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Short Communication: The resistance of *Styrax sumatrana* wood of varying growth sites and stem axial positions to subterranean termite (*Coptotermes curvignathus*) attack

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Abstract. *Iswanto AH, Tambunan J, Susilowati A, Hartono R, Darwis A. 2021. Short Communication: The resistance of* Styrax sumatrana *wood of varying growth sites and stem axial positions to subterranean termite (*Coptotermes curvignathus*) attack. Biodiversitas 22: 3192-3198.* As mega-biodiversity country, Indonesia consists of a large number of flora and fauna, including wood-destroying organisms such as termites. One of the native trees known as a resin producer is Tobanese incense (*Styrax sumatrana*). The existence of this species has been studied for several wood properties such as physical, mechanical, and chemical properties, while its natural durability against termite attack has not been studied. As a country known as a haven for termites, the study on incense wood durability is very important for further utilization. The objective of this research was to analyze the natural durability of *S. sumatrana* wood from two growing locations and different stem positions using a graveyard test. The Graveyard test method was used to investigate the mass loss and percentage of damage of the sampled woods. The test sample used is 2x2x20 cm3 in size. The sample is buried as deep as 15 cm and leaving 5 cm of the part that is above the soil surface. The distance between the samples is 60 cm. The results obtained from this study indicated that the incense wood originating from Pakpak Bharat and North Tapanuli districts can be classified as durable class V (Vulnerable category) and severely damaged (E category) with the respective mass loss percentages ranging from 22.03-31.70% and 18.46-20.79% and damage percentages ranging from 86.55-96.27% and 78.02-86.32%. In conclusion, the positions of the stem and the sites where it grows caused a difference in the natural durability value of *Styrax sumatrana* wood. The incense wood originating from North Tapanuli District had slightly better durability against subterranean termite attacks than that from Pakpak Bharat District, although overall the samples from these two sites fell into the same durability class.

Keywords: Incense wood, *Styrax sumatrana*, subterranean termites

INTRODUCTION

Styrax sumatrana or locally known as Tobanese incense, was resin-producing trees belonging to the member of the Styrax genus. The genus of Styrax known as benzoin rosin producer in the world and widespread but disjunctive distribution occurring in the Americas, eastern Asia, and the Mediterranean region (Frisch, 2001). However, different species of Styrax could also be found in some South East Asia countries such as Indonesia, Laos, Vietnam, and Thailand. The North Sumatra province was reported as the largest distribution site of incense in Indonesia (Susilowati et al. 2017a). Several researchers have carried out previous studies related to the incense from North Sumatra. Iswanto et al. (2016) and Pasaribu et al. (2013) conducted a study of incense wood's physical and mechanical properties. While the potency of its resin as an antioxidant and the chemical constituent has been reported by Hidayat et al. (2018) and Iswanto et al. (2019). Furthermore, Kiswandono et al. (2016) carried out a study of the cinnamic acid content of incense resin originated from North Tapanuli while studying the phylogenetic study of incense grown in North Sumatra has been reported by Susilowati et al. (2017b). Furthermore, the genetic structure of the endemic *Styrax sumatrana* has also been determined (Rachmat et al. 2017). Moreover, research on the morphological aspect, flowering, and fruiting phenology of the incense plant has also been reported (Susilowati et al. 2018). Studies related to the termite resistance of incense wood are still determined yet, even though local people often utilize the unproductive incense wood for light construction.

As known that Indonesia is known as a mega-biodiversity country. As a country with a tropical climate, Indonesia has rich biodiversity, both flora and fauna, including various types of wood-destroying organisms such as fungi, bacteria, borer insects (termites), marine borers, powder post beetles, etc. One of the most common wood-destroying organisms is termites. Termites are basically an organism that functions as natural decomposers by feeding on decaying wood, which is their primary food source, and in some occasions, they also use the decaying wood as a place for breeding (Awadzi et al. 2004). Termites have a positive impact in the context of the whole ecosystem and negative impact from the perspective of anthropogenic activities since their damaging or detrimental effects (UNEP 2000). In human society, termites are considered as destructive insects for wood and wood-based products. For example, the annual economic losses due to termite attack in Indonesia amounted to trillions of Rupiah (Nandika et al. 2003). In 2018, the Association of Indonesian Pest Control Companies calculated the losses caused by termite pests reaching 2.8 trillion rupiahs. This is because the climate and soil conditions in Indonesia are well suited for termite life. Nandika et al. (2003) stated that more than 80% of Indonesia's mainland serves as a good habitat for termites. Furthermore, Nandika et al. (2003) reported that there are at least 40 cities or regions in Indonesia with low to high humidity conditions that are found in various species of termites. In other words, almost all major islands in the archipelago are inhabited by termites. Termites are found in low to high land, forest to urban ecosystems, mineral soils to peat. This condition makes Indonesia a haven for termites.

