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BIOMETRIC CLUSTERING OF COCONUT POPULATIONS OF THREE INDIAN OCEAN ISLANDS*

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Coconut populations of Indian Ocean Islands of Madagascar, Mauritius and Seychelles were clustered using principal component analysis. A total of 28 vegetative, reproductive and fruit characters were used for analysis. Floral, foliar and fruit characteristics analysis indicated the usefulness of 11 characters for clustering. Five clusters were obtained on the basis of these characters. Nut characters were also found to be good for cluster analysis. All the dwarfs were in one cluster when vegetative and nut characters were considered. While selected, characters of two talls, Comoros Tall and Coco Bleu Tall were also included along with dwarfs indicating the doubtfulness of the genetic nature of these materials. These may be in fact dwarfs erroneously recorded as talls. Cluster analysis did not show any geographical affinity within the region.

INTRODUCTION

Biometric clustering in coconut was carried out using Mahalanobis D^2 (Bavappa *et al.*, 1973; Balakrishnan and Namboodiri, 1987; Louis and Chopra, 1989; Fernando *et al.*, 1993), Metroglyph analysis (Raveendra *et al.*, 1987), Scatter diagram (Zizumbo-Villarreal *et al.*, 1993), Canonical method (N'Cho *et al.*, 1993), Principal Component Analysis (Abeywardena and Mathes, 1980; Zizumbo-Villarreal and Pinerio, 1998) and UPGMA (unweighted paired group, based on the arithmetic mean) method of analysis (Ovasuru, 1993). Zizumbo-Villarreal and Pinerio (1998) and Ovarasu (1993) employed Principal Component Analysis (PCA) and UPGMA to study the diversity in the natural habitat of coconut populations of Mexico and Papua New Guinea, respectively. In this study, PCA has been used to identify the contribution of different traits to variation and to use the method to group coconut populations in their native soils/ collection sites from three Indian Ocean Islands of Madagascar, Mauritius and Seychelles.

MATERIAL AND METHODS

Morphological characters of vegetative parts, inflorescence and fruits were collected from coconut populations of the Indian Ocean Islands of Madagascar, Mauritius and Seychelles. All measurements were made in the field and on an average 10 palms were sampled in a systematic manner. Data recorded were subjected to clustering with PCA (Adams and Wiersma, 1978) using the mean values of the characters of palms.

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Table 1. Population means for all morphological characters

