PROPERTIES OF RATTAN CANE AS BASIS FOR DETERMINING OPTIMUM CUTTING CYCLE OF CULTIVATED *CALAMUS MERRILLII*

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ABASOLO W. 2015. Properties of rattan cane as basis for determining optimum cutting cycle of cultivated *Calamus merrillii*. The anatomical, physical, chemical and mechanical properties of cultivated *Calamus merrillii* were determined. These properties were used as basis for determining the optimum cycle age of rattan plantations. Stand age did not affect the basic properties of rattan cane. Cane properties were uniform throughout the age groups (7, 8, 10, 11, 14, 15, 18, 20 years). In wood, age-related variability in properties could be attributed to the secondary growth of stems. Rattan does not undergo secondary growth, thus, age-related variability in properties was not evident. Unlike trees where the cutting age is predetermined due to the presence of juvenile wood, the cutting age of cultivated *C. merrillii* is more flexible. Harvesting could start as early as 7 years after cultivation. However, it could only be used for splits due to its low modulus of rupture (class 3). Nonetheless, with rattan, plantation investors have more flexibility in assigning the appropriate cutting age of the stand. Hence, they would have more control over the rate of return of their investments.

Keywords: Modulus of elasticity, modulus of rupture, fibre percentage, fibre length, cell wall thickness, cell wall chemistry

INTRODUCTION

Due to the overexploitation of wild rattan canes coupled with the unabated destruction of natural forest where wild canes thrive, soon there will be no more canes. Rattan plantation establishment is the way forward for rattan furniture industries. It would not only provide a sustainable supply of raw canes for industrial use but also alleviate the pressure on remaining supply of wild canes by serving as good wild cane substitute. Now that similarities in properties between wild and plantation-grown canes have been clarified (Abasolo 2007, Abasolo 2011) as well as the effect of age on physical and mechanical properties of other *Calamus* spp. (Roszaini 1998, Razak et al. 2007) including strength variation within the stem (Roszaini 2001), the only remaining challenge for plantation developers would be its long cutting cycle.

The recommended cutting cycle of rattan plantations is between 10 and 15 years (Tesoro 2002), similar to the cutting cycle of fast-growing trees species. For this reason, plantation developers could opt to plant fast-growing tree species instead of rattan because trees could generate more volume of biomass per unit area which would mean better revenue.

Optimum rotation of plantations is defined as the life of a stand in which the net present value of underlying investment achieves a maximum value, taking into consideration the land rent (Faustmann 1995). Optimum cutting age is also correlated with the rate of return of investment (Smith & De Bald 1975) where shorter cutting cycle would yield higher rates of return, ultimately better revenues. Revenue is of prime importance in plantation establishment and as such is the main driver in assigning the cutting age of plantations. However, total wood volume generated at the end of the cutting cycle is not the only determinant of potential revenue because the value of the material would still rely on its utility and this is highly dependent on its basic properties.

The present study attempted to use the basic properties (mechanical, physical, anatomical and chemical) of rattan canes as basis for determining the optimum cutting cycle of rattan plantation. This is with the aim of assisting potential plantation developers in considering rattan canes as forest crops during plantation establishment.

MATERIALS AND METHODS

Materials

Cultivated *Calamus merrillii* aged 7, 8, 10, 11, 14, 15, 18 and 20 years were utilised. They were obtained from plantations all over the Philippines. For complete description of individual sites, refer to Abasolo (2006). Samples of 2 m long were obtained from the basal (5 cm from the ground) and top portions (10 cm from the immature shoot) of rattan. Samples from both portions represented the mature and juvenile parts respectively.

Mechanical testing

Mechanical testing was conducted following ASTM D143-52 (ASTM 1972) with modification due to the peculiarities of rattan. Measurements were conducted in green state (> 30% moisture content) by soaking samples in water overnight prior to testing in order to prevent the influence of fluctuating moisture contents on strength properties. A universal testing machine was used. Load was applied at the centre of the cane at constant rate of 0.003 mm min^{-1}. Midspan deflections were measured to the nearest 0.025 mm with a dial gauge. Modulus of elasticity and modulus of rupture were determined. Measurements were replicated eight times.

Specific gravity

After static bending test, samples were cut into halves adjacent to the point of breakage for specific gravity measurement. Four consecutive 1-cm thick discs were prepared. Across the transverse section of these discs, 0.5 cm × 0.5 cm × 1 cm sample blocks were prepared. Twenty blocks were prepared—10 from the basal and 10 from the top portions. Samples were oven dried at 100 ± 3 °C until constant weight. Oven-dry volume was determined using vernier callipers. Specific gravity was computed using the formula:

$$\text{Specific} = \frac{Wo}{Vo} \times Dw$$

where Wo = oven-dry weight (g), Vo = oven-dry volume (cm^3) and Dw = density of water (1 g cm^{-3}).

Softening temperature

The thermal softening behaviour of rattan samples was measured using a fabricated thermomechanical analyser (Abasolo 2011). Sample sticks measuring 0.2 cm × 1 cm × 5 cm were prepared. A constant load of 128 g was applied at midspan. Steam was introduced into the chamber and for every degree increase in temperature, the amount of deflection was recorded. Measurement started at 60 ºC up to 100 ºC. Temperature that gave the largest amount of deflection was the softening temperature of the sample. Five samples for each portion were prepared for each age. Measurements were replicated four times.

