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Analysis of morphological traits between plantation-grown and wild palasan canes (*Calamus merrillii* Becc.) using cluster analysis

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Abstract: Morphological traits that affect the growth characteristics and overall properties of canes were subjected to cluster analysis. This was accomplished to provide additional proof that plantation-grown palasan canes were similar in traits to wild palasan canes. Cluster and principal component analysis revealed that indeed these two materials were more or less same. This would imply that plantation-grown canes would behave similarly to wild canes during processing and as a result the quality of the finished rattan products derived from them would be more or less the same. Therefore, the rattan industry would no longer be restricted to the use of wild canes because they would now have a good alternative plantation-grown raw material.

Key words: Plantation-grown canes, palasan, morphological traits, cluster analysis, principal component analysis.

INTRODUCTION

The scarcity of rattan resources coming from the natural forests has affected tremendously the rattan furniture industry not only in the Philippines but throughout South Asia (Renuka, 2002) and even in Africa (Suntherland, 2002). Alternative sources of raw materials should be identified and tapped in order to sustain the industry. One important source of raw material is rattan plantations because when properly managed, they could provide an inexhaustible supply of raw material. However, before plantation-grown canes would be acceptable, their similarities to wild canes in terms of properties should be verified. This is with the assumption that materials possessing the same properties would behave similarly during processing and would result to similar quality finished products.

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Attempts to promote the utilization of plantation-grown canes by clarifying certain features of this new material are ongoing (Abasolo, 2006a, 2006b). Recently, comparison between wild and plantation canes in terms of mechanical and physical traits was provided. Some sites showed similar traits to wild cane nevertheless, it was still inconclusive because no statistical evaluation was offered. In addition, the extent to which these materials were similar or dissimilar was still unknown. Probably although they were different in some ways, the amount of difference could still be acceptable to manufacturers. These things should be verified so as to further promote the utilization of plantation-grown canes.

Cluster analysis is a good tool to detect the extent of similarities/ dissimilarities within a certain population. It utilizes a group of multivariate statistical algorithms that group individuals or objects based on their characteristics where individuals with similar traits are mathematically gathered into the same cluster (Hair *et al.*, 1995). Analysis can be performed on morphological traits, biochemical and molecular markers or any
combination of these three characters (Mohammadi and Prasanna, 2003). The utility of this technique has been proven in a number of publications (Powell *et al.*, 1996; Matus and Hayes, 2002; Brondani *et al.*, 2005).

Morphological traits that are essential to the efficient conversion of rattan to finished products were subjected to cluster analysis to illustrate the similarities of plantation-grown canes coming from different provenances to canes obtained from the natural forest. This was with the objective of providing additional evidence to manufacturers that plantation-grown canes could be used as alternative raw materials in the manufacture of good quality rattan furniture.

MATERIALS AND METHODS

Palasan (*Calamus merrillii* Becc.) canes obtained from 12 plantations situated all over the Philippines were used in this study. In addition, one coming from the natural stand was sampled. For a complete description of the individual provenances, refer to Abasolo (2006a). After determining the total length of the cane, average internode diameter and length, two meter long samples were derived from the base, middle and top most portions. Poles were submerged in water prior to measurements to prevent the onset of decay.

Sample preparation

Sample disks were cut off from the three portions. The peripheral and core regions of the disk were delineated out. From these regions, 1 cm^3 cubes were dissected out. Parallel to the sample cubes, match-stick samples were prepared. The former was used for the fiber percentage evaluation, while the latter was used to determine the

different fiber parameters *e.g.*, fiber length, fiber diameter, lumen diameter and cell wall thickness.

Fiber biometry

After boiling for several hours, 35–45 ¼m thick cross sectional slices were cut off from the cubes using a sliding microtome. Slices were stained with safranin and fast green then mounted on permanent slides. With a compound microscope equipped with a Nikon Cool Pix digital camera, a total of 5 digital images per region were taken. Fiber area percentage was determined using the procedures given in a previous article (Abasolo *et al.*, 2005). The data from the two regions for the three portions were averaged and this average values were used in the analysis.

