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Original Article

Anatomical Characteristics and Air-dry Density of Young Trees of Teak Clones Planted in Indonesia[1]

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ABSTRACT

The objectives of this study are to obtain the basic knowledge of anatomical characteristics and wood properties of thinning trees of young teak (*Tectona grandis* L.F.) for fulfill the timber demand in Indonesia. Nine thinning trees of 5-year-old teak clone trees were used for analyzing the cell morphology and air-dry density. Vessel diameters in pore and outer pore zones were 165 and 90 μm, respectively. Mean value of fiber diameter, cell wall thickness, and fiber length in outer pore zone were 14.6 μm, 2.07 μm, and 1.04 mm, respectively. In addition, mean value of air-dry density was 0.55 g/cm^3. The measurement and values of vessel diameter, fiber diameter, cell wall thickness, fiber length and air-dry density in the experimental had lower than those in the older teak. Therefore, it could be suggested that the wood from thinning young teaks was not appropriate as construction material, but it could be used for furniture which do not need high of strength properties. Furthermore, since the measurements values of anatomical characteristics were still increasing from pith to bark, it could be suggested that 5-year-old teak clones are still in a juvenile phase. Positively significant correlations were found between air-dry density and cell wall thickness, indicating that cell wall thickness is strongly correlated with wood density of teak.

Keywords : teak, anatomical characteristics, air-dry density, young age, thinning trees

1. INTRODUCTION

Teak (*Tectona grandis* L.F.) is naturally distributed in the Indian Peninsula, Burma, Laos, Thailand and Philippines, and it was also introduced to Java, Indonesia around 400-600 years ago (Soreanegara and Lemmens, 1994). At present, it has been widely planted in many parts of the tropical countries including Indonesia. Teak wood is much favored, because of its characteristics such as durability, strength, and easy working and good appearance. It is extensively used for decking in the house, rail road, bulwarks, latches, weather doors, furniture, boats, and etc (Soerianegara and Lemmens, 1994). Thus, teak wood is considered to be one of the best woods in the world (Ogata *et al*., 2008). Furthermore, it is the most

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important commercial tree species in Indonesia (Na'iem, 2000).

The demand for teak is increasing in Indonesia year by year. In contrast, the total teak wood production is decreasing because of declining teak wood resources and the plantation productivity (Hidayati *et al*., 2014). To solve these problems, many ways have been tried such as utilization of the teak wood from the community forest (usually of small diameter), utilization of thinned teak trees, and development of breeding programs to produce more productive teak forest.

Indonesian State Forest Enterprise (Perhutani) started tree-breeding programs in 1981 (Suseno, 2000). In these programs, two superior clones showed the good performance of growth characteristics. Therefore, these two clones have been extensively planted in several locations in Java Island. These clones were usually planted together (mixed) in a site to prevent the spreading of the disease attacks. On the other hand, thinning was usually conducted in teak plantation. The wood from thinning trees has the potential to fulfill the demand for the teak wood. However, thinning of teak is practically conducted at young age (usually started at 5-year-old in Java island, Indonesia). Bhat *et al*. (2001) reported that mature wood could be formed after 15-20 year-old teak trees. Therefore, it is considered that thinning teak trees in Indonesia only produces the juvenile wood.

Research on anatomical characteristics and wood properties of teak has been conducted by many researchers (Kedharnath *et al*., 1963; Indira and Bhat, 1998; Bhat, *et al*., 2001; Pérez Cordero and Kanninen, 2003; Bhat and Priya, 2004; Moya and Marin, 2011; Hidayati *et al*., 2013a, b, 2014; Marsoem *et al*., 2014). However, researches on these characteristics in thinning young teak trees are still limited in Indonesia. In the present study, anatomical characteristics and air- dry density were clarified in the wood from thinning 5-year-old teak trees planted in Yogyakarta, Indonesia. Furthermore, radial variations and relationships among measured characteristics were determined.

2. MATERIALS and METHODS

Five-year-old thinning *Tectona grandis* L.F. trees were obtained from Wanagama Educational Forest, Faculty of Forestry, University of Gadjah Mada, Gunung Kidul, Yogyakarta, Indonesia (110°52'–110°53'E, 7°9'–7°9'S; 233 m a.s.l. The environmental conditions of the site between 2003 and 2007 were as follows: average temperature, 23.8℃; relative humidity, 91.8%; annual precipitation, 1986 mm; soil, Mediterranean. Vegetatively propagated cuttings from two clones were planted randomly at end of December 2003 with 2 by 6 m spacing.

