Anatomical structure and physical properties of the 13 years old solomon-clone teakwood planted in Bogor, Indonesia

N V Riantin¹, I Wahyudi²*, and T Priadi²

¹Forest Products Science and Technology Study Program, IPB University, Bogor 16680, Indonesia
²Forest Products Department, Faculty of Forestry, IPB University, Bogor 16680, Indonesia

*Email: imyudarw16@yahoo.com

Abstract. Anatomical structure, fiber dimension, and several physical properties of the 13 years old solomon-clone teak (Tectona grandis) wood planted in Bogor District, West Java Province, Indonesia have been studied. Macroscopic characteristics were observed directly by handy loupe, while microscopic characteristics were observed through microtome specimens. Fiber morphology was measured through maceration specimens, while physical properties were measured by modification of British Standard 373.1957. Results showed that anatomical structure and fiber length of this solomon-clone teakwood were not significantly different from those of common teakwood. The wood consists of 53% fiber, 29% vessel, 10% axial parenchyma, and 8% ray parenchyma; with 905.44-1199.36 μm fiber length and 2.50-6.72 μm cell wall thickness. Average of wood density and specific gravity was 1.04 g/cm³ and 0.51, respectively. Compared to those of 29 years old conventional teakwood as well as 4 and 5 years old faster grown teakwood planted at the same area, specific gravity of this wood was higher. In general, this solomon-clone teakwood is suitable as raw material for wooden furniture manufacturing. This wood is classified as the Strength Class of III, has decorative figures, wood grain is straight, wood texture is fine and even, lower in volumetric shrinkage, and without crystal or silica.

1. Introduction

Characteristics of teak (Tectona grandis) wood especially from man-made forests need to be continuously investigated. This is not only to assure its quality as raw material for certain product, but also to evaluate wood characteristics variation among them. Since teakwood supply declines year by year, utilization of faster grown teakwood especially from plantation forest by wooden furniture industries increases every year. Among them is solomon-clone teak which has been planted in several sub districts in Central and West Java Provinces. According to Maskuro [1], solomon-clone teak tree is disease resistant, faster grown and slightly branched, while the stem is straight, round, and rarely broken. Previous study showed that heartwood portion of the 13 years old solomon-clone teakwood planted in Parung Sub-District, Bogor District was more than 70%. This indicates that this wood was durable enough and has potential to be used as raw material for timber industries.
Characteristics of solomon-clone teakwood until now have not been investigated yet. In fact, this information is needed specially to ensure the quality of furniture products produced, or at least to determine proper processing applied and end using purposed [2]. It is known that proper processing applied and appropriate end using purposed are determined by wood characteristics themselves, while wood characteristics of similar species are influenced by growing conditions, seed quality, and tree age.

Therefore, the objective of this study was to investigate anatomical structure, fiber dimension, and several physical properties of 13 years old solomon-clone teakwood planted in Bogor District in order to evaluate its suitability as raw material for wooden furniture manufacture. The results were then compared to similar characteristics found in another teakwood, either fast-grown or conventional one. Anatomical characteristics studied consisted of macro and microscopic characteristics, fiber dimensions (length, diameter, and thickness of the fiber wall), while physical properties consisted of wood density ($\rho$) and Specific Gravity (SG), as well as Volumetric Shrinkage (VS) from green to oven dried condition.

2. Materials and Methods

2.1. Materials

The main material used was disc of solomon-clone teakwood 25.10 cm in diameter and 5 cm thick, 50% nitric acid (HNO$_3$), potassium chlorate (KClO$_3$), distilled water, safranin, glycerin, and filter paper. Wood disc was extracted from basal area of 13 years old tree at 130 cm above the ground from plantation forest area in Bogor, West Java. Three healthy trees were selected and cut. Each disc was converted into 4 cm width wood strip including the pith, and then divided into 6 segments from pith to the bark representing heartwood (segment no.1 to 4), transition (segment no.5), and sapwood (segment no.6). Each segment was then cut: the upper part for anatomical structure observation and fiber dimension measurement, while the lower part for physical properties measurement. Sample dimension was 2 (l) × 4 (w) × 2 (t) cm per segment.

2.2. Anatomical structure observation

Anatomical structures were observed macro and microscopically. Macroscopic characteristics were observed directly by using micro capture loupe, while microscopic features were observed through microtome specimens by using light microscope. Macroscopic characteristics observed consist of the existence of growth ring, wood color and figure, texture, wood grain, and luster [3], while microscopic features i.e. vessel elements, fibers, axial parenchyma, and ray parenchyma were observed IAWA List [4]. Microtome specimens of 25 µm thick were prepared following Forest Products Laboratory method [5] for cross-, radial- , and tangential sections.

2.3. Fiber dimension measurement

Fiber dimension was measured through maceration specimens prepared by Schultze’s method with proper modifications. Fiber length, fiber diameter, and lumen diameter of 50 individual cell per segment were measured, while cell wall thickness was determined as a half of differences between fiber diameter and its lumen diameter. All measurements were carried out using the imageJ software.

