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RADIAL VARIATION OF ANATOMICAL CHARACTERISTICS IN *PARASERIANTHES FALCATARIA* PLANTED IN INDONESIA

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SUMMARY

Radial variation in anatomical characteristics of five 13-year-old *Paraserianthes falcataria* (L.) Nielsen (syn. *Albizia falcataria* (L.) Fosberg), an important commercial tree species in Indonesia, were investigated in order to obtain basic information regarding breeding for wood quality. Both cell wall thickness in wood fibers and vessel percentage showed an almost constant value up to 10 cm from the pith and then increased toward the bark. In contrast, wood fiber percentage decreased from 10 cm toward the bark. The cell wall percentage was lower towards the pith and higher towards the bark. In the five sample trees, significant differences were found in the cell diameter of wood fibers, wood fiber percentage, axial parenchyma percentage, and cell wall percentage. Basic density was affected by the cell wall thickness of wood fibers, but not the vessel percentage and fiber percentage.

Key words: *Paraserianthes falcataria*, cell morphology, proportion of cell types, basic density.

INTRODUCTION

In tree breeding programs, trees are selected mainly based on the growth rate or stem form. Zobel and Van Buijtenen (1989) pointed out that many improvement programs for major tree species have not included wood quality, although wood is the desired product. For the utilization of wood resources, criteria for evaluating wood quality should be included in tree breeding.

The fast-growing *Paraserianthes falcataria* (L.) Nielsen (syn. *Albizia falcataria* (L.) Fosberg) is an important plantation tree species in Indonesia and other tropical countries (Wahyudi *et al.* 2000; Sumiasri *et al.* 2006; Ogata *et al.* 2008). However, information on wood properties of this species is very limited (Ishiguri *et al.* 2007), other than some reports on the anatomical characteristics and basic wood properties (Chauhan & Dayal 1985; Shiokura & Lantican 1987; Wahyudi *et al.* 2000; Ogata *et al.* 2008).

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Previously (Ishiguri *et al*. 2007), we reported the among- and within-tree variation in stress-wave velocity in trees, log properties, and wood properties (basic density and fiber length) of *P. falcataria* planted in Indonesia. Based on the radial variation of the basic density and fiber length, two types of wood were categorized: core wood which is xylem up to 10 cm from the pith, and outer wood, which is xylem from 10 cm to the bark. In addition, a significant difference in the basic density of the core wood was found among the sampled trees. From the results obtained, we concluded that the wood quality of *P. falcataria* could be improved through tree breeding.

The aim of this study was to obtain basic knowledge on breeding for wood quality in *P. falcataria*. A total of five trees of *P. falcataria* grown in Indonesia were used for examining the radial variation of cell morphology and the proportion of cell types. Based on the results obtained, the relationships between anatomical characteristics and basic density are discussed.

Table 1. Diameter and height of trees, basic density, and wood fiber length of five selected trees (Ishiguri *et al*. 2007).

Tree no.	Diameter (cm)	Tree height (m)	Basic density (g/cm^3)	Wood fiber length (mm)
1	40.4	24.4	0.31	1.06
2	38.1	26.0	0.34	1.11
3	33.7	25.2	0.33	1.11
4	37.0	26.2	0.27	0.91
5	41.5	24.6	0.33	1.17
Average	38.1	25.3	0.32	1.07

Note: Diameter of tree was measured at 1.3 m from the ground.

MATERIALS AND METHODS

Sample trees were collected in September 2005 from a stand in the Serpong Botanical Garden, Indonesia. This stand was established from seedlings in December 1991. Of the selected 96 trees in a stand, five trees were harvested to examine wood properties (Table 1) (Ishiguri *et al*. 2007). After the trees were cut down, disks 10 cm in thickness were collected from each tree at 1.3 m from the ground. Strips from the pith to the bark (2 cm in width and 2 cm in thickness) were prepared from these disks.

Small blocks (c. 2 by 2 by 2 cm) were prepared at 2 cm intervals from the pith. Cross sections (30 μm in thickness) were obtained from the small blocks by using a sliding microtome. The obtained sections were stained with 1% safranin and then dehydrated with graded alcohol series. Dehydrated sections were dipped into xylene for one minute and then mounted on slides.

