

ON THE PHYSICAL PROPERTIES AND ANATOMICAL FEATURES OF *DAEMONOROPS ANGUSTIFOLIA* AND *CALAMUS ORNATUS*

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ABSTRACT

This paper discusses the physical and anatomical characteristics of 17 years old *Daemonorops angustifolia* 'rotan getah' and *Calamus ornatus* 'rotan dok' collected from FRIM of Kepong, Selangor. *C. ornatus* had a bigger stem diameter (28 to 37 mm) but shorter in internodes length (14 to 35 cm) than *D. angustifolia* (20 to 27 mm and 23 to 52 cm, respectively). The initial moisture content ranged from 80.22 to 133.51% in *D. angustifolia* and 70.67 to 102.58% in *C. ornatus*. Both species had lower oven-dry density which ranged from 0.31 to 0.49 gcm⁻³. There were also some visible differences in the anatomical features among the species and heights of the stems studied.

INTRODUCTION

Rattans are the most important group of forest species after timber. They are spiny climbing plants belonging to the sub-family Calamoideae, the scaly fruited palms (Uhl and Dransfield, 1987). Their growth confined mainly in the tropical forests of South-East Asia and are deemed capable of making a dramatic contribution to economic development if properly utilized. As a raw material, rattan can either be exported or used locally in accordance with the scale of parallel investments in small or large-scale industrial facilities.

The selection of rattan for industrial uses is more closely related to its physical and anatomical properties. Proper selec-

tion of the cane especially the less popular types; affects the final uses, toughness, workability and its durability (Abd. Latif, 1991). This paper reports on the physical and anatomical features of both species for assessing their potential suitability especially for various end-purposes.

MATERIALS AND METHODS

Two rattan stems from each species of *Daemonorops angustifolia* 'rotan getah' and *Calamus ornatus* 'rotan dok' of about 17 years old were collected from the vicinity of Forest Research Institute Malaysia (FRIM) campus at Kepong, Selangor. Each stem was equally divided into three portions of basal (B), middle (M) and top (T).

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Samples of about 5 cm and 2 cm in length were taken from both ends and middle part of each portion of the stem for the determination of physical properties and anatomical characteristics, respectively. British Standard 373 (1957) was used as a guide for the determination of physical properties viz. moisture content, oven-dry density and shrinkage.

For anatomical studies, the specimens were subsequently embedded in a mixture of 20 ml polyethylene glycol (PEG - MW 2000) with 100 ml distilled water before being dried in an oven at 60°C (about 4 days period) to evaporate all the unrequired water. The transverse and longitudinal sections of about 25 µm thickness were then cut from the PEG penetrated blocks before being rinsed thoroughly with distilled water. The sections were later subjected to double staining with Safranin-O red and Astrablau for better contrast of microscopic images. While the cross section was embedded in glycerin, the more fragile longitudinal section was treated with Canada Balsam (Liese and Weiner, 1987). Measurements of fibre dimensions were then made on fibres macerated in a mixture of hydrogen peroxide and glacial acetic acid (50:50).

From the fibre measurements, the Runkle ratio, coefficient of supleness and L/D ratio factor (Runkle, 1952; Anonymous, 1955) were calculated as follows:

$$\text{Runkle ratio} = \frac{2W}{l}$$

$$\text{Coefficient of supleness} = \frac{l}{D} \times 100$$

$$\text{L/D ratio} = \frac{L}{D}$$

where :

W = fibre wall thickness (µm)

D = fibre width (µm)

l = fibre lumen diameter (µm)

L = fibre length (mm)

RESULTS AND DISCUSSION

Stem characteristics

The physical characteristics of *D. angustifolia* and *C. ornatus* such as length, diameter and internodes length are presented in Table 1.

The stem of *C. ornatus* is ivory yellow, glossy and usually accompanied with clear longitudinal striations and close vertically broken marks. *D. angustifolia*, on the other hand, is reddish and pale. In general, *D. angustifolia* stems are longer than *C. ornatus* (respective length of 30 to 37 m and 8 to 9 m) at the same age, but are smallest in diameter (20 to 28 mm and 28 to 38 mm, respectively). The average number of internodes and internodal length were observed to be 110 to 130 cm and 23 to 53 cm, respectively in *D. angustifolia* than those of 30 to 45 cm and 14 to 35 cm in *C. ornatus*. Eventhough the stems of *C. ornatus* are shorter than *D. angustifolia*, they are