Anatomical analysis

From the discs prepared, 1 cm^3 sample cubes were dissected out. Cross-sectional samples of the specimens were sliced to 35–45 µm using a microtome. These sections were stained with safranin, dehydrated in ethanol sequence (35%–100%), counter stained with fast green and finally mounted on permanent slides. Ten digital images of the cross-sections were taken from every portion (basal and top). Using Image J analysis software for windows, fibre area percentages were determined (Abasolo et al. 2005). Four slides were used in the measurement.

Match-stick sized samples were also prepared from the remaining discs. The sticks were completely soaked in 50:50 solutions of 20% by volume hydrogen peroxide and glacial acetic acid. Samples were heated in a hot water bath until individual fibres were separated. Fibres were mounted temporarily on a clean glass slide and observed under a compound microscope fitted with vernier scales. Thirty randomly selected whole or unbroken fibres were used to directly measure the fibre length and cell wall thickness. Measurements were replicated four times.

Chemical analysis

Samples from the basal and top portions of the cane were ground to 60–80 mesh using a Wiley mill. Holocellulose was determined using ASTM D1104-56(ASTM 1975a), cellulose using ASTM D1103-60 (ASTM 1975b) and lignin using ASTM D1106-56 (ASTM 1975c). Hemicellulose content was indirectly obtained by taking the difference between holocellulose and cellulose. In all analysis, oven-dry sample powder was utilised. Two measurements for every portion (basal and top) were taken and replicated four times.

Statistical analysis

One way analysis of variance was performed in order to determine the variation in properties between the different samples at $\alpha = 0.05\%$. Regression analysis was carried out in order to determine the relationship between age and basic properties of plantation grown canes.

RESULTS AND DISCUSSION

Properties of plantation-grown *Callamus merrillii*

Cane stiffness and specific gravity determine the suitability of rattan for a particular end-use because they directly influence cane flexibility and dimensionally stability. Figure 1 provides the physico–mechanical attributes of the different plantation-grown samples. PNOC-97 gave the lowest modulus of elasticity with 3.23 GPa while NP-93 gave the highest with 6.37 GPa. Modulus of rupture was smallest in QP1-94 with 14.35 MPa and largest in NP-93 with 32.45 MPa. These values fall within the mechanical properties of *Calamus erectus* (Kabir et al. 1994). Comparing these values with the strength classification as outlined by Bhat and Thulasidas (1992), the samples fell under class 3. Specific gravity was lowest in MP-96 and PNOC-97 with 0.38 while it was highest in QP2-84 with 0.51. Both values fall within the range of properties of 11-year-old cultivated *Calamus manan* (Ani & Lim 1991).

A critical stage in cane processing is thermal softening. Heat facilitates the bending of canes by softening the lignin–hemicellulose matrix allowing movement of cellulose within the cell wall until the hemicellulose–lignin matrix hardened once more (Abasolo et al. 2002). This would allow the cane to meet predetermined designs or configurations without significantly altering its mechanical attributes. Hence, the volume of this matrix within the cell wall directly affects cellulose movement during heat-induced bending. The average softening temperature of plantation-grown canes is depicted in Figure 2. PNOC-97 gave the lowest softening temperature with 83 °C while NP-97 gave the highest at 89 °C.

Fibre characteristics and distribution are important anatomical traits because they directly affect cane density (Bhat & Verghese 1991) and stiffness (Bhat & Thulasidas 1992). The samples gave varying fibre distributions and characteristics (Figure 3). Fibre percentage was minimum in QP2-84 with 21.14% and maximum in LP2-86 with 38.42%. Fibre length was shortest in NP-93 with 1.3649 mm and longest in QP1-94 with 1.9124 mm. Fibre cell wall was thickest in MLP-93 with 0.0109 mm and thinnest in QP1-94 with 0.0054. Fibre walls can have alternating broad and narrow layers (Parameswaran & Leise 1985) as the cane matures resulting in varying thicknesses.

Figure 4 shows cell wall chemistry of different samples. The cellulose component comprised 35 (MPL-93) to 46% (LP2-86) of the whole rattan cell wall. Hemicellulose accounted for 23.09 (QP1-94) to 36.43% (MPL-93) of the wall. Lignin content was 22.16 (LP1-90) to 32.10% (QP1-94). These values were approximately similar to the cell wall composition of softwood (Haygreen & Bowyer 1989). Such variation in cell wall chemistry could be attributed to differences in structure, e.g. distribution of fibres and parenchyma between samples. All anatomical, physical, chemical and mechanical properties of cultivated *C. merrillii* were not significantly different between samples except for specific gravity, hemicellulose and lignin content (Table 1).

