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Anatomical Characteristics in Relating to the Quality of Large-Cane Rattan

Somkid Siripatanadilok[1]

ABSTRACT

Five species of the large cane rattan endemic to Thailand were selected for this study. The anatomical characteristics of the best quality cane, *Calamus manan* Miq. (waai kho dam) was investigated to be used as reference characteristics. The anatomy of the similar best quality, *Calamus* sp. (waai nam phueng) and the lower quality species, *C. rudentum* Roxb. (waai khee sian), C. longisetus Griff. (waai kam phuan) and *Plectocomiopsis geminiflorus* (waai kung) were investigated and compared to the reference species. The characteristics investigated were epidermal cell, cortical tissue, fiber cap, metaxylem, protoxylem, ground tissue and the distribution of vascular bundles.

The epidermis and cortical tissue of the large canes were usually peeled off using machines. The hardness of epidermis and the stegmata, silica bodies, impregnated at the boundary of fiber bundles and fiber caps of most rattan species, cause dullness to the machine knives. In the canes of the best quality species, *C. manan* and *Calamus* sp., present only few stegmata in the cortex and none at the peripheral vascular bundles. The silica bodies, however, were frequently found in the cortex and at the peripheral vascular bundles of the lower quality cane species. The distribution of vascular bundles, the thickness of the fiber wall in fiber caps and the thickness of the parenchyma wall of ground tissue were found uniform from the periphery to the center of the canes of *C. manan* and of the similar quality species. In contrast, those anatomical characteristics were ununiform within the canes of the lower quality species. The great difference of the anatomical characteristics from the periphery to the center were found in the poor quality canes of *P. geminiflorus* which was the non-industrial used species.

Key words: anatomical characteristics, largecane rattan, cross-section, epidermis, cortex, vascular bundle

INTRODUCTION

Rattans are the climbing palms of which their stems are only material used for making a typical type furniture so called rattan furniture. There are more than 650 species belonging to 13 genera (Uhl and Dransfield, 1987). Not all but only about 25 species of these become commercially important. In Thailand, about 50 species in 6 genera were reported (Dranfield, 1979).

The stem of rattan is usually called rattan cane. Traditionally and commercially the canes are classified into three types basing on cane's diameter, small cane (mean < 10 mm.), medium cane (10-18 mm.) and large cane (> 18 mm.) (Bhat and Renuka, 1986). The small canes are usually popular for skin stripes using for weaving purpose. The large canes are used as the major structure of furniture which is the most required cane type for the furniture factories. The species used for structural material

[1] Department of forest biology, Faculty of Forestry, Kasetsart University, Bangkok 10900, Thailand.

need to be superior quality because usually it will be bent to be designed shapes even making the circular shape. Only the good quality cane can be made as these successfully with less damage. Generally know that, different species produce the canes of different qualities. Externally it is somewhat difficult to identified the canes from different rattan species even they perform different properties. However, anatomically, the canes can be identified down to the species levels (Pipitvittaya, 1984; Siripatanadilok, 1974). The different in anatomical structure certainly imparts to qualities of the canes. It was found that the best quality cane from *Calamus manan* (waai kho-dam) and *Calamus* sp. (waai nam pheung) cantained significantly smaller lignin content than the lower grade canes species (Siripatanadilok, 1984). Weiner and Liese (1991) had established general criteria using anatomical characteristics for identifying the qualities of rattan canes. However the materials they compared were the canes of *Calamus caesius* which was a small cane rattan famous for making rattan stripes and *Plectocomia elongata* which was a non-commercial large cane species. It is interesting to know that whether the anatomical characteristics can be used as criteria to tell the quality of the canes in the same diameter group, either large canes or small canes.

This work therefore has investigated the anatomical characteristics which could be related to the quality of some large cane species in Thailand.

MATERIALS AND METHODS

Five species of large cane rattan endemic to Thailand were selected for this study. Basing on the quality grading by rattan furniture factories the canes of two solitary stem species, *Calamus manan* (waai kho dam) and *Calamus* sp. (waai nam pheung), are classified as the first grade. The canes of two cluster species, *C. rudentum* (waai khee sian) and *C. longisetus* (waai kam phuan) are the second grade and third grade respectively. The last selecteld species, *Plectocomiopsis geminiflorus* (waai kung) produces cane of very poor quality and does not used in furniture factories.

According to the studied of Pipitvittaya (1984) there was no distinct different in general anatomical characteristics within the individual cane and between the canes of the same species. Here, therefore only one cane of each species was used and only the internodes from the middle of the canes were sampled. The samples of two centrimeters thick were cut from the middle of the internodes and later radially splitted into small wedge shape samples of which included complete tissue from epidermis to the center of the cane.