Var. No.	I*	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
								Accession Number							
1**	78.6	65.0	68.7	70.0	120.0	129.5	132.5	95.5	87.2	98.0	121.0	85.0	70.5	95.5	93.0
2	25.9	25.3	27.0	38.0	36.0	40.3	45.2	43.0	35.6	35.0	39.5	35.0	45.5	30.5	34.0
3	111.5	106.6	108.3	130.0	155.0	149.5	152.8	130.7	136.8	103.0	163.0	168.0	107.8	138.8	110.0
4	279.7	288.7	258.0	280.0	290.0	420.5	436.5	381.0	381.5	331.0	363.0	220.0	375.0	331.2	275.0
5	87.2	96.0	93.3	102.0	102.0	115.8	119.3	102.5	105.0	100.0	127.5	127.5	103.0	103.5	104.0
6	5.1	5.0	5.3	6.0	6.0	6.0	6.6	6.3	6.0	4.0	6.2	5.8	5.1	5.6	5.3
7	77.1	80.0	90.7	95.0	98.0	109.3	126.3	109.0	102.5	104.7	102.5	123.0	109.0	108.7	45.0
8	23.6	27.3	28.3	29.0	37.0	15.3	14.5	14.0	15.0	16.2	13.5	14.5	18.0	24.7	19.0
9	4.3	3.6	3.5	3.5	2.5	6.6	7.1	7.3	6.4	8.8	7.9	5.7	5.5	4.3	5.0
10	79.8	83.6	66.3	118.0	125.0	123.5	127.4	99.4	101.0	79.0	127.0	150.0	86.0	119.8	87.0
11	33.5	43.4	25.7	60.0	55.0	53.3	53.3	48.7	43.8	33.0	59.0	60.0	38.5	63.0	35.0
12	46.2	40.2	40.7	58.0	70.0	70.3	74.3	52.8	57.1	44.0	68.0	90.5	47.5	39.0	52.0
13	34.7	38.4	33.3	38.0	60.0	46.8	46.3	36.0	37.0	37.5	48.0	51.0	35.5	31.8	38.0
14	24.8	30.8	30.7	37.0	38.0	35.5	36.2	40.6	39.5	37.0	48.0	39.0	42.5	36.8	46.0
15	35.5	44.4	28.0	22.0	26.0	18.8	31.5	33.7	35.7	47.5	53.5	44.0	49.0	38.0	26.0
16	15.5	27.3	22.0	12.0	18.0	7.3	9.7	21.3	15.5	22.2	13.0	19.0	17.0	28.8	14.0
17	190.0	62.0	130.0	430.0	490.0	460.0	450.0	390.0	460.0	300.0	160.0	300.0	300.0	100.0	260.0
18	20.0	19.7	17.7	20.3	25.9	25.1	27.5	22.0	25.1	23.4	25.5	29.2	20.5	21.5	28.3
19	15.0	10.5	9.9	14.2	17.1	20.1	19.1	15.9	19.9	15.7	16.6	16.1	15.2	11.1	18.6
20	938.0	505.0	549.0	335.0	1446.7	1840.0	1995.0	1337.0	2155.0	1513.0	1976.0	2118.0	1382.0	785.0	2766.0
21	3.7	3.4	3.2	3.0	5.2	4.0	5.0	3.5	4.4	3.6	4.8	5.7	4.4	4.7	6.0
22	462.2	220.0	265.0	843.0	541.1	1061.0	947.0	584.0	990.0	740.0	571.0	522.0	551.0	293.0	686.0
23	51.9	61.9	50.4	36.8	62.6	42.0	52.1	56.3	53.4	51.1	71.0	72.1	60.4	62.7	75.2
24	1.1	1.1	1.2	1.2	1.5	1.6	1.4	1.7	1.4	1.3	1.5	1.4	1.1	1.4	1.4
25	231.1	133.5	135.0	371.2	281.1	509.0	415.0	322.0	430.0	369.0	294.0	279.0	242.0	168.0	321.0
26	2.3	1.7	2.0	2.8	3.1	2.9	3.3	3.1	3.2	3.4	3.2	3.5	2.9	3.4	3.3
27	127.8	63.5	72.0	201.2	161.2	236.0	230.0	171.0	221.0	203.0	181.0	164.0	161.0	108.0	190.0
28	92.0	22.1	52.0	213.8	75.0	316.0	267.0	97.9	293.0	193.0	105.6	91.0	153.6	36.0	158.9

*I:Pemba Orange Dwarf, II: Pemba Green Dwarf, III:Pemba Yellow Dwarf, IV:Pemba Red Tall, V:Dupay's Tall, VI:Guelle Rose Tall from Mauritius; VII: Sambava Tall, VIII:West African Tall, IX:Sambava Green Tall, X:Comoros Tall from Madagascar; XI:Coco Le Rein Tall, XII:Coco Le Haut Tall, XIII:Coco Bleu Tall, XIV:Coco Raisin Tall, XV:Coco Gra Tall from Seychelles. **1: girth of stem (cm); 2: total number of leaves; 3: length of petiole (cm); 4: length of leaf bearing portion (cm); 5: number of leaflets; 6: breadth of leaflet (cm); 7: length of leaflet (cm); 8: number of leaf scars in 1m of trunk; 9: length of internode (cm); 10: length of inflorescence (cm); 11: length of spikelet bearing portion (cm); 12: length of stalk (cm); 13: length of spikelet (cm); 14: number of spikelet/inflorescence; 15: mean number of female flowers/inflorescence; 16: mean number of nuts/bunch; 17: quantity of tender nut water (ml); 18: length of fruit (cm); 19: breadth of fruit (cm); 20: weight of fruit (g); 21: thickness of husk (cm); 22: weight of husked nut (g); 23: per cent of husk to whole fruit weight; 24: thickness of kernel (cm); 25: weight of kernel (g); 26: thickness of shell (mm); 27: weight of shell (g); 28: quantity of nut water (ml).

