BIOMETRIC ANALYSIS OF DIVERSITY IN PACIFIC OCEAN COCONUT POPULATIONS

By

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INTRODUCTION

Coconut (*Cocos nucifera* L.) is an important perennial multi-purpose palm commonly grown in humid tropics. The crop belongs to the monotypic genus *Cocos* having 2n=2x=32 chromosomes. The crop supports millions of resource poor farm families in islands and coastal ecosystems. Genetic improvement of coconut palm is in progress in many research stations for improving yield and tolerance to biotic and abiotic stress. Knowledge of genetic divergence of the crop is helpful in improvement of the crop. Pacific islands are supposed to contain wild forms and rich diversity of coconut. Genetic divergence studies were carried out using morphological, fruit component characters by many workers. Sugimura *et al*., (1997) analysed the diversity of 39 accessions of coconut as three major groups *typica*, *nana* and *javanica* using agronomic and botanical traits. *Nana* was found to be an aggregate group, which was far distant from *typica*. But, *javanica* was found to be an intermediate type.

Principal component analysis (Kumaran *et al.,* 2000) using the 15 accessions of Indian Ocean islands, indicates the unique

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accessions such as Coco gra Tall having rare trait of jelly like endosperm. It also helps in analyzing the pattern of morphological variation. This analysis along with the correlation between morphological distance and geographical has been reported to show the impact of lethal yellowing disease and its relation with specific area and origin of coconut in Mexico (Zizumbo-Villareal and Pinero, 1998).

Knowledge of breeding behaviour in varieties is important in coconut palm. Tall forms (typical) are known to be allogamous and Dwarf forms are generally autogamous in nature. But there are exceptions to this rule. Niu Leka Dwarf from Fiji is a dwarf form but has allogamous pollination behaviour. Most of the genetic divergence studies have relied heavily on leaf, inflorescence and fruit component characters. Being a monoecious crop with protogyny with entomophily and anemophily, data on breeding behaviour studies are very important as they decide the mating system and evolution of a cultivar. Sangare *et al*., (1978) classified the coconut varieties into four types based on length of female phase and degree of overlapping with male phase in same or following inflorescence in the same palm.

N'Cho *et al.*, (1993) attributed maximum variability in Pacific region as the genotypes from the Pacific islands are located in all the branches of the dendrogram. Ashburner *et al*. (1997a) has studied the diversity of fruit characters in 29 South Pacific populations. They could observe continuous variation in fruit morphology with geographic affinity. (Rao and Koshy,1981) conducted genetic prospection in seven territories of Pacific region. This resulted in 24 accessions native to six of them. These are presently being maintained at World Coconut Germplasm Centre (WCGC), Sipighat, Port Blair, South Andaman.

This work was initiated with an objective of analyzing the coconut diversity of 21 populations native to six islands of Pacific Ocean using the data recorded at the gene bank on characters of stem, leaf, inflorescence, breeding behaviour and fruit components.

The study was based on the data recorded on 21 coconut accessions native to six islands. The list of accessions used is given below:

Solomon Islands:

1. Solomon Tall
2. Rennel Tall

Fiji islands :

3. Fiji Tall Wainigata
4. Niu Drau
5. Niu Lekha Dwarf
6. Niu Bulavu

Am. Samoa :

7. Am. Samoan Tall
8. Niu Oma Dwarf
9. Tutiala

Tonga:

10. Niu Ui
11. Niu Taukave
12. Niu Hako

French Polynesia:

13. Tahiti Tall
14. Pao Pao
15. Haapiti
16. Hari Papua Dwarf

Papua New Guinea:

17. Kiriwana
18. Tall Muwa
19. Nikkore Dwarf
20. Tall Kaveing
21. Natava Tall

The data was recorded on the following traits at World Coconut Germplasm Centre Sipighat Port Balir, Andaman & Nicobar group of islands. The characters recorded are :