The wedge shaped samples were later cut to be thin cross section, 15-20 microns thick, using a sliding microtome. The sections were processed through the technique of making the permanent slide of woody plant material by staining with safranin-0. The permanent slides of the cross sections were investigated at different positions radially from epidermis to the center which included epidemis, cortex and central cylinder of the cane. The central cylinder part which was composed of vascular bundles and ground tissue were investigated at five positions relating to the percentage of distance from the peripheral vascular bundles to the center (Figure 1). The following anatomical features were studied and measured, epidermal cells, cortical cells, stegmata, number and area of vascular bundles, area of fiber cap, wall thickness of fiber, intervascular ground tissue, metaxylem and protoxylem. Measurements of cell dimension were done under light microscope using micrometer with 20 measuring replications. Fiber dimensions were measured only for the larger size of which it was assumed to represent the middle part of the fiber length. Cross sectional area of vascular bundles and fiber caps were copied from photomicrographs with transparent plastic sheets

and measured using a leaf area meter. The number of vascular bundles were measured using eyepiece micrometer for area measurement.

RESULTS AND DISCUSSION

General Anatomical Characteristics of the Canes

In cross section, the canes of all 5 species were distinquished into three zones, epidermis, cortex and central cylinder zone (Pipitvittaya, 1984; Siripatanadilok, 1974; Weiner and Liese, 1988; 1990). Epidermal layers were similar between *C. manan* (waai kho dam) and *Calamus* sp. (waai nam pheung) which were narrow high column shape and thick wall (Table 1). In contrast, the epidermal cells of *C. rudentum*, *C. longisetus* and *Plectocomiopsis geminiflorus* were shorter and

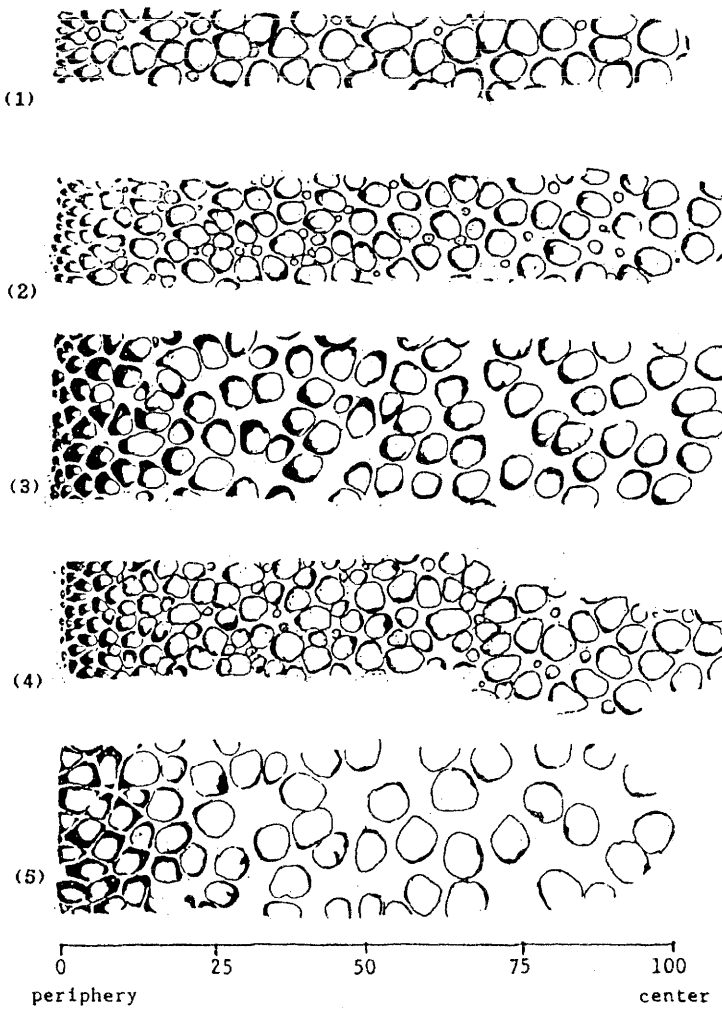


Figure 1 Diagrams drawn from the photographs taken from the cross sections of the canes of five rattan species. These diagrams show the distribution of vascular bundles from periphery across radius. 1 = *Calamus manan*, 2 = *Calamus* sp., 3 = *C. rudentum*, 4 = *C. longisetus* 5 = *Plectocomiopsis geminiflorus*

thinner wall. The high column shape epidermal cells were refered as the better skin of the rattan cane (Siripatanadilok, 1983). It is coincident with *C. manan* and *Calamus* sp. which have been knowing as the first grade species.