Vegetative, inflorescence and fruit characters such as i) girth of trunk one meter from the base, ii) total number of leaves on the crown, iii) length of petiole (cm), iv) length of leaf bearing portion (cm), v) number of leaflets, vi) breadth of leaflet (cm), vii) length of leaflet (cm), viii) number of leaf scars in one meter of trunk, ix) length of internode (cm), x) length of inflorescence (cm), xi) length of spikelet bearing portion (cm), xii) length of inflorescence stalk (cm) and xiii) length of spikelet (cm) were recorded. PCA was carried out individually for vegetative and inflorescence characters and fruit characters, respectively . Based on the PC scores, parameters having very low eigen root/vector values were omitted and a final clustering using PCA was attempted with selected morphological characters.

RESULTS AND DISCUSSION

Population mean of the characters of the palm are presented in Table 1. PCA of the 16 morphological characters of vegetative parts and inflorescence indicated that the first five principal components accounted for 88 per cent of the variations (Table 2). Characters that contributed to the variations were breadth and length of leaflet, length of inflorescence and its stalk, length of spikelet bearing portion, length of spikelet and the number of nuts/bunch. Balakrishnan and Namboodiri (1987) also found inflorescence characters as major factors contributing to divergence.

Among the 12 fruit characters, husk thickness, weight of husked nut and percentage of husk to whole fruit weight contributed to 85 per cent of variation (Table 3). Selected characters were subsequently subjected to PCA and the first three principal components contributed to 79 per cent of the variation (Table 4). Parallel studies with Mexican collections indicated that most of the morphological

Table 2. Latent vectors and latent roots for different vegetative and inflorescence characters

Character	PC1	PC2	PC3	PC4	PC5
Trunk girth (cm)	0.278	0.266	0.328	0.181	0.330
Number of leaves on crown	-0.020	-0.226	0.201	-0.326	-0.049
Petiole length (cm)	0.214	0.194	-0.134	0.314	-0.192
Length of leaf bearing portion (cm)	0.023	0.050	0.050	0.405*	-0.195
Number of leaflets	-0.259	0.274	-0.046	0.043	-0.022
Breadth of leaflet (cm)	0.556*	0.066	-0.028	0.260	-0.140
Length of leaflet (cm)	0.348	-0.577*	0.189	0.059	0.118
Leaf scars in 1 m of trunk (No.)	0.109	0.136	-0.111	-0.288	0.002
Internode length (cm)	0.019	-0.023	0.150	-0.131	-0.028
Inflorescence length (cm)	0.106	-0.195	0.063	0.121	0.653*
Length of spikelet portion (cm)	0.177	-0.066	0.301	-0.429*	-0.217
Length of inflorescence stalk (cm)	-0.500*	-0.439	0.196	0.368	-0.080
Spikelet length (cm)	-0.089	0.067	-0.418*	-0.128	0.510
Spikelets per inflorescence (No.)	-0.031	0.228	0.389	-0.212	0.061
Female flowers/inflorescence (No.)	-0.187	0.096	0.025	-0.032	0.049
Nuts per bunch (No.)	-0.175	0.326	0.547*	0.170	0.170
Eigen root	7.45	2.88	1.70	1.12	0.88
Variance (%)	46.58	18.98	10.65	7.01	5.48
Cumulative variance (%)	46.58	64.56	75.21	82.22	87.70

