Wood Properties of 5-year-old Fast Grown Teak

Ratih Damayanti, Barbara Ozarska, I Ketut N. Pandit, Fauzi Febrianto, and Gustan Pari

Abstract

Jati Unggul Nusantara (JUN) is one of fast growing plantation teak that has been widely cultivated in Indonesia. This teak has been developed to be harvested after 5 years when its diameter reaches 25-32 cm (diameter at breast high). The diameter of JUN is usually three times larger than the conventional plantation teak (teak cultivated from seed) at the same age, and the same as 30-40 year-old mature teak. Preliminary research was conducted to determine anatomical and selected physical properties of 5-year-old JUN teak, as well as its suitability for furniture production. The results revealed that wood color, texture, and grain pattern of JUN were slightly different from the mature conventional teak. The length of fiber cells was similar as in the mature teak. There were differences in ultramicroscopic structure of JUN: the mean micro fibril angle was narrower, and the crystallites degree was larger. Shrinkage values from green to 12% moisture content were: 0.70 (radial-R) and 1.62 (tangential-T), and from green to oven dry were 1.59 (R) and 3.29 (T). T/R ratio was 2.34. Specific gravity in air dry condition was 0.52. Based on the research results it appears that 5-year-old JUN may be suitable for the production of medium quality furniture products. More research is required to investigate and enhance the properties of JUN for high quality products.

Keywords: Young fast grown teak, anatomical properties, physical properties, super teak, conventional teak wood.

Introduction

Teak (*Tectona grandis* Linn. f) is a popular timber for furniture, construction building, pole boat making and luxurious veneer. Naturally, teak is harvested at approximately 80 years old. Period of rotation in established plantation forests such as in India and Indonesia is 50 to 80 years (Soerianegara and Lemmens 1994). This long rotation in planting causes the price of teak wood to increase significantly due to a limited supply. Iskak (2005) states that the shortage of teak as a raw material is estimated at approximately two million cubic meters per year. Consequently, timber industries that use teak as a raw material face difficulties in its continuous supply (Krisdianto and Sumarni 2006).

This condition motivates the silviculturists to investigate various methods which would allow establishing a shorter rotation and a faster growth teak. One of the methods already developed is through vegetative cultivation, such as tissue culture, bud grafting, and shoot cutting. As a result, the rotation of planting is decreasing from 50-80 years to 20-40 years (Yunianti 2012). These fast grown teaks are becoming a solution to overcome the teak supply scarcity.

In Indonesia, there are many varieties of fast grown teak that have been widely cultivated. Timber communities call this timber “super teak”. One of them is Jati Unggul Nusantara (now Jati Utama Nusantara - JUN). The combination of breeding technology and intensive silviculture treatment encourages the teak timber producers to harvest the tree at a very young age, 5-year-old . At this age, the average stem diameter is 20-30 cm which is the same as 30-40-year-old conventional teak (Ministry of Forestry 2012).

However, there is a common opinion that timbers from fast growing or short rotation have inferior wood properties, mainly in natural durability and timber strength (Irwanto 2006; Kininmonth 1986). A faster growth will produce shorter cells that reduce the wood quality (Brown *et al*. 1994; Panshin *et al.* 1964). No matter how small the changes, it will lead to differences in the macro, micro and ultramicroscopic structures of the wood, which may cause the alterations of material characteristics (Pandit and Kurniawan 2008). This study aimed to determine anatomical and selected physical properties of 5-year-old JUN teak, as well as its suitability for furniture production.

Materials and Methods

Sample Preparation

Four and five year-old JUN were collected in September 2009, located in Balapulang, Central Java Province, Indonesia. While as comparison, 4 and 5-year-old conventional teak were also collected in the same time from Brebes, Central Java Province, Indonesia (at around 10 km from JUN plantation). Wood samples in the disc form measuring 10 cm in thickness were taken from the particular tree heights i. e. bottom, middle and top portions of the corresponding logs for anatomical observation and physical properties investigation. Physical properties as examined were green moisture content, density/specific gravity (SG) and radial as well as tangential shrinkages. Sampling and testing of its physical properties followed the ASTM 2007 D 143-94 Reapproved 2007. Remaining timber was used for furniture manufacturing.

