Radial Variation in Fiber Length and Nanostructure of Clone Teak in Different Spacing

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ABSTRACT

Many research on variation of properties within the tree has been done focusing on the wood quality of teak (Tectona grandis L.f.) especially at various age level and different locations. There has been very little attention paid to plant spacing, but plant spacing is very important because that’s influences form stem and final product. This research was aimed to analyze different plant spacing of two different setting (3 m by 3 m and 2 m by 6 m) from clone teak Cepu. Fiber length and nanostructure including of Microfibril Angle (MFA), the dimension of cellulose crystallite (length and thickness) were determined to assess the wood quality of teak from two different spacing. The result shows that fiber length increase from pith to bark, while MFA, the length and the thickness of crystallite cellulose decrease from pith to bark and the thickness of crystallite cellulose tend to be constant. Based on all parameter studied, teak tree spacing of 2 m by 6 m is better than that of 3 m by 3 m, although plantation clone teak were originated from the same location.

Keywords: fiber length, nanostructure, clone teak, spacing

INTRODUCTION

Recently, the production of teak wood has been decreased and fail to meet market demands. Improvement in silviculture treatment shortened teak rotation turning it into fast growing species with the wood quality similar to its origin. Most of research wood quality of teak were focused on determining physical properties (density and specific gravity), wood structure (dimension of fiber and MFA) and mechanical properties (Modulus of Elasticity and Modulus Of Rupture) (Lei et al, 1997; Butterfield, 2003). Variation in terms of wood qualities was widely observed. Variability in properties of wood among trees of the same species, part and location being compared.

According to (Booker and Shell (1998)), wood structure can be identified in term of, macroscopic, microscopic, nanostructure and molecular structure. Nanostructure includes MFA and the dimension of cellulose crystallites, they are visible by X-ray diffraction (indirect methods).

MFA and the cellulose crystallite are the most important factors contributing to the mechanical properties of wood. MFA also influences physical properties and chemistry properties such as density, tensile strength, stiffness, swelling and shrinkage (Stuart & Robert, 1994; Butterfield, 2003; Peura et al. 2008). However, understanding the causes of the variation patterns of wood quality at the nano scale is still lacking.

Tree spacing in plantation is important in controlling rate of tree growth. Cloned teak trees show large variations in their diameter and height in plantation setting, even when trees with identificial cloned code are planted, in same location and, spacing. The question is how this phenomena affect the cloned trees, wood quality, especially their nanostructure. There is little wood quality information available on the relation between these growth rate and nanostructure.

This research aims to analyze variabilities wood quality such as fiber length and nanostructure (MFA and the dimension of cellulose crystallites) from two

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different type of tree spacing (3 m by 3 m and 2 m by 6 m) in one origin of clones, i.e clone Cepu.

MATERIALS AND METHODS

Sample preparation

Two sample trees from cloned teak Cepu were taken from a 7-years-old clonal trials in the research site of Watu Sipat Forests in Yogyakarta. The clonal trials were cultivated from two different plant spacings (3 m x 3 m and 2 m x 6 m). Each sampel tree was sawn 5 cm in length at height 1.3 m from ground level.

After marking pith and bark, the disks were cut per growth rings until near the bark. From these disks, samples for fiber length measurement were cut like matches. Samples for MFA and the dimension of cellulose crystallites measurement with X-ray Diffractometer were cut 1 cm (L) x 5 mm (W) x 0.5 mm (T).

Fiber length measurement

Samples for fiber length was treated with Schulze solution and NaOH (aq) and then made maceration. The fiber length was measured automatically using a Fiber Analyzer (Metzo, FiberLab).

X-ray Diffractometer measurement

An X-ray Diffractometer was used to measure MFA, the length of the cellulose crystallites and the thickness of cellulose crystallites within each growth rings. The radiation source was molybdenum ($\lambda = 0.071$ nm), with 40 kV and 30 mA, the diffraction angle (2θ) measured from 10 until 40 with a step $2^\circ$.

MFA was then determined according formula from Stuart & Evans (1994). The formula is $MFA = 0.6 \ T$. Where $T$ is the Half Width Height Maximum (FWHM) from tangents zero intensity line and diffraction arcs at inflection point. The dimension of cellulose crystallites were then determined according Scherrer formula (Peura et al. 2008):

\[ D_{hkl} = \frac{K \lambda}{\beta \cos (\theta_{hkl})} \]

Where:

\( \lambda \) = wavelength molybdenum (0.071 nm)
\( \beta \) = FWHM in radians
\( \theta_{hkl} \) = half from scattering angle 2\( \theta_{hkl} \)
K = 0.9 for reflex 200, K = 1.0 for reflex 004.