Table 1. Average stem characteristics of rattans

Species	Stem	Length (m)	Number of internode	Diameter (mm)			Internodal length		
				B	M	T	B	M	T
<i>Daemonorops</i>	1	36.57	123	20.7	22.9	27.4	52.9	40.7	23.8
<i>angustifolia</i>	2	34.30	119	26.8	20.3	25.2	34.3	34.5	25.2
<i>Calamus</i>	1	8.07	36	28.0	30.3	35.9	34.2	34.8	14.5
<i>ornatus</i>	2	8.91	43	29.6	35.4	37.3	29.0	14.6	23.5

Notes : B: Basal M: Middle T: Top

suitable to be used for medium quality furniture frames and components, ropes and binds (Abd. Latif, 1991). The reddish stems of *D. angustifolia*, on the other hand, are only suitable for the making of lower quality ropes and binds, and furniture frames (Abd. Latif, 1988).

Anatomical features

Vascular bundles distribution

The anatomical properties of the rattans at different height is given in Table 2. The respective summary of analyses of variance and Duncan's Multiple Range test on anatomical properties are shown in Tables 3 and 4, respectively.

The frequency of vascular bundles varies insignificantly with height of the stem. Generally, the vascular bundles are densely distributed in the outer part than the inner core; and they are usually accompanied with conducting cells, xylem and phloem, which are surrounded by a fibre sheath and thick parenchyma cells.

The vascular bundles found in the central cylinder of *D. angustifolia* are more crowded than those of *C. ornatus* (Figures 1a and 1b). The highest mean concentration of vascular bundles was observed in the middle portion of *D. angustifolia* (4.48 bundles/mm²) and in the basal portion of *C. ornatus* (4.05 bundles/mm²). This is explainable in the sense that both portions are matured and almost established (Grosser and Liese, 1971).

The vascular bundles itself consist of a solitary metaxylem, two phloem fields which are located laterally, and accompanied with narrow protoxylem vessels which are frequently found at the vascular bundle on the open-end of the fibre sheath. In general, the metaxylem vessel diameter of *D. angustifolia* (268 to 278 µm) are smallest than those of *C. ornatus* (271 to 307 µm). However, the fibre bundles situated near the peripheral zone consist of thicker-walled cells and are

Table 2. Anatomical properties of rattans

Species	Portions		
	Basal	Middle	Top
<i>Vascular bundles distribution (No./mm²)</i>			
<i>D. angustifolia</i>	3.80	4.48	4.17
<i>C. ornatus</i>	4.05	3.68	3.63
<i>Metaxylem vessel diameter (µm)</i>			
<i>D. angustifolia</i>	276.68	272.09	269.81
<i>C. ornatus</i>	272.74	306.27	293.64
<i>Fibre length (mm)</i>			
<i>D. angustifolia</i>	1.94	1.97	1.92
<i>C. ornatus</i>	1.58	1.57	1.52
<i>Fibre diameter (µm)</i>			
<i>D. angustifolia</i>	19.53	19.02	19.93
<i>C. ornatus</i>	20.00	19.58	17.67
<i>Fibre lumen diameter (µm)</i>			
<i>D. angustifolia</i>	7.52	8.63	8.87
<i>C. ornatus</i>	8.58	7.73	7.98
<i>Fibre wall thickness (µm)</i>			
<i>D. angustifolia</i>	6.01	5.19	5.53
<i>C. ornatus</i>	5.71	5.93	4.84
<i>Runkle ratio</i>			
<i>D. angustifolia</i>	1.86	1.22	1.87
<i>C. ornatus</i>	1.80	1.40	1.49
<i>Coefficient of suppleness</i>			
<i>D. angustifolia</i>	37.83	44.73	43.81
<i>C. ornatus</i>	42.30	39.25	44.53
<i>L/D ratio</i>			
<i>D. angustifolia</i>	103.02	107.67	99.92
<i>C. ornatus</i>	82.45	82.33	88.98

