Journal of
Plant Sciences

ISSN 1816-4951

Academic
Journals Inc.

www.academicjournals.com

Journal of Plant Sciences 5 (2): 184-193, 2010
ISSN 1816-4951 / DOI: 10.3923/jps.2006.144.153

Physical Characteristics, Anatomy and Properties of Managed *Gigantochloa scortechinii* Natural Bamboo Stands*

[1]Razak Wahab, [1]Aminuddin Mohamad, [2]Hashim W. Samsi,
[1]Awang Ahmad Mohd Yunus and [1]Janshah Moktar
[1]Universiti Malaysia Sabah, 88999 Kota Kinabalu, Sabah, Malaysia
[2]Forest Research Institute Malaysia, 52109 Kuala Lumpur, Malaysia

Abstract: The physical characteristics, anatomy and properties of managed *G. scortechinii* natural bamboo culms stands age 2 and 4 year-old were studied. The physical characteristics vary depending on aged and height along the culms. The cells wall thickness of both parenchyma and fibre were greater in the 4 year-old than in the 2 year-old culms. The increased in the cells wall thickness in parenchyma and fibres is part of by the maturing process in the bamboo culms. The frequency of vascular bundles is greater at the bottom and top portion than in the middle portion of both age-groups. There were no difference in vessel diameter between the 2 and 4 year-old culms at the middle of the culms wall thickness. The anatomical structure in bamboo has a very strong correlation with the moisture content and basic density. The basic density is higher in the 4 year-old culms than in the 2 year-old and increases from lower to upper internodes showing that there is a maturation process going on between the two age-group relative to the two of tissue types.

Key words: Managed bamboo stands, *Gigantochloa scortechinii*, physical characteristics, anatomy and properties

Introduction

The physical characteristics, anatomy and properties are recognised as important factors that influence the mechanical strength of bamboo culms (Liese, 1985). Information on these three characteristics can be used to determine the possible bamboo utilization.

Bamboo being a fast growing plant species is the best possible alternative to future wood. It reached maturity between 3 to 4 years (depending of species) after cultivating. At this age the bamboo is said to possess the best properties for various utilization. Research on bamboo has intensified in recent years. This covers all aspect in silviculture, propagation, processing, properties and utilization of bamboo found growing wild in the forest or cultivated. However, study on managed natural bamboo stands has so far confined to silviculture and fertilizers application to enhance growing (Azmy *et al*., 2004). This study (which was undertaken from Feb. 2003 to July 2005) focus on the physical characteristics, anatomy and properties on managed *G. scortechinii* natural bamboo stands. It was considered that these properties would relate to the durability of the bamboo whether untreated or treated with chemicals.

Two age-groups (2 and 4 years-old) of *G. scortechinii* culms were used in this study. They were chosen to represent the young and the mature culms. The 2 year-old culms were chosen in view of their

Corresponding Author: Razak Wahab, Universiti Malaysia Sabah, 88999 Kota Kinabalu, Sabah, Malaysia
Tel: 006088320584/006088435214

Originally Published in Journal of Plant Sciences, 2006

importance to the basketry and handicraft industry in Malaysia. The 4 year-old culms were chosen because this is the right mature age where the culms are normally used for panel, parquet, furniture and construction purposes.

The physical characteristics such as the culms height, number of internodes per culms, internode length, internode diameter, culms wall thickness and girth were investigated. The physical properties such as moisture content and basic density are considered to be important factors in determining the suitability of bamboo for various application and chemical treatment. Moisture content was studied because it is an important factor influencing the treatability, dimensional changes and attack by insects and fungi. Basic density is important because it reflects the amount of cell wall material per unit volume of culms and relates directly to strength properties.

The anatomical structures were investigated due to their relationship with strength, preservative absorption, distribution and likely pathways for colonisation by micro-organism (Razak *et al*., 2005a; 2002). These are regarded as important factors in determining the strength, natural durability and performance of chemically treated bamboo.