Table 3. Latent vectors and latent roots for different fruit characters

Character	PC1	PC2
Quantity of tender nut water	0.287	0.291
Fruit length	-0.200	0.324
Fruit breadth	0.210	-0.067
Fruit weight	-0.235	-0.148
Husk thickness	-0.829*	0.012
Weight of husked nut	-0.145	0.458*
%husk to whole fruit weight	0.060	0.626*
Kernel thickness	0.195	-0.195
Kernel weight	0.161	0.219
Shell thickness	0.009	-0.142
Shell weight	0.001	-0.266
Quantity of nut water	0.042	0.077
Eigen root	7.294	2.927
Variance (%)	60.78	24.39
Cumulative variance (%)	60.78	85.17

Table 4. Latent vectors and latent roots for selected characters

Character	PC1	PC2	PC3
Length of leaf bearing portion	0.168	0.352*	0.259
Breadth of leaflet	-0.408*	-0.068	-0.157
Length of leaflet	-0.027	-0.112	-0.511*
Inflorescence length	-0.690*	-0.084	-0.142
Spikelet portion	0.069	-0.624*	0.550
Inflorescence stalk length	0.219	0.472*	0.057
Spikelet length	0.359*	-0.303	-0.396
Nuts/Bunch	-0.140	0.356*	-0.074
Husk thickness	0.015	0.000	-0.115
Husked nut weight	-0.355	0.135	0.383*
%husk to whole fruit weight	0.039	-0.052	-0.008
Eigen root	4.87	2.439	1.393
Variance (%)	44.27	22.18	12.66
Cumulative variance (%)	44.27	66.45	79.11

characters, except shell thickness were useful for differentiating the ecotypes Zizumbo-Villarreal and Pinerio (1998). In the present study, breadth of the leaflet, inflorescence length, spikelet length and weight of the husked nut were important in PC1 while length of leaf bearing portion, length of spikelet bearing portion, length of inflorescence stalk, spikelet length and nuts/bunch were important in PC2. In PC3 the length of leaflet, length of spikelet bearing portion, spikelet length and weight of the husked nut were important. Husk percentage and husk thickness did not show any significant contribution. Contrary to the earlier findings (N'Cho *et al.*, 1993; Zizumbo-Villarreal and Pinero,1998; Louis and Chopra, 1989), the data generated in the present study were in agreement with the findings of Balakrishnan and Namboodiri (1987). Contradiction may be due to the diverse genetic nature of the population studied. N'Cho *et al.* (1993) observed that leaf characters, in general, were very stable while inflorescence, stem and certain fruit characters like shape and endosperm thickness showed average variability. On the other hand, production characteristics (nuts/bunch and bunches/tree) and fruit characters like husk and shell thickness and endosperm cavity diameter were highly variable.

PC analysis indicated that the 15 accessions could be grouped into five clusters based on vegetative and inflorescence characters. Cluster I had maximum number of accessions followed by cluster II (Table 5). Inter-cluster distance (Table 6) was maximum between cluster III (the dwarfs) and cluster II, followed by cluster

Table 5. Cluster composition of different accessions based on vegetative and inflorescence characters

Cluster Number	Number of accessions	Name of accessions
I	5	West African Tall, Coco Raisin Tall, Comoros Tall, Coco Bleu Tall, Sambava GreenTall
II	4	Coco Le Rein Tall, Coco Le Haut Tall, Guelle Rose Tall, Sambava Tall
III	2	Pemba Orange Dwarf, Pemba Green Dwarf, Pemba Yellow Dwarf
IV	3	Dupay's Tall, Pemba Red Tall
V	1	Coco Gra Tall

Table 6. Intra and inter cluster distances between cluster centroids based on vegetative and inflorescence characters

Cluster Number	I	II	III	IV	V
I	2.386				
II	4.406	2.580			
III	4.126	7.376	1.182		
IV	4.579	4.523	5.161	1.998	
V	4.264	6.252	4.415	4.997	0.000

