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Morphological and anatomical characteristics of managed natural bamboo stands - *Gigantochloa scortechinii*

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Abstract: Morphological and anatomical characteristics of 2- and 4-year-old managed natural stands of *G. scortechinii* were studied. The morphological characteristics varied depending on age and height level of the culms. The cell wall thickness of both parenchyma and fibre were greater in 4-year-old than in 2-year-old culms. The frequency of vascular bundles was greater at the bottom and top portion than in the middle portion of both the age-groups. There was no difference in vessel diameter between the 2- and 4-year-old culms at the mid part of the culm wall. The anatomical structure in bamboo had a very strong correlation with the moisture content and basic density.

Key words: *Gigantochloa scortechinii*, morphology, anatomical characteristics.

INTRODUCTION

Morphological and anatomical characteristics are recognised as important from the point of view of utilization as they influence the mechanical strength of bamboo culms (Liese, 1985; Razak, 1998). Information on these characteristics is useful in determining the utilization of bamboo as possible alternative to wood. Bamboo culms mature in 3 to 4 years depending on species and at this age, the culms are said to possess the best properties for various end uses.

Research on bamboo was intensified in recent years focusing mostly on silviculture, propagation, processing, properties and utilization of wild bamboos. However, study on managed natural bamboo stands has so far confined to silviculture and fertilizer application to enhance growth (Azmy *et al.*, 2004). The present study focuses on the morphology and anatomical characteristics of managed *Gigantochloa scortechinii* natural stands.

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MATERIALS AND METHODS

Supply of culms and sampling

All bamboo culms used in this study were obtained from the Forest Reserve areas in Nami, Kedah, Malaysia. About 20 ha of the forest areas has been developed by the Forestry Department, Malaysia, FRIM and the International Development Research Centre (IDRC) under the "Management of Natural Bamboo Stands Project" since 1988 (Azmy *et al.*, 1997). Most of the bamboos found in this area are of *G. scortechinii*.

Culms of two age-groups (2- and 4-year-old) of *G. scortechinii* were used in this study. The 2-year-old culms were chosen in view of their importance to the basketry and handicraft industry in Malaysia. The 4-year-old culms are normally used for panel, parquet, furniture and construction purposes.

The morphological characteristics such as the culm height, number of internodes per culm, internode length, internode diameter, culm wall thickness and girth were investigated. The anatomical features investigated include distribution of vascular bundles and vessel size, fibre length and wall thickness of fibres and parenchyma.

Bamboo culms were cut at about 30 cm above the ground level. Culms of known age and which had diameters between 8 to 10 cm were taken from randomly selected clumps. Altogether 36 bamboo culms of 2- and 4-year age groups were harvested in the months of February 2003 immediately after the rainy season. The top parts of the culms with branches were removed leaving culms of about 12 m in length. These culms were later subdivided into three equal lengths consisting of bottom, middle and top portions of 4 m each. Paraffin wax was applied to the cut surfaces of each portion to reduce evaporation and prevent insect and fungal attack (Sulthoni, 1989). Bamboo blocks for anatomical study were fixed in formalin-acetic acid (FAA) immediately after felling and kept in closed bottles. Within a week after harvesting, all the bamboo blocks were taken to FRIM for processing and to UMS for subsequent studies.

Determination of morphological and anatomical characteristics

Culm height, internode length, internode diameter, culm wall thickness and girth were measured from the cut base to the tip. The method used in the morphological study was based on ASTM (ASTM, 1974) and Sulthoni (1989).

For anatomical studies 36 bamboo blocks representing the two age-groups and three height positions with six replicates were used. Bamboo blocks were cut into sections of 10 mm x 10 mm x culm wall thickness, boiled in distilled water for 4 h and sliced into 25 µm thick transverse sections with a sledge microtome. Sections were stained with aqueous Safranin-O and Alcian blue for 4 min. They were washed with 50 per

cent ethanol, dehydrated and mounted in euparal. By this method the thicker cell walls stained red and thinner walls light blue.

