FIBRE MORPHOLOGY AND PHYSICAL PROPERTIES OF 10-YEAR-OLD SENTANG (*AZADIRACHTA EXCELSA*) PLANTED FROM ROOTED CUTTINGS AND SEEDLINGS

AS Nordahlia[1, *], S Ani[1], A Zaidon[2] & S Mohd Hamami[2]

[1]*Forest Research Institute Malaysia, 52109 Kepong, Selangor Darul Ehsan, Malaysia*
[2]*Faculty of Forestry, Universiti Putra Malaysia, 43400 Serdang, Selangor Darul Ehsan, Malaysia*

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NORDAHLIA AS, ANI S, ZAIDON A & MOHD HAMAMI S. 2011. Fibre morphology and physical properties of 10-year-old sentang (*Azadirachta excelsa*) planted from rooted cuttings and seedlings. Fibre morphology and physical properties of 10-year-old sentang *(Azadirachta excelsa)* planted from rooted cuttings and seedlings were determined and compared. Results obtained would determine the appropriate planting technique of sentang to produce high quality timber. Wood produced from rooted-cutting tree had longer and larger fibres as well as thicker fibre walls compared with wood from seedlings. With regard to shrinkage, seedling-planted wood had lower longitudinal and volumetric shrinkages than rooted-cutting wood. However, the radial and tangential shrinkages did not differ significantly. Fibre morphology decreased significantly with height, while basic densities and shrinkages decreased from the bottom to the middle of the trunk and then increased towards the top in both types of wood.

Keywords: Fibre length, fast growth, planting technique, plantation, vegetative propagation

NORDAHLIA AS, ANI S, ZAIDON A & MOHD HAMAMI S. 2011. Ciri-ciri morfologi gentian dan fizikal kayu sentang berusia 10 tahun yang ditanam daripada keratan berakar dan biji benih. Ciri morfologi gentian dan ciri fizikal kayu sentang berusia 10 tahun yang ditanam daripada keratan berakar dan biji benih ditentukan dan dibandingkan. Hasil yang diperoleh akan menentukan teknik penanaman sentang yang sesuai untuk menghasilkan kualiti kayu balak yang tinggi. Kayu yang dihasilkan daripada pokok teknik keratan berakar mempunyai gentian yang lebih panjang dan lebih besar serta dinding gentian yang lebih tebal berbanding kayu daripada biji benih. Teknik biji benih menghasilkan kayu yang mempunyai pengecutan membujur dan pengecutan isi padu yang lebih rendah berbanding teknik keratan berakar. Bagaimanapun, pengecutan jejari dan tangen tidak menunjukkan perbezaan signifikan. Ciri morfologi gentian menurun secara signifikan dengan ketinggian, manakala ketumpatan asas dan pengecutan menurun dari bahagian bawah ke bahagian tengah batang dan kemudian meningkat ke bahagian atas pada kedua-dua jenis kayu.

INTRODUCTION

Forest plantations which are capable of yielding high volumes of timber per unit area and have shorter rotations relieve the pressure from over harvesting of natural forests and help supplement future wood supply. In Malaysia, these plantation species were selected based on their growth performance, availability of seeds or planting stocks, ability to grow under plantation conditions, resistance to pests and diseases, and most importantly, their market potential (Ahmad Zuhaidi et al. 2002). Trees for plantation can be planted by seeds or by different kinds of vegetative propagation, namely, rooted cutting and tissue culture (Aminah et al. 2002).

Rooted cutting and tissue culture are used as an alternative planting material to seedling because some tree species do not fruit regularly, have poor seed viability or produce recalcitrant seed. Vegetative propagation can provide a regular supply of planting stock in large quantities with characteristics that the plantation desire. Diameter and height growths of trees planted using vegetative propagation have been reported to be promising (Ahmad Zuhaidi et al. 2002, Veenin et al. 2005). The wood produced from this technique also has higher quality wood properties than wood from seedling trees. Vegetative propagation has less juvenile wood

*E-mail: nordahlia@frim.gov.my

and a narrower juvenile wood zone than wood cut from seedling trees (Leal et al. 2003, Rao et al. 2003, Veenin et al. 2005). Its basic density was also reported to be higher than wood grown from seedling (Cown et al. 2002).

Sentang *(Azadirachta excelsa)* is one of the species promoted as plantation tree in Malaysia (Krishnapillay & Appanah 2002). At the Forest Research Institute Malaysia (FRIM), this species was planted via rooted cutting in 1997. After 10 years, these trees showed different growth rates, i.e they were superior in terms of growth rate and had more uniformity than trees from seeds. This study was undertaken to gather information on fibre morphology and physical properties of 10-year-old sentang which has been planted from rooted cutting technique. Results obtained were compared with properties of wood from seedling trees. This information is important to determine suitable end products that can be produced from the wood.

