robusta* stem and branch lost their total masses (100%) (Figure 1). Difference between the mass losses for *C.*

Table 1. ANOVA for mass losses of *C. pentandra* andradial positions along the stems and branches of *T. ivorensis* and *A. robusta.*

Sources of variation	Degrees of freedom	Sum of Squares	Mean Squares	F-value	P-value
Model	24	349385.425	14557.726	37.949	0.000*
Error	225	86312.371	383.611		
Corrected total	249	435697.795			

*Significant difference at P (0.000) < 0.05

Table 2. Accelerated termite resistivity of *C. pentandra* and various stem and branch positions of *T. ivorensis* and *A. robusta* after 52 weeks of field exposure.

Wood species	Tree part	Axial position	Radial Position					
			Visual durability rating		*visual durability rating interpretation		Mass loss (%)	
			SW	HW	SW	HW	SW	HW
T. ivorensis	stem	Base	2	1	MA	SA	19.2 ± 1.0^{cd}	4.3 ± 0.8^{d}
		middle	3	2	SV	MA	35.1 ± 2.7^{bc}	8.8 ± 1.2^{d}
		crown	3	2	SV	MA	43.3 ± 1.4^{b}	17.0 ± 1.9^{cd}
	branch	Base	3	2	SV	MA	45.0 ± 2.2^{b}	19.8 ± 2.6^{cd}
		Middle	3	2	SV	MA	46.9 ± 1.8^{b}	23.4 ± 1.3^{cd}
		top	3	2	SV	MA	48.7 ± 2.5^{b}	24.5 ± 1.5^{cd}
A. robusta	stem	Base	4	4	Failed	Failed	100^{a}	100^{a}
		Middle	4	4	Failed	Failed	100^{a}	100^{a}
		Crown	4	4	Failed	Failed	100^{a}	100^{a}
	branch	Base	4	4	Failed	Failed	100^{a}	100^{a}
		middle	4	4	Failed	Failed	100^{a}	100^{a}
		crown	4	4	Failed	Failed	100^{a}	100^{a}
C. pentandra			4	4	Failed	Failed	100^{a}	100^{a}

NB: *Visual durability ratings: Slight attack (SA), moderate attack (MA), severe attack (SV). Mass losses with different alphabets are significantly different (P < 0.05)
******Durability classes: 0-5% very durable (VD), 6-10% durable (D), 11-40% moderately durable (MD), 41-100% non-durable (ND).SW: sapwood HW: heartwood.

pentandra as well as the sapwoods and heartwoods along the stems and branches of *T. ivorensis* and *A. robusta* was significant (P < 0.05) (Table 1). Mass losses of *T. ivorensis* sapwood and heartwood generally increased from the base to the crown of the stem and from the base to the top of the branch (Fig. 1). However, according to Duncan's Multiple Range Test (DMRT), the difference between the *T. ivorensis* stem base and middle heart woods were not significant (P > 0.05) (Table 2). *T. ivorensis* stem crown, branch base, middle and top heartwoods also did not have significant differences (P > 0.05) between their mass losses. Likewise its branch base, middle and top sapwoods did not have significant differences (P > 0.05) between their mass losses (P > 0.05) (Table 2).

For *T. ivorensis,* the heartwood from its stem base was the most durable among all the heartwoods. It was slightly attacked (1), lost only 4.3 ± 0.8% mass and was rated very durable. The middle heartwood of the stem followed with moderate attack (2) and 8.8 ± 1.2%mass loss and was rated durable. The crown heartwood of the stem, heartwoods of branch base, middle and top with 17 ± 1.9 %, 19.8 ± 2.6 %, 23.4 ± 1.3 %, and 24.5 ± 1.5 % mass losses respectively were rated moderately durable to termite attack (2). The corresponding sapwoods were relatively less durable (i.e., less resistant to termites). However, the base sapwood of the stem was comparable to the heartwood of the crown of the stem up to the top of the branch. It had a moderate attack (2) and 19.2 ± 1.0% mass loss; hence, it was rated moderately durable to termite attack. Sapwoods of the middle and crown of stem, as well as those of the branch base, middle and top were severely attacked (3) and were rated non-durable, having lost 35.1 ± 2.7 %, 43.3 ± 1.4 %, 45.0 ± 2.2 %, 46.9 ± 1.8 % and 48.7 ± 2.5 % mass respectively.

