Research Article

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Variability and association among floral traits and pollen recovery in coconut (*Cocos nucifera* L.)

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Abstract

Twenty seven coconut accessions comprising eight dwarfs and 19 tall types were studied for floral traits, pollen yield and pollen germination. PCA indicated that the first three principal components accounted for more than 70% of variation and the important traits that contributed to the variation were length of inflorescence, girth of inflorescence stalk, length of spikelet bearing portion, weight of 1000 male flowers (fresh as well as dry), number of spikelets per inflorescence and pollen yield. Pollen germination percentage showed no differences between Tall and Dwarf accessions. PCA indicated that the 27 accessions could be grouped into eight clusters and cluster composition showed absence of geographical affinity. The level of association among the floral traits was estimated. The inflorescence length, length of spikelet bearing portion, length of inflorescence stalk, length of spikelet and fresh and dry weight of 1000 male flowers showed significant correlation with pollen yield. The number of female flowers in an inflorescence showed highly significant positive correlation with the length of spikelet bearing position. The study reveals that selection of accessions based on the inflorescence traits could be advocated as they contribute to the diversity among the coconut genotypes. Selection of accessions from the diverse clusters would help in harnessing higher heterosis and better utilizing the diversity for crop improvement.

Keywords: inflorescence traits, male flower weight, PCA, pollen germination, yield

Introduction

The coconut palm, *Cocos nucifera* L. belongs to a monotypic genus with pantropic distribution. Though the exact center of origin of coconut is still a matter of debate, coconut domestication is believed to have taken place in the South East Asian region.

The coconut palms are primarily classified based on the stature and breeding habit into two main categories *viz.*, Talls and Dwarfs. Narayana and John (1949) based on the observation of several morphological traits classified the known cultivars of coconut into var. *typica*, var. *nana* and var. *javanica* with two mutant varieties var. *androgena* and var. *spicata*. On the other hand, Harries (1978) categorized the coconut palms into *Niu Vai* and *Niu Kafa* types based mainly on the fruit characters. However, no single method of classification can account for the variability observed in the coconut populations worldwide.

Several workers have studied the extent of variability for different vegetative, reproductive and fruit characters and used them for classification of coconut populations. Ratnambal *et al.* (1995, 2000) documented the vegetative, reproductive and biochemical characters in 74 coconut accessions. The inflorescence characters vary between the accessions and have been found to influence the fruit set and yield of coconut. Pollen production also varies across accessions (Santos *et al.*, 1997).

The present study was undertaken to study the variability among conserved coconut accessions for floral traits, pollen yield and pollen germination and to determine the association among them.

Materials and Methods

The conserved coconut germplasm available at the national field gene bank at Central Plantation Crops

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Research Institute, Kasaragod was used for the study. Twenty seven coconut accessions (Table 1) comprising eight dwarfs and 19 talls were studied for floral traits, pollen yield and pollen germination. The inflorescence traits *viz.*, girth of infloresence stalk (cm), length of inflorescence (cm), length of spikelet bearing portion (cm), length of stalk (cm), length of spikelet (cm), number of spikelets per inflorescence, number of female flowers per inflorescence were recorded on the mother palms as described by Ratnambal *et al.* (1995, 2000). In addition, weight of 1000 fresh male flowers (g), weight of 1000 dry male flowers (g), pollen yield of 1000 flowers (g) and pollen germination (percentage) were observed. The observations were recorded on inflorescences of typical mother palms over a period of seven months from November 2007 to May 2008.

Mature, unopened male flowers were collected from fully opened inflorescences during the morning hours between 8 AM to 10 AM. Flowers were placed between two sheets of blotting paper and slightly crushed using a wooden rolling pin and dried in an oven at 39°C (±1°C) for 24 hours. The pollen was then collected by sieving (0.2 mm mesh sieve) the dried flowers and weighed. The pollen was then tested for germination using a germination media containing 8% sucrose and 1% boric acid. A drop of germination media was taken on a slide and pollen was dusted lightly on it using a small brush. The slide was kept inside a moist petridish for 2-3 hours. The pollen germination percentage was recorded as percentage of germinated pollen to the total number of pollen grains.