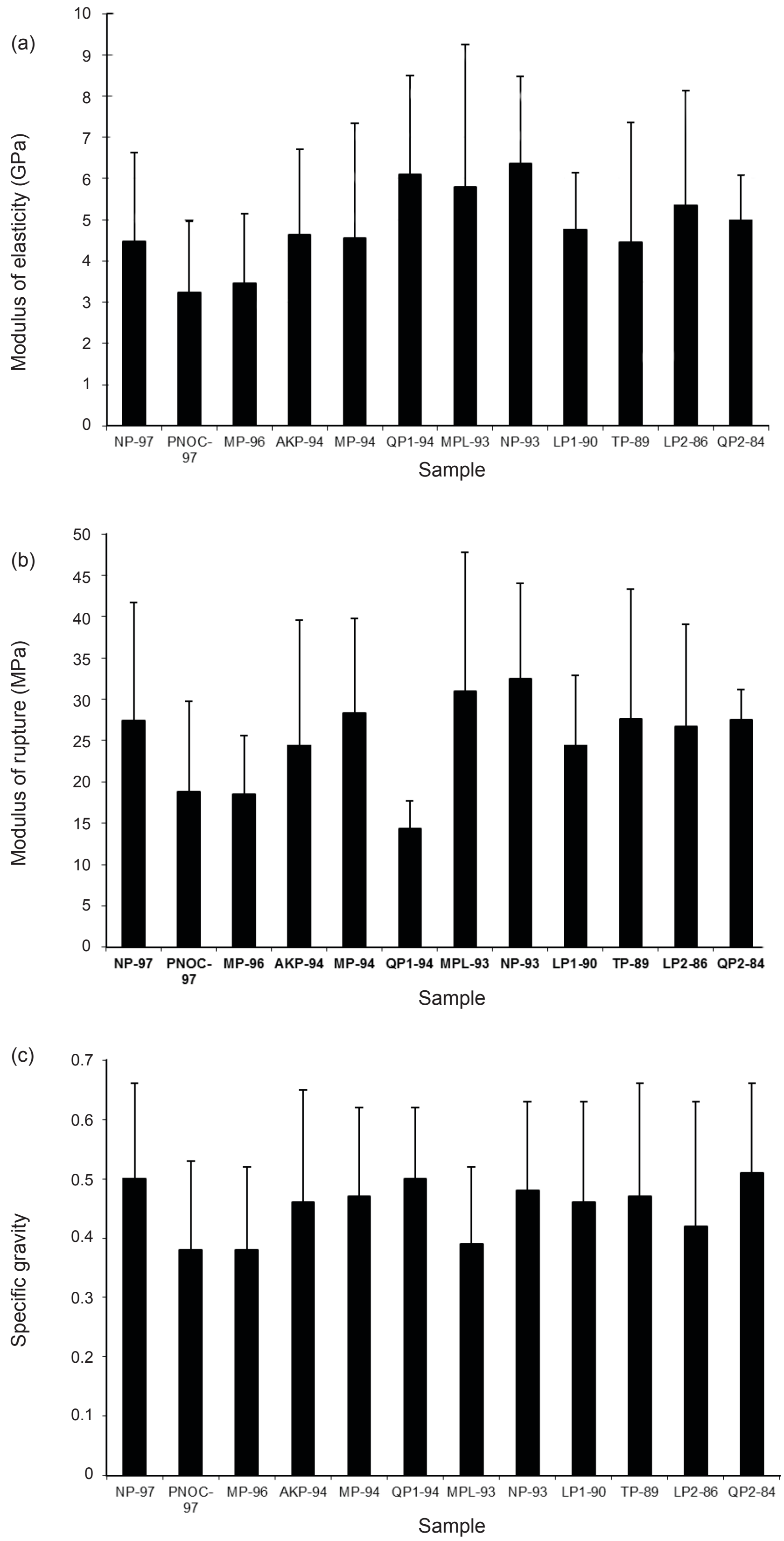

Figure 1 Physico–mechanical properties of plantation-grown *Calamus merrillii*—(a) modulus of elasticity, (b) modulus of rupture and (c) specific gravity