For the measurement of cell morphology (diameter of vessels and wood fibers, and cell wall thickness of wood fibers), at least ten digital images in each radial position were obtained by a microscope (Olympus, BX51) equipped with a digital camera (Olympus, DP11). The images were then entered into a personal computer and printed out as enlarged images. Cell morphology was measured by using a digital caliper (Mitsutoyo, CD-15CP) on the printed images. A total of 30 vessels and 50 wood fibers were measured per image.

The point counting method (Taylor 1973; Denne & Hale 1999; Ohshima 2007) was employed to determine the proportion of cell types. Five digital images were taken in each radial position using the same microscope and digital camera. Grid lines (100 μm interval) were drawn on each image to obtain 400 measuring points. The cell types were classified as vessel wall, vessel lumen, wood fiber wall, wood fiber lumen, ray parenchyma cell wall, ray parenchyma cell lumen, axial parenchyma cell wall, or axial parenchyma cell lumen. The proportion of cell type was calculated as percentage per counted total number (400 points).

To clarify the relationships between anatomical characteristics and basic density, basic density was measured using the same sample used in the previous study (Ishiguri *et al*. 2007) at 2 cm intervals from pith to bark. Basic density was calculated by dividing the oven-dry (105 °C) weight by the green volume measured by water displacement.

RESULTS AND DISCUSSION

Radial variation in vessel morphology

No significant difference in the radial and tangential diameters of vessels was found (Table 2). In the present study, therefore, the average value of the radial diameter and tangential diameter was used as the average diameter. The minimum, average, and maximum values of the vessel diameters were 139, 234, and 291 μm, respectively (Table 2). Ogata *et al*. (2008) reported that the tangential maximum diameter of solitary vessels in *P. falcataria* ranged from 250–330 μm. Chauhan and Dayal (1985) also reported a maximum vessel diameter in *P. falcataria* of 250 μm. These results are similar to ours.

Table 2. Average value of the anatomical characteristics in five sample trees and results of ANOVA tests.

Property		Min	Average	Max	SD	Significance
Vessel	Radial diameter	137	237	306	36	ns
	Tangential diameter	140	231	286	33	ns
	Average diameter	139	234	291	34	ns
Wood fiber (μm)	Cell diameter	15.4	18.2	21.2	1.3	**
	Cell wall thickness	0.76	1.03	1.44	0.17	ns
Proportion of cell type (%)	Vessel	4	8	14	3	*
	Wood fiber	77	85	91	3	ns
	Ray parenchyma	1	4	7	1	ns
	Axial parenchyma	1	2	6	1	*
Cell wall percentage (%)		24	30	37	4	**

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

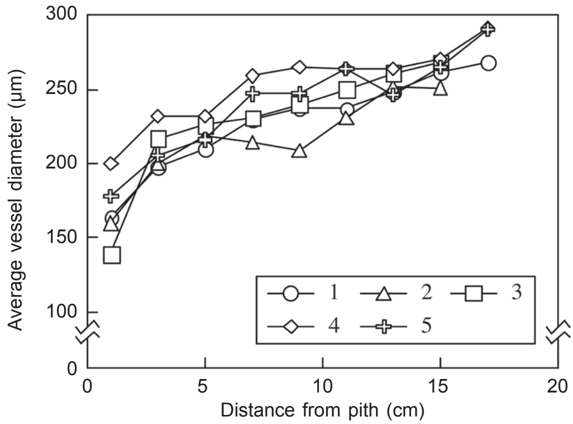

Figure 1. Radial variation of the average diameter of vessels in five sample trees. Note: Vessel diameter is the average value of radial and tangential vessel diameter.

The vessel diameters of the *P. falcataria* specimens rapidly increased up to 5 cm from the pith and then increased slowly (Fig. 1). This vessel diameter increase from the pith to the bark has been reported by others (Taylor 1973; Shiokura & Lantican 1987; Malan & Gerischer 1987; Peszlen 1994). In *P. falcataria*, Shiokura and Lantican (1987) reported that the vessel diameter increased up to a certain distance from the pith and then became constant.

