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Basic density and strength properties of cultivated *Calamus manan*

R. WAHAB [1,*], O. SULAIMAN [2] and H. W. SAMSI [3]

[1] *University Malaysia of Sabah (UMS), Locked Bag 2073, 88999 Kota Kinabalu, Sabah, Malaysia*
[2] *University Science of Malaysia (USM), Penang 11800, Malaysia*
[3] *Forest Research Institute Malaysia (FRIM), Kepong, 52109 Kuala Lumpur, Malaysia*

Abstract—This research investigates the basic density of *Calamus manan* cane grown in plantation and its relationship to strength. Cane samples were obtained from two plantation area in Malaysia. The results indicate that the lower part of the cane shows to have higher basic density compared to the higher part of the cane. The older canes (18 and 24 year-old) show a higher basic density compared to young canes (7 and 11 year-old). Samples with higher basic density show to have higher strength compared to those with lower basic density. Older canes indicate to have a 7–8-times higher strength compared to young canes.

Key words: *Calamus manan*; cane; basic density; strength; MOR.

INTRODUCTION

Canes are the main source of raw materials for furniture and weaving industry. They can be used to make furniture , baskets, mats, hunting and fishing utensil, items for adornment, etc. One of the most popular canes found in Malaysia is *Calamus manan.* It is sometimes called 'king of the cane' by the local furniture industry. It is strong, very flexible, versatile and possesses higher quality over the other cane species.

Utilization of *C. manan* is considered over-exploited. This led to resource exhaustion and the species become scarce and expensive. In the mid-1980s the government of Malaysia encouraged the establishment of cane plantations in the forest and intercropping between the rubber trees. The Forestry Department in Peninsular Malaysia (and FRIM, at that time under Forest Department), Sarawak and Sabah took the leading role in initiating by establishing the cane plantation in forest reserve

*To whom correspondence should be addressed. E-mail: drrazakw@yahoo.com

areas. Several private companies with the support of several government agensies followed this later. Aminuddin and Supardi [1] reported that under this programmed more than 13 000 ha of land was planted with canes.

After more than a decade, these planted canes have reached the recommended harvesting age [1, 2]. Early observations based on the growth performance of the canes show promising returns. As a result, some of these canes were harvested.

Some fundamental studies on wild *C. manan* have been performed by several researchers [3–5]. Ani and Lim [3] studied 11-year-old cultivated *C. manan* and found out that there were differences in the fibre wall thickness between the forest and the cultivated one. However, the fibre length was almost similar. To our knowledge, no study has been carried out on the strength of cultivated canes. Studies on other cane species mostly focused on the physical and mechanical properties of matured with canes of unknown age [6–9].

MATERIALS AND METHODS

Twenty-four stems of planted *Calamus manan*, consisting of six from each age group of 7, 11, 18 and 24 years, were used in the study. Stems of age-group 7 and 11 were taken from the Paka, Trengganu and stems from age-group 18 and 24 were taken from Temerluh, Pahang. The sites where these canes were cultivated were noted to have similar soil characteristics. The determination of age is based on date of planting as provided by the planters.

Each stem was sampled and labelled at six levels of height. A height level or namely a portion consists of a length of 3 meters. Portion 1 represents culm height from 0 to 3 meters, portion 2 represents culm height 3 to 6 meters, portion 3 represents culm height 6 to 9 meters, portion 4 represents culm height 9 to 12 meters, portion 5 represents culm height 12 to 15 meters and portion 6 represents culm height 15 to 18 meters. This length is considered to be a standard length which is commonly practiced by the canes industry in the country for processing and utilization purposes. Only portions 1, 2, 3, 4, 5 and 6 have been taken and used in the studies, due to difficulties in extracting the rest of stem portions and to get uniform characteristics.

Within a week after harvesting, these canes were cured in diesel oil, as this is normal practice in the cane industry. This is also being outlined by Razal *et al.* [10]. The duration of the process was about 20 min. All processed canes were air-dried for about 14 days. These canes were cut into smaller sizes according to size required for physical and mechanical studies. These samples were kept in a conditioning chamber of about 20°C and 65% RH to produce an equilibrium moisture content of about 12±1%. The mechanical tests were conducted using Shimadzu Universal Testing Machine in accordance to BS 373 [11] and ASTM 143-53 [12].