The stem diameter (at 1.3 m above the ground) and tree height of 500 trees in the site were measured at December 2008. The results showed, mean stem diameter and tree height were 13.3 cm and 11 m, respectively. In the present study, nine trees were randomly selected and collected for determining the anatomical characteristics and air-dry density. The

Table 1. Stem diameter at 1.3 m above the ground and tree height in nine sample trees

Sample number	Stem diameter (cm)	Tree height (m)
1	6.4	9
2	7.3	9
3	8.5	7
4	9.7	10
5	10.5	12
6	11.4	12
7	13.3	12
8	13.5	13
9	15.3	13
Mean	10.7	11
Standard deviation	3.0	2

stem diameters at 1.3 m above the ground and tree height for nine trees are listed in Table 1. After cutting, two disks (2 cm in thickness) and one disk (1 cm thickness) were collected at 1.3 m above the ground for measuring the anatomical characteristics and air-dry density.

Small blocks (1 × 1 × 1 cm) were prepared from each growth ring for measuring vessel and fiber diameter, and cell wall thickness of fiber. Cross sections (20 μm in thickness) were obtained from small blocks using a sliding microtome. The obtained sections were stained with 1% safranin and then dehydrated by graded ethanol series. Then, dehydrated sections were dipped into xylol and mounted in Canada balsam. Three digital images in each radial position were obtained by a microscopy (Olympus BX51) equipped with a digital camera (Olympus DP70). The images were then captured into a personal computer and cell morphology was measured using an image analysis software (Image J). Except for vessel diameter (VD), anatomical characteristics, i.e., diameter (FD), and cell wall thickness (FWT) of fiber were measured in outer pore zone. In the VD, radial and tangential diameters were measured in both pore and in outer pore zones. VD was regard as mean values of radial and tangential diameters. A total of 30 individual cells were measured at each radial pile.

Small sticks (0.1 × 0.1 × 2 cm) were prepared from each outer pore zone of growth ring for measuring the fiber length (FL). The sticks were macerated by acetate glacial acid and hydrogen peroxide (1 : 20) under boiling condition. The macerated woods were put on glass microscope slide and stained with 1% safranin. A total of 50 wood fiber lengths were measured at each radial pile using digital images taken by a microscope with a digital camera and an image analysis software.

For measuring the air-dry density, radial strips (2 cm in longitudinal direction and 2 cm in tangential direction) were obtained from

Table 2. Mean values of the anatomical characteristics and air-dry density for nine sample trees

Character		Minimum	Mean	Maximum	Standard deviation
Vessel	Diameter in pore zone (μm)	140	165	195	18
	Diameter in outer pore zone (μm)	73	90	103	9
	Mean (μm)	113	128	142	9
Fiber	Diameter (μm)	10.50	14.60	19.60	1.20
	Wall thickness (μm)	1.71	2.06	2.33	0.09
	Length (mm)	0.86	1.04	1.20	0.06
Air-dry density (g/cm^3)		0.47	0.55	0.65	0.02

Note : * = significant at 5% level; ** = significant at 1% level; ns = no significant

disks with 2 cm thickness. The specimen was prepared from each growth ring except from pore zone. Thus, dimension in radial direction of the specimens ranged from 0.2 to 1.0 cm depending on the size of pore zone. Specimens were kept on laboratory condition (26℃ and relative humidity 65%) to obtain the air-dry condition. As the results, moisture content of the air-dry specimen was 14.9 ± 0.5%.

3. RESULTS and DISCUSSION

3.1. Anatomical characteristics and air-dry density

Table 2 shows the mean values of anatomical characteristics and air-dry density for nine trees. VDs in pore and outer pore zone to be 165 and 90 μm, respectively. Mean values of FD, FWT, and FL were 14.60 μm, 2.07 μm, and 1.04 mm. Hidayati *et al*. (2014) reported that mean value of VD in outer pore zone was 188 μm for 12-year-old trees of 12 teak clones planted in Cepu and Ciamis, Indonesia. In the present study, VD in outer pore zone was lower than that described in a previous report (Hidayati *et al*., 2014). Furthermore, they also reported that mean values of FD, FWT, and FL at outer pore zone were 23.40 μm, 2.78 μm, and 1.42 mm of 12-year-old trees of 9 teak clones planted in Cepu and Ciamis, Indonesia (Hidayati *et al*., 2014). In the present study, FD, FWT, and FL were lower than those reported in the older trees (Hidayati *et al*., 2014).