Notes: Values shown are the means of 30 readings

Table 3. Summary of analyses of variance on anatomical properties of rattans

Source of variation	df	Mean squares and statistical significant								
		Vascular bundle	Metaxylem diameter	Fibre					Coefficient	
				Length	Width	Lumen	Wall	Runkle ratio	of Suppleness	L/D ratio
Species	1	11.74*	2.92E4*	13.52*	15.21ns	5.14ns	0.67ns	0.02ns	0.79ns	3.25E4**
Sample	1	11.03*	9.72E4**	1.12**	1.60ns	3.5E2**	99.75*	35.32*	9.14E3**	2.03E3*
Portion	2	1.19ns	6.28E3ns	0.08ns	28.04ns	4.34ns	13.55*	2.05**	5.06E2**	1.84E2ns
Species x sample	1	9.03*	2.17E4*	0.82**	0.01ns	1.23ns	0.25ns	0.05ns	17.81ns	2.15E3*
Species x portion	2	8.94*	1.16E4ns	0.01ns	77.54**	38.35**	16.26*	3.28**	3.57E2**	1.62E3*
Sample x portion	2	6.36*	9.14E3ns	0.47**	9.57ns	36.52**	2.62*	1.79*	5.39E2**	2.32E3*
Species x sample x portion	2	6.91*	2.59E4**	0.26*	12.14ns	39.06**	18.65*	4.92**	1.24E2**	1.31E3ns

Notes: ns: not significant at P<0.05; *: significant at P<0.05; **: highly significant at P<0.01

Table 4. Duncan's Multiple range test on the anatomical characteristics of rattans

Properties	Duncan's mean		
	Species	Sample	Portion
Vascular bundle distribution (No/mm ²)	3.79 a (Y)	3.79 a (2)	3.90 a (T)
	4.15 b (X)	4.14 b (1)	3.93 a (B)
Metaxylem vessel diameter	272.86 a (X)	265.44 a (1)	274.74 a (B)
	290.88 b (Y)	298.30 b (2)	281.72 a (T)
Fibre length	1.55 a (Y)	1.69 a (1)	1.72 a (T)
	1.94 b (X)	1.80 b (2)	1.76 a (B)
Fibre width	19.08 a (Y)	19.22 a (1)	18.10 a (T)
	19.49 a (X)	19.36 a (2)	19.30 ab (M)
Fibre lumen diameter	8.10 a (Y)	7.23 a (2)	8.05 a (B)
	8.34 a (X)	9.21 b (1)	8.18 a (M)
Fibre wall thickness	5.49 a (Y)	5.01 a (1)	5.19 a (T)
	5.58 a (X)	6.06 b (2)	5.56 b (M)
Runkle ratio	1.55 a (Y)	1.24 a (1)	1.41 a (T)
	1.56 a (X)	1.87 b (2)	1.58 b (M)
Coefficient of supleness	42.03 a (Y)	37.03 a (2)	40.06 a (B)
	42.12 a (X)	47.11 a (1)	41.99 ab (M)
L/D ratio	84.52 a (Y)	91.65 a (1)	92.63 a (B)
	103.54 b (X)	96.41 a (2)	94.45 a (T)
			94.99 a (M)

Notes: 1. Means followed by the same letter(s) differ insignificantly at $P < 0.05$

2. X= *Daemonorops angustifolia* Y= *Calamus ornatus*

3. B= Basal M= Middle T= Top

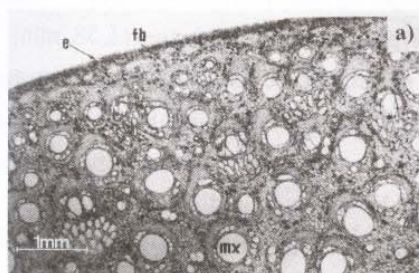


Figure 1. Cross section of *D. angustifolia* (x 22) (a), and *C. ornatus* (x 22) (b)
(e: epidermis, fb: fibre bundles, mx: metaxylem; p: phloem strands)

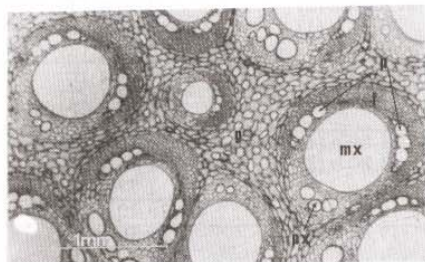


Figure 2a. Cross section of inner portion of *D. angustifolia* (f: fibre sheath; g: parenchyma ground tissue; mx: metaxylem; p: phloem strands; px: protoxylem) (x 44.)

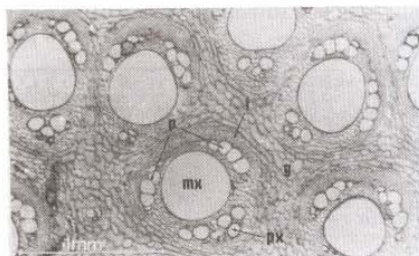


Figure 2b. Cross section of inner portion of *C. ornatus* (f: fibre sheath; g: parenchyma ground tissue; mx: metaxylem; p: phloem strands; px: protoxylem) (x 44.)

bigger than those in the central portion of the stem (Figures 2a and 2b).