Cortical tissue in general was composed of two types of tissue, ground tissue and fiber bundles. Wall of the ground tissue in the cortex of *C. longisetus* and P. geminiflorus were very thick and became sclereid. However the cortical ground tissue of *C. manan*, *Calamus* sp. and *C. rudentum* were the thinner wall parenchyma. Certical fiber bundles were arranged in one row in the cortex of *C. manan* and *P. geminiflonis* but in two rows in the cortex of other three species (Table 2). The present of thicker sclerified cell in the cortex may make the outer part of the cane become harder and may cause dullness to the knife of peeling machine.

Central cylinder is the major tissue of the cane and directly involve to the quality of the canes. It was composed of vascular bundles and ground tissue. Basing on the number of metavessels and the pattern of phloem strand, three types of vascular bundles were classified (Tomlinson, 1961). The

Table 1 Characteristics of epidermal cells.

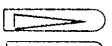
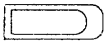
Species	Cell shapes	Mean height (H) (μ m)	Mean width (W) (μ m)	H/W
Calamus manan		62.5	11.25	5.56
Calamus sp.		62.3	20.00	3.13
C. rudentum		17.5	11.50	1.52
C. longisetus		31.25	8.75	3.57
Plectocomiopsis geminiflorus		32.50	15.00	2.17

Table 2 The present of cortical vascular bundles (C.V.B), stegmata and the double wall thickness (2 W) of ground tissue in cortex and in central cylinder of the canes.

Species	C.V.B layers	Stegmata		Mean 2W of ground tissue (m. m.)					
		Cortex	Peripheral VB	Cortex	% Radial distance from cortex				
					0-5	25	50	75	100
C. manan	1	√	-	6.3	6	5	5	5	5
Calamus sp.	2	-	-	4.4	4.2	3.3	3.3	3.3	3.3
C. rudentum	1-2	√	√	10.5	8.8	3	2.2	2.2	2.2
C. longisetus	2	√	√	5	6.8	2.2	2.2	2.2	2.2
Plectocomi-opsis gemi niflorus	1	-	√	15	8.5	2.8	2.6	2.6	2.6

four species of *Calamus* studied here presented the same type of vascular bundle in which there were two phloem strands flanked one metavessel (Figure 2 a). In the cane of *P. geminiflorus*, the vascular bundles differed from the first group but was composed of one phloem strand capped two metavessels (Figure 2 b). Fiber cap is the normal characteristics of rattan vascular bundles. It is the band of fibers generally capped the outer end of vascular bundle.Usually the fiber caps of peripheral vascular bundles were thicker than the caps at the inner. Only peripheral fiber caps of *P. geminiflorus* presented two zones, non-lignified yellow color outside as "yellow cap" zone and normal lignified fiber at inside zone. The present of yellow caps and thicker fiber caps at the peripheral vascular bundles establishes a ring of dense fiber at the peripheral zone in the cane. *P. geminiflorus*