The match-stick samples were macerated in 50:50 solutions of glacial acetic acid and 20 per cent hydrogen peroxide. Upon defibrillation, at least 30 whole fibers were randomly selected. Fiber length, fiber diameter and lumen diameter were measured using an Olympus microscope equipped with a built-in vernier caliper. Cell wall thickness was obtained by getting the difference between fiber diameter and lumen diameter then divided by two. Average values from every portion were used in the evaluation.

Physico-mechanical characteristics

A Shimadzu universal testing machine (UTM) was utilized to determine the mechanical attributes of the individual cane. Static bending tests were performed (ASTM 1975). Modulus of rupture (MOR) and modulus of elasticity (MOE) were computed. Two measurements were performed for the base, middle and top most portion of the cane. The average of these six measurements was obtained to get a general perspective of the mechanical characteristics of the individual cane. After static bending tests, sample disks were again prepared. Similar to the previous preparation, the peripheral and core regions were delineated out. From these regions, 0.5 x 0.5 x 1 cm sample blocks were prepared. A total of ten blocks per region were made. Following the gravimetric method, oven-dried specific gravity was derived. Average values coming from all regions and from all portions were obtained and were used in the analysis.

Statistical analysis

The most commonly used clustering algorithm (Panchen, 1992) particularly the Unweighted Paired Group Method using Arithmetic Averages (UPGMA) was utilized in the analysis. Morphological characters were standardized to eliminate scale differences to give equal weight and contribution of all the characters in the final output. YBAR option of the Stand program in NTSYS-pc 2.1 software (Rohlf, 2000) was designed for this purpose. Using the paired distances, a distance matrix was

generated where the dendrogram was derived. Cophenetic coefficient was computed to indicate whether the data in the matrix were well represented by the dendrogram.

Eigenvectors that reflect the correlation between the original variable and the principle component and eigenvalues that represent the amount of variance accounted for by every component were calculated using the *Eigen* program in the software. The most important morphological traits that influenced the classification of the different plantations into clusters were identified (Berdahl *et al.*, 1999). Principal Components Analysis (PCA) was performed to depict non-hierarchical relationships among the different parameters. Results are presented in a 2-dimensional generated plot.

RESULTS AND DISCUSSION

Summary of the morphological traits used in the evaluation is presented in Table 1. Selection of characters was different from the normal process of utilizing taxonomically important features, leaf shapes, flowers, *etc.* (Sarmah *et al.*, 2007; Campos *et al.*, 2005). Attributes that influence the total harvestable volume (internode length, total length) as well as the overall properties of the cane, anatomical (fiber characteristics), physical (specific gravity) and mechanical (MOE, MOR) were used. These traits are important in cane processing because they influence the quality of the finished products. A total of 11 morphological traits were subjected to the multivariate analysis.

Cluster analysis

The generated dendrogram derived from the distance matrix showed five clusters (Fig. 1). Cluster I consist of six samples, five coming from plantations (QP2-84, NP-93, AKP-94, NP-97, MP-94) and one coming from the natural stand. Cluster II contains three samples (LP2-86, TP-89, LP1-90), while cluster III has only one sample (MP-96). Cluster IV has two samples (QP1-94, PNOC-97) and finally cluster V only has MLP93. It was important to note that the grouping was not based on the age of the cane although a couple of samples of the same age managed to be included in the same cluster. Coincidentally, samples that came from the same origin (LP2-86 and LP1-90) were grouped together.

The cophenetic correlation coefficient indicated a moderate fit (Rohlf, 1992) having an r value of 0.7828. Nevertheless, it does not mean that the dendrogram did not properly represent the distance matrix of the samples. It only indicated that some distortion might have occurred probably due to the lack of independence of the individual coefficient in the dissimilarity matrix (Rincon *et al.*, 1996).