MATERIALS AND METHODS

Field sampling

A total of six 10-year-old sentang trees were randomly extracted from Bukit Hari, FRIM; three trees which were planted from seedlings were felled from plot 48 and another three trees from rooted cuttings were felled from plot 44. The logs were then cut at 1.5 m length into three tree heights, namely, bottom, middle and top to ensure uniform sampling for all trees. At each height level, two 5-cm thick discs were cut and wrapped in plastic and stored in a freezer for fibre morphology and physical properties studies.

Fibre morphology determination

A wood block (10 × 10 × 15 mm) was cut from the sapwood and heartwood portions of each tree height. They were then split into matchstick size pieces before being macerated using a mixture of 30% hydrogen peroxide:glacial acetic acid at a ratio of 1:1 at 45 °C. Macerated fibres were thoroughly mixed and were spread on a glass slide. The quantitative parameters, namely, fibre length, fibre diameter, fibre lumen diameter and fibre wall thickness were measured from the slides using a microscope (Olympus). Magnifications of 40× were used for fibre length and 400× for fibre diameter and fibre lumen diameter. The fibre wall thickness was obtained by subtracting the value of fibre lumen diameter from fibre diameter and dividing by two.

Physical properties determination

Samples of size 20 mm in radial × 20 mm in longitudinal × 40 mm in tangential directions were cut from the woods for analyses of basic density and shrinkage. Test samples were cut in accordance with British Standards 373 (BS 1957). Basic density was determined on the basis of oven-dry weight and green volume.

The shrinkage test was conducted in green to oven-dry conditions. The radial, tangential and longitudinal sections of each sample were marked and measured with a pair of digital vernier callipers to the nearest 0.01 mm. All samples were then placed in an oven maintained at 103 ± 2 °C for 48 hours. The oven-dry dimensions were measured along the points marked earlier. Shrinkage was calculated using the following equations:

$$S_o\ (\%) = \left(\frac{D_i - D_o}{D_i}\right) \times 100$$

where S_o = shrinkage from green to oven-dry conditions, D_i = initial dimension (mm) and D_o = oven-dry dimension (mm).

Statistical analysis

Statistical analysis was carried out using Statistical Analysis Software package (SAS version 6.12, 1996). Analysis of variance (ANOVA) was used to determine if the differences in means were significant. If the differences were significant, least significant difference (LSD) test was used to determine which of the means were significantly different from one another. The relationship between fibre morphology and physical properties was analysed using simple correlation analysis.

RESULTS AND DISCUSSION

Fibre morphology

Fibre morphology of the 10-year-old sentang grown from seedlings and rooted cuttings is given in Table 1. The mean fibre length, diameter, lumen diameter and wall thickness of wood from trees grown from rooted cutting were 1064, 19.6, 13.3 and 3.15 µm. The values for trees grown from seedlings were 975, 16.8, 11.2 and 2.8 µm respectively. Results showed that rooted-cutting wood had longer and thicker cells than seedling wood which indicated that the formation of cells in the former occurred at a shorter period. Similar results were also reported by Sharma et al. (2005) and Veenin et al. (2005) for seven-year-old *Eucalyptus tereticornis* and six-year-old *E. camaldulensis* respectively, both of which were tissue-cultured trees and had longer cells compared with seedling trees. In vegetative propagation (rooted cutting, tissue culture), vegetative materials are taken from a parent tree in which the cells have attained a certain age as compared with seedling where cells grow afresh thus contributing to the longer period required in cell formation (Rao et al. 2003, Veenin et al. 2005).

Fibre length, diameter, lumen diameter and wall thickness decreased significantly at $p \leq 0.05$ with height in both types of wood, except for fibre lumen diameter for samples taken from the bottom and middle positions (Table 1). This typical trend in fibre morphology along the stem was also reported by Lathsamy (1998) in 42-year-old plantation sentang. However, our results contradicted findings by Lim and Gan (2000) for eight-year-old plantation sentang where there was no specific trend in the variation of fibre length, diameter and wall thickness with height. The decreasing trend of fibre morphology towards the top was also observed in other fast-growing species such as 10-year-old *E. citriodorata* and 15-year-old *E. globulus* (Quilho et al. 2000, Bao et al. 2001). This decreasing trend is due to the increase in the proportion of juvenile wood from bottom towards the top (Taylor & Wooten 1973, Zobel & van Buijtenan 1989, Bowyer et al. 2003). Variations in fibre morphology in this study may also be due to variation in the amount of hormones with tree height (Zobel & van Buijtenan 1989, Quilho et al. 2000).