The mean value of air-dry density was 0.55 g/cm^3 (Table 2). Wanneng *et al*. (2014) reported that air-dry densities at 12% moisture content of 10-, 15-, 20-, and 25-year-old teak trees planted in Laos were 0.71, 0.70, 0.71, and 0.66, respectively. Air-dry density of 35-year-old teak from plantation in India was 0.63 g/cm^3 (Thulasidas and Bhat, 2012). In the present study, air-dry density was lower than those in older of teak trees (Wanneng *et al*., 2014, Thulasidas and Bhat, 2012). Based on the result and previous results reported by other researchers, it could be suggested that air-dry density increases until a certain age and then it tended to decrease.

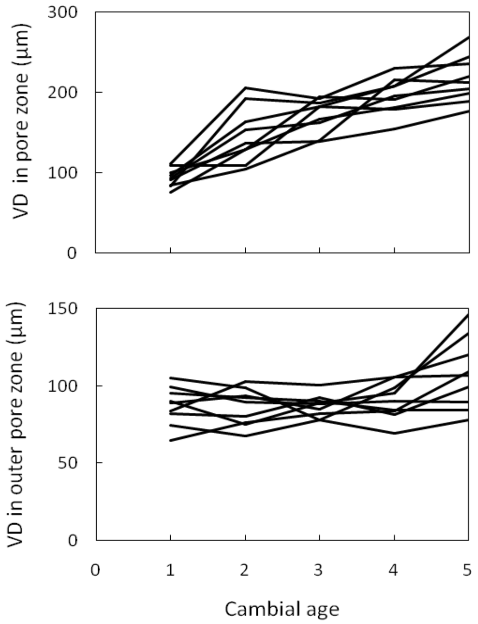
In the present study, measurement results of VD, FD, FWT, FL and air-dry density of

5-year-old teak trees were lower than those in the older teak reported by previous researchers (Hidayati *et al*., 2014, Wanneng *et al*., 2014, Thulasidas and Bhat, 2012). Based on the results, it could be suggested that the wood from thinning young teak was not appropriate for construction material, but it could be used for furniture materials which do not need high of strength properties.

3.2. Radial variations of anatomical characteristics and air-dry density

Fig. 1 shows the radial variations of mean VD in pore and outer pore zones. Mean VD of pore zone increased from pith to bark. On the other hand, mean VD in outer pore zone was almost constant from pith to bark. Bhat *et al*. (2001) reported that VD (included pore and outer pore zone) increased during the juvenile phase and then it stabilized at approximately 20 years from pith to bark. The VD in the outer pore zone gradually increased from pith to bark in 12-year-old teak clones planted in Indonesia (Hidayati *et al*., 2014). Our results of the radial variation on mean VD in pore zone was consistent with previous results (Bhat *et al*., 2001). However, at the outer pore zone it was inconsistent with the results from a previous study (Hidayati *et al*., 2014).

The FD, FWT, and FL increased from pith to bark (Fig. 2). The FL of teak trees increased up to 15-20 years from pith and then it became constant outward (Bhat *et al*., 2001). In 12-year-old teak clones planted in Indonesia,



Note: VD is the average value of diameters in radial direction.

Fig. 1. Radial variations of vessel diameter (VD) in pore and outer pore zone in nine sample trees.

Hidayati *et al*. (2014) reported that FD was slightly increased from pith to bark and FWT and FL was gradually increased from pith to bark. In the present study, radial variation of FD, FWT, and FL were almost similar to these previous studies (Bhat *et al*., 2001, Hidayati *et al*., 2014).

Fig. 3 shows the variations of air-dry density in the radial direction. Air-dry density was almost the same values from pith to bark. Bhat *et al*. (2001) reported that basic density varied relatively little from pith to bark. On the other hand, basic density was gradually increased in teak clones planted in Indonesia (Hidayati *et al*., 2014). In the present study, variation of air-dry density in the radial direction was sim-

Table 3. Correlation coefficients between anatomical characteristic and air-dry density in nine sample trees

Character	VD (pore)	VD (outer pore)	FD	FWT	FL	AD
VD (pore)	-					
VD (outer pore)	0.245 ns	-				
FD	0.525 ns	0.227 ns	-			
FWT	0.021 ns	-0.511 ns	0.074 ns	-		
FL	0.793*	-0.193 ns	0.584 ns	0.546 ns	-	
AD	0.322 ns	-0.410 ns	0.118 ns	0.745*	0.653 ns	-

Note: VD, Vessel diameter; FD, fiber diameter; FWT, fiber wall thickness; FL, fiber length; AD, Air-dry density; *, significance at 5% level; ns, non significance. The number of sample is nine trees.

