

# Palms

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### FRONT COVER

*Adonidia merrillii* on a steep slope in forest over limestone on Danjungan Island, Philippines. See article by E.S. Fernando, p. 57. Photo by E.S. Fernando.

## Palms (formerly PRINCIPES)

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## CONTENTS

- 57**     ***Adonidia merrillii* – a New Wild Population in the Philippines**  
E.S. FERNANDO
- 
- 62**     **A New Nothospecies and Two Cultivars for the Hybrids in Cultivation between *Butia odorata* and *Jubaea chilensis***  
D.R. HODEL
- 
- 72**     **Revisiting the Neotropical Genera *Chelyocarpus*, *Cryosophila* and *Itaya* (Coryphoideae: Cryosophilae)**  
F. CASTAÑO G., R. SPICHTER & F.W. STAUFFER
- 
- 84**     **Phenology and Germination of the Chonta Palm, *Astrocaryum gratum*, in a Sub-montane Forest**  
E. ALIAGA-ROSSEL
- 
- 93**     **Palm Conservation at a Botanic Garden: a Case Study of the Keys Thatch Palm**  
P. GRIFFITH, C. LEWIS & J. FRANCISCO-ORTEGA

### Features

Palm News	56
Palm Literature	102

### BACK COVER

×*Jubautia splendens* 'Don Nelson,' Overfelt Gardens Park, San Jose, California. See article by D. Hodel, p. 62.

# PALM NEWS

Alison Shapcott and Heather James of the University of the Sunshine Coast, Australia, have recently analyzed the genetics of the known population of *Tahina spectabilis* that consists of one main population and two isolated individuals. The analysis discovered evidence suggesting that there are other undiscovered populations in relatively close proximity to the main population. One of the isolated plants appeared to have arisen from another as yet unknown population. A paternity analysis of seedlings produced in 2006 found evidence of pollination from a father plant whose genetic profile is different from all known individuals of *Tahina*. This information prompted recent searches of the region within a certain range by Xavier Metz and his workers and resulted in the **discovery of a new population of *T. spectabilis***. This population had been largely burnt; however, observations of the seedlings present suggested that the parent plant did not flower at the same time as the flowering events in the main population and therefore could not be the father plant. This has encouraged further searches in the hope of finding yet more populations.

Almost 30 palm scientists from all over Europe and even further afield gathered together in the beautiful historic city of St Petersburg, the Russian Federation, for the **annual EUNOPS (European Network of Palm Scientists) meeting** on 16 and 17 April. The meeting was held in the Komorov Botanical Institute situated in the middle of the Peter the Great Imperial Botanic Garden. A wide range of papers and reports were given covering subjects ranging from historical biogeography, evolution and development, DNA-barcoding, reproductive biology, palm domestication, floristics, fossils and conservation. Tours of the wonderful historic greenhouse collections were also provided.

**Researchers in Brazil critically examined *Euterpe edulis* and its synonym *E. espiritosantensis* and concluded that they are two distinct species.** Wendt and colleagues demonstrated that the two species differ in size and duration of the peduncular bract, and in inflorescence and immature fruit color. They have overlapping flowering periods but with distinctly different flowering peaks. These differences in morphological and reproductive features suggest that co-occurring populations are reproductively isolated to a reasonable degree, which supports the recognition of *E. espiritosantensis* as a distinct species from *E. edulis*. The findings are published in the journal *Flora* (206: 144–150. 2011).

**New web tools help palm growers identify the diseases and pests of palms.** The Screening Aid to Pests, has photos, fact sheets and host information for many of the common arthropod (insect and mite) pests of palms. The web site is at <http://itp.lucidcentral.org/id/palms/sap/index.html>. A linked resource assists growers in identifying the diseases and disorders of palms: <http://itp.lucidcentral.org/id/palms/symptoms/index.html>. On a related topic, a recent publication by R. Ocoa and colleagues (*American Entomologist* 57: 26–29. 2011) has vivid SEM photographs of how the red palm mite, *Raoiella indica*, feeds on palms. The mite has telescoping, stylus-like mouthparts that pierce the cells of palms and suck out their content. Even palms with thick, waxy cuticles are vulnerable, as this cunning adversary can insert its mouthparts through the stomata (the tiny “breathing” pores on plant leaves) and feed on cells within them. This feeding behavior is one reason why this mite has become such a vicious pest of palms.

A Resource for Pests and Diseases of Cultivated Palms  
**SCREENING AID TO PESTS**  
 HOME KEYS FACT SHEETS GLOSSARY ABOUT > INSECT ANATOMY

**Leaf Beetles**  
 The vast majority of leaf beetles that are considered pests of palms belong to the Hispanic subfamily Chrysomelidae, and are leaf miners. Adult leaf beetles range from 2-25 mm in length, and are elongate, oval to orbicular in shape.

FACT SHEET

**About This Tool**  
 The pages of this tool offer a variety of resources to aid the user in the identification of arthropod palm pests.

**Taxa Covered**  
 This tool includes arthropod pests of palms from the U.S. and the Caribbean.

**Palm Resource**  
 Learn more about the commodity-based resource A Resource for Pests and Diseases of Cultivated Palms.

OCTOBER 8, 2010

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# *Adonidia merrillii* – a New Wild Population in the Philippines

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1. *Adonidia merrillii* with ripe fruits. Note old infructescences with remnants of fruiting calyx.

A new population of a familiar palm has been discovered in the wild on Danjugan Island, off the southwestern coast of Negros Island, Philippines.

*Adonidia* (Arecoideae: Areceae: Ptychospermatinae) currently has only a single species, *Adonidia merrillii* (Becc.) Becc. It was previously included in the genus *Veitchia* (Moore 1957), but cladistic analyses showed that it is a distinct taxon in an isolated lineage within the subtribe Ptychospermatinae (Zona 1999, Zona & Fuller 1999).

*Adonidia merrillii* is commonly known as “Manila palm” or “Christmas palm.” It is probably the most familiar, most popular and most widely cultivated palm in the world that is native of the Philippines. It was, in fact, in cultivation in Manila since about 1875 (Merrill 1922), and its origin was still unknown when it was first described (as *Normanbya merrillii* Becc.) in 1909 as new to science (Beccari 1909). The species was then locally known as “Bunga de Jolo” and “Bunga de China” as the fruits were also a good substitute for those of *Areca catechu*. The name “Bunga de Jolo” was thought to indicate the true origin of the cultivated palm (Beccari 1909, Brown & Merrill 1920), but this species has, thus far, not been recorded from Jolo Island, nor is there an extant specimen collected in the wild from there.

By 1919, *Adonidia merrillii* was known in the wild from at least two localities, both on Palawan Island: Brooke’s Point, in sandy soil of beach forest (*Elmer 12708*, February 1911, FI, K) and Apulit Island, in Taytay Bay, on

limestone slopes, on the north-eastern part of Palawan (*Merrill 9415*, May 1913, FI) (Beccari 1919a, b). In 1984, during the Palawan Botanical Expedition, the species was also discovered on Malapakan (= Langen) Island in Bacuit Bay on karst limestone cliffs (*Podzorski 832*, April 1984, K), on the north-western side of Palawan (Podzorski 1985, 1986). It is also known on Inabuyan and other similar small islands near the El Nido area in Bacuit Bay and also on nearby Coron Island. The El Nido area is part of the El Nido Managed Resource Protected Area (that includes a large marine sanctuary) in northern Palawan.

*Adonidia merrillii* is no longer restricted to the Philippines, as it is now also known from the large island of Borneo. It has been collected in the wild on a hill slope by the sea in the Lema’as Forest Reserve, Tuaran District, in Sabah, Malaysia (*Diwol Sundaling et al. 140875*, January 2005, K, SAN).

In this paper I report on a new locality for a wild population of *Adonidia merrillii* outside of Palawan in the Philippines. This new locality, Danjungan Island, off the south-western coast of Negros Island, is about 330 km eastward from Apulit Island across the northern part of the vast Sulu Sea.

Danjungan is a relatively small, uninhabited, coral-fringed island, approximately 0.48 km<sup>2</sup> in area, 1.65 km long, and with maximum

2. A group of at least eight individuals *Adonidia merrillii* on a ridge.





3 & 4. *Adonidia merrillii* is a prominent component of the vegetation on Danjungan Island, occurring as scattered individuals and as large, dense groups on the ridges and slopes on the west coast of the island.

width of 0.5 km, with a highest elevation of only 80 m (Beger et al. 2005). The island is mainly of limestone substrate with several cave formations and six lagoons, most of which are surrounded by mangrove forests (see also King et al. 2002, O'Malley et al. 2006).

The island has been privately owned and managed by the Philippine Reef and Rainforest Conservation Foundation Incorporated since 1995. In 2000, it was formally designated as the Danjungan Island Marine Reserve and Sanctuaries (DIMRS) by the municipal

government of Cauayan and provincial government of Negros Occidental (Beger et al. 2005). Access to the island is restricted. This island marine reserve was featured in the book on *The National Parks and Other Wild Places in the Philippines* by Hicks (2002).

The flora of Danjungan Island was briefly described by O'Malley et al. (2006) with the following: "With respect to the island's flora, approximately 75% is forested and 50% of this area is secondary forest where some palms (*Areca catechu* [sic] and *Cocos nucifera*) and figs (*Ficus* spp.) dominate." The *Areca catechu* referred to in this statement is clearly *Adonidia merrillii*, as the former has not been observed, nor is it anywhere dominant, on the island. The coconut palms (*Cocos nucifera*) have obviously been planted.

The discovery of *Adonidia merrillii* on Danjungan Island (Fernando 2230, May 2010, LBC) is rather surprising as wild populations of this species in the Philippines have, for a long time, been known only from the Palawan area. The collection from Sabah, Malaysia cited above is relatively recent. The presence of *Adonidia merrillii* in Palawan, however, has also been regarded as odd and a rare disjunction, as its relatives in the subtribe Ptychospermatinae are found only farther east of Wallace's Line in Maluku, New Guinea, Australia, and Melanesia (Dransfield 1981, Baker et al. 1998, Zona 1999). Although the new locality reported here brings the species just a little closer in physical distance to its relatives, its absence on Mindanao and the adjacent small islands remains a mystery.

*Adonidia merrillii* is included in the Endangered (EN) category of the *National List of Threatened Philippine Plants* issued as Department of Environment and Natural Resources (DENR) Administrative Order No. 2007-01 pursuant to Philippine Republic Act No. 9147, the Wildlife Resources Conservation and Protection Act (Fernando et al. 2008). In the recent IUCN Red List the species is given a Lower Risk/Near threatened (LR/nt) status (IUCN 2010). Under Philippine law there are stiff fines and penalties for the illicit collection and trade of any plant species of wild origin included in the *National List of Threatened Philippine Plants* (Fernando et al. 2008).

On Danjungan Island, *Adonidia merrillii* is a prominent component of the vegetation reaching 10–15 m tall. It occurs singly (Fig. 1) or in small or large dense groups (up to 25 individuals) on the ridges and steep slopes

(Figs. 2–4), with some individuals occasionally reaching the lower rocky slopes near the sandy beach. It tends to be more common on the western side of the island. Many individuals are often in fruit (Fig. 1 and Front Cover), and seedling recruitment is evident (Fig. 5). I estimate no more than a few hundred mature individuals of this species on the small island.

The wild population of *Adonidia merrillii* on Danjungan Island is nationally and globally significant in genetic resource conservation terms. It is hoped that the protected status of *Adonidia merrillii* and that of Danjungan Island and the El Nido area in northern Palawan will help ensure the continued survival of this palm species in the wild.

### Acknowledgments

I am very grateful to Gerardo L. Ledesma and the Philippine Reef and Rainforest Conservation Foundation Inc. (PRRCFI) for allowing me access to Danjungan Island to study *Adonidia*. I thank Apolonio Cariño, Office of the Governor, Negros Oriental Province, for helping facilitate coordination with PRRCFI; Rene Vendiola, an avid plant and bird enthusiast, who first brought my attention to the presence of *Adonidia* on Danjungan Island; and Marlito Bande, Visayas State University, for transport logistics and usual excellent companionship in the field.

5. Seedlings of *Adonidia merrillii* in various stages of development indicating recruitment into the population.





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# A New Nothospecies and Two Cultivars for the Hybrids in Cultivation between *Butia odorata* and *Jubaea chilensis*

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*Butia odorata*, with its characteristic gray-green, formal, recurving, arching leaves, and *Jubaea chilensis*, with its massive trunk, are two of the most distinctive and easily recognizable species in the palm family. Palm growers and collectors have recently recognized the possibility of artificial hybrids between these two species and here I describe and name an artificial hybrid species and two of its cultivars that make handsome ornamentals.

The use of the largely unfamiliar name *Butia odorata* rather than the more familiar *B. capitata* may surprise many palm growers and collectors. However, Noblick (2010), who provided a new interpretation and treatment of *Butia* for the account of the Arecaceae in Lorenzi's Brazilian Flora, has shown rather persuasively that the best name for the distinctive palm long known in cultivation as *B. capitata* is actually *B. odorata*. Noblick's interpretation shows that *B. odorata* occurs in far southern Brazil and Uruguay where it is likely more cold tolerant and suggests that it has long been cultivated in Florida and California but erroneously under the name *B. capitata*. In contrast, *B. capitata* occurs much farther north in Brazil, is likely less cold tolerant, and is probably little cultivated.

*Butia* and *Jubaea* are closely related (Attaleinae subtribe, Cocoseae tribe, Arecoideae subfamily [Dransfield et al. 2008]), and artificial and natural intra- and intergeneric hybrids in the Attaleinae are rather common and well documented. Well known artificial intergeneric hybrids in the Attaleinae include  $\times$ *Butiagrus nabonnandii* (*Butia odorata*  $\times$  *Syagrus romanzoffiana*) and  $\times$ *Lytogrurus dickensonii* (*Lytocaryum weddellianum*  $\times$  *Syagrus romanzoffiana*) (Hodel 2005) while *Attalea* and *Syagrus* both have several, natural intrageneric hybrids (Lorenzi 2010). As more palms are brought into cultivation in gardens and collections and growers and hybridizers, like Patrick Schafer and Richard Douglas in northern California and Jack Ingwersen in Thailand, ardently pursue artificial intra- and



1. *×Jubautia splendens* 'Dick Douglas,' Douglas garden, Walnut Creek, California, type (Hodel 2031).

intergeneric hybrids in the Attaleinae, the likelihood of unintentional or intentional hybrids between closely related species and genera will increase.

The artificial hybrid and its two cultivars presented and discussed here between *Butia odorata* and *Jubaea chilensis*, while intentional or not, have likely occurred in the last 40 to 50 years in two combinations, each the inverse of the other: 1) *B. odorata* as the pistillate or seed parent and *J. chilensis* as the staminate or

pollen parent; 2) *J. chilensis* as the pistillate or seed parent and *B. odorata* as the staminate or pollen parent.

Regardless of which is the pistillate or staminate parent, according to the rules of botanical nomenclature governing hybrids, both are included in the artificial hybrid genus *×Jubautia* that Demoly established for these genera in 2002 based on a plant in the famous Jardin des Cedres at St. Jean-Cap Ferrat near Nice, France. Also according to the rules, both

are included in the same artificial hybrid species; but because Demoly did not specify a hybrid species name when he established the hybrid genus, I provide one here.

