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Original Research

Effectiveness of Wood Vinegar from Tobacco Stalk on Termite Resistance in Bamboo (*Dendrocalamus asper* Backer)

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ABSTRACT

Bamboo (*Dendrocalamus asper* Backer) is commonly used as structural material in the tobacco curing barns of PT Perkebunan Nusantara X, where it is installed in the ground as supporting pillars. However, subterranean termites (*Coptotermes curvignathus* Holmgren) pose a significant threat to bamboo, causing brittleness and structural damage. This study aimed to identify the most effective wood vinegar treatment to protect bamboo against termite attacks. This research conducted at February 2022 to July 2023 in Jember, East Java, Indonesia. This study used explanatory research methods. Tobacco stalk-derived wood vinegar was applied to bamboo using seven different treatments (labeled A to G), each replicated three times, and compared with untreated control bamboo. Wood vinegar made from tobacco stems is effective in suppressing subterranean termite attacks on bamboo. After 18 months of observation, treatment E—where bamboo was soaked in wood vinegar for one day, followed by the application of one liter of wood vinegar to the surrounding soil—proved to be the most effective. This treatment reduced termite damage by 29% compared to the control and minimized brittleness to only 12%, outperforming the other treatments. Consequently, treatment E is recommended for bamboo used in curing barns to enhance resistance against subterranean termite attacks.

Keywords: bamboo, brittleness, dendrocalamu, tobacco, treatment

1 INTRODUCTION

Bamboo, a monocot plant from the family Poaceae, is a highly renewable and versatile resource widely used in various applications, including construction and furniture. It is valued for its rapid growth rate, reaching maturity within three to five years, and its impressive mechanical strength, especially in the direction parallel to its grain. Among the many species, *Dendrocalamus asper* (commonly known as Petung Bamboo) stands out for its durability and structural utility, particularly in regions like Indonesia, where it is commonly used in tobacco curing barns for PT Perkebunan Nusantara X. However, despite these advantages, bamboo's high cellulose and hemicellulose content (ranging from 42.4–53.6%) makes it highly susceptible to damage by pests, particularly termites, which can lead to significant brittleness and reduced longevity (Ibrahim & Febrianto, 2013; Jasni & Rulliaty, 2015).

Subterranean termites, especially *Coptotermes curvignathus*, are notorious pests of bamboo structures. These termites, which belong to the

Rhinotermitidae family, primarily attack bamboo and wood in contact with soil but can extend their reach to above-ground structures by constructing tunnels from the ground. They have a caste-based colony structure that enables efficient, organized destruction of bamboo, often leading to costly damage in industries that rely on bamboo as a structural material (Martawijaya, 1996; Nandika, 2015). Protecting bamboo from termite attacks is therefore crucial for prolonging its utility in agricultural and construction contexts.

A promising protective measure against termite infestation is the application of wood vinegar, a biopesticide derived from the pyrolysis of plant materials. Wood vinegar is known for its antifungal and insecticidal properties, and recent studies have shown its potential as an eco-friendly alternative to chemical treatments in termite management. However, research into the effectiveness of wood vinegar specifically for bamboo preservation remains limited, highlighting the need to explore this natural treatment further (Febrianto et al., 2017). In this study, tobacco stalk-derived wood vinegar was selected as a treatment source due to its local availability and sustainability. Utilizing tobacco stalks not only leverages an agricultural byproduct but also aligns with sustainable practices by minimizing waste and promoting resource efficiency.The objective of this research was to evaluate different wood vinegar treatments to determine the most effective method for protecting *D. asper* bamboo against subterranean termite attack. This study examines various application methods over an 18-month period to assess their impact on both termite resistance and bamboo brittleness. Findings from this study could inform more sustainable, accessible pest control strategies, potentially extending bamboo's lifespan in agricultural applications.

2. METHODS

2.1 Bamboo preparation

Prepare 24 pieces of bamboo for observation with the length of each piece of bamboo being 60 cm. Bamboo is dried at 60 ºC for 48 hours. Three pieces bamboos were used as a comparison (control) and 21 bamboo pieces as samples for seven treatments.

2.2 Wood vinegar process

The raw material for wood vinegar used here is tobacco stalks of the H 382 tobacco variety from tobacco plantation of PTPN X in Jember, East Java. Tobacco stems are chopped and dried then pyrolyzed at 400ºC for 6 hours using a pyrolizer to become wood vinegar (Budaraga *et al.* 2016) ; (Dermibas. 2005). The solution was cooled at room temperature for 7 days to separate the pyroligneous liquor and sludge (Gang *et al.* 2007) This sludge contains a lot of Total Aerosol Residue (TAR). Finally, the wood vinegar was analyzed using Gas Chromatography Mass Spectroscopy (GC-MS Pyrolysis) (Subekti *et al*. 2018).