Materials and Methods

Supply of Culms and Sampling

Bamboo culms used in this study were taken 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 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* species. The activities under this project include the management of the bamboo stock, fertilisation and harvesting. Cleaning of clumps including cutting the unwanted culms were done occasionally so that healthy and vigorous culms can be obtained for successive harvests.

Bamboo culms were cut at about 30 cm above the ground level. These culms of known age were taken from randomly selected clumps all had diameters between 8 to 10 cm. They were harvested in the months of February 2003 immediately after the rainy season. Studies indicated that bamboo harvested during this period contained a very minimum amount of starch (Liese, 1985; Abd. Razak *et al*., 1995). The top parts of the culms with branches were removed leaving bamboo culms of about 12 m in length. All together 36 bamboo culms consisting of 18 of the 2-year and another 18 of 4-year old were harvested and investigated. These culms were later subdivided into 3 equal lengths consisting of bottom, middle and top portions of 4 meters each. Paraffin wax was applied to the cut surfaces of each portion to reduce evaporation and prevent insect and fungal attack (Sulthoni, 1989). 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 culms blocks were taken to FRIM for processing and sampling. They were later transported to UMS for subsequent studies.

Determination of Physical Characteristics and Properties

Measurements for some basic physical characteristics were done in the forest reserve areas in Nami. The culms height, internode length, internode diameter, culms wall thickness and girth were measured from the cut base to the tip. The method used in the physical study was based on ASTM (Anonymous, 1974) and Sulthoni (1989).

Determination of Moisture Content (MC)

Thirty-six blocks representing 2 bamboo age-groups (2 and 4 years), 3 height portions (bottom, middle and top) and 6 replicates were used. All blocks cut from fresh culms were 10 × 10 mm × culms wall thickness. They were weighed and dried in an oven at 105±2°C for 48 h until a constant weight was attained. The blocks were then cooled for half an hour in a dessicator before re-weighing.

Determination of Basic Density

Blocks of 10 × 30 mm × thickness of culms wall were obtained from the middle portion of each internode from the bottom, middle and top culms portions. Six replicates were used in the study. The blocks were oven dried for 48 hours at 105±2°C until a constant weight were attained. The blocks were then weighed to give the oven dried weight.

To obtain the green volume, the blocks were placed in water under vacuum of about 700 mm Hg for 24 h until fully saturated. The volume of the fully saturated blocks was then obtained using the water displacement method. The weight displaced is converted to volume of the sample as a green volume. Formula below was to calculate for the basic density:

$$\text{Basic density (kg m}^{-3}\text{)} = \frac{\text{Oven dry weight (kg)}}{\text{Green volume (m}^3\text{)}} \quad (1)$$

Determination of Anatomical Properties

Thirty six blocks representing the two age-groups and three height portions with six replicates were used in the following study.

Vascular Bundle Distribution and Vessel Sizes

Bamboo blocks were cut into sections of 10 × 10 mm × culms wall thickness, boiled with distilled water for four hours and sliced into 25 μm thick transverse sections by sledge microtome with a 15 degree knife angle. Each section was stained with 4 drops of aqueous safaranin-O and 1 drop of alcian blue for 4 minutes on the slide. They were washed with 50% ethanol then dehydrated through alcohol series of 70, 80, 90, 95% and 3 changes of absolute ethanol for 1 min. One drop of euparal essence was placed on top of the section before mounting on microscope slides using euparal and covering with a cover slip. The slides were then clamped with clothes pegs and placed on a warm plate set at 60°C oven for the euparal to set over a few days. This method stained the thicker cell walls red and thinner walls light blue.

Observations for anatomical structure were made on a Leitz microscope. Anatomical studies on vascular bundles, vessel sizes, fibres, parenchyma and cell walls thickness were carried out according to methods outlined by Jane (1933). The distributions of vascular bundles were determined by counting the number of vascular bundle on a cross-section per mm^2.

