VARIATION IN ANATOMICAL PROPERTIES OF THREE MALAYSIAN BAMBOOS FROM NATURAL STANDS

Abd. Latif Mohmod & Mohd. Tamizi Mustafa

Forest Research Institute Malaysia, Kepong, 52109 Kuala Lumpur, Malaysia

Received August 1992

ABD. LATIF MOHMOD & MOHD. TAMIZI MUSTAFA. 1992. Variation in anatomical properties of three Malaysian bamboos from natural stands. The variation in anatomical characteristics with reference to the distribution and size of the vascular bundles and fibre dimensions of 1- to 3-y-old *Bambusa blumeana, B. vulgaris* and *Gigantochloa scortechinii* was investigated. With the exception of the radial/tangential ratio of vascular bundles in *B. blumeana* and *B. vulgaris,* and the fibre length of *G. scortechinii,* all the anatomical properties studied were insignificantly correlated with age and height of the culms.

Key words: Malaysian bamboos - natural stands - age - height - anatomical properties

ABD. LATIF MOHMOD & MOHD. TAMIZI MUSTAFA. 1992. Kepelbagaian sifat-sifat anatomi tiga buluh dirian asli Malaysia. Kepelbagaian sifat-sifat anatomi terutama pada aspek ukuran dan taburan berkas vaskular serta dimensi gentian pada *Bambusa blumeana, B. vulgaris dan Gigantochloa scortechinii* yang berumur satu hingga tiga tahun dibincangkan. Semua sifat-sifat anatomi yang dikaji didapati tidak mempunyai hubungan yang nyata dengan umur dan ketinggian batang-batang buluh (melainkan nisbah radial/tangen berkas-berkas vaskular di dalam *B. blumeana* dan *B. vulgaris* serta panjang gentian pada *G. scortechinii*).

Introduction

In Malaysia, bamboo is found in abundance although widely scattered in about 5% of the total forest reserve area (Abd. Latif 1987). It has, however, received comparatively little research attention. Forest management in Malaysia, for instance, has not given due emphasis to bamboo as an industrial resource to be exploited systematically. Traditionally, bamboo has been considered a weed in forestry practice such that attempts were made to prevent or control its growth (Abd. Latif & Abd. Razak 1991).

Due to the current demand for disposable items such as chopsticks, the bamboo machine intensive bamboo industry has been booming over the last five years (Abd. Latif & Ashaari 1991). This has encouraged the import of Taiwanese and Japanese made machines for processing Malaysian bamboos. As a result, bamboo is being extensively exploited to meet the demand from consumer countries particularly Japan, the Republic of Taiwan and Korea (Aminuddin & Abd. Latif 1991). Although the number of mills has increased, the Malaysian Department of Statistics reported that Peninsular Malaysia exported only about RM 0.48 million (FOB) worth of bamboo products in 1991, that is approximately less than 1% of the global market. The primary reason for this minuscule export quantity is that the quality of locally made bamboo products is considered relatively poor to meet the high standard imposed by the importing countries. This setback is related to indiscriminate harvesting of bamboo without much consideration given to its basic properties and final intended usage.

The importance of anatomical characteristics and its influence on bamboo and bamboo products cannot be overlooked. Fibre length, for example, influences the physical and mechanical properties, and therefore, the toughness, workability and durability of the material (Parameswaran & Liese 1976, Espiloy 1987, Abd. Latif *et al.* 1990, Abd. Latif *et al.* 1991). In this context, the variation in anatomical properties of three commonly used Malaysian bamboos, *viz Bambusa blumeana, B. vulgaris* and *Gigantochloa scortechinii,* was studied to assess their potential use and to serve as a basic guide for some specific applications.

Materials and methods

Nine bamboo samples, one to three years of age, from each species growing in the Forest Research Institute Malaysia (FRIM), were cut at about 30 *cm* above ground level. Each stem was then marked and cut at about 4.0 *m* interval into basal (B), middle (M) and top (T) portions. From both ends of each portion, bamboo disks of about 2 × 1 *cm* × thickness and 1 × 1 *cm* × thickness were cut for the determination of vascular bundles distribution and fibre dimensions respectively.