×*Jubautia* Demoly, J. Bot. Soc. France 18–19: 189. 2002. **gen. hyb.** (*Jubaea* Kunth × *Butia* Becc.).

×*Jubautia splendens* Hodel **sp. hyb. nov.** (*Butia odorata* (B. Rodr.) Noblick & Lorenzi × *Jubaea chilensis* (Molina) Baill.).

Palma inter *Butiam odoratam* et *Jubaeam chilensem* quasi intermedia et hybridatione harum specierum orta, magnitudine habitus inter parentes media, ad illud habitu maiore, trunco maiore, pinnis pluribus, petiolis et rachidibus foliorum et bracteis pedunculorum longioribus, rachillis brevioribus differt; ad hoc habitu minore, trunco minore, pinnis paucioribus, petiolis et bracteis pedunculorum longioribus, rachillis pluribus et longioribus differt. Typus: CULTIVATED. U.S.A., California, Contra Costa County, Walnut Creek, garden of Richard Douglas. *D. R. Hodel 2031* (holotypus BH, isotypus HNT). Figs. 1–4, 12.

Solitary, moderate to robust, tree palms 10–15 m tall (Figs. 1, 5, 6, Back Cover). Trunks 65–90 cm diam., smooth, grayish, sometimes covered with persistent leaf bases. Leaves 45–60, pinnate, erect to arching and spreading, conspicuously grayish to blue-gray green; base

40 cm wide at attachment, 40–50 cm long, light green with glaucous bloom; petiole 1–1.35 m long or more, 8–14 cm wide and 4–6 cm thick near base, flat adaxially, convex abaxially, light green with glaucous bloom or with silvery and rusty brown tomentum, proximal margins with coarse hair-like fibers 40–60 cm long, each with a short, stiff, nearly woody base, fibers and teeth shortening to 5 mm long near rachis; rachis 2.3–3.2 m long, 4–5 cm wide and 1.5–2.5 cm thick at petiole, tapering to 1.5–3 mm wide and 1 mm thick at apex, flat adaxially with raised costa distally, convex abaxially, twisting 90–150° in the distal one-fourth, light green with glaucous bloom or with silvery and rusty brown tomentum; pinnae 90–100 on each side of rachis, regularly arranged, spaced 3–3.5 cm in midblade, to 6 cm apart distally, congested proximally, thick, stiff, leathery, straight, acuminate, lower middle largest, these to 100 × 3–4 cm, bluish gray-green adaxially, sometimes silvery abaxially, adaxially midrib prominent and elevated, 6–10 primary nerves inconspicuous, secondary and tertiary nerves numerous and faint, abaxially only midrib prominent, other nerves faint, numerous, mostly obscured by waxy bloom, ramenta on abaxial midrib in proximal 5 cm of each pinna, these brown to golden, to 15 mm long, much congested to imbricate, basi- or medifixed, most distal pinnae to 25 × 0.1–0.2 cm, proximal pinnae to

2. Marianne Hodel holds inflorescence of ×*Jubautia splendens* ‘Dick Douglas,’ type (*Hodel 2031*).





×*Jubautia splendens* 'Dick Douglas,' type (Hodel 2031). 3 (left). Staminate flower. 4 (right). Pistillate flower.

60 × 0.4 cm. Inflorescences several, interfoliar, arching to spreading in flower, spreading to drooping in fruit (Figs. 2, 7); peduncle 0.3–1.5 m long or more, 5 or 6 cm wide and 4–4.5 cm thick proximally, tapering to 4 or 5 cm wide and 3.5–4 cm thick at rachis, green-yellow or burgundy colored with glaucous bloom or brownish or tan tomentum; prophyll not seen, peduncular bract 1.95–2.6 m long or more, 25–35 cm wide, long-ovate, boat-shaped, thick, leathery to woody, burgundy to coppery colored adaxially, light green with sometimes dense tan to brownish tomentum abaxially; rachis 1–1.1 m long, tapering distally, burgundy colored with glaucous bloom and sometime conspicuously yellow at rachillae attachment; 140–190 rachillae, to 85 cm long, 12–25 mm wide and 5 mm thick at base, 1 mm diam. at apex, straight to slightly drooping. Flowers variable, in triads consisting of a central early-opening pistillate flower flanked on two sides by later-opening staminate flowers in proximal one-tenth to one-half of rachillae, these 1–1.5 mm distant and in clefts 5–8 mm long, 5 or 6 mm wide, 3 or 4 mm deep, sometimes with greenish yellow

hump on distal side of cleft 1 mm high and 5 mm wide, triad subtended by 3 or 4 bracteoles, 1 subtending each staminate flower, 1 or 2 subtending pistillate flower, all low, 1 mm high, broad; staminate flowers only, solitary or in dyads, in distal in distal two-thirds to one-half of rachillae, these 2–5 mm distant and in superficial clefts, sometimes with yellowish hump on distal side of cleft 0.5 mm high and 1 mm wide, proximal lip of cleft a low, broad bracteole with acuminate lobe 1 mm high, 2<sup>nd</sup> low, broad bracteole with acuminate lobe to 0.5 mm high subtending 1 staminate flower in dyad, sometimes pistillate flowers only in proximal 10 cm of rachillae; staminate flowers variable, 8–14 mm high (including up to 6 mm high calyx tube or stalk), 14–17 mm wide (Figs. 3, 8, 9, 12); calyx variable, to 5.5 mm wide, sepals connate in tubular base or stalk (pseudopedicel) 1–6 × 2 mm, free distal lobes 2–5 × 0.5 mm, these long-triangular, acuminate, erect, exserted 1–4 mm above corolla lobes, burgundy colored; corolla variable, sometimes with tubular base 6 × 1–1.5 mm, free apical petal lobes 7–10 × 2.5–3.5 mm, long-ovate, acuminate, spreading, valvate,



×*Jubautia splendens* 'Don Nelson.' 5. habit, (Hodel 2029), Warner Park, Los Angeles, California. 6. habit, Apollo Arboretum, Oregon House, California.

burgundy or pinkish colored abaxially, lightly burgundy colored and faintly striate adaxially; stamens 6–15, 7 or 8 mm long, erect-spreading, filaments connate briefly or free, 5 or 6 mm long, whitish, anthers 3–5 mm long, dorsifixed just below middle, pistillode short, 1 or 2 mm high, trifid, lobes 1.25–1.50 mm long, spreading. Pistillate flowers 11–12 × 8–10 mm, ovoid (Figs. 4, 10); calyx crown-like, 7 × 8 mm, sepals 7 × 7 or 8 mm, broadly ovate or triangular, cupped, imbricate in proximal one-half, apical lobes broadly rounded, striate adaxially and abaxially, green proximally and burgundy colored distally or entirely burgundy colored with abaxial medial longitudinal ridge; petals variable, 7–9 × 7–9 mm, broadly ovate or triangular, cupped, imbricate in proximal half and apical lobes triangular, acute, or imbricate nearly to apex and then mucronate with tip 1 mm long, acute, striate adaxially and abaxially, green proximally, burgundy colored distally; staminodes connate to form clear, whitish, collar-like ring 1–1.5 mm, scarcely 3- or 4-lobed; pistil 10–11 × 7.5–9 mm, ovoid, green except with pinkish tinge near apex or whitish, tip trifid, lobes 0.3–0.5 mm long, triangular, spreading to recurved or erect. Fruit to 4 × 3 cm, broadly ovoid (Fig. 11); perianth to 1 cm long.

The epithet means shining, gleaming, or brilliant and refers to the bright, mostly grayish or blue-gray leaves and handsome ornamental nature of these hybrids. The two cultivars included in this hybrid species, while more or less intermediate between their parents, tend to favor or resemble the pistillate parent more than the staminate parent, which is typically the case according to Richard Douglas and Patrick Schafer, who are making and developing hybrids between several genera in the Attaleinae. I have assigned cultivar names to them because they represent two distinct and easily recognizable groups of plants.

#### ×*Jubautia splendens* 'Dick Douglas'

(*Butia odorata* (B. Rodr.) Noblick & Lorenzi × *Jubaea chilensis* (Molina) Baill.); Figs. 1–4, 12.

This cultivar name honors Richard Douglas, long-time member of the International Palm Society, who assisted in collecting a specimen (Hodel 2031) in his garden in Walnut Creek, California upon which ×*Jubautia splendens* is based. According to Douglas, he grew the type plant from seeds that he had obtained from the International Palm Society Seed Bank in 1973. These seeds were labeled "*Butia* × *Jubaea* hybrid" and originated from the Huntington



7. Rigoberto Rodriguez holds inflorescence of *×Jubautia splendens* 'Don Nelson' (Hodel 2029).

Library, Art Collections, and Botanical Gardens in San Marino, California, where they are purportedly from an intentional cross that former botanist Fred Boutin had made, although this claim is undocumented.

*×Jubautia splendens* 'Dick Douglas' bears a resemblance to both parents although it is decidedly more similar to the seed parent *Butia odorata*, especially in its overall size, habit and gross morphology. Differences among both parents, *×J. splendens* 'Dick Douglas', and *×J. splendens* 'Don Nelson' are summarized in Table 1. Additional mature specimens of this cultivar in California occur at the Huntington Library, Art Collections, and Botanical Gardens in San Marino, Warner Park in Los Angeles, the Los Angeles County Arboretum and Botanic Garden in Arcadia, and Overfelt Gardens Park in San Jose. Mature specimens are also at several places in Florida and Europe.

#### *×Jubautia splendens* 'Don Nelson'

(*Jubaea chilensis* (Molina) Baill. *× Butia odorata* (B. Rodr.) Noblick & Lorenzi); Figs. 5–12, Back Cover.

The cultivar name honors Donald Nelson, a now retired landscape architect for the Department of Parks and Recreation, City of Los Angeles and a long-time member of the

International Palm Society, who designed and developed the palm garden in Warner Park on Topanga Canyon Boulevard in the Woodland Hills area of Los Angeles where several outstanding specimens of this cultivar currently grow.

The now defunct Tetley Nursery in Corona, California, a long-time grower of a wide variety of ornamental landscape palms, including *Butia odorata* and *Jubaea chilensis*, originally propagated and grew the plants in Warner Park. In 1968, in a going-out-of-business sale, the nursery sold 24 24-inch and 30-inch boxed specimens purportedly of *Jubaea chilensis* to the late Burt Greenberg, a long-time member of the International Palm Society and a palm and cycad grower in the San Fernando Valley area of Los Angeles. About that time, Nelson was designing and developing the palm garden in Warner Park and Greenberg sold the palms to the City of Los Angeles for incorporation into Nelson's palm garden in the park.

As the palms matured it became clear that not all of them were *Jubaea chilensis*. Some of them were intermediate between *J. chilensis* and *Butia odorata*, suggesting that these were hybrids between the two species. Because they were grown and sold as *J. chilensis*, they were obviously propagated from seeds collected



×*Jubautia splendens* 'Don Nelson' (Hodel 2029). 8. Staminate flower. 9. Staminate flower showing stalked calyx.

from that species, and are likely the result of spontaneous, unintentional hybridization with *B. odorata*. Although ×*Jubautia splendens* 'Don Nelson' bears a resemblance to both parents, it is decidedly more similar to the seed parent *J. chilensis*, especially in its overall size, habit, and gross morphology. Differences among both parents and the two cultivars of their hybrid are summarized in Table 1.

Additional mature specimens of this cultivar in California occur in the Huntington Library, Art Collections, and Botanical Gardens in San Marino, the Apollo Arboretum of the Renaissance Winery at Oregon House in the foothills of the Sierra Nevada Mountains east of Yuba City (Fig. 6), and Overfelt Gardens Park in San Jose (Back Cover). Mature specimens are also at several places around the





×*Jubautia splendens* ‘Don Nelson’ (Hodel 2029). 10 (top). Pistillate flower. 11 (middle). Immature fruit. 12 (bottom). Sizes of staminate flowers of the two parents and the two hybrids from smallest to largest. Left to right: *Butia odorata*, ×*Jubautia splendens* ‘Dick Douglas,’ ×*Jubautia splendens* ‘Don Nelson’ and *Jubaea chilensis*.

world, including France and New Zealand. It is sometimes referred to as the “Blue *Jubaea*.”

**Culture**

Both cultivars are of relatively easy culture and appear well adapted to the arid Mediterranean

climate found in California and elsewhere, with its long, dry, warm to hot summers and cool, sometimes moist winters. They grow faster than either parent and are among the more cold-tolerant palms, withstanding temperatures of about -10°C (15°F) during the

**Table 1. Summary of differences between *Butia odorata*, *×Jubautia splendens* 'Dick Douglas', *×Jubautia splendens* 'Don Nelson' and *Jubaea chilensis*.**

Character	<i>B. odorata</i> <sup>a</sup>	<i>×J. splendens</i> 'Dick Douglas'	<i>×J. splendens</i> 'Don Nelson'	<i>Jubaea chilensis</i> <sup>b</sup>
Trunk	30 cm diam., leaf bases persistent	65 cm diam., leaf bases persistent	90 cm diam., leaf bases mostly abscising	100–125 cm diam., leaf bases abscising
Leaf number, disposition and color	15–32, strongly arching, recurved, green to bluish gray-green	40–50, arching, recurved, bluish gray-green	60, arching, slightly recurved, bluish gray-green	40–60, stiffly spreading, green to gray-green
Petiole	30–75 cm long, margins with coarse spines	100 cm long, margins with coarse spines and fibers	135 cm long, margins with needle-like spines and fibers	50 cm long, margins smooth and with fibers
Rachis	1.15(–1.95) m long	2.3 m long,	3.15 m long,	2.5 m long
Pinnae	35–60 per side, regularly arranged	90 per side, regularly arranged	100 per side, regularly arranged	120 per side, slightly clustered in groups of 2–5
Peduncular bract	1.8 m long	2.6 m long	1.95 m long	1.25 m long
Rachillae	35–140, up to 130 cm long	140, up to 80 cm long	190, up to 85 cm long	100, up to 60 cm long
Staminate flowers	10–12 mm wide	14 mm wide	16–17 mm wide	19 mm wide
Petals	long-ovate	long-ovate	long-ovate	broadly ovate
Stamens	6	6–8	12–15	15–30
Pistillate flowers	4–8 × 4–6 mm	12 × 8 mm	11 × 10 mm	7 × 9–10 mm
Fruit	1.8–2.6 × 1.4–3.2 cm	not seen	4 × 3 cm	3.4–4.1 × 3–3.8 cm

<sup>a</sup> From Glassman (1970), Noblick (2010) and measurements from cultivated plants in California.

<sup>b</sup> From Glassman (1987), Henderson et al. (1995) and measurements from cultivated plants in California.

California freezes of 1990 and 2007 with little or no damage.

### Notes

Both cultivars are purportedly not always sterile although this claim is largely undocumented. Other crosses have possibly been made with both these cultivars but most are poorly documented. The Huntington Library, Art Collections, and Botanical Gardens have several plants labeled *Butia* × *Jubaea* from crosses that Merrill Wilcox had made in Florida in the 1970s. However, the *Jubaea* that provided the pollen may itself have been a ×*Jubautia* hybrid. Nonetheless, the Huntington plants bear a strong resemblance to ×*Jubautia splendens* ‘Dick Douglas.’