A. robusta, sapwoods and heartwoods along the stem and branch were completely destroyed by termites

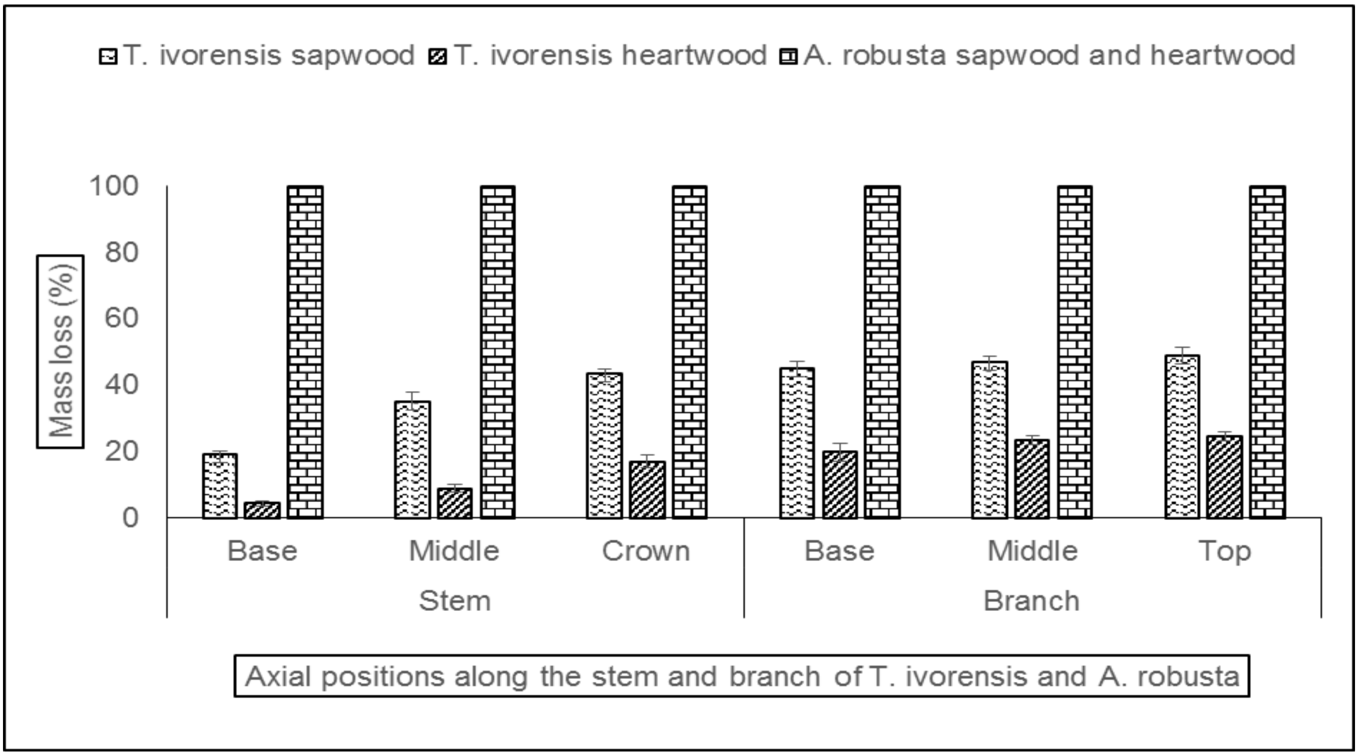

Figure 1. Mass losses for sapwood and heartwood along the stems and branches of *T. ivorensis* and *A. robusta*. Bars: Standard error.

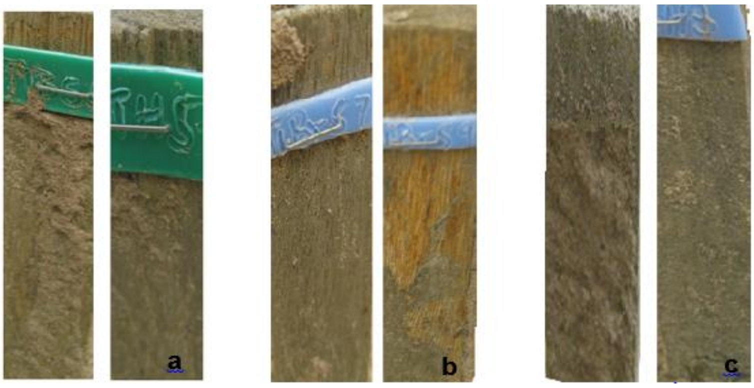

Figure 2. Heartwoods from *T. ivorensis* stem base (a), middle (b) and crown (c) after field exposure.