Fibre Length

Bamboo blocks of 20 mm × 10 mm × culms wall thickness were chipped radially into match stick size splints with a sharp knife. The splints were then put in marked vial. Jeffrey's solution (50:50 mixture of 15% nitric acid and 10% chromic acid) were used to macerate the fibres. A period of 48 h was allowed to soften the splints (Abd. Latif, 1991). At the end of the maceration

period, the softened splints were carefully washed with distilled water. The vials were then half-filled with distilled water and capped securely. A drop of slurry solution was placed on specially etched glass slide bearing three pairs of parallel lines. Drops of safranin-O were introduced to contrast the fibres images, which were then projected on a screen of a fibre-scope at 71 magnifications. Twenty-five complete and reasonably straight fibres in between the parallel lines of the slide were measured. The fibres measurements were done using a flexible millimetre scale in a systematic manner to avoid duplication (Hart and Swindle, 1967).

Fibre and Parenchyma Diameters, Lumen Diameter and Cell Wall Thickness

Slides prepared earlier were used and measurement of the fibre and parenchyma diameters, lumen diameters and cell wall thicknesses were made from them.

Results

Physical Characteristics

The results on the physical characteristics of the 2 and 4 year-old *G. scortechinii* (Table 1) shows that there is not much differences between the height, the number of internodes, internodes length and culms wall thickness of the 2 and 4 year-old culm. There are however a slight decreases in the internodes diameter (9.6 to 9.3 cm) and girth (30.2 to 26.5 cm) from the 2 to the 4 year-old bamboo culms.

Anatomical Properties

The anatomical properties *G. scortechinii* of the two age-group and at different height of the culms (Table 2) shows slight increases in the parenchyma diameter (23.3 to 24.3 μm), fibre diameter

Table 1: Means physical characteristics of *G. scortechinii*

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

* Means of 6 replicates

Table 2: Anatomical properties of 2 and 4 years 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
Means		2.4	2.4
Vessel diameter (μm)	Bottom	119.2	112.9
	Middle	135.7	136.8
	Top	120.4	124.3
Means		125.1	124.7
Parenchyma diameter (μm)	Bottom	22	23
	Middle	25	26
	Top	23	24
Means		23.3	24.3
Parenchyma lumen diameter (μm)	Bottom	19.4	19.4
	Middle	20.8	20.4
	Top	19.9	19.6
Means		20.0	19.8
Fibre diameter (μm)	Bottom	16.0	17.0
	Middle	19.0	20.0
	Top	17.0	18.0
Means		17.3	18.3
Fibre length* (mm)	Bottom	3.9	5.1
	Middle	3.8	4.4
	Top	3.7	3.8
Means		3.8	4.4
Fibre cell wall thickness (μm)	Bottom	6.8	7.3
	Middle	8.2	8.8
	Top	7.2	7.7
Means		7.4	7.9
Fibre lumen diameter (μm)	Bottom	2.5	2.4
	Middle	2.6	2.5
	Top	2.7	2.6
Means		2.6	2.5

*Means of 6 replicates

(17.3 to 18.3 mm), fiber length (3.8 to 4.4 μm) and fibre cell wall (7.4 to 7.9 μm). Decreases in diameter occurred in the vessel (125.1 to 124.7 μm), parenchyma lumen (20.0 to 19.8 μm) and fiber lumen (2.6 to 2.5 μm). The result also shows that there is no change in the vascular bundles distribution (2.4 No. mm^{-2}) between the 2 year-old and the 4 year-old bamboo culms at bottom, middle and top portions of bamboo.

Physical Properties

Moisture Content

The means moisture contents (MC) in green conditions *G. scortechinii* decreases from 98.7 to 95.8% at bottom portion, 93.5 to 91.7% at middle portion and 87.8 to 83.9% in 2 and 4 year-old culms, respectively (Table 3)

Basic Density

The basic density increases from 2 year to 4 year-old bamboo culms. The increases ranged from 4.5 to 7.8% (based on 2 year-old culm value). The value of the basic density of 2 and 4 year-old *G. scortechinii* taken from internode 2 to 18 are presented as in Table 4. The analysis of variance on the basic density of *G. scortechinii* (Table 5) strengthened this statement.