Sl. No.	Character (short form)	Character (description)
1	Pl. Height	Height of the palm measured in cm
2	Girth	Girth of the collar region measured in cm
3	No. leaves	Number of leaves on the crown
4	Lenleaf	Length of the leaf measured in cm
5	len petiole	Length of the petiole measured in cm
6	No.leaflets	Number of leaflets in a single leaf
7	Len leaflet	Length of a single leaflet measured in cm
8	Brleaflet	Breadth of the longest leaflet measured in cm
9	Malephase	Duration of the male phase measured in days
10	femalephase	Duration of the female phase measured in days
11	No. of spikelets	Number of spikelets in a single inflorescence
12	FF No.	Number of female flowers in a single inflorescence
13	FF distrbn	Average number of female flowers per single spikelet
14	Set%	Number of fruits set * 100/ Number of female flowers
15	Ftwt	Weight of the fruit measured in grams
16	Lenft	Length of the fruit measured in cm
17	Brft	Breadth of the fruit measured in cm
18	Huskthick	Thcikness of husk measured in cm
19	Wthusk	Weight of husk in a single fruit measured in grams
20	Wtnut	Weight of the husked nut measured in grams

RESULTS AND DISCUSSION

Variablity:

Mean values of the characters studied in each of the 21 populations, the grand mean, standard error and cv (%) are listed in Table.1. Numbers of female flowers, female flowers distribution, husk weight and fruit weight have recorded cv % values more than 35. Spicata is a mutant form in coconut reported by Jacob (1941). Many workers have appreciated divergence of this form. *Spicata* is accepted one of the taxonomic groups within *Cocos nucifera* by Gangolly *et al*., (1958). Recent molecular markers analysis of ten tall and ten dwarf accessions using SSRs revealed the uniqueness of this variety (Rivera *et al*., 1999). *Spicata* has unbranched inflorescence with a single spike without any spikelets and bears many female flowers. Importance of the female flower number (48.19 %) and their distribution (58.43 %) and their role in divergence has also been confirmed by the high cv values obtained in our studies. Among fruit traits, high cv (%) was found for the trait weight of husk (42.13) followed by fruit weight (35.14). These two traits were also found to be important in divergence in coconut populations. Harries (1978) studied the coconut populations around the world and used these two traits to classify all of them. According to him, small fruited forms were known to be wild progenitors in coconut. Human selection brought medium and large fruited forms in cultivation. Husk weight also has undergone human selection. A coconut variety with huge husk and long fibers (Niu Afa) is available in Pacific region (Ashburner *et al*., 1997a). Large husked forms also have adaptive significance in floating in oceans for long periods without loss of viability.

Clustering of Accession:

Twenty one accessions could be grouped to four clusters based on principal component analysis. First cluster was found to be far distant and unique than others (Fig.1). This cluster possesses two important dwarfs used in the study Niu Oma Dwarf and Hari Papua Dwarf. Another interesting group was the third cluster, which contains the Nikkore Dwarf and Niu Taukave. Other two groups were almost similar having all the allogamous talls and allogamous dwarf Niu Leka. The intracluster distance in cluster IV was less than the intercluster distance between clusters II and IV.

But the cluster II contains true talls and the cluster IV, the intermediate forms. Cluster I had all the characters of dwarf forms. Short stature, slender stems, very few leaves on crown, short leaves, short petiole, short male phase but long female phase, few spikelets but many female flowers distributed well, good set %, short and narrow fruits having low nut weight. They resemble the nana form and the results are similar to Sugimura *et al.*, (1997).

Characters important in divergence:

PC1 axis contributes to the 50.63 % of variation. First three PC axes cover maximum amount (71 %) of variation. Characters contributing to divergence are fruit weight, girth, and breadth of fruit and female phase in PC 1. Fruit size (weight) has been one of the important key to classifying Tall cultivar of coconut (Gangolly *et al*.