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 fibre length of both rattans vary significantly with species, samples and the interactions of species and sample, sample and portion, and species, sample and portion. Regardless of samples and portions, the mean fibre length of each species ranged from 1.92 - 1.97 mm in *D. angustifolia* and 1.52 to 1.58 mm in *C. ornatus*, respectively.

The analyses of variance (Table 3)

indicates that the fibre length varies insignificantly ($P < 0.05$) with stems height but differs significantly ($P < 0.01$) with species and samples. The longest mean fibre length was found in the middle portion of *D. angustifolia* (1.97 mm) and in the basal portion of *C. ornatus* (1.58 mm). The shortest fibre length, contrarily, was found in the top portion of both species (1.92 mm and 1.52 mm, respectively). As stated by Grosser and Liese (1971) and Pattanath (1972), the fibre length within and between the stem may vary as the individual characteristics of the rattans itself. It is conceivable that external factors, such as soil conditions and climatic changes during fibre development might influence fibre length.

Fibre wall thickness

The fibre wall thickness varies insignificantly according to rattan species ($r = 1.28$ at $P < 0.05$) but are significantly affected by samples and portions ($P < 0.01$). The values ranged between 5.1 to 6.1 μm in *D. angustifolia* and 4.8 to 6.0 μm in *C. ornatus*. This could be related to the fact that *D. angustifolia* possesses bigger lumen diameter (19.02 - 19.93 μm) and smaller fibre width (19.00 - 19.99 μm) than *C. ornatus* (respective values of 7.73 to 8.58 μm and 17.67 to 20.00 μm).

The Runkle ratio of rattans obtained from this study ranged between 1.22 to 1.87 in *D. angustifolia* and 1.40 to 1.80 in *C. ornatus*. Based on the reports of Tamolang *et al.* (1957) and Dadswell and Watson (1962); and supported by its low coefficient of suppleness (37 to 45 in *D. angustifolia* and 39 to 45 in *C. ornatus*, respectively) and higher L/D ratio (99 to 105 in *D. angustifolia* and 82 to 89 in *C. ornatus*, respectively), both species are not suitable to be used as a material for papermaking.

Physical properties

Initial moisture content and oven-dry density

The average physical properties of rattans and the respective summary of analysis of variance are presented in

Tables 5 and 6. The Duncan's Multiple Range test on mean values of the properties studied is given in Table 7. The physical properties discussed are the initial moisture content, oven-dry density and shrinkage.

The initial moisture content of rattans varies significantly with species and portion but not with the samples. Regardless of portion, the initial moisture content varies between 80 to 134 percent in *D. angustifolia* and 70 to 103 percent in *C. ornatus*, respectively. The highest mean initial moisture content was observed in the respective middle portion of *D. angustifolia* (133.5 percent) and in the top portion of *C. ornatus* (102.6 percent). The lowest mean initial moisture content, on the other hand, was observed in the basal portion of both samples (80.2 percent in *D. angustifolia* and 70.7 percent in *C. ornatus*, respectively). This could be implied to the thick-walled fibres and greater concentration of vascular bundles distributed within this mature region. Table 5 further reveals that the oven-dry density of green rattan ranges from 0.38 to 0.48 g/cm^3 in *D. angustifolia* and 0.31 to 0.49 g/cm^3 in *C. ornatus*. Its follow somewhat the similar trend to those of the initial moisture content. While the initial moisture content was observed to increase from basal towards the tip, the density decreases along the height. Again, this

Table 5. Average physical properties of rattans

Species	Portion		
	Basal	Middle	Top
<i>Initial moisture content (%)</i>			
<i>D. angustifolia</i>	80.2	133.5	131.9
<i>C. ornatus</i>	70.7	90.7	102.6
<i>Oven-dry density (g/cm³)</i>			
<i>D. angustifolia</i>	0.49	0.42	0.38
<i>C. ornatus</i>	0.49	0.41	0.31
<i>Volumetric shrinkage (%)</i>			
<i>D. angustifolia</i>	6.17	12.92	10.80
<i>C. ornatus</i>	0.49	0.41	0.31
<i>Diameter shrinkage (%)</i>			
<i>D. angustifolia</i>	2.66	2.71	6.85
<i>C. ornatus</i>	3.60	4.34	5.10
<i>Longitudinal shrinkage (%)</i>			
<i>D. angustifolia</i>	0.75	0.77	0.92
<i>C. ornatus</i>	1.42	1.45	1.67