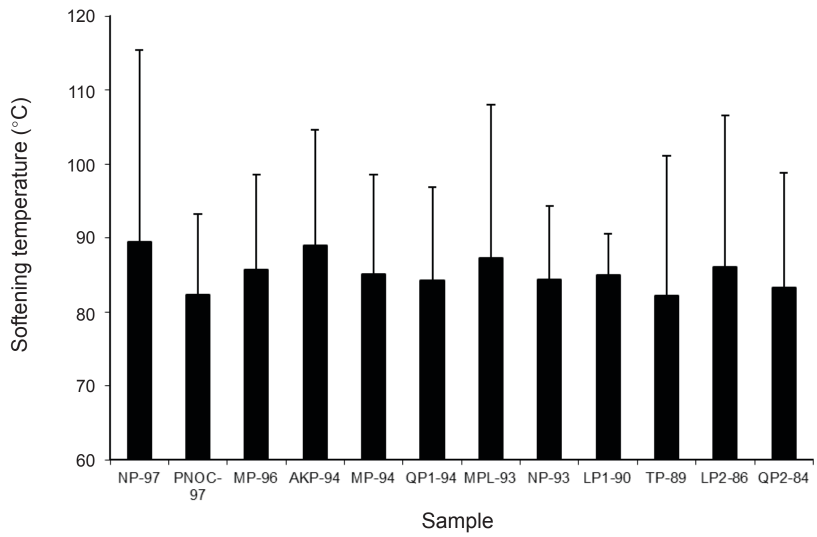

Figure 2 Softening temperature of plantation-grown rattan canes

Effect of age on basic properties of plantation-grown *Callamus merrillii*

In wild rattan, age has significant influence on strength (Bhat & Thulasidas 1992). Regression analysis for plantation-grown rattan showed otherwise. Both modulus of elasticity and modulus of rupture were positively correlated with age (Figure 5). Although the relationship was not that strong at $\alpha = 0.05$, it clearly showed that stiffness slightly increased with age. Similarly specific gravity was not significantly correlated with age (Figure 6). Nonetheless, a positive correlation was still evident. This is in contrast to the findings of Razak et al. (2007) on *C. manan* where significant relationship between age and basic density was observed.

Softening temperature was inversely correlated with rattan age (Figure 7). Apparently, the older the rattan, the more sensitive it is to heat. This relationship was not significant at $\alpha = 0.05$.

Figure 8 provides the relationship between rattan age and fibre characteristics. Regression showed that fibre percentage, fibre length and cell wall thickness were not influenced by age. All three parameters were positively correlated with rattan age. However, such relationship was too small and not significant at $\alpha = 0.05\%$. This is similar to the result of Roszaini (2001) on the influence of stem age on percentage of cultivated *C. scipionum* and *D. angustifolia.*

As for individual chemical components of rattan fibre wall, only cellulose gave positive correlation with age (Figure 9). This was similar to the observation of Siripantok (1984) on lignin content of six Thai rattan species. In addition, such relationship was moderately significant at $\alpha = 0.05\%$.

Age effect on wood properties

In all aspects of properties, plantation-grown rattan was unaffected by plantation age. This is an important piece of evidence because when the main criterion in deciding the cutting age of rattan plantation is its basic properties, rattan plantation can be harvested even earlier than 7 years old. At this age, its properties are similar to the properties of a 20-year-old rattan. Rattan plants produce an over-built stem that could withstand future load requirements (Tomlinson 1990). Hence, a young rattan would have more or less similar strength properties as a more mature one.

It has been reported that age affects wood quality traits. For example, a 10-fold increase in modulus of elasticity with age was observed in loblolly pine (Bendtsen & Senft 1986) while density (Zobel & Sprague 1998) and specific gravity (Matyas & Peszlen 1997) were also correlated with age.

Tree age also influenced wood structure. Studies on *Eucalyptus grandis* showed that fibres

