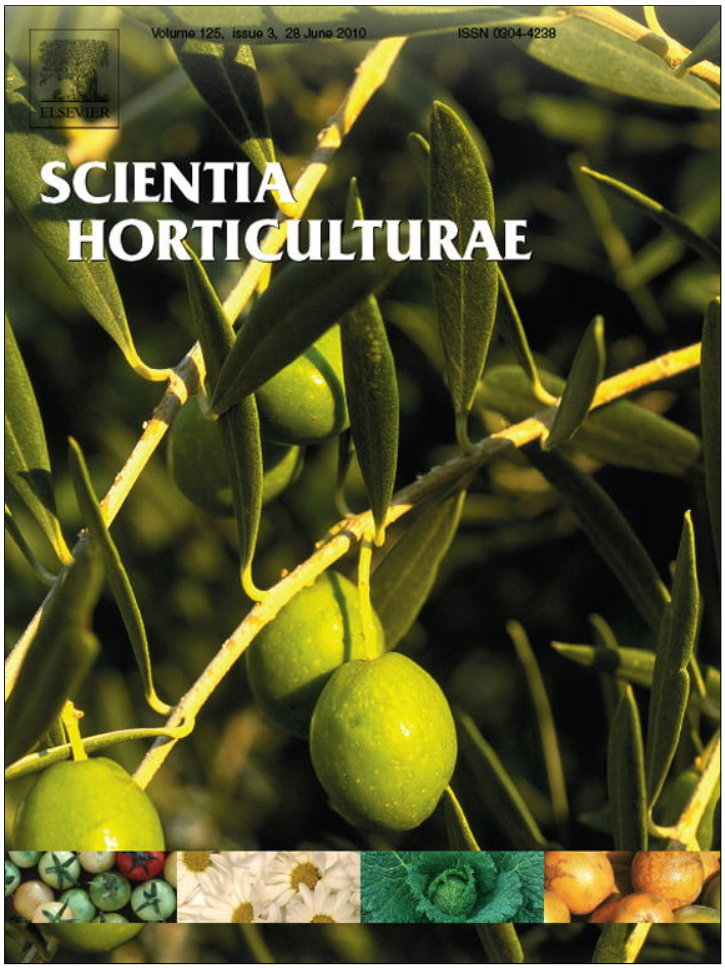

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Microsatellite analysis of distinct coconut accessions from Agatti and Kavaratti Islands, Lakshadweep, India

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ABSTRACT

The Lakshadweep group of islands, located in the south-western part of India in the Indian Ocean is considered unique for its coconut populations owing to its geographic isolation and assumed introgression with mainland coconut populations along west coast of mainland India. A wide range of variability was noticed for morphological characters of Lakshadweep coconut populations. A total of nine accessions were collected from Agatti and Kavaratti Islands of Lakshadweep as part of a germplasm enrichment programme for island coconut populations of India. This includes three Laccadive Micro types, four types of Laccadive Ordinary Tall differing in nut bearing habit, fruit shape and size, one each of sweet husked Kaithathali tall and dwarf type. The microsatellite analysis of the 9 coconut populations with 8 primers revealed a total of 37 alleles. The highest number of eight alleles was detected for the CAC8 primer and the lowest number of three alleles for the CAC10, CAC13 and CnCIRG11 primers. The estimate of heterozygosity was highest (>0.5) for the two Laccadive Micro Tall (LMT02 and LMT03) and the Laccadive Small Tall (LCT02) populations and was lowest (0.24) for the Laccadive Micro Tall (LMT01). The sporadic occurrence of Laccadive Micro Tall is discussed in the context of high outcrossing and inbreeding depression.

1. Introduction

The Lakshadweep group of islands is located in the Indian Ocean and consists of 36 coral islands of which 12 are inhabited. The coconut (*Cocos nucifera* L.) is the main cultivated crop in these islands and the palm occurs in dense clusters, resembling natural forest, in groves or in gardens, as cultivated types. Some of the coconut populations in cultivated gardens are assumed/known to be progenies from the nuts brought from the western coastal region of the Indian mainland. The coconut is cultivated in all the major islands of Lakshadweep viz., Agatti, Androth, Aamini, Bitra, Chetlat, Kavaratti, Kalpeni, Kiltan, Kadamat, Suhelivallakara and Minicoy. The Laccadive Ordinary Tall, Laccadive Micro Tall, Kaithathali Tall and Laccadive Orange Dwarf are the main cultivated types in these islands (Jacob and Krishnamoorthy, 1981).