There is a trend in the size of staminate flowers among both parents and cultivars, from the smallest, *Butia odorata*, to the largest, *Jubaea chilensis*, with the two cultivars being intermediate (Fig. 12). Dransfield et al. (2008) reported that staminate flowers of *J. chilensis* have a “calyx with a solid, elongate stalk-like base” or that they are “stalked” while staminate flowers of *Butia* are “sessile or briefly pedicellate.” In the case of *J. chilensis*, not all staminate flowers are stalked. Indeed, some, especially those that are solitary or paired toward the tip of the rachillae, are frequently sessile while stalked staminate flowers are more common in triads and may be a mechanism for positioning the staminate flower above and beyond the larger, swelling adjacent pistillate flower so it can open unencumbered. Both cultivars have sessile or stalked staminate flowers although the stalk of ×*Jubautia splendens* ‘Dick Douglas’ is decidedly shorter than that of ×*J. splendens* ‘Don Nelson.’

### Acknowledgments

I acknowledge and thank several people who helped with the research for this article. Marianne Hodel helped collect the type specimen of ×*Jubautia splendens* ‘Dick Douglas’ in the Douglas garden. Ana Maria Cardoso provided information about ×*J. splendens* ‘Don Nelson’ at the Apollo Arboretum. Kerry Morris helped collect flowers of ×*J. splendens* ‘Don

Nelson’ at Warner Park. Steve Dunlap and Rigoberto Rodriguez of the Forestry Division, Department of Parks and Recreation, City of Los Angeles provided and operated a bucket lift to make the collection of ×*J. splendens* ‘Don Nelson’ and *Jubaea chilensis* at Warner Park. John Villarreal and Shadi Shihab at the Huntington Library, Art Collections, and Botanical Gardens in San Marino and Jim Henrich at the Los Angeles County Arboretum and Botanic Garden in Arcadia facilitated my studies at their institutions. I thank an anonymous reviewer for nomenclatural comments and help.

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# Revisiting the Neotropical Genera *Chelyocarpus*, *Cryosophila* and *Itaya* (Coryphoideae: Cryosophileae)

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In this paper we provide a review of the three genera *Chelyocarpus*, *Cryosophila* and *Itaya*.

On May of 1960, Harold E. Moore and colleagues discovered an outstanding palm during the course of a reconnaissance survey in the eastern Peruvian Amazon. It took him twelve years to accumulate additional material and knowledge about this species until he recognized it as the sole member of a previously unknown genus, endemic to the Peruvian Amazon (Moore 1972). The new genus was called *Itaya*, and together with other two taxonomically complicated genera, *Chelyocarpus* and *Cryosophila*, they were proposed by Moore as an "alliance." The affinities among the three genera were based on several shared features displayed by the vegetative and reproductive organs. Detailed studies on the floral and leaf anatomy (Uhl 1972a & b) played a key role supporting the close relationship among the three genera and highlighted the presence of several characters that at that time were regarded as ancestral for the palm family.

More recent molecular studies (i.e., Asmussen et al. 2006, Baker et al. 2009) have neither

resolved the phylogenetic relationships among *Chelyocarpus*, *Cryosophila* and *Itaya* nor between these three genera and the rest of the members of the tribe Cryosophileae, within subfamily Coryphoideae. This palm group is not only interesting from a taxonomic and evolutionary point of view, but also for their promising horticultural potential on account of the extraordinary beauty of their leaves and sometimes spectacular inflorescences. The present contribution aims to update our knowledge on the vegetative and reproductive morphology on the three genera and compiles new information critical for the assessment of their conservation status. This study is part of a more detailed investigation on the reproductive structures in the tribe Cryosophileae (Castaño et al. in press).

## Methods and Results

The taxonomical and morphological study of the three genera was carried out at the herbarium and Laboratory of Micro-Morphology of the Conservatory and

Botanical Garden of Geneva, Switzerland. Our research is based on the study of dried specimens and liquid fixed flowers deposited in the following international herbaria: AAU, B, BH, COAH, COL, EAP, F, FTG, G, HUA, JAUM, K, MEDEL, MICH, NY, P and USM. Fresh samples from *Chelyocarpus*, *Cryosophila* and *Itaya* were collected between October and November of 2007 in Fairchild Tropical Botanic Garden (FTG) and the Montgomery Botanical Center (MBC) (Florida, United States). Living populations of *Chelyocarpus repens* and *Itaya amicomum* were studied during a visit to the Jenaro Herrera and the Allpahuayo Mishana National Reserves, both in the Peruvian Department of Loreto, on October of 2007 and November of 2009. In order to study the rare populations of *Chelyocarpus dianeurus*, a field trip to the locality of Tutunendo, in the Chocó biogeographical region of Colombia was carried out on March of 2010. Additional living and cultivated individuals of *Cryosophila kalbreyeri* subsp. *cogolloi* R. Evans were studied at the Río Claro Natural Reserve and the Medellín Botanical Garden (Antioquia, Colombia). The most relevant historical and modern literature associated with the three genera (i.e., Moore 1972, Evans 1995, Henderson 1995, Henderson et al. 1995, Kahn 1997 and Dransfield et al. 2008) was consulted in the library of the Conservatory and Botanical Garden of Geneva.

***Chelyocarpus*** Dammer, Notizbl. Bot. Gart. Berlin-Dahlem 7: 395 (1920).

#### *Morphology.*

Moderate, single- or multi-stemmed, unarmed palms, with the stems erect or procumbent (Figs. 1–3). The leaves are palmate and induplicate; the petioles are elongate, not splitting basally in the sheath and apically ended in an adaxial hastula. The leaf blade is orbicular, frequently covered with a white indumentum in the lower surface; the blade is split into two halves, each half is again divided into paired or irregularly grouped ribbed leaflets, the latter apically divided in several acute segments (Figs. 1–3). The inflorescences are interfoliar, with 1 or less frequently 2 branching orders; the peduncle is dorsiventrally compressed; it bears a dorsally villous prophyll and 1–4 peduncular bracts, which are slightly pubescent on both sides; the rachis is terete to slightly flattened. The flowers are solitary and spirally arranged on the rachillae (Figs. 5, 7); they are hermaphrodite

(Fig. 8a) and subtended by one concave, lanceolate bract (Figs. 6c, 7); the perianth is formed by 2 or 3 sepals, which are congenitally united at a basal level, ovate and imbricate (Figs. 6a & b, 8b); and 2, 3 or rarely 4 free petals, morphologically similar to the sepals (Figs. 6b, 8c); otherwise the perianth is uniseriate (i.e. *Chelyocarpus repens* Kahn & Mejía), with the sepals and petals equal in shape and size (tepals), basally connate and irregular in outline; the androecium consists of 4–8 stamens with fleshy filaments; the anthers are exerted, versatile and dorsifixed (Figs. 6a, 8a). The gynoecium is formed by 1–3 carpels, they are urceolate, globose towards the ovary but narrow up to the level of the style; the stigma is profusely papillate, recurved at anthesis (Fig. 8a); the fruit is globose, with the epicarp smooth or corky-tessellate (Fig. 4).

#### *Distribution and ecology.*

As currently circumscribed the genus *Chelyocarpus* contains four species and is restricted to the Amazon basin and the western Pacific lowlands of Colombia. It is the only genus of the “alliance” that occurs both west and east of the Andes; *C. chuco* (Martius) H.E. Moore (Fig. 2), *C. repens* (Fig. 3) and *C. ulei* Dammer (Fig. 1) are distributed in the western Amazon region, whereas *C. dianeurus* (Burret) H.E. Moore is endemic to the Chocó region of Colombia (Moore 1972, Kahn and Mejía 1988, Henderson et al. 1995, Borchsenius et al. 1998). *Chelyocarpus chuco*, *C. dianeurus* and *C. ulei* are more or less common in the understory of the lowland rain forests, occupying non-inundated or more rarely inundated areas, always below 500 m elevation. *Chelyocarpus repens* is much less frequent and forms small and isolated patches in the understory. The generic name comes from the Greek meaning “turtle carapace-fruited” (Fig. 4), an allusion to the appearance of the cracked surface of the fruits of one species (Henderson et al. 1995).

#### *Conservation status.*

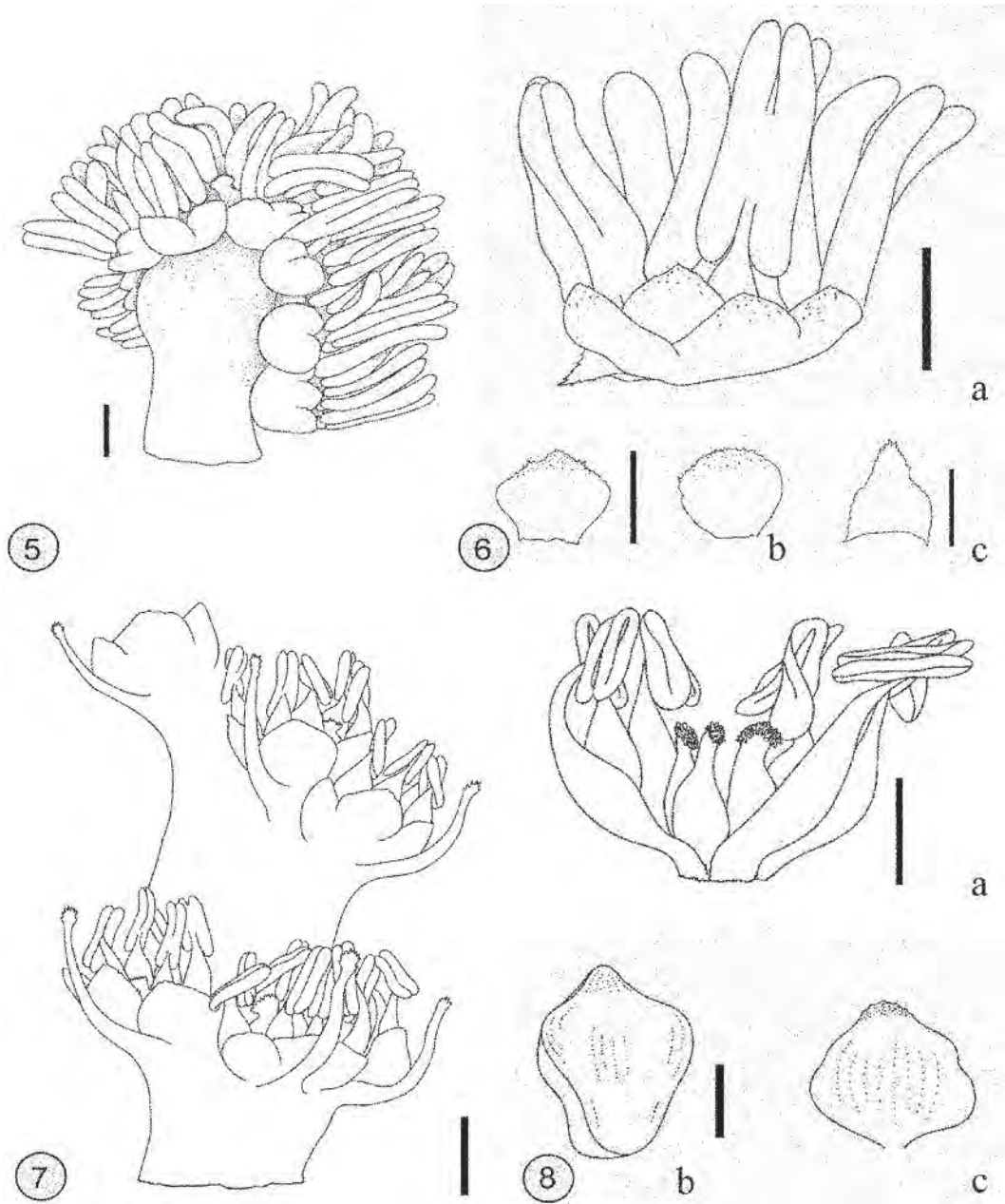
Additional field work in unexplored areas will probably show that the species of *Chelyocarpus* have a much wider distribution than currently reported. The species characterized by an Amazonian distribution would probably not be at immediate risk, as Amazonian ecosystems are relatively well preserved (Bernal & Galeano 2006). *Chelyocarpus repens* was reported to occur in only two small areas in the surroundings of Iquitos and Loreto, in the Peruvian Amazonia (Kahn and Mejía 1988, Henderson et al. 1995); however, we could



1–4. Habit and fruit of *Chelyocarpus*. 1. Habit of *C. ulei* (FTG), single stemmed. 2. Habit of *C. chuco* (FTG), multi stemmed. 3. Habit of *C. repens* (Jenaro Herrera), single stemmed. 4. Fruit of *C. ulei* (USM).

confirm its presence also in Colombia while studying the palm collection of the Amazonian herbarium (COAH). The Colombian

population is restricted to a small area in the department of Amazonas. According to our personal observations of the *C. repens*



5–8. General morphology of the rachillae and the flower of *Chelyocarpus*. *C. dianeurus*. 5. Portion of rachilla, scale bar = 2 mm. 6. Flower at anthesis; a. Complete flower in lateral view, scale bar = 1 mm; b. Sepal (left) and petal (right), scale bar = 1 mm; c. Flower subtending bract, scale bar = 0.5 mm; *C. ulei*. 7. Portion of rachilla, scale bar = 2.5 mm. 8. Flower at anthesis; a. Flower in lateral view (perianth removed), scale bar = 1 mm; b. Sepal; c. Petal, scale bar = 1 mm.

populations in the type locality (Department of Loreto, Peru) (Fig. 3), those are palms that grow in isolated, gregarious patches of 150–200 individuals. Although they are protected in the Jenaro Herrera Natural Reserve, probably additional populations are scattered in non-protected areas. This may be also the case of

*C. chuco*, a palm distributed along the Río Madeira, in the Brazil-Bolivia frontier (Henderson et al. 1995, Lorenzi et al. 1996). The conservation status of *C. repens* and *C. chuco* is still unclear as a consequence of the scarce information about the populations, their reproductive biology and current threats.

The conservation status of *Chelyocarpus dianeurus* and *C. ulei* in Colombia has been recently assessed (Galeano and Bernal 2005, Bernal and Galeano 2006). *Chelyocarpus dianeurus*, an endemic species from Colombia, was considered as near threatened (NT), which supposes a high probability to become vulnerable in a near future. This was clearly confirmed in our visit to the Chocó region, where populations were difficult to find, partly because they grow in very isolated patches of maximum 15–20 individuals, and also because of a great deforestation process due to increasing mining activities. Meanwhile, *Chelyocarpus ulei*, a widely distributed species, was assessed as least concern (LC).