The natural durability of wood in regard to termite attack is closely related its physical and chemical properties. The variations in wood physical and chemical properties are related to various factors, including the species of trees, the trees' location, and the differences in species and stem positions, either axially and laterally. *S. sumatrana* is native to North Sumatra, Indonesia. This plant species has bio-geographical distribution in North Tapanuli, Humbang Hasundutan, and Pakpak Bharat District. Since habitat bio-physical conditions determine the morphological and physiological characteristics of the plants, an interesting phenomenon reported in a previous study by Rachmat et al. (2017) showed that the *S. sumatrana* plants from North Tapanuli districts are very different compared with those from Pakpak Bharat District. A significant difference was also noted from the results of the chemical component analysis of the woods in varying growth sites in North Sumatra (Iswanto et al. 2019).

Studies on the variability of wood properties of *S. sumatrana* plant in varying growth sites and stem positions were previously conducted by Iswanto et al. (2016; 2019). These studies reported that differences in growth sites and stem position resulted in variations of chemical components of the wood as well as its physical and mechanical properties. In the context of *S. sumatrana* plant, Iswanto et al. (2019) stated that based on its chemical properties, the incense wood from North Tapanuli and Pakpak Bharat District had chemical and extractive compositions of 25.94 and 39.87% (α-cellulose), 26.78 and 29.92% (hemicellulose), 4.37 and 20.43% (acid-insoluble lignin), as well as 10.95 and 2.42% (extractive content) respectively. The variations in wood properties in turn will have an impact on the various values of the wood resistance to attack by destructive organisms, one of which is the subterranean termite species *Coptotermes curvignathus* Holmgren.

In this research, the determination of the natural durability of wood against subterranean termite attacks was carried out through the grave test. The grave test is one way to determine the natural durability of wood carried out in nature, where the wood to be tested is planted in a location around which there are termite nests. This is to ensure that a termite infestation causes the damaged wood. Compared to laboratory tests that predict the durability of wood, this grave test will describe in real terms the extent to which wood is resistant to termite attack. In this grave test, there are many influencing factors such as the type of condition of the media used, the organisms that destroy it, climatic conditions including temperature, humidity, etc., which cannot be controlled homogeneously because they are controlled by nature. Therefore, the aim of this study was to analyze the natural durability of *S. sumatrana* wood from two growing locations and different stem positions using a graveyard test.

MATERIALS AND METHODS

Materials

The material used in this study was Tobanese incense wood (*Styrax sumatrana*) collected from two regions in North Sumatra, Indonesia, namely North Tapanuli District (1º20'00" - 2º41'00" N, 98º05' - 99º16' E) and Pakpak Bharat District (2°15' - 3°32' N, 96°00'- 98°31' E).

Methods

Material preparation

Styrax sumatrana wood in the form of a log was divided into three parts, i.e. the base, middle and top. Furthermore, from each log a test sample measuring 2x2x20 cm^3 was made.

Wood resistance testing procedure

The test was conducted in the field using the Graveyard test method. The wood sample was dried in an oven at a temperature of 103 ± 2 °C until the mass was constant to obtain the sample's dried mass before testing (Oven dry wood-ODW_1). The samples that have been tested were then buried in the soil with a distance of 60 cm between the test samples and left the upper part of 5 cm of each sample above the soil surface as shown in Figure 1. Meanwhile, the layout of the wood resistance testing is presented in Figure 2.

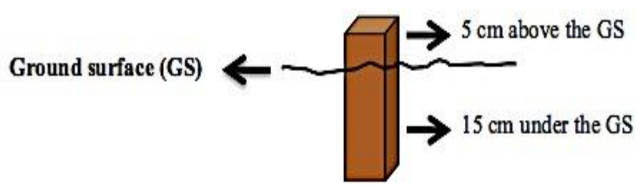

Figure 1. Diagram of wood resistance testing using Graveyard Test method by burying the sample under the soil and left the upper part above the soil.