The relative magnitude of the eigenvectors from the first principal component axis (Table 2) showed that the most important traits that determined the classification of the different provenances into clusters were fiber diameter, cell wall thickness, MOE,

Table 1. Morphological traits used in the preparation of the dendrogram

	TL (m)	IL (cm)	ID (cm)	FL (mm)	FD (mm)	LD (mm)	CWT (mm)	FP (%)	SG	MOR (MPa)	MOE (GPa)
NAT											
Ave.	22	29.96	2.95	1.3649	0.0191	0.0099	0.0046	33.53	0.50	31.65	6.40
Std Dev.	*5.6*	*8.22*	*0.60*	*0.1886*	*0.0018*	*0.0016*	*0.0005*	*6.93*	*0.15*	*10.16*	*1.22*
n	2	22	22	30	30	30	30	20	60	6	6
QP2-84											
Ave.	16	28.30	2.95	1.5140	0.0254	0.0102	0.0076	21.14	0.51	27.55	4.99
Std Dev.	*4.5*	*8.47*	*0.60*	*0.3437*	*0.0078*	*0.0026*	*0.0036*	*8.40*	*0.15*	*3.62*	*1.08*
n	2	16	16	30	30	30	30	20	60	6	6
LP2-86											
Ave.	41	29.75	3.73	1.5363	0.0254	0.0112	0.0079	38.42	0.42	26.75	5.35
Std Dev.	*8.74*	*4.45*	*0.30*	*0.4446*	*0.0046*	*0.0049*	*0.0027*	*23.42*	*0.21*	*12.30*	*2.78*
n	2	41	41	30	30	30	30	20	60	6	6
TP-89											
Ave.	33	24.30	4.86	1.5805	0.0240	0.0082	0.0079	31.25	0.47	27.62	4.46
Std Dev.	*4.66*	*6.75*	*0.55*	*0.2800*	*0.0126*	*0.0016*	*0.0066*	*15.32*	*0.19*	*15.67*	*2.90*
n	2	33	33	30	30	30	30	20	60	6	6
LP1-90											
Ave.	53	25.73	3.92	1.7044	0.0190	0.0081	0.0057	36.15	0.46	25.13	4.76
Std Dev.	*8.96*	*4.85*	*0.59*	*0.4849*	*0.0020*	*0.0032*	*0.0011*	*16.57*	*0.17*	*7.79*	*1.38*
n	2	53	53	30	30	30	30	20	60	6	6
NP-93											
Ave.	3	21.67	4.56	1.3649	0.0208	0.0079	0.0065	30.42	0.48	32.45	6.37
Std Dev.	*1.55*	*7.01*	*0.38*	*0.1886*	*0.0015*	*0.0012*	*0.0008*	*15.77*	*0.15*	*11.58*	*2.11*
n	2	3	3	30	30	30	30	20	60	6	6
MLP-93											
Ave.	11	28.79	3.66	1.6559	0.0314	0.0097	0.0109	33.38	0.39	30.97	5.79
Std Dev.	*4.3*	*8.50*	*0.36*	*0.3078*	*0.0654*	*0.0031*	*0.0330*	*13.91*	*0.13*	*16.82*	*3.45*
n	2	11	11	30	30	30	30	20	60	6	6
QP1-94											
Ave.	6	19.67	3.15	1.9124	0.0191	0.0082	0.0054	30.70	0.50	14.35	6.11
Std Dev.	*2.75*	*5.39*	*0.83*	*0.4137*	*0.0037*	*0.0023*	*0.0014*	*16.41*	*0.12*	*3.31*	*2.39*
n	2	6	6	30	30	30	30	20	60	6	6
AKP-94											
Ave.	10	26.52	3.71	1.5339	0.0214	0.0072	0.0071	31.58	0.46	25.20	4.64
Std Dev.	*3.5*	*5.67*	*0.30*	*0.1836*	*0.0033*	*0.0014*	*0.0013*	*15.75*	*0.15*	*11.43*	*2.77*
n	2	10	10	30	30	30	30	20	60	6	6
MP-94											
Ave.	8	28.09	3.57	1.4240	0.0192	0.0075	0.0058	25.63	0.47	28.38	4.56
Std Dev.	*2.86*	*10.96*	*0.29*	*0.1732*	*0.0014*	*0.0015*	*0.0006*	*10.84*	*0.19*	*14.33*	*2.06*
n	2	8	8	30	30	30	30	20	60	6	6
MP-96											
Ave.	17	36.39	4.41	1.4183	0.0211	0.0094	0.0059	27.37	0.38	18.52	3.46
Std Dev.	*3.56*	*6.40*	*0.44*	*0.2864*	*0.0074*	*0.0017*	*0.0038*	*7.54*	*0.14*	*7.06*	*1.69*
n	2	17	17	30	30	30	30	20	60	6	6
PNOC-97											
Ave.	5	18.47	3.41	1.7630	0.0215	0.0091	0.0062	29.53	0.38	18.85	3.23
Std Dev.	*1.25*	*8.52*	*0.52*	*0.5716*	*0.0034*	*0.0024*	*0.0014*	*12.29*	*0.15*	*10.91*	*1.73*
n	2	5	5	30	30	30	30	20	60	6	6
NP-97											
Ave.	11	23.85	3.48	1.3778	0.0216	0.0063	0.0077	30.21	0.50	27.38	4.47
Std Dev.	*3.85*	*6.70*	*0.42*	*0.1155*	*0.0090*	*0.0018*	*0.0045*	*13.00*	*0.16*	*14.31*	*2.16*
n	2	11	11	30	30	30	30	20	60	6	6