#### Taxonomic notes

The genus *Chelyocarpus* was first described by Udo Dammer in 1920 based on a specimen collected in 1901 by Ernst Ule in Belem State (Brazil) and *C. ulei* was designated as the type species. It is only after 52 years that two more species were added to the genus. In 1972 Harold E. Moore included also in his treatment of the genus *C. chuco* and *C. dianeurus* and provided a key to all species recognized at that time. The taxonomic history of one of them, *C. chuco* is particularly complex. After its original description by Martius in 1847 as *Thrinax chuco*, this taxon has been assigned to five different genera. Walpers transferred it to the genus *Trithrinax* in 1849 and Drude transferred it to *Acanthorrhiza* in 1882. Burret proposed the genus *Tessmanniophoenix* for the palm in 1928 but in 1941 decided that *Tessmanniophoenix* and *Chelyocarpus* were congeneric taxa and proposed the genus *Tessmanniodoxa*, for all taxa contained in the two genera. Meanwhile, *Chelyocarpus dianeurus* was originally placed in the genus *Tessmanniophoenix* (Burret 1932b), and then transferred to the genus *Tessmanniodoxa* (Burret 1941). Detailed studies on the most recently described species of the genus *Chelyocarpus*, *C. repens*, have shown that its floral structure is almost unique within the tribe *Cryosophileae* (Castaño et al. in press).

***Cryosophila*** Blume, *Rumphia* 2: 53 (1838 [1836]).

#### Morphology

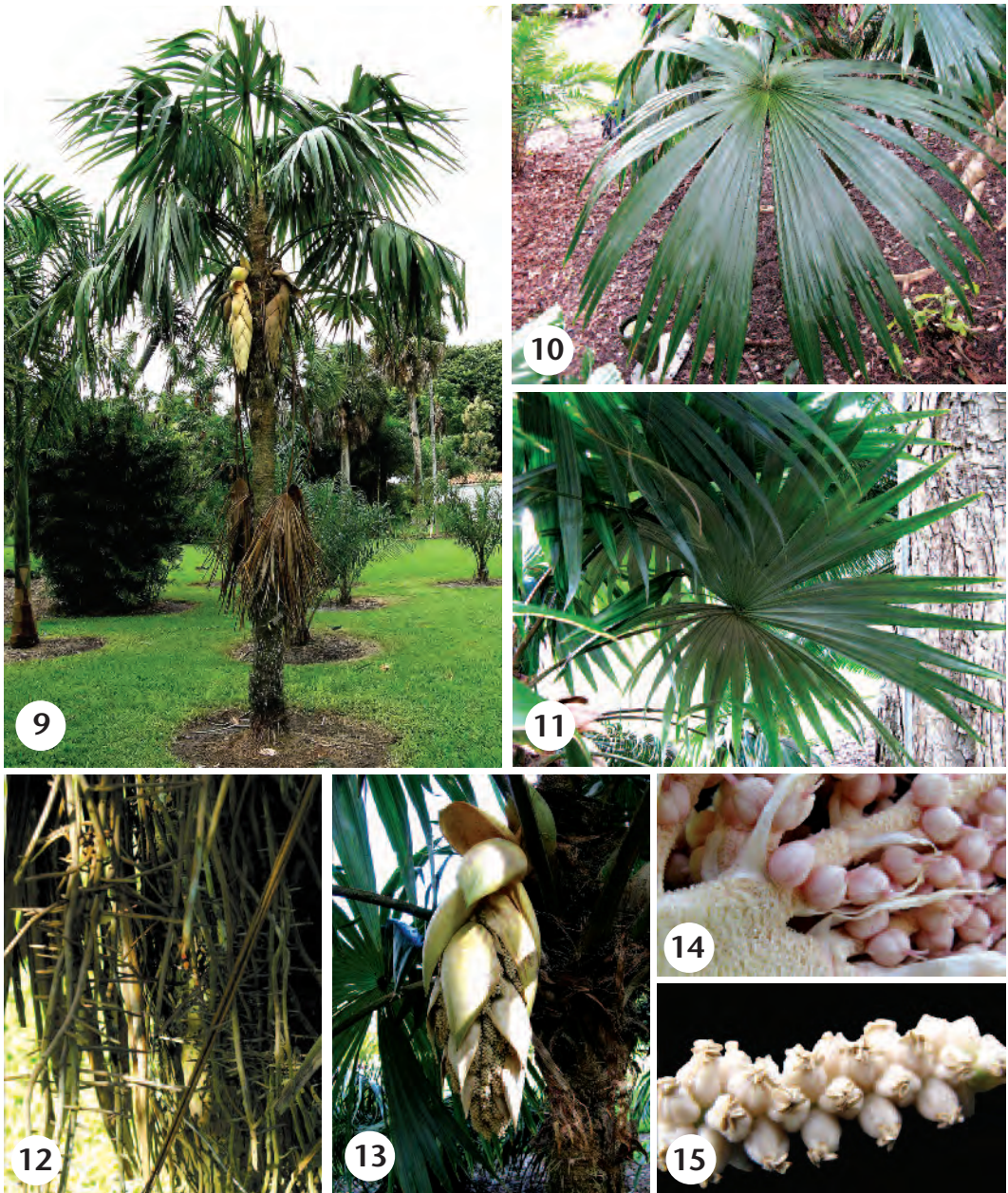
Moderate, single stemmed, armed palms. Stems almost always erect, bearing branched spines; the latter sharply pointed and derived from roots (Figs. 9, 12). The leaves are

induplicately palmate, flabelliform, with the abaxial surface silvery pubescent (Fig. 11); the leaf has a central abaxial split usually near to the base, dividing the blade into two more or less equal halves, each half further deeply divided into elongated, wedge-shaped, many-fold segments, which divide again into single-fold, acute or briefly bifid segments (Fig. 10). The petiole is elongated and splitting basally during maturity, it bears an adaxial, deltoid hastula. The inflorescences are interfoliar with 1–3 branching orders; the peduncle is terete or slightly compressed; the prophyll and the peduncular bracts are tubular and pubescent along the dorsal side (Figs. 9, 13). The flowers are closely packed on the rachillae (Figs. 14–16, 20), they are solitary, hermaphrodite and subtended by small, acute bracteoles (Figs. 16, 17a); the perianth consists of 3 basally connate sepals, which are concave and coriaceous (Figs. 17a & b, 23); and 3 broadly ovate, distinct petals (Figs. 17c, 24). The androecium consists of 6 stamens, with filaments that are congenitally united at the base in a membranaceous tube (Figs. 18, 21), the anthers are radiate at anthesis, exerted and with clearly extrorse dehiscence (Figs. 16, 17a, 18); the gynoecium is apocarpous, consisting of three slender bottle shaped carpels (Figs. 19, 22), the upper portion of the style and the stigmas are exerted, the stigma is profusely covered with multicellular papillae (Figs. 19, 20); the fruits are spherical or ovoid with smooth epicarp.

#### Distribution and ecology

The genus *Cryosophila* contains ten species (Govaerts & Dransfield 2005), all of them immediately recognizable by the numerous spines densely covering the stem. The genus is distributed from southwestern Mexico to northwestern Colombia, representing the only coryphoid genus with a distribution centered in Central America that extends east into northern South America and north into Mexico (Evans 1995). It is a genus of forest understory trees found in the lowland humid to wet or dry forests, from sea level to 1700 m elevation. Although the genus is relatively widely distributed, all species of *Cryosophila* have rather restricted geographical distributions (eight of the ten species are confined to only one or two countries) and several represent extremely local endemics (Evans 1996). The name *Cryosophila* comes from the Greek words meaning “cold-loving” (Henderson et al. 1995).



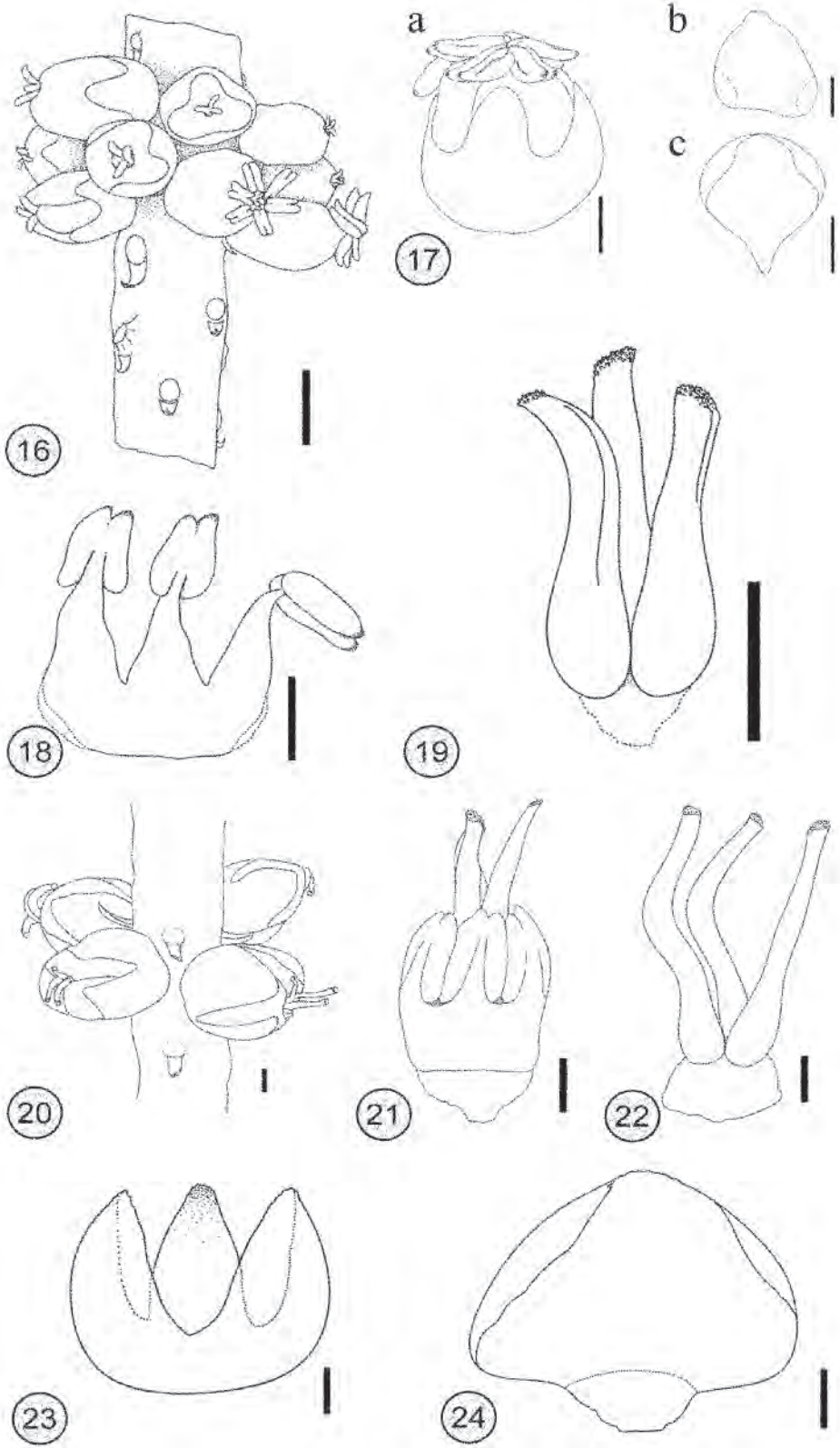


9–15. Habit, vegetative and reproductive organs of *Cryosophila*. 9. Habit of *C. guagara* (MBC). 10. Leaf (adaxial side) of *C. kalbreyeri* (FTG). 11. Leaf (abaxial side) of *C. kalbreyeri* (FTG). 12. Spines of the stem of *C. guagara* (MBC). 13. Inflorescence of *C. kalbreyeri* (FTG). 14. Portion of inflorescence of *C. guagara* (MBC). 15. Portion of rachilla of *C. warszewiczii* (FTG).

#### Conservation status

The contribution of (Honduras); and regarded five additional species (*C. bartlettii*, *C. grayumii*, *C. guagara*, *C. nana* and *C. kalbreyeri*) as currently endangered or threatened. According to Evans (1996), Galeano and Bernal (2005) and Bernal and Galeano (2006), there are not

enough data to assess the conservation status of *C. macrocarpa*, a species recently described and distributed exclusively in the Chocó biogeographic region of Colombia. Two subspecies were proposed by Evans (1995) for *C. kalbreyeri* based on geographic disjunction. However, the recognition of these infra-specific taxa is not supported by recent detailed studies



of their reproductive structures (Castaño et al. in press). *Cryosophila kalbreyeri* extends from north western Colombia to south eastern Panama and has been regarded as vulnerable (VU) by Galeano and Bernal (2005). Large forested areas remain intact in the western portion of its distribution range, but much less have been preserved of the original vegetation in the eastern side (Department of Antioquia). The population of this species observed in the Río Claro Natural Reserve is formed by few individuals scattered along a stream, where isolated patches of secondary forest still remain. Although this reserve is regarded as protected, its total area is relatively small and the increasing extraction of marble represents a high danger for all adjacent areas. Among the threatened species, we had the opportunity to observe *C. kalbreyeri* cultivated at the Medellín Botanical Garden and *C. guagara* (Figs. 9, 12, 14), *C. kalbreyeri* (Figs. 10, 11, 13) and *C. williamsii* growing in excellent conditions at Fairchild Tropical Botanic Garden and the Montgomery Botanical Center.

#### Taxonomic notes

There have been many attempts to clarify the obscure taxonomic history of *Cryosophila*, which is characterized by remarkable transfer of species from one genus to another. The genus was first proposed by Blume in 1836, including at that time only one species (*Cryosophila nana*) a palm that was originally described by Kunth in 1816 as *Corypha nana*: the species was based on a specimen collected by the famous naturalists Humboldt and Bonpland in their western Mexico field trip during 1804. Hermann Wendland proposed the genus *Acanthorrhiza* in 1869 and included two species: *Acanthorrhiza aculeata* (currently regarded as synonym of *Cryosophila nana*) and *Acanthorrhiza warscewiczii* (currently regarded as synonym of *Cryosophila warscewiczii*). Between 1877 and 1881 Wilhelm Kalbreyer collected an important number of palms in northern Colombia. One of these palms was

#### opposite page

16–24. General morphology of the rachillae and the flower of *Cryosophila*. *C. warscewiczii*. 16. Portion of rachilla, scale bar = 2.5 mm. 17. Flower at anthesis; a. Complete flower, scale bar = 1 mm; b. Sepal; c. Petal, scale bar = 1 mm. 18. Portion of androecium, scale bar = 1 mm. 19. Gynoecium, scale bar = 1 mm. *C. guagara*. 20. Portion of rachilla, scale bar = 1 mm. 21. Flower without perianth, scale bar = 1 mm. 22. Gynoecium, scale bar = 1 mm. 23. Calyx, scale bar = 1 mm. 24. Petal, scale bar = 1 mm.

described by Burret as *Acanthorrhiza kalbreyeri* in 1932a; and transferred to the genus *Cryosophila* by Dahlgren in 1936. Bartlett described three new species of *Cryosophila* in 1935 and two more were described by Allen in 1953. The most comprehensive systematic account for the genus was published by Evans (1995); he described three new species and recognized two subspecies for *C. kalbreyeri*.

*Itaya* H.E. Moore, Principes 16: 85 (1972).

