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A SURVEY OF WOOD BORER *Apate terebrans* TUNNELS ON *Terminalia mantaly* IN NIGERIA WITH SPECIAL REFERENCE TO THE NIGER DELTA REGION

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ABSTRACT

This study was conducted to count *Apate terebrans* opened tunnels in *Terminalia mantaly* at the 3 Parks of the University of Port Harcourt. All trees were assessed visually for the presence and absence of tunnels, frass, and exudates during the 6-months (January-July) field survey in 2018. The mean numbers of tunnels/tree were 16.12±2.13 from 58 trees representing 19.9% of 291 total trees. The spread of attack was fairly scattered and more closely associated with diameter at breast height (DBH) of tree ($\chi 2= 12.763$, df = 4, $\alpha 0.012^*$). While a majority (67.0%) of the trees experienced breaking reflecting both the immediate and residual impact of opened and closed tunnels, respectively, 10.7% experienced tearing of branches, and 5.5% experienced both breaking and tearing. Strong wind was found as a contributory factor to breaking and tearing. The findings suggest *T. mantaly* as a poor adaptable environmental species in Nigeria ecosystems and its current utilisation as ornamental tree may be revisited.

Contribution/Originality: This study documents the resurgence of wood borer, *Apate terebrans* and its impacts on the *Terminalia mantaly* used as one of the current popular urban trees in Nigeria.

1. INTRODUCTION

A world-wide-spread problem in wood utilisation is related to the protection of wood products that are often attacked by insects. The same problem is encountered in the environmental utilisation of trees (living woods). Until now a satisfactory solution to control the trees' degradation by wood-boring beetles had not been found, and the applied conservation methods offered only temporary reduced controls [1, 2] without guaranteeing a real and durable effectiveness. Beetles are one of the major devastating pests of plants worldwide with many types economically, environmentally and socially attacking healthy trees [3, 4]. Among these, wood-boring beetles are the most common disturbance of trees worldwide [5, 6] with a high prevalence from Bostrichidae [7, 8] and higher incidence in introduced species than native ones [9].

The black beetle, *Apate terebrans* (Pallas, 1772) (Coleoptera: Bostrichidae), is a widely distributed pest in Africa and Neotropical climes [10, 11]. Also, the occurrence of this beetle in Austria, and Europe has been reported [1].

Its primary hosts include many agricultural and forest trees [12]. In Nigeria, Murray [13] in 1867 listed *A. terebrans* among the Coleoptera insects found in Old Calabar but the tree species that the beetle attacked was not documented. The presence of *A. terebrans* was reported on *Delonix regia* in 1913 by Peacock [14] and later on *Azadirachta indica* in 1988 by Akanbi and Ladipo [15]. *A. terebrans* feeds on wood and can bore tunnels between 21.3 and 39.4 cm deep. And this remarkably weakens the strength of the hosts, resulting in tree's breaking [1, 16]. *A. terebrans* can cause severe wood tunnels on diversity of tree, often followed by tree mortality [14, 17] and its infestations can become a worldwide problem. Since 2015, an unprecedented re-emergence of this beetle infestations on *Terminalia mantaly* used as urban tree in Nigeria has been observed.

T. mantaly is probably native to Madagascar and its cultivation has been spread to other West African countries [18] and South America especially Brazil [19]. *T. mantly* (Figure 1) is a fast growing tree with an umbrella-like branching shape. The tree can grow up to up to 22.86 m high [20]. Recently, it is widely introduced and highly valued as urban (ornamental) tree in Nigeria more importantly in institutions' landscape [21-23]. Despite increasing spread of this killing insect (*A. terebrans*) on *T. mantaly* in Nigeria, observationally-based research of this topical issue has received little attention. Hence, this study intended to fill this gap in literature and broadens the current research base by investigating the tunnels severity of the wood borer, *A. terebrans*, which was recently reported to be one of the most damaging *T. mantaly* insect pests in southern Nigeria [16].

