Journal of Plantation Crops, 2003, 31 (1) : 14

Floral biology of some coconut accessions

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(Manuscript Received : 17-7-2002; Revised : 16-10-2002; Accepted : 16-10-2002)

Abstract

Studies on floral biology of eighty coconut accessions, comprising 64 talls and 16 dwarfs, showed significant differences with respect to most of the floral biology characters. Seasonal variation was also observed for many of the characters studied. Genetic diversity using PCA was attempted and four clusters were obtained. The cultivar Standard Kudat Tall, a *spicata* type, formed a single cluster accession, indicating the uniqueness of this cultivar. The clustering pattern emphasizes the importance of floral biological characters in breeding programmes. The important characters contributing to divergence were the length of male phase and setting percentage.

Key words: Coconut, talls, dwarfs, floral biology, genetic diversity

Introduction

Coconut, *Cocos nucifera* L., is a monotypic genus with no known wild or domesticated relatives. The present day population of this palm presents a unique array of variability due to the long history of cross-pollination. The preliminary classification of coconut based on stature was made by Narayana and John (1949), Gangolly *et al.* (1957) and Menon and Pandalai (1958) and they recognized two forms – the talls and the dwarfs. Fremond *et al.* (1966) divided the coconuts into two groups – the allogamous or cross-pollinating talls and the autogamous or self-pollinating dwarfs.

Several authors have attempted to characterize and classify coconut cultivars based on fruit component traits (Whitehead, 1968; Harries, 1978; Ashburner *et al.*, 1997b; Ratnambal *et al.*, 2002), botanical and agronomical traits (Sugimura *et al.*, 1997), polyphenol analysis (Jay *et al.*, 1989 & 1991; Chempakam and Ratnambal, 1991), by isozyme analysis (Benoit, 1979; Meunier, 1992; Canto-Canche *et al.*, 1992; Sugimura *et al.*, 1997) and by DNA markers such as RAPD, RFLP, AFLP and SSR (Rohde *et al.*, 1995; Ashburner *et* 1997a; Lebrun *et al.*, 1998a,b; Perera *et al.*, 1999, Te et al., 2000 and Perera, 2001). Exhaustive descrip were prepared by Ratnambal *et al.* (1995 & 2000) fo coconut germplasm accessions based on morpholog reproductive, fruit and biochemical traits.

Detailed information on floral biology in coco is indispensable for the choice of parents and adapt of breeding methods as well as working out techni of artificial pollination and seed production.

Genetic diversity has been recognized a important factor to improve yield, quality and resis to disease (Harland, 1957; Whitehead, 1968). In coc genetic improvement has been achieved using cro between two genetically distinct ecotypes (Meun *al.*, 1984; Sangare *et al.*, 1988; Bourdeix *et al.*, 19

A study was undertaken at Kasaragod o coconut germplasm accessions comprising 64 tall 16 dwarfs from six regions, to examine the variabi breeding characters. Attempt was also made to

CPCRI Contribution No. 1139

xtent of genetic variability with respect to breeding viour traits.

Materials and Methods

Floral biology was studied in coconut accessions prising of 64 talls, 16 dwarfs (Table 1 & 2) by rding observations on individual palms starting from opening of the spathe till the end of the receptivity of last female flower for the whole period of one year. age of the palm was 20-25 years and six palms per ession were identified for this purpose. The rvations were recorded in each palm every day, for period January-December.

observations recorded were:

Date of opening of the spadix

Date of opening of the first male flower

Date of shedding of the last male flower

Date of receptivity of the first female flower (date on which honey secretion starts for the first time from a female flower in a bunch)

Date of receptivity of the last female flower (date on which the last female flower in a bunch blackens)

Number of spikes in an inflorescence

Number of female flowers in an inflorescence

Number of nuts set (number of fist-size nuts retained in the bunch about 4 months after fertilization)

above data was used to deduce the following:

(i) Male phase – the duration between the opening of the first male flower and shedding of the last male flower

(ii) Female phase – the duration between the receptivity of the first female flower and the receptivity of the last female flower

(iii) Intra-spadix overlapping – The period of overlapping between the receptivity of the first female flower and pollen shedding of the last male flower in the same inflorescence

(iv) Inter-spadix overlapping – The period of overlapping between opening of the last male flower of the inflorescence and the receptivity of the first female flower of the preceding inflorescence

(v) Counting the total number of female flowers in an inflorescence

(vi) Setting percentage was calculated by :

$$\frac{\text{Number of nuts set} \times 100}{\text{Total number of female flowers}}$$

(vii) Counting the total number of spikelets in an inflorescence

Principal Component Analysis (PCA) was used to group the cultivars and five traits viz., length of male phase, length of female phase, number of female flowers, setting percent and number of spikelets.