#### Morphology

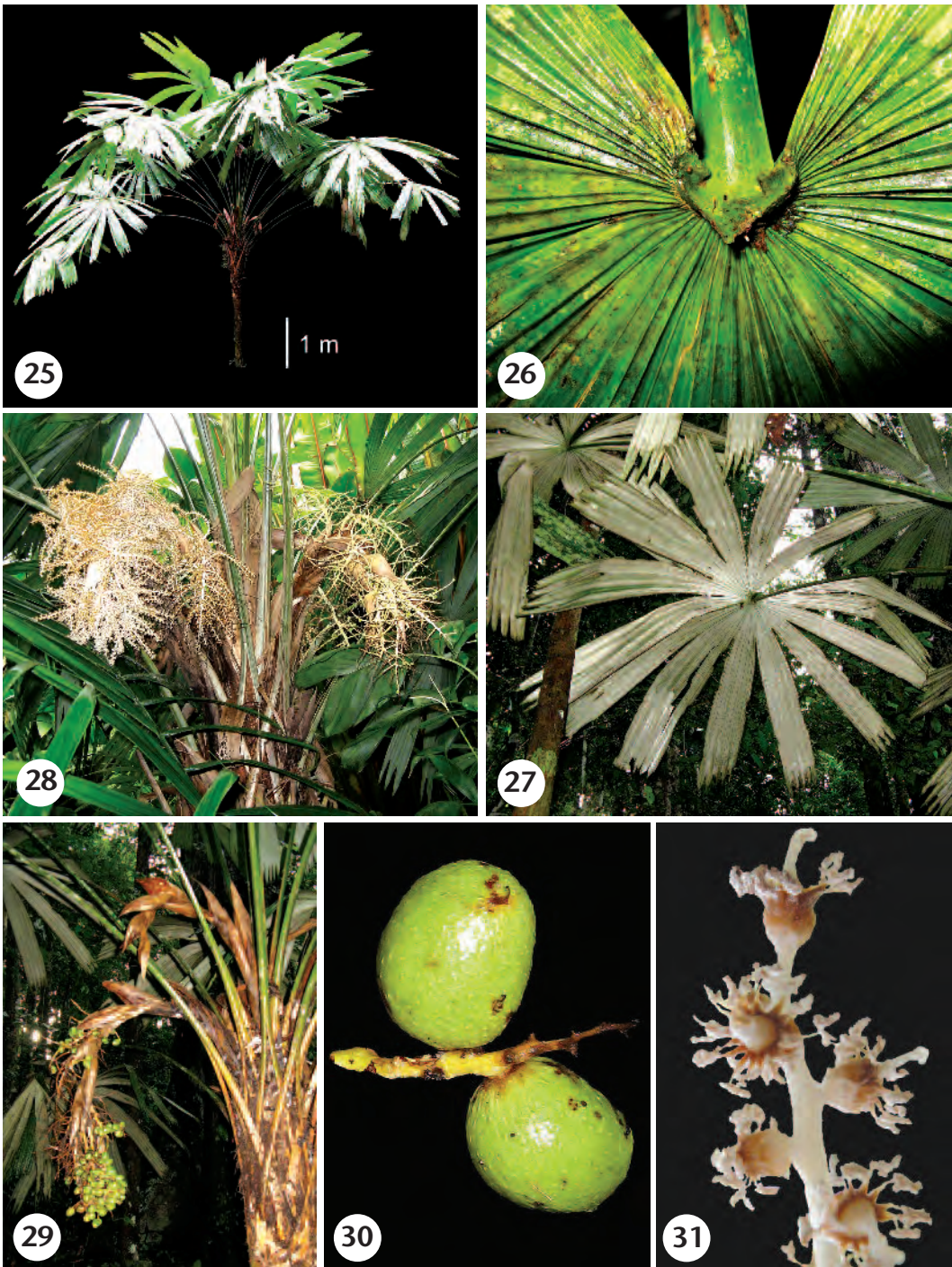
Moderate, single stemmed, unarmed palms. The stems are frequently covered by the old leaf-sheaths (Fig. 25); the leaves are induplicately palmate with their blades orbicular, divided at the middle, each half again deeply divided into 4–7 wedge-shaped segments, these divided apically into briefly bifid, 1-fold segments, abaxially lighter (Fig. 27); the petiole is elongate, split towards the base (Figs. 28, 29), it bears an adaxial hastula towards the distal portion (Fig. 26). The inflorescence is interfoliar, arcuate, with two branching orders (Fig. 28); the peduncle is terete or a little bit flattened; the prophyll and the peduncular bracts are striated and dorsally pubescent. The flowers are hermaphrodite, borne solitary on a conspicuous pedicel subtended by a small acute bracteole (Figs. 31–33); the perianth is profusely covered with very short papillae, it is formed by three connate sepals which are basally adnate to the corolla (Fig. 33); three connate petals, which are congenitally united to an androecium consisting of 15–17 stamens; the stamen filaments are congenitally united forming a tube, the anthers are versatile and dorsifixed (Figs. 33, 34); the gynoecium is unicarpellate (Figs. 31–33), the ovary is globose, the style is elongated and the stigma is flattened and papillate (Fig. 35); the fruit is subglobose, with the epicarp minutely granular (Figs. 29, 30).

#### Distribution and ecology

*Itaya* remains a monotypic genus from the Amazon lowland rain forests of Colombia, Peru and neighboring areas of Brazil. This palm grows in wet areas along rivers and streams, as well as on *terra firme*, below 300 m elevation (Henderson 1995). The genus gets its name from the Itaya River, in the Peruvian Department of Loreto.

#### Conservation status

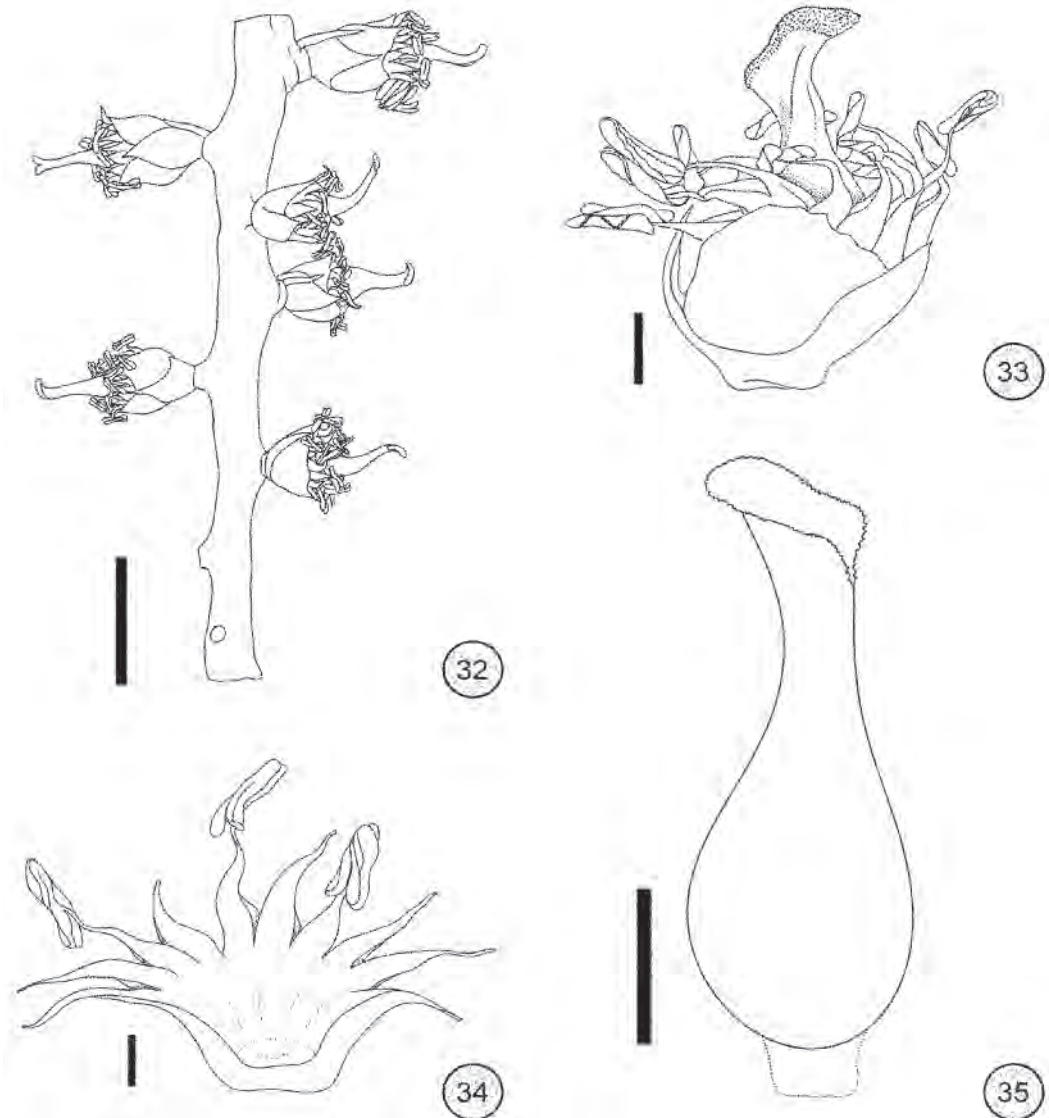
*Itaya amicum* was assessed as least concern (LC) in Colombia (Galeano & Bernal 2005,



25–31. Habit, vegetative and reproductive organs of *Itaya amicorum*. 25. Habit (Allpahuayo Mishana). 26. Leaf (adaxial side) showing the hastula (Allpahuayo Mishana). 27. Leaf (abaxial side). 28. Inflorescence (FTG). 29. Infurcated inflorescence (Allpahuayo Mishana). 30. Detail of the fruit. 31. Portion of rachilla (FTG).

Bernal & Galeano 2006) but its conservation status is much less promising in Peru. In 2007 we could not find the palm in its type locality, near the Itaya River in Peru, and another visit to the region in 2009 showed that it remains

a relatively difficult palm to observe. The few populations observed of this palm, always composed of a reduced number of individuals, were found in the highly threatened forests along the Iquitos–Nauta road, in the



32–35. General morphology of the rachillae and the flower of *Itaya amicornum*. 32. Portion of rachilla, scale bar = 5 mm. 33. Flower at anthesis, scale bar = 1 mm. 34. Portion of androecium, scale bar = 1 mm. 35. Carpel, scale bar = 1 mm.

Department of Loreto. At least for the Peruvian populations of this palm we may propose the category of vulnerable (VU). Fortunately, there is an awesome exemplar of this species cultivated at the greenhouses of the Fairchild Tropical Botanic Garden (Fig. 28), from which we could obtain excellent material for our morphological and anatomical studies.

#### *Taxonomic notes*

The first palm corresponding to the genus *Itaya* was discovered by H.E. Moore (Fig. 36) and colleagues in 1960 along the margins of the Itaya River, in the department of Loreto of the

Peruvian Amazon. Since then, no other species have been discovered for the genus and it remains monotypic.

#### **Final remarks**

Our current knowledge of the vegetative and reproductive morphology in related genera of Cryosophileae (Castaño et al. in press) and Sabaleae (Castaño et al. 2009) shows that most of the features that once supported the establishment of an “alliance” formed by the three genera are now recognizable in other Coryphoid groups. *Chelyocarpus*, *Cryosophila* and *Itaya* display some vegetative and

reproductive features putatively regarded as ancestral for the entire palm family; however, this hypothesis should be re-evaluated on the light of a more solid phylogenetic framework given that the current efforts have not been able to clarify relationships within Cryosophileae. In any case, the general vegetative and reproductive structure observed in the three genera is very interesting and deserves further study. A complete taxonomic knowledge of these palms, especially *Chelyocarpus* has been hindered by the presence of fragmentary and frequently uninformative herbarium material. More field work to remote areas of the distribution range of these palms, nowadays much more accessible, seems to be necessary for a better understanding of this group.

#### Acknowledgments

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36. Harold E. Moore taking a ride in the "Oroya Cable" in the locality of Quispicanchi – Río Araza (Department of Cuzco) on June 12, 1960. Photo courtesy of the Herbarium of the Natural History Museum of the University of San Marcos (USM), Lima, Peru.



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# Phenology and Germination of the Chonta Palm, *Astrocaryum gratum*, in a Sub-montane Forest

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Chonta palm (*Astrocaryum gratum*) is found in sub-montane neotropical forests, and its basic biology has been little studied. The phenology of *Astrocaryum gratum* was observed during 25 months in Madidi National Park and Pilón Lajas Biosphere Reserve and Indigenous Territory (Bolivia). The effect of light availability on seed germination of Chonta was also evaluated. The percentage of emerging seeds regardless of whether they were in the shade or sun was not significant; however, buried seeds germinate in higher proportion than ones left uncovered. *Astrocaryum gratum* plays an important role as a food resource for wildlife, affecting its distribution and movement, and therefore must be considered when designing wildlife management plans.

The palm *Astrocaryum gratum* Kahn & Millan (locally called Chonta palm) is distributed along the eastern Andean piedmont and adjacent areas of the southwest Amazon basin and its periphery in Bolivia and Peru (Kahn

2008). It is scattered throughout the forest, but high density aggregations per hectare can also be found (Beck & Terborgh 2002), all growing in sandy soils, and areas temporarily flooded as well as sub-mountane forest (Kahn 2008).



*Astrocaryum gratum* and the other species of *Astrocaryum* subg. *Monogynanthus* section *Huicungo* were joined together in a large species complex called *Astrocaryum murumuru* by Henderson (1995); this position was not followed by Govaerts and Dransfield (2005) and Kahn (2008). Section *Huicungo* includes 15 species. *Astrocaryum gratum* belongs to subsection *Sachacungo* (with *A. macrocalyx*, *A. urostachys*, *A. perangustatum* and *A. cuatrecasananum*), which differs from subsection *Murumuru* (this includes *A. murumuru*, *A. chonta* and *A. ulei*) in the calyx of the pistillate flower that is longer than the corolla. Moreover, *Astrocaryum gratum* is a solitary trunked palm, while *A. murumuru* is a multistemmed (caespitose) palm

*Astrocaryum gratum* (Fig. 1) is shade-tolerant and can grow up to 15 m tall. *Astrocaryum gratum* has 6–25 pinnate leaves, which are flat and very large, and spread horizontally. They have 90–105 pinnae on each side, regularly distributed and arranged in the same plane. Flat black spines are present along the stem and leaf midrib (especially at early ages). The calyx of the pistillate flower is glabrous or glabrate with bristles (Kahn & Millan 1992, Kahn 2008). The interfoliar inflorescences, branched to one order, are 1–1.5 m long (Kahn 2008). The orange-yellowish fruits are ovoid, covered with tiny spinules, and the fresh succulent pulp is very aromatic and covers a single endocarp (herein called the seed).

As with other species of the genus, *A. gratum* is pollinated by bees and other insects (Listabarth 1992). Seed dispersal patterns normally occur both with a natural seed rain or seed rain caused by birds or arboreal mammals, particularly monkeys, which consume the mesocarp and drop the seeds to the ground. On the ground, the seeds often attract a large number of terrestrial animals capable of secondary dispersal, such as the agouti (*Dasyprocta punctata*), which hoards the seeds at distances up to 200 m. Seed predators, such as the white-lipped peccary (*Tayassu pecary*), also consume seeds that have fallen to the ground (Henderson 1995, Beck & Terborgh 2002, Aliaga-Rossel et al. 2008, Aliaga-Rossel & Painter 2010). This palm is considered a keystone species, because it supports many animal species with its fruits, seeds and seedlings during periods of food scarcity (Terborgh 1986, Cintra & Horna 1997).