The methods used for the determination of distribution of vascular bundles were based on the methods outline by Jane (1933). Measurements of the fibre dimensions were made on macerated fibres obtained after treating with Jeffrey's solution (50-50 mixture of 15% nitric acid and 10% chromic acid) as suggested by Wilson (1954). Three slides were prepared from each sample. About a hundred complete and straight fibres in between the parallel lines of the slide were measured using a flexible millimeter scale.

Results and discussion

The anatomical properties of the three bamboo species of the three age groups and at different portions of the culm are presented in Table 1. The summary of analyses of variance of the properties is given in Table 2. Table 3 gives the correlation coefficients of different anatomical properties with age and height of bamboo. For convenience, each anatomical property is discussed individually below. The anatomical properties discussed include distribution and radial/ tangential ratio of vascular bundles, fibre length and fibre wall thickness.

Variation in vascular bundles distribution

The vascular bundles of all the three species were examined and classified. According to the classification of vascular bundles by Grosser and Liese (1971), *B. blumeana* may be categorised under Type III consisting of one central vascular strand and single fibre strand. *B. vulgaris* and *G. scortechinii,* however, are both classified as Type IV, that is, each vascular bundle consists of three parts, namely a central vascular strand accompanied by two fibre strands which are located outside and inside the central strand.

Table 1. Anatomical properties of the three bamboo species

Bamboo	Age (y)								
	1			2			3		
	Butt	Middle	Top	Butt	Middle	Top	Butt	Middle	Top
	Vascular bundle: Distribution (number per cm^2)								
a	212	200	290	247	258	365	237	300	330
b	255	223	245	270	215	307	278	227	252
c	188	132	145	198	167	223	182	167	200
	Vascular bundle: radial/tangential ratio								
a	1.33	0.80	0.88	1.06	0.81	0.87	1.22	0.88	0.76
b	1.47	1.29	1.38	1.64	1.30	1.05	1.42	1.29	1.27
c	0.94	0.59	0.99	1.44	1.03	1.62	1.14	0.90	1.28
	Fibre: length (*mm*)								
a	2.06	2.13	1.76	1.94	1.92	1.74	1.99	2.00	1.85
b	3.12	3.45	3.44	3.11	3.66	3.12	4.16	3.85	3.28
c	3.83	3.46	3.23	3.92	3.76	3.72	5.00	4.41	3.31
	Fibre: diameter ($\times 10^{-1}mm$)								
a	0.18	0.19	0.16	0.19	0.20	0.20	0.21	0.17	0.21
b	0.19	0.17	0.16	0.16	0.19	0.17	0.17	0.17	0.18
c	0.19	0.17	0.16	0.16	0.19	0.17	0.17	0.17	0.18
	Fibre: wall thickness ($\times 10^{-1}mm$)								
a	0.04	0.05	0.06	0.05	0.06	0.05	0.05	0.05	0.05
b	0.07	0.07	0.06	0.07	0.08	0.06	0.06	0.06	0.06
c	0.08	0.06	0.07	0.07	0.08	0.07	0.07	0.07	0.10
	Fibre: lumen diameter ($\times 10^{-1}mm$)								
a	0.10	0.09	0.10	0.10	0.08	0.10	0.01	0.09	0.08
b	0.02	0.02	0.02	0.03	0.03	0.02	0.03	0.02	0.02
c	0.03	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.03