RESULTS AND DISCUSSION

The cross-section of 11-year-old and 24-year-old canes from portion 1 from the same height are shown in Fig. 1. It shows variation in culm density between the outer and inner part of the culm. The outer part of older canes (24 years old) shows a much higher density compared to younger one (11 years old). Figure 2 shows variation in density along the height of canes. Portion 1, that is near the base, is smaller in diameter compared to portion 6. The diameter of the canes increases from the bottom portion to the top.

The basic density is a measure of the relative amount of solid cell wall material. The results of basic density studies are shown in Table 1. The trend of the relation of basic density with portion is shown in Fig. 3. This result indicates that the basic density is significantly higher as the canes mature. The analysis of variance (ANOVA) of the results is summarized in Table 2. The multiple range

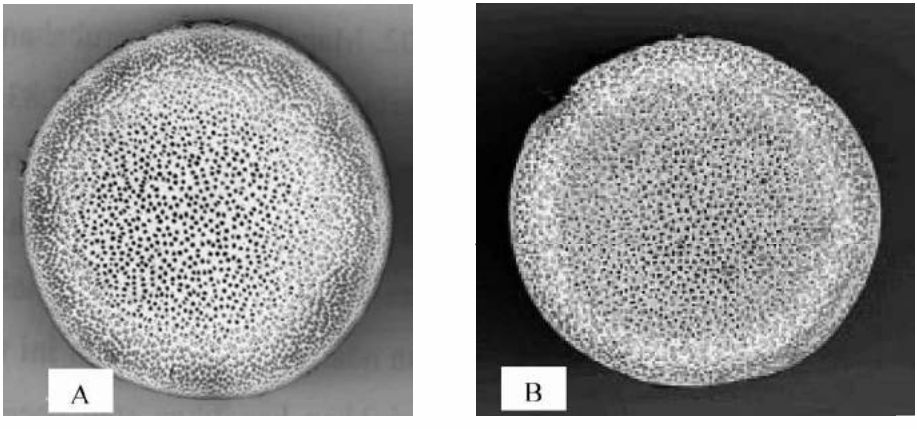

Figure 1. Cross-section showing a distinct variation in density between outer and inner portion of cultivated 11-year-old *C. manan* (panel A). An image of 24-year-old *C. manan*, which considered matured, is seen in panel B.

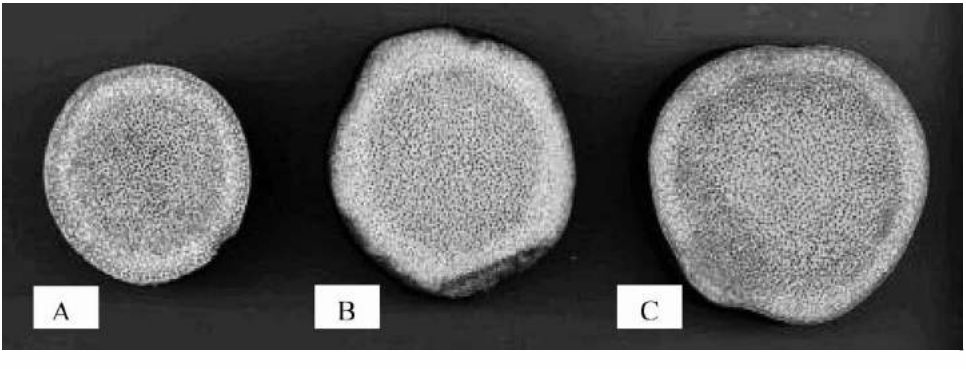

Figure 2. Cross-section showing the variation in density between the outer and inner portion of cultivated 7-year-old *C. manan* at different height. A represents portion 1, B portion 3 and C portion 6.

Table 1.
Means value for basic density of age-group 7, 11, 18 and 24-year-old culm

Age	Basic density of portions (kg/m^3)					
	1	2	3	4	5	6
7	0.51	0.45	0.41	0.39	0.38	0.36
11	0.55	0.50	0.48	0.46	0.44	0.44
18	0.67	0.65	0.62	0.60	0.58	0.53
24	0.75	0.74	0.73	0.71	0.67	0.59

Table 2.
Summary of analysis of variance on basic density of planted *C. manan* at different ages, culms and portions

Source of variation	*df*	*F*-value and statistical significance
Age	3	801.55^{**}
Culms	4	1.94^{ns}
Portion	5	87.44^{**}

ns, not significant at $P < 0.05$; **significant, $P < 0.01$.