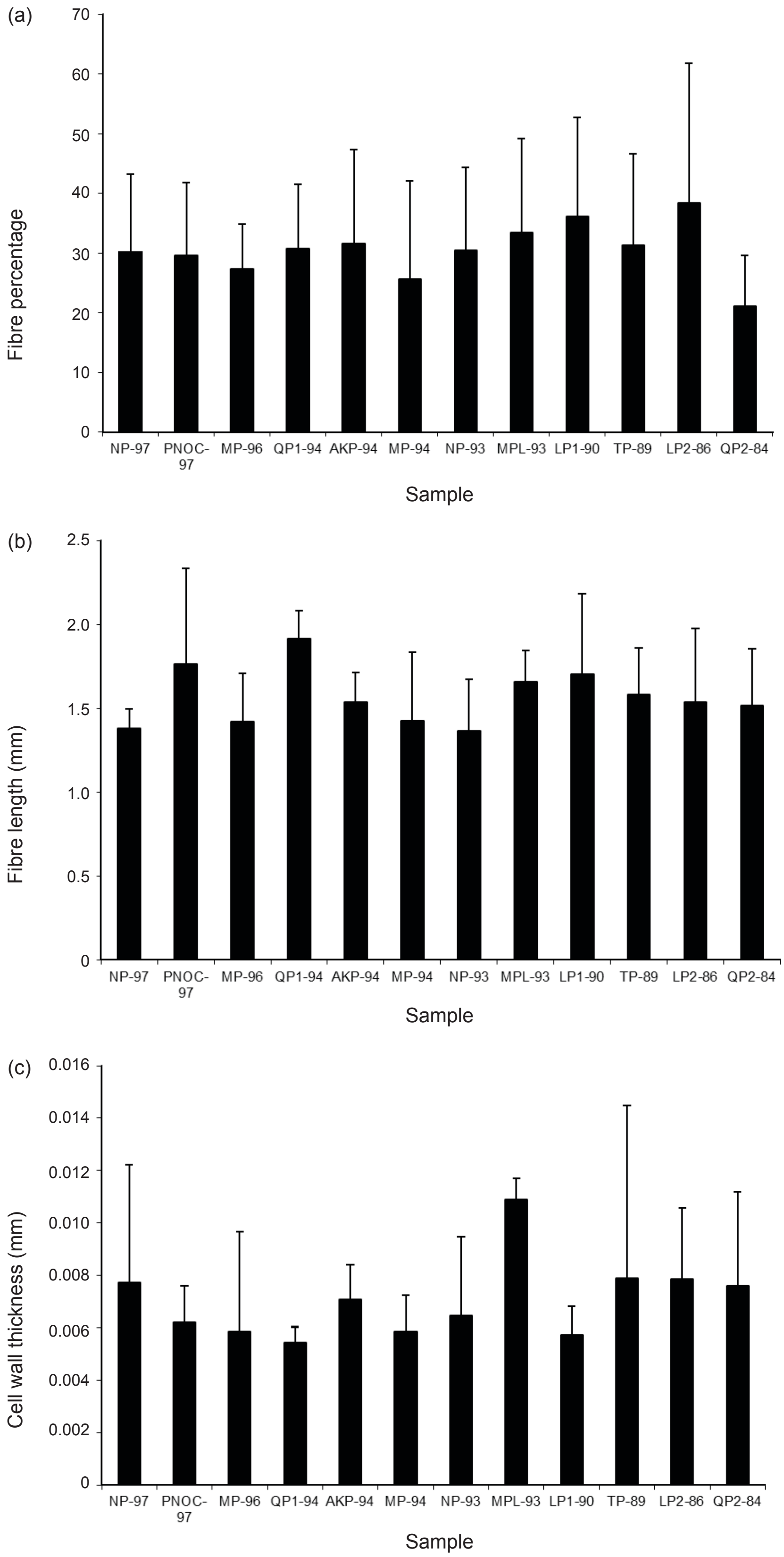

Figure 3 Fibre distribution and characteristics of plantation-grown rattan canes—(a) fibre distribution, (b) fibre length and (c) cell wall thickness

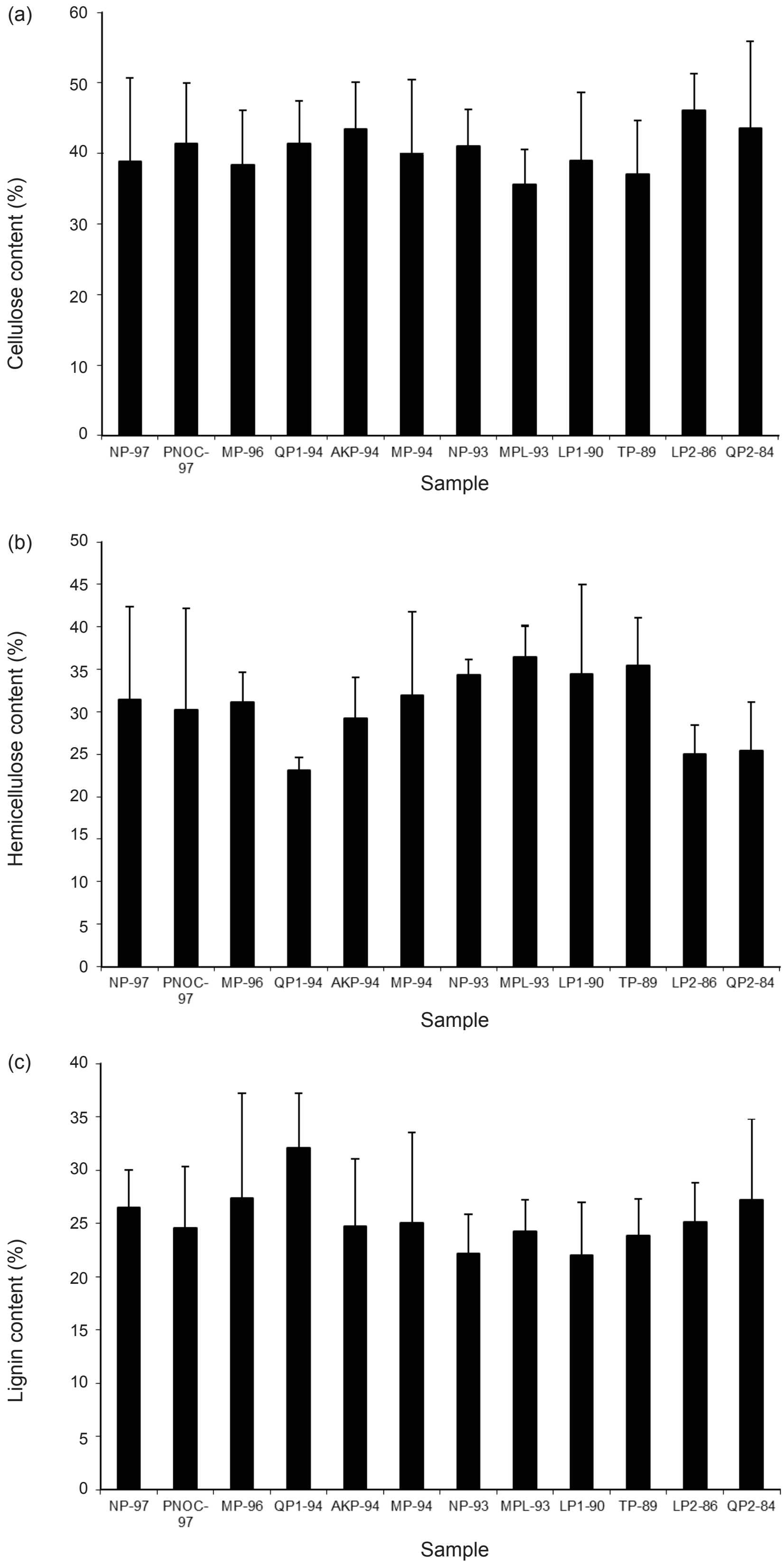

Figure 4 Cell wall chemistry of plantation-grown rattan canes—(a) cellulose content, (b) hemicellulose content and (c) lignin content

