Palms

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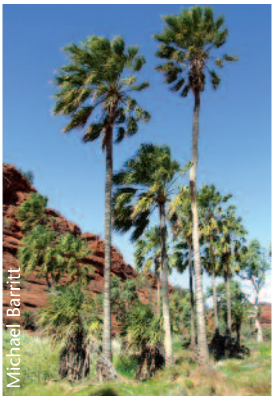
PALM NEWS



Livistona mariae is an endemic palm from arid regions of central Australia, separated by about 1000 km from its closest relative, *L. rigida*. Botanists have long assumed that central Australian populations became isolated from a more widespread ancestor when Australia became drier and less hospitable to palms some 15 million years ago. Now comes research news from T. Kondo et al. (published on-line before print in the Proceedings of the Royal Society. B. Biological Sciences) that DNA markers show that the two species split apart only 15,000 years ago, about the time when indigenous people began settling in central Australia. Kondo and colleagues hypothesize that humans brought the palm to central Australia as a source of food (the terminal bud) or fiber, and that over only 15,000 years, the two species diverged along separate evolutionary paths. ***Livistona mariae*** **should no longer be called a "relict" palm but is, in fact, a recently evolved species.**

Andrew Henderson has produced an important **monograph of the genus *Pholidostachys***. The new analysis brings the total number of taxa to 12 (11 species and one subspecies). Four of the species are described at new. Although this genus is not common in cultivation, all of the species are handsome palms. Henderson's new treatment should foster interest in this seldom-seen gem. The monograph can be downloaded for free at http://www.mapress.com/phytotaxa/content/2012/f/pt00043p048.pdf. The prolific Dr. Henderson also published **a monograph of *Desmoncus*** in late 2011 in which he recognized 31 taxa, seven of which were newly described species and two were new subspecies. It too is available for free downloading at http://www.mapress.com/phytotaxa/content/2011/f/pt00035p088.pdf.

Also appearing in late 2011 was a report from a research lab in Tunisia where **a procedure for cryopreservation of date palm tissue** was developed. The report, which appeared in the journal Cryo Letters, described how vegetative tissue could be transformed *in vitro* into proembryogenic cell masses, which could be frozen. The cell masses could later be thawed, treated with hormones and used to produce somatic (asexual) embryos, which could be grown under laboratory conditions into small plantlets. The research team did not investigate if their technique could be applied to other palm species. (L. Fki et al. Palm cryobanking. Cryo Letters 32: 451–462. 2011.)

An investigation of palm stem elongation revealed **a novel way by which a palm stem increases in length**. In a recent publication (Amer. Jour. Botany. 99: 607–613. 2012.), Heidi J. Renninger and Nathan Phillips examined *Iriartea deltoidea* in Ecuador over a two-year period. Although the unspecialized cells that make up the palm stem can divide and elongate, the precious water- and nutrient-conducting cells cannot. How, then, does the palm stem elongate without breaking the conducting vessels? The answer lies in the unique way vessels are arranged in palms. The courses followed by vessels are helical, like a coiled springs, and Renniger and Phillips were able to demonstrate that the vessel coils "stretched" as the stem elongated by as much as 12%.

Syagrus × *mirandana*, a Naturally Occurring Hybrid of *S. coronata* and *S. microphylla*

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1. A *Syagrus* × *mirandana* inflorescence extending far above its own foliage.

A naturally-occurring hybrid between *Syagrus coronata* (Mart.) Becc. and *S. microphylla* Burret was found in Bahia, Brazil, and is herein described.

