WOOD PROPERTY VARIATION IN *ACACIA AURICULIFORMIS* GROWING IN BANGLADESH

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Abstract. This study examined the radial variations of wood properties in 11-yr-old *Acacia auriculiformis* grown in Bangladesh having diameters of 222 ± 38 mm. The basic density, fiber length, and fiber length increment increased up to about 80 mm radial distance from the pith and then were almost constant toward the bark. The compressive strength (CS) increased from the pith to 50 mm and then became nearly constant to the bark. Conversely, the specific compressive strength, the ratio of CS to air-dried density, was almost constant from pith to bark, indicating positive relationships. However, the air-dried density explained only 50% variation of the CS. On the basis of radial variation of basic density, the core wood and outer wood boundary can be delineated at 70 – 90 mm from the pith. Similarly, the fiber length and fiber length increment curves showed that this boundary could be marked at 60 – 90 mm from the pith. The selected wood properties except CS varied significantly among the trees, which indicated the potential of tree selection for wood quality improvement through tree breeding.

Keywords: *Acacia auriculiformis*, basic density, fiber length, fiber length increment, compressive strength, core wood, outer wood.

INTRODUCTION

Acacia auriculiformis is a fast-growing tropical species that grows naturally in Australia, Papua New Guinea, and Indonesia (Pinyopusarerk et al 1991). The species is also planted in Malaysia and India as well as in some African countries such as Zaire, Tanzania, and Nigeria (Wickneswari and Norwati 1993; Shukla et al 2007). As an exotic tree in Bangladesh, *A. auriculiformis* grows quickly, has a high biomass yield, and adapts well to degraded soil conditions (Islam et al 1999). The government of Bangladesh is currently striving to establish plantations of fast-growing species to ensure an adequate wood supply to sustain the country's existing wood-based industries. Therefore, it is listed as a short-rotation species among the national priority species of the Bangladesh Forest Department (Islam 2003). A multipurpose tree, *A. auriculiformis* is used to provide shade, form windbreaks, and reduce soil erosion in agroforestry systems. Moreover, the wood has been used widely for charcoal, fuel, and pulp (Pinyopusarerk et al 1991; Ishiguri et al 2004) and is also recommended for tool handles, oars, paddles, packing cases, ammunition boxes, and small structures (Shukla et al 2007). Information on wood property variations is therefore essential for better utilization. Moreover, understanding the magnitude of wood property variations will provide a basis for the improvement of the species.

Research on wood properties in *A. auriculiformis* has been mainly concentrated on a few basic wood properties representing only mean values (Verghese et al 1999; Ishiguri et al 2004; Shukla et al 2007), except Kojima et al (2009), in which they reported the radial variation of the fiber length. However, comprehensive wood property variability has not yet been determined. Therefore, it is essential to understand the wood property variation to incorporate into tree-breeding programs to produce high-quality timber.

The objective of this study was to investigate the wood property variation in plantation-grown *A. auriculiformis* in Bangladesh. The radial variations of basic density, fiber and vessel element lengths, and compressive strength

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parallel to grain were investigated. In addition, the occurrence of core and outer wood was defined.

MATERIALS AND METHODS

Samples were collected from an 11-yr-old plantation in Cox's Bazar Forest Division, Bangladesh. The mean monthly rainfall and temperature in the area indicate a monsoonal climate with dry (November – April) and wet (May – October) seasons. The trees were grown from seedlings with a spacing of 2 × 2 m. Twenty trees were randomly harvested and 20 discs (13 50-mm thick; 7 100-mm thick) were collected at 1.3 m above ground level. Without bark, the mean tree diameter of the collected samples was 222 ± 38 mm.

To examine wood properties, thin radial strips (20-mm wide and 20-mm thick) were prepared from each disc. The strips were cut into small blocks at 10-mm intervals from pith to bark. These samples were used to measure basic density, fiber length, and vessel element length. Basic density was calculated as the ratio of oven-dry weight and green volume determined by water displacement (Ishiguri et al 2007). To measure the fiber length and vessel element length, the blocks were macerated with Schultz' solution (Ishiguri et al 2007). Fifty fibers and 30 vessel elements were measured for each sample under a microprojector (Nikon, V-12) with a digital slide caliper (Mitsutoyo, CD-30C).