2.3 Application of wood vinegar to bamboo

After being cut and dried to a constant weight, the bamboo pieces got wood vinegar application with seven types of treatment and each treatment had three replications.

Table 1. Types of wood vinegar applications on bamboo (*Dendrocalamus asper* Backer)

Treatment code	Bamboo		Soil	
	Dipped in wood vinegar	Soaking in wood vinegar	No wood vinegar	Added wood vinegar
K1-K3	-	-	√	-
A1-A3	√	-	√	-
B1-B3	-	√ (1 day)	-	-
C1-C3	-	√ (1 day)	-	-
D1-D3	-	√ (1 day)	-	-
E1-E3	-	√ (1 day)	-	√
F1-F3	-	√ (1 day)	-	√
G1-G3	-	√ (1 day)	-	√

After the bamboo pieces have received different wood vinegar treatments, starting from treatment A to G, the bamboo pieces are stuck into the ground. The control treatment was compared to bamboo which is a pillar in the curing barns of PTPN X. Observations include the appearance of subteraranean termites on bamboo and the level of bamboo brittleness. Observations were carried out every month for 18 months (February 2022 to July 2023).

3. RESULTS AND DISCUSSION

The application of wood vinegar derived from tobacco stalks to bamboo (*Dendrocalamus asper* Backer) aims to mitigate subterranean termite infestations. This choice is motivated by the dual benefits of utilizing tobacco waste and harnessing the insecticidal properties of nicotine, which has a historical precedent as an insecticide since its recommendation for aphid control in 1763 (Hadikusumo, 2007). Nicotine operates by disrupting the central nervous system of insects, leading to paralysis and eventual death at elevated concentrations. However, while the efficacy of wood vinegar as a natural pesticide is acknowledged, a comparative analysis with existing commercial treatments could elucidate its relative effectiveness and broaden the understanding of its application in pest management.

Figure 1. Bamboo has been applied by wood vinegar

Insect that attack bamboo are caused by the starch contained in the bamboo fiber tissue. At the age of one and two years, the starch content of bamboo is high, then at older ages the content is lower (Nafed. 2011). Petung bamboo (*Dendrocalamus Asper* Backer) has an alpha cellulose content of 44.94% (Loiwatu & Manuhuwa. 2008).

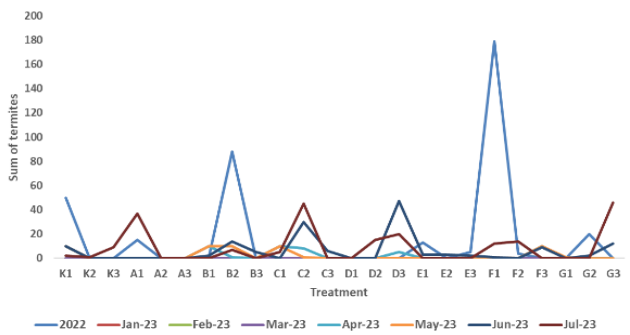

Figure 2. Sum of termites on each treatment

Regarding to its resistance to termite attacks, Petung Bamboo (*Dendrocalamus asper* Backer) is classified as bamboo category IV (non-resistant), which is the number of termites that lived was around 73-84 after four weeks of testing (Jasni & Pari. 2017). Based on the results of observations for 18 months, from seven types of treatments and compared with the control, the number of termites was obtained as shown in Figure 2. Figure 2 describes quantity of termites in each bamboo sample of seven treatments. Sample A2, A3, and D1 are free from termites attacks (zero subterranean termites). In other side, sample B2 and F1 got attack from 120 and 193 subterranean termites respectively. bamboo sample of seven treatments. Sample A2, A3, and D1 are free from termites attacks (zero subterranean termites). In other side, sample B2 and F1 got attack from 120 and 193 subterranean termites respectively.

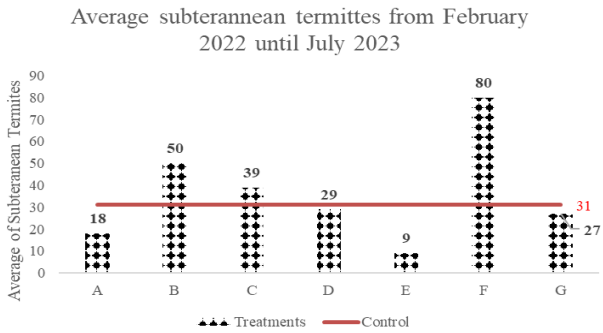

Figure 3. The average termite lives for 18 months

Figure 3 explains that the control bamboo on average only had 31 termite attacks after 18 months of observation. Bamboo received 50, 39 and 80 termite attacks respectively in treatments B, C, F or higher than control bamboo (31). Then in treatments A, D, E, G, termite attacks on bamboo were lower than control, specifically 18, 29, 9, and 27 termites respectively. It proves that the application of wood vinegar made from tobacco stalks is effective in inhibiting subterranean termite attacks on bamboo because within 18 months it can reduce the termite population to below 50%.