Table 1 Analysis of variance of the different basic properties of cultivated *Calamus merrillii*

Property	No. of samples	Average	Standard deviation	Significance
Modulus of elasticity	96	4.97 GPa	2.28	ns
Modulus of rupture	96	25.75 MPa	11.78	ns
Specific gravity	960	0.45	0.16	**
Softening temperature	480	85.41 C	7.00	ns
Fibre percentage	960	30.78%	14.53	ns
Fibre length	2880	1.57 mm	0.17	ns
Cell wall thickness	2880	0.007 mm	0.002	ns
Cellulose content	96	41.06%	9.63	ns
Hemicellulose content	96	30.46%	9.79	**
Lignin content	96	25.24%	7.10	**

**significant at $\alpha = 0.05$, ns = not significant

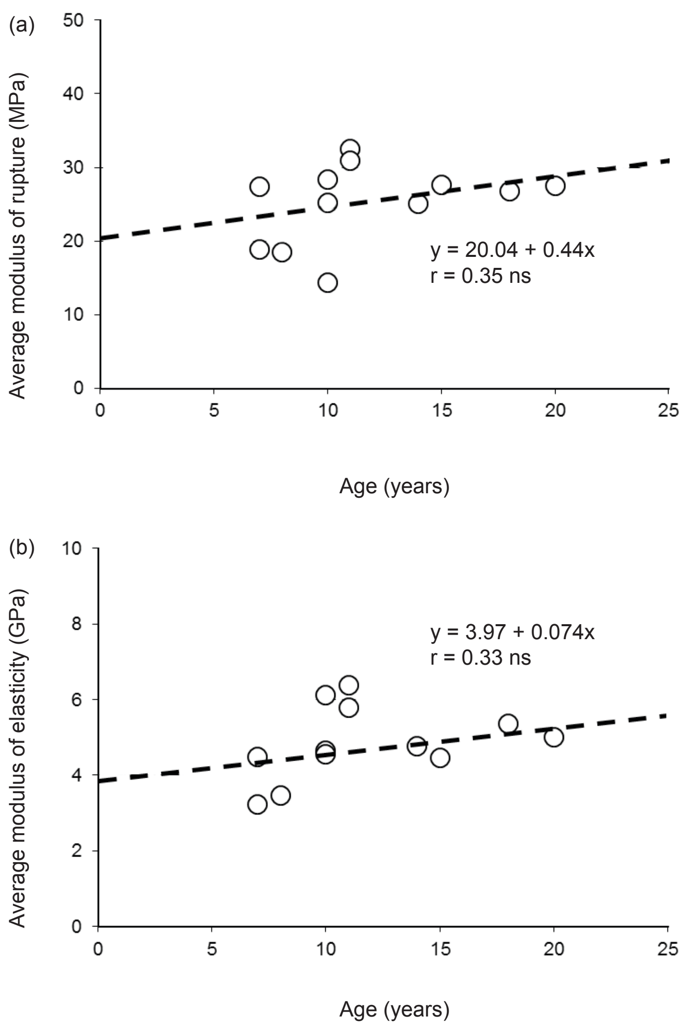

Figure 5 Influence of age of the rattan stand on (a) modulus of rupture and (b) modulus of elasticity

of 3-year-old trees were 29% shorter than 9-year-old ones (Bhat et al. 1990). In Douglas-fir, a steady increase in tracheid lumen diameter was correlated with cambial age (Spicer & Gartner 2001).

With regard to fibre wall chemistry, glucose, the main component of cellulose, was observed to increase with age due to the increase in cell wall thickness (Larson 1966). However, hemicellulose particularly galactose and arabinose showed an inverse relationship with age. This age-related patterns were inherent to trees but not invariable (Larson et al. 2001).

Differences in the growth behaviour of rattan and trees

The age of stand has direct effect on wood properties because it affects the percentage of juvenile wood (Zobel & Van Buijtenen 1989) or the type of wood formed by an immature vascular cambium. As the tree ages, these cambial cells would also mature and would produce more mature cells whose properties are completely different from the immature ones. Hence, wood property variability as affected by tree age is basically caused by secondary growth of