Table 1. Distribution of accessions based on region / country of collection
(Figures in parentheses denote the serial numbers listed in Table 2)

A. Exotic Accessions

Region	Country	Accessions
South East Asia	Malaysia (5 talls, 3 dwarfs)	Klapawangi Tall (59), Malayan Tall (25), Federated Malay States Tall (4), SS Apricot Tall (26), SS Green Tall (5), Malayan Green Dwarf (71), Malayan Yellow Dwarf (72), Malayan Orange Dwarf (67)
	Indonesia (4 talls)	Borneo Tall (49), Java Tall (1), Kong Thein Yong Tall (64), Standard Kudat Tall (57)
	Philippines (7 talls)	Philippines Ordinary Tall (3), Laguna Tall (9), Philippines Dalig Tall (33), Philippines Lono Tall (42), Philippines Palawan Tall (36), Philippines Kalambahim Tall (24), San Ramon Tall (43)
	Vietnam (1 tall)	Cochin China Tall (52)
Pacific Ocean Islands.	Solomon Is. (1 tall)	British Solomon Is. Tall (14)
	Fiji (3 talls, 1 dwarfs)	Fiji Tall,(54) Fiji Rotuma Tall (53), Fiji Longtongwan Tall (58), Niu Leka Dwarf (78)
	Guam (3 talls)	Guam Tall Type I (16), Guam Tall Type II (61), Guam Tall Type III (17)
	Papua New Guinea (9 talls)	Karkar Tall (28), Markham Tall (29), New Guinea Tall (2), Nuwallis Tall (23), Nufella Tall (10), Nugili Tall (11), Nuquawen Tall (13), Nuwehung Tall (12), Nuhimi Kupien Tall (22)
	Lifou Is. (1 tall)	Lifou Tall (55)
Central & South America and Atlantic Region	Jamaica (3 talls)	Jamaica Tall (62), Jamaican Sanblas Tall (37), Panama Tall (35)
	Surinam (1 tall, 1 dwarf)	Surinam Dwarf (66), Surinam Tall (21)
	Trinidad Tobago (2 talls)	Blanchisseus Tall (34), St. Vincent Tall (40)
African Region	Tanzania (1 tall)	Zanzibar Tall (15)

Table 1. Contd

	Nigeria (2 talls, 1 dwarf)	Kenya Tall (30), Nigerian Tall (31), Nigerian Dwarf (68)
	Ivory Coast (1 tall, 1 dwarf)	West African Tall (20), Cameroon Red Dwarf (69)
Indian Ocean Islands	Sri Lanka (2 talls, 1 dwarf)	Sri Lanka Tall (41), Gon Thembili Tall (51), King Coconut Tall (79)
	Seychelles (1 tall)	Seychelles Tall (8)

B. Indigenous Accessions

State	Accessions
Kerala (2 talls, 2 dwarfs)	West Coast Tall (50), Kappadam Tall (56), Chowghat Green Dwarf (73), Chowghat Orange Dwarf (74)
Karnataka (1 tall, 1 dwarf)	Tiptur Tall (19), Kenthali Orange Dwarf (65)
Tamil Nadu (1 tall, 4 dwarfs)	Ayiramkachi Tall (27), Pattukottai Green Dwarf (70), Kulasekharam Orange Dwarf (75), Kulasekharam Yellow Dwarf (76), Kulasekharam Green Dwarf (77)
Andhra Pradesh (4 talls, 1 dwarf)	Gangapani Tall (32), Rangoon Kobbari Tall (63), Verikkobbari Tall (60), Gangabhavani Tall (18), Gangabondam Green Dwarf (80)
Goa (2 talls)	Benaulim Tall (44), Nadora Tall (45)
Lakshadweep (2 talls)	Laccadive Ordinary Tall (38), Laccadive Micro Tall (39)
Andaman & Nicobar Islands (4 talls)	Andaman Ordinary Tall (6), Andaman Giant Tall (7), Andaman Ranguchan Tall (47), Nicobar Tall (46)
Gujarat (1 tall)	Gujarat Tall (48)

Results and Discussion

Significant differences were noticed with respect to most of the floral biological characters (Table 2). The duration of the male phase in talls varied from 13.3 days in Standard Kudat to 21.6 days in Surinam Tall with an average of 19.2 days. Menon and Pandalai (1958) observed that the average duration of male phase was 21 days in talls. The average duration of the male phase in three talls at Port Bouet was 21.3 days (Rognon, 1976). Sangare *et al.* (1978) observed that there was little variation in the average length of male phase (19.5 – 22.7 days) among coconut cultivars.

