PHYSICAL PROPERTIES, FIBRE DIMENSIONS AND PROXIMATE CHEMICAL ANALYSIS OF MALAYSIAN RATTANS

Abd. Razak Mohd. Ali [1] **Abd. Latif Mohmod** [1]
K.C. Khoo [1] **Jamaludin Kasim** [2]

ABSTRACT:- The physical properties, fibre morphology and chemical constituents of five Malaysian canes, viz. *Calamus manan* (rotan manau), *C. palustris* var. *malaccensis* (rotan manau langkawi), *C. scipionum* (rotan semambu), *Korthalsia rigida* (rotan dahan) and *Plectomiopsis griffithii* (rotan mantang gajah), are reported.

There is a wide variation in the fibre dimensions as well as the physical properties of all the species studied. The fibres are relatively short (1.34-2.17 mm) and thick-walled. The oven-dry density ranges between 0.33 and 0.61 gcm^{-3} and tends to decrease from the basal towards the top portion. With the exception of the holocellulose content, the chemical constituents differs significantly in content with species and height. The higher contents of water and alkali solubles of the rattans observed in the study indicate that proper selection, preparation and treatment should be considered in order to prolong their service lives.

INTRODUCTION

Rattan, a palmae, is an important non-timber forest produce in Peninsular Malaysia. Of the 600 species found throughout the world, about 106 species in 8 genera can be found in the forest of Peninsular Malaysia (Dransfield, 1979; Aminuddin & Abd. Latif, 1993). However, only about 20 species are widely used commercially. Among these are Rotan manau (*Calamus manan*), Rotan mantang (*C. ornatus*), Rotan semambu (*C. scipionum*), Rotan dahan (*Korthalsia rigida*) and Rotan sega (*C. caecius*).

The preparation and selection of rattan either for processing or manufacturing are dictated by its basic characteristics such as anatomical features, physical properties and chemical constituents (Abd. Latif, 1991; Abd. Latif, 1992). Since the available informations on such properties are lacking and many rattan species remain unutilized, research is needed to determine the properties of those species and develop their appropriate utilization technology. The present study deals with the physical properties, fibre morphology and chemical composition of five Malaysian rattan species.

[1] Forest Research Institute Malaysia (FRIM), Kepong, 52109 Kuala Lumpur, Malaysia
[2] MARA Institute of Technology (ITM), 40450 Shah Alam, Selangor, Malaysia.

MATERIALS AND METHODS

Five rattan stems from each of the species, *Calamus manan* (rotan manau), *C. palustris* var. *malaccensis* (rotan manau langkawi), *C. scipionum* (rotan semambu), *Korthalsia rigida* (rotan dahan) and *Plectomiopsis griffithii* (rotan mantang gajah) were used for the present study (Table 1). The stem length, diameter and number of internodes were recorded (Table 2). Each stem was then divided into three levels of height, i.e. basal (B-10% height), middle (M-50% height) and top (T-90% height).

Samples of about 5 cm and 2 cm in length were taken from both ends and middle part of each portion of the stems for the assessment of physical properties and fibre dimensions. The methods used for the determination of physical properties such as moisture content, oven-dry density and shrinkages were based on BS 373 (Anonymous, 1957). Measurement of the fibre dimensions was made on macerated fibres obtained after treating with a 50-50 mixture of hydrogen peroxide and glacial acetic acid.

Chemical analysis for determining the percentage of some chemical constituents was conducted on oven dry milled rattan samples according to the following standard methods:

Table 1. Location of samples collected

Species	Estimated age (Y)	Locality	Remark
C. manan	17	Compartment 10, Sungai Buloh, Selangor	Planted
C. scipionum	14	Kg. Terlang, Lepar, Pekan, Pahang	Wild
C. palustris	8	Kampung Talang, Kuala Kangsar, Perak	Planted
K. rigida	12	Kg. Terlang, Lepar, Pekan, Pahang	Wild
P. griffithii	11	FRIM, Kepong, Selangor	Planted