Lakshadweep coconut population consists of palms with large to medium sized nuts (commonly called as Lakshadweep Ordinary Talls) and small nuts (commonly called as Micro Talls). The Laccadive Ordinary Tall is the widely cultivated type while the Laccadive Micro is found sporadically amidst the Laccadive Ordinary population. Among the Micro Talls, the palms exhibit high variability for size and shape of nuts, production levels i.e. regular or alternate bearing habit and copra content. The Kaithathali Tall has edible husk at button or immature stages of coconut fruit development. The edibility of the Kaithathali husk may be attributed to comparative sweetness, less tannin and less fibre content of young husk. The Laccadive Orange Dwarf is cultivated mainly in home gardens in almost all the inhabited Islands of Lakshadweep and is believed to have been brought from the Indian mainland and adapted to island conditions. The possible D × T and T × D late generation progenies have not been recognized in the existing coconut population as the original population itself is having wide variability for most of the important traits. Besides, Green and Yellow dwarfs are also present sparsely in the Islands. CPCRI has made use of these dwarf types, for producing hybrids and evaluated them for yield under Lakshadweep conditions. The hybrids involving Lakshadweep Ordinary Tall and Green Dwarf have been identified as the best hybrid for island conditions for high nut and copra yield (CPCRI, 2008).

The Laccadive Ordinary Tall yield high number of nuts (an average of 98 nuts/year) and is comparable to the main cultivar West Coast Tall (90 nuts/year) under the germplasm evaluation trial at Kasaragod, India. The Laccadive Micro Tall yield higher number of nuts (an average 185 nuts/year) than West Coast Tall (90 nuts/year) but the copra content in Micro Talls is low (about 50% less) (90 g) as compared to Laccadive Ordinary (176 g) (Ratnambal et al., 1995). The oil content of the kernel is 74% which is

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significantly higher than other cultivars and coconut hybrids in India (Patil et al., 1993). Ratnambal et al. (1995) reported the oil percent as 75 and 70% in Laccadive Micro Talls and Laccadive Ordinary Tall, respectively, which are part of conserved germplasm of CPCRI. John and Narayana (1949) had described the Laccadive Micro Tall as a unique form and classified as pusilla type with high female flower production, setting percentage and small nuts but with high nuts and oil yield. The high yield of oil in Laccadive Ordinary Tall has made this cultivar an important component in the hybrid coconut seedling production programmes in India. The Laccadive Ordinary Tall is also reported to have high fruit setting percentage, better combining ability and a faster germination rate when compared to the West Coast Tall (WCT) and some other talls (Nampoothiri et al., 1973). Considering the nut yield, oil yield and drought tolerance, a selection from Laccadive Ordinary Tall (LCT) has been released as a variety for commercial cultivation. Besides, LCT has been identified as a best general combiner among nine coconut accessions tested for combining ability (Nampoothiri et al., 1999). Two hybrid varieties have been released for cultivation in India using LCT as female parent viz., Lakshaganga (LCT × GBGD) and Chandralaksha (LCT × COD) and these were found to have a high degree of drought tolerance (Bhaskara Rao et al., 1988; Rajagopal et al., 1988).

The Laccadive Micro is prolific bearer with a record of 400 nuts/palm/year (average 280 nuts/palm/year) but with small sized nuts that are not liked by the local people. As many as 18 female flowers per spikelet have been observed although many abort and do not develop into mature nuts. The Laccadive Micro, which is considered to be the wild type coconut population of the islands long before human settlement, now faces the threat of slow elimination because of human preference for bigger nuts and regular yield. The low percentage of germination under natural conditions due to the small amount of water per nut (9.1%) to whole fruit was also cited (Jacob and Krishnamoorthy, 1981) as an important reason for the reduction in the number of palms over the years. A variant form of Laccadive Micro, with small round nuts and regular bearing habit has been reported from these islands (Jacob, 1993).

As part of the ongoing coconut germplasm prospection, collection, maintenance and evaluation activities at Central Plantation Crops Research Institute (CPCRI), Kasaragod, the coconut germplasm accessions were collected from these two islands in 1999. Agatti Island, situated at 10°51′N latitude and 72°11′E longitude, is the westernmost island in the territory and is over 5.6 km in length and about 1 km wide at the broadest point. Kavaratti Island is situated at 10°33′N latitude and 72°38′E longitude. It lies between Agatti and Androth but a little to the south. The island is about 6 km in length and 1 km breadth. At the southern end, the land shrinks to a width of 47 m.