A recent paper by Hodel (2011) nicely summarized *Syagrus* hybrids that occur naturally or have been made by man. Many of these were reported by Glassman (1987). However, there is one unreported naturally-occurring hybrid that needs to be added to the list. It should come as no surprise that one of the parents of this newly described hybrid is *Syagrus coronata*, which I often refer to as the "Don Juan" of the genus, because it easily crosses with other *Syagrus* species. Thus far *S. coronata* is known to cross with *S. cearensis* Noblick, *S. romanzoffiana* (Cham.) Glassman, *S. schizophylla* (Mart.) Glassman and *S. vagans* (Bondar) A.D. Hawkes to form respectively: *S.* ×*costae* Glassman, *S.* ×*camposportoana* (Bondar) A.D. Hawkes, *S.* × *tostana* (Bondar) Glassman and *S.* ×*matafome* (Bondar) A.D. Hawkes. Hodel (2011) even mentioned a man-made hybrid with *S. picrophylla* Barb.Rodr. The following is a description of its natural hybrid with *S. microphylla*.

Syagrus* ×*mirandana Noblick **sp. hyb. nov.** Palma acaulis, tronco subterraneo. Pinnae irregulariter 2–3 aggregatae, lobis apicalibus obtusis. Rhachis foliorum 56–95 cm valde recurvata. *Syagrus microphyllae* similis sed major rachillis longioribus et numerosis. Inflorescentia altitudem foliorum multo excedens. Typus: BRAZIL. Bahia: Municipio de Sento Sé, Serra do Alegre 3 km S of Campo Largo in the Serra do Pau d'Arco, ca. 9E40'S 41E18'W, 7 Oct 1988, *L.R. Noblick & J.L. dos S. Lima 4613* (holotypus, CEPEC; isotypi, F, CPATSA, BAH, NY, MO, US). Figs. 1–4.

Palm, small, solitary or appearing clustered, unarmed. **Stem** subterranean. **Leaves** 5–12 in crown, spirally arranged and spreading, strongly recurved; sheathing leaf base not measured, fibrous; petiole 6–28 cm long with untoothed margins, channeled; rachis 56–95 cm long; leaflets waxy green on upper surface and whitish on the lower, 28–38 along each side, irregularly distributed in clusters of 2 or 3 along rachis in divergent planes, those of middle series 14–34 × 1.4–2.7 cm, with mostly asymmetric tips. **Inflorescence** androgynous, interfoliar, prophyll 18–20 × 2 cm wide, 2-keeled; peduncular bract woody, finely sulcate, light grayish green, total length approximately 89–146 cm long, expanded or inflated portion 30–41 × 3.5–4 cm, bearing a 1.5–3 cm beak; peduncle ca. 55–118 × 0.8 cm, rachis 25–42 cm long, rachillae 8–18, 13–26 cm long and 5 mm in diameter at the base and 1 mm in diameter at the tip, each rachilla subtended by a bract 2–3 mm long and 3 mm wide, pistillate portion 4–11 cm long, with (1–)7–11 pistillate flowers or fruits per rachilla, staminate portion 9–14 cm long. **Staminate flowers** arranged

2. The habit and desolate habitat of *Syagrus × mirandana,* which is easily visible among the other native plants, especially during the dry season.

spirally in triads (1 pistillate and 2 staminate) on the lower portion and in dyads or singly on upper portion of the rachilla, cream in color, 5–7 × 3.0–3.5 mm, sepals and petals 3, sepals 1 × less than 1 mm, glabrous, petals valvate, 6–7 × 2.5–3.0 mm with acute tips, glabrous with indistinct nerves, stamens 6, ca. 4–5 mm long, anther 3–4 mm long, filaments 1–2 mm long, pistillode 1.0–1.5 mm and trifid.; **Pistillate flowers** grayish brown in color, 6–7 × 4–5 mm, sepals and petals 3, sepals 5–7 × 4–5 mm, petals imbricate, 4–6 × 2–3 mm, pistil 3 × 2 mm (aborted?), stigmas 3, staminodial ring about 1 mm high. **Fruit** none seen, seeds none seen.

COMMON NAME: None recorded.

ETYMOLOGY: The specific epithet *mirandana* is named to honor Dr. E.E. Miranda, who first drew our attention to the existence of this palm. He is a researcher at CPATSA (Centro de Pesquisa Agropecuario Tropico Semiárido, EMBRAPA), a federally supported research center for the tropical semiarid areas of Brazil based in Petrolina, Pernambuco.