Table 2. Mean stem characteristics of five Malaysian canes

Species	Length	Number of	Diameter (mm)			Internode length (cm)		
	(m)	internode	B	M	T	B	M	T
C. manan	46.6	192	30.9	34.6	40.8	13.7	21.8	16.8
C. scipionum	8.5	22	21.9	26.3	25.8	33.5	39.6	46.6
C. palustris	36.2	152	13.5	16.4	18.1	18.6	27.9	38.6
K. rigida	9.8	35	19.4	22.5	22.2	27.9	30.2	27.2
P. griffithii	57.4	136	36.3	49.2	61.0	20.4	41.4	49.2

Note : B = Basal M = Middle T = Top

a. Hot water solubles : TAPPI T 207 (Anonymous, 1978)
b. Cold water solubles : TAPPI T 207 (Anonymous, 1978)
c. 1% NaOH solubles : TAPPI T 212 (Anonymous, 1978)
d. Alcohol-benzene solubles : TAPPI T 204 (Anonymous, 1978)
e. Lignin : TAPPI T 222 (Anonymous, 1978)
f. Holocellulose : Wise *et al.* (1946)
g. Ash : TAPPI T 15 (Anonymous, 1978)

RESULTS AND DISCUSSION

Fibre morphology

Results on the fibre dimensions of the five rattan species, the summary of analyses of variance and Duncan's Multiple Range tests on mean values of the properties studied are shown in Tables 3, 4 and 5 respectively.

All the fibre dimensions of all the rattans obtained in this study varied significantly with the species, height (except for fibre width) and the interaction of species and height. In sequential order, the fibre length of *P. griffithii* (1.72-2.17 mm) is the longest and followed by *K. rigida* (1.70-1.82 mm), *C. manan* (1.62-1.79 mm), *C. scipionum* (1.53-1.66 mm) *and C. palustris* (1.34-1.41 mm). With regards to height, Duncan's Multiple Range test further reveals that fibre length was lowest in the top than the middle and basal portions (1.62 mm, 1.63 mm and 1.75 mm respectively). This could be due to the fact that the top portions of rattan stems are immature compared to the basal and middle portions.

Table 3. Fibre morphology of the five rattan species

Species	Height	Fibre			
		Length (mm)	Width (μm)	Lumen (μm)	Wall thickness (μm)
C. manan	Basal	1.79	21.17	6.32	7.92
	Middle	1.73	20.18	6.04	7.07
	Top	1.62	21.10	7.81	6.64
C. scipionum	Basak	1.62	19.58	8.39	5.59
	Middle	1.66	20.42	9.44	5.49
	Top	1.53	19.13	10.83	4.15
C. palustris	Basal	1.41	15.85	7.64	4.11
	Middle	1.34	16.03	8.40	3.82
	Top	1.35	15.50	7.49	4.00
K. rigida	Basal	1.78	20.43	7.72	6.35
	Middle	1.70	19.45	7.96	5.74
	Top	1.82	20.11	8.01	5.89
P. griffithii	Basal	2.17	21.97	8.93	6.33
	Middle	1.72	20.66	4.10	8.28
	Top	1.80	21.98	8.49	6.74

Note : Value shown are the means of 50 readings.

Table 4. Summary of analyses of variance on fibre morphology of the five rattan species

Source of variation	df	Mean squares and statistical significant			
		Fibre			
		Length	Width	Lumen	Wall thickness
Species	4	1.07**	1.40E2**	31.31**	51.26**
Height	2	0.24**	4.97ns	20.19**	5.09**
Species x height	8	0.11	3.97**	17.01**	3.78**

Notes: ns : not significant at $p < 0.05$, * : significant at $p < 0.05$, ** : highly significant at $p < 0.01$