The period of wood resistance testing or feeding of the wood sample was 100 days. After such period, the samples were taken and cleaned off the sticky soil. Then the test samples were oven-dried at a temperature of 103 ± 2 °C until it was constant, so that the dried mass after testing (ODW_2) was obtained. The parameters observed in this study included mass loss and the level of damage due to termite attacks following Sornnuwat et al. (1996) as presented in Tables 1 and 2.

Data analysis

This study used a Two-factor Completely Randomized Design in which Factor A was the growth site (i.e., Pakpak Bharat and North Tapanuli) while Factor B referred to the axial position of the stem (i.e., base, middle, and top). There were four replications for each treatment, resulted in total samples of 24. Analysis of variance (ANOVA) was conducted to test significant differences and followed by the Duncan Multiple Range Test (DMRT) to identify the difference among treatments.

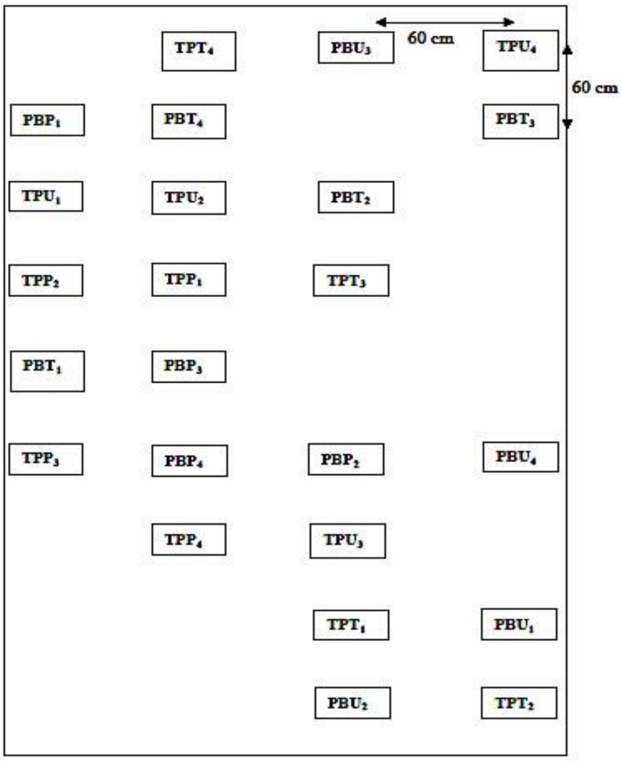

Figure 2. The layout of the wood resistance testing using Graveyard Test method

RESULTS AND DISCUSSION

Mass loss

One parameter to assess wood resistance against termite attacks in this study was the mass loss of the wood sample after being fed for 100 days. The higher the percentage of mass loss, the lower the wood resistance is to termite attacks. According to Smythe et al. (1971) and Carter and Smythe (1974), several factors that affect the level of termite attack on wood include the type of wood, its hardness, toxic substances, food inhibitors, and moisture content of wood and soil. The result of this study showed that mass loss of wood samples due to termite attacks varied greatly, both for the incense wood samples from Pakpak Bharat and North Tapanuli (Figure 3).

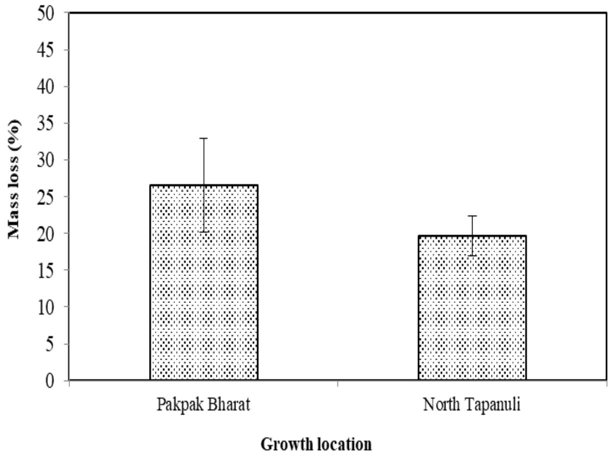

Figure 3. The average loss of wood mass of *Styrax sumatrana* wood based on the growing location.

