IMPACT OF REDUCING AND INCREASING SHADE DISTANCE ON THE NATURAL DURABILITY AND MICROFIBRIL ANGLES OF RED MERANTI WOOD

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INTRODUCTION

Red Meranti (Shorea leprosula Miq.), a significant species in the Dipterocarpaceae family, is widely distributed across Kalimantan and Sumatra in Indonesia. Its broad distribution and resilience make it a prime candidate for plantation forestry, with the potential to enhance both ecological sustainability and economic profitability in these areas (Effendi and Kurniawan, 2003). A notable characteristic of Red Meranti is its adaptability to a wide range of soil conditions, which promotes robust growth and makes it suitable for varied planting environments (Hendromono and Hajib, 2001).

For the effective establishment and growth of Red Meranti plantations, a thorough understanding of silvicultural techniques is essential. Research indicates that optimized planting density significantly influences stem diameter growth in Red Meranti. Specifically, investigations by Mawazi and Suhaendi (2012) demonstrate that appropriate spacing not only supports healthy tree development but also maximizes overall timber yield.

Beyond spacing considerations, silvicultural interventions such as thinning and shade management are critical for enhancing growth dynamics and wood quality. Thinning practices allow for the strategic removal of surplus trees, mitigating intra-specific competition for resources and promoting enhanced growth in the residual stand. Concurrently, shade management can create optimal light conditions, further facilitating vigorous growth and, ultimately, superior wood quality (Sukowati, 2013).

The relationship between silvicultural interventions and wood growth underscores the significance of these practices in forest management. Empirical studies have shown that modifying stand conditions through targeted silvicultural treatments can substantially affect stem diameter growth and induce notable alterations in wood properties. This manipulation is pivotal not only for increasing wood volume but also for improving its quality, underscoring the integral role of strategic silvicultural planning in ensuring the sustainability and productivity of Red Meranti plantations (Uner et al., 2009).

Reduced and expanded shading clearance in forest stands negatively affects the physical, mechanical, and extractive properties of red meranti wood (Sukowati 2013). Wood's mechanical characteristics are influenced by intrinsic factors, particularly cell wall thickness, the proportions of latewood and earlywood, the distribution of sapwood versus heartwood, the microfibril angle (MFA), and the cellular composition of the wood. Additionally, woods with a higher proportion of mature wood components, characterized by thicker-walled cells, demonstrate superior strength. The mechanical and physical properties of wood also depend on the chemical composition of the cell wall. For instance, increased lignin content contributes to greater stiffness and bending resistance, while elevated levels of extractive compounds correlate with improved durability and dimensional stability (Barnett and Jeronimidis 2003).

Microfibrils are the fundamental building blocks of the cell wall, comprising ensembles of cellulose molecules (protofibrils) encapsulated by hemicellulose layers (Barnett and Bonham 2004). The microfibril angle (MFA) is the orientation of cellulose microfibrils within the secondary wall relative to the long axis of fibers or tracheids (Barnett and Bonham 2004; Stuart and Evans 1994). MFA is a critical microscopic feature influencing wood quality, and its variation is markedly greater in Angiosperms than in Gymnospermae (Barnett and Bonham 2004). Specifically, the microfibril angle within the S2 layer of the secondary wall is pivotal in determining the mechanical properties of wood (Cowdrey and Preston 1966). Techniques for assessing MFA include iodine crystal alignment measurements, cell wall examination, inner node angle analysis, confocal microscopy, and X-ray diffraction (Barnett and Jeronimidis 2003).

Taylor et al. (2003) emphasized that the concentration of extractive substances can significantly affect the natural durability of wood. This durability is contingent upon both the type and concentration of extractive compounds, which can vary in toxicity to insect pests. Generally, a higher concentration of wood extractives correlates with enhanced wood durability (Wistara et al. 2002). The concentration of extractive substances varies by wood species, tree age, and anatomical position within the trunk, leading to differences in inherent durability among wood types. Yet knowledge of the impact of silvicultural practices on MFA and natural preservation remains limited, particularly regarding fire resistance.