Table 5. Duncan's Multiple Range test on the fibre morphology of the five canes

Proprerties	Duncan's means			
		Species		Height
Fibre length (mm)	1.37a	*C. palustris*	1.62a	Top
	1.61b	*C. scipionum*	1.63a	Middle
	1.71c	*C. manan*	1.75b	Basal
	1.77c	*K. rigida*		
	1.90d	*P. griffithii*		
Fibre width (μm)	15.79a	*C. palustris*	19.35a	Middle
	19.71b	*C. scipionum*	19.57ab	Top
	19.99b	*K. rigida*	20.00b	
	21.15c	*C. manan*		
	21.54c	*P. griffithii*		
Fibre lumen (μm)	6.72a	*C. manan*	7.19a	Middle
	7.17ab	*P. griffithii*	7.80b	Basal
	7.84b	*C. palustris*	8.53c	Top
	7.90b	*K. rigida*		
	9.56c	*C. scipionum*		
Fibre wall thickness (μm)	3.98a	*C. palustris*	5.49a	Top
	5.08b	*C. scipionum*	6.06b	Basal
	5.99c	*K. rigida*	6.08b	Middle
	7.12d	*P. griffithii*		
	7.21c	*C. manan*		

Note : Means followed by the same letter (s) are not significnatly different at $p < 0.05$.

The fibre walls tend to be thinner with stem height. This could be associated with the increase in the fibre width and fibre lumen with height. In addition, the thicker fibre wall at the basal portion is probably due to the nature of growth whereby the fibre wall thickness increases with age almost throughout the life time of the plant (Parathasarathy & Klotz, 1976). The fibre wall thickness of the rattans observed in this study, nevertheless, ranged from 6.64-7.92 μm (*C. manan*), 4.15-5.59 μm (*C. scipionum*), 3.82-4.11 μm (*C. palustris*), 5.74-6.35 μm (*K. rigida*) and 6.33-8.28 μm (*P. griffithii*)

Physical properties

The average physical properties of the five rattan species is presented in Table 6. The respective summary of analysis of variance and the Duncan's New Multiple Range test on mean values of the properties studied are presented in Tables 7 and 8 respectively.

The initial moisture content of the rattans differs significantly with species, height of the stems and the interaction of species and height. The highest and lowest mean initial moisture content were observed in the top portion of *P. griffithii* (118.9%) and basal portion *of C. palustris* (38.1%) respectively. The Duncan's Multiple Range test further disclosed that the moisture content is lowest in the basal portion but increases towards the top of the stem. This could be associated to the considerably thicker walls of the fibres, smaller metaxylem diameter and lower percentage of parenchymatous tissues in the mature regions of the basal than those of the upper portions (Abd. Latif & Siti Norralakmam, 1993).

The oven-dry density, on the other hand, follows a somewhat similar pattern to that of the initial moisture content, i.e. it varies significantly with all the parameters studied. While the initial moisture content was observed to increase from basal to top, the density decreases with height of the stem. Thicker fibre wall and bigger concentration of vascular bundle within the mature tissues of the basal region may contribute to this (Abd. Latif & Siti Norralakmam, 1993). The density of rattans was observed to be in the range of 0.47 - 0.60 gcm^{-3} in *C. manan*, 0.41-0.45 gcm^{-3} in *C. scipionum*, 0.44 - 0.60 gcm^{-3} in *C. palustris*, 0.54 - 0.61 gcm^{-3} *in K. rigida* and 0.33 - 0.36 gcm^{-3} in *P. griffithii*. The lowest oven-dry density and high initial moisture content in *P. griffithii* (0.34gcm^{-3} and 114.7% respectively) as shown in the Duncan's Multiple Range test (Table 8) further revealed for the unfavorable use of this material compared to the other species.

All the shrinkage values of the rattans vary significantly with species but not with height and the interaction of stem height and species (except for diameter shrinkage). Regardless of rattan species and their height levels, the shrinkage values ranged from 1.83-5.39% (diameter), 0.13-1.01% (longitudinal) and 3.28-12.54% (volumetric). The lowest mean shrinkage values were observed in the middle portion of *C. scipionum* (1.83%, diameter), basal portions *of C. manan* (0.13%, longitudinal) and *C. scipionum* (3.28%, volumetric). The highest mean value, on the other hand, was found in the top portion of *C. scipionum* (5.39%, diameter), basal portions of *K. rigida* (1.01%, longitudinal) and *C. manan* (12.54%, volumetric).