Radial variation in wood fiber morphology

In the present study (Table 2), the diameter of the wood fibers averaged 18.2 µm (range 15.4 to 21.2 µm) and the cell wall thickness averaged 1.03 µm (range 0.76 to 1.44 µm). Ogata *et al*. (2008) reported tangential diameter and cell wall thickness of wood fibers in *P. falcataria* of 25 µm and 1.5–2.0 µm, respectively. In each case, these values were somewhat lower than those reported by Ogata *et al*. (2008).

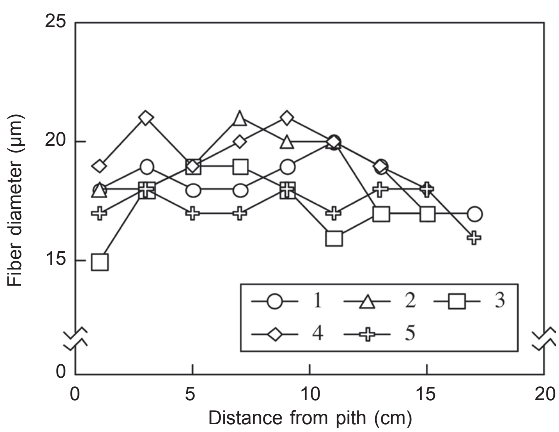

Figure 2. Radial variation of the fiber diameter in five sample trees.

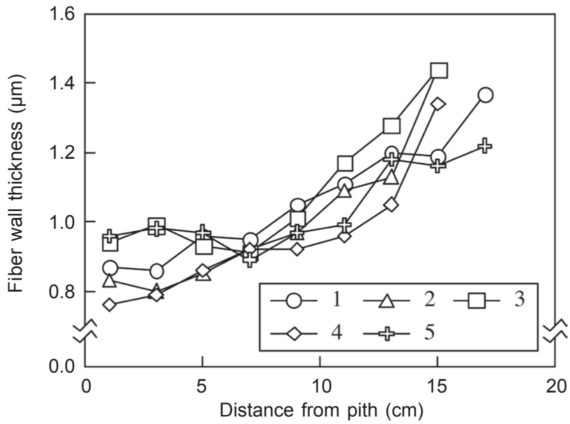

Figure 3. Radial variation in fiber wall thickness in five sample trees.

Figure 2 shows the radial variation found for the cell diameter of wood fibers, which was almost constant (15 to 20 μm) from pith to bark. On the other hand, the cell wall thickness of wood fibers showed a different radial variation (Fig. 3); an almost constant value up to 10 cm from the pith and then an increase toward the bark. These results are comparable to those found by other researches on five Mississippi Delta hardwoods, black willow, willow oak, sycamore, pecan, and sugarberry (Taylor & Wooten 1973), on *Eucalyptus grandis* (Malan & Gerischer 1987) and on *E. camaldulensis* (Ohshima *et al*. 2003).

Radial variation in proportion of cell type

Radial variations in proportion of cell type are shown in Figures 4 to 7. The vessel percentage and axial parenchyma percentage showed an almost constant value up to 10 cm from the pith and then increased toward the bark (Fig. 4 & 7). In contrast, the wood fiber percentage decreased from 10 cm to the bark (Fig. 5). On the other hand, no consistent

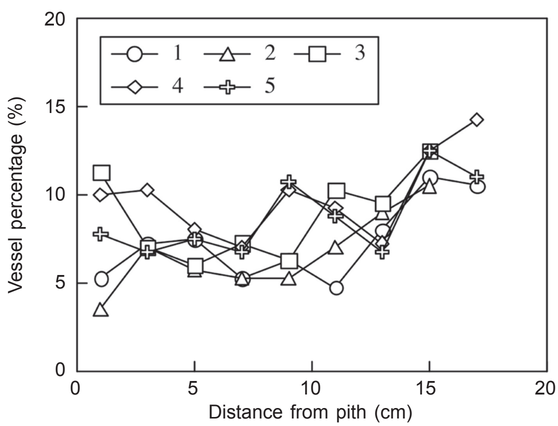

Figure 4. Radial variation of the vessel percentage in five sample trees.

