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VARIATION IN THE WOOD PROPERTIES OF *PARASERIANTHES FALCATARIA* PLANTED IN INDONESIA

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SUMMARY

In many tree breeding programs, plus trees have been selected according to growth rate or stem form in trees. Trees that have a high growth rate or good stem form do not always produce industrially desirable wood. Therefore criteria for wood quality should be considered in tree breeding programs. The objective of this study is to obtain the basic knowledge for breeding for wood quality in *Paraserianthes falcataria,* an important commercial tree species of Indonesia. Variation in the growth, log properties, basic density, and fiber length in 13-year-old *P. falcataria* was investigated. Even though all trees were the same age, diameter at breast height showed high variation, indicating a significant variance in the growth rate of seedlings. Significant differences in the log properties (green density, dynamic Young's modulus, and stress-wave velocity) were observed among the trees. Basic density showed a constant value up to 10 cm from pith, at which point it began to increase. The fiber length increased up to 10 cm from the pith and then showed an almost constant value. According to the radial variation of the basic density and fiber length, wood is categorized as core wood, which includes that up to 10 cm from the pith, and outer wood, which is that from 10 cm to the bark. In addition, a significant difference in the basic density of core wood was observed among the trees, indicating that the selection of a plus tree with high-density wood in this species is possible at a relatively early stage. These results indicate that the wood quality in *P. falcataria* can be improved through tree breeding.

Key words: *Paraserianthes falcataria*, dynamic Young's modulus, stress-wave velocity, basic density, fiber length.

INTRODUCTION

Paraserianthes falcataria (L.) Nielsen is a fast-growing tree native to Indonesia that also has been widely planted throughout the tropics (Soerianegara & Lemmens 1994; Sumiasri *et al.* 2006). The wood of *P. falcataria* has been used for furniture, lightweight-

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packing materials, veneer, pulp, and light-construction materials (Soerianegara & Lemmens 1994). The mean annual increment of a *P. falcataria* plantation for producing construction wood is up to 45 m^3/ha (Marsoem 2005), and therefore this species as well as another species, *Acacia mangium* Willd., was selected by the Indonesian government for the development of the industrial forest estates and reforestation (Sumiasri *et al.* 2006). These two species have become common as the supply from natural forests has diminished, while demand for forest products increased (Wahyudi *et al.* 2000). To promote the establishment of plantation forests in tropical regions using *P. falcataria*, the yield and quality of wood should be enhanced by a tree breeding program. However, there have only been a few tree breeding programs targeting *P. falcataria* (Chigira *et al.* 2005). Furthermore, improvement programs of many major tree species do not include wood quality improvement, although wood is the desired product (Zobel & Van Buijtenen 1989). There are some reports on the wood anatomy and properties of *P. falcataria* (Chauhan & Dayal 1985; Shiokura & Lantican 1987; Akutsu *et al.* 1998; Wahyudi *et al.* 2000; Yamamoto *et al.* 2005), although information on the wood properties of *P. falcataria* to be targeted for tree breeding programs is very limited.

Basic density and fiber length are very important factors affecting wood properties (Zobel & Van Buijtenen 1989). Wood density strongly affects the physical and mechanical properties of wood (Kollman & Côté 1984). Most pulp and paper properties are directly related to wood density (Zobel & Van Buijtenen 1989). In addition, fiber length directly connects to the strength of interfiber bonding and tear strength (Perez & Fauchon 2003).

The stress-wave method is a well-known method of nondestructive testing for evaluating wood quality, especially mechanical properties. There is a significant, positive relationship between the stress-wave velocity (SWV) of standing trees and the Young's modulus (MOE) of a log or lumber (Ikeda & Arima 2000; Wang *et al.* 2001; Ishiguri *et al.* 2006). Therefore, the stress-wave method has been used to evaluate wood quality parameters, such as stiffness, in tree breeding programs (Jayawickrama 2001).