Table 6. Average physical properties of the canes

Property	Height	*C.manan*	*C. scipionum*	*C. palustris*	*K. rigida*	*P.griffithii*
Moisture	Basal	64.3	48.1	38.1	48.6	110.7
content	Middle	84.8	48.4	43.8	66.0	114.5
(%)	Top	107.0	57.6	48.1	75.5	118.9
Oven-dry	Basal	0.60	0.42	0.60	0.61	0.36
density	Middle	0.54	0.45	0.50	0.57	0.33
(gcm¯3)	Top	0.47	0.41	0.44	0.54	0.34
Diameter	Basal	3.34	1.92	2.90	4.62	5.00
shrinkage	Middle	2.57	1.83	2.51	5.21	5.27
(%)	Top	3.05	5.39	2.37	3.14	3.88
Longitudinal	Basal	0.13	0.68	0.28	1.01	0.34
shrinkage	Middle	0.22	0.72	0.38	0.78	0.51
(%)	Top	0.26	0.68	0.43	0.75	0.30
Volumetric	Basal	12.54	3.28	8.82	8.10	10.58
shrinkage	Middle	9.96	4.19	11.24	8.89	10.67
(%)	Top	12.32	4.18	10.72	8.14	10.58

Table 7. Summary of analyses of variance on physical properties of the canes

Source of variation	df	Mean squares and statistical significant				
		Moisture content	Oven-dry density	Shrinkage		
				Diameter	Longitudinal	Volumetric
Species	4	1.9783**	0.10**	1.03El**	8.19E-1**	1.12E2*
Height	2	1.53E3**	0.03**	4.80E-2ns	8.00E-3ns	1.41ns
Species x height	8	3.04E2**	5.00E-2**	6.01*	4.18E-1ns	3.80ns

Notes: ns : not significant at p< 0.05, * : significant at p < 0.05, ** : highly significant at p < 0.01

Chemical properties

Table 9 shows the proximate chemical composition of the five rattan species at different portions of the stem. The summary of analyses of variance and Duncan Multiple Range test are presented in Tables 10 and 11, respectively. With the exception of holocellulose, the results indicate that the contents of all the chemical constituents of the rattans differed significantly with species, height and the interaction of species and height.

The extractives content, particularly of the cold and hot water solubles, are important in indicating the amounts of water soluble extractives such as tannin, starch, sugar, pectin and phenolic compounds within the woody materials (Janes, 1969).

Higher concentration of these water soluble extractives may influence the durability of the rattan materials. The hot water solubles contents which ranged from 4.4-15.1 % fall within

Table 8. Duncan's Multiple Range test on the physical properties of Malaysian canes

Physical properties	Duncan's means	Species		Height
Moisture content (%)	43.4a	*C. palustris*	53.9a	Basal
	51.3b	*C. scipionum*	63.5b	Middle
	63.4c	*K. rigida*	71.4c	Top
	85.4d	*C. manan*		
	114.7e	*P. griffithii*		
Oven-dry density (gcm^{-3})	0.34a	*P. griffithii*	0.44a	Top
	0.43b	*C. scipionum*	0.48b	Middle
	0.51c	*C. palustris*	0.52c	Basal
	0.54c	*C. manan*		
	0.57d	*K. rigida*		
Diameter shrinkage (%)	2.59a	*C. palustris*	3.48a	Middle
	2.99ab	*C. manan*	3.56a	Basal
	3.05ab	*C. scipionum*	3.57a	Top
	4.32bc	*K. rigida*		
	4.72c	*P. griffithii*		
Longitudinal shrinkage (%)	0.21a	*C. manan*	0.49a	Basal
	0.36a	*C. palustris*	0.52a	Middle
	0.38a	*P. griffithii*	0.48a	Top
	0.69b	*C. scipionum*		
	0.84b	*K. rigida*		
Volumetric shrinkage (%)	3.89a	*C. scipionum*	8.66a	Basal
	8.38b	*K. rigida*	8.99a	Middle
	10.61c	*P. griffithii*	9.19a	Top
	10.26bc	*C. palustris*		
	11.61c	*C. manan*		

Note : Means followed by the same letter (s) are not significantly different at $p< 0.05$.