RESULTS AND DISCUSSION

Variation from Pith to Bark of Fiber Length and MFA

Figure 1 presents the variation of fiber length and MFA from pith to near the bark per growth rings at spacing 3 m by 3 m and 2 m by 6 m. The mean of fiber length was 0.700 mm±0.182 at spacing 3 m by 3 m and 0.835±0.093 mm at spacing 2 m by 6 m. The mean of MFA was 28.7°±4.84 at spacing 3 m by 3 m and 24.3°±4.41 at spacing 2 m by 6 m.

Figure 1. Variation of fiber length and MFA from pith to bark in each growth rings. A: spacing plantation 3 m x 3 m, B: spacing plantation 2 m x 6 m.

The fiber length of the cloned teak wood tended to increase from pith to near the bark at both spacing plantation or with increasing growth ring number (Figure 1). Lei et al. (1997) reported that fiber length increased from pith to bark in *Alnus rubra* Bong.

The mean MFA decreased from pith to near the bark in two spacing plantation or MFA values conversely decreased with the increasing growth-ring number (Figure 1), implying that the MFA is inversely related to wood-fiber length. Many researcher reported (Andersson 2006; Krisdianto 2008; Yin et al. 2011), the mean value MFA reduced from pith to near the bark.

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The effect of spacing on fiber length and MFA are different growth rate, this common type of variation in radial is particularly evident for those axial element which undergo post cambial elongation.

The shortest fiber length and the greater MFA are found in near the pith until the sixth growth rings not constant. The phenomena indicates that the teak is juvenile wood. Gaspar et al. (2008) noted that the way to minimize some of the negative effects of short rotation on wood quality is by breeding to improve juvenile wood. Juvenile wood is usually characterized by a shorter fiber and cell walls thinner than in mature wood, lower specific gravity and severe spiral grain (Panshin & de Zeeuw, 1998).

**Variation from Pith to Bark of The Length and the Thickness of Cellulose Crystallites**

Figure 2 presents the variation of the length and thickness of cellulose crystallites from pith to bark per growth rings at spacing 3 m by 3 m and 2 m by 6 m. The mean of the length of cellulose crystallites at the spacing 3 m by 3 m and 2 m x 6 m were 38.8±7.7 nm and 45±5.9 nm, respectively. The mean of the thickness of cellulose crystallites at the spacing 3 m by 3 m and 2 m by 6 m were 21.5±2.4 nm and 24±2.4 nm, respectively.

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Figure 2. Variation from pith to bark of the length and thickness of cellulose crystallites in each growth rings. A: spacing plantation 3 m x 3 m, B: spacing plantation 2 m x 6 m.

The mean length and thickness of cellulose crystallites in two types of spacing in plantation (3 m by 3 m and 2 m by 6 m) in each growth rings increases from pith to near the bark. Variability wood quality from pith to near the bark are influenced by several factors (Panshin & de Zeeuw 1980): ages or changes in the cambium, factor genetic (form trunk, growth tree) and environment (rainfall, temperature, soil and silviculture treatment).

This is corresponding with this study results that variation in micro structure (fiber length and MFA) and nano structure (length as well as thickness of cellulose crystallites) of the cloned teak wood were most likely related to the intensity of physiological plant activities caused by different planting spacing. The characteristic of nanostructure are affected growth rate. The length of the cellulose crystallites longer from the irrigation and fertilization treatment compared to the untreated (Peura et al. 2008). This indicates dimension of cellulose crystallites influenced nutrient and water in cambial as long as the tree growth up. The tree growth of plant spacing of 2 m x 6 m were better than that at the plant spacing of 3 m by 3 m because the wide growing space make secondary growth for addition diameter.

CONCLUSIONS

The fiber length and nanostructure of the cloned teak wood tended to increase from pith to near the bark at both spacing plantation. The fiber length and nanostructure at the spacing of 2 m by 6 m were better than that at the spacing of 3 m by 3 m. This spacing is considered importantly for wood quality cloned teak development.

REFERENCES


Certificate

This is certify that

Audi Detti Yunianti

has participated as

Participant

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