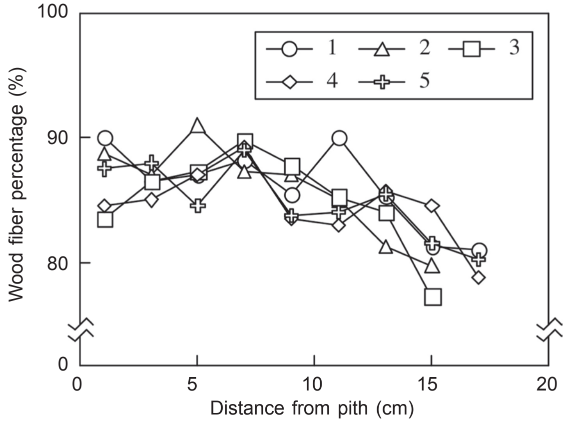

Figure 5. Radial variation of the wood fiber percentage in five sample trees.

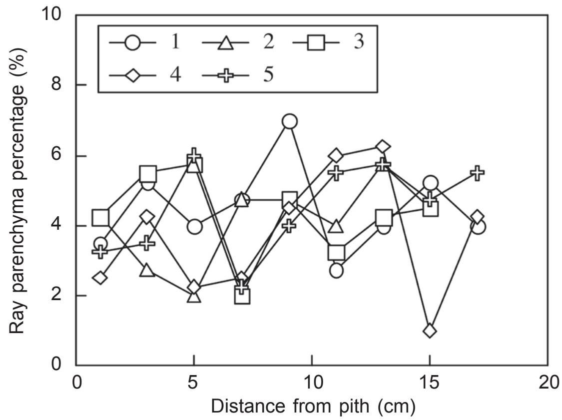

Figure 6. Radial variation of the ray parenchyma percentage in five sample trees.

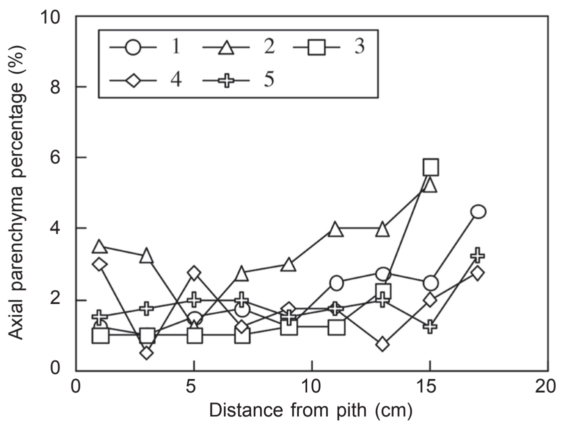

Figure 7. Radial variation of the axial parenchyma percentage in five sample trees.

radial pattern was recognized in the ray parenchyma percentage (Fig. 6). Thus, our results were similar to those obtained for the five Mississippi Delta hardwoods mentioned above (Taylor & Wooten 1973) and for *Nothofagus nervosa* (Denne & Hale 1999).

The radial variation patterns of cell wall percentage was slightly different among the trees, but in general they showed low values near the pith and high values near the bark (Fig. 8). The average value of cell wall percentage was 30 % (Table 2). There were significant differences in cell wall percentages among the five sample trees (Table 2). The radial pattern in the cell wall percentage (Fig. 8) was similar to that of the cell wall thickness of wood fibers (Fig. 3), suggesting that changes in cell wall percentage reflected variations in cell wall thickness in wood fibers.

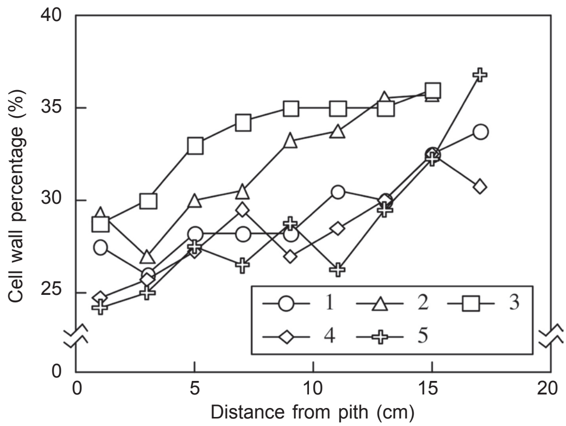

Figure 8. Radial variation of the cell wall percentage in five sample trees.