Given the intensified *A. terebrans* outbreaks in many African Countries such as Ghana [24] Guinea-Bissau [17] Republic of Benin [1] etc., understanding the knowledge of tunnels numbers per tree is critical for predicting the trees health status and severity of tree community vulnerability to secondary disturbances. More importantly for species that could be potentially pose risk to humans [25]. The previous study focused on the healing response of *T. mantaly* wood to *A. terebrans* tunnelling [16]. Some of the most important parameters of beetles-trees interactions that are crucial for the control and prevention of risks to humans are little known in Nigeria. To ensure secured sound future environmental sustainability in Nigeria, sufficient understanding the population indicators of pest on host is necessary. This study was therefore, conducted with a goal of inventorying the *A. terebrans* active tunnels in *T. mantaly* at the University of Port Harcourt, Nigeria. Specific objectives included estimation of the active tunnels/tree and thus determine the severity of attack, determination of spatial patterns of attack, and assessment of physical impact(s) of attack on *T. mantaly* growth. Bio-indicators are widely used in scientific research to quantify environmental impacts such as the effects of disturbances [25-27]. The outcomes of the study may be useful for arresting the trees-beetle pest situations in Nigeria and Africa as a whole.

Figure-1. Pictorial of *T. mantaly.*

2. MATERIALS AND METHODS

2.1. Description of Study Area

The study was carried out at the three Parks (Abuja, Delta, and Choba) of the UNIPORT, Nigeria. The University is 43 years old, located at 4°53′15′′ to 4°54′45′′ N and 6°54′15′′ to 6°55′30′′ E, occupying a spatial extent of about 4 km^2 along East west road within Obia Akpo Local Government Area of Port Harcourt – the headquarters of Rivers State. The East west road and Aluu road from Choba junction trisect the study area into three parts called Choba, Delta and Abuja Parks. The topography of UNIPORT is generally low with varying floodplains. The mean annual amount of precipitation in the area is over 2500 mm [28]. The University landscape is dominated by low coverage of diverse trees, among which are *Anacardium occidentale*, *Azadirachta indica*, *Chrysophyllum albidum*, *Delonix regia*, *Ficus elastica*, *Gmelina arborea*, *Mangifera indica*, *Peltophorum pterocarpum*, *Polyalthia longifolia*, *Spondias cytherea*, and *Terminalia mantaly*. Based on the recent preliminary survey conducted in early 2018 before the commencement of this study, only *T. mantaly* was found being attacked by *A. terebrans* in UNIPORT.

2.2. Tree Inventory

To enumerate *A. terebrans* opened tunnels (Figures 2 and 3) in *T. mantaly*, a total enumeration method was used across the 3 Parks of UNIPORT during the 6-months (January-July) field survey in 2018. All *T. mantaly* trees were closely assessed visually for the presence and absence of tunnels, frass and exudates. The Diameter Breast Height (DBH) of the trees was measured and recorded.

2.3. Determination of Severity of Attack

To quantify the severity of attack by *A. terebrans* on *T. mantaly*, the beetle opened tunnels were heuristically determined by visual assessment and was categorised into four: 1) 0 = no attack; 2) 1-10 = moderately attack; 3) 11-20 = heavily attack and 4) 21 above = extremely attack as the proposed method.

2.4. Determination of Spatial Patterns of Attack

To visualise the current spatial patterns of attack by *A. terebrans* on *T. mantaly*, the coordinates of all the trees across the 3 parks were recorded by using Geographic Positioning System (GPS) Garmin GPSMAP 78sc and mapped by employing ArcGIS 10.5 [28]. The currently attacked and non-currently attacked trees were differentiated by indicating the presence of tunnels on each tree as either "Yes or No" on the map produced.

2.5. Assessment of Physical Impact(s) of Attack on T. mantaly Growth

To assess the tunnels' impacts of damaging beetles on the trees, data on numbers of trees experiencing branches breaking and/or tearing were recorded. The data were analysed using Venn diagram approach while some snapshots were used to demonstrate the dimensions of breaking and tearing.