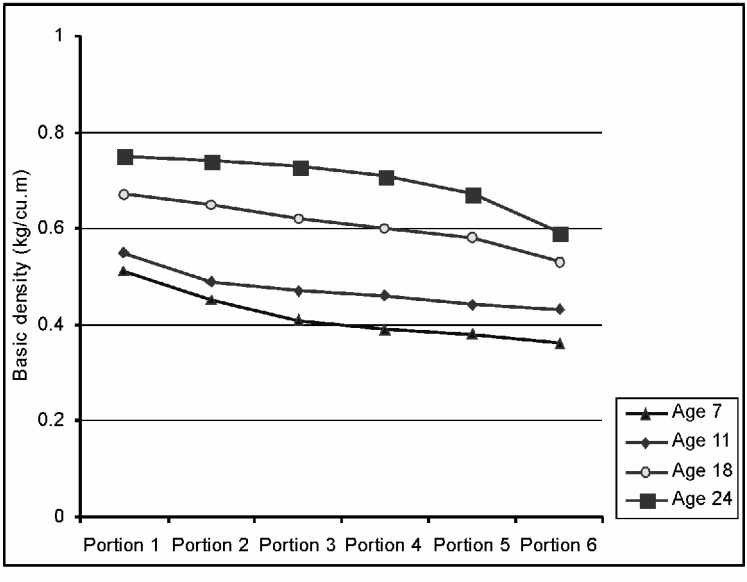

Figure 3. Trend of basic densities in portions of *C. manan* from different agegroups.

tests (MRT) on effects of age, portion and culm on basic density of cultivated *C. manan* are shown in Table 3. The basic densities significant decrease from the basal to the upper portions. These findings were in agreement with previous studies [10, 13–15]. This relationship is probably related to the percentage amount of fibre

Table 3.
Multiple range tests (MRT) on effects of age, portion and culm on basic density of planted *C. manan*

	Basic density					
Age	7	11	18	24		
	0.43[a]	0.47[b]	0.61[c]	0.70[d]		
Culm	1	2	3	4	5	
	0.55[b]	0.55[b]	0.54[a]	0.54[a]	0.56[b]	
Portion	1	2	3	4	5	6
	0.62[f]	0.58[e]	0.56[d]	0.54[c]	0.51[b]	0.47[a]

ns, not significant at $P < 0.05$; **highly significant, $P < 0.01$. Means in the same rows followed by the same letter are not significantly different at the 0.05 probablity level.

Table 4.
Relationship between basic density and age-groups

Equation	Intercept (a)	Slope (b)	R^2	Standard error	P-value
Basic density $= a + b \times$ age	0.302	0.0164	0.81	0.0121	<0.0000

base on height of the canes. The lower portion contain higher amount of fibres as compared to the upper part of the canes.

The relationship of basic density and age factor was analysed using regression, as shown in Table 4. The correlation coeffient indicated a moderately strong relationship between both variables. This value can be used to predict limits for new observations in age and even for the strength properties.

The results of mean values of modulus of rupture (MOR), modulus of elasticity (MOE) for static bending tests and modulus of rupture (MOR) for compression tests are tabulated in Figs 4–6 and Table 5. Generally, the mean strength values of canes decrease with the portion. Portion 1 shows the highest strength value, while portion 6 has the lowest strength. Canes from the 24-year-old group exhibited the highest strength value as compared to other age-groups. The MORs from static bending ranged from 168.3 MPa to 167.8 MPa. These are expected, as they possess the highest basic density. This is followed by 18 year-old age-groups having the MOR from static bending range from 30.5 MPa to 42.9 MPa. However, there was a sudden decrease in strength values for the 11-year-old and 7-year-old age-groups canes. The strength values ranged from 4.7 MPa to 7.7 MPa and 3.9 MPa to 6.6 MPa, respectively. These strength values for both age-groups are considered as too low and might not be suitable for industrial utilization. The strength properties related very well with the density, as discussed earlier.