Among the dwarfs, the length of male phase was highest (20.6 days) in Niu Leka Dwarf and lowest (16.3 days) in Gangabondam Green Dwarf (Table 2). The average duration of the female phase in talls was 4.2 days and in dwarfs, the duration was a little longer i.e.,6.7 days . According to Gangolly *et al.* (1957), duration of male phase in dwarfs varied from 15-24 days with an average of 21 days, while the female phase was 8 d Liyanage (1950) reported that the female phase was long in King Coconut in Sri Lanka. In the present st also, the authors observed longer female phase in Ki Coconut with 8.3 days (Table 2).

A gap between male and female phases noticed in all talls except in SS Apricot Tall and it ran from 1.4 days each in Guam III Tall and Malayan Ta 4.4 days in Standard Kudat Tall, thereby showing absence of intra-spadix overlapping (overlapping of m and female phases in the same inflorescence). Me and Pandalai (1958), Rognon (1976) and Sangare e (1978) also observed the absence of intra-spa overlapping in talls. Bhaskara Rao *et al.* (1991) classi SS Apricot as a semi-tall variety and in the present st intra-spadix overlapping was observed in this culti But in dwarfs, intra-spadix overlapping was routi observed and it was as high as 100 per cent, excep Nigerian Dwarf, Kulasekaram Green Dwarf and Leka Dwarf, where a gap of 2.0, 3.0 and 2.1 d respectively was noticed, thereby showing the abs of intra-spadix overlapping in these three dwarf culti like talls. Whitehead (1965) observed the extent of in spadix overlapping in Malayan Dwarf palms from n complete, the absence of overlapping was found on one green fruited dwarf. In the present study also authors found the variation of intra-spadix overlapp in dwarfs to be from 0-100.

Inter-spadix overlapping (overlapping of phases in the succeeding inflorescences) was obse in all the talls except in West African Tall and onl five dwarfs (Table 2). Sangare *et al.* (1978) also obse the absence of inter-spadix overlapping in yellow red dwarfs and in Sri Lankan Green Dwarf. percentage of overlapping varied from zero in W African Tall to 66 in San Ramon Tall. The overlapp period varied from 0.5 days in Gangapani Tall to days in Malayan Tall. Among the five dwarfs, overlapping period ranged from 2.5 days each in Mal Green Dwarf and Gangabondam Green Dwarf to days in Niu Leka Dwarf and cent percent overlapp was observed in Nigerian Dwarf (Table 2).

Based on the observations on inter and intra-sp overlapping, the cultivars can be classified as sugge by Rognon (1976):

Type-I : Strict cross-pollination: There wa intra or inter-spadix overlapping. These types strictly allogamous. eg. West African Tall. Sim observation was made by Rognon (1976) and Sanga *al.* (1978).

Floral biology studies in 80 coconut germplasm accessions (64 talls & 16 dwarfs)