1957). Ovasuru (1993) could get 5 clusters from 78 coconut populations of Papua New Guinea using *in situ* data. He found that fruit size and water content played a significant role in clustering. According to him, Polynesians preferred carrying of large fruited coconuts with huge water per nut during their voyages. Kumaran *et al.* (1998) also demonstrated the importance of fruit size in deciding the divergence in Indian Ocean coconut populations *in situ*. Zizumbo-Villarreal and Pinero (1998) also found a large fruited morphotype. Pacific Tall 1 which according to them could have descended from Solomon islands introduction. According to them, two contrasting forms for fruit size are commonly known to occur in coconut. i.e. Small nut types characterized by high female flower / nut production are known in different names in different places (Ayiramkachi, Laccadive Micro (India), Takome (Indonesia), Klapa laga (Malaysia), Vanautu Red Dwarf , Haari Papua Dwarf (Pacific is.). Large fruited types producing small number of nuts having large copra or water are seen in different populations in different locations (Andaman Giant, Kappadam (India), San Ramon (Philippines), Pacific Tall 1 group (Mexico). Because, types with large number of small fruits offer the reproductive fitness advantage to the wild form whereas the type with small number of larger fruits are preferably maintained by human selection. Ashburner *et al*., (1997a, b) after analyzing the RAPD and fruit component data of Pacific Ocean coconut populations, emphasize the importance of fruit weight and composition as most important in deciding the divergence.

Girth of the stem is important in coconut palm. In nature, the palm undergoes severe stress due to heavy winds especially in coasts and small islands. Breadth of the fruit decides the shape of the fruit. It also decides the ability of float in sea. Wild forms are normally elongated in shape whereas the cultivated ones are round in shape. Female phase in a cultivar decides the setting %, thereby production of nuts. Sangare *et al*., (1978) used female phase trait along with overlapping to classify coconut cultivars into four main groups.

Number of female flowers, fruit weight, breadth of leaflet and number of leaflets are found to be important in PC 2. More the number of female flowers, maximum are the possibility of getting more nuts. Palm's ability to produce maximum nuts helps its adaptation due to the increase in propagation coefficient. Earlier workers report importance of breadth of leaflet in divergence also. Mutant forms of coconut are shown to possess wide leaflets (Arunachalam *et al*., 2001).

ACKNOWLEDGEMENT

We thank Director and, Head, Division of Crop Improvement, CPCRI, Kasaragod for the facilities, guidance and keen interest in this work.

Table. 1. Table of mean values of pacific populations:

Ac. No.	Population	Pl. Height	Girth	No. leaves	Length of leaf	Length of petiole
1	Solomon Tall	680	100	26.67	600	160
2	Rennel Tall	525	87.5	23.5	555	150
3	Fiji Tall Wainigata	697	98.4	28.02	574.82	151.32
4	Niu Drau	758.53	92.47	25.88	574.41	159.29
5	Niu Lekha Dwarf	335.04	106.4	26.22	455.78	127.8
6	Niu Bulavu	574.08	103.14	27.3	560.57	153.59
7	Am. Samoan Tall	528.82	94.63	25.33	508.61	144.98
8	Niu Oma Dwarf	425	72	19.6	468.5	125
9	Tutiala	568.4	93.6	24.4	538.6	145
10	Niu Ui	660.13	86.05	29.28	513	137.88
11	Niu Taukave	548.75	74	22.44	518.13	125.63
12	Niu Hako	623.25	88.75	28.15	537.85	144.97
13	Tahiti Tall	521.52	87.39	26.22	562.61	148.48
14	Pao Pao	643.1	97.31	29.38	545.55	145.33
15	Haapiti	647.9	94.1	28.94	544.68	144.35
16	Hari Papua Dwarf	425	61	19.25	426.56	125.31
17	Kiriwana	740.59	92.68	26.3	594.95	156.43
18	Tall Muwa	811.89	92.43	25.7	603.92	151.08
19	Nikkore Dwarf	441.67	70.56	24.89	434.4	120
20	Tall Kaveing	710.85	95.15	25.96	584.81	163.37
21	Natava Tall	628.94	91.96	29.64	565.38	165.91
	Grand mean	595.02	89.50	25.86	536.58	145.03
	Std. Dev.	123.33	11.38	2.87	52.51	13.52
	Std. Err	26.93	2.48	0.63	11.46	2.95
	CV (%)	20.73	12.72	11.09	9.79	9.32

Table 1. Continues..