2.6. Data Analyses

Descriptive statistics (tables, map, and Venn diagram) were performed to present results on numbers of tunnels and severity of attack, spatial pattern of attack and impacts of attack. Pictures were also taken to further provide insights into the dimensions of attack and impacts. The influence (association) of DBH on numbers of tunnels was determined by Chi-square test at $\alpha_{0.05.}$

3. RESULTS

3.1. Number of Tunnels and Severity of Attack

A total of 935 opened tunnels (Figures 2 and 3) with an average of 16.12±2.13 tunnels/tree were found in 58 trees representing 19.9% of 291 total *T. mantaly* trees across the 3 parks (Table 1). While 10.6% were moderately severely attacked, 2.4% and 6.9% were highly and extremely severely attacked, respectively (Table 2). The number of tunnels increased from 14 to 36 at DBH category of 1-20 to 21-40 cm before declining to 8 tunnels at DBH class of 41-60 cm (Table 3). The association between DBH categories and the presence of the tunnels bored by *A. terebrans* in *T. mantaly* was significant ($\chi^2 = 12.763$, df = 4, $\alpha_{0.012*}$) Table 3.

Figure-2. Tunnels on *T. mantaly* main stem at UNIPORT.

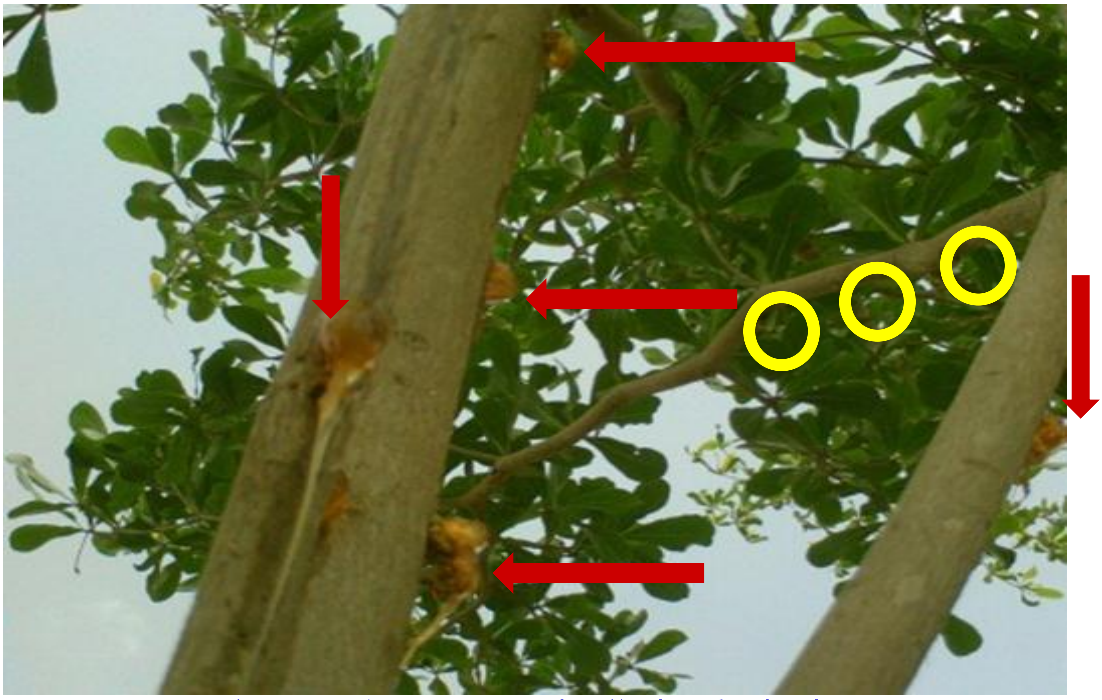

Figure-3. Gum (response parameter of attack) and tunnels on branches.

Table-1. Number of tunnels across the 3 parks of UNIPORT.