Note: TL = Total length; IL = Internode length; ID = Internode diameter; FL = Fiber length; FD = Fiber diameter; LD = Lumen diameter; CWT = Cell wall thickness; FP = Fiber percentage; SG = Ovendried specific gravity; MOR = Modulus of rupture; MOE = Modulus of elasticity.

Table 2. Eigenvectors from the first four principal component axes for traits used classify the 13 provenances into 5 clusters

Morphological traits	Principal Component Axis			
	1	2	3	4
Total length	3.6805	1.7991	-5.7700	5.6410
Internode length	5.1323	-1.9175	2.5384	5.5267
Internode diameter	2.4623	1.5526	2.1948	4.0743
Fiber length	-1.1532	7.1006	-4.8157	-4.2182
Fiber diameter	8.6098	6.2896	1.5847	-4.5893
Lumen diameter	6.1126	1.0468	-2.5908	2.5668
Cell wall thickness	7.5966	3.5541	2.1283	-4.8509
Fiber percentage	3.4696	4.5441	-7.5336	1.8704
Ovendried specific gravity	-5.1085	-7.0047	-1.9038	-1.5199
Modulus of rupture	4.2225	-8.1347	6.7850	-2.8857
Modulus of elasticity	6.1659	-6.4557	-5.1518	-3.6722

lumen diameter and internode length. Table 3 provides the summary of the morphological traits of the individual clusters. Based on this, it was not so clear how these 5 characters influence the grouping of each cluster. Nevertheless, cluster I was probably grouped according to MOE because of its very small standard deviation. Cluster II, on the other hand, was more related in terms of its fiber diameter. Cluster III was separated from the rest because of its very long internode, while cluster IV was arranged according to its very short internode. Cluster V stands out from the rest because it has the thickest cell wall. Nonetheless, interaction between these 5 important characters was also possible which could not be ruled out as one of the possible reasons for the grouping.