Cultivar	Male phase (days)	Female phase (days)	Gap (days)	Intraspadix overlapping		Interspadix overlapping		No. of female flowers	Setting %	No. of spikelets
				%	Days	%	Days			
I. Talls										
Java Tall	20	4.3	2.7	0	0	10.0	3.6	22.5	28.4	32.6
New Guinea Tall	18.6	4.9	2.6	0	0	5.0	3.0	21.3	13.3	33.2
Philippines Ordinary Tall	18.9	4.7	2.1	0	0	60.4	3.6	21.1	31.7	42.2
Federated Malay States Tall	19.1	5.3	2.2	0	0	33.5	4.0	55.6	14.2	38.1
S.S.Green Tall	20.7	5.7	2.1	0	0	45.0	2.7	39.7	25.3	38.1
Andaman Ordinary Tall	20.6	5.5	2.7	0	0	46.7	5.1	25.1	22.7	44.1
Andaman Giant Tall	19.8	4.5	2.6	0	0	26.1	3.0	22.6	35.7	37.9
Seychelles Tall	19.4	5.2	2.9	0	0	20.0	4.4	57.9	15.4	40.1
Philippines Laguna Tall	19.1	4.0	2	0	0	33.8	4.6	26.0	35.4	35.7
Niufella Tall	18.6	4.8	1.9	0	0	36.7	3.9	44.9	27.6	35.5
Nugili Tall	18.9	4.5	2	0	0	49.1	5.0	22.4	30.0	38.8
Nuwehung Tall	19.5	4.9	2.8	0	0	57.3	4.4	32.7	22.1	39.9
Nuqueawen Tall	18.9	4.8	2.2	0	0	58.8	5.9	24.2	24.6	42.3
British Solomon Is. Tall	18.6	4.5	2.2	0	0	36.4	4.0	27.9	34.6	35.3
Zanzibar Tall	19.6	4.4	2.6	0	0	27.8	3.7	24.9	46.2	28.3
Guam I Tall	20.7	5.5	1.8	0	0	42.4	2.7	39.1	32.5	40.6
Guam III Tall	19.7	3.7	1.4	0	0	63.7	4.5	15.9	56.6	35.3
Gangabhavani Tall	20.8	3.4	1.7	0	0	26.3	4.0	17.4	49.1	40.1
Tiptur Tall	20.3	3.4	1.5	0	0	41.6	2.5	12.4	40.5	35.8
West African Tall	20.8	3.2	1.5	0	0	0.0	0.0	9.5	37.2	34.8
Surinam Tall	21.6	3.8	1.7	0	0	57.1	3.2	16.2	42.2	36.5
Nuhimi Kupien Tall	19.2	3.9	1.9	0	0	32.5	3.6	20.8	40.9	39.1
Nuwallis Tall	19.5	4.1	1.5	0	0	27.8	4.4	27.2	35.1	41.9
Philippines Kalambahim Tall	21.2	3.8	1.5	0	0	28.3	3.3	13.6	47.5	35.9
Malayan Tall	19.6	3.9	1.4	0	0	22.1	6.2	19.9	43.0	37.6
SS Apricot Tall	18.9	4.9	0	10.0	2.7	11.5	1.8	13.6	36.0	30.9
Ayiramkachi Tall	19.5	3.9	1.7	0	0	32.2	2.4	20.1	42.7	36.9
Karkar Tall	19.4	3.6	1.7	0	0	3.8	2.2	24.6	37.6	35.7
Markham Tall	19.3	3.6	1.9	0	0	25.8	2.7	21.4	30.9	40.0
Kenya Tall	19.4	3.2	1.7	0	0	13.3	4.7	13.7	37.8	37.7
Nigerian Tall	18.9	3.7	1.9	0	0	8.1	3.7	25.3	29.6	39.6
Gangapani Tall	19.6	4.2	1.7	0	0	4.1	0.5	41.4	20.5	37.4
Phil. Dalig Tall	19.3	3.6	1.8	0	0	7.9	2.5	26.2	31.9	39.9
Blanchisseus Tall	19.3	3.8	1.8	0	0	26.2	3.0	29.3	33.2	38.6
Panama Tall	19.2	3.9	1.9	0	0	29.1	2.4	26.3	34.2	41.0
Phil. Palawan Tall	19.5	3.9	1.8	0	0	61.0	2.9	29.9	31.6	42.0
Jamaican Sanblas Tall	19.7	3.7	1.7	0	0	30.0	4.0	21.9	39.4	41.7
Laccadive Ordinary Tall	20.9	3.5	1.8	0	0	36.5	3.5	15.2	50.2	34.3
Laccadive Micro Tall	20.4	3.6	1.6	0	0	31.3	3.5	37.9	47.3	34.9
St.Vincent Tall	20.0	3.7	1.7	0	0	21.4	2.8	24.0	27.9	43.6
Sri Lankan Tall	19.8	3.6	1.7	0	0	33.3	1.9	22.6	27.9	41.3
Phil. Lono Tall	18.2	3.6	1.6	0	0	38.8	3.3	25.4	28.9	40.5
San Ramon Tall	19.0	3.6	1.8	0	0	66.0	4.2	17.1	34.6	41.3
Benaulim Tall	19.7	3.7	1.7	0	0	23.8	2.4	26.9	49.1	44.6
Nadora Tall	20.3	3.7	1.7	0	0	22.5	2.4	19.3	47.0	41.3
Nicobar Tall	19.7	3.5	1.7	0	0	23.8	2.9	22.9	30.9	40.9
And. Ranguchan Tall	19.4	3.5	1.7	0	0	34.9	3.6	19.9	42.3	42.5
Gujarat Tall	19.8	3.6	1.8	0	0	27.8	3.7	11.9	51.4	33.6
Borneo Tall	20.2	3.6	1.7	0	0	31.2	3.4	18.7	27.5	45.6
West Coast Tall	20.4	3.6	1.7	0	0	17.1	2.5	19.3	47.3	40.9