V and II and cluster III and IV, respectively. On the other hand, dwarfs (cluster III) were closely related to the Talls of cluster I than the rest of the clusters. This closeness was reflected in the similarity in mean values of a majority of the leaf and inflorescence characters (Table 7). This cluster includes West African Tall (WAT), Sambava Green Tall and Comoros Tall from Madagascar and Coco Raisin Tall and Coco Bleu Tall from Seychelles. Intra-cluster distance (Table 6) was maximum in cluster II followed by cluster I and least in cluster III. Accessions in cluster III differ mainly for characters which contribute less to the variations while accessions in cluster II differ with respect to most of the major characters contributing to the variability. Cluster II includes the populations possessing long leaves (Sambava Tall, Guelle Rose Tall) and short leaves (Coco Le Haut Tall) as well as accessions with higher (Coco Le Rein Tall, Sambava Tall, Guelle Rose Tall) and lower girth (Coco Le Haut Tall).

Clustering of accessions using morphological characters of the fruit was different from that of vegetative and inflorescence characters (Table 8). Populations exhibited dwarf characters grouped in to a single cluster (I) based on fruit characters while Coco Raisin Tall formed a single accession cluster (III). Coco Gra Tall formed a single accession cluster based on vegetative and inflorescence characters (Table 5) merged with other Talls in cluster IV owing to similarity in fruit morphology (Table 8). Coco Raisin Tall is entirely different from other talls in terms of smaller fruit size while it is different from the Dwarfs since it possess higher husk and shell thickness than dwarfs (Table 9). This is reflected on lesser inter-cluster distance (Table 10) between Coco Raisin Tall (cluster III) and the Dwarfs (cluster I). Cluster I with smaller nuts was very divergent from the Talls of cluster II as evidenced from the higher inter-cluster distance as well as the cluster means. Coco Raisin Tall with smaller nuts was also distantly placed from cluster II which possess huge nuts. Intra-cluster distance was least in cluster II and maximum for cluster V. Cluster II has larger nuts with higher husk and shell content and accessions within the

Table 7. Cluster means for vegetative and inflorescence characters

Cluster number	Variables* 1*	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
I	89.34	37.92	123.36	359.94	102.80	5.41	106.78	17.58	6.45	97.04	45.39	48.09	35.56	39.48	40.78	20.96
II	117.00	39.99	158.32	360.25	122.51	6.15	115.26	14.44	6.82	131.98	56.39	75.76	48.01	39.67	36.94	12.24
III	70.77	26.07	108.80	275.47	92.17	5.14	82.60	26.40	3.80	76.57	34.20	42.37	35.47	28.77	35.97	21.60
IV	95.00	37.00	142.50	285.00	102.00	6.00	96.50	33.00	2.97	121.50	57.50	64.00	49.00	37.50	24.00	15.00
V	93.00	34.00	110.00	275.00	104.00	5.30	45.00	19.00	5.00	87.00	35.00	52.00	38.00	46.00	26.00	14.00
Mean	93.02	35.00	128.60	311.13	104.70	5.60	89.23	22.08	5.01	102.82	45.70	56.44	41.21	38.28	32.74	16.76
SEm	7.37	2.43	9.60	20.07	4.93	0.20	12.33	3.36	0.74	10.42	5.00	5.99	3.02	2.77	3.27	1.90

*1: girth of stem (cm); 2: total number of leaves; 3: length of petiole (cm); 4: length of leaf bearing portion (cm); 5: number of leaflets; 6: breadth of leaflet (cm); 7: length of leaflet (cm); 8: number of leaf scars in 1m of trunk; 9: length of internode (cm); 10: length of inflorescence (cm); 11: length of spikelet bearing portion (cm); 12: length of stalk (cm); 13: length of spikelet (cm); 14: number of spikelet/inflorescence; 15: mean number of female flowers/inflorescence; 16: mean number of nuts/bunch