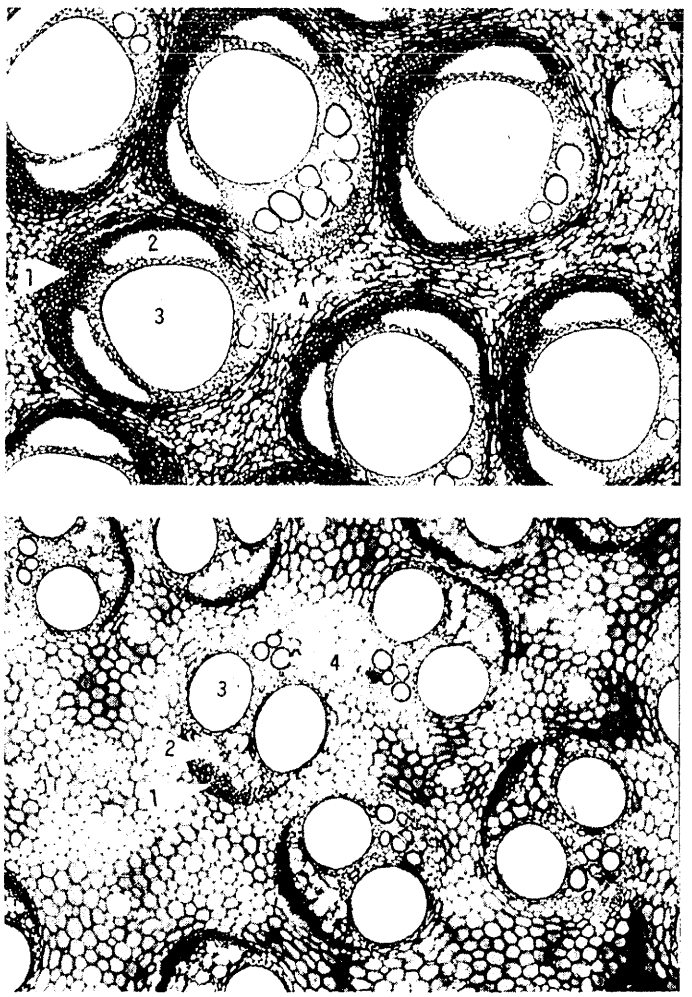


Figure 2 a. Vascular bundles of *Calamus manan*;
b. Vascular bundles of *Plectocomiopsis geminiflorus*.
1 = fiber cap, 2 = phloem strand, 3 = metaxylem vessel 4 = protoxylem vessel

showed the widest of ring zone while *C. manan* and *Calamus* sp. contained very thin ring zone or even absent (Figure 1)

Protoxylem of all species was composed of protovessels embedded in parenchyma or sclerenchyma. The number of protovessels were varied. The average area covered by protoxylem for all species were between 20-50% of vascular bunndle area. The area of protoxylem was largest (35-50%) in *C. longisetus* and smallest (20-25%) in P. geminiflorus. While the average area of protoxylem in the canes of *C. manan*, *Calamus* sp. and *C. rudentum* were similar which were between 25-35%. The increase and decrease of the protoxylem area may affect the area of fiber cap.

Stegmata, silsica bodies impregnated at the boundary of fiber caps and fiber bundles, were found in all species. Relating to utilization and quality, only stegmata at the fiber bundles in cortex and at the peripheral vascular bundles were considered. The stegmata could not be found at both cortical fiber bundles and peripheral vascular bundles of *Calamus* sp. It was also absent at the peripheral vascular bundles and less frequent at the cortical fiber bundles of *C. manan*. However, the stegmata was frequently found in all cortical fiber bundles and the fiber caps of *C. rudentum*, *C. longisetus* which were the lower grade rattan (Table 2). The stegmata may cause dullness to the knife of rattan processing machines.

Variation of Anatomical Characteristics in Radial Direction

Density of vascular bundles

At the periphery inside the cane, about 5% of radial distance, the size of vascular bundles were usually smaller than the inner ones. The smaller size vascular bundles bring to the bigger number of the bundles per giving area, density. (Figure 3)

Density of vascular bundles was abruptly reduced as moving inward about 10-15% of radius and then gradually reduced to the center. The first grade cane of *C. manan* contained smallest vascular bundle density and being uniform to the center of the cane. The cane of *Calamus* sp. (waai nam pheung) which is similar grade to *C. manan*

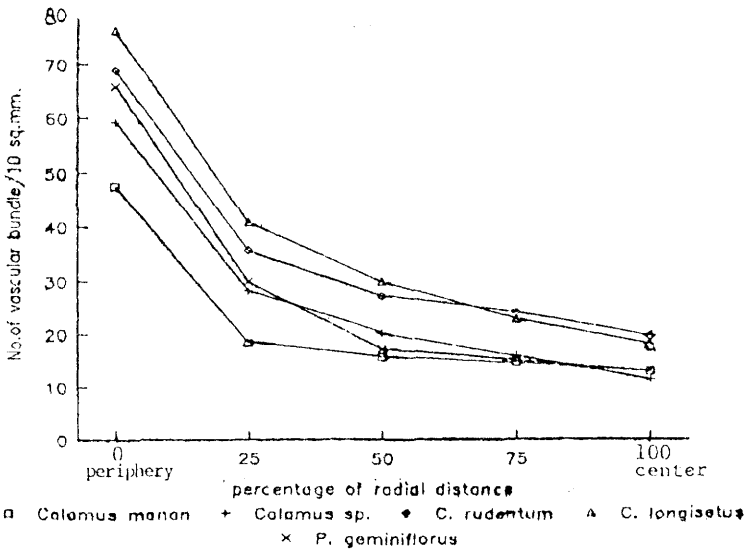


Figure 3 Variation of the number of vascular bundles across the cane's.

contained slightly greater vascular bundle density than those of *C. manan*. However the medium quality cane of *C. longisetus* and *C. rudentum* showed the greatest vascular bundle densities. Except *C. manan*, the densities of vascular bundles for all species were gradually decrease from the position after peripheral zone to the center of the canes. The poor grade cane from *P. giminiflorus* showed somewhat abruptly decreasing of vascular bundle densities from the periphery to the center. The size of the vascular bundle density did not show the clear picture relating to the cane qualities. The uniformity of within cane densities must affect the quality of cane in some extend.