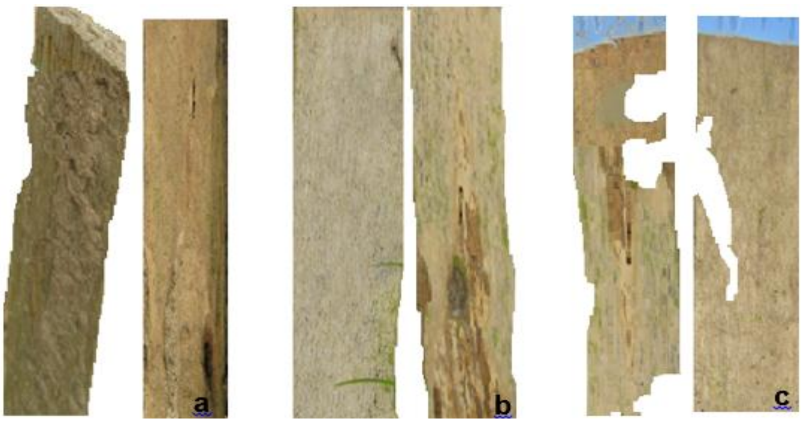

Figure 3. Heartwoods from *T. ivorensis* branch base (a), middle (b) and top (c) after field exposure.

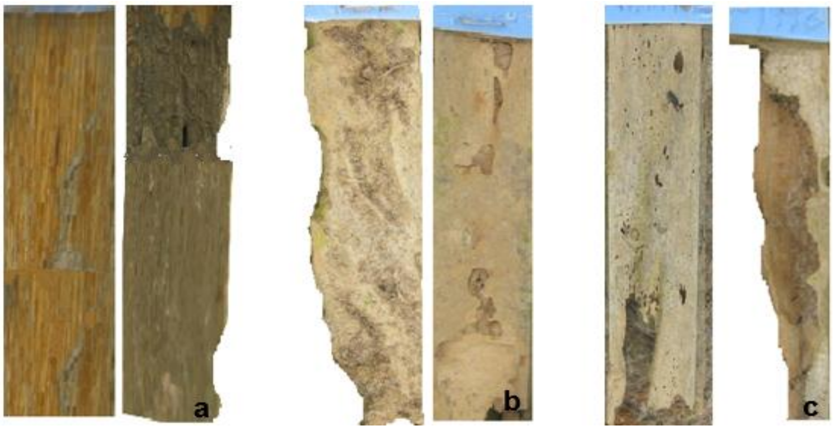

Figure 4. Sapwoods from *T. ivorensis* stem base (a), middle (b) and crown (c) after field exposure.

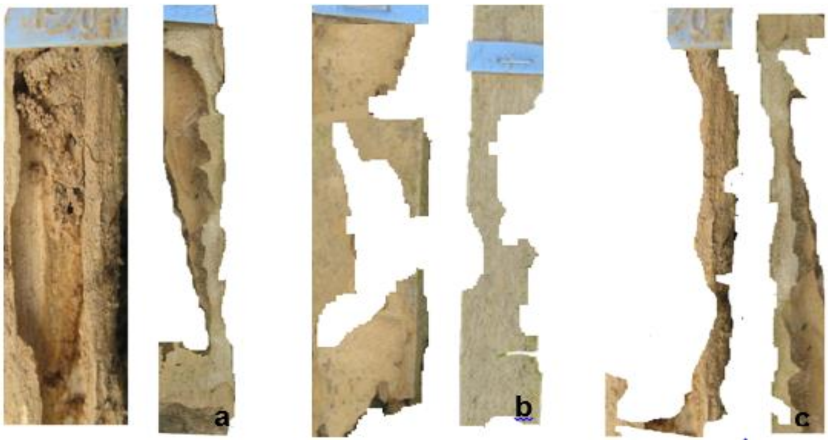

Figure 5. Sapwoods from *T. ivorensis* branch base (a), middle (b) and top (c) after field exposure.
NB: All replicates of *A. robusta* stem and branch woods as well as *C. pentandra* (the control) were completely destroyed at the end of the experiment. The state of their stakes cannot be represented.

