Effects of age and height variation on physical properties of mangium (*Acacia mangium* Willd.) wood

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Summary

Moisture content, basic density, and tangential, radial and longitudinal shrinkage of wood were assessed in samples from three different heights in trees of *Acacia mangium* 10, 15 or 20 y old grown in Bangladesh. Mean initial moisture content was 73%, mean basic density 560 kg m^{-3}, and mean tangential, radial and longitudinal shrinkages were 6.7%, 3.2% and 0.3% respectively from green to oven-dry. There were no significant differences in moisture content, shrinkage and basic density with increasing height in the tree, but these properties (except longitudinal shrinkage) were affected by tree age. Wood with highest density was found in 20-y-old age class and the lowest in the 10-y-old age class.

Keywords: wood properties; moisture content; density, shrinkage; age; height; *Acacia mangium*

Introduction

Bangladesh is faced with the problem of a large gap between the supply of and demand for wood materials. Illegal cutting, high fire hazard, improper management and other degrading factors have resulted in poor supplies of wood being available from native forests. Extensive afforestation is thus required to provide a sustainable supply of forest products, as well as for environmental reasons. As in many other tropical countries, plantations of fast-growing species have become a necessity. *Acacia mangium*, an exotic species from Australia, is such a species now extensively planted in social forestry and agro-forestry in Bangladesh (Siddiqi and Ali 1994). Its relatively good tolerance of very poor soil, rapid growth, resistance to disease, high biomass production and good wood properties make it attractive for use in plantations. It has hard, pale yellow-brown heartwood with a narrow band of light-coloured sapwood, and close grain. The timber kiln-dries well without serious defects, and can be easily sawn, drilled, turned and polished. It is stable after drying (Razali and Hamami 1992); heartwood is moderately resistant to preservative treatment (Keating and Bolza 1982). The trees form large resources which are economically, environmentally and socially significant. The wood is being used extensively for pulp and paper; other uses include fuelwood, building materials, furniture and particleboard.

Information on wood structure and properties, and the influence of tree age on these, is required for better utilisation. In this study we assessed the effects of tree age and sample height in the stem on some physical properties of wood of *A. mangium* grown in Bangladesh.

Materials and methods

Samples were collected from Kula Ura range of Sylhet Forest Division, Bangladesh (a range is an administrative sub-unit of a Forest Division). The soils of the area are sandy to clay loam, and the area has a moist tropical climate characterized by a period of high precipitation from April to September and a comparatively dry period from November to March. With minor variation, humidity remains high at 70–85% throughout the year (Anon. 1998). Details of the site of the stand sampled, which was established on a denuded hillside, are given in Table 1.

A sample plot of 10 m x 10 m (0.01 ha) was established in each of the three age classes of the plantation to be assessed — 10 y old, 15 y old and 20 y old. At least two rows of trees separated the plots from the edge of the stand. The diameter at breast height over bark (dbhob) of all trees within each plot was measured, and six trees with diameter around the mean dbhob were randomly selected from each of the three plots.

After felling, each bole was cut, if possible, into three 3-m logs (butt, middle and top), with 48 mm minimum diameter over bark. In the 10-y-old trees the total log length was only 8.24 m and the top log was consequently shorter. Details of the total log length and mean mid-point diameter of the three logs in each age class are given in Table 2. A sub-log about 500 mm long was cut from

Table 1. Characteristics of the site of the sampled plantation of *Acacia mangium* (Anon. 1998)

Characteristic	Value
Altitude (m)	30
Slope (%)	20
Annual rainfall (mm)	3987
Min. to max. temperature (°C)	21.0–26.4

Table 2. Characteristics of logs from the sample trees of *Acacia mangium*

Log dimensions	Age class (y)		
	10	15	20
Mean total length in tree (m)	8.24	9.20	10.40
Mean mid-point diameter (cm)	6.75	7.01	7.50

an internodal area clear of knots and other defects or injury in the centre of each log, and a bark-to-pith longitudinal section 25 mm thick was removed. Three 25 mm (tangential) x 25 mm (radial) x 100 mm (longitudinal) specimens were prepared from each section of the tree.

Moisture content was measured using the oven-dry method, and shrinkage in the three dimensions was evaluated as the percentage dimensional change from green to oven-dry condition. Oven-dry measurements were taken after drying to constant weight at 103 ± 2°C, which took 24 h. The dimensions in green and oven-dry condition were measured by Vernier caliper to an accuracy of 0.01 mm, and weights were measured by electronic balance to an accuracy of 0.01 g. Basic density was estimated from specimens based on oven dry weight and green volume, with the volume measurements made by the water displacement method.

The data were analysed by ANOVA, followed by a factorial analysis to determine the effects of age and height on moisture content, basic density and shrinkage. Duncan's Multiple Range Test (DMRT) was used for comparison among the age groups.

Results and discussion

The amount of water in wood affects weight, decay susceptibility, permeability, strength, electrical conductivity, thermal conductivity and dimensional stability. In this study, mean initial moisture content of *Acacia mangium* was 73%, while tangential, radial and longitudinal shrinkage from green to oven-dry were 6.7%, 3.2% and 0.3% respectively (Table 3).

Peh and Khoo (1984) reported moisture content of 119% for the species when grown in Sabah, Malaysia.

Initial moisture content varied with age of the tree, but not consistently with height in the tree (Table 3). The amount of shrinkage and swelling is affected by the amount of moisture lost or gained by wood when its moisture content fluctuates between the oven-dry state and fibre saturation point. The relationship is linear and applies in tangential, radial and longitudinal directions, and therefore to volumetric changes (Tsoumis 1991).

