Philippine Journal of Science
140 (2): 153-159, December 2011
ISSN 0031 - 7683
Date Received: 28 Oct 2009

Thermal Softening and Cell Wall Chemistry of Plantation-Grown Palasan (*Calamus merrillii* Becc) Canes

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Softening temperature of plantation-grown palasan (*Calamus merrillii* Becc.) cane was measured. The chemical constituents of its cell wall were likewise determined using standard procedures used in wood. Softening temperature was about 84.44°C to 86.37°C which is within the range of wild palasan canes and it was unaffected by the origin of the sample. Holocellulose content was about 64.54% - 75.38%, in which 37.08% - 48.08% is cellulose and 23.09 % - 36.43% is hemicellulose. Lignin constitutes approximately 22.16% - 32.10% of the wall. Relationship between the chemical constituents and softening temperature was not detected. The fabricated thermomechanical analyzer was limited to the detection of macrostrains occurring in the sample and could not detect deflection down to the microstrain level where these individual chemical constituents normally move. Nonetheless, the device was able to prove that plantation-grown palasan canes have the same softening temperature as that of wild palasan canes. This material could be converted into furniture of the same quality as that of wild rattan canes. This confirms the utility of plantation-grown palasan canes to the rattan furniture Industry.

Key Words: cellulose, hemicellulose, holocellulose, lignin, Palasan canes, softening temperature, Thermomechanical analyzer

INTRODUCTION

The natural forest could no longer sustain the raw material requirements of the rattan furniture industry. This is brought about by the unhampered destruction of natural forest habitat vis-à-vis the unabated extraction of raw rattan canes. Rattan plantation will therefore play a key role in sustaining the rattan furniture industry. Properly managed plantations will not only provide the industry with a sustainable source of raw materials but would also offer a more stable livelihood for rattan gatherers, farmers, manufacturers and other people engaged in the enterprise.

There are rattan plantations ready for harvest. However manufacturers are still reluctant to use this material because of the uncertainties particularly on their basic properties from where the qualities of finished products are dependent. Unless proven that plantation-grown canes could be converted into products that satisfy accepted standards, manufacturers would not risk their investments and continue to utilize wild rattan canes even if they have to import it.

There are attempts to promote the utilization of plantation-grown palasan canes to solve the raw material scarcity. Comparing the mechanical attributes of wild canes and plantation-grown canes showed that the two materials were basically the same (Abasolo 2007). Structural, physical and other morphological traits showed a great deal of similarities (Abasolo 2008) which are unaltered regardless of age, elevation, and amount of sunlight exposure (Abasolo & Lomboy 2009). All these findings concluded that plantation-grown

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canes behave similarly as wild canes during processing. However, their actual behavior during processing has not been determined, thus this study was done.

One critical stage in cane processing is thermal softening. Heat facilitates the bending of rattan canes to meet predetermined designs or configurations. In wood, there are several ways in which the optimum softening temperature could be acquired. Hilliz & Rozsa (1985) observed the rate of movement of a strip of sample under a constant load at a steadily increasing temperature. Tejada et al. (1998) on the other hand, determined this temperature by observing the temperature when maximum collapse of a column of wood powder took placed inside a capillary tube. Creep measurements are observed to be advantageous because it is able to detect structural changes in wood caused by heat (Dwianto et al. 2000). Adapting these concepts, the softening temperature of match-ending blocks of rattan canes derived from the natural stand was detected (Abasolo et al. 2002a) and was correlated to the hemicellulose-lignin matrix (Abasolo et al. 2002b) as well as to the cellular make-up of the cane (Abasolo et al. 2005). With these studies, the behavior of wild rattan to heat has been described but for plantation grown canes, this has yet to be determined.

The study was a pioneering attempt to determine the softening point and cell wall chemistry of plantation-grown palasan for these to be accepted and utilized by the rattan furniture manufacturers.