Note: a: *B. blumeana* b: *B. vulgaris* c: *G. scortechinii*

The amount of vascular bundles varies with species but not with age, height of the bamboos and their interaction (Tables 2 and 3). The highest mean concentration of vascular bundles was observed in the top portion of the 2-*y*-old *B. blumeana* (365 bundles/cm^2) followed by 307 bundles/cm^2 in the *B. vulgaris* and 223 bundles/cm^2 in *G. scortechinii*. The higher density of vascular bundles at the top portion of bamboo has been explained by Grosser and Liese (1971) as a result of the decrease in culm wall thickness. Since the decrease compensates for the gradual decrease in the actual number and size, the vascular bundles get close together in thinner culm walls (towards the top). The lowest mean reading of the vascular bundles was found in the middle portion of the 1-y-old *G. scortechinii* (132 bundles/ cm^2). The lowest value in each of the other two species was 215 bundles/ cm^2 in the 2-y-old *B. vulgaris* and 200 bundles/ cm^2 in the 1-y-old *B. blumeana.*

Table 2. Summary of analyses of variance on anatomical properties of the three bamboo species

		Mean squares and statistical significance					
		Anatomical properties of bamboo					
Source of variation	Df	Vascular bundle distribution	Radial/ tangential ratio	Fibre length	Fibre diameter	Fibre wall thickness	Lumen diameter
Species	2	1079.24**	3.24ns	19.99**	1.98E-5ns	5.34E-5**	4.39E-4**
Age	2	129.80ns	12.96ns	0.63ns	4.24E-6ns	1.41E-6ns	1.30E-7ns
Height	2	185.35ns	8.80ns	1.40**	1.47E-5ns	1.03E-5ns	1.69E-6ns
Species × Age	4	14.68ns	3.24ns	0.14ns	9.85E-6ns	5.60E-6ns	1.44E-6ns
Species × Height	4	56.41ns	7.41ns	0.25ns	7.71E-6ns	1.15E-5ns	1.24E-6ns
Age × Height	4	34.13ns	8.80ns	0.40ns	2.31E-5ns	1.17E-5ns	4.60E-7ns
Species × Age × Height	8	6.35ns	7.41ns	0.14ns	1.56E-5ns	5.70E-6ns	2.14E-6ns

Note: ns: not significant at P<0.05 **: highly significant at P<0.01

Table 3. Correlation coefficients of different anatomical properties with age and height of bamboo

Characteristic	Bamboo	Age	Height
Vascular bundle distribution	a	0.06 ns	-0.03 ns
	b	0.18 ns	0.25 ns
	c	0.19 ns	-0.07 ns
Radial/tangential ratio of vascular bundle	a	0.00 ns	-0.65 **
	b	0.02 ns	-0.54 *
	c	0.06 ns	0.28 ns
Fibre length	a	0.27 ns	-0.30 ns
	b	-0.03 ns	-0.24 ns
	c	0.33 ns	-0.58 *
Fibre diameter	a	-0.20 ns	0.24 ns
	b	0.26 ns	0.04 ns
	c	-0.02 ns	0.05 ns
Fibre wall thickness	a	-0.27 ns	-0.19 ns
	b	0.44 ns	0.31 ns
	c	0.21 ns	0.36 ns
Lumen diameter	a	0.32 ns	-0.40 ns
	b	-0.13 ns	-0.19 ns
	c	0.22 ns	0.07 ns

Note: a: *B. vulgaris* ; b: *B. blumeana* ; c: *G. scortechinii* ; ns: not significant at P<0.05; * : significant at P<0.05 ; ** : highly significant at P<0.01

The variation in vascular bundles size (measured as 'radial/tangential ratio') follows a somewhat similar trend with the vascular bundles distribution. The radial/tangential ratio is defined as the ratio of radial diameter (length of the vascular bundles) to tangential diameter (width of the vascular bundles) (Grosser & Liese 1971). The ratios correlate insignificantly with age in all species but decrease significantly (Table 3) with height except in *G. scortechinii* (r= 0.28 at P<0.05). While the highest mean radial/tangential ratio of *B. blumena* was observed in the basal portion of the 1-*y*-old culm (1.33), the highest values for *B. vulgaris* (1.64) and *G. scortechinii* (1.44) were respectively found in the basal portions of the 2-*y*-old culms. The lowest mean ratio, however, happened to be at the top of the 3-*y*-old *B. blumeana* (0.76) followed by the top portion of the 2-*y*-old *B. vulgaris* (1.05) and the middle portion of the 2-*y*-old *G. scortechinii* (0.59). The reason for the higher ratio of vascular bundle size nearer the butt region is probably due to presence of more matured tissues (whereby the radial diameter decreases faster than the tangential diameter of the vascular bundles within the height of a culm) in this region.