Physical properties

Results of this study showed that the basic density of wood was not significantly affected ($p \leq 0.05$) by the propagation technique, with values of 496 and 495 kg m^{-3} for seedling wood and rooted-cutting wood respectively (Table 2). Theoretically, wood from rooted-cutting technique should give higher basic density than wood from seedling trees as vegetative materials used in the culture are derived from high quality mother trees. Bosman (1997) and Cown et al. (2002) proved this in an experiment using 6-year-old *Shorea* spp. and 27-year-old *Pinus radiata* whereby wood cut from vegetative propagation trees had higher basic density than wood cut from seedling trees.

Table 1 Fibre morphology along tree height of 10-year-old sentang grown from seedlings and rooted cuttings

Propagation technique	Height level	Fibre length (µm)	Fibre diameter (µm)	Fibre lumen diameter (µm)	Fibre wall thickness (µm)
Seedling	Bottom	1045 a	17.7 a	11.4 a	3.2 a
		(148)	(3.09)	(2.79)	(0.92)
	Middle	991 b	16.8 b	11.3 a	2.7 b
		(135)	(3.15)	(2.93)	(0.80)
	Top	890 c	15.8 c	10.8 b	2.5 c
		(144)	(3.24)	(3.10)	(0.80)
	Mean	975	16.8	11.2	2.8
Rooted cutting	Bottom	1126 a	21.1 a	13.9 a	3.6 a
		(143)	(3.58)	(3.12)	(1.12)
	Middle	1083 b	19.8 b	13.4 a	3.2 b
		(143)	(3.69)	(3.60)	(0.99)
	Top	985 c	18.0 c	12.7 b	2.7 c
		(159)	(3.69)	(3.54)	(0.97)
	Mean	1064	19.6	13.3	3.2

Means followed by the same letter in the same column are not significantly different at $p \leq 0.05$; values in parentheses are standard deviations; number of sampling fields = 1800

Table 2 Physical properties along tree height of 10-year-old sentang grown from seedlings and rooted cuttings

Propagation technique	Height level	Basic density (kg m^{-3})	Shrinkage from green to oven dry (%)			
			Tangential	Radial	Longitudinal	Volumetric
Seedling	Bottom	520 a	6.86 a	4.61 a	0.38 a	11.00 a
		(40.6)	(0.94)	(0.87)	(0.37)	(1.08)
	Middle	483 b	5.65 b	3.16 b	0.30 a	8.62 c
		(33.5)	(0.66)	(1.19)	(0.21)	(1.28)
	Top	484 b	5.91 b	3.50 b	0.38 a	9.04 b
		(23.3)	(0.78)	(1.22)	(0.18)	(1.22)
	Mean	496	6.14	3.80	0.35	9.55
Rooted cutting	Bottom	510 a	7.16 a	4.15 a	0.54 a	11.3 a
		(33.5)	(1.64)	(0.98)	(0.52)	(1.76)
	Middle	476 c	5.48 c	3.55 b	0.36 a	9.00 b
		(26.3)	(1.22)	(0.93)	(0.31)	(1.67)
	Top	498 b	6.06 b	4.11 a	0.50 a	10.20 a
		(25.4)	(1.02)	(0.88)	(0.27)	(1.40)
	Mean	495	6.20	3.90	0.48	10.02

Means followed by the same letter in the same column are not significantly different at $p \leq 0.05$; values in parentheses are standard deviations; number of samples = 360

Rooted-cutting wood was found to have higher longitudinal and volumetric shrinkages than the seedling wood from green to oven-dry conditions as shown in Table 2. However, the total tangential and radial shrinkages did not differ significantly ($p \leq 0.05$) between these two woods. Higher longitudinal and volumetric shrinkages in rooted-cutting wood were possibly due to the thicker fibre wall compared with seedling wood. Thicker fibre wall in wood is responsible for higher shrinkage (Rao et al. 2003). A similar result was also recorded for 30-year-old *Eucalyptus* sp. and 10-year-old *E. tereticornis* where wood from vegetative propagation had higher shrinkage compared with seedling wood (Kothiyal et al. 1998, Sharma et al. 2005).