Table 1. Criteria in determining the level of wood resistance to subterranean termite attack

Mass loss (%)	Level of wood resistance
0	High Resistance
1-3	Resistance
4-8	Average Resistance
9-15	Lower Resistance
>15	Vulnerable

Table 2. Visual assessment of Graveyard Test to assess wood resistance to subterranean termite attack

Class	Qualitative assessment		Quantitative assessment
	Attack level	Remarks	
A	Not attacked	Wood is not attacked (0%)	0
B	Little attacked	Termite attacks found, such as bite marks with 12.5% depth	1-10
C	Light attack	Tunnels found with 25% depth	11-20
D	Heavy attack	Substantial Tunnels found to the depth of 37,5%	21-30
E	Severely Damaged	Attack found to the depth of >50% of solid wood	31-40

Based on Figure 3, the mass loss of incense wood from Pakpak Bharat was higher than that from North Tapanuli. The difference in the mass loss was resulted from the differences in the levels of cellulose and the extractive substances the wood contained. The incense wood from North Tapanuli had a lower cellulose content compared to Pakpak Bharat. In addition, the extractive content of the incense wood from North Tapanuli was also higher. Results from previous research conducted by Iswanto et al. (2019) reported that the cellulose content and the extractive content of the incense wood from North Tapanuli were 25.94% and 39.87%, respectively, while those from Pakpak Bharat were 10.95 and 2.42% respectively. Cellulose is the main food source for termites. According to Scheffrahn (1991), termites pose the most threat to wood life among wood-destroying organisms because these organisms feed on the cellulose in wood.

Meanwhile, wood extractive substances are considered as a contributing factor in evaluating the durability of wood (Kirker et al. 2013). Ragon et al. (2008), Rowell (2005), and Miller (1999) stated that extractive substances in wood affect termite attack. Some types of extractive substances are toxic and can cause an increase in the mortality of termites that feed on the wood (Kadir 2017). This is in line with the statement from Syofuna et al. (2012) who stated that the extractive substances contained in wood have an important role in resistance to termite or fungal attack.

The high lignin content of the incense wood from North Tapanuli was also thought to have contributed to its lower mass loss value. According to Walcott (1946) and Syafii et al. (1988), lignin serves as a physical barrier which termites do not favour. Shanbhag (2012) stated that wood species that had low cellulose content with high lignin and high total phenol contents result in wood being resistant to termites, and vice versa.

The number of termites attacking wood also greatly affects the damage and the mass loss of the wood they feed on. One of the important factors involved in termites' search for food is the number of wandering passages that are closely related to their foraging pathways (Jeon et al. 2010). In general, *Coptotermes* build wandering tunnels in the ground that function to protect colony members (Syaukani 2013). The availability of food around the nest greatly affects the construction of the termite nests (Ladley and Bullock 2005). Termites will build a wandering tunnel that is a pathway for termites to obtain food so that finding food is not hampered (Cornelius and Osbrink 2011). Based on the field observations, it was found that the number of termites that attacked incense wood from Pakpak Bharat was greater than the number of termites that attacked the North Tapanuli incense wood. This number of termites was in line with the mass loss that occurred in both samples. The comparison of termites that attacked the two types of test samples can be seen in Figure 4.

The average mass loss percentage of incense wood from Pakpak Bharat and North Tapanuli based on its axial stem position ranged from 22.03-31.70% and 18.46-20.79% respectively, as presented in Figure 5.

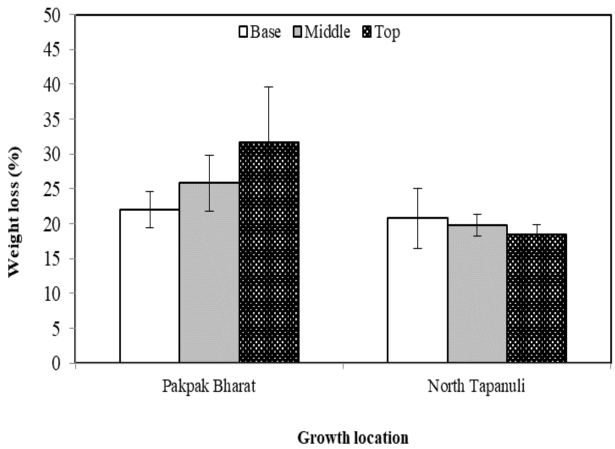

Figure 5. The mass loss of *Styrax sumatrana* wood by termites (red circles) from two sites based on the axial positions of the stem

Figure 4. Termites' attacks on *Styrax sumatrana* wood samples collected from: A. Pakpak Bharat, B. North Tapanuli

Based on Figure 5, it can be seen that the mass loss in incense wood originating from Pakpak Bharat had an increasing trend from its base to top. This is due to the greater proportion of heartwood at the base, which decreases towards the top of the wood. Heartwood contains higher extractive substances compared to sapwood so that the part that has a larger proportion of heartwood will have a better level of resistance (Owoyemi and Olaniran 2014). Yang et al. (2020) reported that in teak wood (*Tectona grandis*), the area of heartwood and sapwood decreased from base to top. The proportion of heartwood on each stem was greater than the sapwood. This caused the base part to have a lower percentage mass loss or was considered to be more durable or resistant than the middle and top parts. This condition was similar to the research conducted by Iswanto et al. (2020) in that the mass loss of Raru wood (*Cotylelobium melanoxylon*) was increasing from its base to top part.