The influence of cane age and the characteristics of the different provenances were not considered in the analysis because these parameters were beyond the scope of this

Table 3. Summary of the morphological traits of the individual clusters of the dendrogram

Cluster	TL	IL	ID	FL	FD	LD	CWT	FP	SG	MOR	MOE
I											
Ave	11.67	26.3983	3.5367	1.4299	0.0212	0.0082	0.0066	28.7501	0.4867	28.7686	5.2391
Std dev	*6.59*	*3.0993*	*0.5950*	*0.0763*	*0.0023*	*0.0016*	*0.0012*	*4.5467*	*0.0193*	*2.7617*	*0.9075*
II											
Ave	42.33	26.5933	4.1700	1.6070	0.0228	0.0092	0.0072	35.2734	0.4500	26.4978	4.8595
Std dev	*10.07*	*2.8257*	*0.6051*	*0.0871*	*0.0034*	*0.0018*	*0.0012*	*3.6623*	*0.0266*	*1.2625*	*0.4539*
III *	17.00	36.3900	4.4100	1.4183	0.0211	0.0094	0.0059	27.3709	0.3776	18.5152	3.4568
IV											
Ave	5.50	19.0700	3.2800	1.8377	0.0203	0.0086	0.0058	30.1169	0.4364	16.5994	4.6727
Std dev	*0.71*	*0.8485*	*0.1838*	*0.1056*	*0.0018*	*0.0007*	*0.0005*	*0.8246*	*0.0843*	*3.1800*	*2.0371*
V *	11.00	28.7900	3.6600	1.6559	0.0314	0.0097	0.0109	33.3830	0.3870	30.9714	5.7929

* Only one representative in the cluster hence standard deviation could not be performed.
For notation of the labels please refer to Table 1.

Table 4. Eigenvalues and proportions of variability of the 11 principal components

Component	Eigenvalue	Per cent	Cumulative %
1	2.7283	24.8023	24.80
2	2.1528	19.5707	44.37
3	1.6888	15.3525	59.73
4	1.6079	14.6177	74.34
5	1.3678	12.4344	86.78
6	0.5719	5.1993	91.98
7	0.4247	3.8612	95.84
8	0.3261	2.9648	98.80
9	0.1157	1.0516	99.85
10	0.0144	0.1308	99.99
11	0.0016	0.0148	100.00

study. Nevertheless, it does not mean that they did not have an effect on the clustering. Especially when it was observed that any factor that influences the growth and development of the plant has an impact on its quality (Zobel and van Buijtenen, 1989).

The first 4 principal components axes (PCA) accounted for 74.34 per cent of the total variability (Table 4). The first PCA was responsible for 24.80 per cent of the variation, while the second PCA was responsible for 19.57 per cent of the differences. For the first PCA, the sources of variation came from the fiber characteristics and MOE, while the second PCA was negatively affected by the physical and mechanical attributes of the cane (Table 3).

