Unexploited diversity in coconut palm (*Cocos nucifera* L.)

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Summary

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The morphological characters of four coconut palms possessing mutant traits are described: plicata (fused leaflets) bi-spatheate (double spadix cover), persistent petioles and inflorescence, and rosette seedling with 12 leaves. Of 71 palms in a Niu Leka Dwarf population, one palm (no. 5/36) has a high degree of fused (plicata) leaflets (>70%) and two palms are bi-spatheate (nos. 5/18 and 5/16). The plicata palm had a long juvenile period (13 years), which agrees with other reports. The bi-spathe palm has reduced leaf length, also in agreement with earlier reports. A palm in Hut Bay, Little Andaman having a persistent petiole, and a rosette seedling in a farmer's garden are also described. Reports on plants with such novel traits supported by morphological, genetic, biochemical, cytological and ecological data are discussed. These traits result mainly from inbreeding or recessive mutations. After detailed investigation on these mutant traits, they could serve as markers in identifying inbred palms or palms with recessive alleles in a population. This could help to exploit the hybrid vigour in coconut palm.

Key words: Bi-spatheate, coconut, *Cocos nucifera*, plicata, World Coconut Germplasm Centre (WCGC)

Résumé

Une diversité non exploitée chez le coconut palm (*Cocos nucifera* L.)

Les charactéristiques morphologiques de quatre cocotiers possédant des traits mutants sont décrits: plicata (feuilles en fuseau) bi-spatheate (couverture par un double spadice), petiole persistant et inflorescence, et rosette faisant des graines avec 12 feuilles. De 71 palmiers d'une population de Niu Lekha, un palmier (no. 5/36) atteint un haut degree de feuilles en fuseau (plicata) (>70%) et deux palmiers sont bi-spatheate (nos. 5/18 et 5/16). Le palmier plicata a eu une longue prériode juvenile (13 ans), ce qui est en accord avec d'autres rapports. Le palmier bi-spathe a des feuilles de longueur réduite ce qui est également en accord avec des rapports précédents. La description est également faite d'un palmier à Hut Bay, Little Andaman ayant un petiole persistant et une rosette plantule chez un fermier. Des rapports contenant les données morphologiques, génétiques, biochimiques, cytologiques et écologiques sur des cultivars ayant ces traits recherchés sont discutés. Ces traits sont principalement le produit d'une reproduction intraspécifique ou de mutations recessives. Après une investigation détaillée de ces charatères mutants, ils pourraient être utilizes comme marqueurs dans l'identification de palmier issu de reproduction intraspécifique ou des palmiers possédant des alleles recessives dans une population donnée. Ced pourrait aider l'exploitation de la vigueur des hybrides chez le cocotier.

Resumen

Diversidad no explotada del cocotero (*Cocos nucifera* L.)

Se describen las características morfológicas de cuatro cocoteros con rasgos mutantes: plicata (hojas plegadas), bi-spatheate (doble capa de espata), peciolos e inflorescencia persistentes, y plántula en roseta con 12 hojas. De 71 cocoteros en un rodal de Niu Lekha Dwarf, uno (n° 5/36) tiene una alta proporción de hojas plegadas (plicata) y dos cocoteros son bi-spatheate (n° 5/18 y n° 5/16). El cocotero plicata tuvo un largo periodo juvenil (13 años), lo que concuerda con otros informes. El cocotero bi-spathe tiene hojas cortas, también de acuerdo con informes anteriores. Se describen asimismo un cocotero en Hut bay, Little Andaman, con un peciolo persistente, y una plántula en forma de roseta en el jardín de un granjero. Se analizan Informes sobre plantas con rasgos novedosos apoyados en datos morfológicos, genéticos, bioquímicos, citológicos y ecológicos. Estos rasgos resultan principalmente de la endogamia o de mutaciones recesivas. Una vez investigados detenidamente estos rasgos mutantes, podrían servir como marcadores para identificar cocoteros endogámicos o cocoteros con alelos recesivos en un palmeral, lo que podría ayudar a explotar el vigor híbrido del cocotero.