Table 3: Means moisture content (%) of *G. scortechinii* at green condition

		2 year-old*	4 year-old*
Bottom portion	Outer layer	84.6	80.4
	Middle layer	98.7	96.2
	Inner layer	112.8	110.8
	Means	98.7	95.8
Middle portion	Outer layer	78.4	78.2
	Middle layer	92.5	90.4
	Inner layer	109.6	106.6
	Means	93.5	91.7
Top portion	Outer layer	71.2	66.8
	Middle layer	89.6	86.7
	Inner layer	102.6	98.3
	Means	87.8	83.9

*Means of 6 replicates

Table 4: Basic density along the culms height and age

	Basic density (kg m^{-3})		
Internode No.	2 year-old	4 year-old	Increase in basic density* (%)
2	457.1	488.9	7.0
4	491.6	529.7	7.8
6	506.4	542.3	7.1
8	515.2	547.1	6.2
10	526.9	549.9	4.5
12	534.1	554.6	3.8
14	538.1	562.6	4.6
16	543.5	569.8	4.8
18	549.8	576.4	4.8

*based on 2 year-old value

Table 5: Analysis of variance for basic densities of 2 and 4 years old bamboo

	Sum of square	df	Means square	F-ratio
Age	9631.856	1	9631.8560	17.881*
Internode	62339.813	8	7792.4766	14.467*

**significant at $p<0.01$

Discussion

Physical Characteristics

The physical characteristics of *G. scortechinii* vary depending on the age and height along the culms. The culms generally taper from the middle portion towards the tip with a decrease in diameter, girth and culms wall thickness. As seen from Table 1, the culms diameter decreased by 9.0% from middle to top portion in the 2 year-old culms and 12.0% in the 4 year-old culms. The same also goes for the culms wall thickness where there is a decreased in thickness by 25.0% from bottom to middle portion and 16.7% from middle to top portion in the 2 year-old culms. In the 4 year-old culms the decreased in the culms wall thickness from bottom to middle portion is by 33.3% and from middle to top portion by 16.7%.

The total number of internodes per culms and the length of the internode vary. The length of the internodes increases from the basal region to the middle portion of the culms and decreases towards the top. Unlike dicotyledons, bamboo does not show any secondary thickening and thus attains its final diameter during the sprouting stage (Liese, 1985). With age increment, mature tissue starts to develop and continue to change in density, strength properties.

Selection of blocks at the right location along the culms 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 culms height.

Anatomy of *G. scortechinii*

Vascular Bundles

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 of the vascular bundle consists of the xylem with one or two smaller protoxylem element and two large metaxylem vessels and the phloem with thin walled, unlignified sieve tubes connected to the companion cells. The bundles were larger in the inner parts, becoming smaller and denser towards the periphery of the culms wall. More parenchyma but few fibres and conducting cells were present in the inner part of the culms wall than in the periphery. The frequency of the vascular bundles was greater at both the bottom and top portion of both the 2 and 4 year-old culms than the middle. The 2 year-old culms had slightly a higher frequency of vascular bundles.

Vessels

The diameters of vessels were measured in radial and tangential directions for the vascular bundles across the culms wall. The vessels were found not to be truly circular but 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 culms wall.

Vessels progressively increased in diameter from the outer to the inner part. The means diameters were found to be 119.2 μm at the bottom portion, 135.7 μm at middle portion and 120.4 μm at top portion of the 2 year-old culms. For the 4 year-old culms the means vessel diameter were 112.9 μm at the bottom portion, 136.8 μm at middle portion and 124.3 μm at top portion. The size of the vessels between the 2 and 4 year-old culms were not significantly different indicating that it is not affected during maturation.