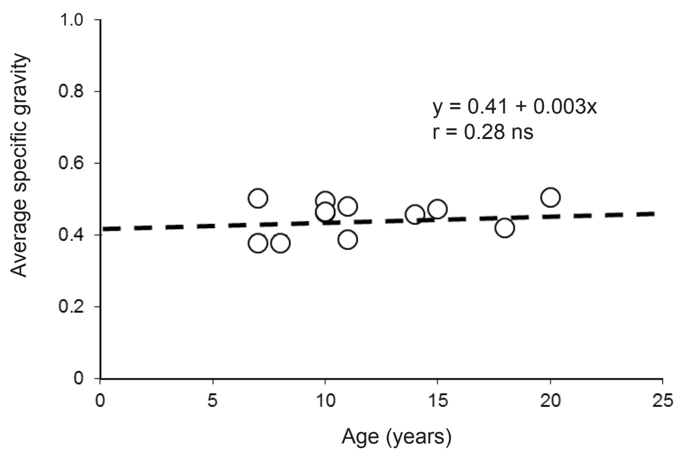

Figure 6 Influence of age of stand on specific gravity of rattan

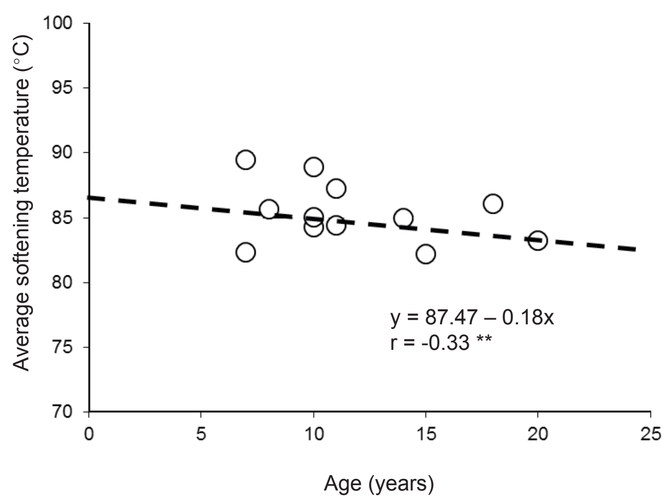

Figure 7 Influence of age of stand on the softening temperature of rattan

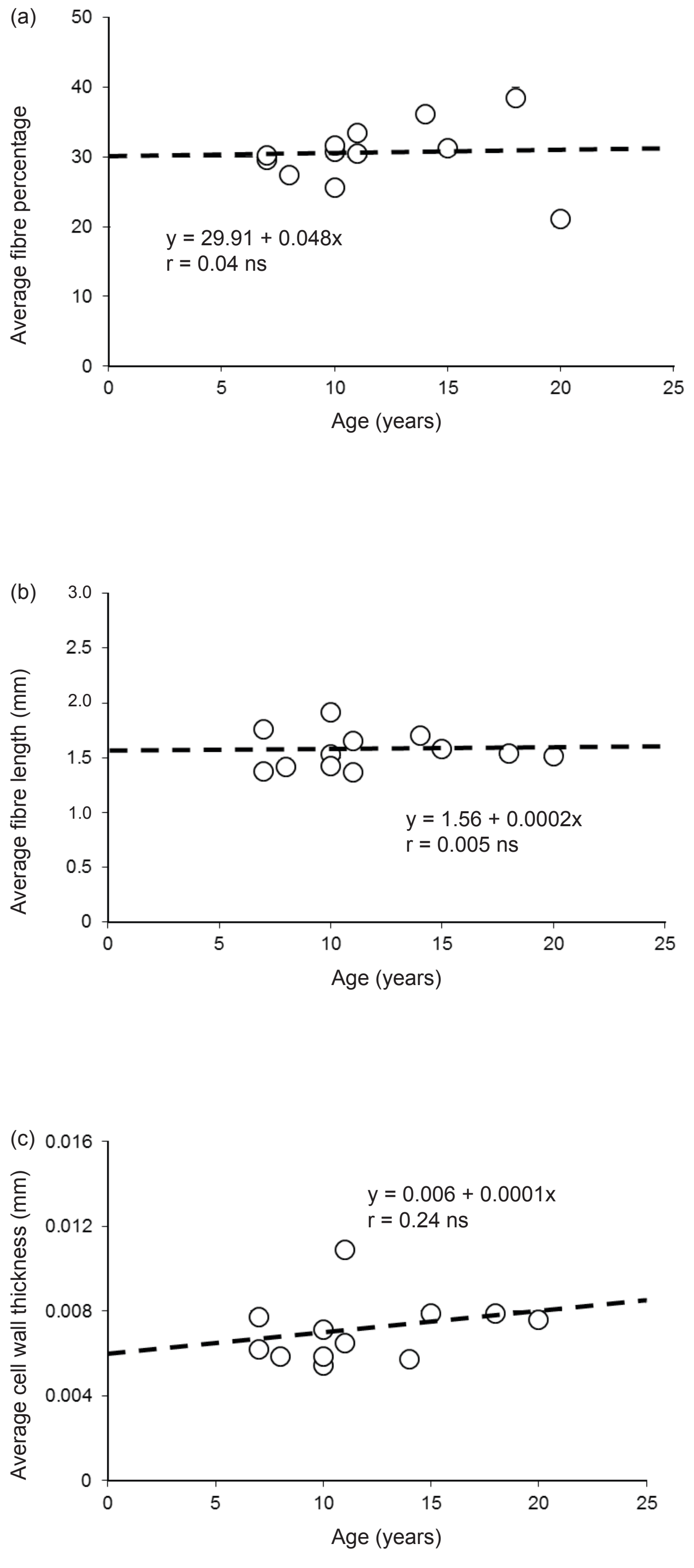

Figure 8 Influence of age of rattan stand on (a) fibre distribution, (b) fibre length and (c) cell wall thickness; ns = not significant