Table 1. List of germplasm studied

Accession	Accession Name	Country of origin
Tall Types		
IND004	Fiji Tall (FJT)	Fiji Islands
IND006	Andaman Giant Tall (AGT)	India
IND009	Straits Settlement Tall (SSGT)	Malaysia
IND010	Federated Malay States Tall (FMST)	Malaysia
IND014	Philippines Ordinary Tall (PHOT)	Philippiness
IND015	Sri Lankan Tall (SLT)	Sri Lanka
IND016	Cochin China Tall (CCNT)	Vietnam
IND017	Adirampatnam Tall (ADRT)	India
IND018	Andaman Ordinary Tall (ADOT)	India
IND022	Java Tall (JVT)	Indonesia
IND024	Borneo Tall (BONT)	Indonesia
IND030	Laccadive Ordinary Tall (LMT)	India
IND036	British Solomon Island Tall (BSIT)	Solomon Islands
IND041	Sakhigopal Tall (SKGT)	India
IND069	West Coast Tall (WCT)	India
IND071	Calangute Tall (CALT)	India
IND073	Benaulim Tall (BENT)	India
IND082	Ayiramkachi Tall (AYKT)	India
IND127	East Coast Tall (ECT)	India
Dwarf Types		
IND003	Gangabondam Greed Dwarf (GBGD)	India
IND007	Chowghat Orange Dwarf (COD)	India
IND047	Kulashekaram Yellow Dwarf (KYD)	India
IND048	Malayan Orange Dwarf (MOD)	Malaysia
IND049	Malayan Green Dwarf (MGD)	Malaysia
IND058	Malayan Yellow Dwarf (MYD)	Malaysia
IND086	Niu Leka Dwarf (NLGD)	Fiji Islands
IND092	Cameroon Red Dwarf (CRD)	Cameroon

The fresh weight of 1000 male flowers was recorded on the fresh unopened male flowers collected for extraction of pollen. The dry weight of these 1000 male flowers was recorded after drying at 39°C (±1°C) for 24 hours.

The mean values of all the above characters on all the 27 accessions were subjected to statistical analysis. The mean, standard error and coefficient of variation were calculated according to Panse and Sukhatme (1961).

To estimate the association among the different characters observed, simple correlation coefficients were worked out according to the methods suggested by Panse and Sukhatme (1961). The data was subjected to clustering with Prinicipal Components Analysis (PCA) as per the method of Adams and Wiersma (1978) using the SPAR software.

Results and Discussion

Wide variability was observed for most of the traits studied as reflected in the coefficient of variation (Table 2). The tall coconut accessions showed higher values for inflorescence stalk girth, inflorescence length, length of spikelet bearing portion, length of inflorescence stalk, length of spikelet, weight of male flowers and pollen yield. The number of spikelets and number of female flowers per inflorescence was higher in talls as well as IND086 a dwarf accession, indicating the uniqueness of this accession, which is reported to have some features of Tall varieties (Ratnambal *et al.*, 2000). Bavappa *et al.* (1974) also reported female flower production as one of the factors contributing to genetic divergence in coconut. Sugimura *et al.* (1997) observed wide variation for most floral traits, except number of female flowers per inflorescence, female flower area and stigma length. These findings are in itself an indication of the variability existing in different coconut population for different traits. The pollen germination percentage showed no differences between Tall and Dwarf accessions with higher

Table 2. Mean performance of coconut cultivars for inflorescence traits and pollen yield