Sl. No.	Population	No. leaflets	Len leaflet	Br leaflet	Male phase	Female-phase	No. of spikelets	FF No.	FF distrbn
1	Solomon Tall	120.33	121.67	6	18	3.8	35.1	15.8	0.5
2	Rennel Tall	113	115	4.5	17.8	4	36.5	20.2	0.6
3	Fiji Tall Wainigata	108.77	117.04	4.77	17.9	3.9	35.2	40.3	1
4	Niu Drau	111.12	119.53	5.15	18.1	4	38.2	48.6	1.3
5	Niu Lekha Dwarf	104.47	109.87	5.88	17.2	4.5	35	36.2	1.1
6	Niu Bulavu	108.78	114.76	5.01	17.5	4.4	33.6	27.1	0.8
7	Am. Samoan Tall	113.96	114.93	5.39	17.4	4.3	30.1	18.9	0.6
8	Niu Oma Dwarf	105.2	113	4.65	16.5	5.1	27.6	60.4	2.5
9	Tutiala	109.56	110.04	4.79	17.6	4.3	31.6	14.7	0.5
10	Niu Ui	113.68	104.55	5.98	17.3	4.1	31.1	20.2	0.7
11	Niu Taukave	85.5	90.88	5	19.1	4.2	35.9	51.5	1.4
12	Niu Hako	111.87	116.99	6.23	17.7	4.8	32.5	18.6	0.6
13	Tahiti Tall	128.02	116.22	5.15	16.8	4.1	31.9	18.7	0.6
14	Pao Pao	111.21	122.36	5.65	17.9	4.3	37.5	18.4	0.5
15	Haapiti	118.32	117.16	5.98	17.2	4.1	30	18.4	0.5
16	Hari Papua Dwarf	85.31	98.38	4.5	16.3	4.8	24	51	2.2
17	Kiriwana	109.51	132.7	5.28	16.8	4.5	33.1	31.1	0.9
18	Tall Muwa	116.57	122.19	5.27	17.7	4.2	27.5	20.7	0.7
19	Nikkore Dwarf	98	93.89	4.39	20.5	4.6	28.3	40.6	1.4
20	Tall Kaveing	109	130.63	6.94	18.1	4	32.7	14.9	0.5
21	Natava Tall	106.3	122.13	5.15	17.2	4.7	31.4	32.4	1.1
	Grand mean	108.98	114.47	5.32	17.65	4.32	32.32	29.46	0.95
	Std. Dev.	9.98	10.62	0.66	0.90	0.34	3.62	14.20	0.56
	Std. Err	2.18	2.32	0.14	0.20	0.07	0.79	3.10	0.12
	CV (%)	9.16	9.28	12.44	5.12	7.84	11.19	48.19	58.43

Sl. No.	Population		Set%	Ft Wt	Len ft	Br ft	Husk thick	Wt husk	Wt nut
1	Solomon Tall		28.8	2168.75	23.37	18.25	2.84	1087.5	1000
2	Rennel Tall		20.3	1675	20.47	18.1	2.7	762.5	787.5
3	Fiji Tall Wainigata		30.5	958.5	20.43	15.69	2.69	411.5	510.75
4	Niu Drau		35.8	1106.25	21.68	15.16	2.56	588.33	567.52
5	Niu Lekha Dwarf		16.1	1406.41	18.91	14.56	3.14	594.94	774.74
6	Niu Bulavu		23.2	1060.63	19.27	15.62	2.56	380.63	603.27
7	Am. Samoan Tall		20.9	1689	20.62	15.53	3.24	741.92	814.73
8	Niu Oma Dwarf		24.3	432.5	18.77	11.04	1.5	143.5	277.5
9	Tutiala		18.1	1374.5	20.42	14.41	2.33	606.5	676