Table 6. Summary of analyses of variance on physical properties of rattans

Source of variation	Df	Mean squares and statistical significance				
		Moisture content	Oven-dry density	Shrinkage		
				Volume	Diameter	Longitudinal
Species	1	4.45E3**	0.004*	63.30*	0.45ns	2.89**
Sample	1	1.48ns	0.008*	61.42*	2.22ns	0.02ns
Portion	2	4.16E3**	0.044**	37.79*	19.01*	0.10ns
Species x sample	1	3.10E3**	0.000ns	47.58*	0.22ns	0.21ns
Species x portion	2	5.59E2*	0.003ns	13.16ns	6.36ns	0.003ns
Sample x portion	2	7.63E2*	0.001ns	44.07*	11.26*	0.07ns
Species x sample x portion	2	1.87E3**	0.019**	10.71ns	16.63*	0.07ns

Notes: ns: not significant at $P < 0.05$; *: significant at $P < 0.05$; **: highly significant at $P < 0.01$

reflects to the thicker fibre walls and bigger concentration of vascular bundles distribution within the mature tissues of the basal portion (Abd. Latif and Norra-lakmam, 1992).

The volumetric shrinkage of rattans vary significantly with species, sample,

portion, the interactions of species and sample; and sample and portion but not with the interactions of species and portion; and between species, sample and portion. Diameter shrinkage, contrarily, varies significantly ($P < 0.05$) with portion, the interactions between sample and

Table 7. Duncan's New Multiple Range test on the physical properties of rattans

Physical properties	Species	Duncan's means Sample	Portion
Initial moisture content (%)	87.9 a (Y)	101.4 a (1)	75.4 a (B)
	115.2 b (X)	101.9 a (2)	112.1 b (M)
			117.3 b (T)
Oven-dry density (gcm-3)	0.40a (Y)	0.40a (1)	0.34 a (T)
	0.43b (X)	0.44b (2)	0.42 b (M)
			0.49 c (B)
Volumetric shrinkage (%)	6.72a (Y)	6.74a (2)	5.89 a (B)
	9.96b (X)	9.94b (1)	8.79 ab (T)
			10.25 b (M)
Diameter shrinkage (%)	4.07a (X)	3.90a (1)	3.13 a (B)
	4.34a (Y)	4.51a (2)	3.52 a (M)
			5.97 b (T)
Longitudinal shrinkage	0.82a (X)	1.13a (2)	1.08 a (B)
	1.15b (Y)	1.19a (1)	1.11 a (M)
			1.29 a (T)

Notes: 1. Means followed by the same letter(s) are not significantly different at $P < 0.05$

2. X= *D. angustifolia*, Y= *C. ornatus*,

3. B= basal, M= middle, T= top

portion and between species, sample and portion. Longitudinal shrinkage, on the other hand, differs significantly ($P < 0.01$) with the species but not with the sample, portion and their interactions.

Regardless of species, samples and height levels, the shrinkage values ranged from 6.17 to 12.92 percent in *D. angustifolia* and 5.78 to 7.59 percent in *C. ornatus* (volumetric), 2.66 to 6.85 percent in *D. angustifolia* and 3.60 to 5.10 percent in *C. ornatus* (diameter) and 0.75 to 0.92 percent in *D. angustifolia* and 1.42 to 1.67 percent in *C. ornatus* (longitudinal). Compared to those of *Calamus manan* (0.43 to 1.73 percent and 1.77 to 6.04 percent for the respective longitudinal and diameter shrinkages) (Haron *et al.*, 1989), both

species (*D. angustifolia* and *C. ornatus*) can be expected to possess better dimensional stability. As mentioned by Abd. Latif and Zin (1992), the published reports on other rattan species studied are lacking but from the utilization perspective of view, rattan may shrink less than those of bamboo and timber of the similar density.

CONCLUSION

The stem characteristics, physical properties and anatomical features of *D. angustifolia* and *C. ornatus* canes were ascertained. Anatomically, there are some appreciable differences between the species. With the exception of fibre cell wall thickness, Runkle ratio and coefficient of suppleness, all the anatomical

properties differ insignificantly with stem height.

The initial moisture content of both species increased from basal towards the top portions while the density decreased within the same trend of height. The relatively lower shrinkage values within these two species as observed in the study indicated for their better dimensional stability than those of the most commonly utilized rattan species in Peninsular Malaysia, *C. manan*.

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