Anatomical studies on vascular bundles, vessel size, fibre, parenchyma and cell wall thickness were carried out according to the methods outlined by Jane (1933). The distribution of vascular bundles was determined by counting the number of vascular bundles per mm^2. Bamboo blocks of 20 mm x 10 mm x culm wall thickness were chipped radially into splints with a sharp knife. The splints were then macerated in Jeffrey's solution (50:50 mixture of 15% nitric acid and 10% chromic acid). A period of 48 h was allowed to soften the splints (Abd. Latif, 1991). The softened splints were washed with distilled water stained with Safranin-O and measured on a projection microscope. Twenty-five complete and reasonably straight fibres were measured (Hart and Swindle, 1967). Slides prepared earlier were used for measurement of wall thicknesses of fibres and parenchyma.

RESULTS AND DISCUSSION

Morphological characteristics

Results on the morphological characteristics of the 2- and 4-year-old *G. scortechinii* (Table 1) show that there was not much difference in height, number of internodes, internodal length and culm wall thickness between the 2- and 4-year-old culms. There was however a slight decrease in the internode diameter (9.6 to 9.3 cm) and girth (30.2 to 26.5 cm) from 2- to 4-year-old bamboo culms.

The total number of internodes per culm and the length of the internode vary slightly. The length of the internodes increases from the basal region to the middle portion of the culm and decreases towards the top. With age increment, mature tissue starts to develop and continue to change in density and strength properties.

Selection of bamboo blocks at the right location along the culm height and age plays an important role in determining a consistent quality of raw material for treatment and utilization purposes. This is mainly because basic density and strength properties vary along the culm height.

Anatomical properties

The anatomical properties of *G. scortechinii* of the two age-groups and at different height levels of the culms (Table 2) showed slight increase in the parenchyma diameter (23.3 to 24.3 μm), fibre diameter (17.3 to 18.3 μm), fiber length (3.8 to 4.4 μm) and fibre wall thickness (7.4 to 7.9 μm). Decrease in diameter occurred in the vessel (125.1 to 124.7 μm), parenchyma lumen (20.0 to 19.8 μm) and fibre lumen (2.6 to 2.5 μm). The result also shows that there is no change in the distribution of vascular bundles (2.4/ mm^2) between the 2- and 4-year-old culms at bottom, middle and top portions.

Table 1. Mean morphological characteristics of *G. scortechinii*

Characteristics	Age	
	2 years*	4 years*
Culm height (cm)	1545	1550
Number of internodes per culm	37.6	37.5
Internode length (cm)		
Bottom	53.7	57.2
Middle	63.1	60.0
Top	45.3	53.5
Mean	55.4	56.9
Internode diameter (cm)		
Bottom	9.7	9.5
Middle	10.0	9.8
Top	9.1	8.5
Mean	9.6	9.3
Culm wall thickness (cm)		
Bottom	1.2	1.3
Middle	0.8	0.9
Top	0.6	0.6
Mean	0.9	0.9
Girth (cm)		
Bottom	30.5	30.6
Middle	31.4	31.3
Top	28.6	27.7
Mean	30.2	26.5

* Mean of 6 replicates

The vascular bundles of *G. scortechinii* were found to be of Type IV according to the classification of vascular bundles by Grosser and Liese (1971). Each vascular bundle consisted of the xylem with one or two smaller protoxylem elements and two large metaxylem vessels and the phloem with thin-walled, unlignified sieve tubes connected and companion cells. The bundles were larger in the inner parts, becoming smaller and denser towards the periphery of the culm wall. More parenchyma but few fibres and conducting cells were present in the inner part of the culm wall than in the periphery. The frequency of the vascular bundles was greater in the bottom and top portions of both the 2- and 4- year-old culms than the mid height level. The 2-year-old culm had slightly a higher frequency of vascular bundles.

The diameter of vessels was measured in the radial and tangential directions for the vascular bundles. The vessels were slightly elliptical in shape with the radial diameter larger than tangential. This was the same for both the 2- and 4-year-old bamboo throughout the culm wall. Vessels progressively increased in diameter from the outer to the inner part. The size of the vessels between the 2- and 4-year-old culms was not significantly different indicating that it is not affected during maturation.