10	Niu Ui		22.6	1555	21.29	16.06	2.4	690.17	839.92
11	Niu Taukave		17.6	560	15.76	11.3	1.75	230	334.58
12	Niu Hako		19.2	1429.73	22.04	16.9	4.02	652.32	753.39
13	Tahiti Tall		23.4	1508.75	17.35	13.85	1.95	625	818.13
14	Pao Pao		18.4	1452.46	18.42	14.41	2.52	518.42	898.65
15	Haapiti		18.2	1652.44	23.31	17.27	2.65	744.26	859.08
16	Hari Papua Dwarf		29.2	783.75	7.58	5.36	1.57	403.75	404.75
17	Kiriwana		19.3	1598.57	33.1	16.06	2.7	701.25	887.41
18	Tall Muwa		21.6	887.5	21.6	15.65	2.36	245	626.25
19	Nikkore Dwarf		11.8	532.58	18.36	11.81	1.59	158.21	360.39
20	Tall Kaveing		29.2	1447.13	20.52	15.2	2.41	613.07	810.06
21	Natava Tall		18	1522.5	8.74	7.28	1.99	681.92	857.5
	Grand mean		22.21	1276.28	19.62	14.26	2.45	551.46	688.67
	Std. Dev.		5.73	448.45	5.09	3.28	0.61	232.35	208.59
	Std. Err		1.25	97.91	1.11	0.72	0.13	50.73	45.54
	CV (%)		25.80	35.14	25.93	23.02	24.76	42.13	30.29

Table. 2. Cluster mean values *:*

Cluster No.	Pl. Height	Girth	No. leaves	Length of leaf	Length of petiole	No. leaflets	Len leaflet	Br leaflet	Male phase
I	425.00	66.50	19.42	447.53	125.15	95.25	105.69	4.57	16.40
II	733.14	95.19	26.42	588.82	156.91	112.55	123.96	5.57	17.77
III	495.21	72.28	23.67	476.27	122.82	91.75	92.38	4.69	19.80
Iv	568.74	93.71	27.12	535.24	146.21	112.65	114.91	5.43	17.42

Cluster No.	Female -phase	No. of spikelets	FFNo.	FF distrbn	Set%	Ft wt	Len ft	Br ft	Husk thick
I	4.95	25.80	55.70	2.35	26.75	608.12	13.18	8.20	1.54
II	4.07	33.63	28.57	0.82	27.53	1361.12	23.45	16.00	2.59
III	4.40	32.10	46.05	1.40	14.70	546.29	17.06	11.56	1.67
Iv	4.33	32.84	22.16	0.69	19.85	1484.22	19.17	14.91	2.68

Cluster No.	Wt husk	Wt nut
I	273.62	341.12
II	607.78	733.66

III	194.12	347.48
IV	636.23	789.36

Fig.1. Cluster diagram of pacific coconut populations:

