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In situ approach for rapid characterization to aid on farm conservation of coconut germplasm - A case study of two ecotypes from West coast of India

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Abstract

Characterization and evaluation of coconut germplasm have conventionally been undertaken in *ex situ* gene banks, which take a minimum duration of fifteen years. On the other hand, utilization of coconut populations *in situ* can effectively reduce the time required for characterization of the populations. Hence, a concept to make a paradigm shift in the existing approach of coconut germplasm characterization is advocated in this study with a view to broaden the conservation base and facilitate inclusion of identified diverse ecotypes. The methodology has been applied to identify, locate and characterize two tall coconut ecotypes *viz*., Bedakam and Kuttiyadi, from northern Kerala. Agronomic traits, *viz*., higher number of nuts per palm, higher copra content and better performance under marginal management conditions along with adaptation to the environment, were the major reasons for preference of these ecotypes among the farmers. Comparison of the two ecotypes revealed that the traits, trunk girth, length of internode, number of leaves, number of bunches with nuts, number of nuts, shell weight, husked fruit weight and fruit weight were higher in Kuttiyadi than in Bedakam ecotype. On the other hand, number of leaf scars per meter, length of inflorescence, fruit breadth, husk weight, nut cavity volume and copra weight were higher in Bedakam compared to Kuttiyadi ecotype. Relevance, utility and importance of the study are discussed from the perspective of effective utilization of the coconut diversity *in situ* and their possible further use in coconut improvement efforts through conservation strategies.

Keywords: Coconut, ecotypes, genetic resources, *in situ* conservation

Introduction

Coconut, *Cocos nucifera* L., is a monotypic species under the genus *Cocos* with no known wild or domesticated relatives. It is a diploid species with a chromosome number 2n = 32 and belongs to the family Arecaceae under monocotyledons. Coconut gene pool comprises of cultivars found in the different geographical regions around the tropical world.

Coconut has a long history of cultivation and human association. It was suggested that population differentiation in coconut occurred as a result of geographic isolation, introgressive hybridization, mutation, and selection (Perera *et al.,* 2000). During the long history of evolution under domestication, cultivars branched out in different geographical situations, which are now known by the name of the place where it occurs (Ashburner *et al.,* 1997a, 1997b; Samsudeen *et al.,* 2006a). Every coconut growing region now has more or less distinctive populations commonly described as ecotypes with continuous variation that can be classified in to Afro-Indian, South-East Asian and Polynesian groups (Ramanatha Rao *et al.,* 2005). Coconut landraces or ecotypes were suggested as a product of farmer selection and farmer breeding (Riley, 1996). Several ecotypes are known to the farming community in

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the coconut growing regions of the world (Riley, 1996; Samsudeen *et al*., 2006b).

West Coast Tall (WCT) is a known coconut population from the West coast of India and named by the region where it is predominantly cultivated. Though the origin of WCT is not traceable to any progenitor or area from where it has spread, it is obvious that sea journey of nuts had a definite role in the initial establishment of the population. The cultivar migration from coastal region to interior areas, cultivation over the years, adaptation to new environments and human selection have probably contributed to the present day diversity in the cultivar. Such adapted WCT populations in certain localities were designated with local names by farmers to differentiate it from generic WCT population. Kuttiyadi, Neduvarayan, Karinthengu, Bedakam, Annur, Arasampatti Tall, Tiptur Tall *etc*. are a few such ecotypes reported (Arulraj *et al.*, 2002; Remany and Merlee Teresa, 2004).

As in most crops, germplasm collection, characterization and conservation in coconut has mainly concentrated on the method of *ex situ* gene banks. In the *ex situ* gene banks collected accessions are planted systematically for conservation, characterization and evaluation. Due to the long juvenile period of coconut, this method takes nearly fifteen to twenty years for reliable characterization. On the other hand, native *in situ* populations of such accessions (in most of the cases the same identified palms from which the original collections made) are available in the field for more than fifty years due to the long economic life of coconut. By utilizing these populations for characterization, time duration could be effectively reduced to two to three years. By this approach, a paradigm shift in the coconut germplasm characterization has been attempted, which would combine the merits of field gene banks and participatory approaches in on farm conservation and utilization. The farmer participatory approach to characterize the ecotypes and *in situ* on farm conservation will compliment *ex situ* field gene bank in coconut breeding.