(visual rating: 4) just as the control (*C. pentandra*) (Table 2). *A. robusta* was hence considered non-durable (perishable), susceptible to termite attack. Thus, *T. ivorensis* sapwood and heartwood were more resistant to termite attack than those of *A. robusta* (Table 2).

DISCUSSION

Visual durability ratings are subjective and difficult to rate accurately (Kenneth et al., 1996). Hence, greater reliance and referencing would be made to percentage mass loss in the discussion of the results. According to Hunt and Garratt (1967), Eaton and Hale (1993), Sulaiman and Choon (1993), Desch and Dinwoodie (1996) and Antwi-Boasiako (2004), sapwoods are low in durability or totally non-durable because of their starch and sugar contents, as well as very low or lack of toxic extractives. In support, sapwoods from all the axial positions of *T. ivorensis* stem and branch had lower termite resistance than their corresponding heart-woods. Nevertheless, the sapwood along the stem and branch of *T. ivorensis* revealed several degrees of termite resistance; they were moderately resistant (i.e., sapwood of the base of the stem) to severely attacked (i.e., from the middle of the stem to the branch top sapwoods), according to the visual durability rating, and lost between 19.2-48.7% mass. Consequently, both sapwood and heartwood of *T. ivorensis* stem and branch revealed termite resistance. Likewise, Lukmandaru and Takahashi (2008) observed termite resistance for both heartwood and sapwood of *Tectona grandis* L. f. and related this trend to factors including *n*-hexane extractive content and total extractive content.This study however did not include the factors that influenced the variations in termite resistivity. However, Browning (1974) confirmed that the amount of extractives in the sapwoods of certain timbers provides some resistance against bio-degradation. Moreover, the sapwood of *T. ivorensis* stem and branch were also more resistant to termite attack than the heartwood (from the stem and branch) of *A. robusta*. Similarly, Antwi-Boasiako (2004) found the sapwood of

Corynanthe pachyceras K. Schum.to be durable, while Quartey (2009) found the sapwoods of *Albizia. ferruginea*, *Amphima pterocarpoides*, *Blighia sapida*, *Sterculia rhinopetala* and *Petersianthus macrocarpus* to be more durable (termite resistant) than the heartwoods of *A. toxicaria* and *Canarium schweinfurthii*. Both the visual durability ratings (4) and percentage mass losses (100%) indicated that *A. robusta* wood was easily degraded irrespective of the within-tree position. Similar to *C. pentandra*, the sapwood and heartwood along *A. robusta* stem and branch were completely consumed by the end of the exposure period. Many of its stakes were completely destroyed by the 12^{th} week. Likewise, Usher and Ocloo (1980) reported from an earlier studies that many stakes of *A. robusta* were totally consumed within 12 weeks of field exposure and concluded that this timber is extremely susceptible to termites. The findings of this study again supported the report by CIRAD (2011) that *A. robusta* is susceptible to attack by termites. Haygreen and Bowyer (1996) explained that irrespective of its within-tree position, wood that lacks toxic extractives would be susceptible to bio-degrading agents such as termites. Regardless of its low termite resistivity, the stem wood of *A. robusta* is a commercially important wood with several end-uses including the production of sliced veneer, interior joinery, moulding, light carpentry work and cabinet work (high class furniture) (Chudnoff, 1984; Insidewood, 2014). Thus, with similar termite resistivity, *A. robusta* branch (sapwood and heartwood) could suitably supplement its stem in order to increase the supply of its wood to the timber industry and reduce pressure on this timber. Besides, *T. ivorensis* stem and branch sapwoods can be employed for interior joinery, moulding, light carpentry work and cabinet work, as they were more termite resistant than *A. robusta* heartwood. They could also be used for services, which do not require much durability and for products such as matchsticks, blackboards, artefacts and pencils for which durability is not essential. On the other hand, *A. robusta* heartwood and sapwood and *T. ivorensis* sapwood could be treated with preservative chemicals to enhance their durability.