Variation in fibre length

The fibres make up the sclerenchymatous tissue and occur as caps of vascular bundles or isolated strands. They are long and tapered at both ends. The analysis of variance (Table 2) indicates that the fibre lengths between the bamboo species are significantly different (P<0.05). The mean fibre length from 100 fibres of each species obtained in this study ranges from 1.74 to 2.13 *mm* in *B. blumeana*, 3.11 to 3.85 *mm* in *B. vulgaris*, and 3.23 to 4.24 *mm* in *G. scortechinii* respectively.

The analysis also indicates that the effect of culm age on fibre length of bamboos is not significant (P<0.05). While the fibre length of both *B. vulgaris* and *G. scortechinii* generally increases with age (r = 0.27 and 0.33 respectively), that in *B. blumeana* decreases (r = - 0.03 at P<0.05). The fibre length decreases towards the top portion, particularly in *G. scortechinii* (r = -0.58 at P<0.05). While the longest mean fibre length of *B. blumeana* (2.13 *mm*) was found in the middle portion of the 1-*y*-old culm, the longest fibres in *B. vulgaris* (4.16) and *G. scortechinii* (5.00 *mm*) were observed in the basal portions of the 3-*y*-old culms. As mentioned by many researchers, the fibre length within and between the bamboo culms may vary as the individual characteristics of the bamboo itself (Grosser & Liese 1971, Pattanath 1972, Espiloy 1987, Widjaja & Risyad, 1987). A satisfactory explanation for the variation of fibre length with age cannot be provided in this study since environmental and growth data are not available. The life history of the bamboo culms should account for some of the variation. It is conceivable that external factors, such as soil conditions and climatic changes, during fibre development might influence fibre length.

Variation in fibre wall thickness

The fibre wall thickness was measured as the fibre diameter less lumen diameter divided by two (Ezell 1977). The results indicate that the fibre wall thickness varies significantly according to bamboo species. The values of the fibre wall thickness from this study were observed to be within the range of 0.006 to 0.01 *mm* in *G. scortechinii*, followed by 0.006 to 0.008 *mm* in *B. vulgaris* and 0.004 to 0.006 *mm* in *B. blumeana.* These could be related to the fact that *G. scortechinii* possesses smaller lumen and fibre diameter (ranging from 0.002 to 0.003 *mm* and 0.016 to 0.019 *mm* respectively) than *B. blumeana* (ranging from 0.009 to 0.010 *mm* and 0.016 to 0.020 *mm* respectively).

The correlation coefficients in Table 3 indicate that the effects of age, height and their interactions towards fibre diameter, lumen diameter and fibre wall thickness are not significant ($P<0.05$). While the fibre wall thickness of *B. vulgaris* decreases with increment of age and height ($r = -0.27$ and -0.19 at $P < 0.05$ respectively), that in both *B. blumeana* and *G. scortechinii* increases. Furthermore, while the fibre diameter of *B. blumeana* increases with thinner lumen diameter, both fibre diameters of *B. vulgaris* and *G. scortechinii* decrease with the increment of lumen diameter. While the lumen diameter in *B. vulgaris* and *B. blumeana* correlates negatively ($r = -0.40$ and -0.19, respectively), the fibre diameter of bamboo correlated positively with increase in culm height. No published reports are available to explain the uncertainty of these anatomical properties of bamboo with the exception of their variation between and within culms.

Conclusion

In all the anatomical properties studied (except radial/tangential ratio of vascular bundles in *B. vulgaris* and *B. blumeana* and the fibre length of *G. scortechinii*), no significant correlation with age and height was observed statistically. The variation in distribution and size of the vascular bundle was somewhat greater at both the basal and top than the middle portions.