Basic densities and shrinkages in both types of wood decreased from the bottom to the middle of the trunk and then increased towards the top (Table 2). However, at longitudinal direction shrinkages from green to oven-dry conditions in the rooted-cutting and seedling woods showed no significant differences ($p \leq 0.05$) along the tree height. The shrinkage variation along the tree height in both wood types was associated with the variation in basic density whereby wood with higher basic density, i.e. the bottom portion, shrank more than wood with lower basic density.

The trend of basic density seen in the present study has also been reported for 5-, 8- and 10-year-old plantation sentang (Lim & Gan 2000, Lim et al. 2001, 2002). However, a continuous decreasing trend from bottom to the top portions has been reported for 42-year-old plantation sentang (Lathsamy 1998) and other fast-growing species such as 9-year-old *Acacia mangium* (Moya & Muñoz 2010). Thick fibre walls in the bottom portions of both the seedling and rooted-cutting woods contribute to the high density at the bottom portion. In addition, the higher basic density could also be due to the longer fibre length at the bottom in both types of wood. Basic density decreased in the middle portion of the trunk due to the decrease of fibre wall thickness and fibre length. This was confirmed by the correlation analysis where fibre length and fibre wall were positively correlated with basic density in both types of wood (Table 3). However, basic density was found to increase slightly upwards in both types of wood while fibre wall and fibre length continued to decrease. This observation contradicted results reported by Bowyer et al. (2003), who demonstrated that higher basic density was always related to longer fibre length and thicker fibre wall. It is clear that relationships among dimensions of several different cell types

Table 3 Correlations between fibre morphology and physical properties of the 10-year-old sentang grown from seedlings and rooted cuttings

Propagation technique	Fibre morphology and physical properties	Basic density	Shrinkage			
			T	L	R	V
Seedling	Fibre length	0.20 *	0.14 *	0.12 *	0.32 **	0.34 **
	Fibre diameter	0.14 ns	0.20 *	0.10 ns	0.18 *	0.22 **
	Fibre lumen diameter	0.20 *	0.05 ns	0.07 ns	0.13 ns	0.12 ns
	Fibre wall thickness	0.10 *	0.14 ns	-0.08 ns	0.06 ns	0.13 ns
	Basic density	1	-0.20 *	-0.07 ns	-0.04 ns	-0.06 ns
	Tangential shrinkage		1	0.10 ns	0.40 **	0.71 **
	Longitudinal shrinkage			1	0.06 ns	0.20 **
	Radial shrinkage				1	0.86 **
	Volumetric shrinkage					1
Rooted cuttings	Fibre length	0.10 *	0.11 *	0.05 ns	0.06 ns	0.08 ns
	Fibre diameter	0.07 ns	0.09 ns	0.08 ns	0.12 *	0.06 ns
	Fibre lumen diameter	0.03 ns	0.08 ns	0.09 ns	0.07 ns	0.04 ns
	Fibre wall thickness	0.24 **	0.08 ns	0.08 ns	0.15 *	0.06 ns
	Basic density	1	-0.08 ns	-0.08 ns	-0.08 ns	-0.24 **
	Tangential shrinkage		1	0.10 ns	0.08 ns	0.71 **
	Longitudinal shrinkage			1	0.05 ns	0.36 **
	Radial shrinkage				1	0.32 **
	Volumetric shrinkage					1

* = significant at $p \leq 0.01$, ** = significant at $p \leq 0.05$, ns = not significant; T = tangential, R = radial, L = longitudinal, V = volumetric; number of samples = 360

in hardwoods are independent of one another or often very weakly correlated with each other as shown by the high density of red maple which was associated with short fibres (Zobel & van Buijtenan 1989).

CONCLUSIONS

Results of this study concluded that fibre morphology of wood cut from rooted cutting trees are better than wood cut from seedling trees due to the longer fibre length and thicker fibre wall thickness. On the other hand, basic density, total tangential and radial shrinkage from green to oven-dry conditions of wood cut from rooted-cutting trees were similar to the wood cut from seedling trees. This reflects that rooted cutting can be used as an alternative source of planting material for sentang in forest plantation besides propagation from seeds. In addition, high quality planting stocks can be produced using cutting materials from selected mother trees known to have high quality wood. However, further research is needed to determine fibre morphology and physical properties of mature trees propagated from rooted cuttings since the 10-year-old trees examined in this study are considered juvenile, possibly with different wood properties.

Based on the present findings, sentang at the age of 10 years old with low density and thin fibre wall is considered suitable for light duty purposes such as joinery works, furniture component, panelling, veneer and plywood. Thus, industries do not have to wait for the trees to reach the 15-year rotation. Nevertheless, we need to acknowledge that mature trees have higher potential for wider scope of uses.

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