Trees	Number of tunnels	Cumulative number of tunnels
1	5	-
2	2	7
3	28	35
4	32	67
5	47	114
6	2	116
7	44	160
8	21	181
9	3	184
10	40	224
11	24	248
12	4	252
13	4	256
14	8	264
15	12	276
16	5	281
17	4	285
18	2	287
19	4	291
20	13	304
21	7	311
22	9	320
23	2	322
24	43	365
25	5	370
26	5	375
27	4	379
28	6	385
29	4	389
30	15	404
31	1	405
32	39	444
33	33	477
34	1	478
35	21	499
36	7	506
37	14	520
38	23	543
39	2	545
40	5	550
41	1	551
42	7	558
43	76	634
44	36	670
45	9	679
46	2	681
47	7	688
48	3	691
49	25	716
50	13	729
51	13	742
52	33	775
53	19	794
54	54	848
55	7	855
56	26	881
57	28	909
58	26	935
Total (average ± Standard Error)	935 (16.12±2.13)	-

Table-2. Severity of attack.

Severity	Frequency	Percentage (%)
No tunnel	233	80.1
Moderately severe	31	10.6
Highly severe	7	2.4
Extremely severe	20	6.9
Total	**291**	**100**

Table-3. Association between DBH categorisation and the presence of the tunnels bored by *A. terebrans* on *T. mantaly*.

DBH Categorisation (cm)		Presence of tunnels		Total	Chi Square Statistics
		Yes (%)	No (%)		
Categories	No DBH	0 (0)	33(11.3)	33 (11.3)	χ^2= 12.763 df = 4 $\alpha_{0.012*}$
	1-20	14(4.8)	36(12.4)	50 (17.2)	
	21-40	36 (12.4)	121(41.6)	157 (54.0)	
	41-60	8 (2.7)	37(12.7)	45 (15.4)	
	61-80	0(0)	6(2.1)	6 (2.1)	
	Total	58 (19.9)	233 (80.1)	291 (100)	

3.2. Spatial Patterns of Attack

While, the planting arrangement patterns and numbers of the tree species deferred remarkably in the 3 parks (Choba, n = 8; Delta, n = 46; Abuja, n = 237), the presences of *A. terebrans* currently attacking *T. mantaly* (Choba, n = 2; Delta, n = 7; Abuja, n = 49) were found across the 3 parks. The spatial distribution of attack was fairly scattered Figure 4.