Despite the importance and abundance of Chonta palm, there are few studies related to

its phenology, fruit cycle and germination. This information is relevant not only to understand plant dynamics but also to provide insight into wildlife movements and distribution. This work describes the phenology and germination of the Chonta palm in two regions of a sub-montane forest in Bolivia.

## Material and Methods

This study was conducted in Madidi National Park and Natural Area of Integrated Management; MNP (13°20'–14°00' S, 68°10'–69°10' W), and Pilón Lajas Biosphere Reserve and Indigenous Territory; RBIT (14°25'–15°27' S, 66°55'–67°40' W). The study sites are similar in elevation gradient and present similar habitats, ecosystems and landscapes, and thus similar biodiversity composition. Soil and other abiotic characteristics are similar for both areas.

The mean precipitation in this region is estimated at over 2000 mm annually with northeastern slopes receiving the majority of the rainfall; there is a marked rain shadow to the southwest. The mean annual temperature is 26°C (Navarro & Maldonado 2004), the area is tropical, with well defined, seasonal dry (June to September) and rainy periods (October to May) (Fig. 2). The vegetation in the region is a piedmont sub-montane evergreen forest (Navarro & Maldonado 2004) with transitions into moist lowland forest with Amazonian affinities; similar forest types are found on abandoned river terraces of piedmont areas. The floristic diversity of the lowland forest is considerable, with 204 species of 2.5 cm or more diameter at breast height (dbh) per 0.1 ha, a large number of plant families, and high densities of other palm species (Foster & Gentry 1991, Navarro & Maldonado 2004).

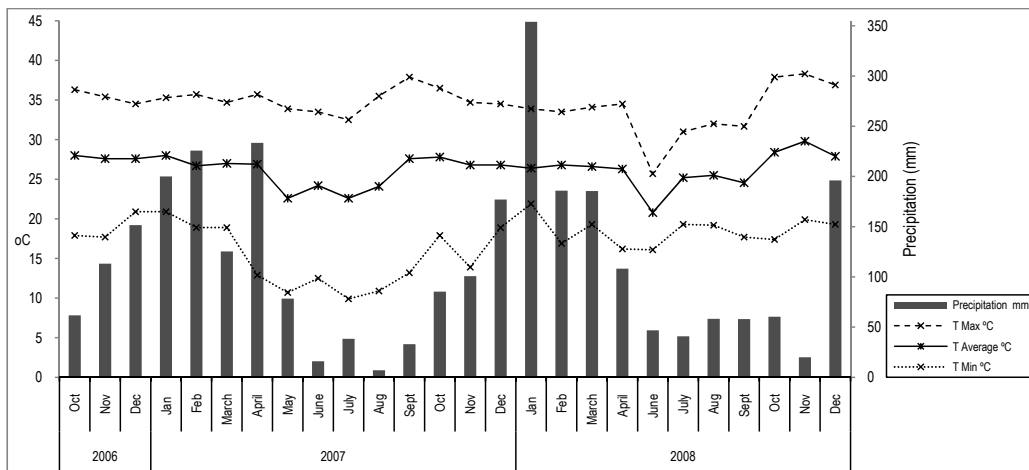
This study was done during “El Niño” (2007) and “La Niña” (2008) events, but carried out from November 2006 to December 2008, with no data collected in November 2008. Different patches of Chonta palms (*Astrocaryum gratum*) in each of the study sites were randomly selected, each at least 1.5 km apart from one another, and one transect (250 × 25 m) was established in each patch, within which all adults of *A. gratum* (capable of producing flowers and fruits) were identified and their DBH measured. Each individual was tagged. In order to understand fruiting patterns of the palms, I observed the reproductive status of the palms once a month and categorized them



1. *Astrocaryum gratum*. Photograph by H. Montecinos.

into one of two groups: a) Flowers (includes flower buds and open flowers) and b) Infructescences (including immature and mature fruits). Different stages of the inflorescence (buds, open flowers, etc.) were not distinguished due to the difficulty of observing the inflorescences among the leaves. If an individual had two bunches in different stages (e.g., flowers and immature fruits), the two bunches were analyzed independently. I observed the approximate distance that mature fruits drop naturally and noted the general abundance of fruits and seeds found on the forest. Finally, I randomly collected 13 fruit bunches from different trees and counted the number of fruits on each.

To determine the influence of light availability on seed germination and to test the importance of the presence a known palm secondary seed disperser (Agouti, *Dasyprocta punctata*) on germination, I collected 300 fruits from different fruit bunches on different individuals. The fruits were washed and the fresh the pulp was removed to reduce attracting other predators and remove pulp previously infected by fungus or insects. The seeds were inspected for any sign of damage or insect predation. Only intact, undamaged seeds were used for the experiment. An area where adult palms were not present was selected to avoid direct seed predation by animals attracted to these sites. There, in five



2. Precipitation (mm) and temperature (°C; maximum, minimum, average). From October 2006 to December 2008. Data obtained by the National Service of Hydrography and Meteorology (SENAHMI), Bolivia.

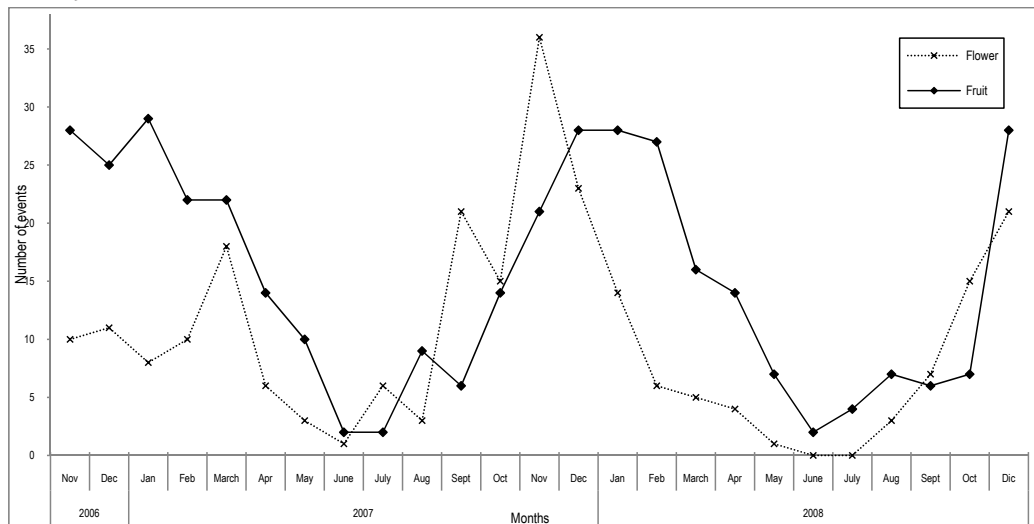
replicates, 15 seeds per treatment were buried 3–5 cm below the surface, imitating the hoarding burial activity of an agouti. There were four treatments: a) Seeds left at the soil surface just covered with a thin layer of dead leaves (placed in the shade), b) Seeds left at the soil surface covered with a thin layer of dead leaves (directly exposed in a sunny area), c) Seeds buried in the shade, d) Seeds buried in soils exposed to the sun. The seeds were set in rows of 5 seeds, 10 cm apart. Sun and shade treatments were approximately 70 m apart. To observe the growth of the radicle and the plumule (i.e., germination), it is necessary to dig up and disturb the seed; to avoid this and

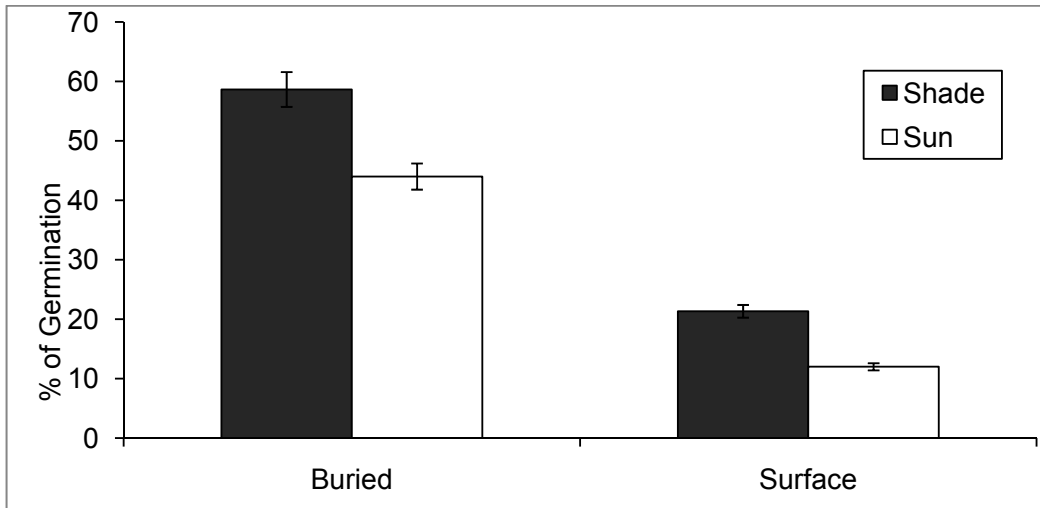
any possible damage to the radicle, germination was considered successful when seedling leaves reached the surface. The fate of the non-emerged seeds was not followed; therefore I cannot indicate if they were predated, attacked by fungus or were naturally non-viable seeds. The different germination treatments were analyzed using a one-way Anova.

**Results**

During the 25-month period, 62 healthy adults of *A. gratum* were identified. Reproductive individuals are approximately 10–25 m tall, with a DBH of 14.3–28.65 cm (average 20.1

3. Flower and fruit production of Chonta palm (*Astrocaryum gratum*) during “El Niño” (2007) and “La Niña” (2008) events in a sub-montane forest. Several mature fruits are found on the floor from December to mid-February.





4. Percentage of *Astrocaryum gratum* seeds germinated (percentage of emergence) under two treatments (dark blocks are located in shade areas; light blocks buried in sunny area) under different light availability. Error bars 5% value.

cm SD=3.21) and 8–19 ( $n=72$ , mode 9; median 10) leaves. Precipitation and temperature in the region are presented in Figure 2.

#### Phenology

Each flowering period was relatively short, starting with the peduncular bract opening. Pistillate flowers were immediately receptive and soon pollinated. When the pistillate flowers were no longer receptive the staminate flowers open. After fertilization the gynoecium and the accrescent perianth grew into a young fruit, which developed slowly. The majority of adult trees was observed with flower buds and open flowers during almost all months (83%), with no apparent synchronization (Fig. 3). In 2008, no flowers were observed in July. Some trees were observed to produce two infructescences at the same time.

Fruiting started in August with a peak between December and March. Individual palms of *A. gratum* produced one to three (average two) infructescences every year, each containing from a few hundred to thousands 6–10 cm long fruits (average 700.3, SD 237. 3;  $n=13$ ), although several adult individuals (10%) did not produce any fruits in a year.

Fruiting for *Astrocaryum gratum* was not synchronized; however, a higher number of infructescences was observed during the rainy season (from November to end of February), with the highest peak from December to February.

Mature fruits fell one at a time, and ripe fruits were found generally 5 m away from the

parental tree, where many terrestrial animals (vertebrates and invertebrates) feed on them. The highest number of fruits was observed on the forest floor during December to February, decreasing in the dry season. No ripe fruits were observed on the floor in June–July during the “La Niña” event in 2008.

#### Seeds and germination

Seeds in all treatments germinated (i.e. had emerged) after 8–11 months (34%). The first plumule appeared at the eighth month, but the majority of seeds emerged after 11 months. Of the seeds left on the soil surface, 21% of the seeds in the shade germinated, but only 12% seeds in the sun germinated (12%) (Fig. 4). There was a significant difference in germination between all seeds buried and seeds left uncovered (d.f. 1;  $F=52.22$ ;  $p>0.000$ ) in shade and sunny areas. There was no significant difference between seeds buried in the shade or the sun (d.f. 1;  $F=1.76$ ;  $p>0.2$ ). These results suggest that natural germination is highly dependent on seed burial, as a result of scatter-hoarding activity from rodents such as the agouti (*D. punctata*).

#### Discussion

This may be the first study on the phenology of *Astrocaryum gratum* anywhere in its distribution. Cabrera and Wallace (2007) studied the phenology of palms for a period of 11 months, including an *Astrocaryum* species ( $n=10$ ), identified as *A. murumuru* by the authors; this was probably *A. gratum*, since it is the only *Astrocaryum* species of section *Huicungo* growing in the region (Kahn 2008).

During the study period three *A. gratum* trees died when a big tree fell due to strong winds. These gaps caused by the collapse of big trees play an important role in the community structure (Denslow 1987, Hubbell et al. 1999) by permitting seedlings to grow faster and possibly replace the parental tree. One of the adult trees died after 17 months of recording without producing flowers or fruit, but it was a reproductive individual, as indicated by the one-year old seedlings and old endocarps observed around it.

The inflorescence is characterized by the presence of several white to yellowish flowers, which attract several insect species. The flowering period is relatively short, and flowers rapidly transform into immature fruits. However, flowering is preceded by a period of inflorescence enlargement, which is longer for a larger species with massive inflorescences; these emerging inflorescences appear one or two months before anthesis begins (Henderson 2002). Like other palm species, *Astrocaryum* produces many young inflorescences, but some of these abort early in development, due to factors such as abnormal development, strong winds or heavy tropical storms. For example, from May to August (lowest production of flowers and fruits), several cold fronts characterized by temperatures as low as 10°C, heavy rains and wind (Fig. 2), arrived in the region and destroyed many flowers.

Phenological patterns in palms are not always synchronized, even within a single population of a species, and are highly related to environmental characteristics such as seasonality, weather and insolation levels. For example, Foster (1996) found that if the preceding dry season was too wet, many tree species flowered but failed to produce fruit. Although different *A. gratum* trees flower regardless of the season, the population showed a flowering peak between June to August, months which coincide with less intense precipitation (end of the dry season and the beginning of rainy season). In contrast, Cintra and Horna (1997) found that for a species of section *Huicungo* identified as *A. murumuru*, flowering was abundant in the rainy season, from October to January. Other species of *Astrocaryum* also appear to be synchronous and seasonal in their flowering and fruiting. *Astrocaryum aculeatum* has flowers from July to January and fruit production from February to August, and *A. vulgare* flowering and fruit production are from January to July. The two species are clearly asynchronous in

their flowering with respect to each other (Moussa & Kahn 1997). Foster (1996) and Leigh and Windsor (1996) indicated that flower production might be triggered by water stress caused by the dry season.

The relatively low number of fruit bunches per year produced by each palm is similar to those found in other species of *Astrocaryum*. This genus varies greatly in the number of fruits produced. *Astrocaryum gratum* produced 700 ( $\pm 237.2$ ) per bunch compared with the species identified as *A. murumuru* in Peru, which produced 349.2 ( $\pm 184.7$ ) fruits per bunch (Cintra & Horna 1997), or *A. standleyanum* in Central America, which produced 300–800 fruits per bunch (Smythe 1989).

Fruit production is dependent on the numbers of flowers produced during the flowering period. Inflorescences may have up to 3000 individual flowers; however, only 19% become fruit. Sist (1989) indicated 36% fruit-set for *Astrocaryum sciophilum*. These low numbers are explained by several factors that affect the number of fruits produced by a palm, including early abortion and predation of immature fruits (Henderson 2002).