Introduction

Coconut palm is one of the multipurpose perennial crops of the humid tropics. It is grown in more than 80 countries in an area of nearly 11 million hectares. The crop supports small and marginal farm families living in the Developing World, especially in and is part of the fragile ecosystems of small islands. Genepool enrichment is one of the proven methods of coconut improvement. A compilation by Batugal and Ramanatha Rao (1998) gives progress on germplasm collections of different countries. Bourdeix *et al.* (1989) suggest the use of individual combining ability tests to obtain planting materials of 20-30% superiority over currently available hybrids. The efforts made on coconut improvement so far have concentrated on utilizing variation over a geographical range. However, the quarantine risk of germplasm exchange poses a serious limitation in exploiting that variation. Therefore it is important to use morphological diversity within a region to its maximum potential. The use of Macapuno (the jelly-like endosperm) in the food industry is a good example of successful utilization of morphological diversity. There are other morphological variants (Menon and Pandalai 1960) such as albinism (lack of chlorophyll), aromatica (fragrant endosperm), change in sex expression and plicata (fused leaflets). These traits have not been used to their potential. This report discusses such

Table 1. Reported variants for morphological traits in coconut palm

	Variants
Habit	Tall, dwarf and intermediate forms
Leaf	Normal, albinism, plicata, small or long leaf/leaflet
Floral	Vegetative transformation (bulbils), midget/hapxanthic, very early to very late flowering/bearing, spicata, secondary spikelets, apocarpy, persistent inflorescences on stem
Sex expression	(Dioecy) Male/female, male sterility, hermaphrodite
Fruit	Jelly like endosperm, fragrant endosperm, edible husk Variable size of fruit (<50 g to 3 kg) and husk proportion (20-80%) Beak, ring or horn-like structures on fruit

variants and the relevance of these rare traits to the plant breeder. Arunachalam (1999) reviewed the range of variability of morphological traits in coconut (Table 1).

The variations in such traits could be either genetic or physiological in nature. Tall and Dwarf are the two morphological contrasting forms of coconut which have given sufficient scope in hybrid production to lead to a reduction in the pre-bearing age and improvement in nut yield. Rare traits such as plicata, late flowering / bearing, bi-spatheate (spadix covered by two spathes instead of one) and secondary spikelets (further branching of spikelets) have been reported in Talls. Dwarfs possess other rare traits such as polyembryony, vivipary (general observation) and pigment variation in leaf / nuts (de Lamothe and Rognon 1977; Ratnambal *et al.* 1995).

Materials and methods

In the World Coconut Germplasm Centre (WCGC), Sipighat Farm located in Sipighat village of Port Blair, Andaman & Nicobar Islands, India, 20 Tall and 4 Dwarf exotic accessions of coconut collected from six Pacific Ocean territories and 6 Tall indigenous accessions from Nicobar islands are being maintained. Out of the 4 Dwarf accessions, Niu Leka (Fig. 1) Dwarf (Fiji Islands), is an important accession because it combines the traits of Dwarfs—short internodal distance and early flowering/bearing—with that of Tall variety traits such as allogamy and large fruits. There are 71 palms in this population, which are 17 years old. One palm (no. 5/36) has shown a high degree of fused (plicata) leaflets (>70%), two palms have shown bi-spathes (nos. 5/18 and 5/16). Apart from these, another two palms and two seedlings were studied for the following traits of interest:

- A palm of local Tall at Hut Bay, Little Andaman, India possessing persistent petioles and inflorescences (Rao and Sampathkumar 1998)
- A palm showing bispatheate and secondary spikelets with leaves of plicata nature (Fig. 2) at CPCRI field trials, Kasaragod, Kerala, India (TT 50)
- Two seedlings with rosette leaves (Fig. 3).

Results and discussion

Morphological details of the palms having mutant traits are given in Table 2. The details of palms having such mutant traits reported by earlier workers along with the genetic, biochemical, ecological, cytological basis are discussed below.

Fig. 1. Niu Leka dwarf.

Fig.2. TT 50 coconut palm.