Farmer participatory approach to characterize the traditional cultivars and *ex situ* conservation of promising population was suggested to facilitate the utilization of landraces for breeding efforts (Batugal and Bourdeix, 2005). Participatory characterization of coconut varieties was also carried out under the aegis of International Coconut Genetic Resources Network (COGENT) in two coconut communities in India and also in other COGENT member countries. The aim of this network was to characterize and evaluate coconut varieties according to farmer's perception and also to analyze problems faced by coconut farmers (Thamban *et al.*, 2007; Batugal and Bourdeix, 2005; Jayashree, 2005). The present concept takes it further to scientific characterization as per coconut descriptors, after identification of ecotypes based on participatory methods and suggests it as base information for *in situ* on farm conservation. Major difference in the two methods is that the earlier one was community-based, while the present one is ecotype-based in approach. The new methodology has been applied to identify, locate and characterize two coconut ecotypes *viz*. Bedakam and Kuttiyadi, from northern Kerala, India. Kuttiyadi was selected as it is reported to be high yielding and widely distributed for cultivation in Kerala (Remany, 2003; CPCRI, 2008). Bedakam is a popular cultivar among the farmers in Kasaragod district, renowned for its suitability under rainfed conditions (CPCRI, 2009).

Materials and methods

Identification and location of desirable ecotypes

Identification and location of desirable ecotypes in its natural home is the pre-requisite for further characterization of the population. In the present investigation, this was undertaken through two steps. In the first step, preliminary information on local population or ecotypes were collected from extension personnel working at the grass root level offices of the Department of Agriculture, Government of Kerala and by discussion with selected personnel associated with coconut research and development from the locality of the targeted ecotype. In the second step, explorative surveys of targeted area using participatory assessment tools like key informant interviews and focus group discussion were conducted to get further information on ecotypes. Participatory rural appraisal (PRA) tools such as transect walk and resource mapping were employed to analyse the land use, local agro-ecology and problems and opportunities in the

coconut farming. This participatory diagnostic exercise provided detailed information on precise sites in the target regions, agro-ecological and socio-economic situations and diversity in the target ecotype. Matrix scoring was employed by the farmers for analyzing the traits of ecotypes in comparison with WCT, the common tall cultivar from coastal region. A total of nine attributes were considered by the farmers for comparing the cultivars (Table 1). Scores between 1 and 10 were assigned for each of the attribute considered.

Table 1. Matrix ranking of farmer selection criteria for coconut ecotypes (score 1 - 10 scale)

Sl. No.	Trait	Bedakam	Kuttiyadi
1.	Number of nuts per palm	2	1
2.	Seedling availability	6	5
3.	Performance under average management	1	2
4.	Adaptation to the environment	4	4
5.	Copra content	3	3
6.	Early flowering	7	9
7.	Drought resistance	5	6
8.	Response to organic manure	8	7
9.	Oil content	9	8

Sampling of ecotypes

Identification and location of ecotypes were followed by sampling from the respective regions for studies on palm characters and fruit components. For sampling, the targeted region was divided into sites based on the ethnic diversity, fragmentation of land holdings and presence of diverse niche environments. One or more farmer fields were selected from each site depending on the population of palms. From selected farmers' field high yielding palms were sampled for further analysis. Random selection approach was used for selection among high yielding palms from each farmer's field. High yield (above 40 nuts per palm) was used as an indication of adaptation of palms to the environment.

Selected palms were marked for further observations. Accordingly, 171 palms from 14 farmer fields in nine sites were sampled from Kolathur, Bedadka and Munnad villages in Kasaragod taluk of Kasaragod district for studying Bedakam ecotype. Kuttiyadi ecotype was sampled from Chakkittappara and Chempanode villages in Koyilandy taluk; Kuttiady, Kavilumpara and Maruthomkara villages in Vadakara taluk of Kozhikode district. Accordingly, 180 palms were identified for sampling from 20 farmer fields spread over ten sites for studying Kuttiyadi ecotype.