CONCLUSIONS

The lower part shows to have higher basic density compared to higher part of the canes. The older canes (18 and 24 years old) have a higher basic density

Table 5.
Means value for modulus of rupture for compression, modulus of rupture and modulus of elasticity for static bending tests at 12% moisture content for *C. manan* of age-groups 7, 11, 18 and 24-year-old

Age (years)	Portion	Compression	Static bending	
		MOR (MPa)	MOR (MPa)	MOE (MPa)
7	1	6.6	91.5	2790
	2	5.0	84.6	2460
	3	4.8	75.7	2250
	4	4.4	63.8	2020
	5	4.1	60.0	1870
	6	3.9	57.9	1640
11	1	7.7	105.1	3260
	2	6.9	101.4	2850
	3	6.4	94.0	2780
	4	5.5	85.1	2190
	5	5.0	80.5	2050
	6	4.7	79.8	1960
18	1	42.9	114.3	3890
	2	42.0	107.5	3780
	3	41.6	92.6	3600
	4	39.9	88.3	3310
	5	37.6	83.4	3130
	6	30.5	78.1	2990
24	1	51.3	168.3	7520
	2	50.2	167.8	7490
	3	49.6	166.9	7310
	4	47.5	163.6	7020
	5	42.7	145.6	6250
	6	38.4	126.2	5810

Values are means of four replicates.

Table 6.
Summary of analysis of variance on mechanical properties of planted manau at different ages, culms and portions

Source of variation	*df*	*F*-value and statistical significance		
		Compression MOR (MPa)	MOR Bending (MPa)	MOE Bending (MPa)
Age	3	3333.08**	586.27**	3245.00**
Culms	4	0.50 ns	1.56 ns	0.99 ns
Portion	5	35.61**	50.51**	109.18**

ns, not significant at $P < 0.05$; ** highly significant, $P < 0.01$.

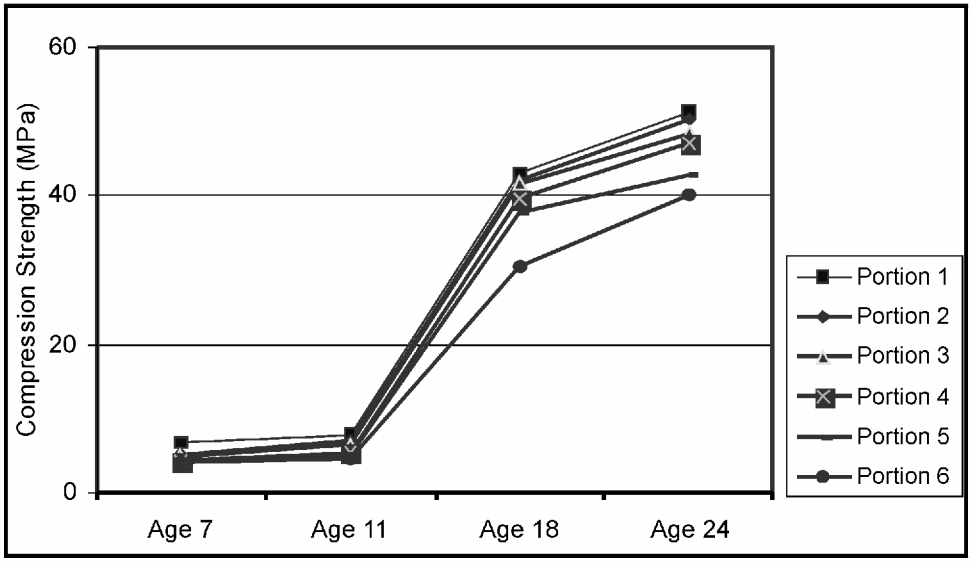

Figure 4. Modulus of rupture on compression tests at different age-group of planted *C. manan* at portions 1, 2, 3, 4, 5 and 6.