Cross section area of vascular bundles

In the cane of *C. manan*, the area covered by the vascular bundle cross sectional area was greatest and more uniform across the radius. In the poorest grade cane of P. geminiflorus, the vascular bundle area was very high at the periphery and steeply reduced arcoss the radius becoming smallest at the center (Figure 4). The cross section area of the vascular bundles in the medium grade canes of *C. rudentum* and *C. longisetus* were intermediate between the best and the poorest grade. Considering the area covered together with the density of vascular bundle could bring out the picture of the size of vascular bundles. As in *C. manan*, its cane contained lower density but greater area covered by vascular bundles indicated the larger size of vascular bundles. In contrsast, *P. geminiflorus* presented the smallest figure of both density and area of vascular bundles indicated containing the smaller size of vascular bundles.

Intervascular ground tissue

The area of intervascular ground tissue was the inverted figure of the area covered by vascular bundles (Figure 4 and 5). The ground tissue between vascular bundles was narrowest, less than 30% of total area and was similar figures from the periphery to the center for better grade species. (Figure 5). In contrast, the ground tissue of P. geminiflorus was very narrow at the periphery and abruptly increased to be the largest, about 60% of total area, at the

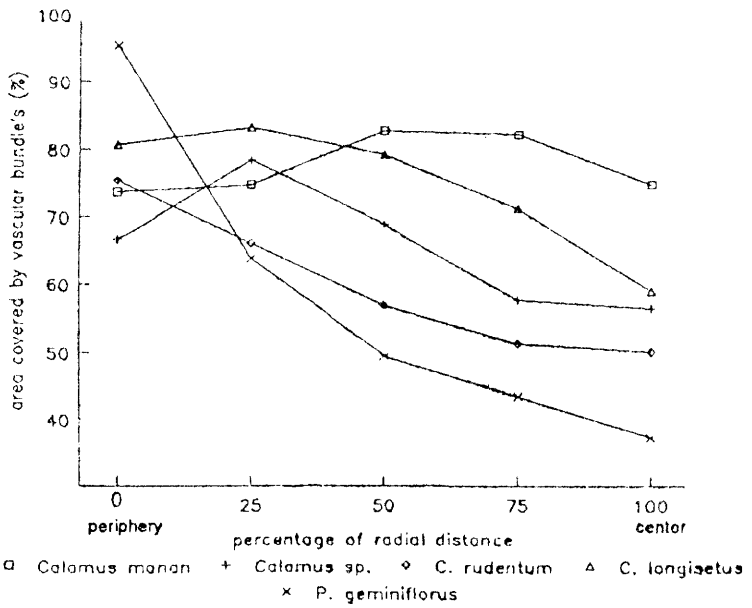


Figure 4 Variation of vascular bundles across the cane's radius.

center. The other species were intermediate. The wider ground tissue contained, the softer material obtained.

The double wall thickness of the intervascular ground tissue was usually thicker at the periphery and thinner at the inner core of the cane. For all species, in the inner core at before 25% of radius across to the center, the wall thickness was uniform (Table 2). In the cane of *C. manan* the wall thickness at the inner core was about two times thicker than those of the other species. Moreover they were similar to the wall thickness at the peripheral ground tissue and the cortical ground tissue. In the lower grade cane of *C. rudentum*, *C. longisetus* and *P. geminiflorus*, the double wall thickness was very big at the periphery and much reduced at the inner core zone, 25% - 100% of the radial distance.

Area of fiber cap

Fiber cap is only a major mechanical tissue of the rattan canes. The percentage of area covered by fiber cap was distinctly different between the commercial and non-commercial canes (Figure 6). However, within the group of commercial species the area of fiber cap at positions from 25% to 100% of radial distance were somewhat uniform for the first grade cane of *C. manan* and *Calamus* sp. but gradually decreased to the center for the lower grade canes of *C. rudentum* and *C. longisetus*.