The objective of the present study is to obtain basic knowledge for breeding wood quality in *P. falcataria*. The diameter at breast height (DBH) and SWV of 96 13-year-old trees of *P. falcataria* planted in Serpong, Indonesia, were measured. Five trees selected from standard trees having almost average DBH were harvested, and the dynamic Young's modulus (DMOE) and SWV of logs as well as the radial variations of basic density and fiber length at the DBH position were measured. From the results obtained, the possibility of wood quality breeding in *P. falcataria* will be discussed.

MATERIALS AND METHODS

Materials

The study site was located in the Serpong Botanical Garden, Indonesia. Seedlings of *Paraserianthes falcataria* were planted in a 4 by 4 m spacing in December 1991. The environmental conditions of the site in 2004 were as follows: average temperature, 26.7 °C; annual precipitation, 1453 mm; soil, latosol. The DBH and SWV of 96 trees growing at the site were measured in September 2005 to select standard trees. The

Table 1. DBH and stress-wave velocity of 96 trees.

Property	Min.	Ave.	Max.	SD
DBH (cm)	12.3	38.5	77.4	13.8
SWV (km/s)	2.57	3.08	3.61	0.22

Table 2. DBH, height, and stress-wave velocity in five harvested trees.

Tree No.	DBH (cm)	Height (m)	SWV (km/s)
1	40.4	24.4	2.88
2	38.1	26.0	3.08
3	33.7	25.2	3.30
4	37.0	26.2	3.03
5	41.5	24.6	3.21
Ave.	38.1	25.3	3.10

stress-wave time of 96 stems was measured by using a commercial, handheld stress-wave timer (Alnus, FAKOPP). Start and stop sensors were set at 150 cm and at 50 cm above the ground level. The SWV of standing trees was calculated by dividing the span between sensors (100 cm) by the stress-wave time. Average values of the DBH and SWV of 96 trees are listed in Table 1. Five trees with average DBH were harvested and 60 logs were obtained at every 1-m-length from the ground level (Table 2).

Log properties

A total of 60 logs were obtained from the five selected trees, and the weight and volume of logs were measured to calculate the density in the green condition, then the DMOE and SWV of logs were measured. The DMOE was measured by the tapping method, as described in a previous paper (Ishiguri *et al.* 2005). For measuring the stress-wave time of logs, start and stop sensors were set at the center of both ends of the log.

Basic density and fiber length

After harvesting the five trees, disks of 10 cm thickness were collected at breast height of each tree. For measuring the basic density and fiber length, 2-cm-wide and 2-cm-thick strips were taken through the pith from each disk. The basic density and fiber length were measured at 2-cm intervals from pith. The basic density (*c.* 2 by 2 by 2 cm^3) was calculated by dividing the oven-dry weight (105 °C) by the green volume measured from the water displacement. For measuring the fiber length, small strip specimens were macerated with Schulze's solution, and 50 fibers projected on a microprojector (Nikon, V-12) were measured using a digital caliper (Mitsutoyo, CD-15CP).

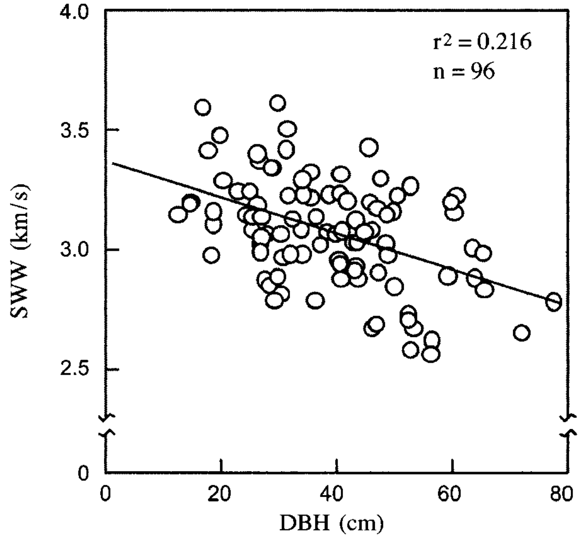

Figure 1. Relationship between the DBH and SWV of standing trees.

RESULTS AND DISCUSSION

Relationship between DBH and SWV of standing trees

Figure 1 shows the relationship between DBH and SWV of the 96 standing trees. A significant but weak, negative correlation was found between DBH and SWV of standing trees.