Fibres

The fibres constitute the sclerenchymatous tissue and occur in the internodes as caps of vascular bundles or isolated strands. The fibres are grouped in bundles and sheaths around the vessels. They are long and tapered at both ends. The fibre length from 100 fibres range between 3.7-3.9 mm for the 2 year-old culms and 3.83-5.1 for the 4 year-old culms. Fibre pits could be seen sparsely in the fibre wall as thin lines that continue to the neighbouring fibre.

The fibre cell wall thickness in the 4 year-old culms was commonly greater than in the 2 year-old culms. This is consistent with 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 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 thickness. 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.

Parenchyma

The ground tissue consisted of parenchyma cells, which were mostly vertically elongated with short, cube-like ones inter-spread in between. The former are characterised by thicker walls with a polyamellate 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 varies from 22 μm at the bottom and 23 μm at the top portion, having the larger diameter of 25 μm at the middle portion of the 2 year-old culms. The diameter increase was slightly smaller in the 4 year-old culms with 23 μm at the bottom, 26 μm at the middle and 24 μm. The sizes of the lumen in parenchyma also varies from 19.4 μm at the bottom and 19.9 μm at the top portion, having the larger diameter of 20.8 μm at the middle portion of the 2 year-old culms. The lumen decrease was slightly smaller in the 4 year-old culms with 19.4 μm at the bottom, 20.4 μm at the middle and 19.6 μm. These variation in the diameter of the parenchyma cells and lumens sizes shows that there was some maturation occurring, resulting in the cell wall thickening from 2 years to 4 years age.

Some parenchyma cells were observed to contain starch, however the amount was quite small. Starch in the 4 year-old culms was more frequent than in the 2 year-old culms. Liese and Weiner (1997) also made similar observations to this and according to them very young culms (3 month old) does 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 the harvesting. The starch content in bamboo has been known to vary with seasons, which are higher in the dry than in the rainy season.

Physical Properties

Moisture Content

This study shows that "fresh" *G. scortechinii* possess a high moisture content which is influenced by age, height and position in the culms wall thickness. The moisture content decreases with age, from bottom portion to top portion and from inner to outer layer in the culms wall. The 2 year-old culms have means moisture content of 98.7, 93.5 and 87.8% at bottom, middle and top portions height respectively. In the 4 year-old culms the means moisture content was 95.8% at the bottom, 91.7% at the middle and 83.9% top the portions.

Differences in moisture content might be due to anatomical structure and chemical composition between the culms age and location along the culms. The lowest and highest moisture occurred at the periphery and inner layer respectively particularly near the bottom portion of the 2 year-old culms. The trend shows that the moisture increases roughly by 30% from periphery to the inner layer and 20% from top to bottom portion. This has a very strong correlation with the anatomical structure particularly the vascular bundles and parenchyma cell distributed over the culms and also its density.

Considerable differences in the moisture content of freshly felled culms have to be considered when determining the amount of preservative retention possible during treatment process.

Basic Density

Basic density of 4 years culms were consistently higher than in the 2 year old culms. The basic density increased from the lower to the upper internodes. The basic density varied from about 457 to 550 kg m^{-3} for the 2 year-old bamboo culms and 489 to 576 kg m^{-3} for the 4 year-old culms. There was an increase in basic densities between the two-age group based on the 2 year-old culms, which ranged

between 4.5 to 7.8%. This shows that there is a maturation process going from the 2 year to the 4 year-old bamboo culms. Fibre and parenchyma cell walls increased in means thickness from 2 to 4 years age, starch deposition occurred and the lignification process which increases with age took place. This is supported by Alvin and Murphy (1988) who found that the cell wall increased in thickness along with an increase in lignification between the first and third year of growth in *Sinobamboo tootsik*. These processes contribute significantly to increase the density in the older bamboo. The variation in basic density between different internodes were due to the maturation process that starts from the lower internodes to the upper internodes (Itoh, 1990). This was also due to the presence of higher proportion of fibres in the higher internodes. Liese (1985) also notes that the higher internodes have higher basic density than the lower.