Table 2. Contd

51	Gonthembili Tall	19.4	4.5	2.7	0	0	4.2	2.0	22.4	23.5	31.0
52	Cochin China Tall	19.7	3.9	1.6	0	0	43.2	2.8	21.7	29.8	41.2
53	Fiji Rotuma Tall	19.9	4.1	1.8	0	0	56.3	3.3	23.0	20.4	42.3
54	Fiji Tall	19.4	3.8	1.7	0	0	50.0	4.8	17.4	31.2	40.1
55	Lifou Tall	19.2	3.9	1.8	0	0	40.0	2.8	20.4	24.9	44.3
56	Kappadam Tall	20.0	3.4	1.7	0	0	41.3	4.1	8.3	40.2	38.7
57	St.Kudat Tall	13.3	6.4	4.4	0	0	31.0	2.7	152.0	5.4	0.0
58	Fiji Longtongwan Tall	19.7	3.7	1.8	0	0	12.5	4.0	15.2	35.3	33.2
59	Klapawangi Tall	19.6	4.2	1.6	0	0	35.7	2.7	27.3	30.7	45.0
60	Verikkobbari Tall	19.7	4.0	1.7	0	0	6.3	1.0	18.8	22.4	37.0
61	Guam II Tall	17.2	5.6	2.5	0	0	6.3	1.0	19.9	32.5	40.0
62	Jamaica Tall	17.8	6.1	2.7	0	0	42.6	2.5	24.1	24.1	32.6
63	Rangoon Kobbari Tall	17.6	5.5	2.8	0	0	64.6	3.6	34.1	36.6	26.0
64	Kong Thein Yong Tall	17.3	5.3	2.9	0	0	48.3	3.6	28.1	32.9	30.7
II. Dwarfs											
65	Kenthali Dwarf	19.7	10.0	0.0	100	8.0	0.0	0.0	24.8	25.0	32.3
66	Surinam Dwarf	17.5	4.9	0.0	100	5.1	0.0	0.0	26.9	39.5	31.4
67	Malayan Orange Dwarf	17.1	8.4	0.0	100	5.1	0.0	0.0	24.5	38.1	37.2
68	Nigerian Dwarf	19.4	3.9	2.0	0	0.0	100.0	3.3	28.5	26.8	40.1
69	Cameroon Red Dwarf	18.7	6.3	0.0	100	2.1	0.0	0.0	30.3	37.7	36.2
70	Pattukottai Green Dwarf	18.6	8.9	0.0	100	10.6	0.0	0.0	14.5	36.6	33.2
71	Malayan Green Dwarf	20.3	5.1	0.0	100	3.9	0.0	2.5	14.9	33.3	39.4
72	Malayan Yellow Dwarf	19.2	6.1	0.0	100	7.6	0.0	0.0	16.9	26.5	38.4
73	Chowghat Green Dwarf	19.9	8.2	0.0	100	9.4	0.0	0.0	13.8	39.0	28.5
74	Chowghat Orange Dwarf	19.1	8.4	0.0	100	6.6	0.0	0.0	11.9	25.9	29.8
75	Kulasekaram Orange Dwarf	17.2	6.5	0.0	100	6.9	0.0	0.0	20.8	24.4	25.1
76	Kulasekaram Yellow Dwarf	17.5	6.9	0.0	100	6.5	0.0	0.0	18.8	22.4	35.0
77	Kulasekaram Green Dwarf	17.6	5.2	3.0	0	0.0	32.7	2.6	19.0	26.0	33.7
78	Niu Leka Dwarf	20.6	4.4	2.1	0	0.0	26.8	5.9	21.9	22.6	42.6
79	King Coconut	18.6	8.3	0.0	100	8.0	0.0	0.0	20.8	19.6	29.8
80	Gangabondam Green Dwarf	16.3	6.1	0.0	100	5.9	16.8	2.5	15.7	27.9	36.1
	Gen.Mean	**19. 24**	**4.68**	**1.68**	**81.26***	**6.31***	**26. 54**	**2.83**	**25.12**	**32. 61**	**37. 09**
	C.V.	**3.57**	**12.52**	**19.33**	**49.61***	**38.16***	**18.65**	**21.04**	**45.57**	**21.93**	**9.56**
	C.D.	**1.14**	**0.97**	**0.65**	**—**	**—**	**9.86**	**1.19**	**18.75**	**11.68**	**5.80**

* Only the values of the dwarf cultivars are taken for analysis.

Type-II: Indirect self-pollinating: Overlapping occurred exclusively with the succeeding inflorescence. All the talls listed in Table 1, except West African Tall, came under this category. Also the three dwarfs viz., Nigerian Dwarf, Kulasekaram Green Dwarf and Niu Leka Dwarf could be included under this category.

Type-III: Direct self-pollinating: Overlapping occurred within the same inflorescence in all the dwarfs listed in Table-1, except in Nigerian Dwarf, Kulasekaram Green Dwarf and Niu Leka Dwarf.

Type-IV: Semi-direct self-pollination: Partial or simultaneous opening of the male and female phases. eg. SS Apricot Tall.

The number of female flowers in an inflorescence in talls ranged from 8.3 in Kappadam Tall to 152 in Standard Kudat Tall, while the setting percentage varied from 5.4 in Standard Kudat Tall to 56.6 in Guam-III Tall. Davis *et al.* (1980) reported several hundreds of female flowers in a *spicata* tree and setting percentage of th variety varied from 0-20. In the present study also, t cultivar Standard Kudat Tall, a *spicata* type, had nea 152 female flowers with lowest setting (5.4%). Am dwarfs, the setting percent was highest in Surinam Dw (39.5). The number of spikelets varied from 0 (Standa Kudat Tall) to 45.6 (Borneo Tall).