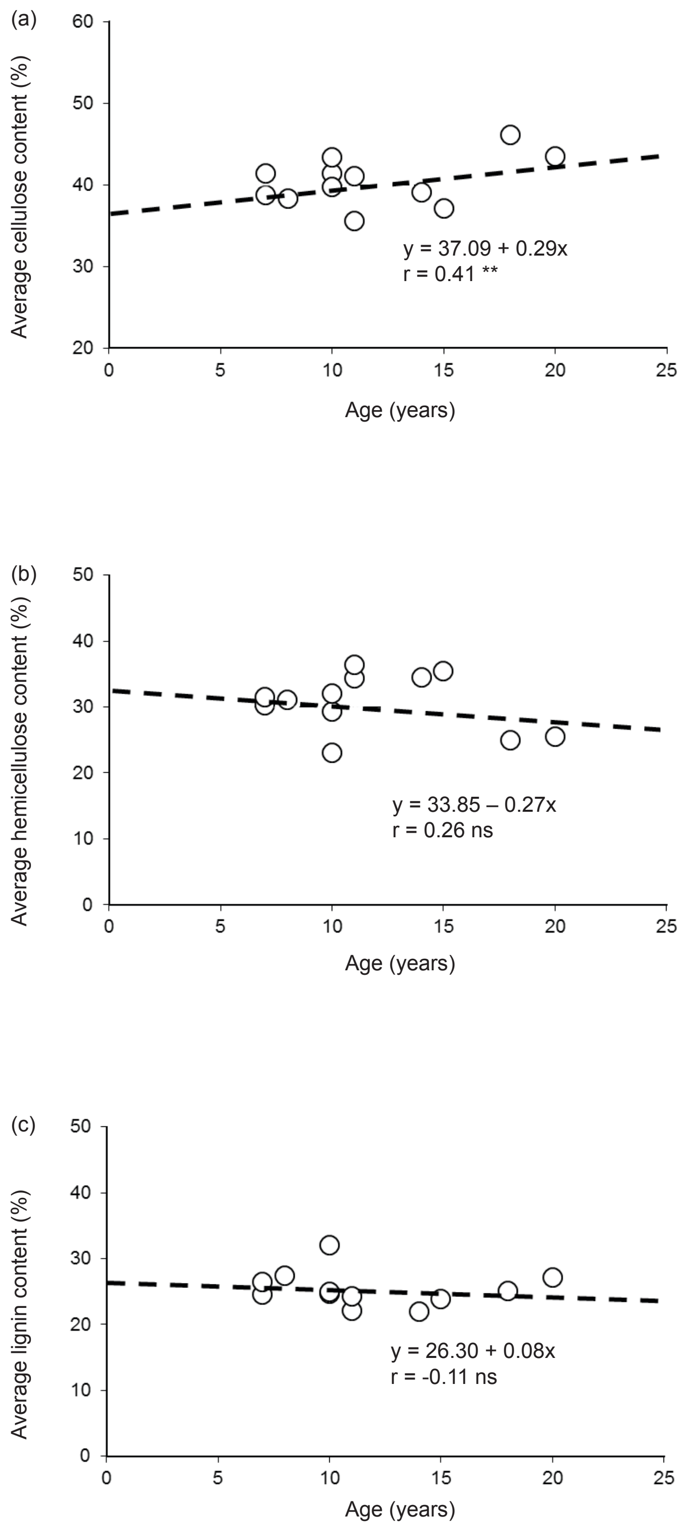

Figure 9 Influence of age of rattan stand on (a) cellulose content, (b) hemicellulose content and (c) lignin content; ns = not significant

the stem. Rattan, being a monocot, lacks the necessary lateral meristems to undergo secondary growth. Only limited diameter growth is possible through ground parenchyma cell enlargement (Tomlinson 1961). For this reason, age of *C. merrillii* was not influenced by its properties. However, the results contradicted the studies by Roszaini (1998, 2001) and Razak et al. (2007). This fact is advantageous to *C. merrillii* as it could serve as an incentive to plantation developers to establish rattan plantations instead of tree plantations. Unlike trees, where the cutting age is fixed based on the proportion of juvenile wood, in *C. merrillii*, plantation developers would have more flexibility in deciding on the harvesting age of rattan. Hence, they could have more control over the rate of return of their investment.

CONCLUSIONS

Almost all aspects of material properties, e.g. physico–mechanical, thermomechanical, structural and cell wall chemistry of cultivated *C. merrillii* were not affected by the age of the stand. Cultivated *C. merrillii* could be utilised as early as age 7 years old. However at this age, the cultivated rattan belongs to class 3 having modulus of rupture of less than 40 MPa.

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