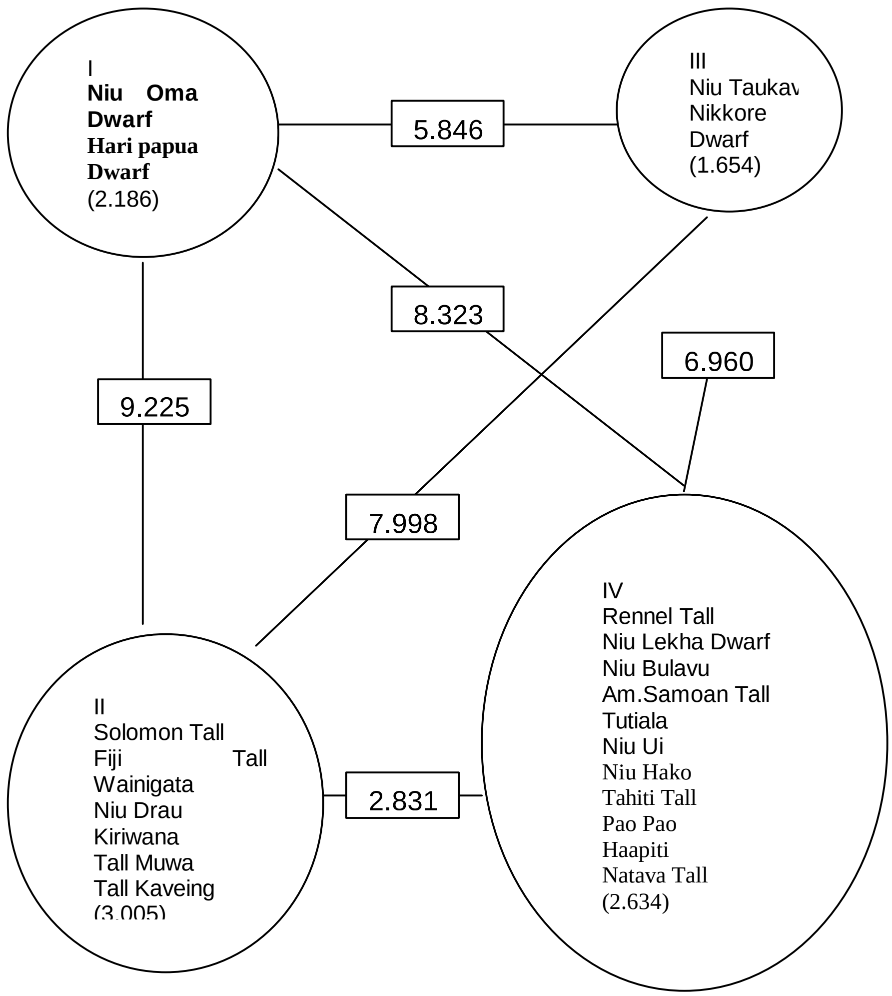

Table.3. Latent vectors and roots

Character		1	2	3	4
1	Pl. Height	0.202	0.26	0.231	0.249
2	Girth	-0.390*	0.028	0.113	-0.341
3	No. leaves	0.081	0.052	0.099	0.033
4	Lenleaf	-0.005	0.049	-0.198	-0.045
5	len petiole	-0.329	0.066	-0.269	-0.196
6	No.leaflets	-0.002	0.331*	0.347*	-0.015
7	Len leaflet	-0.247	0.220	-0.028	0.142
8	Brleaflet	0.198	-0.383*	-0.234	0.122
9	Malephase	0.082	-0.018	-0.230	0.092
10	femalephase	0.310 *	-0.209	0.604*	-0.137
11	No. of spikelets	-0.270	-0.107	0.007	-0.179
12	FFNo.	-0.073	0.584*	0.047	-0.230
13	FF distrbn	-0.057	0.190	-0.158	0.488
14	Set%	-0.174	0.097	0.154	0.049
15	Ftwt	-0.484*	-0.408*	0.334	0.070
16	Lenft	0.195	0.070	0.036	-0.060
17	Brft	0.315*	0.006	-0.169	-0.609
18	Huskthick	-0.038	-0.052	-0.147	-0.114
19	Wthusk	-0.054	0.018	-0.013	0.026
20	Wtnut	-0.043	-0.029	0.067	-0.009
Eigen root		10.126	2.128	1.163	1.089
% variation explained		50.63	10.64	9.64	5.81
Cumulative variation explained %		50.63	61.27	70.91	76.72

* Characters contributing to divergence are fruit weight, girth, breadth of fruit and female phase in PC 1. Number of female flowers, fruit weight, breadth of leaflet and number of leaflets are found to be important in PC 2. Female phase and no. of leaflets are found to be important in PC 3

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