MATERIALS AND METHODS

Sample Material

Plantation-grown palasan (*Calamus merrillii* Becc) canes were gathered from several plantations in the Philippines (Table 1). Sample age varied from 7 to 20 years old with lengths ranging from 3 to 53 m. To have a representative of the most mature and youngest portion of the rattan stem, samples from the base and top respectively, were obtained. Across the diameter, the peripheral and central regions were delineated. From these regions, 0.2 cm x 1cm x 5 cm sample sticks were prepared. Four sticks per zone (periphery-core) for all portions (base-top) were made.

Thermomechanical device fabrication

A thermomechanical device (Figure 1) was fabricated using the principles of a thermomechanical analyzer. It is composed of a steel box that could be sealed during measurement. At the top center of the box, a hole was made to hold the digital strain gauge. This gauge was fixed and detects deflection of up to 0.01 mm in bending test. Steam was introduced to the box and temperature was raised slowly up to a maximum temperature of 100 °C.

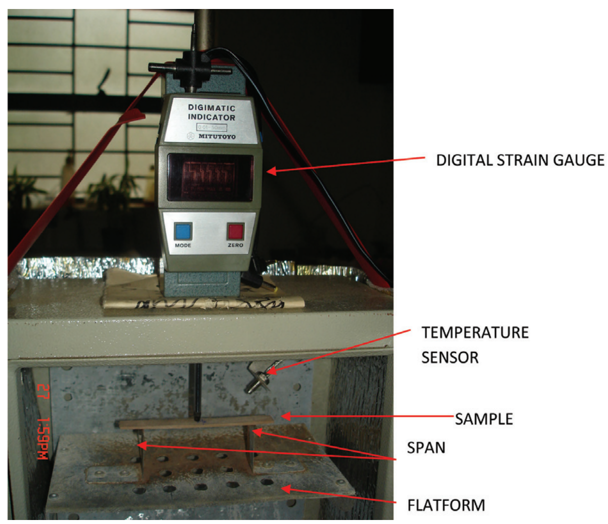

Figure 1. Fabricated thermomechanical analyzer.

Table 1. Sample description

Sample Code	Age (yrs)	Length (m)	Diameter (cm)	Location of site	Area (ha)
Nat	Unknown	22	2.95	Los Baños, Laguna	Unknown
QP2-84	20	16	2.95	Pagbilao, Quezon	4
LP2-86	18	41	3.73	Daraga, Legaspi	4
TP-89	15	33	4.86	Ormoc, Leyte	150
LP1-90	14	53	3.92	Daraga, Legaspi	4
NP-93	11	3	4.56	Southern Negros	25
MLP-93	11	11	3.66	Ormoc, Leyte	40
QP1-94	10	6	3.15	Pagbilao, Quezon	4
AKP-94	10	10	3.71	Ormoc, Leyte	25
MP-94	10	8	3.57	Southern Negros	30
MP-96	8	17	4.41	Southern Negros	60
PNOC-97	7	5	3.41	Sorsogon	2
NP-97	7	11	3.48	Southern Negros	30

To ensure that the digital strain gauge device was unaffected by heat, a steel flat bar was used to calibrate the apparatus. With a constant load of 128 g applied at the center of the bar the amount of strain was measured as temperature was raised from 0 - 100°C. Based from several measurements conducted, no deflection was recorded, proving that the strain gauge was not affected by heat (Figure 2).

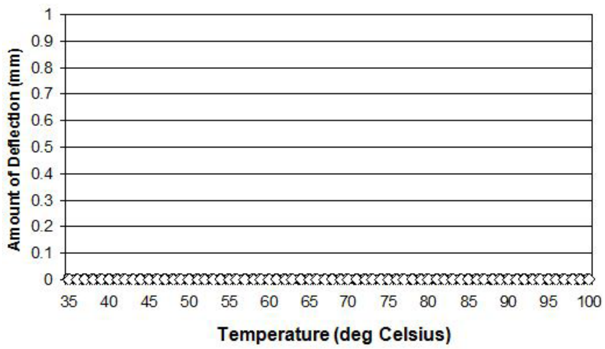

Figure 2. Results from the calibration of the thermomechanical analyzer using steel flat bar. ◊ = data points

Softening temperature
The sample stick was placed on the span one at a time. A constant load of 128 g was applied at the middle of the stick. The amount of load was just enough to provide stress on the stick without causing any significant deflection prior to steaming. The chamber was steamed and for every degree change in temperature the amount of deflection was recorded until the temperature reached 100º C. The amount of deflection was plotted against temperature. The temperature which caused the largest deflection was considered as the softening temperature of the sample. Four replicates per zone (periphery-core) for all portions (base-top) were made.