This study was undertaken to understand the genetic variability and relationship among the Lakshadweep coconut populations sampled from Agatti and Kavaratti Islands using co-dominant microsatellite markers.

2. Materials and methods

Nine coconut accessions from Agatti and Kavaratti of Lakshadweep Islands collected during a germplasm expedition undertaken by CPCRI in the year 1999 were utilized for the present study. The morphological traits of the mother palms were recorded and fruit component analysis was carried out using the nuts collected from the palms (Table 1). The leaf samples collected from the seedlings were used for the DNA extraction. The important coconut cultivars of the India such as the West Coast Tall (WCT), Andaman Ordinary Tall (ADOT) and Chowghat Orange Dwarf (COD) and South East Asian cultivars such as Strait Settlements Green (SSGT) – Malaysia, Borneo Tall (BONT) – Indonesia, Philippines Ordinary Tall (PHOT) and Malayan Orange Dwarf (MOD) were use as control samples to relate the Lakshadweep germplasm to other accessions.

2.1. DNA extraction

DNA was extracted from the spear leaf of the young seedlings following the procedure of Upadhyay et al. (1999), whereby 5 g of spear leaf tissue was ground in liquid nitrogen and transferred to extraction buffer containing 10% SDS. The contents were boiled at 65 °C, cooled and extracted with an equal volume of 24:1 chloroform:isoamyl alcohol mixture. The supernatant was transferred to a new tube and DNA was precipitated with 70% ethanol.

2.2. PCR assay and gel analysis

The PCR reaction mix consisted of 12.5 ng of DNA template, 200 μM deoxynucleotide triphosphate (dNTPS), 1 unit of *Taq* polymerase (Bangalore Genie, India) and 1 μM of each primer. The polymerase chain reaction (PCR) conditions were identical to those of Perera et al. (2000) for CAC primers and 51 °C annealing temperature was set for the CnCIRG11 primer. The amplified products were resolved in a 5% denaturing polyacrylamide gel and the bands were visualized by silver staining (Bassam and Caetano-Anolles, 1993). The microsatellite bands were scored manually and the alleles were sized with reference to a 30–330 bp ladder (Gibco Brl).

2.3. Statistical analysis

The calculation of genetic diversity values, heterozygosity, inbreeding coefficient and construction of the unweighted pair group method with arithmetic mean (UPGMA) dendrogram using Nei's genetic distance (Nei et al., 1983) was carried out using the POWERSSR v 1.2. Software (Liu, 2001). The analysis of molecular variance was done using GENALEX software (Peakal and Smouse, 2001) with a significance setting permutation value of 999. The maternal parentage analysis was carried out with Cervus 3.0 software package (Kalinowski et al., 2007).

3. Results

3.1. Microsatellite analysis of Lakshadweep coconut populations

The observed gene diversity and heterozygosity were found to be highest for two of the Laccadive Micro Talls (LMT02 and LMT03) while the other Laccadive Micro Tall bearing small nuts (LMT01) showed the lowest. The inbreeding coefficient was highest for Laccadive Orange Dwarf (LCOD01) and lowest for LMT02 (Table 1).

3.2. Fruit component analysis of Lakshadweep coconut populations

The fruit component data of the nine accessions (Table 2) showed that the accessions vary widely for fruit shape and size. Wide variability was observed for weight of fruit, weight of kernel, weight of shell and quantity of nut water. The weight of fresh kernel ranged from 93 g to 345 g indicating the diversity among the coconut palms for fruit component traits and the importance of selection based on this trait.

3.3. Alleles detected and genetic distance

The highest number of alleles ($n = 8$) was detected for CAC8 primer and lower number of three alleles was detected by CAC10, CAC11 and CnCirG11 primers (Table 3)

The pairwise population matrix formed by Nei's genetic distance of all the nine coconut accessions showed that the LCT02 was genet-

Table 1
Lakshadweep germplasm accessions used in this study.

Acc. no.	Abbreviation	Description	No of samples	Place of collection	Observed gene diversity	Heterozygosity	Inbreeding coefficient
IND222	LCT01	Laccadive Ordinary Tall (Agatti)	4	Agatti	0.430	0.340	0.210
IND223	KAIT01	Kaithathali Tall	3	Agatti	0.400	0.380	0.130
IND224	LMT01	Laccadive Micro Tall (very small nuts)	4	Agatti	0.390	0.240	0.330
IND225	LMT02	Laccadive Micro Tall (small round nuts green or brown, regular bearer)	4	Agatti	0.480	0.590	−0.068
IND226	LMT03	Laccadive Micro (uniform nut size) (in all seasons)	4	Agatti	0.550	0.570	0.065
IND227	LCT02	Laccadive Small (round nuts)	3	Agatti	0.560	0.580	0.130
IND228	LCT03	Laccadive Ordinary Tall—triangular nuts (Kavaratti)	4	Kavaratti	0.440	0.380	0.220
IND231	LCOD01	Laccadive Orange Dwarf	2	Kavaratti	0.440	0.310	0.400
IND232	LCT04	Laccadive Ordinary (elongated orange nuts)	4	Agatti	0.470	0.440	0.260
Mean					0.46	0.43	0.19