The fibres of both the *Bambusa* species were shorter than those of *G. scortechinii.* While the fibre length of *B. blumeana* ranged from 1.74 to 2.13 *mm*, that of *B. vulgaris* and *G. scortechinii* ranged from 3.11 to 4.16 *mm* and from 3.23 to 5.00 *mm* respectively. The fibre length was also observed to increase from the basal to middle portions but decrease towards the top portion.

Fibre wall thickness was not significantly affected by either age or height positions. However, the variability that exists along the culm of different bamboo species may be due to the different growth rates of the respective species. Nevertheless, the average fibre wall thickness of the bamboo fibres ranged from 5 to 7 μm.

References

ABD. LATIF MOHMOD. 1987. Guideline on the manufacturing of blinds and satay sticks. *Forest Research Institute Malaysia Technical Information* 2. 8 pp.

ABD. LATIF MOHMOD & ABD. RAZAK OTHMAN. 1991. Availability, distribution of bamboo resource and its industrial status in Peninsular Malaysia. Paper presented at the *IV International Bamboo Workshop.* November 27-30, 1991. Chiangmai, Thailand.

ABD. LATIF MOHMOD & ASHAARI HJ. AMIN. 1991. Non-wood forest products as a major resource for rural development - Its status, problems and prospects. Pp. 286-292 in *Proceedings of ASIATECH 1991 Conference-Technology for Rural Development.* August 12-14, 1991.Kuala Lumpur, Malaysia,

ABD. LATIF MOHMOD, WAN TARMEZE WAN ARIFFIN & FAUZIDAH AHMAD. 1990. Anatomical features and mechanical properties of three Malaysian bamboos. *Journal of Tropical Forest Science* 2(3): 227-234.

ABD. LATIF MOHMOD, WAN TARMEZE WAN ARIFFIN & HAMDAN HUSAIN. 1991. Variation in physical properties of some Malaysian bamboos. Paper presented at the *IV International Bamboo Workshop.* November 27-30, 1991. Chiangmai, Thailand.

AMINUDDIN MUHAMAD & ABD. LATIF MOHMOD. 1991. Bamboo in Malaysia: Past, present and future research. Paper presented at the *IV International Bamboo Workshop.* November 27-30, 1991. Chiangmai, Thailand.

ESPILOY, Z. B. 1987. Physico-mechanical properties and anatomical structure relationships of some Philippines bamboos. Pp. 257-264 in Rao, A.N., Dhanarajan, G. & Sastry, C.B. (Eds.) Recent Research on Bamboos. *Proceedings of the International Bamboo Workshop.* October 6-14, 1985. Hangzhou, China.

EZELL, A.W. 1977. *Variation of Selected Anatomical and Physical Properties of Sweetgum Grown on Upland and Bottomland Sites in Louisiana.* Ph.D. thesis. Louisiana State University.

GROSSER, D. & LIESE, W. 1971. On the anatomy of Asian bamboos, with special reference to their vascular bundles. *Wood Science Technology* 5: 290-312.

JANE, F.W. 1933. The microscopic examination of woody material. *Watson Microscope Record* 30: 1-19.

PARAMESWARAN, N & LIESE, W. 1976. On the fine structure of bamboo fibres. *Wood Science Technology* 10: 231-246.

PATTANATH, F.G. 1972. Trend of variation in fibre length in bamboos. *Indian Forester* 98(4): 241-243.

WIDJAJA, W. & RISYAD, Z. 1987. Anatomical properties of some bamboos utilized in Indonesia. Pp. 244-246 in Rao, A.N., Dhanarajan, G. & Sastry, C.B. (Eds.) Recent Research on Bamboos. *Proceedings of the International Bamboo Workshop.* October 6-14, 1985. Hangzhou, China.

WILSON, J.G. 1954. Specific gravity of wood substances. *Forest Products Journal* 16(1): 55-61.