Compressive strength parallel to grain (CS) was conducted according to Japanese Industrial Standards (JIS 1994). Small specimens [23 (R) × 23 (T) × 50 (L) mm] were prepared from 7 of 20 disks (100-mm thick). Air-dried density was measured before conducting the test at 11.0 ± 0.2% MC. CS of the samples was performed on a universal testing machine (Shimadzu, DCS-5000) with the load speed of 1 mm/min. The CS was calculated by dividing the maximum load by the area of the specimen. Specific compressive strength (SCS) was calculated as the ratio of CS to air-dried density.

RESULTS AND DISCUSSION

The mean annual growth rate at breast height was 22 mm and varied 15 – 27 mm among the sample trees. The growth rate was similar to that reported by Islam et al (1999), in which it was about 20 mm in 3-yr-old trees planted at another site (Chittagong) in Bangladesh. Although the growth rings were visible on the sanded disks, their numbers were inconsistent with plantation age. Therefore, we investigated variations of wood properties as a function of radial distance rather than tree age.

Basic density and fiber length gradually increased to about 80 mm from the pith and then was nearly constant to the bark (Figs 1 and 2). This type of radial gradient is because of the transition from juvenile/core to mature/outer wood, in which cambium maturity occurs after a certain stage of radial growth. The radial trends of both properties were quite similar in that less variable wood was produced after the same radial distance from the pith in the sampled trees regardless of tree diameter. Thus, the results indicate that radial variations of these properties are related to the growth rate, and therefore, accelerating radial growth from an early growing stage will tend to produce more homogeneous wood. Similarly, radially dependent basic density and fiber length variation has been described in *A. auriculiformis, A. mangium,* and *Paraserianthes falcataria* growing in

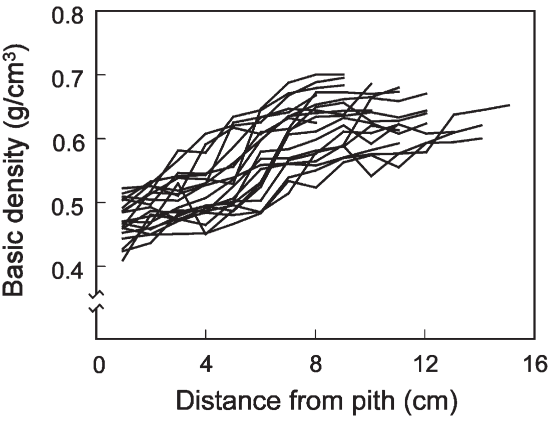

Figure 1. Radial variation of basic density with respect to distance from pith to bark.

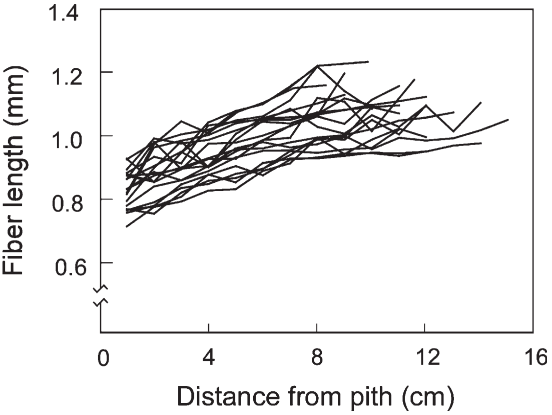

Figure 2. Radial variation of fiber length with respect to distance from pith to bark.

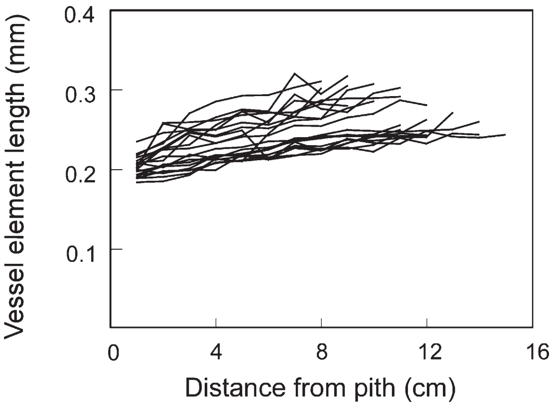

Figure 3. Radial variation of vessel element length with respect to distance from pith to bark.

Indonesia (Ishiguri et al 2007; Kojima et al 2009). Conversely, our results differed from Shukla et al (2007), in which they reported that wood property variation was related to tree age in *A. auriculiformis* growing in India, but by comparing only the mean values among three age groups (8-, 12-, and 13-yr-old).