ically distinct from all other accessions studied (Table 4). The F_{st} value of pairwise population differentiation was highest between the LCT02 and LMT01 followed by KAIT01 and LCT02 (Table 5). The molecular variance between populations was found to be 9% while among individuals it was 13% (Table 6).

The inbreeding coefficient was found to be highest for the LCOD01 (40%) followed by LMT01 (33%). The lowest inbreeding coefficient was found for the LMT02 and LMT03.

3.4. UPGMA clustering pattern of Lakshadweep coconut populations

The UPGMA dendrogram classified the accessions studied into two major groups. The South East Asian Talls, the Andaman and the dwarf accessions Malayan Orange Dwarf (MOD) and Chowghat Orange Dwarf (COD) formed one major group and the Indian West Coat Tall (WCT) and the Lakshadweep accessions as another group (Fig. 1).

All the Lakshadweep accessions were classified as a sub-group within the West Coast Tall cultivar. Two sub-groups could be distinguished among the nine coconut germplasm accessions from the Lakshadweep Islands. The Laccadive Orange Dwarf (LCOD01) and Laccadive Ordinary Tall with elongated Orange nuts (LCT04) forming one group and the rest of the seven Tall cultivars forming another group. Among these seven cultivars, the Kaithathali Tall (KAIT01) formed a major group which again could be classified into two groups. The Laccadive Micro Tall (LMT02), Laccadive Micro Tall with uniform nut size in all seasons (LMT03), Laccadive Ordinary (Agatti) (LCT01), Laccadive Micro (Very small nuts) (LMT01) formed one sub-group while the other group was formed by the Laccadive Small (LCT02) and Laccadive Ordinary (Kavaratti) (LCT03).

4. Discussion

In this study nine accessions from Agatti and Kavaratti Islands were analyzed for the genetic diversity. It is believed that the Agatti Island was among the first Islands to be inhabitated in the Lakshadweep territory after ship wreckage during the 9th century AD that forced the sailors to land here (Ellis, 1924) and hence it is the main land for the human interference in coconut populations in this territory. Our previous microsatellite studies on major coconut germplasm accessions showed that the LCT has the highest mean genetic diversity (0.59) (Devakumar et al., 2005). Niral et al. (2008), based on isozyme analysis in 12 coconut accessions collected from Agatti, Kalpeni and Kavaratti Islands of Lakshadweep reported a heterozygosity index ranging from 0 to 0.17.

Fruit component analysis of Lakshadweep coconut populations have also been reported by Bhaskara Rao and Pillai (1982) and Krishnamoorthy and Jacob (1982). The studies classified the tall forms from the Lakshadweep Islands as Niu Kafa types characterized by high husk and endosperm proportions of the total fruit weight in contrast to low husk and endosperm proportions of Niu Vai types (Harries, 1982). Samsudeen et al. (2006), based on a study of fruit components of Laccadive Ordinary Tall and Laccadive Micro Tall coconut populations from Kadamat and Amini Islands reported a high level of intra population variability among the coconut accessions and occurrence of both Niu Vai and Niu Kafa types.

Three types of Laccadive Micro Tall with variation like very small nuts (LMT01), regular bearing small round nuts (LMT02) and uniform nut size in all seasons (LMT03) were collected as germplasm accessions from these islands. Among the micro talls, LMT01 and