This study aims to assess the natural durability and microfibril angle (MFA) of red meranti wood subjected to thinning treatments and increased final shade clearance.

METHODS

The natural preservation testing sample consists of pieces of patio wood collected from each specimen tree selected for examination. To assess the natural durability of these wood samples, a combination of laboratory and field testing methods is employed. The laboratory testing adheres to the SNI 01-7207-2006 standard, which outlines procedures for evaluating various properties of wood. In contrast, field testing follows the ASTM D1756:2008 standard, ensuring that the findings reflect real-world conditions.

To investigate the microfibril angles (MFAs) in the wood samples, X-ray diffraction (XRD) is used. Specific wood samples, measuring 12 mm in width, 15 mm in length, and between 0.5 mm and 1 mm in thickness, are carefully extracted from the tangential plane of a wooden slab that is 5 cm thick. It is noted that there is no significant difference in MFA values between samples taken in the radial and tangential directions, as previously reported by Stuart and Evans in 1994.

In this study, X-rays are generated from copper (Cu), with a wavelength $\lambda = 1.54060$ Å. The XRD equipment operates under a voltage of 40 kV and a current of 30 mA. Notably, an auto slit feature is not employed during the scanning process. The dimensions of the spread and the receiver gap are set to 1 mm and 0.3 mm, respectively. Continuous scanning is conducted using a Beta (Theta/2 Theta) guide axis, with the scanning region defined between 10° and 40°.

The measurement scanning is conducted at a consistent speed of 2° per minute, enabling thorough data collection. The resulting data is processed without applying curve smoothing to preserve the integrity of the original readings, and the software used for the analysis automatically identifies the curve peaks.

Measurements are taken in two distinct orientations: vertical (transmission) and horizontal (reflection), providing a comprehensive understanding of the wood's microstructure. The determination of microfibril angles follows the established procedure outlined by Stuart and Evans in 1994. To calculate the angle of the microfibrils, the Cave formula is used, expressed as MFA = 0.6T, where T represents the thickness of the wood sample (Meylan, 1976, as cited in Stuart and Evans, 1994). This method allows for a precise evaluation of the wood's structural characteristics, which is crucial in assessing its natural durability.

Where $T = 2\sigma$

$$= 2\left(\frac{F}{2\sqrt{2\ln(2)}}\right)$$

RESULTS AND DISCUSSION

Natural Durability of Meranti Wood: Laboratory Testing

The assessment of natural wood durability against soil termite infestation analyzed two main metrics: the percentage of weight loss in the wood samples and the mortality rate of the termites exposed to the wood. After a four-week feeding period, we conducted a thorough evaluation of the wood samples and determined the average weight loss across the samples tested. The detailed results of this investigation, including the observed variations in weight loss among different wood types, are visually represented in Figure 1. This figure clearly illustrates the extent to which each wood type was affected by termite feeding over the specified period.