Compared with fiber length (Fig 2), the vessel element length slightly increased up to about 70 mm from the pith and then had a nearly constant value to the bark (Fig 3). In the present study, radial variation of vessel element length was very similar to, but much less than, basic density and fiber length (Fig 3). This small variation in vessel element length is because of radial growth, but could also be from a small elongation of the fusiform initial (Baiely 1920; Honjo et al 2005), which accompanies cambial maturation.

In the present study, the mean basic density, fiber length, and vessel element length from pith to bark was 580 ± 60 kg/m^3, 0.99 ± 0.07 mm, and 0.24 ± 0.02 mm, respectively (Table 1). On the other hand, Shukla et al (2007) noted that the mean basic densities at breast height in 8- (122-mm DBH), 12- (136-mm DBH), and 13-yr-old (162-mm DBH) *A. auriculiformis* growing in India were 570, 600, and 620 kg/m^3, respectively. Despite methodological differences, the mean basic density obtained in our study was similar. The range of the mean fiber length of the present study was also similar to a previous study (Kojima et al 2009), in which they reported that the mean fiber length was 0.91 mm in 11-yr-old trees growing in Indonesia.

CS increased to 50 mm from the pith and then was nearly constant to the bark (Table 2). Hence, CS of wood produced near the pith can be considered to be somewhat lower than that of outer wood. In contrast to CS, the SCS was almost constant from pith to bark (Table 2). The stable SCS indicates that the CS was positively influenced by the air-dried density. However, the relationship between them was moderate with the air-dried density explaining 50% of the CS variation (Fig 4). It is widely assumed that strong relationships exist between mechanical properties and air-dried density (Kollmann and Côté 1984). Thus, further investigation is required with a larger number of samples to determine this relationship. In the present study, the mean value of CS was 66.0 ± 4.4 MPa (Table 1), which was higher than that found by Shukla et al (2007), who reported that in the air-dried condition, CS (12 MPa) was lowest in 8-yr-old trees, medium (45 MPa) in 12-yr-old trees, and highest (50 MPa) in 13-yr-old trees growing in India.

In this study, the core and outer wood boundaries were delineated by the radial variations in basic

Table 1. *Mean values of the wood properties and their variation among the trees.*

Properties	n	Min	Mean	Max	SD	Significance
Basic density (g/cm^3)	20	0.53	0.57	0.61	0.03	**
Fiber length (mm)	20	0.89	0.98	1.06	0.06	**
Vessel element length (mm)	20	0.22	0.24	0.28	0.02	**
Air-dried density (g/cm^3)	7	0.61	0.69	0.76	0.05	**
CS (MPa)	7	57.0	66.0	71.2	5.7	NS

** Significant at 1% level; NS, not significant.
n, number of sample trees; SD, standard deviation,

Table 2. *Radial variation of air-dried density, compressive strength (CS) and specific compressive strength (SCS).*

		Air-dried density (g/cm^3)		CS (MPa)		SCS	
Position	n	Mean	(Minimum – Maximum)	Mean	(Minimum – Maximum)	Mean	(Minimum – Maximum)
I	7	0.61	(0.53 – 0.68)	57.0	(51.1 – 62.5)	94.3	(81.1 – 102.8)
II	6[a]	0.67	(0.59 – 0.75)	66.6	(64.3 – 71.8)	100.5	(90.1 – 110.2)
III	7	0.70	(0.61 – 0.77)	66.3	(58.7 – 70.0)	94.4	(82.9 – 105.7)
IV	7	0.71	(0.65 – 0.78)	68.6	(61.6 – 74.7)	95.5	(90.4 – 98.7)
V	5[b]	0.76	(0.66 – 0.79)	71.2	(65.9 – 76.9)	93.9	(84.9 – 99.8)

[a] One sample was damaged as a result of compression failure.
[b] Radial distance only for five trees.
n, number of sample trees.
I, 0 to 2.5 cm; II, 2.5 cm to 5 cm; III, 5 to 7.5 cm; IV, 7.5 to 10 cm; V, 10 cm to 12.5.