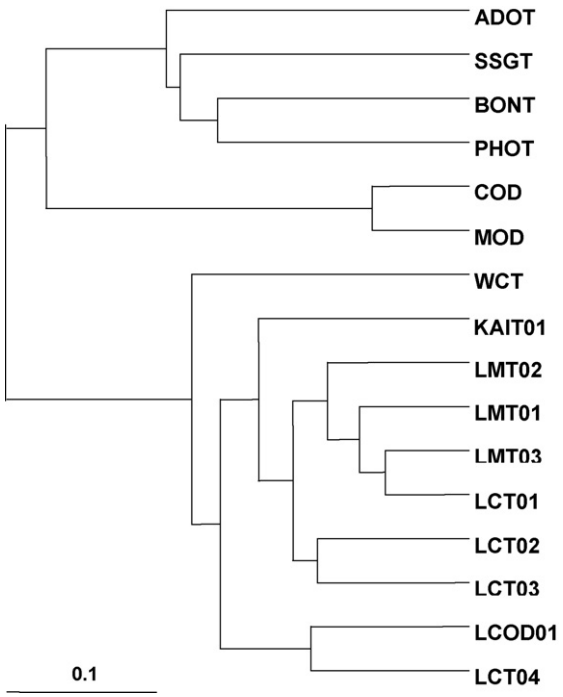

Fig. 1. UPGMA dendrogram showing the relationship among the Lakshadweep coconut accessions with respect to coconut accessions from India (West Coast Tall (WCT), Andaman Ordinary Tall (ADOT) and Chowghat Orange Dwarf (COD) and South East Asia (Strait Settlements Green Tall (SSGT), Borneo Tall (BONT), Philippines Ordinary Tall (PHOT) and Malayan Orange Dwarf (MOD)).

Table 2
Fruit component traits of coconut accessions from Agatti and Kavaratti Islands.

S. no.	Nut characteristics/accession	IND222 LCT01	IND223 KAIT01	IND224 LMT01	IND225 LMT02	IND226 LMT03	IND227 LCT02	IND228 LCT03	IND231LCOD01	IND232LCT04
1	Colour of the fruit	Green to brown	Green to brown	Green to brown	Green to brown	Green to brown	Green to brown	Green to brown	Orange	Orange
2	Shape of the fruit	Oval	Oval	Oval	Round	Oval	Oval	Oblong	Oblong	Round
3	Shape of nut	Oval	Round	Oval	Round	Oval	Round	Round	Round	Round
4	Length of the fruit (cm)	24.50	25.00	15.50	12.50	19.50	20.00	28.00	20.00	21.00
5	Breadth of fruit (cm)	18.50	23.00	11.50	11.00	11.50	15.50	17.30	18.00	18.00
6	Weight of fruit (g) with water	1062.00	1610.00	390.00	435.00	381.00	860.00	1104.00	1190.00	1100.00
7	Weight of fruit (g) without water	977.00	1420.00	372.50	425.00	370.20	745.00	1044.00	1090.00	1010.00
8	Thickness of the husk (cm)	2.00	2.00	1.20	1.60	1.20	1.50	2.10	1.50	1.50
9	Weight of husk	639.00	900.00	227.00	245.00	221.00	350.00	688.00	750.00	590.00
10	Weight of nut (g) with water	423.00	710.00	163.00	190.00	160.00	510.00	416.00	440.00	510.00
11	Weight of nut (g) without water	338.00	520.00	145.50	180.00	149.20	395.00	356.00	340.00	420.00
12	Weight of nut water (g)	85.00	190.00	17.50	10.00	10.80	115.00	60.00	100.00	90.00
13	Thickness of kernel (cm)	1.20	1.30	1.30	1.00	1.30	1.20	1.25	1.20	1.20
14	Weight of kernel (g)	228.00	345.00	95.00	101.00	93.00	270.00	205.00	230.00	240.00
15	Thickness of shell (cm)	2.10	2.00	1.10	2.75	1.10	3.00	2.00	2.00	2.00
16	Weight of shell (g)	111.00	145.00	55.00	70.00	54.00	120.00	112.00	110.00	115.00
17	Percentage of husk of whole fruit	60.20	55.90	58.20	56.30	58.00	40.70	62.30	63.00	53.60
18	Percentage of kernel of whole fruit	23.34	24.30	25.50	23.76	25.12	36.24	19.64	21.10	23.76
19	Percentage of shell of whole fruit	11.36	10.21	14.77	16.47	14.59	16.11	10.73	10.09	11.39
20	Percentage of water of whole fruit	5.10	9.59	1.53	3.46	2.29	6.95	7.34	5.81	11.25

Table 3
Details of Microsatellite loci, alleles detected in Lakshadweep coconut accessions.