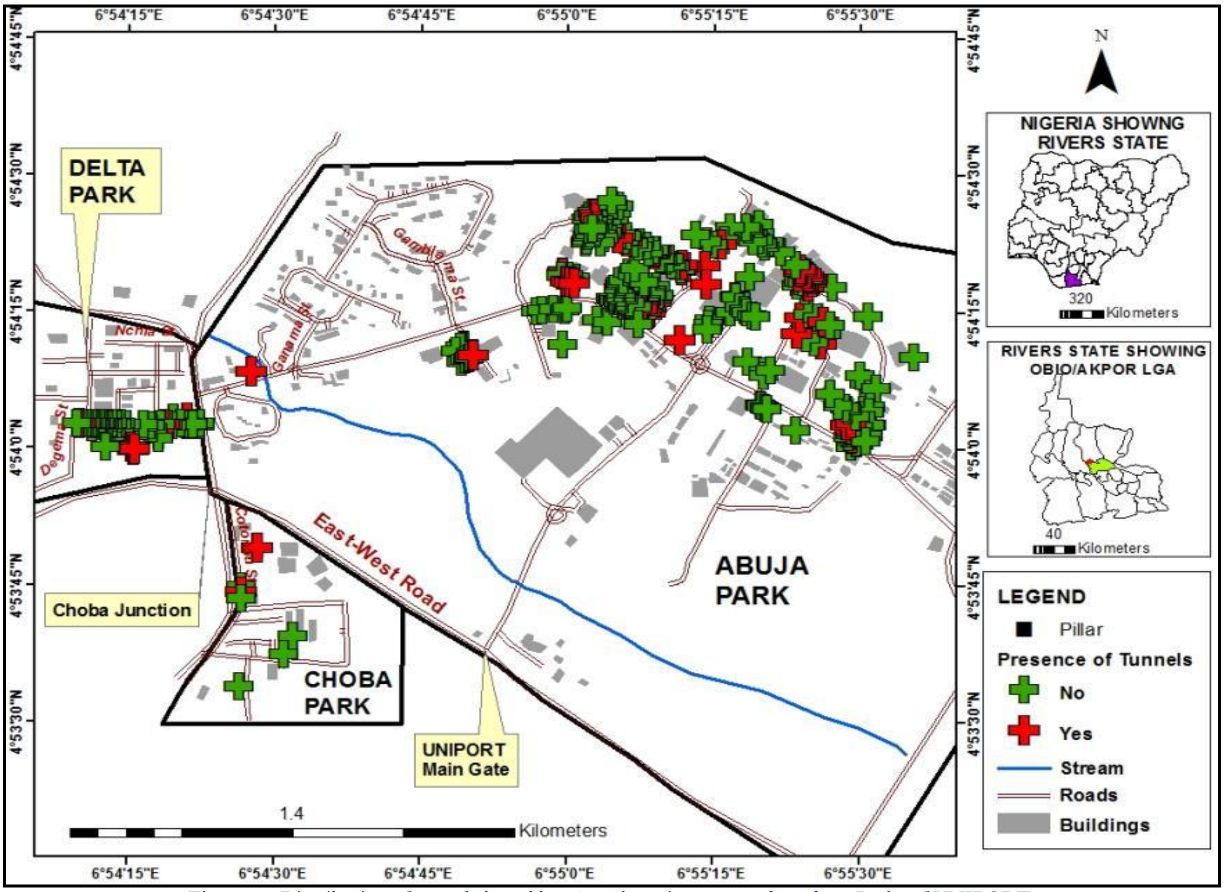

Figure-4. Distribution of tunnels bored by *A. terebrans* in *T. mantaly* at the 3 Parks of UNIPORT.

3.3. Impacts of Attack

In all, majority (67.0%) of the trees experienced breaking, 5.5% experienced both breaking and tearing, 10.7% experienced only tearing of branches while 16.8% experienced no breaking or tearing (Figure 5). Two dimensions of branches wood breaking (A = complete, B = partial) were recognised (Figure 6). Also, two dimensions of branches tearing (C = crossing over, D = point) were recorded Figure 7.

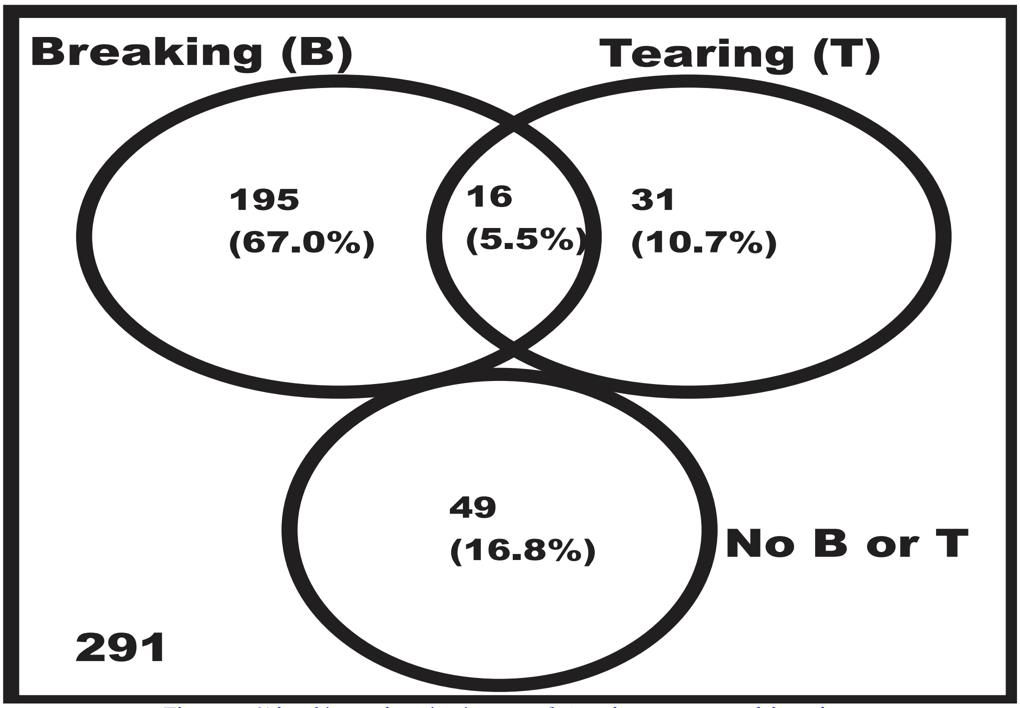

Figure-5. % breaking and tearing impacts of *A. terebans* on *T. mantaly* branches.