Fiber wall thickness

Fiber wall thickness in term of double wall thickness (2W) was distinct differently between the best quality cane group (*C. manan* and *Calamus* sp.) and the lower grade (*C. rudentum* and *C. longisetus*) or/and the poor quality group (*P. geminiflorus*). The double wall thickness of the best quality group was thicker than 8 microns which was twice as thick as the lower grade. The wall thickness was also reported distinctly different between species (Bhat *et al.*, 1990)

The fiber wall thickness was less variation or uniform from the position next to periphery to the center for all studies species (Figure 7). The variation of fiber wall thickness across the radius was reported the same pattern on the cane of *C. hookerianus* and *C. pseudotenuis* (Bhat *et al.* 1990).

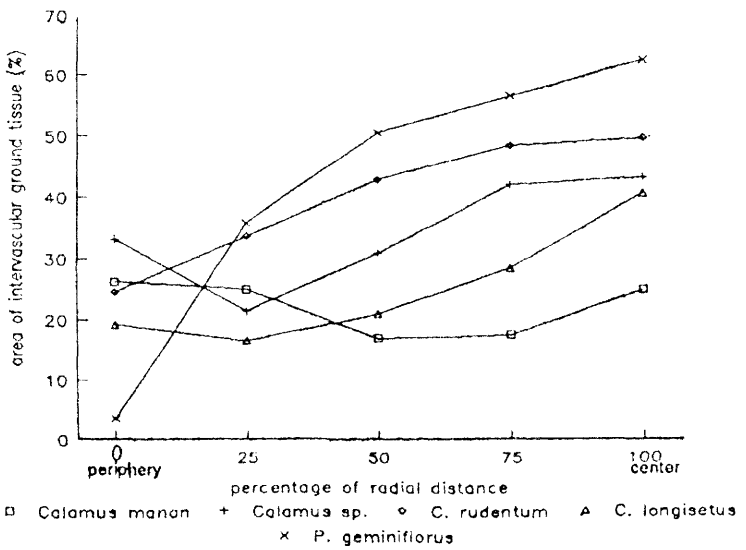


Figure 5 Variation of area of intervascular ground tissue across the cane's radius.

However they also reported the abrupt decrease of fiber wall thichness across the radius in the cane of other species.

Lumen diameter

In contrast to the wall thickness, the lumen diameter found greater for the lower grade cane, *C. rudentum* and *C. lonbgisetus* while the top quality cane group contained the smallest size of fiber lumen (Figure 8). The size of lumen was somewhat uniform across the radius for most species except

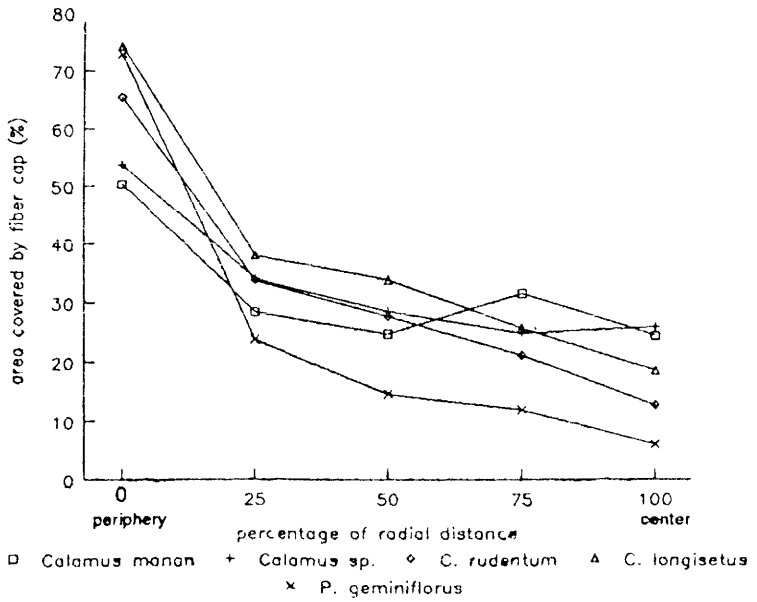


Figure 6 Variation of fiber cap across the cane's radius.