I also observed the highest concentration of ripe fruits on the forest floor during the rainy season from December to February. In contrast, Cintra and Horna (1997) found a concentration of ripe fruit from March to April for *A. murumuru*, while Peres (1994) in Brazil reported fruiting during rainy season (January to May) for the same species. This fruit and seed rain in different seasons has an important implication for wildlife. *Astrocaryum gratum* is used by wildlife for a long period of time (ca. 10 months of fruit availability). The seed then may be picked by secondary dispersers, such as rats and agoutis (Aliaga-Rossel et al. 2008, E. Aliaga-Rossel unpubl. data) or by seed predators, such as peccaries (Janzen 1971, Beck & Terborgh 2002). In this study, a snail (Mollusca: Gastropoda) was observed eating a ripe fruit.

Between May and June, when there is a low number of fruits available, many of the *Astrocaryum* seeds found on the floor of this study are infected with Coleoptera (family Bruchidae) (Delobel et al. 1995), which may attract different mammals to eat them (Silvius 2002). Also, the high concentration of fruit on the floor can be inversely related to fauna. For example, in areas with high concentration of white-lipped peccaries, they arrived at a fruiting tree and immediately destroyed all the

seeds or young seedlings by turning over all the soil around the area. In contrast, in a defaunated forest, large numbers of fruits can be found below the parental tree (E. Aliaga-Rossel unpubl. data).

The seed experiment was started at the beginning of the rainy season when most of the seeds and ripe fruits are normally found on the forest floor. The experiments were set in an area with no chance of inundation, in order to minimize the potential effects that the events of the "La Niña" might have on the experiments on seed germination and emergence. *Astrocaryum* seeds are resistant and hard, resulting in slow germination. In this study the plumule of *A. gratum* appeared from 8 to 11 months; this period is within the range of rates of germination of other palm species (Cintra & Horna 1997, Rauch 1998, Meerow 2004); however, the emergence of the plumules is not always uniform, and variation could be related to the different degrees of maturation of the seed, humidity and angle. This rate of germination and the percent of total germination will vary among years, region or even from plant to plant collected in different seasons (Rauch 1998, Meerow 2004). For example, *Astrocaryum aculeatum* seeds germinated in artificial conditions took approximately 253 days for the complete expansion of the first bifid leaf, but in natural conditions germination could take up to 1044 days (Rauch 1998, Gentil & Ferreira 2005, Meerow 2004).

As was anticipated, buried seeds germinated in higher proportion than the ones left at the surface, reinforcing the relevant effect of secondary dispersers (agoutis, squirrels) that scatter hoard seeds and reducing the probability of seed predation from insects or other mammals (Cintra & Horna 1997, E. Aliaga-Rossel pers. obs.). Burial of the seeds by secondary dispersers also provides protection from exposure to drying and the necessary conditions to germinate. The results of this study indicate that when seeds are buried in the soil, they are more likely to germinate and emerge. Therefore, the hoarding of seeds is an important event for the survivorship of new individuals, the removal of these dispersers can affect the recruitment of this palm.

Heavy rains during the period of this study might have had a profound effect on the process of germination, by reducing direct sun exposure, by increasing sedimentation and leaf fall or by softening the soil and facilitating the

growth of the radicle. Seeds left at the surface in this experiment were covered with a single layer of dead leaves, but after some months these were naturally covered with a fine layer of soil and another layer of dead leaves fallen from adjacent trees. This cover protects and increases moisture for the seed.

The experiments were set in an area without adult *Astrocaryum* palms in order to avoid seed predators, because a positive correlation exists between predation and seed density (Janzen 1971). In areas outside the zone of the experiment, at the end of May, seeds showed signs of fungus or insect infestation. In the experiments only two seeds, both in the unburied, shade area, showed signs of bruchid predation. This very low percentage of infestation can be the result of the removal of the fruit pulp (reducing the fruits' chances of being found) and the long distance from parental trees. In general, high aggregations of seeds are heavily predated by white-lipped peccaries, bruchids and other granivorous creatures and have a low likelihood of establishing into seedlings (Beck & Terborgh 2002, Silvius 2002).

The relatively low percentage of germinated seeds is common among palms. At a site in Peru, only five seeds of *Astrocaryum* (identified as *A. murumuru*) germinated with 5% survivorship (Cintra & Horna 1997). Despite the low germination rate and the high seed predation, prolific seed production maintains the population dynamics.

In contrast to other *Astrocaryum* species, such as *A. aculeatum* or *A. vulgare* which are used for ice cream or wine (juice) in Brazil (Moussa & Kahn 1997), *A. gratum* is not extensively used in the area. The indigenous people use the trunks for arrows, the hard endocarp for handicrafts such as rings and the leaves and stems are occasionally used as fences. The utilization of this common species has the potential to be expanded to satisfy the market for handicrafts for people living close to the touristic town of Rurrenabaque, Bolivia, so a knowledge of the phenology of this species is important to develop management plans for this use.

This study was done during "El Niño" (2007) and "La Niña" (2008) events. Two of the areas where I plotted the palms flooded twice due to the river overflow (abnormal rainy season for both years, Fig. 2), but this did not affect the survivorship of adult trees, because *A.*

*gratum* has a preference for wet areas (Svenning 1999, Henderson 2002). The results presented here on flowering or fruiting are still representative.

The regular precipitation cycles (dry or rainy season) are part of the natural cycle in the Amazon basin (Sioli 1984). However, the global current effects known as the “La Niña” or “El Niño” are becoming more frequent and intense. Both phenomena signify continuous and long lasting droughts or flooding much higher than in a normal year. Therefore it is important to continue long term studies related to climate change and the response of the tree and of the community to a “normal year.”

Although *A. gratum* flowers and fruit can be observed most of the months, there is a peak season for both. Flowering might be stimulated by environmental conditions such as water stress. Fruiting peaks correspond to the rainy season, when the palm is an important food resources for wildlife affecting distribution and movement. Therefore the palm must be considered when designing wildlife management plans. Future studies should examine pollinator populations, presence of pollinators in different seasons and factors influencing reproductive patterns of *A. gratum*. Also studies are needed of the role of water in seed germination, the fate of seeds in the wild, and relationship between seed predators and dispersers.

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# Palm Conservation at a Botanic Garden: a Case Study of the Keys Thatch Palm

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Botanic garden palm collections are among the world's best examples of *ex situ* plant conservation. Palm conservation collections are central to two botanic gardens in South Florida. Recent research funded by the International Palm Society sought to evaluate the effectiveness of garden collections in maintaining the genetic diversity of palms. Studies focused on *Leucothrinax morrisii* are reviewed here. For these botanic garden collections, maintaining more individual plants per population results in greater capture of genetic diversity. As the number of plants increases, the genetic diversity captured increases more slowly. Maintaining multiple accessions (i.e., progeny from more than one mother plant) helps to capture greater diversity, but for this case, the effect was much less significant than simply increasing the number of plants. Balancing genetic capture with efficiency of the garden operation is challenging, but best accomplished with specific data. *Ex situ* conservation remains an expedient and feasible strategy to ensure against extinction of palm species.

Palm collections have long been a beloved and celebrated part of botanic gardens worldwide (Fig. 1). In the Victorian period, major gardens invested heavily in the acquisition and care of palm collections. This is exemplified by the

great Palm House, a central feature at gardens in Belfast, Brooklyn, Edinburgh, Frankfurt, Glasnevin and Kew. In frost-free parts of the world, outdoor palm collections are central to the visitor experience at Bogor Botanic Garden

(Indonesia), the Huntington Botanical Gardens, the Harold L. Lyon Arboretum and the Singapore Botanic Gardens. Palms reach a singular focus in the Palmetum of Santa Cruz de Tenerife (Canary Islands) and Palmetum of Townsville (Australia).

Traditionally for purposes of research, education and display, botanic gardens have greatly expanded their scope of work. One primary enlargement of the botanical mission is the work of plant conservation, especially since the late 20<sup>th</sup> century. To advance conservation goals, botanic gardens have worked in policy development, scarcity assessment, land stewardship, public outreach, climate change research and advocacy, student engagement initiatives, among many other areas. Recent calls for further broadening the scope of garden conservation have also been made (Dunn 2008, Chen et al. 2009, Donaldson 2009). All of these are important objectives.

Yet, a central and fundamental contribution of a botanic garden remains in the living collection of plants around which the institution has grown. For gardens, horticulture and botany are the areas of deep institutional skill, real physical capacity and authentic staff expertise. *Ex situ* (off-site) conservation is the area of conservation work that is both uniquely rooted in the garden

tradition and is a unique conservation activity not served by most other organizations. Therefore, *ex situ* conservation is the modern, relevant, undiluted purview of botanic gardens and is a clear path forward for the 21<sup>st</sup> century.

Palm collections show many straightforward examples of the value of *ex situ* conservation. A leading example, *Hyophorbe amaricaulis*, survives as a single individual in Curepipe Botanic Gardens (Ludwig et al. 2010) and is thus extinct in the wild, (although the IUCN lists this species as Critically Endangered). *Corypha taliera*, also potentially extinct in the wild (Basu 1987, Dhar 1996, Maunder et al. 2001a), is maintained in four botanical gardens, with perhaps as few as 20 individuals left. Two individuals of *Pritchardia aylmer-robinsonii* remain in the wild, but at least 30 botanical gardens cultivate documented collections (Chapin et al. 2004). *Hemithrinax ekmaniana*, found on just two hilltops in central Cuba (Morici 2000), is now established and reproducing at Montgomery Botanical Center (MBC). These are just four readily recalled examples, and many others are provided by the IUCN Palm Specialist Group (IUCN 2010). Botanic garden collections are critical to species conservation efforts for most imperiled palm species. For this reason, we sought to assess and explore the effectiveness of this collection-focused conservation work.

1. The Montgomery Palmetum at Fairchild Tropical Botanic Garden. Colonel Robert Montgomery established the Coconut Grove Palmetum in 1932 and Fairchild Tropical Garden in 1938 (the two gardens are now known as Montgomery Botanical Center and Fairchild Tropical Botanic Garden). The first palm collection planted at FTBG, named in honor of Colonel Montgomery, sought to display the palm family's great diversity of form, texture, and color, and thus comprised great taxonomic breadth.





2. *Leucothrinax morrisii* living collections at MBC. Sandra Namoff (FTBG) and Sandra Rigotti-Santos (MBC) collected DNA samples from each plant in the living collection in August 2007. Adequate investment in mapping, labeling, and data tracking for each living collection ensures utility for *ex situ* conservation and for research purposes.

### Two Gardens for Palm Conservation

Colonel Robert Montgomery worked with some of the world's most talented botanists and conservationists to establish two important palm collections in South Florida. From 1932 forward, the Colonel developed a leading palmetum, now known as MBC, and from 1936 forward developed a leading public garden, now known as Fairchild Tropical Botanic Garden (FTBG). Located less than one mile apart, these two botanical institutions together may represent the world's densest concentration of cultivated palm diversity, with over 500 palm taxa on 200 acres. Since the 1930s, these gardens have grown to emphasize complementary areas of work.

Recently, the authors assessed the specific assets and needs of both gardens with regard to *ex situ* conservation. Specifically, we aimed to leverage the conservation protocols and collections management of MBC palm collections and the laboratory expertise and infrastructure of the joint molecular systematic laboratory of Florida International University (FIU) and FTBG in order to explore a fundamental question for gardens: How many plants should a garden maintain, if the collection is designated for conservation purposes?

#### Designing a model system

By carefully considering this question, we determined that prior work placed the authors

**Table 1: *Leucothrinax morrisii* accessions from Big Pine Key, Florida.**

MBC Accession	Number of plants
951261	8
951262	11
951263	3
951264	1
951266	6
951268	3
951269	14
951270	3
951456	1
951457	4
951459	5
<b>Total</b>	<b>59</b>

in a favorable position to explore strategies for *ex situ* palm conservation. There was one model group available which was an exceptionally good fit for the question. *Leucothrinax morrisii* is a familiar palm species from the Caribbean that occurs over many island groups (Zona et al. 2007). Yet, in Florida the species is found in a limited geographic range and is considered Endangered within the state (Coile & Garland 2003). Further review of the biology of this species showed some other advantages for our study. *Leucothrinax* is a long-lived perennial plant, pollinated by wind, monoecious and pleoanthic. So, it is very generalized in its biology, making the data generalizable to a broader group of other species that are of conservation interest – all traits of a good model system.

As part of MBC's renewed collections development work beginning in the 1990s, extensive living palm collections were developed (Zuckerman 1997). Montgomery Botanical Center maintains a robust living collection of *L. morrisii* from a single collecting event at a single locally abundant population. While performing research fieldwork in October 1995, Larry Noblick, Bill Hahn and Laurie Danielson collected seeds of *L. morrisii* in the Florida Keys, Monroe County, Florida (Noblick 5075, 5077 and 5078, FTG). The team collected seeds from 11 different mother plants and accessioned them separately. Those seeds germinated and grew, and the majority of the resulting palms left the nursery to be planted

on the grounds in 2000 and 2001, with a few others planted in 2004. Currently, 59 plants are maintained in the living collection at MBC from that fieldwork (Fig. 2), and the plants can be traced back to their respective half-sibling groups, through independent accession numbers (Table 1). So, these plants comprise a well-documented, robust number of living *ex situ* palm collections from a single collecting event from one population, making an ideal test case for the research.

In the last decade, research developments at FIU and FTBG positioned the team to bring new tools and techniques to bear on this question (Francisco-Ortega 2003). Recent focus on the conservation mission between FIU and FTBG directed the team to augment strengths in plant molecular systematics with population-level genetic approaches (e.g., Cariaga et al. 2005). With a robust tradition in palm research, this approach was leveraged for research in Arecaceae (e.g., Roncal et al. 2007). One ongoing project at that time looked at genetic diversity within *Coccothrinax argentata* in South Florida using Inter Simple Sequence Repeat (ISSR) markers (Davis et al. 2007). Other molecular analysis showed a close relationship between *Coccothrinax* and *Leucothrinax* (Lewis & Zona 2008), so the team saw potential in adapting these population genetic approaches to answer our *ex situ* conservation question.

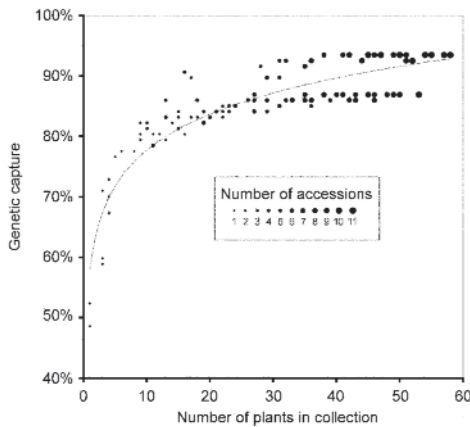
Having determined a suitable test case and an assessment tool – *Leucothrinax* and ISSR DNA

**Table 2: Definition of terms used for groups of plants in this case study.**

**Accession** An individual or group of plants from the same collecting event, assigned a unique number for tracking purposes. MBC accessions are from the same mother plant. Therefore, this represents a group of siblings or half-siblings. Accessions at MBC can be of variable size (see Table 1.).