Chemical analysis
Analogous to the zoning for both portions along the length of the cane, 60-80 mesh powdered sample was prepared using a Wiley mill. Following the American Society for Testing Materials (ASTM) (1975a, 1975b, & 1975c) standards, the chemical constituents of the cell wall particularly holocellulose (D1104-56-ASTM 1975a), cellulose (D1103-60-ASTM 1975b), and lignin content (D1106-56-ASTM 1975c) were determined. Hemicellulose content was indirectly determined by taking the difference of holocellulose and cellulose. Analyses were replicated 3 times.

Statistical analysis
Factorial Experiment in Random Complete Block Design (RCBD) was employed in order to detect the variation in both thermomechanical and chemical properties between and within samples. Blocking was based on the position along the length as well as across the diameter of the cane e.g., base- top and periphery-core. Regression analyses were done to determine the influence of the individual chemical constituents on the softening temperature of the material.

RESULTS AND DISCUSSION

Thermomechanical analyzer fabrication
Figure 3 shows a typical softening behavior of the plantation-grown palasan canes (NP 93) using the fabricated thermomechanical analyzer. At lower temperature, deflection was zero and movement only occurred at about 60° - 65° C. Largest deflection was observed at approximately 85° - 90° C. These results were closely similar to earlier findings using a computerized thermomechanical analyzer (Abasolo et al. 2002b). Although the sensitivity of these two devices was different (0.01 mm and 0.001 mm, respectively), the observed behavior was basically the same. This showed that the fabricated device was accurate.

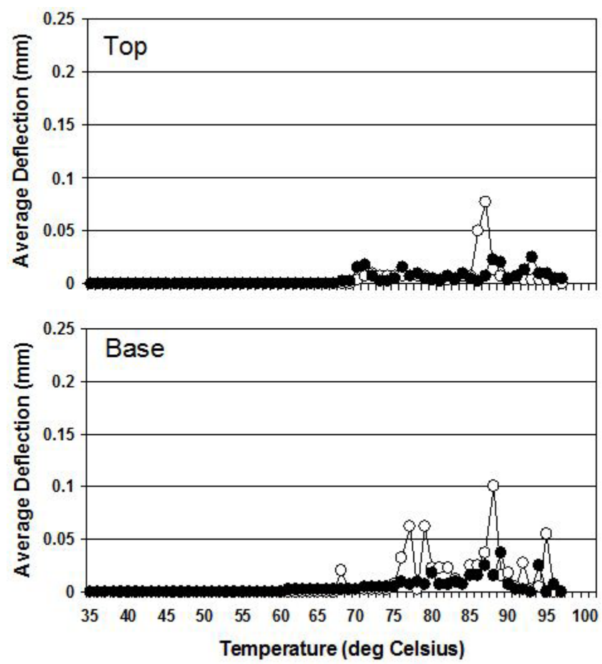

Figure 3. Typical softening behavior of plantation-grown palasan canes. ● = periphery; ○ = core

Absence of the right kind of instrument normally impedes the conduct of good research. In third world countries where research funding is minimal and often times lacking, fabrication of devices is the only resort. The current undertaking showed that fabrication would work as long as the basic principles involved in the measurements are considered in the design.

Softening temperature

The average softening temperature between the wild palasan canes and the plantation-grown canes is depicted in Figure 4. At the top portion, softening temperature of the core region ranged from 79°C - 90°C while at the periphery, it was from 79°C - 94°C. At the basal portion, softening temperature ranged from 80°C - 93°C and 75°C - 91°C for core and peripheral region, respectively. This means that the overall softening temperature of plantation-grown palasan canes was from 84.44°C to 86.37°C. No distinct difference in softening temperature was observed between the core and peripheral region. Similarly from these figures, no obvious variation in softening temperature was observed between top and basal portion.