Very durable, durable and moderately durable heartwoods for *T. ivorensis* stem base, middle and crown respectively are generally indicative of an axial decrease in termite resistance along its stem. The findings thus support Côté et al. (1966), Scheffer and Cowling (1966), Haygreen and Bowyer (1996), De Bell et al. (1999) and Antwi-Boasiako (2004) that the natural resistance of trees to bio-degradation decrease with height above the ground with the heartwood of stem base is usually most resistant. The stem heartwood of *T. ivorensis* was rated moderately resistant to termites (Chudnoff, 1984; Forest Product Laboratory, 1974). Under temperate conditions, CIRAD (2011) also rated it susceptible to termites. Presently, *T. ivorensis* stem heartwood has been found to be very durable to moderately durable. Such variations of *T. ivorensis* termite resistivity may be directly associated with variations in the inherent termite resistance of the individual trees employed for the studies (Scheffer and Hopp, 1949; Zobel and Jett, 1995), differences between the field test protocols (Wong et al., 1998) and variations in the termite species, magnitude of termite hazard and moisture condition at the test field sites (Zobel and Jett, 1995; Scheffer and Morrell, 1998). Similarly, variations of termite resistance observed for various studies on *Thuja plicata* was related to variations among test materials, termite populations, and test methods (Stirling et al., 2015). Actually, the service life of wood determined by the degree of termite hazard may vary widely depending on the area (State Forests Technical Publication, 1995). Consequently, the greater termite resistance, especially for the heartwood of the base and middle of the stem (which were very durable and durable respectively), may vary under termite hazards in different environments.

Even though mass loss increased with height above the ground along *T. ivorensis* stem and branch, their differences were not significant between their heartwoods along the branches and the crown of stem. Similarly, the visual rating being moderate attack (2), just as their percentage mass losses also classified them as moderately durable. Therefore, this termite resistance consistently supports the reports by Chudnoff (1984) and Forest Product Laboratory (1974) that *T. ivorensis* stem heartwood is moderately resistant. This shows a comparable termite resistivity of *T. ivorensis* stem and branch heartwoods. Okai et al. (2004) had earlier found the physical and mechanical properties of their stem and branch woods to be “strong”. The specific gravity, Modulus of Elasticity, Modulus of Rupture, compression parallel to grain and shear parallel to grain are 0.459, 9200N/mm^2, 82.42 N/mm^2, 49.58 N/mm^2 and 12.81 N/mm^2 respectively for *T. ivorensis* branch, 0.433, 9443 N/mm^2, 85.31 N/mm^2, 45.22 N/mm^2 and 11.95 N/mm^2 respectively for its stem, 0.562, 12450 N/mm^2, 88.64 N/mm^2, 63.04 N/mm^2 and 18.13 N/mm^2 respectively for *A. robusta* branch and 0.502, 12783N/mm^2, 90.48N/mm^2, 56.55N/mm^2 and 14.94N/mm^2 respectively for its stem. On the whole, *T. ivorensis* and *A. robusta* stemwood and branchwood termite resistivity confirms the potential of branchwood to ensure regular supply of wood and sustain the wood industry and other related sectors**.**

CONCLUSION

The stem and branch woods of *A. robusta* were susceptible to termites. *A. robusta* wood is however regarded as commercially important Thus, with similar termite resistivity, its branchwood (sapwood and heartwood) could also be utilized in the timber industry for various products including interior joinery, veneer, cabinet and light carpentry works. *T. ivorensis* stem heartwood was very durable to moderately durable and its branch heartwood and sapwood of base of stem were moderately durable. The branchwood of *T. ivorensis* could be utilized in addition to its stemwood to increase the raw materials to meet the ever-increasing demand for the Wood Industry. The sapwoods of both timbers could also be utilized for products (such as matchsticks, arte facts, and blackboards) and services (e.g. ceiling joints, light frame construction and cabinet-making) for which durability is not extremely essential.

ACKNOWLEDGEMENT

We are grateful to the Staff of the Kumasi and Bekwai Districts of Forestry Services Division, Ashanti Region, Ghana for the supply of the wood samples, and Messrs. Johnson Addae (Department of Wood Science and Technology, Kwame Nkrumah University Science and Technology, Kumasi-Ghana) for his assistance in the wood sample preparation.

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