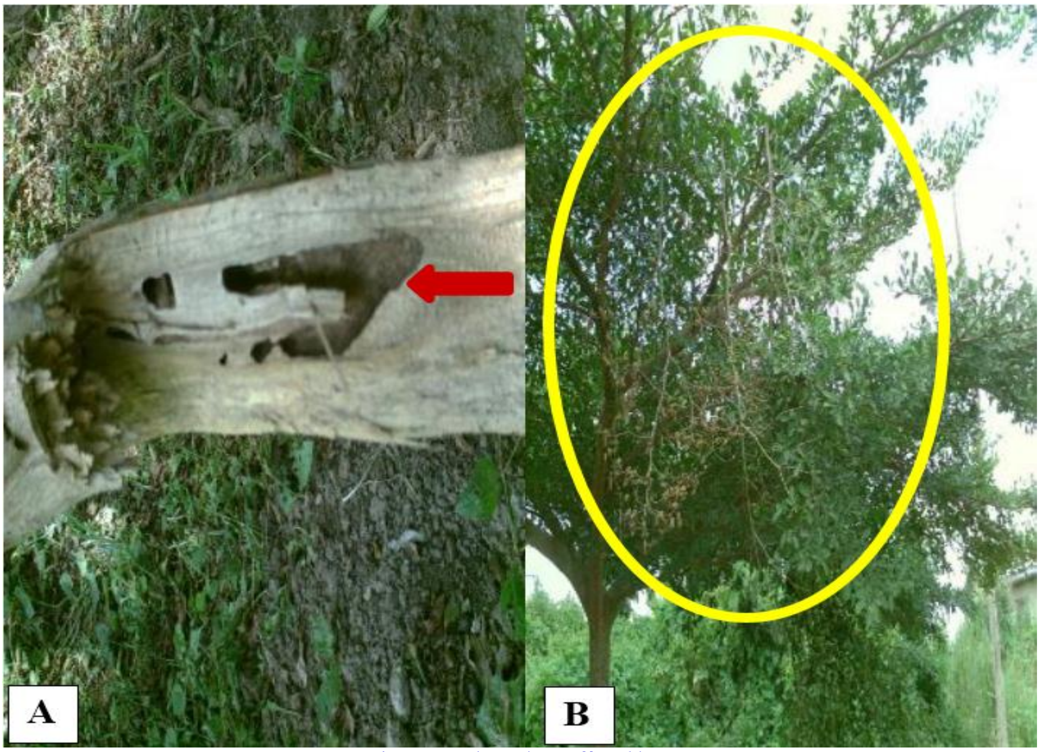

Figure-6. Dimensions of breaking.

Figure-7. Dimensions of tearing.

4. DISCUSSION

4.1. Number of Tunnels and Severity of Attack

The presence of wood-cavity causing organisms in trees indicates reduced tree strength status [29]. *A. terebrans* is known to be one of the environmentally and economically most important wood destructive beetles in Africa [1] and it has been previously noted to bore an average length of 27.11±5.94 on *T. mantaly* stem wood [16]. The average number of tunnels/tree recorded in this study portends high percentage of strength reduction in stem and branches woods of attacked trees. This implied the expectation of poor serviceability and posing of risks of the affected trees to immediate consumers. The result was higher than 10.73±2.10 holes/tree reported on Cashew trees in Republic of Benin by Onzo, et al. [2]. This indicates that *A. terebrans* are massive attackers thus supporting the findings of Vorster, et al. [30] that beetles are known for mass attack through the secretion of pheromone. The percentage of the trees currently affected in this study was within the range reported by Tchetangni, et al. [31] but relatively lower compared to 60.0±9.0% of *A. terebrans* infestations rate documented on Cashew trees in Republic of Benin by Onzo, et al. [2].