Seasonal variation

Seasonal variation with respect to breeding tr was worked out and it was observed that the length male and female phases varied with the season (Table & 3b). In general, male phase was short in March-M (hot season) and long during August-December (co season). Similar observations were made by Ro (1976) and Sangare *et al.* (1978) at Port Bouet. Fem phase was short during October and November and l in June-July. Intra-spadix overlapping was l influenced by the season. It was always total in dw

...3a. Seasonal variation in talls with respect to breeding traits

...th	Male phase (days)	Female phase (days)	Gap (days)	Intraspadix overlapping		Interspadix overlapping		No. of female flowers	Setting %	No. of spikelets
				%	Days	%	Days			
...ry	20.1	4.1	2.0	0	0	31.6	2.1	22.2	38.2	36.4
...ary	19.9	4.0	2.4	0	0	14.2	1.3	27.5	30.9	38.0
...ch	19.1	3.9	1.9	0	0	32.5	2.2	24.4	35.8	39.4
...l	19.0	4.7	2.4	0	0	38.3	2.5	33.2	33.0	36.1
	18.4	4.2	2.2	0	0	50.8	3.5	28.9	30.5	39.6
	19.0	4.8	2.6	0	0	22.5	1.1	28.1	23.8	36.0
	20.5	4.8	2.3	0	0	13.3	1.0	24.8	25.4	40.7
...st	20.7	4.4	2.1	0	0	12.0	1.0	24.2	31.1	39.2
...mber	20.7	4.4	2.2	0	0	11.7	1.2	27.5	34.2	38.6
...ber	20.2	3.8	1.8	0	0	18.8	1.6	20.2	27.8	39.6
...mber	20.7	4.1	2.1	0	0	31.7	1.5	17.2	28.8	34.9
...mber	20.2	4.2	2.2	0	0	20.0	2.0	17.9	29.7	35.6
Mean	**19.9**	**4.3**	**2.2**	**0**	**0**	**24.8**	**1.75**	**24.68**	**30.0**	**37.84**
	4.1	**8.0**	**10.3**	**0**	**0**	**49.5**	**42.7**	**19.2**	**13.5**	**5.2**
	2.0	**0.9**	**0.6**	**0**	**0**	**30.8**	**1.9**	**11.9**	**1.4**	**4.9**

...the duration of overlapping period was more during ...to September (Table 3b). Inter-spadix overlapping ...fluenced by the speed of emission of the inflorescence ...ogare *et al.*, 1978). In the present study, overlapping ...lls was maximum (50.8%) in May and minimum ...7%) in September. Similar trend was observed by ...l (1938), Gangolly *et al.* (1957) and Menon and ...dalai (1958). Female flower production in talls was ...est during April-June, while the setting was highest ...uly. Menon and Pandalai (1958) observed higher ...ale flower production during March-July at ...aragod. Sreelatha and Kumaran (1991) observed ...er female production during February to May in T x ...ybrids.

Marechal (1928) reported that dwarf palms in Fiji produced more female flowers during November to March. But at Kasaragod, the female flower production in dwarfs was higher during August and September (present study), while the setting was higher in May and during October to December (Table3b). Sreelatha and Kumaran (1991) also observed high setting during August, September and October and lowest in June at Nileshwar (Kerala). Spikelet production was highest during July-August (Table-3). Patel (1938) reported very low spadix production between October and January and high in March in West Coast Tall at Nileshwar. Same trend was observed by Sreelatha and Kumaran (1991) in T x D hybrids.

...3b. Seasonal variation in dwarfs with respect to breeding traits

	Male phase (days)	Female phase (days)	Gap (days)	Intraspadix overlapping		Interspadix overlapping		No. of female flowers	Setting %	No. of spikelets
				%	Days	%	Days			
	18.2	6.5	0	100.0	6.4	0	0	17.8	38.9	35.5
...ary	18.1	6.6	0	100.0	6.9	0	0	26.4	29.1	34.4
	17.4	6.6	0	100.0	7.7	0	0	20.8	28.1	32.4
	17.4	5.5	0	100.0	5.3	0	0	22.6	32.8	34.3
	16.6	5.9	0	100.0	6.3	0	0	24.8	40.9	38.4
	17.2	6.7	0	100.0	6.4	0	0	24.2	33.2	35.2
	18.8	7.2	0	100.0	7.5	0	0	18.5	23.1	37.9
	18.9	7.5	0	100.0	7.8	0	0	27.2	27.9	38.4
...ber	18.8	6.8	0	100.0	6.9	0	0	26.3	33.9	36.7
	18.5	5.6	0	100.0	5.9	0	0	20.9	38.7	32.1
...ber	18.1	6.4	0	100.0	6.2	0	0	17.6	37.4	34.3
...ber	18.5	6.5	0	100.0	6.2	0	0	15.6	42.7	32.4
...an	**18.04**	**6.48**	**0**	**100.0**	**6.63**	**0**	**0**	**21.89**	**33.89**	**34.68**
	3.94	**9.39**	**0**	**0**	**11.48**	**0**	**0**	**17.97**	**17.76**	**5.64**
	1.78	**1.48**	**0**	**0**	**1.91**	**0**	**0**	**9.89**	**15.11**	**5.05**