the ranges of those of Malaysian hardwoods (0.1-14.4%)(Khoo & Peh, 1982). Between the species, *K. rigida* possesses the lowest value (5.8%) followed by *C. scipionum* (5.9%), *C. manan* (6.2%), *P. griffithii* (8.0%) and *C. palustris* (13.3%). While the values of hot water solubles contents of *K. rigida*, *C. manan*, *C. scipionum* and *P. griffithii* resemble those values of 5.8% in the moderately durable untreated Malaysian heavy hardwoods of *Dialium laurinum* (Keranji tebal besar), 5.9% in *Lithocarpus* cf. *falconeri* (Mempening), 6.5% in *Sindora coriacea* (sepetir) and 8.1% in medium hardwood of *Shorea roxburghii* (meranti temak nipis) respectively, that of *C. palustris* falls under the same class with *Horsfieldia superba* (penarahan daun besar), the non-durable Malaysian timber (Khoo & Peh, 1982; Mohd. Dahlan & Tam, 1987).

Table 9. Proximate chemical composition of rattans

Species	Portion	Hot water solubles (%)	Cold water solubles (%)	1% alkali solubles (%)	Alcohol benzene solubles (%)	Holo-cellulose (%)	Lignin (%)	Ash (%)
K. rigida	Basal	6.9	6.6	20.4	3.5	76.6	24.5	1.4
	Middle	5.9	4.1	22.6	2.7	75.4	26.1	1.8
	Top	4.4	1.8	25.3	0.6	73.9	30.5	0.9
C. scipionum	Basal	5.2	3.9	25.6	1.5	77.3	24.2	2.0
	Middle	7.0	6.2	23.7	4.1	76.6	21.0	2.1
	Top	5.7	4.5	28.9	3.9	73.0	26.7	2.2
P. griffithii	Basal	8.9	4.9	27.8	3.8	77.4	28.5	3.4
	Middle	7.5	6.0	26.7	3.7	76.9	25.8	4.2
	Top	7.7	5.8	32.1	2.5	74.9	23.6	2.5
C. manan	Basal	6.2	2.7	18.8	3.9	79.5	22.0	0.8
	Middle	7.2	5.8	25.2	3.6	76.9	23.6	1.5
	Top	4.8	2.4	23.4	1.2	78.9	20.3	1.8
C. palustris	Basal	12.5	5.7	29.6	4.0	76.0	26.4	4.8
	Middle	15.1	13.7	33.0	7.8	73.4	23.9	3.8
	Top	12.3	10.9	33.9	6.1	75.0	26.1	3.1

Table 10. Summaries of the analysis of variance on the chemical properties of rattans

Source of variation	df	Solubles				Holo-cellulos e	Lignin	Ash
		Hot water	Cold water	1% alkali	Alcohol-benzene			
Species	4	93.75**	84.84**	162.53**	17.65**	23.25n	33.60**	13.08**
Height	2	9.72**	29.38**	76.91**	9.17**	28.26n	8.25**	1.27**
Species x height	8	3.11*	15.04**	10.48**	6.86**	5.93n	19.73**	1.21**

Notes: ns : not significant at $p < 0.05$, * : significant at $p < 0.05$, ** : highly significant at $p < 0.01$

The alkali solubles varied significantly with rattan species and stem height. The highest and lowest mean percentages of alkali solubles were observed in the top portion of *C. palustris* (33.9%) and basal portion of *C. manan* (18.8%). Between the species, *C. palustris* possesses the highest value (32.2%) followed by *P. griffithii* (28.9%), *C. scipionum* (26.2%), *K. rigida* (22.8%) and *C. manan* (22.5%). High alkali solubles could be associated with high degradation of cellulose and high polyphenol content (Clayton, 1969; Tadena & Villaneuva, 1971). Compared to Malaysian hardwoods (Khoo & Peh, 1982), these rattan species seems to have high alkali solubility thus indicate that they have to be treated properly in order to prolong their service performance.