Carter *et al.* (2005) reported a weak negative trend between DBH and SWV in Douglas-fir. They also reported that the trend in the unthinned plot is less marked than in the thinned plot, although the trends converge for the larger diameter trees that were presumably in the dominant crown class. On the other hand, Ikeda and Arima (2000) found a weak negative correlation between DBH and SWV in standing trees of Japanese cedar. They concluded that Young's modulus is independent of the radial growth, because the obtained correlation is very weak. Koizumi *et al.* (1990) reported that no correlation was found between DBH and trunk MOE in Japanese larch trees. They concluded that parent trees having suitable performances for both growth and mechanical properties can be selected for propagation. Thus, the relationship between DBH and MOE is still unclear.

In general, there is a significant positive correlation between the SWV of standing trees and the DMOE of logs or the MOE of small clear specimens (Wang *et al.* 2001; Ishiguri *et al.* 2006). In the present study, as shown in Figure 1, a weak negative correlation between DBH and SWV was found, indicating that MOE might decrease as the DBH increases.

Log properties

Green density, SWV, and DMOE of logs from the five sample trees are shown in Table 3 and 4. Significant differences (ANOVA, 1% level) in the log properties were

Table 3. Average values of log properties, basic density, and fiber length in five sample trees and results of ANOVA.

Property	Min.	Ave.	Max.	SD	Significance
Log					
Green density (g/cm^3)	0.45	0.62	0.77	0.07	**
SWV (km/s)	3.72	4.15	4.45	0.17	**
DMOE (GPa)	5.03	7.73	9.38	1.29	**
Basic density (g/cm^3)	0.22	0.32	0.46	0.06	ns
Fiber length (mm)	0.69	1.07	1.27	0.15	**

Note: SWV, stress-wave velocity; DMOE, dynamic Young's modulus; ns, not significant; **, significant at 1% level.

Table 4. Average values of the log properties of each tree.

Tree No.	Green density (g/cm^3)	SWV (km/s)	DMOE (GPa)
1	0.62 b	4.13 b	7.52 b
2	0.65 a,b	4.21 a,b	8.46 a
3	0.64 b	4.28 a	8.72 a
4	0.52 c	3.93 c	5.62 c
5	0.68 a	4.19 a,b	8.55 a

Note: Average values followed by the same letter are not significantly different at the 5% level.

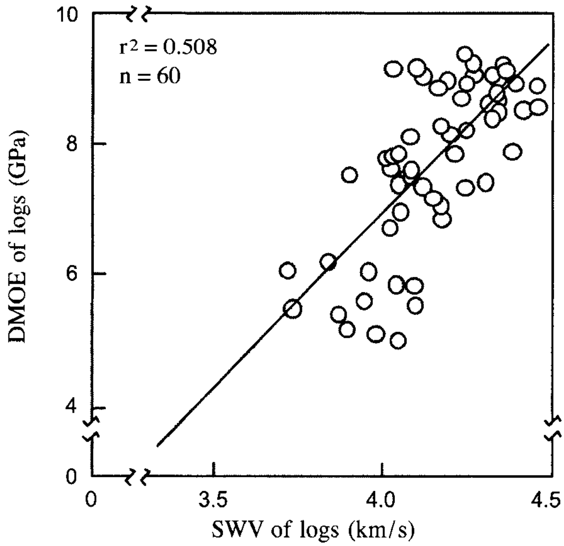

Figure 2. Relationship between the SWV and DMOE of logs.