Anatomical Observation

Observation on anatomical structure covered macro, micro and ultra microscopic characters. Macroscopic characteristics involved appearance (including wood discoloration), texture, lustrous, hardness and grain direction. Observation on microscopic structure was prepared by sectioning (Sass 1961) and maceration process (modification of Franklin method in Damayanti *et al.* 2016), covered cells dimension, cells structure (Wheeler *et al*. 1989), and juvenile percentage. The juvenile percentage was determined with the aid of regression curve that related the fiber length to the successive positions of wood segment moving all the way from the pith to the bark in radial direction (Darwis *et al*. 2005) following the growth ring. Furthermore, ultramicroscopic characters assessment covered micro fibril angle, chrystallite degree and sellulose crystallite size using X Ray Diffractometer (Stuart and Evans 1994) from the pith towards bark following the growth ring, taken from the early and late wood portions. Dimension of cellulose crystallite in the cell wall was calculated by *Scherrer Formula* (Andersson 2006):

$$B_{hkl} = \frac{K\,\lambda}{\Delta\, 2\theta \cos\theta'}$$

Distance among cellulose crystallite was estimated by the formula:

$$d = \frac{\lambda}{2\ \sin\theta'}$$

where K is a shape factor, the value is 0.9 to determine sellulose crystallite dimension; λ is wave length of Cu; β (=$\Delta\ 2\theta$) is FWHM value divided by 2 (in radian); and θ' is 2 theta value divided by 2 (in radian).

Quality Assessment as Furniture

Some furnitures from JUN timber were manufactured to evaluate the quality of JUN as raw material for furniture. A set of quantitative criteria as minimum requirements for wood as a raw material for furniture has been established by National Standardization Board (1989). From physical aspect, furniture components need to be produced from timber with minimum strength class III and specific gravity (SG) at least 0.40. Some interviews were also conducted to gain opinion from an experienced technician.

Results and Discussion

Results assesment on wood properties of JUN as furniture material are presented in Table 1. The criteria were determined by Menon and Burgess (1979), PIKA (1979), Pandit *et al*. (2009) and National Standardization Board (1989). Macroscopically, JUN had straight grain direction and sometimes interlocked, the same as 5-year-old conventional teak, while mature teak had majority interlocked grain direction. JUN also had coarse texture, slightly glossy until opaque surface, light color and there was a pattern in wood surface as a result of wood discoloration (secondary heartwood) and multiseriate rays. The latter two characteristics were not observed in conventional teak (Fig. 1). The straight grain direction may ease in furniture processing, and this is a positive aspect because diagonal grain direction usually will reduce wood strength (Pandit *et al.* 2009). The coarse texture in JUN will affect in finishing process such as need more lavish filler or putty, and it may make a problem in sherlak application. Less natural lustrous in JUN requires more effort to increase its luster.

Table 1. Timber properties requirement for furniture and asssement of JUN as furniture material.

Wood Properties	Desired Properties	JUN Properties
Macroscopic structures	Straight grain direction, fine to medium texture, good natural lustrous, good color and appearance	Straight grain direction, coarse texture, slightly glossy until opaque surface, light color and there was a pattern in wood surface due to the presence of wood discoloration and multiseriate rays
Microscopic structures	Medium cell wall thickness, low juvenile wood portion, no crystals , tyloses and silica	Very thin cell wall thickness, 100% juvenile wood portion, no silica, and there was a presence of tyloses
Physical properties	Medium density/specific gravity (SG), high dimensional stability	Shrinkage values from green to 12% moisture content were 0.70 (radial-R) and 1.62 (tangential-T), and from green to oven dry were 1.59 (R) and 3.29 (T). T/R ratio was 2.34. Specific gravity in air dry condition was 0.52. In conclusion, JUN has medium density/SG and rather good dimensional stability

Figure 1. Wood discoloration as a result of secondary heartwood in 5-year-old JUN; compared to 5-year-old conventional teak where the discoloration or secondary heartwood formation was not observed (arrow).

The parts of furniture intended to accept loads, either continuously or intermittently. These loads are evenly distributed including on the connection. Thus, although the strength is important, it is not considered necessary really very strong raw material. Furthermore, wood strenght usually associated with wood density, in consequence, very strong wood means very heavy timber. Furniture made of heavy wood is generally less desirable because it is difficult to move. Besides a complicate removing, heavy timber also causes rapid blunting of the knife. Wood with dry oven density in approximately 0.5 g cm^{-3} has proven to be quite good for furniture (Menon and Burgess 1979).