Geographical distribution of Bedakam is between latitudes of 12°27' to 12°29' and longitudes of 75°08' to 75°12'. Individual land holdings ranged from 10 ha to less than 1 ha. Average land holding size was 1 ha and number of coconut palms in a single holding ranged from 25 to 300 palms. Most of the farmers, about 80 per cent, apply green leaves; a few of them apply cow dung along with green leaves. Majority of the coconut gardens were under rain fed condition. Geographical distribution of Kuttiyadi is between latitudes of 11°36' to 11°41' and longitudes of 75°43' to 75°51'. Individual land holdings ranged from 20 ha to less than 2 ha. Average land holding size was 4 ha and number of coconut palms in a single holding ranged from 50 to 500 palms.

Morphological observations

Observations on palm morphology were undertaken during April-May to facilitate collection of nuts for fruit component analyses as well as for studying germination and seedling characters in the nursery. Six nuts each were collected from the identified palms out of which, two nuts were used for fruit component analysis and four nuts for raising nursery. The morphological characters of the palm were recorded at the location itself. The vegetative and reproductive traits *viz*., plant height, girth at 1 m from ground, number of leaves, number of leaf scars m^{-1}, length of petiole, length of leaf bearing portion, number of leaflets, breadth of leaflets, length of leaflets, length of internodes, length of inflorescence, length of spikelet bearing portion, length of stalk, length of spikelet, number of spikelets, number of female flowers, number of bunches, number of nuts (above fist size), number of bunches with buttons and number of bunches with nuts were recorded on the mother palms as described in coconut descriptors (Ratnambal *et al.*, 1995).

Fruit components like fruit weight, fruit length, fruit breadth, husk weight, husk thickness,

husked fruit weight, nut length, nut breadth, shell weight, shell thickness, endosperm thickness, cavity volume, copra (dried endosperm) weight and oil percentage in copra were recorded from two nuts of each selected palm. Computation of mean, standard deviation and coefficient of variation were carried out as per the standard procedure using SAS software.

Results and discussion

Participatory assessment techniques involving key informant interviews and focus group discussion to understand farmer's criteria for identification, valuation and selection of their varieties revealed the ranking of factors by farmers in order of importance. Results indicated that nut yield in terms of number of nuts per palm, performance under marginal management conditions; copra content and adaptation to the environment have emerged as important criteria for selection of varieties (Table 1). In the case of Bedakam ecotype, two to three generations of selection has gone into the development of the existing population. This ecotype is adapted to a narrow geographical area of approximately 200 square kilometers in Kasaragod district. In Kuttiyadi ecotype, more than five generations of selection has taken place as the population moved towards east from the coastal region. Geographical areas from where the ecotypes collected differed in altitude, soil characteristics, temperature range and rainfall (Table 2). The geo-morphological data of the samples sites of the two ecotypes revealed the distribution pattern of the ecotypes under low to high altitudes.

Table 2. Site parameters

Sl. No.	Parameters	Ecotype name	
		Bedakam	Kuttiyadi
1.	Max./Min. Temperature (°C)	36 / 20	35 / 18
2.	Rainfall (mm)	2800 - 3400	3200 - 3800
3.	Humidity (%)	70 - 90	70 - 93
4.	Soil type	Laterite	Laterite
5.	Soil pH	5.21	5.05
6.	N (ppm)	2201.60	2322.33
7.	P (ppm)	151.62	464.91
8.	K (ppm)	194.00	150.00
9.	Organic carbon (%)	2.19	1.93

Ten morphological and reproductive characters of the palm were recorded. Age of the selected palms varied from 40 to 100 years and all the trees were under the tall category. Palm characters of Bedakam and Kuttiyadi ecotypes exhibited differences among them (Table 3). Kuttiyadi palms were comparatively taller, higher girth, broader internodes, less number of leaf scars, and more number of leaves compared to Bedakam ecotypes. These characters in Kuttiyadi palms are more towards typical tall types while it is towards intermediate type in palms from Bedakam. The leaf was slightly longer in Bedakam palms. Number, breadth and length of leaflets were higher in Kuttiyadi palms. Inflorescence stalk was slightly longer in Bedakam and all other inflorescence traits like length of spikelet, number of spikelets, number of female flowers and number of bunches were more in Kuttiyadi palms. Kuttiyadi ecotype also had more number of nuts per palm compared to Bedakam ecotype (Table 3). The differences may be attributed to the independent selection procedure happened over the generations in the two different environments.