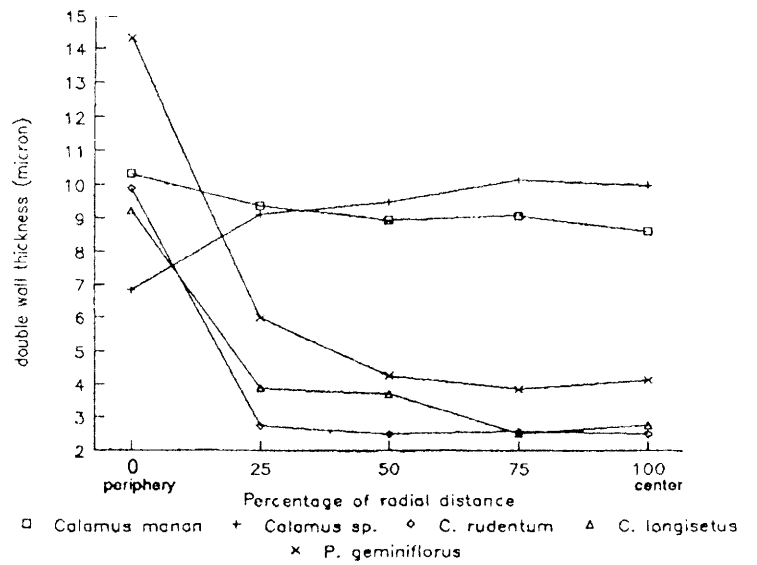


Figure 7 Variation of double wall thickness across the cane's radius.

C. longisetus of which the fiber lumen diameter increase greatly to the center. The increase of lumen size will add void area to the cane which certainly affect to the strength properties.

Total fiber wall area

Generally know that the fiber impart to the major strength of plant organs. The bigger fiber wall contained, the greater strength obtained. The ratios of double wall thickness (2W) to the cross section fiber diameter (D) represents the proportion of the fiber wall to the total cross section dimension of fiber. This figure (2W/D) can be used to estimate

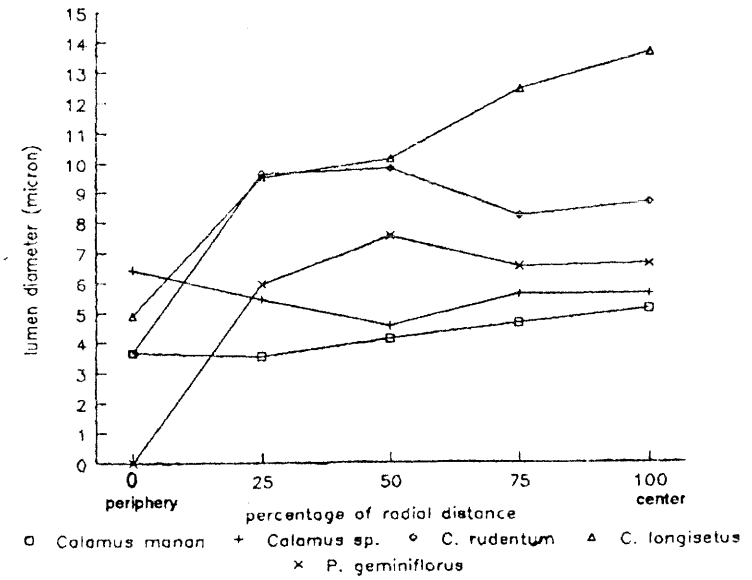


Figure 8 Variation of lumen diameter across the cane's radius.

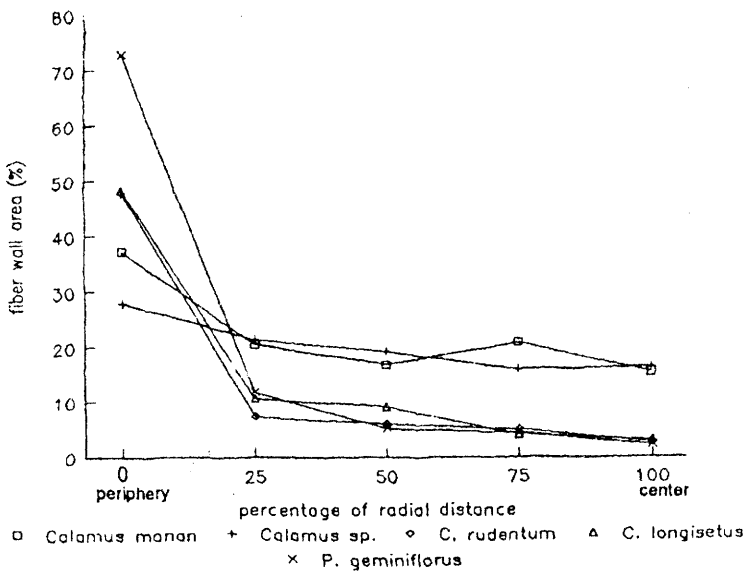


Figure 9 Variation of fiber wall area across the cane's radius.