The attack severity of *A. terebrans* on *T. mantaly* was significantly associated with DBH, which was likely to be the most important determining host factor involved in the scales of preference found in this study. This result agrees with findings of Lih and Stephen [32]; Graf, et al. [33] that host tree diameter is an important predictor of the population dynamics of pine beetles. Hart, et al. [34]; Hart, et al. [35] reported the overwhelming preference of spruce bark beetle infestations on ≥ 23 and > 24 cm DBH of spruce-fir stands. These findings fall within the peak range of DBH attacked by wood beetles in this study. The result implied that as the trees were aging above a DBH of 40 cm, they were less attacked but younger trees of below 20 cm DBH were more preferred which is a common characteristics of insect pests of switching host from the older ones to the more succulent and nutritious younger trees in this case in order to meet up with their biological demands to perpetuate the next generation.

4.2. Spatial Patterns of Attack

The spatial patterns of attacked trees, is of importance to predict the spread of risks. Despite the dissimilar planting arrangement and population of *T. mantaly* across the 3 parks, the spread of attack was found to be fairly scattered and seemed somewhat proportionate. The spatial patterns of attack found in this study may be attributed to the significant diverse DBH sizes of available *T. mantaly* trees from which the beetles chose the desirable ones. Our result was in contrast to the earlier findings of Agboton, et al. [1] that *A. terebrans* attack showed aggregated spatial distribution on Cashew in Republic of Benin for the first year of study. They however obtained different pattern in succeeding year of study, concluding that the beetle may generally show preference for new trees. Young adults were strictly found on branches while full adults were majorly found on the main stem but some found on big branches. Tunnels were generally more found on the branches than the stems.

4.3. Impacts of Attack

A. terebrans tunnels have breaking effect on *T. mantaly* branch wood (Figure 6) as breakings occurred around the previously attacked closed and opened tunnels entries. However, strong but not critical wind was identified as a contributory important factor for breaking of previously attacked closed tunnels (Figure 6A). *A. terebrans* is known to inflict their damage on trees mainly through tunnelling of wood along the grain [12, 16]. The dimensions of wood breaking (Figure 6) found in this study suggests the medium and short-term breaking impacts of *A. terebrans* attack. These breaking impacts were found causing asymmetric tree crowns. The revelation of closed cavities (Figure 6A) indicates that healing response of *T. mantaly* documented by Adedeji, et al. [16] was just a mere superficial closure. This implied that many trees seeing with beetle tunnel's scars may have in-wood tree cavities. Cavity defects in wood are a determinant of mechanical strength loss causing tree failure and human death in urban environments [36-38].

This and the tearing character of the *T. mantaly* raised concerns about the greater threat the tree may impose on humans in Nigeria. Though the tearing could not be linked to the beetle activity but can be explained as reflection of poor affinity between stems and branches due to strong wind effect. Studies on wind have demonstrated its impacts as dangerous driver of wood damages exerting mechanical crack giving rise to splitting of weak branch union, sap flowing or bleeding [25, 36, 39]. These findings support our obtained characteristics of wind impacts found in this study. This poor bonding of branches to the mother stem is a further indication that *T. mantaly* is a very poor urban tree in Niger Delta, Nigeria.

5. CONCLUSIONS

The result shows that *A. terebrans* severely attack considerable numbers of *T. mantaly* with an average of 16.12±2.13 tunnels/tree. The spread of attack was fairly scattered and more closely associated with tree DBH. Tunnelling impact of *A. terebrans* could be immediate (short-term) or medium-term. The medium-term represents the residual weakness from the previously attacked and healed trees waiting for contributory factor such as strong wind to break. Although the present study focused on tunnels effects, the reported findings suggest that tearing may be attributed to other factors like strong wind. The findings established that *T. mantaly* is extremely susceptible to insect pest infestation and climatic factor like wind speed. Its utilisation as urban tree in Nigeria may represent a multiple big danger to humans, properties, and even to food security in the nearest future. Further study should examine the host possible shift from available susceptible species.

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Competing Interests: The authors declare that they have no competing interests.
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