Analysis of fourteen fruit component traits also showed differences among the ecotypes. The whole fruits and dehusked fruits were heavier in Kuttiyadi ecotype with Bedakam ecotype showing more husk by weight. Though fruit and husked fruit length was almost similar in both, Bedakam fruits and dehusked fruits were broader. Shell weight was more in Kuttiyadi ecotype, but Bedakam ecotype had slightly thicker shell. Endosperm was slightly thicker in Kuttiyadi than in Bedakam ecotype. Cavity volume within the fruit was higher in Bedakam ecotype. Dried endosperm (copra) weight was more in Bedakam compared to Kuttiyadi ecotype. However, oil content was higher in Kuttiyadi than Bedakam ecotype (Table 4).

Traditionally, coconut genetic resources collected and conserved in *ex situ* genebanks were being utilized for characterization and evaluation. Coconut palms of targeted types are naturally conserved and are available for *in situ* characterization as most coconuts have a life span of more than 100 years. Identification of location and specific ecotype for such *in situ* characterization

Table 3. Palm characters of Bedakam and Kuttiyadi ecotypes

Sl. No.	Characters	Bedakam ecotype				Kuttiyadi ecotype			
		Mean	CV	Min	Max	Mean	CV	Min	Max
1	Plant height (cm)**	1454.27	18.58	947.00	2085.00	1554.22	13.89	1120.00	2375.00
2	Girth at 1m (cm)**	76.91	9.91	52.00	95.00	80.79	9.08	62.00	105.00
3	Number of leaves**	24.72	13.22	16.00	36.00	34.81	17.71	26.00	48.00
4	Number of leaf scars m^{-1} **	14.70	21.09	9.00	24.00	11.60	15.52	8.00	18.00
5	Length of petiole (cm)	108.44	16.46	50.00	167.00	107.97	12.96	75.00	145.00
6	Length of leaf bearing portion (cm)	343.58	13.86	185.00	539.00	341.01	10.97	245.00	435.00
7	Number of leaflets*	109.10	8.23	83.00	131.00	111.21	6.21	94.00	129.00
8	Breadth of leaflets (cm)	5.33	15.65	4.00	8.00	5.47	15.52	3.00	8.00
9	Length of leaflets (cm)	107.70	14.79	73.00	148.00	110.17	12.15	73.00	153.00
10	Length of internodes (cm)**	6.91	22.03	4.20	11.10	8.90	14.83	5.50	13.20
11	Length of inflorescence (cm)	97.43	13.40	60.00	136.00	96.10	10.43	69.00	128.00
12	Length of spikelet bearing portion (cm)	34.32	19.56	17.00	68.00	34.39	18.53	24.00	55.00
13	Length of stalk (cm)	40.93	17.27	21.00	60.00	40.29	16.32	23.00	59.00
14	Length of spikelet (cm)	36.58	14.70	25.00	52.00	37.10	13.69	25.00	53.00
15	Number of spikelets	32.60	18.40	18.00	48.00	33.60	17.26	21.00	55.00
16	Number of female flowers	18.80	45.64	5.00	52.00	20.16	33.30	7.00	48.00
17	Number of bunches**	14.01	18.42	7.00	19.00	15.07	10.80	8.00	22.00
18	Number of nuts (above fist size)	81.60	47.03	5.00	16.00	82.88	22.24	6.00	17.00
19	Number of bunches with buttons**	2.39	26.18	1.00	5.00	2.13	17.93	2.00	5.00
20	Number of bunches with nuts**	11.63	21.15	40.00	188.00	12.92	12.11	40.00	132.00

*Significant at 0.05; **Significant at 0.01

involves participatory approaches coupled with the systematic recording and analysis of specific agro-morphological traits that can be completed within a span of two to three years for a particular ecotype.