Accession	Girth of stalk (cm)	Length of inflorescence (cm)	Length of spikelet bearing portion (cm)	Length of stalk (cm)	Length of spikelet (cm)	No. of spikelets per flowers	No. of female flowers	Weight of 1000 fresh male flowers (g)	Weight of 1000 dry male flowers (g)	Pollen yield of 1000 flowers (g)	Pollen Germination (per cent)
IND036	10.50	119.50	52.50	67.00	54.75	43.00	47.50	85.04	35.02	2.47	65.54
IND016	9.50	96.00	39.00	57.00	47.50	39.00	25.50	96.60	41.97	2.94	68.13
IND015	9.00	82.00	34.00	48.00	42.50	39.00	17.50	106.18	43.45	2.57	27.38
IND007	8.25	57.25	33.00	24.25	36.00	31.50	16.50	77.63	33.76	1.38	68.48
IND092	9.00	78.00	33.00	45.00	30.00	40.50	32.50	84.88	32.83	2.54	40.78
IND004	8.55	90.50	34.75	55.75	45.25	38.50	36.00	73.13	32.40	2.15	66.42
IND010	9.25	86.50	32.00	54.50	50.50	33.50	21.50	93.97	44.77	2.60	46.70
IND003	8.00	68.50	30.00	38.50	39.00	31.00	15.00	62.23	27.10	1.53	63.74
IND030	10.00	78.00	34.50	43.50	47.50	39.50	37.00	74.55	28.50	2.22	40.00
IND009	9.20	72.55	32.00	40.55	41.50	44.50	25.00	76.72	34.00	2.05	53.26
IND047	10.00	60.00	29.00	31.00	37.50	50.50	33.50	64.71	32.71	1.57	65.44
IND049	10.40	77.50	37.00	40.50	43.00	41.50	27.50	85.95	33.05	2.78	80.50
IND048	8.50	68.00	36.00	32.00	27.00	44.00	35.50	60.20	27.50	0.66	88.13
IND058	9.00	56.25	30.75	25.50	26.75	36.25	36.75	70.74	31.15	1.30	69.93
IND041	8.50	81.00	35.50	45.50	43.50	24.50	47.50	92.70	43.55	2.16	30.86
IND069	11.75	88.50	45.00	43.50	47.50	45.00	24.00	103.19	41.57	2.12	80.02
IND073	10.00	74.50	44.00	30.50	40.00	44.00	58.00	85.17	40.53	2.67	72.80
IND017	9.00	100.00	44.50	55.50	48.50	29.50	48.50	101.43	45.00	3.26	76.33
IND086	10.50	99.00	42.50	56.50	37.50	47.00	47.50	62.17	30.97	1.90	74.03
IND006	12.75	102.00	45.50	56.50	44.75	35.00	37.50	103.85	45.38	2.52	75.15
IND018	9.85	102.00	41.50	60.00	43.25	44.00	31.00	109.47	45.71	2.42	65.26
IND071	9.56	98.00	43.00	55.00	40.00	38.00	36.00	95.17	35.07	2.45	45.32
IND014	12.65	92.50	38.00	54.50	46.00	38.00	23.50	80.60	40.70	1.46	72.88
IND022	8.83	94.67	38.00	56.67	44.00	34.67	20.33	89.97	36.38	3.09	73.47
IND127	8.50	93.50	38.00	55.50	46.25	33.00	17.00	100.34	39.69	2.44	67.87
IND082	8.90	68.50	30.50	38.00	43.25	34.50	22.00	73.11	30.19	1.91	66.94
IND024	11.25	69.00	34.50	34.50	40.00	45.50	18.00	104.68	44.48	2.72	59.83
Mean	9.67	83.47	37.33	46.12	41.97	38.70	31.04	85.72	36.94	2.22	63.16
SE	0.242	3.029	1.119	2.226	1.269	1.166	2.241	2.879	1.174	0.116	2.962
CV %	13.01	18.85	15.57	25.08	15.71	15.65	37.51	17.45	16.51	27.26	24.37

germination percentage (>80%) in IND058, IND048 and IND069, and lower germination percentage (<45%) in IND015, IND041, IND030 and IND092.

PCA indicated that the first seven principal components accounted for 95.87% of variation, with the first three principal components accounting for more than 70% of variation. The important traits that contributed to the variation were length of inflorescence, girth of inflorescence stalk, length of spikelet bearing portion, weight of 1000 male flowers (fresh as well as dry), number of spikelets per inflorescence and pollen yield (Table 3). Balakrishnan and Namboodiri (1987) also found inflorescence traits as major factors contributing to divergence of coconut genotypes. Similarly, Kumaran *et al.* (2000) reported that length of inflorescence contributed to the variation among the coconut populations of Indian Ocean Islands. Ratnambal *et al.* (2003) based on their study on floral biology of some coconut accessions, concluded that the length of male phase and setting percentage contributed to divergence.

PC analysis indicated that the 27 accessions could be grouped into eight clusters based on the 11 characters studied (Fig. 1). The accessions from different geographical regions were not necessarily grouped in the different clusters. Two dwarf accessions, IND049 and IND092 grouped with tall accessions indicating their proximity with talls in genetic architecture for inflorescence traits. Similarly, a tall accession IND082 clustered with the dwarfs IND007 and IND003 suggesting that the inflorescence traits of IND082 closely resemble that of indigenous dwarfs. The dwarfs IND047, IND048 and IND058 clustered together and formed a