Table 3 shows mean values for tangential shrinkage of 6.4–7.1%, radial shrinkage of 3.1–3.3% and longitudinal shrinkage of 0.3–0.5%. Panshin and de Zeeuw (1980) indicated that tangential shrinkage is generally about double radial shrinkage, and this study gave such results. Kollman and Cote (1968) explained that shrinkage differs in tangential and radial directions due to the restraining effect of the rays and the effects of fibril angle in the cell walls, while Schniewind (1989) considered that the variation between shrinkage of different surfaces was due to cellular structure and physical organization of cellulose chain molecules within the cell walls.

Razali and Hamami (1992) considered that *Acacia mangium* wood is fairly stable, and quoted green to oven-dry tangential shrinkage of 6.4% and radial shrinkage of 2.7%. Peh and Khoo (1984) found tangential shrinkage of 8.5% and radial shrinkage of 2.5%. Tangential and radial shrinkage did not vary significantly with increasing height in the tree, but did vary with age (Table 5). Longitudinal shrinkage did not vary significantly with either age or height.

Wood density is an important indicator of the strength properties of wood. In this study, the mean basic density of *Acacia mangium* among different age groups was 520–600 kg m^{-3}, the maximum being observed in wood from 20-y-old trees and the minimum in wood from 10-y-old trees (Table 4). In comparison, Hagde (1987) reported a basic density of 400–600 kg m^{-3} for the species grown in India, and Razali and Hamami (1992) reported values of 500–600 kg m^{-3} from Malaysia. With regard to air-dry density, Keating and Bolza (1982) reported 645–720 kg m^{-3} for samples from Australia, almost certainly from natural stands, and 575–640 kg m^{-3} for samples from plantations in Malaysia.

The basic density decreased with increasing height in the tree. This trend may be attributable to the thicker walls of fibres in mature wood in the butt, as reported by Mitchell and Denne (1997) for Sitka spruce. However, the analysis of variance indicated that height did not significantly affect basic density, while tree age did have a significant effect (Table 5).

Table 3. Moisture content and shrinkage of *Acacia mangium* wood from trees of different ages and height in the stem (mean ± SD)

Age group (y)	Position	Moisture content, green (%)	Shrinkage from green to oven dry (%)		
			Tangential	Radial	Longitudinal
10	Bottom	74 ± 2.4	6.8 ± 0.45	3.1 ± 0.32	0.3 ± 0.10
	Middle	76 ± 2.3	7.0 ± 0.44	3.1 ± 0.32	0.4 ± 0.09
	Top	77 ± 2.3	7.1 ± 0.44	3.2 ± 0.33	0.5 ± 0.10
	Average	75 ± 2.3	7.0 ± 0.44	3.1 ± 0.32	0.4 ± 0.10
15	Bottom	72 ± 2.2	6.5 ± 0.47	3.3 ± 0.30	0.3 ± 0.12
	Middle	76 ± 2.2	6.5 ± 0.45	3.3 ± 0.31	0.3 ± 0.10
	Top	75 ± 2.2	6.8 ± 0.46	3.3 ± 0.30	0.3 ± 0.12
	Average	74 ± 2.2	6.6 ± 0.45	3.3 ± 0.30	0.3 ± 0.11
20	Bottom	65 ± 2.4	6.0 ± 0.39	3.3 ± 0.36	0.3 ± 0.10
	Middle	73 ± 2.4	6.5 ± 0.42	3.2 ± 0.36	0.3 ± 0.10
	Top	74 ± 2.4	6.6 ± 0.43	3.3 ± 0.36	0.3 ± 0.10
	Average	71 ± 2.4	6.4 ± 0.41	3.3 ± 0.36	0.3 ± 0.10
Mean		73 ± 2.3	6.7 ± 0.43	3.2 ± 0.33	0.3 ± 0.10

Table 4. Basic density (kg m^{-3}) of *Acacia mangium* wood from trees of different ages and height in the stem (mean ± SD)

Age group (y)	Log position in stem: Butt	Middle	Top	Mean
10	550 ± 120	510 ± 100	500 ± 110	520 ± 110
15	570 ± 110	560 ± 120	550 ± 90	560 ± 110
20	620 ± 120	600 ± 110	590 ± 120	600 ± 120
Mean	580 ± 110	560 ± 120	550 ± 110	560 ± 110

Table 5. Summary of ANOVA tests of some physical properties of *Acacia mangium*

Source of variation	Moisture content	Shrinkage: Tangential	Radial	Longitudinal	Basic density
Age	**	*	*	NS	**
Height	NS	NS	NS	NS	NS

*Significant at $P < 0.05$; **significant at $P < 0.01$; NS = not significant

Table 6. Physical properties of different age classes of *Acacia mangium*

Property	Age class (y): 20	15	10
Moisture content (%)	71	74	75
Tangential shrinkage (%)	6.4 a	6.6 a	7.0 b
Radial shrinkage (%)	3.3 a	3.3 a	3.1 b

Means with the same letter are not significantly different from each other. Differences are significant at $P < 0.001$.

Duncan's Multiple Range Test (DMRT) test showed that variations in physical properties were not significant between the 20-y-old and 15-y-old age classes, but the 10-y-old age class varied significantly from the other two classes ($P < 0.001$; Table 6).

Conclusion

Moisture content, shrinkage and basic density of *Acacia mangium* were not affected significantly by increasing height in the tree, but these properties, with the exception of longitudinal shrinkage, varied significantly with tree age. As expected, the wood from 20-y-old trees was denser than wood from 10-y-old trees.

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