Relationship between anatomical characteristics and basic density

In our previous report (Ishiguri *et al.* 2007), the basic density of *P. falcataria* showed an almost constant value up to 10 cm from the pith and then increased toward the bark. The correlation coefficients between anatomical characteristics and basic density were examined to clarify the radial variation of basic density in *P. falcataria* (Table 3).

Panshin and De Zeeuw (1980) pointed out that, in general terms, the density of wood depends on (1) the size of cells, (2) the thickness of the cell walls, and (3) the interrelationship between the two. In the present study, significant correlation coefficients were found between anatomical characteristics and basic density, except for ray parenchyma percentage. The highest positive correlation coefficient (r = 0.87) was found between the cell wall thickness of wood fibers and basic density. However, there was a significant negative correlation (r = -0.64) between cell diameter of wood fibers and basic density. These fiber morphology and basic density results were similar to those in *E. tereticornis* reported by Sharma *et al.* (2005). As shown in Figure 3, the radial variation pattern of the cell wall thickness of wood fibers was similar to its variation with basic density, indicating that cell wall thickness of wood fibers was strongly related to the basic density in *P. falcatara*. On the other hand, a positive correlation was obtained between vessel diameter and basic density (Table 3).

Table 3. Correlation coefficient between anatomical characteristics and basic density for *Paraserianthes falcataria*.

	Property	Correlation coefficient with basic density
Cell morphology	Average vessel diameter	0.49 **
	Cell diameter of wood fiber	-0.64 **
	Cell wall thickness of wood fiber	0.87 **
Proportion of cell type	Vessel	0.55 **
	Wood fiber	-0.72 **
	Ray parenchyma	0.24 ns
	Axial parenchyma	0.61 **
	Cell wall percentage (%)	0.72 **

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

In hardwood species, it has been reported that high density is generally associated with an increase in fiber volume and a decrease in vessel volume (Taylor & Wooten 1973). In the present study, as shown in Table 3, a significant positive correlation was found between vessel percentage and basic density, and a significant negative correlation between fiber percentage and basic density. Hence, our results were contradictory to those reported by Taylor and Wooten (1973). In *E. grandis*, although the correlation coefficients were not always statistically significant, density always increased when there was an increase in fiber volume and decreased when the volume of parenchyma increased (Taylor 1973). In the five Mississippi Delta hardwoods mentioned above, the relationship between density and ray volume was not very strong, suggesting that an increased ray volume does not detract from the density (Taylor & Wooten 1973). As shown in Table 3, no significant correlation was obtained between the ray parenchyma percentage and basic density ($r = 0.24$), but there was a significant correlation between axial parenchyma percentage and basic density ($r = 0.61$). In *P. falcataria*, diffuse axial parenchyma cells were scattered evenly among fibers and were exclusively crystalliferous (Ogata *et al*. 2008), resulting in an increase of the basic density with an increase in the axial parenchyma percentage. A relatively high correlation coefficient ($r = 0.72$) was found between the cell wall percentage and basic density (Table 3). From the results obtained, we conclude that the basic density of *P. falcataria* is largely affected by the cell wall thickness of wood fibers rather than the vessel and fiber percentages.

CONCLUSIONS

The radial variation in the anatomy of *P. falcataria* is as follows:

1) Vessel diameter rapidly increased up to 5 cm from the pith and then showed an almost constant value. The cell diameter of wood fibers was an almost constant value from pith to bark. On the other hand, cell wall thickness showed an almost constant value up to 10 cm from the pith and then increased to the bark.

2) The vessel and axial parenchyma percentages showed an almost constant value up to 10 cm from the pith and then increased toward the bark. In contrast, the wood fiber percentage decreased from 10 cm to the bark.

3) Significant differences among the five sample trees were found in the cell diameter of wood fibers, wood fiber percentage, axial parenchyma percentage, and cell wall percentage.

4) Significant correlation coefficients were found between percentages of anatomical characteristics, except for ray parenchyma percentage and basic density. The highest positive correlation coefficient was found between the cell wall thickness of wood fibers and basic density.

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