Table 3. Latent vectors and latent roots for floral traits

Character	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Girth of stalk	0.212	0.413	0.354	0.384	0.362	-0.038	0.075
Length of inflorescence	0.368	0.140	0.358	0.011	-0.087	0.453	0.357
Length of spikelet bearing portion	-0.473	0.256	0.127	0.285	0.090	-0.375	0.463
Length of stalk	0.015	-0.196	0.085	-0.309	-0.294	0.146	0.667
Length of spikelet	-0.104	-0.130	0.189	-0.272	-0.141	-0.584	0.130
Number of spikelets per inflorescence	-0.550	0.018	0.046	0.000	-0.216	0.401	-0.136
Number of female flowers per inflorescence	0.130	-0.297	-0.195	-0.302	0.696	-0.015	0.173
Weight of 1000 fresh male flowers	-0.513	-0.036	0.094	-0.101	0.431	0.351	0.072
Weight of 1000 dry male flowers	-0.026	-0.054	0.650	-0.396	0.136	-0.073	-0.246
Pollen yield of 1000 flowers	-0.032	0.026	0.369	-0.136	-0.107	-0.028	-0.276
Pollen germination	0.002	0.772	-0.282	-0.570	0.000	0.002	-0.002
Eigen roots	4.637	2.019	1.267	0.884	0.783	0.530	0.424
Variance %	42.15	18.36	11.52	8.04	7.12	4.82	3.86
Cumulative Variance %	42.15	60.51	72.03	80.07	87.19	92.01	95.87

distinct cluster indicating the affinity of these accessions. The IND086, a dwarf accession from Fiji Islands, grouped with IND073, an Indian accession from West Coast of India. IND036 formed a distinct single accession cluster indicating the diverse nature of this accession for inflorescence traits. Selection of this genotype for improvement of any inflorescence trait would be useful in exploiting the diversity. The tall accessions from Andaman and Nicobar Islands clustered into two groups consisting of other tall accessions suggesting the diverse nature of the coconut population of Andamans and Nicobar Islands. IND069 and IND127, representing the coconut populations of West and East Coast of peninsular India, respectively, grouped with other talls into different clusters indicating the genetic divergence of these two ecotypes. Exotic accessions IND016, IND010, IND022 grouped with indigenous accessions suggesting the similarity of these accessions with the indigenous types and also indicating that these exotic accessions are well adapted to the climate of our country.

The inter cluster distances (Fig. 1) showed that cluster VIII (IND036) exhibited greater distance from the rest of the clusters followed by cluster II having three dwarf accessions. Among the eight clusters compared, cluster VI exhibited high intra cluster distance, which was formed by exotic and indigenous talls suggesting the variability and diversity among these talls for the inflorescence traits studied.

The cluster means of variables (Table 4) showed that cluster IV consisting of tall accessions ranked first for the girth of inflorescence stalk, which was found to be contributing to the diversity while the Cluster VII

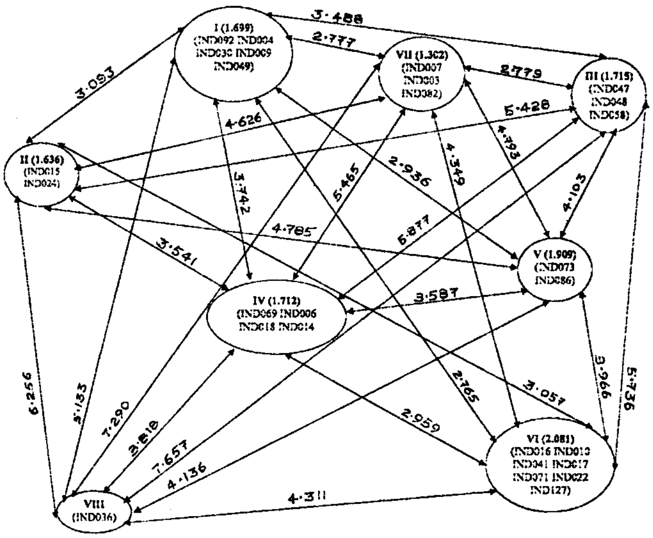

Fig. 1. Cluster diagram indicating intra and inter cluster distance among accessions

consisting of two dwarfs (IND007, IND003) and IND082 ranked least for this trait. Similarly, the length of inflorescence which was found to be important trait contributing to the diversity, was higher in cluster VIII having IND036 and lower in cluster VII having IND007, IND003 and IND082. The number of spikelets per inflorescence, another diversity contributing trait, was higher in cluster V (IND086, IND073) and lower in Cluster VII (IND007, IND003, IND082). The mean pollen germination was high in clusters III, IV and V whereas it was less in Cluster II. The information from PCA revealed that selection of palms based on the inflorescence traits could be advocated as they contribute to the diversity among the coconut accessions.