Table 8. Cluster composition of different accessions based on fruit characters

Cluster Number	Number of accessions	Name of accessions
I	3	Pemba Orange Dwarf, Pemba Green Dwarf, Pemba Yellow Dwarf
II	3	Guelle Rose Tall, Sambava Green Tall, Sambava Tall
III	1	Coco Raisin Tall
IV	4	Coco Le Rein Tall, Coco Le Haut Tall, Dupay's Tall, Coco Gra Tall
V	4	Pemba Red Tall, West African Tall, Comoros Tall, Coco Bleu Tall

Table 9. Cluster means for fruit characters

Cluster Number	Variables 1*	2	3	4	5	6	7	8	9	10	11	12
I	127.33	19.13	11.80	664.00	3.43	315.73	54.73	1.13	166.53	2.00	87.77	55.37
II	423.33	25.90	19.70	1996.67	4.47	999.33	49.17	1.47	451.33	3.13	229.00	292.00
III	100.00	21.50	11.10	785.00	4.70	293.00	62.70	1.40	168.00	3.40	108.00	36.00
IV	302.50	27.24	17.10	2076.68	5.43	580.03	70.22	1.45	293.80	3.27	174.05	107.62
V	355.00	21.55	15.24	1391.75	3.62	679.50	51.15	1.32	326.05	3.05	184.05	159.58
Mean	261.63	23.06	14.99	1382.82	4.33	573.52	57.59	1.35	281.14	2.97	156.55	130.11
SEm	63.52	1.51	1.61	294.31	0.37	129.95	3.91	0.06	53.42	0.25	25.88	45.84

1: quantity of tender nut water (ml); 2: length of fruit (cm); 3: breadth of fruit (cm); 4: weight of fruit (g); 5: thickness of husk (cm); 6: weight of husked nut (g); 7: per cent of husk to whole fruit weight; 8: thickness of kernel (cm); 9: weight of kernel (g); 10: thickness of shell (mm); 11: weight of shell (g); 12: quantity of nut water (ml)

clusters show variation only for shell characters which contribute least to the variability. Cluster V, with medium-sized nuts, however, includes accessions with lesser husk percentage (Pemba Red Tall) as well as medium husked accessions (West African Tall, Comoros Tall, Coco Bleu Tall). The percentage of husk to fruit content is a major contributor to variability. Nut characters have been found to be more dependable and have been used by Qvarasu (1993) and Zizumbo-Villarreal and Pinerio (1998).

When clustering was attempted with selected vegetative and reproductive characters (Table 4), the distribution of accessions within the clusters varied (Table 11). Coco Gra, a makapuno type, formed a single accession cluster (cluster V) and was the most divergent as it had larger inter-cluster distance with all other clusters. From the cluster means (Table 12), it was evident that this cluster had a different vegetative (leaf), inflorescence and fruit characters. However, in this clustering the Pemba Dwarfs of Mauritius in cluster I were joined by two Talls, Coco Bleu Tall of Seychelles and Comoros Tall of

Table 10. Intra and inter cluster distances between cluster centroids, based on fruit characters

Cluster Number	I	II	III	IV	V
I	1.349				
II	7.407	1.060			
III	3.417	6.809	0.000		
IV	5.906	3.997	4.193	1.480	
V	4.357	3.347	4.018	3.506	1.897

Table 11. Cluster composition of different accessions based on selected characters

Cluster Number	Number of accessions	Name of accessions
I	5	Pemba Orange Dwarf, Pemba Green Dwarf, Pemba Yellow Dwarf, Comoros Tall, Coco Bleu Tall
II	4	Pemba Red Tall, Guelle Rose Tall, Sambava Tall, Sambava Green Tall
III	2	West African Tall, Coco Raisin Tall
IV	3	Dupay's Tall, Coco Le Rein Tall, Coco Le Haut Tall
V	1	Coco Gra Tall