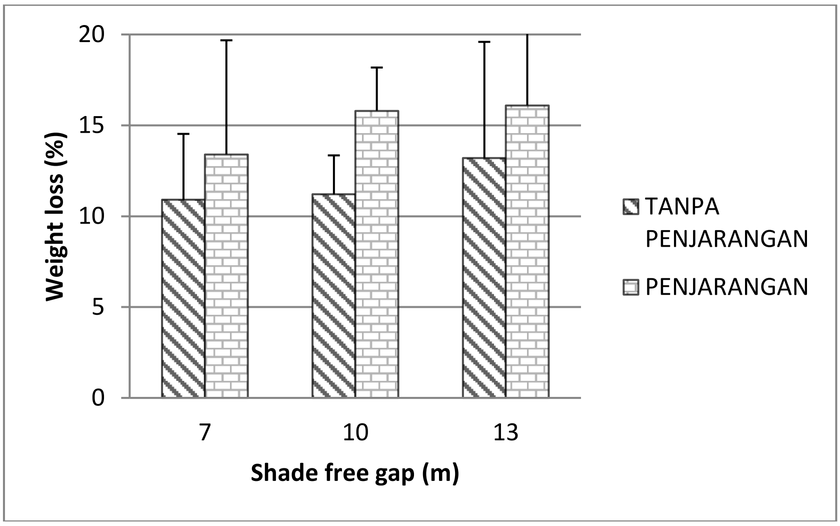

Figure 1: Percentage of weight loss in termite testing

The findings on the average percentage of weight loss indicate that red meranti wood falls within the durable class III-IV, as specified by SNI 01-7207-2006. This designation suggests that red meranti is somewhat susceptible to attacks by wood-destroying organisms, which can compromise its structural integrity over time.

Research by Sukowati (2013) provides further insight into how environmental factors affect the characteristics of red meranti wood, revealing that both thinning practices and shading clearance can reduce the wood's specific weight. This is significant because wood with a lower specific density tends to be more susceptible to termite degradation. Lempang and Asdar’s 2007 study supports this assertion, emphasizing that termites prefer wood with low specific density during feeding.

Additionally, wood hardness plays a crucial role in a termite's ability to digest it. According to Arif (1998), termites initiate cellulose digestion in wood through a mechanical process. This involves biting and grinding the wood into smaller, more manageable particles—a necessary step before subsequent enzymatic digestion can take place.

In this study, beyond analyzing the average percentage of weight loss in red meranti wood, we also evaluated the percentage of termite mortality. This was determined by counting the termites that died during the specified testing period for the wood samples. For a visual representation of the findings, the percentage of termite mortality is shown in Figure 2. This comprehensive analysis not only underscores the durability and susceptibility of red meranti wood but also highlights the complex interactions between wood properties and termite behavior.

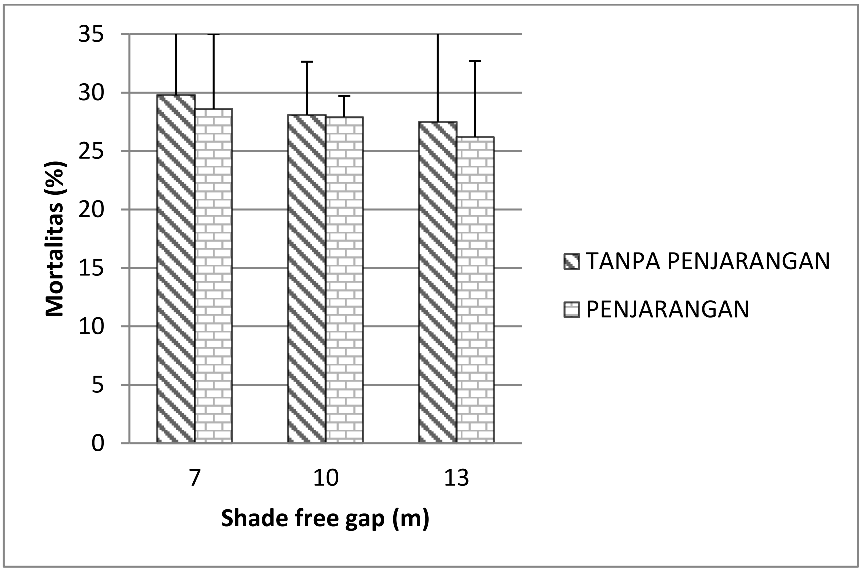

Figure 2: Percentage of soil termite mortality after the feeding period.

Figure 2 shows a significant trend indicating that termite mortality rates decrease in response to thinning and shading-clearance treatments. This reduction in mortality is inversely correlated with the percentage weight loss in the wood samples. Specifically, as termite mortality declines, the weight loss in the wood samples tends to increase, highlighting a direct relationship between these variables.