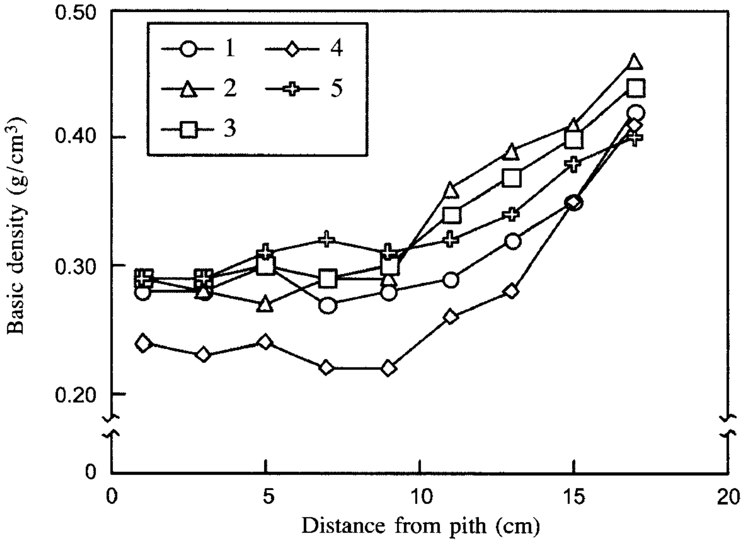

Figure 3. Radial variation of the basic density in five sample trees.

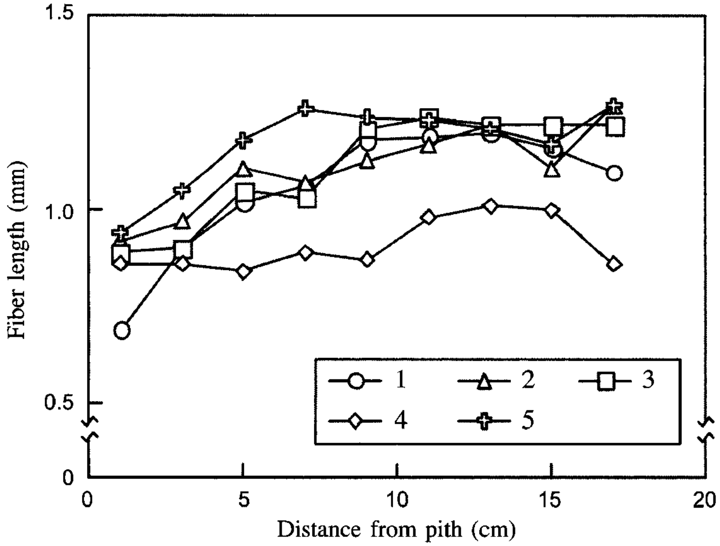

Figure 4. Radial variation of the fiber length in five sample trees.

observed among the trees. Tree No. 4 showed significantly lower values in the log properties than the other trees (Fig. 3 & 4; Table 4). These results indicate that, even though DBH showed almost the same value, the log properties differ among trees. The log properties are very important when plus trees are selected from plantations or natural forests in breeding for wood quality. Therefore, trees like tree No. 4 should be eliminated from tree breeding programs. The variation in DMOE suggests that tree breeding for wood quality of this species has a great potential.

As shown in Figure 2, a significant relationship between SWV and DMOE of logs is present. Iizuka *et al.* (2006) reported that there was a significant, positive relationship between SWV and DMOE of Japanese cedar logs. Our results are similar to their results. In addition, Wang *et al.* (2004) reported that grades estimated from log stress wave analysis corresponded to the lumber grades and concluded that logs with high stress wave grades produced high-grade lumbers. These results suggest that DMOE and SWV can be applied for evaluating mechanical properties of logs in *P. falcataria*.

Basic density and fiber length

Figure 3 shows the radial variation in the basic density of the five trees. Basic density showed an almost constant value within 10 cm of the pith and then increased with distance from the pith. There were almost no differences in the radial variation patterns of the five trees. In addition, no significant differences in the average value of the basic density were observed among the trees (ANOVA, 5% level, Table 3). The average value of the basic density of the five trees was 0.32 ± 0.06 g/cm^3 (Table 3). On the other hand, Wahydi *et al.* (2000) reported that in *P. falcataria* higher density values corresponded with the occurrence of tension wood. Similar results were reported by Shiokura and Lantican (1987). In our study we did not observe tension wood in the trunks of the five sample trees. Therefore the radial variation of basic density may be the result of some other anatomical changes in wood (*i.e.* decrease of the vessel frequency, increase of the cell wall thickness of wood fibers, *etc.*).