density, fiber length (Ishiguri et al 2007; Chowdhury et al 2009), and fiber length increment of individual trees (Honjo et al 2005). The fiber length increment derived from the fusiform initials was from intrusive growth, calculated as the fiber length minus the vessel element length at the same sampling position (Honjo et al 2005). Because vessel elements show little elongation after differentiation from the fusiform initial cell (Baiely 1920), the vessel element length was taken as a substitute for the fusiform initial length. The fiber length increment increased from the pith to about 80 mm and then was nearly constant to the bark (Fig 5). As shown in Fig 5, the radial variation of fiber length increment had a similar pattern to those of basic density and fiber length (Figs 1 and 2). The radial variation curves of basic density indicated that there was a rapid increase to 70 – 90 mm from the pith and that this portion could be defined as core wood. Similarly, the fiber length and fiber length increment showed a rapid increase up to 60 – 90 mm from the pith, and this area could be designated core wood. Thus, the boundary found between core and outer wood at 60 – 90 mm from the pith depends on the property measured. In a study of the same species in Indonesia, Kojima et al (2009) divided core wood and outer wood at 75 – 133 mm from the pith based on radial variations in fiber length at 1.0, 0.7, 0.5, 0.3, and 0.1% elongation. Although the exact demarcation in hardwoods is arbitrary, the boundary in the present study is quite similar to the range of the previous study (Kojima et al 2009). Thus, the width of the core wood in this species can be expressed as a function of the growth rate when the wood is formed in the vicinity of the pith. Presently in Bangladesh, the rotation age of *A. auriculiformis* is 10 yr, and the material is mainly used for pulp and small construction. However, the results indicate that extension of the rotation age could produce more homogenous outer wood that could be used for structural material.

Table 1 shows variations of wood property among the sample trees. The studied wood properties varied significantly among the trees except the CS. Because the trees within the stand were the same age, had been planted at the same spacing, and received the same silvicultural treatments throughout their history, it is likely

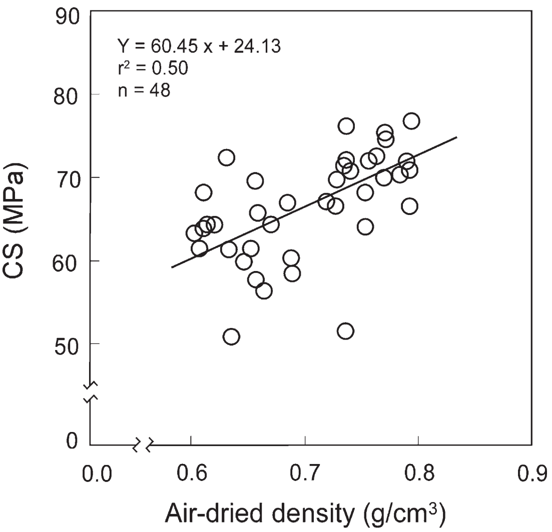

Figure 4. Relationship between air-dried density and compressive strength (CS) parallel to grain.

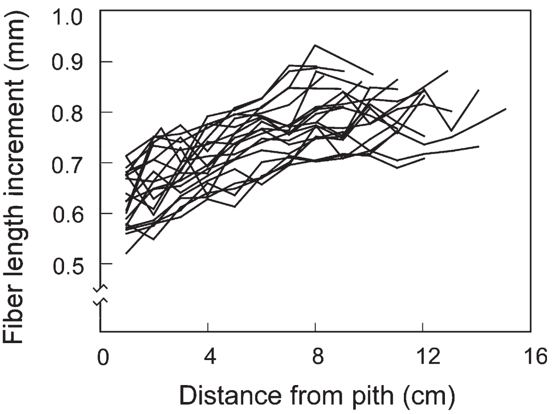

Figure 5. Radial variation of fiber length increment with respect to distance from pith to bark.

that a considerable degree of this variation was genetic. Thus, there is potential for wood quality improvement through tree breeding.

CONCLUSIONS

In this study, the radial variations of selected wood properties in *A. auriculiformis* were examined. From the pith to bark, radial variations of basic density and fiber length suggest that uniform wood formation starts after a certain radial distance (80 mm) from the pith. The variations of basic density and fiber length also indicate that the wood property variation in this species is radius-dependent. Therefore, accelerating growth from the early growing stage has positive implications in forest management to produce more uniform wood. Based on radial variation patterns of basic density, wood can be divided into two groups: core and outer wood, 70 – 90 mm from the pith. Similarly, fiber length and fiber length increment showed that the boundary ranged 60 – 90 mm from the pith. Significant variations among the trees were found in basic density, fiber and vessel element length, and air-dried density. Considerable variations in wood properties among the trees were of sufficient magnitude and could provide an opportunity to select trees for tree-breeding programs to improve the wood quality of this species.

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