S. no.	Microsatellite	No of alleles	Allele sizes (bp)
1.	CAC3	4	187, 197, 199, 201
2.	CAC4	5	182, 186, 188, 200, 204
3.	CAC6	7	150, 152, 154, 156, 158, 160, 162
4.	CAC8	8	188, 196, 198, 200, 202, 204, 206, 208
5.	CAC10	3	195, 197, 201
6.	CAC11	4	156, 158, 170
7.	CAC13	3	158, 162, 172
8.	CnCIRG11	3	180, 184, 188

LMT03 are grouped with LCT01 whereas LMT02 is grouped with KAIT01 and LCT02 grouped with LCT03. This indicates the diverse nature of Laccadive Micro Talls and the possibility of micro talls arising from the Laccadive Ordinary population. However, the dwarf accession LCOD01 formed a cluster with LCT04. LCT04 may be a hybrid derivative of Dwarf × Tall or Tall × Dwarf, the identity of which could be the orange coloured nuts whereas the rest of the Laccadive Ordinary and Micro Talls produced only green or brown nuts. To test the hypothesis, whether the Laccadive Ordinary (Elongated Orange nuts) LCT04 is actually a first or later generation hybrid of Laccadive Orange Dwarf (LCOD) or other dwarfs such as, Chowghat Orange Dwarf and Malayan Orange Dwarf, we used the maximum likelihood estimate of LOD and Delta score (Kalinowsky et al., 2007) implemented in Cervus 3.0 software. The LCOT 04 was compared with the Laccadive Orange Dwarf (LCOD01) and Chowghat Orange Dwarf, (COD) the widely cultivated dwarf from the Indian mainland and the Malayan Orange Dwarf (MOD) for its first generation relationship as female parent. The Dwarfs are highly homozygous, unlike the talls and hence the possibility of LCT04 as F1 generation arising from the cross between any of the Talls and Dwarfs can be ascertained with a certain degree of confidence. Only one palm (Palm ID 3) from the accession LCT04 showed a high positive LOD score of 2.11 for the Palm ID 1 of the LCOD01 cultivar while all other LCOT04 showed a negative LOD score for the all the dwarfs analyzed indicating the possibility of it being a later generation hybrid (Table 7).

The micro talls, in general, can be assumed to possess the inherent variability exist in Laccadive Ordinary with the distinction of producing smaller sized nuts of varying size and bearing habit. The regular or irregular bearing habit as well as the nut size variation over seasons highlights the importance of selection among micro talls for nut size and bearing behaviour for successful utilization of this type for desirable traits. The low germination rate of micro nuts under storage makes them suitable for ball copra production which needs eight to nine months of storage under dry conditions. In larger nuts, owing to the larger cavity and high nut water, the germination and subsequent spoilage of kernel during storage was high whereas in micro nuts, the germination and spoilage was found to be less (CPCRI, 2008). Careful selection and *inter se* mating of the selected micro talls could be useful in developing superior varieties suitable for ball copra production.

The Laccadive Islands are also home to the smallest known coconuts in the world (named as Laccadive Mini Micro) with the husked nut measuring little bigger than a pea in diameter. The whole fruit has an average circumference of 13.62 cm in polar regions and 9.21 cm in equatorial region with an average fruit weight of 31.25 g. The husked nut weighs only an average of 5.76 g with a copra weighing 5.02 g. The smallest fruit and nut size is not due to any disease or pest attack as those palms produce similiar nuts throughout the year on all branches. In a recent survey, more than 30 mini micro palms were identified and documented in the Minicoy Islands of Lakshadweep Islands (CPCRI, 2009). Only a few drops of coconut water are available in these nuts but the embryo is normal sized (Fig. 2). These nuts cannot germinate due

Table 4
Pairwise population matrix of coconut populations from Agatti and Kavaratti Islands of Lakshadweep (Nei's Genetic Distance), WCT (Control).

Accession	LCT01 (IND222)	KAIT01 (IND223)	LMT01 (IND224)	LMT02 (IND225)	LMT03 (IND226)	LCT02 (IND227)	LCT03 (IND228)	LCOD01 (IND231)	LCT04 (IND232)	WCT (Control) (IND069)
LCT01 (IND222)	0									
KAIT01 (IND223)	0.039	0								
LMT01 (IND224)	0.007	0.024	0							
LMT02 (IND225)	0.074	0.019	0.068	0						
LMT03 (IND226)	0.046	0.126	0.088	0.114	0					
LCT02 (IND227)	0.305	0.421	0.397	0.305	0.116	0				
LCT03 (IND228)	0.164	0.051	0.139	0.027	0.243	0.430	0			
LCOD01 (IND231)	0.110	0.200	0.176	0.177	0.028	0.116	0.315	0		
LCT04 (IND232)	0.147	0.087	0.155	0.024	0.124	0.203	0.055	0.177	0	
WCT (IND069)	0.110	0.057	0.124	0.027	0.118	0.278	0.055	0.118	0.043	0

Table 5
Pairwise population F_{st} values of coconut population from Agatti and Kavaratti Islands of Lakshadweep, WCT (Control).