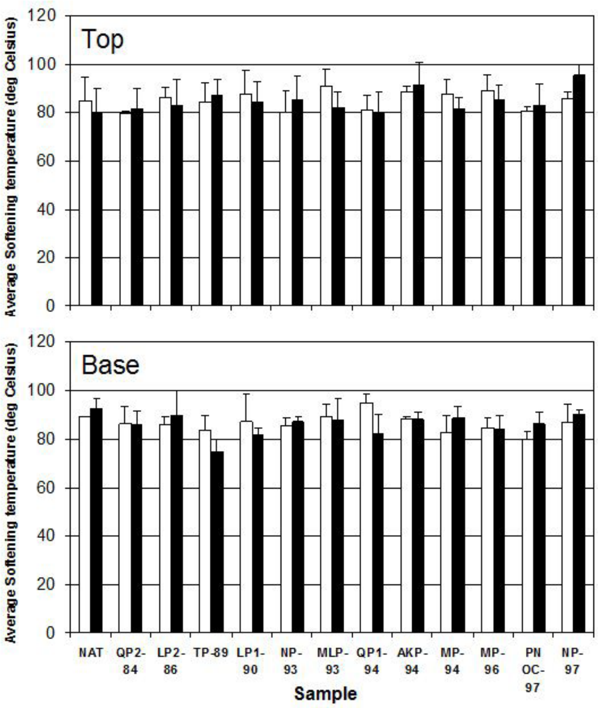

Figure 4. Average softening temperature of the individual samples. ● = periphery; ○ = core

Analysis of variance further revealed the similarities between the samples (Table 2). There was very minimal variation in softening temperature at α = 5%. In general, wild canes soften at the same temperature as that of plantation-grown canes. Interaction between the individual samples and both the position across the radius (periphery – core) and along the length of the cane (base – top) did not show any significant difference. Apparently, the overall temperature when the sample softens is the same with the samples obtained from the wild or from the plantations. This explicitly proved that during this critical stage of processing, both materials would behave similarly. Hence, plantation-grown palasan canes could be converted into furniture without apprehension that the quality of the finished products would be inferior to products derived from wild palasan canes. Plantation-grown canes could be relied on for the raw material requirements of the rattan furniture industry.

Cell wall constituents

Holocellulose content of the samples ranged from 64.54% - 75.38% (Figure 5) a little higher than normal wood and bamboo (PROSEA 1995). The basal portion showed slightly higher values than the top portion. Basically, the plantation samples gave comparable holocellulose values to wild canes with the exception of QP1-94. This is probably due to some abnormalities within the stem caused by fungi or other organisms prior to measurements.

Table 2. ANOVA summary of softening temperature for plantation-grown Palasan.

Source of Variance	df	Sum of Squares	Mean Squares	F com	F tab 5%	F tab 1%	Remarks
Replicates	3	38.05	12.68	0.29	2.67	3.91	NS
Treatments	51	3428.01	67.22	1.54	1.59	1.91	NS
A	12	979.45	81.62	1.87	1.82	2.3	*
B	1	98.31	98.31	2.25	3.91	6.81	NS
C	1	12.50	12.50	0.29	3.91	6.81	NS
AB	12	933.88	77.82	1.78	1.82	2.3	NS
AC	12	746.93	62.24	1.43	1.82	2.3	NS
BC	1	0.24	0.24	0.01	3.91	6.81	NS
Error	153	6678.20	43.65				
Total	207	10144.26					

Note: NS = Not significant C = Top-Base
A = individual samples B = Periphery-Core
AB = interaction between A&B; AC = Interaction between A&C;
BC = interaction between B&C * = Significant at α = 5%