Genetic Diversity

Based on Principal Component Analysis (PCA), four clusters were obtained. The first cluster included 40 cultivars (36 talls and 4 dwarfs), second cluster comprised of 17 cultivars (5 talls and 12 dwarfs), third cluster formed a single cluster with accession Standard Kudat and fourth cluster was formed with 22 tall cultivars (Fig. 1).

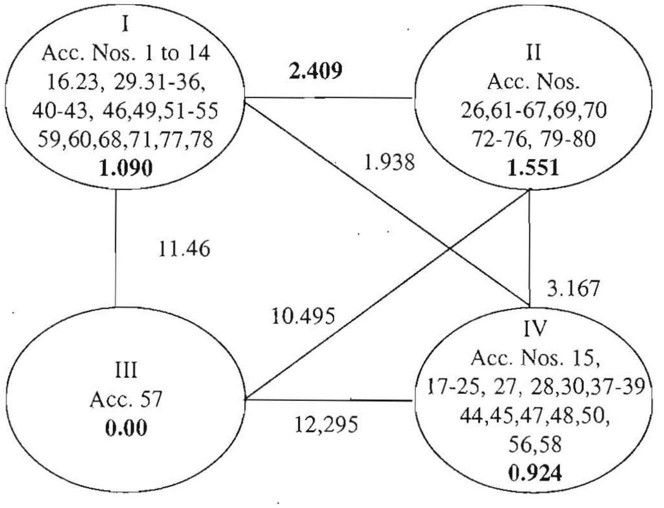

Fig. 1 Cluster diagram of coconut germplasm using reproductive traits by Principal Component Analysis

In cluster-I, the dwarfs like Nigerian Dwarf, Malayan Green Dwarf, Kulasekaram Green Dwarf and Niu Leka Dwarf were clustered along with other talls, indicating that these are not pure dwarfs. Based on fruit components, Harries (1978) confirmed that Niu Leka is not a pure dwarf and might have originated through introgression.

Cluster-II contained 12 dwarfs grouped along with 5 talls viz., SS Apricot Tall, Guam Tall Type II, Jamaica Tall, Rangoon Kobbari Tall and Kong Thien Yong. These talls had shorter male phase and comparatively longer female phase like dwarf cultivars.

Cluster-III formed a single accession cluster with Standard Kudat. Cluster IV comprised of 22 cultivars and popular among them are exotic type like Zanzibar Tall, West African Tall, Malayan Tall, Sanblas Tall and indigenous types like West Coast Tall, Tiptur Tall, Laccadive Ordinary Tall and Benaulim Tall. It is surprising to note that popular local cultivars like West Coast Tall, Tiptur Tall, Laccadive Ordinary Tall, Benaulim Tall, Laccadive Micro Tall and Ayiramkachi Tall formed one cluster along with popular exotic tall cultivars like Zanzibar Tall, West African Tall, Malayan Tall, Karkar Tall, Kenya Tall and Sanblas Tall.

The inter-cluster distances between clusters III & IV were more, followed by clusters I & III and clusters II & III. The distance between clusters I & II and I & IV were comparatively lesser indicating their closeness.

Factor loadings for each trait are given in Table 4.

Table 4. Latent vectors and roots of characters

Characters	PC1	PC 2	PC3	PC4	PC5
Length of male phase	0.512	-0.382	-0.470	0.390	0.469
Length of female phase	0.024	-0.738	-0.552	-0.331	0.201
No. of female flowers	0.116	-0.332	-0.200	-0.731	0.550
Setting percent	-0.851	-0.210	-0.302	0.120	0.335
No. of spikelets	-0.011	-0.394	0.586	0.437	0.557
Eigen root	**2.64**	**0.86**	**0.85**	**0.41**	**0.25**
% Variation	**52.72**	**17.11**	**16.97**	**8.24**	**4.96**
Cumulative Variation	**52.72**	**69.83**	**76.80**	**85.04**	**90.00**

PC1 contributed to 52.72% of the variation. The PC was mainly due to traits like length of male phase and setting percentage. PC2 contributed to 17.1% of the variation. Length of female phase was the important factor in PC2. Out of 5 traits studied, only two traits viz. duration of male phase and setting percentage contributed more to divergence.