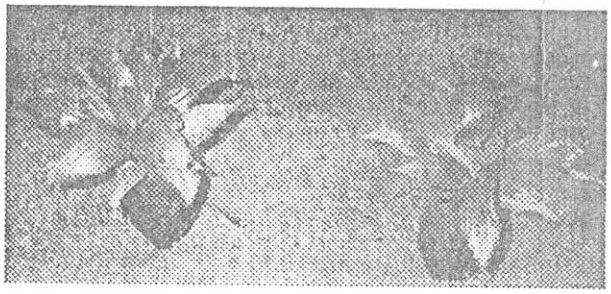

Fig. 3. Rosette seedlings.

Plicata

Plicata is a situation in which the leaflets remain fused, as seen in seedling leaves (Sugimura *et al.* 1994b). Palm no. 5/36 of WCGC has the characteristic plicata leaves (recapitulation/embryonic similarity). It remained in the vegetative phase for 13 years. As it has been reported that boron deficiency can cause similar symptoms in coconut, palm 5/36 was given a regular application of borax (50 g/plant annually). In contrast to the palms suffering with boron deficiency, plicata palms applied with boron did not show any response. In spite of the treatment, it produced only one inflorescence without fruits. However, species and varietal

Table 2. Morphological characterization of palms with mutant traits

Character	5/18 regular bi-spathe	5/16 recent bi-spathe	5/36 plicata	TT 50 (bi-spatheate + plicata + secondary spikelets)	Persistent inflorescence palm at Little Andaman
Plant height (cm)	265	260	453	973	1200
Girth of collar (cm)	106	107	110	108	213
No. leaves on crown	20	21	14	23	15
Petiole length (cm)	115	126	116	135	145
Length of leaf-bearing portion (cm)	266	275	244	370	310
No. leaflets	196	215	183	86	98
Breadth of leaflet (cm)	5.4	5.7	5.6	7.6	3.8
Length of leaflet (cm)	96	100	85	130	100
No. leaf scars in 1 m	32	45	24	17	12
Internodal length (cm)	3.12	2.224.16	4.16	5.88	8.12
Length of inflorescence (cm)	98	95	NA	90	102
Length of spikelet-bearing portion (cm)	50	52	NA	50	33
Length of spikelet (cm)	23	23	NA	40	35
No. spikelets/inflorescence	66	58	NA	(204)† 12	(122) †51
No. female flowers/inflorescence	34	58	NA	14	90

NA—Not available †Figures in parentheses are number of secondary spikelets.

differences in uptake and translocation of boron have been observed in tomato (Bellaloui and Brown 1998). In Oil Palm, this is controlled by a single recessive gene (Zeven 1964). The genetics of this trait in coconut have not been studied yet. In future we could analyze this trait to study its heritability, so that the trait could be utilized better.

The degree of fusion of leaflets in any leaf of this palm was more than 70%. Poor people use plaited coconut leaves as housing materials in coastal areas. Leaves of these variant palms could be used in those areas to save work, as plaiting (knitting the leaflets by hand) the leaves is not necessary.

Amphiblastic species produce two types of leaves. One form of leaf structure persists only during the juvenile stage. The other form persists throughout the rest of the plant's life. In species from dry regions, seedling type of leaf production stops at a relatively early age (Stebbins 1964). Plicata palms are known to begin flowering late compared with other palms. A delay of 29 months in flowering was observed in a plicata palm by Sugimura *et al.* (1994b). The cytological nature of an abnormal palm, which remained without fruits even after 14 years, was analyzed and found to have meiotic abnormalities leading to sterility (Thankamma Pillai and Vijayakumar 1972). Plicata palm is reported to have sterility (Mao and Lai 1993), delayed flowering (Sugimura *et al.* 1994b) and no female flower/fruit formation. A palm having similar traits at Batlagundu village (Dindigul Dt. Tamil Nadu, India) in a farmer' s garden (Fig. 4) also had produced no fruits 15 years after planting.

Fig. 4. Plicata palm.