Air dry density of JUN was 0.52 g cm^{-3} with specific gravity 0.48, and it makes 5-year-old JUN will quite ideal to be used for furniture. Although it is advisable to use a timber with larger specific gravity for products that endure heavy load, 5-year-old JUN can be used to manufacture furniture for home and office, such as desks, cabinets, shelves, including bookcases. So far, the manufactured product is strong enough to support loads.

Wood for furniture should be easy to sawn, planed, polished or drilled (Menon and Burgess 1979). In this study, machining properties were not studied quantitatively. Wood surfaces should be smooth with no tear grain that will result in a hairy surface. Qualitatively, at planing process, JUN was easily planed and produced an even surface. It was possibly due to the straight direction of wood grain and the smaller crystal size. Selulose crystallite dimensions for JUN were 5.9 nm (thickness) and 17.78 nm (length) with distance among crystallite was 0.3913 nm, while, thickness, length and distance of crystallite sellulose for conventional teak were 6.36 nm, 23.88 nm, and 0.3938 nm, respectively. In sawmills process, rough surface of JUN made it rather difficult to sawn. The technician called the wood processing properties of JUN was like *Dryobalanops* wood, and it was possible because there was a similarity in their vessels pattern.

Juvenile portion both in JUN and conventional teak were 100%. This high juvenile wood percentage will decrease its quality as furniture. Characteristics of juvenile wood generally have a low density, high moisture content, and high longitudinal shrinkage; making it is easy to deform. The most feared nature of juvenile wood is disabilities called brittle, especially for structural timber, so its use as component for construction is not recommended (Anisah and Siswamartana 2005). For the furniture industry, wood with a high percentage of juvenile wood would also tend causing a lot of problems during the processing. However, in the same age, JUN has more declivous regression line (Fig. 2). It meant that JUN may reach a wood maturity faster than conventional teak wood, however it needs more study on the older ages. Furthermore, the narrower MFA of JUN enables JUN to overcome the high longitudinal shrinkage in common wood. MFA of JUN was 22.09° while conventional teak was 25.29°. Another study stated that MFA of 7-year-old fast growing teak from Penajam, East Borneo, was 23.29°, decreasing from pith to bark, while MFA of 7-year-old conventional teak was smaller, 22.05°, with the same pattern (Krisdianto 2008). The narrower MFA in JUN was predicted as a result of shoot cutting cultivation technique from mature parent trees and a combination with compound support root (Fig. 3) that enables JUN has narrower MFA without having broken in the early growth.

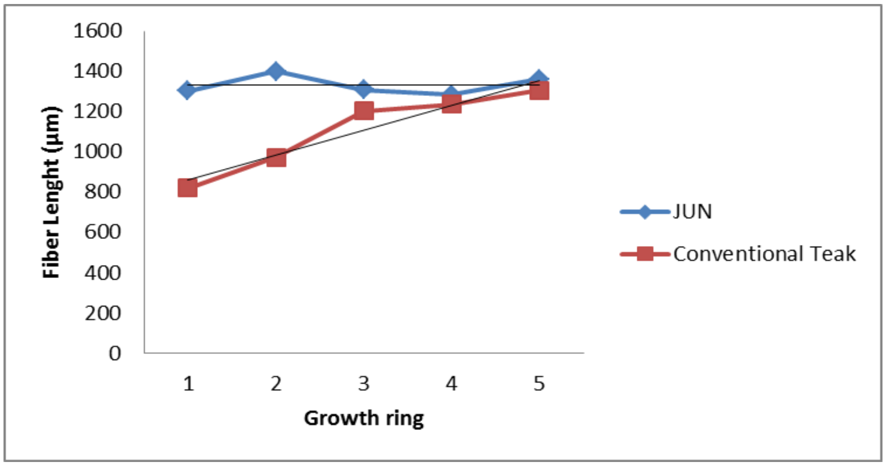

Figure 2. Regression curves of the fiber length from pith towards bark for 5-year-old JUN and conventional teak. It appears the trend is still pointing upwards, yet there is a constant point. It can be seen that the fiber length of JUN started above 1200 µm (similar as in mature teak), and fiber length addition of JUN is more sloping than conventional teak. JUN may reach a wood maturity faster than conventional teak wood.