Table 4. Means of variables among the Clusters

Characters/ Cluster No.	Girth of stalk (cm)	Length of inflores-cence (cm)	Length of spikelet bearing portion (cm)	Length of stalk (cm)	Length of spikelet (cm)	No. of spikelets per inflores-cence	No. of female flowers per inflorescence	Weight of 1000 fresh male flowers (g)	Weight of 1000 dry male flowers (g)	Pollen yield of 1000 flowers (g)	Pollen Germin-ation (per cent)
I	9.43	79.31	34.25	45.06	41.45	40.90	31.60	79.05	32.16	2.35	56.19
II	10.12	75.50	34.25	41.25	41.25	42.25	17.75	105.43	43.97	2.64	43.60
III	9.17	61.42	31.92	29.50	30.42	43.58	35.25	65.22	30.45	1.18	74.50
IV	11.75	96.25	42.50	53.62	45.38	40.50	29.00	99.28	43.34	2.13	73.33
V	10.25	86.75	43.25	43.50	38.75	45.50	52.75	73.67	35.75	2.29	73.42
VI	9.02	92.81	38.57	54.24	45.75	33.17	30.90	95.74	40.92	2.71	58.38
VII	8.38	64.75	31.17	33.58	39.42	32.33	22.17	70.99	30.35	1.61	66.39
VIII	10.50	119.50	52.50	67.00	54.75	43.00	47.50	85.04	35.02	2.47	65.54

Table 5. Association among the inflorescence traits in coconut

Traits	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
X_1	1.000	0.347*	0.484*	0.229	0.296	0.417*	0.126	0.287	0.371*	0.121	0.266
X_2		1.000	0.804**	0.955**	0.668**	-0.028	0.283	0.488**	0.436*	0.544**	0.058
X_3			1.000	0.590**	0.463*	0.138	0.520**	0.432*	0.386*	0.408*	0.317
X_4				1.000	0.676**	-0.109	0.124	0.444*	0.397*	0.534**	-0.081
X_5					1.000	-0.178	-0.012	0.484**	0.482**	0.580**	-0.085
X_6						1.000	0.128	-0.169	-0.170	-0.114	0.235
X_7							1.000	-0.128	0.006	0.097	0.071
X_8								1.000	0.881**	0.717**	-0.211
X_9									1.000	0.584**	-0.134
X_{10}										1.000	-0.197
X_{11}											1.000

X_1 - Girth of stalk (cm) X_2 - Length of inflorescence (cm) X_3 - Length of spikelet bearing portion (cm)
X_4 - Length of stalk (cm) X_5 - Length of spikelet (cm) X_6 - Number of spikelets per inflorescence
X_7 - Number of female flowers per inflorescence X_8 - Weight of 1000 fresh male flowers (g) X_9 - Weight of 1000 dry male flowers (g)
X_{10} - Pollen yield of 1000 flowers (g) X_{11} - Pollen Germination (per cent)

The level of association among the floral traits was estimated and is presented in Table 5. Significant correlations were observed among the floral traits. The inflorescence length, length of spikelet bearing portion, length of inflorescence stalk, length of spikelet, fresh and dry weight of 1000 male flowers showed significant correlation with pollen yield. There was no significant correlation of pollen germination with the floral traits, but genotypic differences were observed for this trait.

The number of female flowers in an inflorescence showed high significant positive correlation with the length of spikelet bearing position. However, it showed non significant but negative correlation also with length of spikelet. Jerard *et al.* (2006) also reported similar observations. The weight of the dry male flower showed significant positive correlation with most floral traits, except number of spikelets/inflorescence, number of female flowers/inflorescence and pollen yield with which non significant negative correlation was seen. The length of the inflorescence, length of inflorescence stalk, length of spikelet bearing position, length of spikelets and girth of inflorescence stalk showed significant positive correlation among them. The number of spikelets per inflorescence showed significant and positive correlation with inflorescence girth. However, the character showed non significant but negative correlation with spikelet length. The length of spikelet showed significant positive correlation with length of inflorescence, length of inflorescence stalk, length of spikelet bearing portion, weight of 1000 male flowers (fresh as well as dry) and pollen yield. Therefore, it is to be expected that a large inflorescence will contain more number of male and female flowers and this coupled with higher pollen yield will result in higher nut yield per palm.

The study highlights the importance of floral traits as they contribute to the diversity among the coconut accessions. Further, selection of accessions from the diverse clusters would help in harnessing higher heterosis and better utilizing the diversity for crop improvement. The association observed between floral traits, can also be utilized to improve coconut productivity through identification of superior mother palms with desirable inflorescence characters.

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