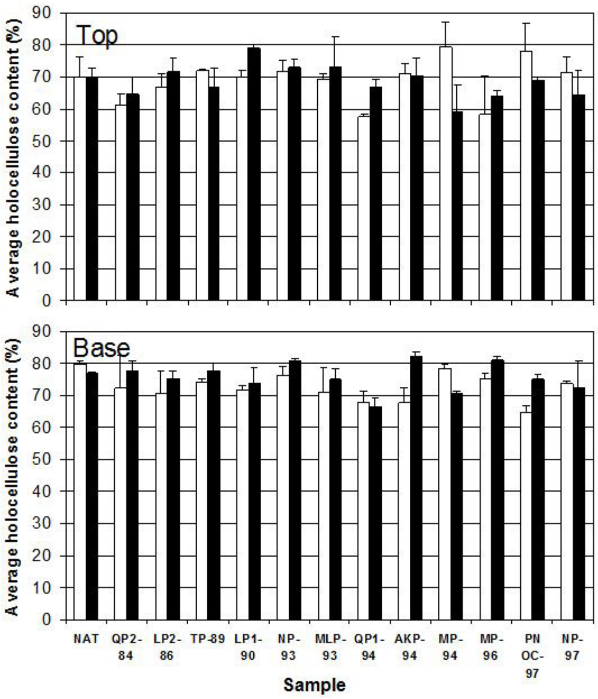

Figure 5. Average holocellulose content of the individual samples. ● = periphery; ○ = core

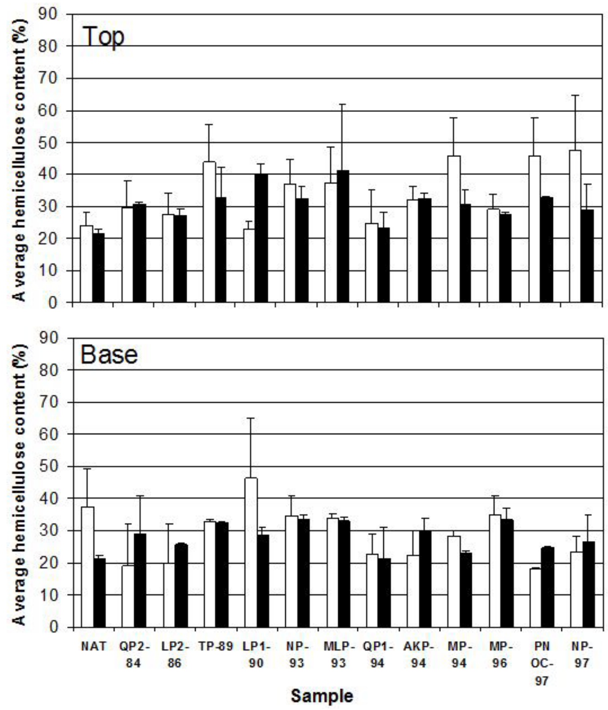

Figure 7. Average hemicellulose content of the individual samples. ● = periphery; ○ = core

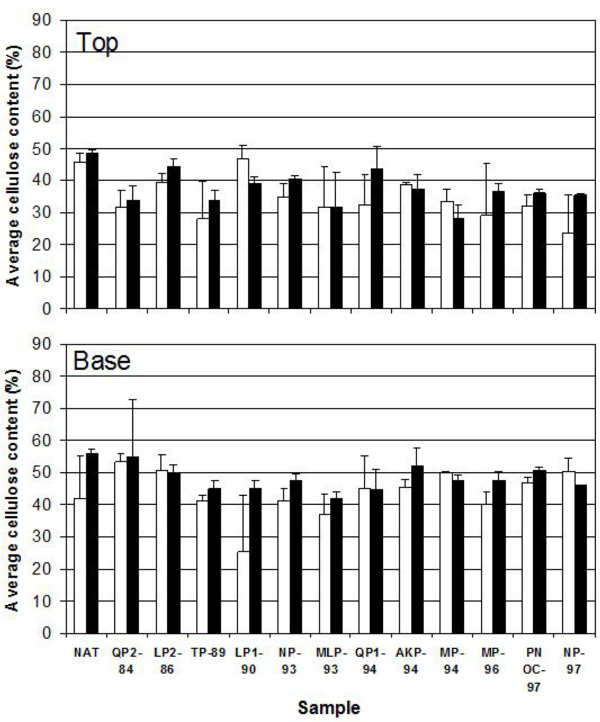

Figure 6. Average cellulose content of the individual samples. ● = periphery; ○ = core