Conclusions

- The physical characteristics vary depending on age and height along the *G. scortechinii* culms. The culms taper from the middle portion towards the tip with a decrease in diameter, girth and culms wall thickness.
- Age, height and position in the culms wall thickness influence the fresh moisture content in *G. scortechinii*. The anatomical structure in bamboo has a very strong correlation with the moisture content.
- The basic density is higher in the 4 year-old culms than in the 2 year-old and increases from lower to upper internodes showing that there is a maturation process going on between the two age-group relative to the two of tissue types.
- The means parenchyma and fibre cells wall thickness was greater in the 4 year-old than in the 2 year-old culms. The increased in the cells wall thickness in parenchyma and fibres is part of by the maturing process in the bamboo culms.
- 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.
- There was no difference in vessel diameter between the 2 and 4 year-old culms at the middle of the culms wall thickness.

References

Abd. Latif, M., 1991. Effect of age and height on selected properties of three Malaysian bamboo species. M. Sc. thesis, Universiti Pertanian Malaysia.

Abd. Razak, O., M. Abd. Latif, W. Liese and H. Norini, 1995. Planting and utilization of bamboo in Peninsular Malaysia. FRIM research Pamplet No. 118.

Alvin, K.L. and R.J. Murphy, 1988. Variation in fibre and parenchyma wall thickness in culms of the bamboo *Sinobambusa tootsik*. IAWA Bull., 9: 353-361.

Anonymous, 1974. Annual book of American Standards for Testing Materials: D 143-52.

Azmy, M., W. Razak, W.S. Hashim and S. Othman, 2004. Application of organic fertilizers on natural stand bamboos for sustainable management in Peninsular Malaysia. Journal of Bamboo and Rattan. International Network for Bamboo and Rattan, 3: 301-309.

Azmy, M., H. Norini and W.M. Razali, 1997. Management guidelines and economics of natural bamboo stands. FRIM Technical Information Handbook No. 15.

Grosser, D. and W. Liese, 1971. On the anatomy of Asian bamboos, with special reference to their vascular bundles. Wood Science and Technol., 5: 290-312.

Hart, A.C. and B.F. Swindle, 1967. Notes on the laboratory sampling of mascerated wood fibres. TAPPI, 50: 379-381.

Itoh, T. 1990. Lignification of bamboo (*Phyllostachys heterocyla* Mitf) during its growth. Holzforschung, 44: 191-200.

Jane, F.W., 1933. The microscopic examination of woody materials. Watson's microscopic record No. 30, pp: 1-9.

Liese, W., 1985. Bamboos: Biology, silvics, properties, utilization. Schriftenreihe der GTZ, No. 180.

Liese, W. and G. Weiner, 1997. Modification of bamboo culms structures due to ageing and wounding. The bamboos. Linnean Society Symposium Series No. 19. Published Academic Press, pp: 313-322.

Murphy, R.J. and Alvin, K.L, 1997. Fibre maturation in the bamboo *Gigantochloa scortechinii*. IAWA J., 18: 147-156.

Razak, W., S. Mahmud and W.S. Hashim, 2005a. Fungal colonization and decay in tropical bamboo species. J. Applied Sci. 5, ISSN 1812-5654. Asian Network for Scientific Information., pp: 897-902.

Razak, W., W.S. Hashim, M. Azmy and M. Janshah, 2005b. Energy dispersive x-ray analysis on preservatives treated tropical bamboo species. J. Biol. Sci., 2005, ISSN 1727-3048. Asian Network for Scientific Information, 5: 837-841.

Razak, W., R.J. Murphy and W.S. Hashim, 2002. SEM observations on decay of *Gigantochloa scortechinii* bamboo exposed in tropical soil. J. Trop. For. Prod., 8: 12, pp: 168-178.

Sulthoni, A., 1989. Bamboo: Physical properties, testing methods and means of preservation. Chapter 4, in a Workshop on Design and Manufacturing of Bamboo and Rattan Furniture held in Jakarta, Indonesia, pp: 1-15.