Accession	LCT01 (IND222)	KAIT01 (IND223)	LMT01 (IND224)	LMT02 (IND225)	LMT03 (IND226)	LCT02 (IND227)	LCT03 (IND228)	LCOD01 (IND231)	LCT04 (IND232)	WCT (Control) (IND069)
LCT01 (IND222)	0									
KAIT01 (IND223)	0.064	0								
LMT01 (IND224)	0.033	0.061	0							
LMT02 (IND225)	0.059	0.044	0.093	0						
LMT03 (IND226)	0.054	0.134	0.128	0.071	0					
LCT02 (IND227)	0.175	0.222	0.252	0.126	0.053	0				
LCT03 (IND228)	0.117	0.062	0.133	0.024	0.130	0.157	0			
LCOD01 (IND231)	0.095	0.171	0.179	0.105	0.018	0.054	0.161	0		
LCT04 (IND232)	0.101	0.103	0.160	0.019	0.056	0.072	0.043	0.081	0	
WCT (IND069)	0.095	0.086	0.153	0.020	0.063	0.104	0.044	0.067	0.019	0

to insufficient nut water to support its growth and therefore require the embryo culture technique for its rescue. Efforts are underway to rescue these plantlets and conserve it as germplasm collections (CPCRI, 2002).

According to the theory on origin, domestication and dissemination of coconuts around the world, while the whole *Cococeae* tribe probably originated in the South American region of the original Gondwana land mass, coconuts disseminated by floating between offshore islands as plate tectonics separated the Indian sub-continent from Africa. These wild type coconuts evolved as long angular fruit by natural selection, capable of long distance dissemination by sea, in both Indian and Pacific oceans. Domestic type coconuts, selected by early cultivators in South East Asian countries for large nut volume as a refreshing drinking water source were subsequently carried during long voyages by ancestors of the Polynesians, who reached Madagascar in the west and Samoa in the east. Introgressive hybridisation between the domesticated type (large, spherical coconuts having desirable attributes for human consumption and cultivation) and the wild type, (long angular coconuts, evolved by natural selection for large distance dissemination by sea) gave rise to the present diversity of coconuts around the world (Harries, 1978).

Fig. 2. Laccadive Mini Micro, smallest known coconut form in the world.

The fruit component and molecular analysis of coconut populations around the world distinguished two main groups of coconuts viz., the South East Asian and South Pacific coconut comprising the Dwarfs and the Indian Ocean types. The fruit component analysis of Indian Ocean coconuts showed that these coconuts types are Niu Kafa types. The occurrence of small sized nuts in the Lakshadweep Islands raises questions about the evolutionary and genetic advantages of these nuts. Is the occurrence of the Laccadive Micro Tall coconut palms a genetic compensation for the large number of female flowers/bunch or severe inbreeding depression or high outcrossing? Out of the three Laccadive Micro Tall types studied two types showed high outcrossing and heterozygosity while the other one showed high inbreeding coefficient comparable to dwarf type coconuts, indicating extreme forms of pollination may contribute to the occurrence of Micro Tall types. Alternatively, the sporadic occurrence of the Micro Tall types can be explained by the introgressive hybridisation with other coconut types and the resurfacing of these alleles in specific ratio to give rise to these types. Similar, Micro forms of coconut types have been reported from southern tip of Indian mainland and popularly called in vernacular name as Ayiramkachi (meaning 1000 nuts bearer) Tall (Ramachandran et al., 1977) and identified and collected from uninhabited places in Andaman and Nicobar Islands also. The relatively high frequency

Table 6
Molecular variance among the nine coconut accessions from Agatti and Kavaratti Islands.

Source	df	SS	MS	Est. Var.	%
Among Pops	8	172.375	21.547	1.181	9%
Among Indiv.	23	303.250	13.185	1.671	13%
Within Indiv.	32	315.000	9.844	9.844	78%
Total	63	790.625		12.696	100%

Table 7
Maternal parentage analysis for the four Laccadive elongated Orange nuts (LCT04) with the Orange Dwarf cultivars such as Laccadive Orange Dwarf (LCOD01), Chowghat Orange Dwarf (COD) and Malayan Orange Dwarf (MOD).