2.4. Physical properties measurement

Physical properties of wood i.e. $\rho$, SG, and VS were measured using the following the equations:

\[ \rho \ (g/cm^3) = \frac{BA}{VA} \]  

\[ SG = \frac{BKT}{VA} / \rho_{water} \]  

\[ \% \ VS = \frac{VA - VB}{VA} \times 100 \]
where, $BA =$ Sample weight in green condition (g), $BKT =$ Sample weight in oven dried condition (g), $VA =$ Sample volume in green condition (cm$^3$), and $VB =$ Sample volume in oven-dried condition (cm$^3$).

3. Results and Discussion

Anatomical structures of solomon-clone teakwood are as follows: heartwood is reddish brown which is very easily distinguished from the yellowish white sapwood (Figure 1a). Growth ring is distinct. The wood is lustre and rather oily without specific odour. Texture fine and even, wood grain straight (Figure 1b), and have decorative pattern (Figure 1c). Vessels solitary and in radial multiples of 2-3 cells, the latter is dominant (Figure 2, 3, and 4); porosity ring porous in sapwood and transition zone, but diffuse porous in heartwood zone; pores somewhat circular; average tangential diameter 22.36 μm, 1-5 cells per mm$^2$; perforations simple; inter-vessel pits alternate; vessel-ray pits simple; deposits materials frequent in transition zone only; tyloses infrequent. Axial parenchyma paratracheal-zonate in earlywood and relatively sparsely vasicentric in latewood, 3-11 cells per strand (Figure 3, 4, and 5). Rays uni- to multiseriate (4-6 series) (Figure 3, 4, and 5), heterocellular, and without coloured content. Fibers exclusively septate; 993.35 μm long; 2.50-6.72 μm wide with tangential diameter of 8-14.53 μm. Crystals absent, but silica presents in some vessels. The wood consists of 53% of fiber, 29% of vessel, 10% of axial parenchyma, and 8% of ray parenchyma. In general, anatomical structure of solomon-clone teakwood is not different from that of common teakwood as [6,7].

![Figure 1](image1.png)

**Figure 1.** Macroscopic characteristic. (a) cross-, (b) radial-, and (c) tangential section

Result also showed sapwood and heartwood portions were 25.86 and 74.14%, respectively. Heartwood portion in this study was higher than that of 5-year-old fast growing teakwood as stated by [8,9] which are only 18 and 22%, respectively. However, it is lower than that of 76 years old conventional teakwood as stated by Wahyudi [10]. Because heartwood colour of this wood was darker than that of 4 and 5 years old fast growing teakwood planted at the same location [9] and not significantly different from 76 years old conventional teakwood planted at Cepu, Central Java Province [10], it can be deduced that solomon-clone teakwood is durable enough for destructive biological factors. The higher the proportion of heartwood, the higher the natural durability [11,12].
Results also showed that fiber length tends to increase from pith (segment no.1) to bark (segment no.6) (Figure 6). From the ANOVA, it is known that fiber length is significantly different among segments. Average values of fiber length in heartwood, transition, and sapwood were 905.44, 1139.02, and 1199.36 μm, respectively. Since fiber length increases from pith to bark, it can be said that mature wood has not been produced yet within the trees. According to IAWA [13], fibers of this wood was classified as medium class (900-1600 μm).
Figure 6. Radial variation in fiber length

Compared to 29 years old conventional teakwood planted in Bogor [14], our results are longer; but compared to 70 years old conventional teakwood [6,7], our results are shorter. These findings were similar to that of 14 years old conventional teakwood from Gunungkidul, Yogyakarta Province [15], and also to 4 and 5 years old fast growing teakwood planted in Bogor [8,16]. These differences indicate that fiber length is influenced by tree age and growing location.

Result showed that cell wall thickness was significantly influenced by sample location within stem (Figure 7). Fiber wall in transition zone was the thinnest (2.50 μm).

Figure 7. Radial variation in cell wall thickness

Wood density as well as SG in all parts (heartwood, transition, and sapwood zones) were almost similar (Figure 8 and 9). With an average of 0.53, therefore, solomon-clone teakwood studied was classified as the Strong Class of III [17]. Compared with [8,14,16], our values were higher; but compared to [6,15], our SG was lower.

Figure 8. Radial variation in wood density
Average value of VS from green to oven-dried was 6.75% (Figure 10). The smallest was found in transition zone (3.47%), while VS in heartwood and the sapwood were 8.20 and 8.59%, respectively. The smallest shrinkage in transition zone was related to diameter vessel size and deposit materials within vessel elements. Compared to [6,16], our value was lower.

The glue-ability has to be good and the SG should be moderate (0.50-0.75). Considering to some indicators stated, therefore, the solomon-clone teakwood studied is suitable enough to be utilized as raw material. The wood has decorative figures, less deformation (VS from green to oven-dried condition < 10%), strong enough (strong class III), texture fine and even, straight grain, durable, and good in machining properties dues to medium in SG (0.50-0.55). Glue-ability will be studied in the next future.