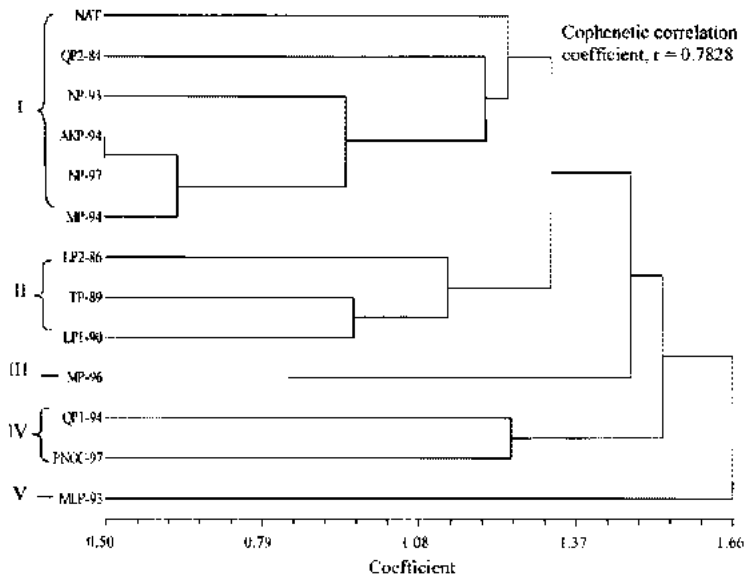

Figure 1. Dendrogram derived from the distance matrix showing 5 clusters

Principle component analysis

Principal component analysis provides independence between variables and balanced weighting of traits, leading to an effective contribution of the different characters on the basis of respective variation. The result of the analysis was depicted in Figure 2. Apparently, 9 out of 12 samples coming from plantations clumped together with the samples from the wild. This means that approximately 75 per cent of the plantation-grown canes showed close relationship with one another. They were similar in terms of growth characteristics, anatomical, physical and mechanical properties. Because of this, it was assumed that they would behave in the same manner to wild canes during processing. Thus, there is a big possibility that products derived from them would be more or less the same in terms of quality.

Members of clusters IV (QP1-94, PNOC-97) and V (MLP-93) were separated from the rest of the samples. They have become outliers in the analysis. Although LP2-86 was close to one of the outliers (MLP-93), it was more associated to the other 10 samples as illustrated in the dendrogram. Nevertheless, it could be said that only 25 per cent of the samples did not exactly conform to the characteristics of the wild canes. However, considering the spatial distances of these three outliers to the main cluster, it could be perceived that their differences were not that great. Probably, it would only require minor modifications in the processing techniques for these samples to still be acceptable.

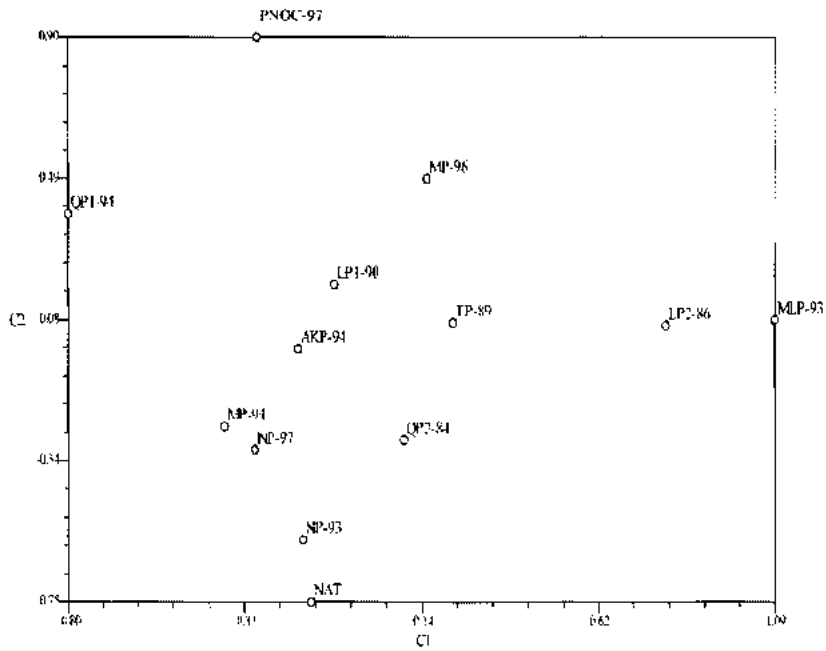

Figure 2.. The results of PCA showing the relationship among the samples

Implications

The raw material pool of the rattan furniture industry would no longer be restricted to canes derived from the natural forest. The study showed that regardless of age and where the plantations were established, plantation-grown canes would behave in the same way to wild canes during processing. Sometimes minor modifications in the existing processing techniques would be needed, so that even samples that were slightly different from the wild canes would be acceptable to manufacturers. Plantation-grown canes would serve as a good alternative raw material in the manufacture of superior quality rattan furniture.

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