The reduced durability classification of red meranti wood enhances its susceptibility to termite infestation, which subsequently leads to lower mortality rates during feeding. This species, characterized by its inherent vulnerability, is favored by termites, which may account for continued feeding activity despite reduced mortality. Additionally, the low concentration of extractive compounds in red meranti, as documented in earlier studies by Risnasari and Ruhendi (2006), likely influences these outcomes. The diminished extractive content weakens the wood's natural deterrent properties, further contributing to the observed decrease in mortality rates among termites that consume this wood type.

Natural Durability of Meranti Wood: Field Testing

The findings from our field testing, particularly the graveyard test, concentrate on the percentage of weight loss observed in red meranti wood specimens. This metric, which indicates the degree of mass reduction during the experimental phase, is shown in Figure 3. The data elucidate the influence of environmental variables and temporal factors on the mass alteration of the wood, offering critical insights into its durability and performance characteristics.

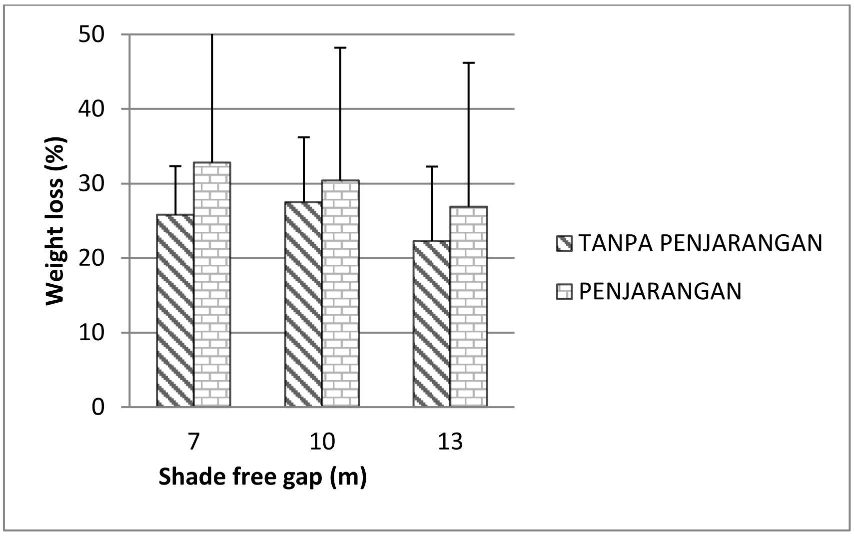

Figure 3: Percentage of severe hypocrisy in the grave test

According to the natural hardiness classification for wood outlined in ASTM D1756-2008, the degree of damage observed in meranti wood in this study has been quantified as 7. This classification places meranti in natural hardiness class III, indicating it is subject to moderate levels of attack and penetration by biological agents.

It is important to note that the percentage of weight loss observed in field tests differs from that recorded in laboratory tests. Despite these disparities, both testing methods are valuable tools for assessing whether a particular wood species requires preservation for its intended applications.

Furthermore, the findings of this study emphasize the necessity of considering the specific wood durability class, the organisms that may pose a threat to the wood, and the methodologies employed in testing. This perspective aligns with the insights provided by Sumarni and Muslich (2008), who assert that the classification of wood durability is influenced not only by the type of attacking organism but also significantly by the methods used in testing. This highlights the complexity of wood preservation decisions and the importance of a comprehensive evaluation approach.

Microfibril Angle

Microfibril angle measurement can be conducted using X-ray diffraction, a precise technique for analyzing the orientation and arrangement of microfibrils within a material. This method relies on X-ray scattering, in which X-rays are directed at a sample and the resulting diffraction patterns are analyzed to determine the angle of the cellulose microfibrils. By interpreting the intensity and distribution of these patterns, researchers can gain insights into the material's structural properties, such as its mechanical strength and stability. This technique is particularly valuable in fields like materials science and biology, where understanding the microstructure is crucial for applications ranging from bioengineering to the development of sustainable materials.