4. Conclusion
Anatomical characteristics of 13 years old solomon-clone teakwood from Bogor are not different from those of teakwood in general. The wood consists of 53% fiber, 29% vessel, 10% axial parenchyma, and 8% ray parenchyma. Fiber length was 905.44-1199.36 μm, while cell wall thickness was 2.50-6.72 μm. Average of wood density and specific gravity was 1.04 g/cm$^3$ and 0.51, respectively. Specific gravity of this wood was higher than that of 29 years old conventional teakwood as well as 4 and 5 years old fast growing teakwood from similar location, but comparable to 14-year-old conventional teakwood from Gunungkidul, Yogyakarta Province. Generally, this solomon-clone teakwood studied is suitable as raw material for wooden furniture manufacturing.

References
[1] Maskuro A 2012 Deskripsi Tumbuhan Jati dan Peranannya dalam Kehidupan Sehari-hari (Jember: Fakultas Keguruan dan Ilmu Pendidikan Universitas Muhamadiyah Jember)
[2] Wahyudi I 2013 *Hubungan Struktur Anatomi Kayu dengan Sifat Kayu, Kegunaan dan Pengolahannya* (Bogor: Fakultas Kehutanan Institut Pertanian Bogor)

[3] Pandit IKN and Ramdan H 2002 *Anatomi Kayu: Pengantar Sifat Kayu Sebagai Bahan Baku* (Bogor: Yayasan Penerbit Fakultas Kehutanan IPB)

[4] Wheler EA, Baas P, and Gasson PC 1990 *IAWA List of Microscopic Features for Hardwood Identification* (IAWA, US: IAWA Bull.)

[5] Sass JE 1961 *Botanical Microtechnique* (Iowa: The Iowa State University Press.)

[6] Martawijaya A, Kartasujiana I, Kadir K, and Prawira SA 2005 *Atlas Kayu Indonesia Jilid 1* (Bogor: Badan Penelitian dan Pengembangan Kehutanan)

[7] Ogata K, Fujii T, Abe H, and Baas P 2008 *Identification of the Timbers of Southeast Asia and the Western Pacific* (Japan: Kaiseisha Press)

[8] Muhran 2013 Kualitas pertumbuhan dan karakteristik kayu jati (*Tectona grandis* L. f.) hasil budidaya [Skripsi] Fakultas Kehutanan Institut Pertanian Bogor

[9] Wahyudi I, Priadi T, and Rahayu IS 2014 Karakteristik dan sifat-sifat dasar kayu jati unggul umur 4 dan 5 tahun asal Jawa Barat *JIP* 19(1) 50-6

[10] Wahyudi I 2000 Study on growth and wood qualities of tropical plantation species [Dissertation] Nagoya University Japan

[11] Butterfield BG 1993 *The Structure of Wood: An overview* Ed. Walker JCF *Primary Wood Processing, Principles and Practice* (Melbourne: Chapman and Hall)

[12] Darwis A, Hartono R, and Hidayat SS 2005 Presentase kayu teras dan kayu gubal pada Jati (*Tectona grandis* L.f.) *Jurnal Ilmu dan Teknologi Kayu Tropis* 3(1) 6-8

[13] IAWA 2005 *Identifikasi Kayu: Ciri mikroskopis untuk identifikasi kayu daun lebar* (Bogor: Pustekolah)

[14] Zawawi Y 2014 Dimensi serat, sudut mikrofibril, dan beberapa sifat fisis kayu jati (*Tectona grandis*) umur 29 tahun [Skripsi] Fakultas Kehutanan Institut Pertanian Bogor

[15] Hidayati F, Fajrin IT, Ridho MR, Nugroho WD, Marsoem SN, and Na’iem M 2016 Sifat fisika dan mekanika kayu jati unggul “mega” dan kayu jati konvensional yang ditanam di hutan pendidikan Wanagama, Gunungkidul, Yogyakarta. *Jurnal Ilmu Kehutanan* 10(2) 98-107

[16] Damayanti R 2016 Wood quality of young fast grow plantation teak and the relationship among ultrastructural and structural characteristics with selected wood properties [Dissertation] School of Ecosystem and Forest Sciences, Faculty of Science, the University of Melbourne

[17] PKKI-NI5 1961 *Peraturan Konstruksi Kayu Indonesia* (Jakarta: Yayasan Dana Normalisasi Indonesia)

[18] Bowyer JL, Shmulsky R, and Haygreen JG 2003 *Forest Products and Wood Science: An Introduction* (IOWA (US): IOWA State University Pr.)

[19] [BSN] Badan Standardisasi Nasional 2011 *Persyaratan Keamanan dan Pengujian Kayu dan Produk Kayu untuk Kursi Santai, Kursi Goyang, dan Kursi Teras SNI 7555.16, 17, dan 18* (Jakarta: Badan Standardisasi Nasional)

[20] [BSN] Badan Standardisasi Nasional 2016 *Persyaratan Keamanan dan Pengujian Kayu dan Produk Kayu untuk Meja Tamu, Meja Makan, dan Meja Dapur SNI 7555.1, 2, dan 3* (Jakarta: Badan Standardisasi Nasional)