Table 11. Duncan's Multiple Range T-tests on the chemical constituents of rattans

Species	Hot water	Cold water	1% alkali	Alcohol-benzene	Holo-cellulose	Lignin	Ash
C. palustris	13.3a	10.6a	32.2a	5.8a	74.8a	25.5ab	3.9a
P. griffithii	8.0b	5.6b	28.9b	3.4b	76.2a	25.9a	3.4a
C.manan	6.2c	3.5d	22.5d	3.0bc	78.6a	22.0c	1.4c
C. scipionum	5.9c	4.9bc	26.2c	2.9bc	75.8a	24.2b	2.1b
K. rigida	5.8c	4.2cd	22.8d	2.4c	75.3	27.0a	1.4c
Portion							
Basal	7.6ab	4.7b	24.1c	3.3b	77.3a	25.1ab	2.5ab
Middle	8.5a	7.6a	26.3b	4.4a	75.7a	24.1b	2.6a
Top	6.9b	5.3b	28.2a	2.8b	74.8a	25.4a	2.1b

Note : Means followed by the same letter (s) are not significnatly different at $p< 0.05$.

The alcohol-benzene solubles of the rattan species are found to be comparable to those of Malaysian hardwoods (Khoo & Peh, 1982) and that of the commonest bamboo in Peninsular Malaysia (Abd. Latif *et al*., 1994). Generally, the alcohol-benzene solubles increased from basal (3.35%) to the middle portions (4.38%) but decreased towards the tip (2.85%) (Table 11). *C. palustris* possesses the highest value of alcohol-benzene (5.79%) while *K. rigida* the lowest (2.36%).

The holocellulose content of rattan, regardless of species and stem height, varied from about 73-79%. The results (Table 9) also reveal that the decrease in holocellulose content within and between species and stems was generally accompanied by the increasing amount of hot and cold water solubles content. This similar trend was also reported by Abd. Latif *et al*. (1994) in their study on one- to three-year-old culms of *Gigantochloa scortechinii*, the most commonly utilized Malaysian bamboo. The highest and lowest mean percentages of holocellulose content were found to be in *C. manan* (78.6%) and *C. palustris* (74.8%) (Table 11). With regards to stem height, the trend observed was that the holocellulose content tends to decrease with the increase of stem height (except for *C. manan* and *C. palustris*).

The amount of lignin generally decreased from the basal to the top portion (except for *K. rigida* and *C. scipionum*). Chen *et al*. (1987) and Abd. Latif *et al*. (1994) also found similar trends of variation in their studies on bamboos from China and Malaysia respectively. The different array of lignin contents with stem height in *K. rigida* and *C. scipionum*, on the other hand, could be associated to the individual characteristics of the rattan itself. With regards to species, *K. rigida* generally possesses the highest value of lignin content (27%) followed by *P. griffithii* (25.9%), *C. palustris* (25.5%), *C. scipionum* (24.2%) and *C. manan* (22.0%). The present findings are similar to those of Siripatanadilok (1984) who uncovered that the lower percentage of lignin content can be observed in species known to be the better grades in the Thailand rattan trade. Nevertheless, the lignin contents of all the five rattan species are within the range for Malaysian timbers (Khoo & Peh, 1982).

The ash contents of *K. rigida*, *C. scipionum*and *C. manan* (0.92-1.77%, 2.03-2.21% and 0.85-1.78% respectively) fall within the ranges of those of Malaysian hardwoods (0.1-2.5%) (Khoo & Peh, 1982). Since the ash content is commonly associated with the amount of silica in a material like rattan, thus affecting the working properties (Wong, 1976), the selection of this three species with relatively low silica content for specific products such as ropes, binds, cores, splits and polished canes is significant. The ash contents of *P. griffithii* and *C. palustris*, on the other hand, exceed the values of those of Malaysian hardwoods. While the lower processing performance of *C. palustris* due to its high ash content may be compensated by its relatively good physical properties, the use of *P. griffithii* for products such as ropes and binds is only limited to its peripheral portion due to the high initial moisture content and low density of the core.

CONCLUSION

All the rattan species had fibre dimensions (except for fibre width) that varied significantly with species and height of the stem. These dimensions, tended to decrease with stem height from basal towards the top portion. The average fibre length and fibre wall thickness were observed to be within the ranges of 1.34-2.17 mm and 3.82-8.28 μm respectively.