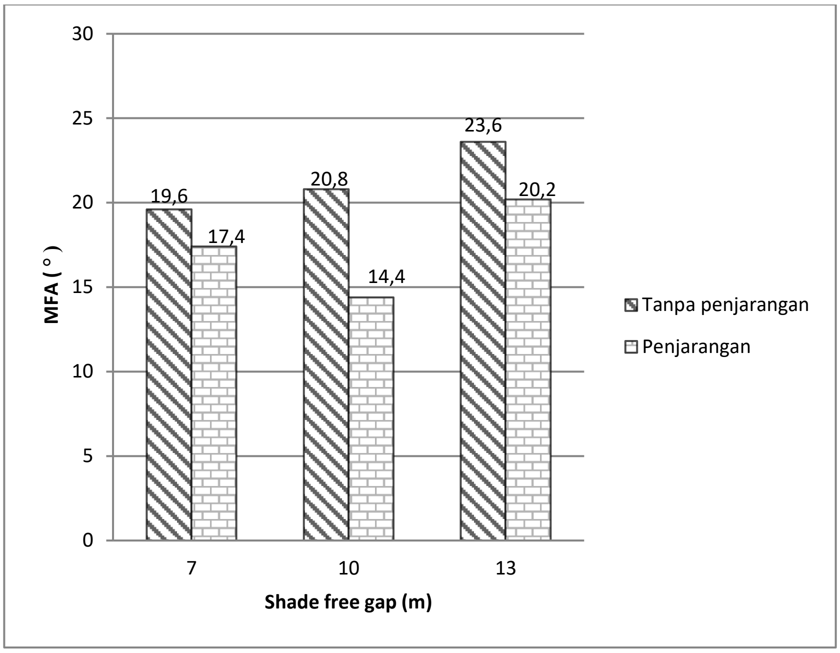

Figure 4 Microfibril Angle Values

Figure 4 shows a clear correlation between increased shading clearance and increased microfibril angle (MFA) in wood. This observation aligns with Lundgren's (2004) findings, which indicate that silvicultural interventions tend to elevate the MFA, thereby significantly influencing the overall properties of wood.

In their research, Basri and Wahyudi (2013) noted that MFA tends to rise concurrently with reductions in fiber length and wall thickness. These observations are supported by Sukowati's (2013) study, which confirmed that silvicultural practices not only increase the MFA but also reduce both fiber length and wall thickness. The configuration of microfibrils is critical in determining various physical and mechanical properties of wood, such as density, tensile strength, stiffness, and shrinkage tendencies.

Sukowati (2013) also pointed out that targeted silvicultural practices, including thinning and modification of shading clearance, can enhance properties associated with longitudinal shrinkage. However, these treatments can adversely affect certain mechanical properties, including the Modulus of Elasticity (MOE), Modulus of Rupture (MOR), parallel compressive strength, splitting strength, and overall wood hardness.

As indicated by Stuart and Evans (1994), even small variations in the angular orientation of microfibrils can result in substantial changes in fiber properties. This is further supported by Deresse et al. (2003), who found that larger microfibril angles correspond with decreased MOE values, highlighting the complex interplay between wood structure and its mechanical performance.

CONCLUSION

Red meranti wood falls into durability classes III to IV, indicating a moderate level of durability. Notably, this classification remains stable and is not significantly affected by thinning processes or the expansion of shading clearance in its growth environment. Additionally, research indicates that as shading clearance in a stand increases, the Microfibril Angle (MFA) value also increases. This suggests that the availability of light and space can enhance certain structural properties of the wood, potentially impacting its performance and utility.