The present study showed that most of the South East Asian cultivars and Pacific Ocean cultivars were grouped together in one cluster indicating that they are genetically closer. Teulat *et al.* (2000) and Perera (2001) based on the DNA relationship using RFLPs and SSR's also found that the palms in South East Asia and the Pacific are genetically closer and in contrast they are genetically quite different from what is found in South Asia and Africa. In the present study, some of the popular cultivars from African countries like Zanzibar Tall, West African Tall, Kenya Tall were grouped together with popular South Asian Talls like West Coast Tall, Tiptur Tall, Laccadive Ordinary Tall, Laccadive Micro Tall, Ayiramkachi Tall, Benaulim Tall and Nadora Tall showing their closeness. Ratnambal *et al.* (2002) observed that coconut tall cultivars across the world have similar fruit characters indicating their closeness. The RFLP analysis carried out by Lebrun *et al.* (1998) showed that South Asian varieties are closer to African varieties. Harries (1978) suggested that coconuts from South Asian and Pacific Regions are predominantly naturally selected Niu Kafa type, while coconuts in South East Asia are predominantly domesticated ones (Niu Vai type).

Most of the dwarf cultivars were grouped together with a few talls like SS Apricot Tall, Guam Type II, Jamaica Tall, Rangoon Kobbari Tall and Kong Thien Yong Tall. The cultivar SS Apricot was considered a ll variety by Bhaskara Rao *et al.* (1993). Dwarfs gely self-pollinating due to overlapping of the in the same inflorescence. However, this was not in the case of Nigerian Dwarf, Kulasekaram Dwarf and Niu Leka Dwarf. Green varieties of palms were reported to throw a proportion of semi-lms (Gangolly *et al.,* 1957). Based on the logy and fruit size, Harries (1978) concluded that ka is not really a dwarf cultivar. The present study ows that Niu Leka Dwarf is cross-pollinating and s like a tall cultivar. Ratnambal *et al.* (2002) based fruit characters of 79 cultivars, found that Nigerian and Niu Leka Dwarf were clustered with other nd concluded that these two dwarfs were not pure. on RFLP markers, Lebrun *et al.* (1998b) also ed that dwarf cultivars are grouped together and utogamy results in the utmost total advance of ediate frequency bands and with two exceptions iu Leka Dwarf (the only truly allogamous dwarf r) and the Malayan Green Dwarf (known to be allogamous). They found that Niu Leka Dwarf is r to Pacific Talls like Tonga Tall and Fiji Rotuma In the present study also, Niu Leka Dwarf was ed along with other talls including Pacific and a Tall. Similarly, populations from Panama were to South East Asian and South Pacific types *et al.*, 2000).

Cluster III consisted of only one cultivar, Standard Tall, which is very distinct with more number of flowers and less number of male flowers. Jacob recognized *spicata* as a new variety and based on gy and genetics, concluded that it might have ted from a tall variety. Fremond *et al.* (1966) ized *spicata* as a separate allogamous variety.

Cluster IV consisted of 22 talls from Africa, , South and South East Asia, which may be red intermediate types between talls and dwarfs. roup showed high level of within population n and showed a high-level of diversity.

Conclusion

The present study clearly shows that autogamy is e in talls even though it was thought that talls are heterozygous due to cross-pollination (Harries Rognon, 1976; Sangare *et al.,* 1978). This type of dge is important for:

- *rtificial pollination:* The length of the female phase of the dwarfs of the type III necessitates the pollination of the same inflorescence several times, while the early receptivity of the female flowers leads to emasculation and bagging of the inflorescence before spontaneous dehiscence of the spathes.
- Dwarfs of type IV, on the other hand, can be treated as talls.
- Seed production by assisted pollination – the number of pollinations per inflorescence and therefore, the quantity of pollen used vary with the length of female phase of mother palms.

Determination of genetic diversity based on breeding behaviour was the first attempt and it agrees with the observations made with the fruit component traits and DNA markers by many authors.

The clustering pattern of the present study also emphasizes the importance of floral biology characters. The important characters that contributed to divergence are the length of male phase and setting percentage. Moreover, research workers like Lakshamanachar (1959), Liyanage and Sakai (1960), Nambiar *et al.* (1970), Narasimhayya and Sukumaran (1975) have worked out the heritability of yield and yield components and found that heritability for yield attributes like number of spathes, female flower production and setting percentage were high indicating advantages of selection based on these characters. This could be favourably utilized in coconut breeding programmes to exploit heterosis using divergent ecotypes especially talls in the production of DxT, TxD and TxT hybrids for improving production and productivity in coconut.

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