The physical properties of all the rattans were observed to be governed significantly by species and stem height (except for the diameter, longitudinal and volumetric shrinkage). While the initial moisture content and shrinkage generally increased with stem height from basal toward the top, the density decreased.

Except for the holocellulose content, all the chemical components of rattan varied significantly with species and height. The top portion contained the highest alkali solubles and lignin content while the water, and alcohol-benzene solubles and ash content were found to be at the peak in the middle portion. In the case of holocellulose, the value tends to decrease from basal towards the tip.

REFERENCES

Abd. Latif, M. 1991. Guidelines for the selection and preparation of rattan for industrial use. Rattan Information Centre Handbook 2: 1-27.

Abd. Latif, M. 1992. Processing of rattans. *In:* W.M. Wan Razali, J. Dransfield & N. Manokaran (*eds.*). Guide to the Cultivation of Rattan, pp. 239-260. Malayan Forest Record 35. Forest Research Institute Malaysia.

Abd. Latif, M. and Y. S. Norralakmam. 1993. Anatomical characteristics of 5 Malaysian canes and its relationship with physical and mechanical properties. *In:* S. Chand Basha & K.M. Bhat (*eds.*). Rattan Management and Utilization, pp 207-213. Proceedings of the Rattan (Cane) Seminar India. January 29-31, 1992. Trissur, Kerala, India.

Abd. Latif, M., K.C. Khoo, K. Jamaludin & A. Abd. Jalil. 1994. Fibre morphology and chemical properties of *Gigantochloa scortechinii*. Journal Tropical Forest Science 6(4): 397-407.

Aminuddin, M. and M. Abd. Latif. 1993. Rattan research in Malaysia. *In:* S. Chand Basha and K.M. Bhat (*eds.*). Rattan Management and Utilization, pp 1-8. Proceedings of the Rattan (Cane) Seminar India. January 29-31, 1992. Trissur, Kerala, India.

Anonymous. 1957. British Standard 373. Methods of testing small clear specimens of timber. British Standard Institute.

Anonymous. 1978. TAPPI Testing Procedures. Technical Association of the Pulp and Paper Industry, USA.

Clayton, D.W. 1969. The chemistry of alkaline pulping. *In:* R.G. Macdonald and J.N. Franklin (*eds*). Pulp and Paper Manufacture-The Pulping of Wood. Second Edition, Volume I, pp 347-438. McGraw Hill Book Company, New York.

Dransfield, J. 1979. A manual of the rattans of the Malay Peninsular. Malayan Forest Record 29. Forest Department, Peninsular Malaysia.

Janes, R.L. 1969. The chemistry of wood and fibers. *In:* R.G. Macdonald and J.N. Franklin (*eds*). Pulp and Paper Manufacture-The Pulping of Wood. Second Edition, Volume I. pp. 33-72. McGraw Hill Book Company, New York.

Khoo, K.C. and T.B. Peh. 1982. Proximate chemical composition of some Malaysian hardwoods. Malaysian Forester 45(2):244-262.

Mohd. Dahlan, J. and M.K. Tam. 1987. Natural durability of Malaysian timbers. Timber Trade Leaflet 28:1-12.

Parthasarathy, M. V. and L.H. Klotz. 1976. Palm wood I. Anatomical Aspects. Wood Science and Technology 10:215-229.

Siripatanadilok, S. 1984. Variation in lignin content of six species of Thai rattan. Thai Journal of Forestry 3(3):212-225.

Tadena, O.B. and E.P. Villaneuva. 1971. Proximate Chemical Analysis of Pulp as a Basis for Its Paper Making Qualities. FORPRIDECOM Technical Note 11.

Wise, L.E., M. Murphy, and E.E. D'Addieco. 1946. Chlorite holocellulose, its fractionation and bearing on summative wood analysis and on studies on the hemicelluloses. Paper Trade Journal 122 (2): 35.

Wong, T.M. 1976. Wood structure of the lesser known timber of Peninsular Malaysia. Malayan Forest Record No. 28. 115p.