On the other hand, the incense wood from Pakpak Bharat had a different pattern of termite attacks based on the axial positions of the stem. The top of the wood had a better resistance than the base part, indicated by a low percentage value of mass loss. This was due to the fact that after the Graveyard test was conducted for 100 days, it was shown that the termites attacking the sample test at the base of the North Tapanuli incense wood were seen to be in a greater number compared to those attacking the middle and top parts of the wood. As previously stated, the number of termites that attacked wood also greatly affects the level of the damage and the mass loss of the wood being fed. Termite attack at the base part of the wood occurred more comprehensively starting from the circumference to the inner part of the wood. Meanwhile, termite that attacked the middle and top parts of the wood occurred only slightly in the circumference and formed small holes.

Based on the mass loss, according to Sornnuwat et al. (1996), the incense wood from these two sites can be categorized in class V (vulnerable category) because it had a mass loss value of > 15%. Visualization of damage due to termite attack in incense wood from North Tapanuli is presented in Figure 6. Analysis of Variance for mass loss parameters showed that the correlation between the growth sites and the axial stem positions showed a significant difference as presented in Table 3.

Based on Table 4, the severity of termite attacks on top part of the incense wood originating from North Tapanuli was significantly different from that on the middle and top parts of the incense wood from Pakpak Bharat. Meanwhile, the severity of termite attacks on the top part of the incense wood from Pakpak Bharat was significantly different from that of all axial stem positions of the incense wood from North Tapanuli.

Damage percentage

The average value of the degree of the attack (damage percentage) on the incense wood from Pakpak Bharat and North Tapanuli based on the axial stem positions ranged from 86.55-96.27% and 78.02-86.32%, respectively as shown in Figure 7. The results from further testing with the Duncan Multiple Range Test (DMRT) at a 95% confidence interval are presented in Table 4.

Table 3. ANOVA of mass loss of *Styrax sumatrana* wood due to termite attacks based on growth location and axial stem position

Source	Sum of Squares	df	Mean Square	F	Sig.
Growth location (GL)	281.330	1	281.330	15.368*	.001
Axial stem	55.097	2	27.548	1.505ns	.249
GL * axial stem	145.849	2	72.924	3.984*	.037
Error	329.511	8	18.306		
Corrected total	811.786	3			

Note: (*) significant difference at 95% confidence interval, (ns) not significant

Table 4. DMRT for mass loss of *Styrax sumatrana* wood due to termite attacks based on growth location and axial stem position

Treatment	N	Subset		
		1	2	3
NT-Top	4	18.4650		
NT-Middle	4	19.7675	19.7675	
NT-Base	4	20.7900	20.7900	
PPB-Base	4	22.0300	22.0300	
PPB-Middle	4		25.8300	25.8300
PPB-Top	4			31.7050
Sig.		.294	.081	.068

Note**:** NT (North Tapanuli), PPB (Pakpak Bharat)

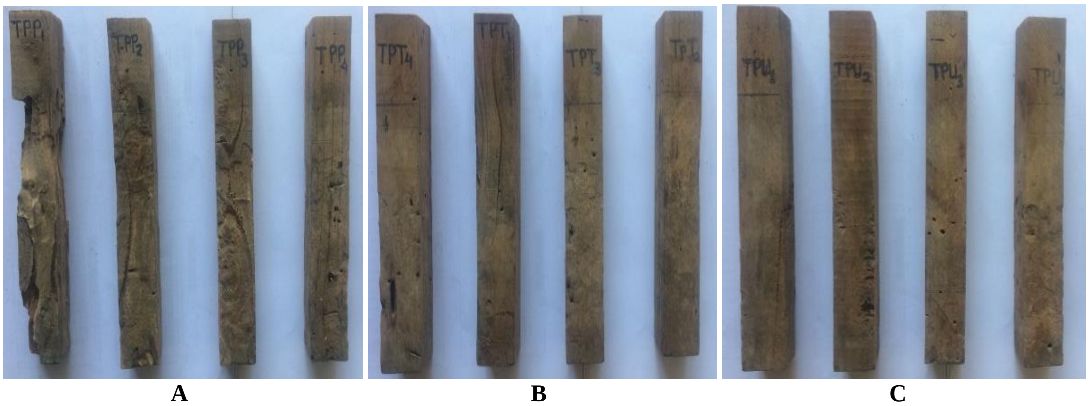

Figure 6. The appearance of *Styrax sumatrana* wood from North Tapanuli after 100 days of testing based on the axial positions of the stem: A. Base, B. Middle, C. Top