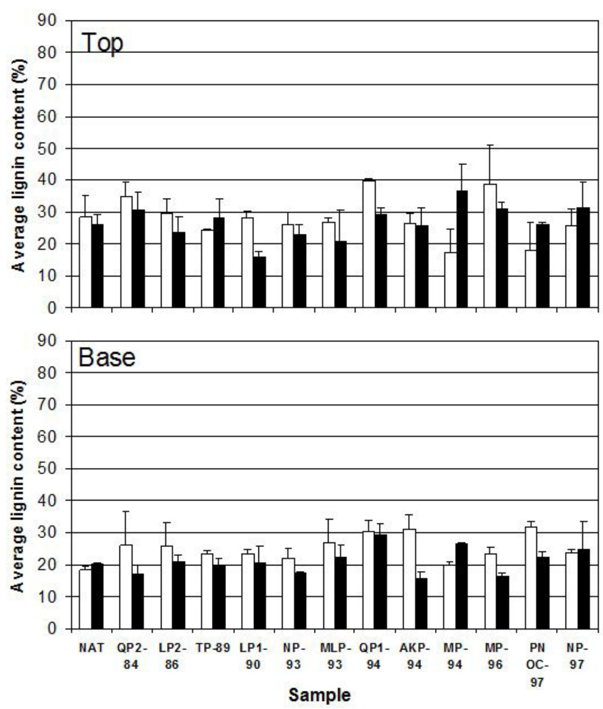

Figure 8. Average lignin content of the individual samples. ● = periphery; ○ = core

Figure 6 gave the cellulose content of the samples. Cellulose content was a little unpredictable at the top portion than at the basal portion. Of the average, cellulose was about 37.08% - 48.08% of the total polysaccharide fraction of the cell wall. Hemicellulose, on other hand, accounted for 23.09 % – 36.43%of the former (Figure 7). These values were approximately similar to that observed in softwoods (Haygreen & Bowyer 1989). Finally, lignin content was about 22.16% - 32.10% (Figure 8). It was more or less static across and along the length of the cane with exception to QP1 and MP-96.

Table 3. ANOVA Summary of the individual chemical constituents of the Palasan rattan cell wall.

Source of Variance	F- computed			
	Holocelullose	Cellulose	Hemicellulose	Lignin
Replicates	9.27**	13.40**	30.12**	10.16**
Treatments	5.13**	5.45**	3.98**	4.78**
A	4.46**	4.25**	5.31**	4.20**
B	56.59**	110.91**	19.52**	37.60**
C	1.72NS	13.58**	5.63*	6.01NS
AB	4.20NS	4.97**	4.18**	3.89**
AC	4.75NS	0.80NS	1.55NS	4.98**
BC	6.32NS	0.5NS	1.06NS	3.90NS

Note:
A = Individual samples
AB = interaction between A&B;
BC = interaction between B&C;
* = Significant at α = 5%;
B = Periphery-Core
AC = Interaction between A&C;
* * = Significant at α = 1%
NS = Not significant
C = Top-Base

Statistical analysis showed a great deal of variation between samples including both across the radius (periphery-core) and along the length (base – top) of the cane (Table 3). This corroborates earlier findings on how the cell wall chemistry of rattan was affected by the distribution of the different cell types e.g., fiber, ground parenchyma cells, metaxylem vessels, etc.; across and along the length of the cane (Abasolo et al. 2002a).

Effect of cell wall chemistry on thermal softening

Thermal softening is an instantaneous but reversible physical process (Hilliz & Rozsa 1978) involving the movement of cellulose molecules within the softened hemicellulose-lignin matrix. Heat first degrades the hemicellulose component followed by increasing the regularity of the crystalline lattice within the microfibrils, and finally by decomposing the lignin-hemicellulose matrix (Dwianto et al. 2000). Although, heating is essential during the molding processes, over heating could increase the cleavage of the hemicellulose-lignin bonds leading to the disruption of the intrafiber load sharing capacity of the fibers resulting to the reduction in strength of the material (Sweet & Winandy 1999).