Figure 3. Compound support root in JUN enables JUN has narrower MFA without having broken in the early growth.

Table 2. Radial (R) and tangential (T) shrinkages of 4- and 5-year-old JUN and conventional teak wood

Type of Teak	From green to 12% moisture content		From green to oven dry		T/R ratio
	R	T	R	T	
JUN	0.70	1.62	1.59	3.29	2.34
Conventional teak	1.88	3.03	2.77	4.43	1.68

Qualitative testing for JUN hardness showed that JUN had low hardness. Positively it may ease the wood processing including the drilling, however negatively its strength on nails holding may rather weak. Weakness in nails holding and easier drilling properties were due to the very thin wall of JUN's cells.

Timber for furniture raw material should not contain to much wood extractive such as resin, and also silica because it will accelerate blade blunting. Since JUN was harvested in very young age, macroscopic observation showed that extractive and silica content was low, and it will ease in processing.

Timber with high shrinkages will not be preferred for any utilisations. Dimensional alterations will cause distorsion in furniture component, hard to pull the drawers, hard to open cupboard's door, and sometimes open wood joints (Menon and Burgess 1979). Average shrinkages values from green to 12% moisture content and from green to oven dry for 4 and 5-year-old JUN and conventional teak wood presented in Table 2. T/R ratio for JUN was 2.34 while conventional teak was 1.68. The conventional teak wood had very good dimensional stability, whereas T/R ratio of JUN that was above 2 but under 2.5 showed that JUN had medium stability. An effort, such as an appropriate drying treatment or quality enhancement treatment such as densification and impreganation (Corryanti and Muharyani 2018) absolutely is needed to increase the wood dimensional stability of 5-year-old JUN.

Particular attention, however, must be applied when the wood furniture will be used in air-conditioned room. Therefore, wood with low shrinkage is ideal for furniture production. Changes in water content of the dried wood can be minimized by using proper coating varnish, paint, or even a plastic sheet. The latter method is the latest development in wood protection techniques. If possible, the board should use radial board because it has a smaller shrinkage (Menon and Burgess 1979), and the radial shrinkage of JUN was very high due to the wider rays, higher crystallite degree, and narrower micro fibril angle (MFA). Crystallite degree and MFA of JUN was 43.89% and 22.09°, respectively, while conventional teak was 40.32% and 25.29°, respectively.

In conclusion, regarding to its properties, 5-year-old JUN may be used as raw material for furniture. Requirements in terms of strength, wood processing, wood density, and dimensional stability were met the minimum limit even though there were weakneses in nails holding strenght and lavis finishing. Teak popularity enables JUN with a lower hardness and lighter wood properties sometimes preferably to use because easier to processed and moved. In terms of appearance, its quality as a luxury product will decrease, especially for furniture that requires wood beauty, as of, JUN more suitable for making light-colored furniture that is preferred by certain consumers. However, there is a possibility that its appearance will appeal if used at an older age.

Conclusions

Efforts to accelerate teak growth in Jati Unggul Nusantara led to changes in the anatomical structure of wood and some properties. Until the age of 5 years, input technologies given can improve the properties of the wood to the ultrastructural level where the mean micro fibril angle was narrower, and the crystallites degree was larger. The properties of JUN will facilitate JUN as raw material for furniture, although there was a decrease in appearance and wood texture.

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Ratih Damayanti
Plant Anatomy Researcher,
Forest Products Research and Development Centre,
Ministry of Environment and Forestry,
Jl. Gunung Batu No. 5, Bogor, Indonesia.
E-mail: ratih_turmuzi@yahoo.com,

Barbara Ozarska
Professor,
Dept. of Forest and Ecosystem Science,
The University of Melbourne,
Burnley Campus, Richmond, Victoria, Australia.
E-mail : bo@unimelb.edu.au

I Ketut N. Pandit
Professor,
Forest Product Dept., Forestry Faculty,
IPB University,
Darmaga Campus, Bogor, Indonesia.

Fauzi Febrianto
Professor,
Forest Product Dept., Forestry Faculty,
IPB University,
Darmaga Campus, Bogor, Indonesia.
E-mail : febrianto76@yahoo.com

Gustan Pari
Forest Products Research and Development Centre,
Ministry of Environment and Forestry,
Jl. Gunung Batu No. 5, Bogor, Indonesia.
E-mail : gustanp@yahoo.com