Tabel 2. ANOVA Test of Various Wood Vinegar Application on Bamboo

Source	DF	Sum of squares	Mean squares	F	F table	
					0.05	0.01
Treatment	6	36,710.67	6118.4	2.34	2.85	4.46
Error	14	36,614.7	2615.3			
Corrected Total	20	73,325.3				

Table 2 shows that the results of ANOVA test at the 5% and 1% significance levels described that seven types of wood vinegar application treatments on bamboo gave no significantly different results against subterranean termite attacks.

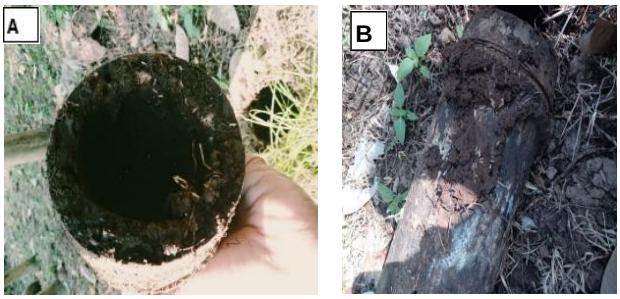

Figure 4. Visual bamboo after treatment

Bamboo's low cellulose content contributes significantly to its resistance against subterranean termite attacks. Research indicates that bamboo experiences an approximate weight loss of 21.14% after four weeks of exposure to these pests (Jasni & Pari, 2017). However, the natural resistance of bamboo varies among species, with some exhibiting greater resilience to different destructive organisms, including fungi and insects (Kaur et al., 2015; Mayasari et al., 2015). Termites, particularly subterranean species, are known to be major biological agents that compromise the structural integrity of bamboo, leading to substantial damage. For instance, studies have shown that subterranean termites can cause significant damage to bamboo structures, although specific figures may vary across studies. Despite the existing knowledge about bamboo's resistance, there remains a notable gap in the literature regarding the comparative effectiveness of bamboo against subterranean termites relative to other materials and treatments. Hapukotuwa & Grace (2011) found that certain bamboo species exhibit varying levels of resistance to termite attacks, suggesting that specific phenolic compounds may enhance this resistance. Additionally, the exploration of alternative pest control methods, such as the use of natural insecticides derived from plant materials, has gained traction in recent years (Ahmed et al., 2015). These studies highlight the need for further investigation into the efficacy of bamboo vinegar and other natural treatments as viable alternatives to conventional chemical pesticides in termite management. Moreover, the integration of wood vinegar as a treatment for bamboo could potentially enhance its resistance to termite damage, as indicated by recent findings on the termiticidal activity of bamboo vinegar (Arsyad et al., 2020). This underscores the importance of conducting comparative studies that evaluate the effectiveness of wood vinegar against commercial treatments and other natural pest control methods. Such research could provide valuable insights into sustainable pest management strategies that leverage the natural properties of bamboo while addressing the challenges posed by subterranean termites.

The lowest level of visual brittleness of bamboo is shown by bamboo that has been applied with wood vinegar with treatment E, namely the bamboo is soaked in wood vinegar for a day and then before the bamboo is plugged in, the soil is doused with one liter of wood vinegar (Figure 4A). Meanwhile, the highest level of visual brittleness of bamboo was shown by bamboo that was applied with wood vinegar with F treatment, namely the bamboo was soaked in wood vinegar for five days then before the bamboo was plugged in, the soil was doused with one liter of wood vinegar (Figure 4B).

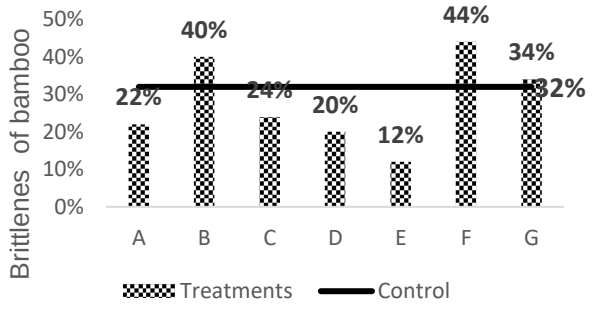

Figure 6. Bamboo brittleness level after wood vinegar application with seven treatments

From Figure 6 is known that bamboo with treatments B, F, and G has a level of brittleness above the brittleness of control bamboo, namely 40%, 44%, and 34% respectively. Meanwhile, bamboo with treatments A, C, D, and E has a brittleness level below 32%, namely 22%, 24%, 20%, and 12% respectively.