Table 12. Cluster means for selected vegetative and reproductive characters

Cluster number	Variables										
	1*	2	3	4	5	6	7	8	9	10	11
I	306.48	4.91	92.30	78.94	34.82	43.72	35.88	20.80	3.66	447.64	55.14
II	379.88	6.15	108.26	117.47	52.59	64.91	42.01	11.11	4.10	960.25	46.07
III	356.10	5.97	108.85	109.60	55.83	45.92	33.90	25.05	4.10	438.50	59.50
IV	291.00	6.00	107.83	134.00	58.00	76.17	53.00	16.67	5.24	544.70	68.56
V	275.00	5.30	45.00	87.00	35.00	52.00	38.00	14.00	6.00	686.00	75.20
Mean	321.69	5.67	92.45	105.40	47.25	56.54	40.56	17.53	4.62	615.42	60.89
SEm	19.90	0.24	12.26	10.05	5.11	6.14	3.39	2.47	0.43	97.04	5.09

*1: length of leaf bearing portion (cm); 2: breadth of leaflet (cm); 3: length of leaflet (cm); 4: length of inflorescence (cm); 5: length of spikelet bearing portion (cm); 6: length of stalk (cm); 7: length of spikelet (cm); 8: mean number of nuts/bunch; 9: thickness of husk (cm); 10: weight of husked nut (g); 11: per cent of husk to whole fruit weight

Madagascar due to similarity for most inflorescence characters. Besides, these could be intermediate types or in fact dwarfs misnomered as Talls. Most closely related clusters were cluster I and cluster III which have similarity in fruit characters and a few inflorescence characters.

A comparison of the intra-cluster distances (Table 13) showed diversity within a cluster. Intra-cluster distance was least in cluster IV. Though the accessions in this cluster belonged to two different island nations, they were closely related. Under constant selection of segregating populations such similar types were expected to be established (Ashwath *et al.*, 1997). Another possibility is that these accessions might have been introduced into these regions from a common origin. A study of the cluster means showed that these cultivars had intermediate sized fruits with average number of nuts per bunch. This cluster included accessions with high husk content and since this trait contributed least to the variation these accessions might have been grouped into a single cluster.

Cluster II showed maximum intra-cluster divergence (Table 13). Cultivars with large-sized nuts and lesser number of nuts per bunch were grouped in this cluster. However, lot of diversity was observed within the cluster for leaf characters which contributed variations. This group included accessions with long leaves as well as short leaves . Cluster I included the Dwarfs of Mauritius as well as two talls, Comoros Tall of Madagascar and Coco Bleu Tall of

Table 13. Intra and inter cluster distances between cluster centroids based on selected characters

Cluster Number	I	II	III	IV	V
I	1.652				
II	4.495	1.875			
III	3.085	3.722	1.475		
IV	5.189	3.792	4.032	1.391	
V	4.309	5.660	5.271	5.129	0.000

Seychelles. Diversity within the cluster was reflected in the intra-cluster distance. Accessions grouped in this cluster have similarity for a few of the inflorescence and leaf characters. Fruits have a comparatively lower husk content, though differences in fruit size exists between accessions.

In general, there was no correlation between genetic diversity and geographical diversity as accessions collected from different islands grouped into a single cluster. This is in agreement with the earlier findings of Balakrishnan and Namboodiri (1987), Louis and Chopra (1989) and Ovarasu (1993). This could be due to the introduction of genotypes from different regions into a country (Zizumbo-Villarreal and Pinerio, 1998) or due to genetic drift and natural selection forces within a region which could have a considerable effect on genetic diversity (Murthy and Arunachalam, 1966).

Cluster means in conjunction with the inter and intra cluster divergence can be used for selection of suitable parents for making appropriate cross combinations for exploiting the heterotic effect. The study also revealed that the diversity existing in coconut populations within a country and between countries which are geographically located close to each other. PCA identified the variables contributing most to the diversity while clustering helped in grouping the cultivars based on their degree of relationship to each other. Genetic distance coupled with the characteristics of each cluster can be utilized in the breeding programme for selection of appropriate parents for crop improvement. However, further studies using germplasm of uniform age and populations grown under uniform environmental and cultural conditions need to be carried out to conclude the present findings. Comparative studies of different methods of estimating genetic diversity should be carried out to find the best method of estimating genetic diversity.

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