The radial variation in fiber length of the five sample trees is shown in Figure 4. The fiber length increased in the early stage of growth (up to 10 cm from the pith) and then showed an almost constant value. The trend was similar in all trees except for the No. 4 tree. Significant differences in fiber length were observed among the trees (Table 3; Fig. 3). The average value of the fiber length was 1.07 ± 0.15 mm. Shiokura and Lantican (1987) reported that the fiber length of *Albizia (Paraserianthes) falcataria* increased with distance from the pith up to 12 cm, and then maintained an almost constant value. As shown in Figures 3 and 4, the results of basic density and fiber length obtained in this study were similar to those of Shiokura and Lantican (1987).

The radial variation of the basic density and fiber length suggested that woods used in this experiment can be categorized as core wood or outer wood from a wood property viewpoint (Fig. 5). Table 5 shows the average values of the basic density and fiber

Table 5. Average values of basic density and fiber length.

Property	Position	Min.	Ave.	Max.	SD	Significance
Basic density	Core	0.22	0.28	0.32	0.03	**
(g/cm^3)	Outer	0.26	0.36	0.46	0.05	ns
Fiber length (mm)	Core	0.69	1.00	1.26	0.14	*
	Outer	0.86	1.15	1.27	0.11	**

Note: ns, not significant; *, significant at 5% level; **, significant at 1% level.

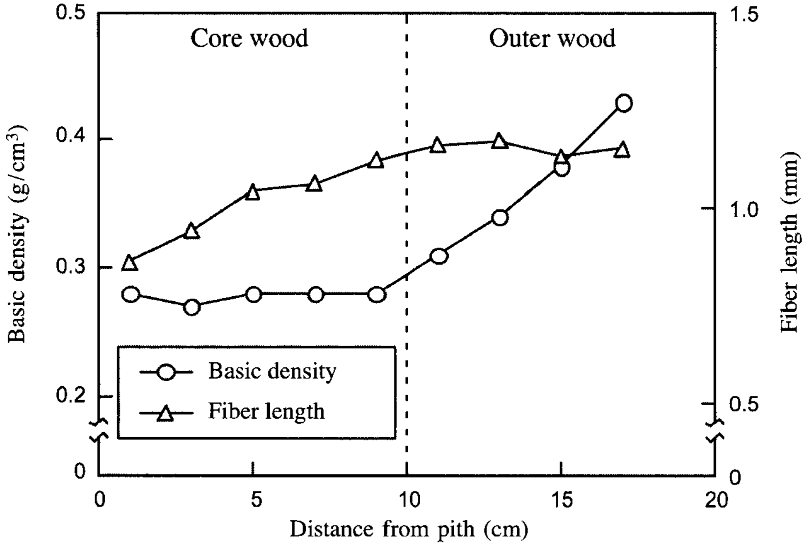

Figure 5. Boundary between the core wood and outer wood from the viewpoint of the radial variation of the basic density and fiber length. – Note: Values of basic density and fiber length are averaged values of five harvested trees. The dotted line indicates a boundary between core and outer wood.

length in core and outer wood. They were 0.28 and 0.36 g/cm^3 and 1.00 and 1.15 mm, respectively. In addition, significant differences in basic density and fiber length were observed in the trees, except for the basic density of outer wood. As shown in Table 3, there were no significant differences in basic density among the trees, when wood was not categorized into core and outer wood. However, when the wood was categorized into the core and outer wood, a significant difference in the basic density of core wood was observed among the trees (Table 5). These results suggest that the basic density of core wood is a very important factor for the selection of a plus tree in tree breeding for wood quality. In addition, it is very noteworthy that a significant difference in the basic density of the trees was observed exclusively in core wood, suggesting that the evaluation at a relatively early stage is possible to select high-density wood in *P. falcataria.*

CONCLUSION

This study demonstrated a significant variation in the growth rate and wood properties of *P. falcataria* trees. Log properties were different among trees. The DMOE and SWV can be used to evaluate the mechanical properties of *P. falcataria* logs. Significant differences in the basic density and fiber length were observed between the core and outer wood. In particular, the basic density of core wood showed significant differences among trees, suggesting that, in this species, it is possible to select a plus tree with high density wood at a relatively early stage. These results suggest that breeding for wood quality in *Paraserianthes falcataria* has a strong potential.

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