Table 3. ANOVA application of wood vinegar to bamboo to bamboo brittleness

Source	DF	Sum of squares	Mean squares	F	F table	
					0.05	0.01
Treatment	6	21.90	3.65	19.31	2.85	4.46
Error	14	2.65	0.19			
Corrected Total	20	24.55				

The results of Anova at the 5% and 1% significance levels showed that seven types of wood vinegar application treatments on bamboo gave significantly different results on bamboo brittleness. (Table 3).

Because Anova showed significantly different results, a follow-up test was carried out, namely the Least Significant Difference Test. It is known that the t table value is: 2.145 and the smallest real difference value is 0.76. Table 4 explains that treatments A to G made no difference to the level of bamboo brittleness.

Table 4. Least Significant Different Test

Treatment	Average of treatment	Code
A	0.7	a
B	1.4	a
C	1.1	a
D	0.9	a
E	1.1	a
F	1.1	a
G	1.0	a

4. CONCLUSIONS

Wood vinegar made from tobacco stems proves effective in suppressing subterranean termite attacks on bamboo, with treatment E showing the most promising results compared to treatments A, B, C, D, F, and G. Treatment E not only reduced termite survival rates but also minimized bamboo brittleness, highlighting its superior efficacy. This may be attributed to specific factors such as the application method and concentration used, which should be further explored in future studies. Investigating the effects of varying wood vinegar concentrations or comparing its effectiveness with other treatments could provide additional insights. Furthermore, implementing treatment E on bamboo used as structural pillars in PTPN X curing barns could extend their durability, offering both practical and economic benefits. These findings underscore the potential of wood vinegar as a sustainable solution for termite control in bamboo structures

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APPENDICES

Table 1. Visual of bamboo

MONTH / CODE	Year 2022											Year 2023						
	Feb-22	Mar-22	Apr-22	Mei-22	Jun-22	Jul-22	Agu-22	Sep-22	Okt-22	Nov-22	Des-22	Jan-23	Feb-23	Mar-23	Apr-23	Mei-23	Jun-23	Jul-23
K1	A	A	A	A	A	A	A	A	B	B	A	A	A	A	B	B	C	C
K2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
K3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
A1	A	A	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A
A2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
A3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
B1	A	A	A	A	A	A	A	A	B	A	A	A	A	A	B	B	B	B
B2	A	A	A	A	A	A	A	A	B	B	A	B	B	B	C	C	C	C
B3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C
C1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	A	A
C2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	B	B
C3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C
D1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
D2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C
D3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C
E1	A	A	A	A	A	A	A	A	A	A	B	A	A	B	A	A	C	C
E2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	C
E3	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C
F1	A	A	A	A	A	A	A	A	A	A	B	C	C	C	C	C	C	C
F2	A	A	A	A	A	A	A	A	A	A	B	B	A	A	A	A	A	A
F3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	C	C
G1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	A	A
G2	A	A	A	A	A	B	A	A	A	A	A	A	A	A	A	A	C	C
G3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C

Code:

A = No Subterranean termites

B = There are subterranean termites but bamboo still good (whole)

C = There are subterranean termites and bamboo getting damage (brittle nor break)

Table 2. Sum of Subterranean termites

MONTH / CODE	Year 2022											Year 2023							SUM
	Feb-22	Mar-22	Apr-22	Mei-22	Jun-22	Jul-22	Aug-22	Sep-22	Okt-22	Nov-22	Des-22	Jan-23	Feb-23	Mar-23	Apr-23	Mei-23	Jun-23	Jul-23	
K1	0	0	0	0	0	0	0	0	35	15	0	0	0	0	10	10	10	2	82
K2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
K3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	9
A1	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	37	52
A2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	10	10	2	0	23
B2	0	0	0	0	0	0	0	0	17	21	0	13	20	17	1	10	14	7	120
B3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	5
C1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	5	25
C2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	1	30	45	84
C3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	6
D1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	15
D3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	47	20	72
E1	0	0	0	0	0	0	0	0	0	0	6	0	0	7	0	0	3	0	16
E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3
E3	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	7
F1	0	0	0	0	0	0	0	0	0	0	54	51	42	32	0	1	1	12	193
F2	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	14	18
F3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	9	0	29
G1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
G2	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	2	0	22
G3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	46	58