Regression analysis did not reveal any significant relationship between the individual cell wall components and the softening temperature of the material (Figure 9). The data tend to clump together giving no definite pattern on the influence of cell wall chemistry to thermal softening. Movement within the cell wall domain involves very minute displacement within the individual polymers at the microstrain level (Abasolo et al. 2002b). The fabricated thermomechanical analyzer was only able to detect deflection up to the macrostrain level, hence, movement of the individual cell wall components as influence by heat was not detected. This was the limitation of the fabricated device. The measurement showed that thermal softening

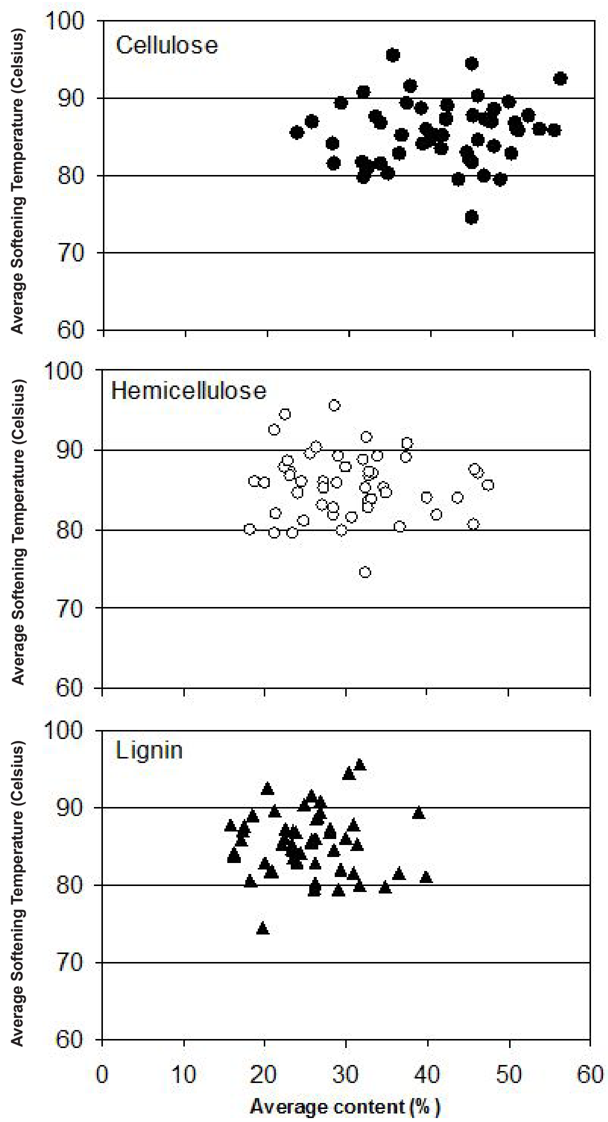

Figure 9. Relationships between the individual cell wall component and softening temperature.

occurred, within the samples as in the wild palasan canes and the plantation-grown samples. The two samples gave practically the same softening temperature. From this, it is expected that plantation-grown samples would behave similarly to wild canes during processing.

CONCLUSION

Thermal softening of plantation-grown canes was not significantly different from wild canes. This means that during processing, plantation-grown canes would behave similarly as the wild canes. Although, a great deal of variation was observed, chemical components of the rattan cell wall were comparable to wild canes. Distribution and concentration of a particularly cell type e.g., fiber, ground parenchyma cells, metaxylem vessels, etc.; could have contributed to these discrepancies. Softening temperature and cell wall chemistry was not related. Movement within the different cell wall polymers was not detected by the fabricated device due to its inability to measure deflection below the 0.01mm level. Nonetheless, the study was able to show that the wild and plantation-grown canes soften at the same temperature range. Hence, the two would behave similarly during processing proving that plantation-grown canes can be converted into products of approximately the same quality as that derived from wild palasan canes. Furniture manufacturers can rely on plantation-grown palasan canes for their raw material needs because they are readily available and are cheaper than imported rattan canes. Plantations would solve the raw material scarcity at the same time help preserve/conserve the remaining natural rattan stock in the wild.

ACKNOWLEDGEMENTS

This study was funded by the University of the Philippines Los Baños Basic Research Program with project code no. 88-D74-22.

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