In Bedakam and Kuttiyadi ecotypes, participatory analysis has revealed that number of nuts, copra yield and performance under marginal management conditions were the criteria used by the farmers for selection of progenies. In an earlier work six ecotypes (Kuttiyadi Tall, King Coconut, Elite Tall, Jappanan, Komadan and Chowghat Green Dwarf) were identified in different agroclimatic regions of Kerala, through a farmer participatory survey. Here, farmers cited productivity, kernel quality, toddy yield and fibre output as the major criteria for ranking cultivars (Remany, 2003; Remany and Merlee Teresa, 2004).

Table 4. Fruit characters of Bedakam and Kuttiyadi ecotypes

Sl. No.	Characters	Bedakam ecotype			Kuttiyadi ecotype		
		Mean	SD	CV	Mean	SD	CV
1.	Fruit weight	814.1	174.0	21.37	819.2	167.7	20.47
2.	Fruit length	17.5	2.0	11.43	17.4	1.7	9.77
3.	Fruit breadth**	14.4	1.9	13.19	12.3	1.9	15.45
4.	Husk weight	384.0	103.5	26.95	375.4	112.2	29.89
5.	Husk thickness**	2.6	0.5	19.23	2.7	0.5	18.52
6.	Husked fruit weight**	429.8	98.8	22.99	443.2	97.5	22.00
7.	Nut length	10.8	1.3	12.04	10.8	1.0	9.26
8.	Nut breadth**	9.6	1.2	12.50	9.0	1.0	11.11
9.	Shell weight**	114.6	21.7	18.94	118.2	20.7	17.51
10.	Shell thickness**	0.5	0.1	16.67	0.5	0.1	13.33
11.	Endosperm thickness**	1.2	0.1	8.33	1.3	0.1	7.69
12.	Cavity volume*	123.8	36.3	29.32	115.5	30.8	26.67
13.	Copra weight	152.6	29.1	19.07	150.8	34.4	22.81
14.	Oil (%)	66.7	3.6	5.43	68.4	2.4	3.54

*Significant at 0.05; **Significant at 0.01

Agro-morphological characteristics are determined through the interaction between the genotype and the environment which can be used as indirect measures of genetic diversity. Genetically homogenous local crop populations in slightly different agro-ecological niches could have very different phenotypic qualities, and some morphological characteristics will be affected by the environment more heavily than others. Likewise, distinct local varieties may appear similar in different environments (Newbury and Ford-Lloyd, 1997). Analysis of agro-morphological traits revealed that Kuttiyadi and Bedakam ecotypes differed in palm morphology as well as in fruit traits. Though these ecotypes have originally developed from the West Coast Tall cultivar, differences occurred as a result of adaptation to different agro-ecological niches.

From the study, Bedakam ecotype could be described as intermediate in plant height having spherical crown, slender trunk, closely arranged leaf scars, retention of less than 28 leaves on the crown, spaciously arranged leaflets, spaciously arranged spikelets, more than 46 per cent husk, fruit length to breadth ratio 1.2, thick shell and thin endosperm. Kuttiyadi ecotype could be described as a tall type having spherical crown, bold trunk, broad internodes, retention of more than 28 leaves on the crown, closely arranged leaflets, compact spikelets, less than 46 per cent husk, fruit length to breadth ratio 1.4, thin shell and thick endosperm.

Analyses of agro-morphological performance *in situ* coconut genetic resources could very well be a significant method of arriving at empirical understandings of farmers' perceptions of the traits when coupled with participatory appraisal. This approach is of additional potential value because the characterization of crop varieties *in situ* is of direct relevance to farmers as well as plant breeders in the use of germplasm in focus. The approach of collecting and analyzing data on agro-morphological traits *in situ* is less expensive and simple in comparison with other ways of measuring genetic diversity thorough *ex situ* management. *In situ* characterization and documentation followed by conservation and possible utilization is a viable alternative to *ex situ* germplasm conservation for utilizing the valuable indigenous genetic resources in coconut. The benefit of *in situ* conservation is that it maintains populations in the naturally adapted environment with their distinct properties. This strategy also helps to ensure the ongoing processes of evolution and adaptation within their environments.

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