REFERENCES

Arif A. 1998. *Ketahanan kayu asetilasi dan kayu furfurilasi terhadap biodeteriorasi*. [tesis]. Program Pascasarjana IPB. Bogor.

Barnett JR, Bonham VA. 2004. Cellulose microfibril angle in the cell wall of wood fibers. *Biol Rev*. 79: 461-472.

_________, Jeronimidis G. 2003. *Wood quality and its biological basis*. Blackwell Publishing (Australia) dan CRC Press (Canada). Hlm 8-9.

Basri E, Wahyudi. 2013. Sifat dasar kayu jati plus Perhutani dari berbagai umur dan kaitannya dengan sifat dan kualitas pengeringan. *Jurnal Penelitian Hasil Hutan.* 3(2): 93–102.

Cowdrey D, Preston R. 1966. Elasticity and microfibrillar angle in Sitka spruce wood. *Poc.R.Soc.Lond*.B. 166:245-272.

Deresse T, Robert K, Stephen M. 2003. Microfibril angle variation in red pine (Pinus resinosa Ait.) and its relation to the strength and stiffness of early juvenile wood. *Forest Prod J.* 53(7/8): 34–40.

Effendi R, Kurniawan A. 2003. Pertumbuhan *Shorea leprosula* Miq. (meranti merah) di berbagai tempat. *Jurnal Dipterokarpa* 7(1).

Hendromono, Hajib N. 2001. Prospek pembangunan hutan dan pemanfaatan kayu jenis khaya, mahoni, dan meranti. *Prosiding Ekspose Hasil-hasil Penelitian: Pengembangan Jenis Tanaman Potensial (Khaya, Mahoni, dan Meranti) untuk Pembangunan Hutan Tanaman*, pp. 29-40. Bogor: Pusat Penelitian dan Pengembangan Hutan dan Konservasi Alam.

Lempang M, Asdar M. 2007. Ketahanan alami kayu jati (*Tectona grandis* l.f.) Asal Sulawesi tenggara terhadap rayap tanah. *Jurnal Penelitian Hasil Hutan.* 25(4): 1–11.

Mawazi, Suhaendi H. 2013. Pengaruh jarak tanam terhadap diameter *Shorea leprosula* Miq. Umur lima tahun. *Jurnal Penelitian Hasil Hutan dan Konservasi Alam.* 9(2):189–197.

Risnasari I, Ruhendi S. 2006. Sifat dasar perekat likuid kayu dari beberapa jenis kayu (characteristics *of wood liquid adhesives from several wood species*). *Peronema Forestry Science Journal* 2(2): 66-70.

Stuart SA, Evans R. 1994. *X-ray diffraction estimation of the microfibril angle variation in eucalypt increment cores*. Research Report. The CRC for Hardwood Fibre & Paper Science.

Sukowati Munawar. 2013. *Pengaruh Penjarangan dan Pelebaran Jarak naungan Terhadap sifat Dasar Kayu Meranti Merah*. [skripsi]. Bogor: Institut Pertanian Bogor.

Sumarni G, Muslich M. 2008. Kelas awet jati cepat tumbuh dan jati konvensional pada berbagai umur pohon. *Jurnal Penelitian Hasil Hutan.* 26(4):342-351.

Taylor AM, Barbara, Gartner, Morrel JJ. 2003. Co-incident variations in growth rate and heartwood extractive concentration in douglas-fir. *J. Forest Ecol. Manag.* 186: 58–63.

Uner B,Oyar O, Var AA, Altnta OL. 2009. Effect of thinning on the destiny of Pinus nigra trees using X-ray computed tomography. *J. Environ. Biol.* 30(3): 359-362.

Wistara IN, Rachmansyah R, Denes F, Young RA. 2002. Ketahanan 10 Jenis Kayu Tropis Plasma CF4 Terhadap Rayap Kayu Kering (*Cryptotermes cynocephalus* Light). *Jurnal Teknologi Hasil Hutan* 15(2): 48–56.