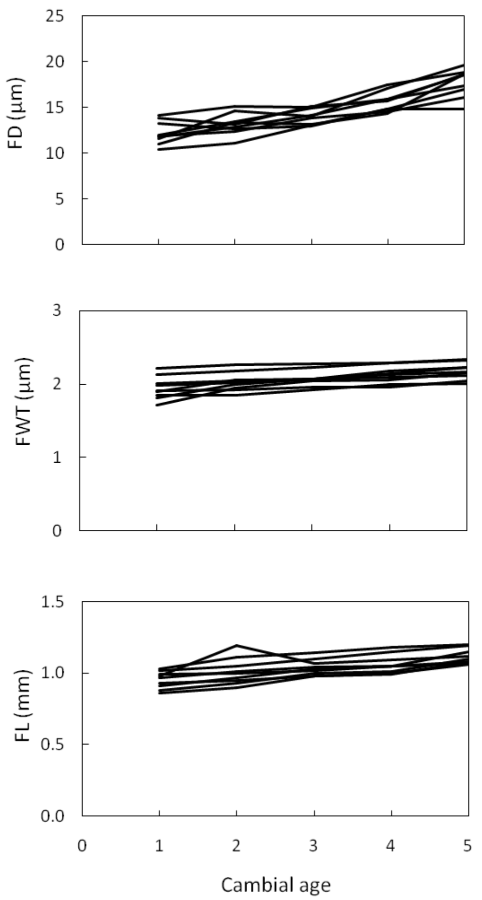


Fig. 2. Radial variations of fiber diameter (FD), fiber wall thickness (FWT), and fiber length (FL) in nine sample trees.

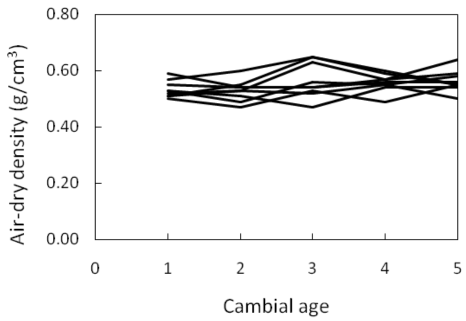


Fig. 3. Radial variation of air-dry density in nine sample trees.

ilar with the result reported by Bhat *et al.* (2001). In addition, the values of anatomical characteristics were still increased from pith to bark, suggesting that these 5-year-old teak clones are still producing juvenile wood.

3.3. Relationships between anatomical characteristics and air-dry density

Table 3 shows the relationship between characteristics in nine sample trees. In the present study, positively significant correlations were found between FL and average VD of pore zone and between air-dry density and FWT. On the other hand, no significant correlations were found among other characteristics. Hidayati *et al*. (2014) reported that basic density has positively significant correlation with FWT in 12-year-old teak clones planted in Cepu and Ciamis, Indonesia. Air-dry density has positively significant correlation with double wall thickness in 35-year-old teak trees planted in India (Thulasidas and Bhat, 2012). In other hardwood species, positive significant correlation was found between air-dry density and FWT of *Casuarina equisetifolia* growing in Bangladesh (Chowdury *et al*., 2012). A similar result was also found in *Falcataria moluccana* (Syn. *Paraserianthes falcataria*) planted in Indonesia (Ishiguri *et al*., 2009). Based on the results, it could be indicated that FWT is strongly correlated with wood density in teak.

4. CONCLUSION

The objectives of this study were to clarify the anatomical characteristics and air-dry density of 5-year-old teak clones, variations of those characteristics in the radial direction, and relationships among measured characteristics. Total of nine trees of two teak clones were investigated. VD of pore and outer pore zone were 165 and 90 μm, respectively. Mean value of FD, FWT, and FL were 14.60 μm, 2.07 μm, and 1.04 mm, respectively. In addition, mean value of air-dry density was 0.55 g/cm^3. The values of VD, FD, FWT, FL, and AD in the present study showed relatively lower values compared to the value obtained from older teak trees, suggesting that juvenile teak wood was not appropriate for construction material, but it could, however, be used for furniture materials which do not need high of strength properties. The values of anatomical characteristics were increased from pith to bark, suggesting that wood from thinning 5-year-old teak clones are juvenile wood. Furthermore, positively significant correlations were found between air-dry density and FWT, indicating that FWT was strongly correlated with wood density even in such a young trees.

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