**Collection** A group of plants brought together for a purpose, or an individual plant in such a group, or the act of bringing an individual into such a group, for example, the *L. morrisii* plants cultivated in the garden that were used for the DNA study ( $n = 59$ ).

**Population** A group of individual plants of the same species inhabiting a certain area, for example, the *L. morrisii* plants growing on Big Pine Key used in the DNA study ( $n = 100$ ).



3. Genetic capture for collections of various sizes (adapted from Namoff et al. 2010). The x-axis shows the number of palms in each resample, and the y-axis shows the observed genetic capture for that re-sample. The size of the points represents the number of accessions (see Table 2) in each re-sample. As the collection size increases, the rate of increase in genetic capture diminishes. The curve represents the logarithmic fit of the points ( $R = 0.83$ ).

microsatellite data – the team designed a way to approach the question. We proposed a fairly simple data gathering strategy: revisit the original field site, collect 100 DNA samples from the parent population, collect DNA samples from the garden collection at MBC and gather data with the ISSR techniques used by Davis et al. (2007). We would then compare the collection to the population to see how effective the MBC *ex situ* conservation protocol is at conserving genetic diversity.

### Exploring the Question: How many plants to grow?

The methods and results of this investigation (Griffith & Husby 2010, Namoff et al. 2010) can illustrate some principles for managing palm conservation collections, and these findings could potentially be generalized more broadly. The results have a specific bearing on the work of MBC and allow for an assessment of current practice. The results are detailed below within the context of general principles and recommendations. To clarify terms used in this case study, please see Table 2.

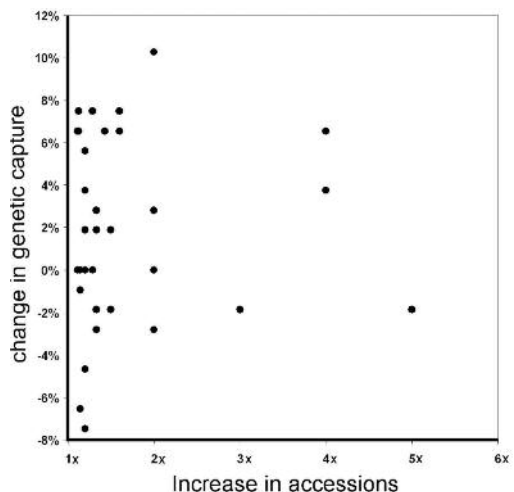
#### *Single individuals and multiple plants capture genetic diversity.*

Many garden collections are designed for taxonomic breadth (Dosmann 2006). These synoptic collections are essential educational and outreach resources. The fundamental

method of developing such collections has been to fill in taxonomic gaps, often with single specimens. Ever since studies for crop resource planning have employed models based on maximizing genetic diversity (Gale & Lawrence 1984), garden conservation collections have been more often structured to include representative population samples. Recommendations on sample size are especially well developed for seedbank work (Guerrant et al. 2004), yet are lacking for the typical botanic garden flora. For plants with recalcitrant seeds, like most palms, garden cultivation is essential. Given the much larger amount of space needed for mature plants, maintaining viable population sizes in cultivation requires significant resources.

We examined the relationship of sample size and genetic capture through random re-samples of the collection (composed of entire half-sibling groups) compared to the wild population. In our case study, the following principle holds true: more individual plants maintained gave a higher percent of genetic capture (Fig. 3). Importantly, though, a single-specimen collection recovered about half of the alleles that we found in the wild population – going from no specimens to a single specimen gave the single biggest

4. Effect of collecting seed from multiple mother plants (adapted from Namoff et al. 2010). To investigate the effect of accessions breadth, we compared re-samples with the same number of plants but with different numbers of accessions represented. The average effect of increased accessions breadth was positive: the 95% confidence interval for increased accession breadth did not include zero (0.45%, 3.11%). The overall contribution of increased accession breadth is less significant than increased collection size.



increase in genetic capture. So, objectively reading the numbers, even a synoptic collection is better than no collection, where conservation is concerned. Increasing from a single specimen to more than one gave the next biggest increase in genetic capture.

The basic parameter we sought to evaluate here: how many plants should we maintain per population to capture adequate diversity? The MBC collections policy has long recommended maintaining a collection of 15 palms to represent each population, with at least 3 accessions represented. In this case study, the current protocol would capture around 83% of the genetic diversity of the population. This finding has direct bearing on our work. MBC seeks to preserve a high proportion of population genetic diversity, so these data confirm that we should continue to maintain collections of at least 15 plants per population or perhaps more if resources allow. As shown in Figure 2, the rate of increase in genetic capture slows as the number of plants maintained increases. This is discussed further below.

*Multiple accessions may not be as important as number of plants.*

For this case study, we structured the random re-samples to be composed of entire half-sibling cohorts (i.e., accessions, or seeds collected from the same mother plant); the half-sibling groups were not split up, regardless of the number of individuals in each group. This gave the data set an additional parameter to explore: does collecting seed from multiple plants give better genetic capture than collecting seed from one plant? This can be explored by examining paired comparisons of re-samples that have the same number of plants, but different numbers of accessions (Fig. 4). Our finding here was that on average, increasing the representation of different half-sibling groups gave a positive increase, but the increase was much less significant than simply increasing the number of plants in the collection. One inference here is that *L. morrisii* appears consistent with a panmictic mating system (no assortment of paternity), as expected for a wind-pollinated species.

For plants of different life histories and different biology, this relative unimportance of accession breadth may or may not hold true. Dioecious palms, plants with shorter life histories, palms with very limited numbers or insect-pollinated species may assort paternity to some degree, and therefore making

collections from multiple accessions could be more important.

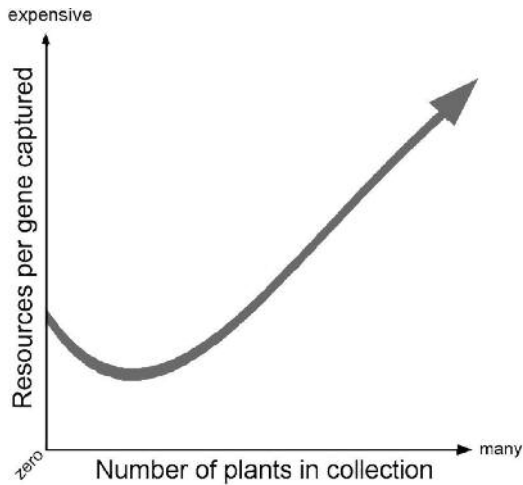
*Garden conservation collections have a point of maximum efficiency.*

Resources for accomplishing the work of botanic gardens are limited. Therefore, exploring these data in contrast with resource expenditures can help allocate work with greater efficiency. As noted above, the genetic capture increases at a slower rate as the number of plants in the collections is increased (cf. the "law of diminishing marginal returns"). A section of this study looked at the genetic capture curve (Fig. 3) and compared this to financial spending data from MBC over a ten year period (Griffith & Husby 2010). The cost of maintaining any individual plant at a botanic garden includes the initial costs of collecting fieldwork, followed by all direct horticultural and record keeping costs (including personnel), but not administration or overhead. We measured efficiency as the unit cost of genetic capture; i.e. for each collection of a certain size, the cost of maintaining that collection divided by the percent genetic capture (Figure 6). After the initial investment in bringing collections into the garden, there is a great increase in efficiency (lower unit cost), a most efficient collection size (lowest unit cost) and then a steady decrease in efficiency (higher unit cost), as the collection size increases. In the *Leucothrinax* study, the most efficient collection size was around 5 plants, and a collection of 20 plants was as efficient (same unit cost) as a single plant. This efficiency appears to be determined more by the population genetic side of the equation than the financial side.

*Other circumstances can make a big difference.*

By design, this case study is for a single population of a single palm. Great diversity of circumstance can make other strategies necessary. In one of the examples mentioned above, *Corypha taliera*, it may be wise to grow as many individuals of these as possible, given the great paucity of known plants and the current lack of genetic data. Additionally, genetic drift in small collections is a primary concern (Gale & Lawrence 1984). In the botanic garden, drift can occur with the unplanned loss of individuals and is one reason to build redundancy into *ex situ* collections.

At our gardens, the experience with hurricanes serves to underscore this need for redundancy



5. Behavior of the collections conservation efficiency curve (adapted from Griffith & Husby 2010). After the initial costs of bringing the collection into cultivation are expended (y-intercept), the resources used per gene captured goes down as the collection increases above zero. After reaching a point of maximum efficiency (lowest y-value) the resources needed for additional genetic capture increase steadily. In this case study, the collection size with greatest efficiency is around 5 individuals, and a collection of 20 individuals has the same unit cost as a single-specimen collection.

(Klein 1992, Griffith et al. 2008). Redundancy at multiple sites adds an additional layer of protection for very rare palms, as these can provide a range of environmental conditions and therefore increased likelihood of success. *Attalea crassispatha* provides a good example here (Timyan & Reep 1994). In its native range in southwest Haiti, this species survives with fewer than 30 individuals and is imperiled by habitat reduction and seed consumption. Significant living collections at MBC, FTBG and the Tropical Research and Education Center (Homestead) of the University of Florida ensure that this Critically Endangered species can survive in cultivation.

### How effective is botanic garden conservation?

There are many examples of plant species that would simply be extinct were it not for garden collections. Yet, one thread in the literature debates the value of *ex situ* conservation, subordinates it to other work, or otherwise diminishes these efforts (Hamilton 1994, Aplin 2008). This critique is often rooted in philosophy (see Rolston 2004), but sometimes also in data (Clement et al. 2009). Conservation priority is sometimes determined

through subjective means (see nic Lughadha et al. 2005 for discussion). The value of garden collections for conservation can sometimes be inflated (Aplin 2008), and this is often due to insufficient data (Maunder et al. 2001b).

The opposite of insufficient data, of course, is adequate, relevant data. Data appear to be the best way forward for rigorous assessment of conservation value. We propose that one strength of the current approach is that it represents direct assessment of an existing conservation collection with an objective and direct measure of "conservation value," genetic capture. Targeted study remains the most accurate way to make inferences and develop strategies. For conservation workers at botanic gardens, this approach may provide a starting point to adapt a potential evaluation method. This will depend on the specific case of the population in question. In the case study here, collaborative analysis and planning between gardens achieved the best results.

The straightforward expediency and established technical feasibility of *ex situ* work keep it relevant and vital (Li & Pritchard 2009, Calonje et al. 2010, Seaton et al. 2010; Vitt et al. 2010). The current work suggests that significant genetic diversity can be conserved with proper planning. Therefore, it is important to continue the work of *ex situ* conservation and to develop new data to assess effectiveness and plan future strategies.

Regardless of how one feels about the relative merits of *ex situ* or *in situ* conservation, or any other aspect of conservation work, the least effective plan is to do nothing. A statement by Dr. Margaret From expresses this truth best: "conservation must be more than conversation."

### Acknowledgments

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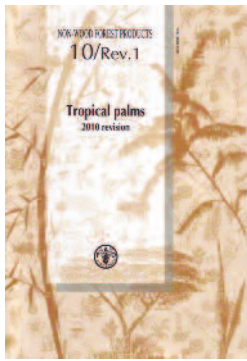
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## PALM LITERATURE

Dennis V. Johnson, *Tropical Palms*. 2010 Revision. Non-Wood Forest Products 10/Rev. 1, Food and Agriculture Organization of the United Nations (FAO), Rome, 2011. ISBN 978-92-5-106742-0 ISSN 1020-3370. 252 pages. Price US\$ 45.00. [publications-sale@fao.org](mailto:publications-sale@fao.org)



This work takes us through a large part of the uses that are made of palms throughout the tropical world. The introduction is an easy-to-read description of what a palm is, goes through the variations found in growth habits, leaves, fruits and habitats and ends up with an interesting compilation of examples of plants that are called “palms” but that are not palms in a technical botanical sense, including screw palms (*Pandanus* spp.), palm ferns (*Cyathea* spp.), palm grass (*Setaria palmifolia*) and others.

The following section is an account of how palms have contributed to human culture in a historical perspective. It reminds us of the evidence of how ancient cultures used palms and then goes on to mention examples of the many uses that have been made and are still being made of palms. This includes beverages, a particularly important use of palms in Asia and Africa where palm wine has been tapped from *Borassus flabellifer*, the palmyra, and *Elaeis guineensis*, the African oil palm, and many other species. Building material from palms, for example for thatch, is one of the oldest and most ubiquitous uses of palms. Cosmetics, animal feeds, fertilizer, handicrafts and many more uses of palms are described. This section also mentions some case studies that have demonstrated the importance of palms to indigenous communities, for example Iban in Sarawak who use 47 native palm species, the Shipibo in Peru who use 19 palms from the forest surrounding their villages and the Kwanyama Ovambo in Namibia who use far fewer species of palms but for a high number of different purposes. The Trukese from the Pacific island Truk have only three species of palms, which are, however, used for a great many purposes. Only a few palms have been domesticated, and this chapter mentions the

betel nut palm (*Areca catechu*), the coconut palm (*Cocos nucifera*), the date palm (*Phoenix dactylifera*), the African oil palm (*Elaeis guineensis*) and *pejibaye* (*Bactris gasipaes*) as examples.

A section on current palm products goes through all the categories that palms have been used for and especially mentions the use of palms in agro-forestry systems and as extractive products. This is followed by regional treatments of palm uses in Asia, Pacifica, Latin America, Africa and the western Indian Ocean regions. Region by region threatened and not-threatened palms are listed with mention of their local names, distribution and products derived from them. These regional treatments reiterate the well known fact that tropical Asia is the most species-rich palm region, followed by tropical America, the Pacific and Africa, and the number of used palms and palm uses is more or less proportional to the palm richness in each region. Interesting, but also well known, differences between regions are the great importance of rattans in Asia and the almost lack of climbing palms in the Americas, which is accompanied by corresponding differences in use patterns. It is also remarkable to see how few palms have been domesticated and that palm use throughout the tropics still depends almost entirely on extraction from wild or only lightly managed palm species.

The overwhelming dominance of palm uses based on wild or lightly managed species naturally leads to the next section of the book that deals with palms with development potential. This section mentions over 20 different palm species that could potentially be developed further and possibly be domesticated. One example mentioned is the Asian sugar palm, *Arenga pinnata*, which could be a candidate for domestication for its sap that can be used to produce sugar, wine, alcohol and vinegar. Several ornamental *Chamaedorea* species from Central America are also mentioned as candidates for domestication or for increased management of natural populations. The *moriche* (*Mauritia flexuosa*) palm that abounds in west Amazonian swamp forests is also said to have management potential for multiple products such as edible fruit mesocarp, edible oil and starch from the very large stems. To underline the potential uses of the wild palm species the next section compiles a large amount of data on nutritional values, chemical composition,

etc., of fruits and other organs of wild palm species.

The book ends with a 27-page long list of cited references and several pages with references to additional sources of information about palms and their uses.

This book is a treasure trove for those interested in palms and their uses. It is stuffed with information and all is duly referenced, so one can go to the original source. There are some illustrations, but the text itself is what

makes this volume really interesting. It will be most useful as a reference source. The information presented and tabulated has not been much analyzed or digested for the reader. The book is soft-covered and printed in a rather unpretentious style so it is not a coffee-table book to be enjoyed for its esthetic value but rather an indispensable source of information for anyone interested in palms and palm uses.

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