Multi-spatheate

Coconut palm produces a single spathe to cover an individual inflorescence. In some rare palms, two to five spathes are seen covering a single inflorescence. These palms are known as multi-spatheate palms. Multispatheate palms have been reported by many workers to occur in West Coast Tall populations: bispatheate by Davis and Menon (1952), tri-spatheate by Thomas and Mathew (1960) and penta-spatheate by Michael (1963). Multi-spatheate palms have been reported at Hainan Island of China (Mao and Lai 1993). These multi-spatheate palms provide sufficient mechanical strength to the inflorescence to protect it from insect attack in the early stage of development (Michael 1963). Presence of this trait may offer protection against wind and reduce buckling (instead of being erect) of bunches. In Port Blair, the wind velocity ranges from 4.5 to 19.0 km/h, reaching a peak in June of 17–19 km/h. During cyclones, the wind velocity is very high.

At WCGC, palm 5/18 produced bispathes in every inflorescence. This palm is a very poor yielder. The other palm (5/16), which was a good regular bearer, has recently started the habit of producing bi-spatheate inflorescences (Fig. 5). This palm is growing on a portion of undulated land and there is a serious problem of wind damage causing buckling of bunches.

It triggers the interest of a breeder when the trait is seen in a new palm of the same population at a later stage. The implication of this trait offering evolutionary fitness and the nature of developmental genetics of the trait needs to be understood. A regular bi-spatheate palm at WCGC had brown petioles, which indicates its hybrid origin (possibly involving green and other coloured types).

Fig. 5. Bi-spatheate inflorescence.

Change in sex expression

Coconut palm is monoecious in nature, producing male and female flowers on spikelets in the same inflorescence. Female-dominant palms have no spikelets and are known as spicata. Male-dominant palms show branching of spikelets and are known as androgena. Spicata palms were reported in the Philippines by Sugimura *et al.* (1994c). Two of the five inbred lines of Markham Valley Tall had mutants (Sugimura *et al.* 1994a) showing secondary spikelets but with a normal pre-bearing period. This indicates the trait to be due to either recessive alleles or inbreeding depression. Secondary spikelets were always known to occur with an increased number of male flowers. Open-pollinated progenies of spicata palm segregated in 1:1 ratio of spicata and normal palms. Thus, earlier workers assumed the spicata trait to be in the (Ss) heterozygous state and dominant over normal (ss) inflorescence. Spicata palm also has shown many meiotic irregularities and a high degree (12%) of pollen sterility (Ninan and Satyabalan 1963). Androgena palms have shown meiotic abnormalities such as aneuploidy ($2n-1$) in a few cells (Ninan *et al.* 1960).

Palms with persistent petiole bases / inflorescences

A palm in Hut Bay of Little Andaman showed persistent petiole bases and inflorescences. This character is common in other palms such as Palmyrah (*Borassus flabellifer*). When we characterized this palm for morphological traits, the collar girth was very large (213 cm). Trunk diameter is an important character in classifying coconut forms. Self pollinated Dwarfs are known to have slender trunks. Selfing up to three generations in families of Mapanget Tall (Indonesia) has reduced trunk diameter (Novarianto *et al.* 1991). This palm started bearing very late and the inflorescences had secondary spikelets (Fig. 6).

Rosette seedlings

Two-rosette seedlings found in a farmer's garden at Batlagundu village (Dindigul Dt. Tamil Nadu, India) had an unusually high number of leaves and large collar girth (Fig. 3). Seedlings with high collar girth and large number of leaves are known to have good yield potential (Satyabalan and Mathew 1984). As bulk seed nuts were used, the parental palms which resulted in these seedlings could not be traced. However the performance of these seedlings could be studied in the future.

Biochemical / molecular markers

In makapuno mutant endosperm, the activity of alpha galactosidase enzyme was found to be 8300-fold lower than the normal endosperm. Makapuno and normal endosperms also differed in the activity of peroxidase and tryptophan aminotransferase enzymes (Mujer *et al.* 1984).

Molecular markers were helpful in analyzing the genetic divergence and understanding the origin and domestication process (Perera *et al.* 2000). Furthermore Teluat *et al.* (2000) noticed the heterogeneity of Niu Leka Dwarf (Fiji) using (AFLP and SSRs) molecular markers. They attributed it to the cross-pollinating nature of the accession.