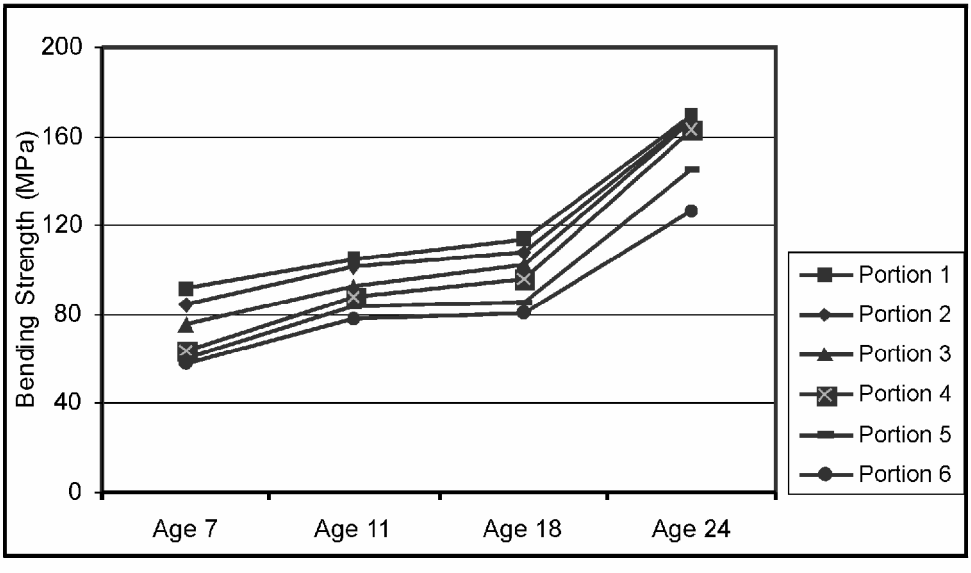

Figure 5. Modulus of rupture (MOR) on bending tests at different age-group of planted *C. manan* at portions 1, 2, 3, 4, 5 and 6.

compared to young canes (7 and 11 years old). Samples with higher density have a higher strength compared to canes with lower density. Older canes indicate to have higher strength compared to younger canes. generally, it can be concluded that the

Table 7.
Duncan multiple range test (MRT) of MOR bending, MOE bending and MOR compression tests on planted cane manau

Age	Compression strength	Bending strength MOR (MPa)	MOE (MPa)
7	6.5[a]	93.1[a]	2860[a]
11	7.3[b]	93.2[a]	2890[a]
18	39.8[c]	104.3[a]	4120[b]
24	43.7[d]	134.9[b]	5830[c]

Means in the same rows followed by the same letter are not significantly different at the 0.05 probablity level.

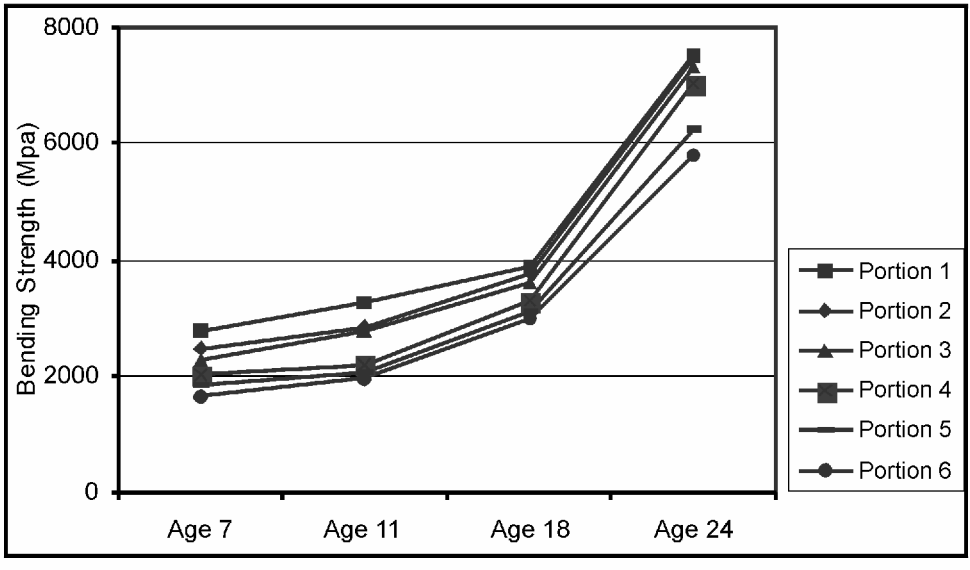

Figure 6. Modulus of elasticity on static bending tests in different age-groups of planted *C. manan* at portions 1, 2, 3, 4, 5 and 6.

cultivated *Calamus manan* of age 18 and above possess mechanical characteristics that makes them suitable for utilization.

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