Offspring	Palm ID	Candidate mother	Palm ID	Loci typed	Pair loci compared	Pair loci mismatching	Pair LOD score	Pair delta
LCOT04	1	LCOD01	2	7	7	2	−3.72	0.00
LCOT04	1	MOD	1	6	6	2	−7.86	0.00
LCOT04	1	COD	2	6	6	3	−2.99	0.00
LCOT04	1	COD	4	7	7	4	−4.05	0.00
LCOT04	1	COD	3	7	7	4	−4.05	0.00
LCOT04	1	COD	1	7	7	4	−4.05	0.00
LCOT04	1	MOD	4	7	7	4	−4.05	0.00
LCOT04	1	MOD	2	7	7	4	−4.05	0.00
LCOT04	1	MOD	3	7	7	4	−4.05	0.00
LCOT04	1	LCOD	1	8	8	5	−5.27	0.00
LCOT04	2	LCOD	1	8	8	2	−5.84	0.00
LCOT04	2	MOD	3	7	7	3	−2.94	0.00
LCOT04	2	MOD	2	7	7	3	−2.94	0.00
LCOT04	2	MOD	4	7	7	3	−2.94	0.00
LCOT04	2	COD	1	7	7	4	−4.27	0.00
LCOT04	2	COD	3	7	7	4	−4.27	0.00
LCOT04	2	COD	4	7	7	4	−4.27	0.00
LCOT04	2	COD	2	6	6	4	−4.32	0.00
LCOT04	2	MOD	1	6	6	4	−4.35	0.00
LCOT04	2	LCOD01	2	7	7	5	−4.95	0.00
LCOT04	**3**	**LCOD01**	**1**	**8**	**7**	**1**	**2.11**	**2.11**
LCOT04	3	LCOD01	2	7	6	3	−9.53	0.00
LCOT04	3	MOD	3	7	6	3	−3.18	0.00
LCOT04	3	MOD	4	7	6	3	−3.18	0.00
LCOT04	3	MOD	2	7	6	3	−3.18	0.00
LCOT04	3	COD	2	6	6	4	−4.32	0.00
LCOT04	3	COD	4	7	6	4	−4.32	0.00
LCOT04	3	COD	1	7	6	4	−4.32	0.00
LCOT04	3	COD	3	7	6	4	−4.32	0.00
LCOT04	3	MOD	1	6	6	4	−4.35	0.00
LCOT04	4	LCOD01	1	8	8	2	−6.52	0.00
LCOT04	4	MOD	3	7	7	3	−3.13	0.00
LCOT04	4	MOD	2	7	7	3	−3.13	0.00
LCOT04	4	MOD	4	7	7	3	−3.13	0.00
LCOT04	4	COD	1	7	7	4	−4.27	0.00
LCOT04	4	COD	3	7	7	4	−4.27	0.00
LCOT04	4	COD	4	7	7	4	−4.27	0.00
LCOT04	4	COD	2	6	6	4	−4.32	0.00
LCOT04	4	MOD	1	6	6	4	−4.35	0.00
LCOT04	4	LCOD01	2	7	7	5	−4.95	0.00

The bold values indicate the likelihood of LCOT04 (palm ID-3) being a first generation hybrid of LCOD01 (palm ID-1) on account of high LOD score. The others palms may be a later generation hybrids.

of occurrence of this micro coconut forms in thinly populated areas like Lakshadweep and Andaman and Nicobar Islands may be due to less human intervention on selection. The genetic and environmental factors favouring these small types are yet to be determined.

The present study exhibits the diverse nature of Lakshadweep coconut populations. The high oil and drought tolerance nature are common to Lakshadweep coconuts over the diversity observed for morphological traits and microsatellite profile. There is a need to collect and conserve the desired types from the existing natural coconut populations of Lakshadweep Islands where human selection played very little role to minimise the natural diversity among standing coconut plantations. Reports about the smallest coconut types, sweet husked coconut, and giant sized coconut underline the need to explore the Islands for conserving new variability in coconut and use them in future improvement programmes. Laccadive Micro Tall accession conserved at CPCRI was found to be suitable for ball copra production (CPCRI, 2009) which is the common form of coconut consumption in non-traditional areas of northern India. Although farmers prefer growing Laccadive Ordinary Tall for local consumption and for oil extraction, the promotion of Laccadive Micro would open an avenue for production of high quality ball copra which would fetch premium price in the market. The ball copra, due to its increased sweetness because of absorption of nut water by the kernel and free from microbial contaminants is favoured by the confectionary industries over the cup copra and normal nuts. The diversity available within this Laccadive Micro Tall for fruit size and regular or irregular bearing habit may have influence over the yield potential of the palms. Hence further selection of micro talls using molecular markers would be helpful in utilizing this type for further improvement and utilization.

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