Table 3 The dimensions of fiber from fiber cap.
2W = double wall thickness (micron), D = diameter (micron) L = lumen (micron)

Species	Radial distance (%)	2W X	2W sd	D X	D sd	L	(1) 2W/D	(2) Area fiber cap (%)	Area fiber wall(%) (1) x (2)
Calamus manan	0-5	10.31	.7293	13.98	1.2043	3.67	.74	50.32	37.24
	25	9.38	.6858	12.94	1.0938	3.56	.72	28.52	20.53
	50	8.95	.4105	13.1	1.2248	4.15	.68	24.78	16.85
	75	9.06	1.2745	13.73	0.4055	4.67	.66	31.70	20.92
	100	8.6	1.185	13.75	1.6095	5.15	.63	24.62	15.51
Calamus sp.	0-5	6.83	.6595	13.25	1.3075	6.42	.52	53.66	27.60
	25	9.11	.9683	14.56	1.4778	5.45	.63	34.08	21.47
	50	9.49	.9123	14.06	1.5108	4.57	.67	28.70	19.23
	75	10.13	1.0035	15.75	1.579	5.62	.64	25.04	16.03
	100	9.93	1.4093	15.63	1.1825	5.65	.63	26.10	16.44
Calamus rudentum	0-5	9.9	.4545	13.56	1.598	3.66	.73	65.44	47.77
	25	2.73	.5375	12.38	1.854	9.65	.22	33.88	7.45
	50	2.49	.3845	12.31	1.585	9.82	.22	27.80	6.12
	75	2.56	.2795	10.81	1.2998	8.25	.24	21.30	5.11
	100	2.49	.056	11.19	0.949	8.70	.22	12.79	2.81
Calamus longisetus	0-5	9.23	.9593	14.13	1.2235	4.9	.65	74.40	48.36
	25	3.88	.4625	13.38	1.4108	9.5	.28	38.13	10.68
	50	3.7	.853	13.88	1.6173	10.18	.27	34.04	9.19
	75	2.5	.1623	15	5.4108	12.5	.16	25.84	4.13
	100	2.75	.538	16.5	5.8855	13.75	.17	18.69	3.18
Plectocomiopsis geminiflorus	0-5	14.31	.949	14.31	.949	9.0	1.0	72.92	72.92
	25	6.0	1.0545	11.94	1.6953	5.94	.50	23.78	11.89
	50	4.25	.8508	11.81	1.7435	7.56	.36	14.60	5.26
	75	3.84	1.2255	10.38	1.863	6.54	.37	11.98	4.43
	100	4.11	0.5285	10.75	1.6918	6.64	.38	6.06	2.30

total cross section wall area of fibers by multiplying to the fiber cap area (Table 3). Among five species of the canes investigated here, the two first grade species (*C. manan* and *Calamus* sp.) showed distinctly higher percentage of total fiber wall area while those remained species were smaller fiber wall area (Figure 9). However, the fiber wall area of the fiber cap was similar between the poor grade (*P. geniniflorus*) and the medium grade (*C. rudentum* and *C. longisetus*) . This may due to the present of thicker fiber wall (Figure 7) but smaller area of fiber cap (Figure 6) in *P.geminiflorus*.

CONCLUSION

The results reveal that anatomical characteristics can be used to classify the qualities of rattan canes. The most importance character is the characteristics of the tissue in the central core of the cane. The following anatomical structures were distinctly different between the canes of different qualities; stegmata, fiber wall thickness, fiber cap area, fiber wall area, vascular bundle area, area of the intervascular ground tissue and the uniformity of the characteristics across the radius of the cane.

The characteristics presented in the first grade canes of *Calamus manan* and *Calamus* sp.;

- absent of stegmata at peripheral vascular bundles.
- very thick fiber's double wall thickness, thicker than 8 microns.
- larger area covered by vascular bundles, about 60-80% of the total area.
- smaller area covered by intervascular ground tissue.
- larger fiber wall area.
- uniformity of characteristics across the radius.

The characteristics presented in the medium grade canes of *C. rudentum* and *C. longisetus*;

- frequent of stegmata at peripheral vascular bundles.
- very thin fiber's double wall thickness, thinner than 4 microns.
- small fiber wall area, about 10% of the total area.
- intermediate area covered by vascular bundles.
- intermediate area covered by intervascular ground tissue.
- slightly change of the characteristics across the radius.

The characteristics presented in the non-commercial grade of *Plectocomiopsis geminiflorus;*

- smallest area covered by vascular bundles.
- smallest area covered by fiber cap.
- largest area covered by intervascular ground tissue.
- abruptly change of the characteristics across radius.

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