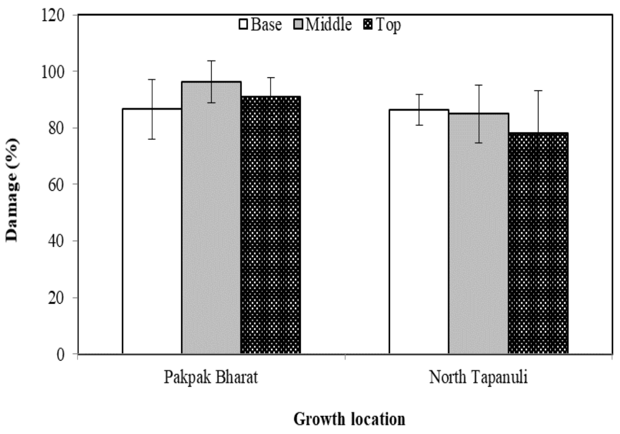

Figure 7. The percentage of damage of *Styrax sumatrana* wood due to termite attacks based on growth location and axial stem position

Based on Figure 7, it can be indicated that the highest percentage of damage occurred on the incense wood from Pakpak Bharat, particularly at the middle position of the stem, while the lowest damage value occurred on the incense wood from North Tapanuli at the top part of the stem. The value in Figure 7 illustrated the quantification of the visualization of test sample damage due to subterranean termite attack. Overall, based on the level of damage, wood from both locations can be categorized as class E (the severely damaged category reached a depth of > 50% of solid wood).

Based on Figures 8 and 9, the forms of termite attack on the test samples varied both on wood from Pakpak Bharat and North Tapanuli. Some of the test samples were attacked by termites, but it only occurred on the whole edges surrounding the samples. However, in several other test samples, the termites attacked gradually starting from one side and then began attack by perforating the sample and the hole was also used as a place to live.

Analysis of Variance for the damage percentage parameter showed that the growth sites, the position of the stems, and their correlations were not significantly different at the 95% confidence interval as presented in Table 5.

Table 5. ANOVA of damage percentage of *Styrax sumatrana* wood due to termite attacks based on growth location and axial stem position

Source	Sum of squares	df	Mean square	F	Sig.
Growth location (GL)	398.046	1	398.046	4.163^{ns}	.056
Axial stem	157.758	2	78.879	$.825^{ns}$	.454
GL * axial stem	190.693	2	95.346	$.997^{ns}$	.388
Error	1721.049	18	95.614		
Corrected total	2467.547	23			

Note**:** ns: not significant

A B C

Figure 8. Damage caused by termites to the samples of *Styrax sumatrana* wood from Pakpak Bharat: A. Heavy, B. Moderate, C. Light

A B C

Figure 9. Damage caused by termites to the samples of *Styrax sumatrana* wood from North Tapanuli: A. Heavy, B. Moderate, C. Light

Considering the high value of mass loss and damage percentage based on visualization, it can be stated that the extractive content in *S. sumatrana* wood could not protect against subterranean termite attacks. Therefore, if this wood is being used as a light construction material, furniture, and handicrafts, preservation treatments must be taken first.

In conclusion, the positions of the stem and the sites where it grows caused a difference in the mass loss value of *S. sumatrana* wood. The incense wood originating from North Tapanuli had slightly better durability against subterranean termite attacks than that from Pakpak Bharat, although overall the samples from these two sites fell into the same durability class. Based on Graveyard test, both *S. sumatrana* wood from Pakpak Bharat and North Tapanuli can be classified into Vulnerable (V) and severely damaged (E), with mass loss of 22.03-31.7% and 18.46-20.79%, respectively, and the percentage of damage was 90.93-

96.26% and 78.06-86.31%, respectively. As such, it is necessary to perform wood preservation treatments before the wood is used as a raw material for processing.

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