The fibres occurred in the internodes as caps of vascular bundles or as isolated strands. They were also grouped in bundles and sheaths around the vessels. The fibre length ranged between 3.72-3.91 mm for the 2-year-old culms and 3.83-5.01 for the 4-year-old culms (Table 2). The fibre cell wall thickness in the 4-year-old culms was greater than in the 2-year-old culms. This is consistent with the work of Alvin and Murphy (1988) and Murphy and Alvin (1997) on *Sinobambusa tootsik* and *G. scortechinii*, who found similar thickening of fibre wall during maturation. A similar finding was also observed by Abd. Latif (1991) in his work on effect of age and height on selected properties of Malaysian bamboo species.

The outer zone showed the lowest increase in wall thickness from 2 to 4 years. This is a reflection of the early maturation of this zone compared with the middle and the inner parts of the culms. In the young culms, the tissues of the outer zone are early maturing resulting in the minimal increment of cell wall thickness with further ageing. The middle and inner zones showed much higher increments in fibre wall thickening.

The ground tissue consisted of parenchyma cells, which were mostly vertically elongated with short, cube-like ones in between. The former were characterised by thicker walls with a polylamellate structure. They become lignified in the early stages of shoot growth. The shorter cells have a denser cytoplasm, thinner walls and retain cytoplasmic activity for a long time.

The parenchyma diameter varied from 22.2 µm at the bottom and 23.4 µm at the top portion, having the larger diameter of 25.5 µm at the middle portion of the 2-year-old culms (Table 2). The diameter increased slightly in the 4-year-old culms.

The sizes of the lumen in parenchyma also varied from 19.4 µm to 20.8 µm in the 2-year-old culms. The lumen decrease was slightly smaller in the 4-year-old culms. These variation in the diameter of the parenchyma cells and lumen sizes shows that there was some maturation occurring, resulting in the cell wall thickening from 2 years to 4 years age.

Starch granules were observed in some of the parenchyma cells of the 2- and 4-year-old culms. The amount varied from cell to cell. However, the 4-year-old culms contained more starch granules than those of the 2-year-old.

Liese and Weiner (1997) also made similar observations and according to them very young culms (3-month-old) do not contain starch; the parenchyma of older culms were filled with starch grains. The low starch content in most of the culms used in this study could be attributed to the time of harvesting. The starch content in bamboo has been known to vary with seasons, which is higher in the dry than in the rainy season.

Table 2. Anatomical characteristics of 2- and 4-year old *G. scortechinii*

	Height		2-year-old*	4-year-old*
Vascular bundle (VB)	Bottom		2.4	2.4
frequency	Middle		2.2	2.3
(VB no./ mm^2)	Top		2.6	2.5
		Mean	2.4	2.4
Vessel diameter	Bottom		119.2	112.9
(μm)	Middle		135.7	136.8
	Top		120.4	124.3
		Mean	125.1	124.7
Fibre diameter	Bottom		16.0	17.0
(μm)	Middle		19.0	20.0
	Top		17.0	18.0
		Mean	17.3	18.3
Fibre length* (mm)	Bottom		3.9	5.1
	Middle		3.8	4.4
	Top		3.7	3.8
		Mean	3.8	4.4
Fibre cell wall	Bottom		6.8	7.3
thickness	Middle		8.2	8.8
(μm)	Top		7.2	7.7
		Mean	7.4	7.9
Fibre lumen diameter	Bottom		2.5	2.4
(μm)	Middle		2.6	2.5
	Top		2.7	2.6
		Mean	2.6	2.5
Parenchyma diameter	Bottom		22.2	23.4
(μm)	Middle		25.5	26.6
	Top		23.4	24.3
		Mean	23.7	24.8
Parenchyma lumen	Bottom		19.4	19.4
diameter	Middle		20.8	20.4
(μm)	Top		19.9	19.6
		Mean	20.0	19.8

* Mean of 6 replicates

CONCLUSIONS

i) The morphological characteristics vary depending on age and height along the *G. scortechinii* culms. The culm diameter decreases slightly from 2- to 4-year-old culms and taper from the middle portion towards the tip with a decrease in diameter, girth and culm wall thickness.

ii) The mean parenchyma and fibre cell wall thickness was greater in the 4-year-old than in the 2-year-old culms. The increase in the cell wall thickness in parenchyma and fibres is part of the maturing process in the bamboo culms.

iii) The vascular bundles of *G. scortechinii* were of Type IV with the frequency greater at the bottom and top portion than in the middle portion.

iv) There was no difference in vessel diameter between the 2- and 4-year-old culms at the middle of the culm wall.

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