Relationship with other traits

The measurements of morphological characters of these rare palms improve the understanding of relationship between traits. The palms with Horned fruits (Jerard *et al.* 1999) had the widest leaflets (7.5 cm) and a harder shell (0.45 cm). Generally, the leaflet breadth in coconut ranges from 4.0 to 6.0 cm and shell thickness varies from 0.2 to 0.3 cm (Ratnambal *et al.* 1995). The palm TT 50 (Fig. 2) having plicata, bispatheate and secondary spikelets also had the widest leaflets (7.6 cm) and as hard a shell (0.4 cm) as the Horned fruit type. Reduced leaf length was also observed in dual and multi-spatheate plams by Mao and Lai (1993). During the germplasm survey in the Seychelles, Kumaran *et al.* (1998) observed that the mutant Macapuno type having jelly-like endosperm ('Coco Gra Tall') had reduced leaflet length. This macapuno trait results in abortion of embryo and is known

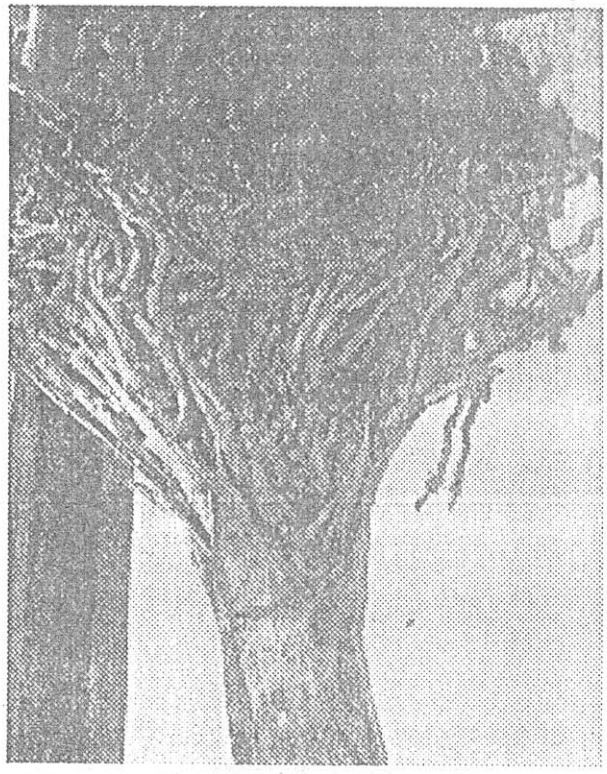

Fig. 6. Secondary spikelets.

to be due to a lethal recessive gene (Cedo *et al.* 1984). Embryo culture could rescue plants with this trait. Reduced leaflet length also was observed in spicata palms in CPCRI field trials. Normally self-pollinated Dwarfs also have short leaf / leaflet. Selfing up to three generations in family 55 of the Mapanget Tall (Indonesia) form showed reduction in leaf and petiole length (Novarianto *et al.* 1991). Of the four pure F_2 Macapuno bearing palms (progenies of Dwarf x Macapuno Tall), two showed very good vigour and early (36-37 months) flowering (Nunez and Depaz 1994). This indicates the importance of the mutant traits in exploiting the hybrid vigour / transgressive segregation.

Generally Dwarfs are early bearing. Hybrid progeny between Tall and Dwarf accessions generally resemble the Dwarf parent in early bearing trait. Dominance of long leaf, early bearing and single branching over short leaf, late bearing and secondary spikelets respectively is generally seen in the hybrid progenies. However, a detailed investigation on the genetics of traits associated with rare palms such as late bearing, short leaves and secondary spikelets is required to confirm this idea. Selfing of the palms 5/18 and 5/16 at Port Blair and a palm (TT-50) with secondary spikelets is in progress, which is expected to yield interesting results. Molecular biological investigations of these traits could provide additional information.

Markers for Inbred palms

This information hints at the possibility of linkage between novel traits and recessive alleles or of those of an inbred nature. Development of inbred lines in a perennial crop such as coconut would take decades as there is no viable vegetative propagation method available in this crop. The inferences from the study will aid in locating palms of use in hybrid development using morphological markers. The results after confirmation have practical implications in aiding the coconut breeder.

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