DISTRIBUTION AND HABITAT: To date, this palm has been found only in the Serra do Alegre, Sento Se, Bahia. However, it could potentially be found wherever the ranges of *S. coronata* and *S. microphylla* populations overlap. It grows above 1000 m in a disjunct cerrado (called *gerais* or *campo limpo*), or open savanna, which has few other tree species other than the occasional *S. coronata*, thus the name *campo limpo* meaning clean field. The soil is very poor, fine grain whitish to brownish sand or gravel. The cerrado is disjunct in that it is surrounded by arid caatinga vegetation at the lower elevations and is disjunct from the cerrados west of the São Franciso River.

CONSERVATION: This hybrid is not common, it was found only once, but with several plants of it at the locality where it was first collected. A Brazilian colleague searched for it as recently as 2009 and was unable to locate any plants (Harri Lorenzi, pers. comm.). However, the area is large, desolate, monotonously repetitive, and the plants are short enough, that it might be difficult to spot if they were not in flower at the time. Conditions apparently must be ideal for the hybrid to form, because it occurs infrequently and has not been seen in other areas where the two parent species are known to overlap.

PHENOLOGY: Collected in flower in October.

USES: None recorded.

OBSERVATIONS: This infrequent palm hybrid is intermediate in several characters (Table 1) between the only other two *Syagrus* species in the area, *S. coronata* and *S. microphylla*, and is most definitely the hybrid between these two species. It demonstrates hybrid vigor in at least two associated characters: the peduncle and peduncular bract. The peduncle grows to 118 cm long (vs. 90 cm and 55 cm for *S. coronata* and *S. microphylla* respectfully). The total peduncular bract length grows to 146 cm long (vs. 112 cm and 68 cm for *S. coronata* and *S. microphylla* respectively)(Fig. 1). It is easily distinguished from *S. coronata* by its acaulescent growth habit, smaller branched inflorescence, and smaller leaves with fewer leaflets (Table 1). One can separate it from *S. microphylla* due to its larger size, longer and strongly recurved leaf rachis (Fig. 2), a larger inflorescence with more numerous rachillae (8–18 vs. 3–13), and a longer peduncle that protrudes above the height of its own foliage

3. A *Syagrus × mirandana* inflorescence with its narrow 3.5–4 cm peduncular bract, similar to *S. microphylla*.

4. The short *Syagrus microphylla* is the probable mother plant of *Syagrus* × *mirandana* with short leaves and an inflorescence that is about the same height as its foliage.

or surrounding vegetation (Fig. 1). In many characters this hybrid is closer to *S. microphylla*, the mother plant (Fig. 4), with its acaulescent habit, similar number of leaves in the crown, narrow peduncular bract (to 3–4 cm in width vs. 8–21 for *S. coronata*) and similar sized female or pistillate flowers (5–7 mm vs. 7–12 mm long for *S. coronata*). The height of the inflorescence above the rest of the plant is an especially good field character for spotting this acaulescent palm because *S. microphylla* has an inflorescence that rarely extends much above the height of its own foliage (Fig. 4) and the plants themselves are often not much higher than the surrounding vegetation. The pistil is very small in the hybrid and may be aborted.

ADDITIONAL SPECIMENS EXAMINED: BRAZIL. Bahia: Municipio de Remanso [Sento Se?], *Miranda s.n.* (Herbarium at CPATSA).

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I would like to acknowledge Jose Luciano de Santos Lima for his help in the field and CPATSA , EMBRAPA for the use of their vehicle and facilities. I also acknowledge the Montgomery Botanical Center for supporting my research and Fairchild Tropical Botanic Garden for the use of their facilities and collections.

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Table 1. Medial measurements demonstrating hybrid nature of *S.* × *mirandana*.

Character	*S. coronata*	*S.* × *mirandana*	*S. microphylla*
Leaf rachis (cm)	100–275	56–95	29–62
Leaflet number	80–130	28–38	18–36
Middle leaflet length (cm)	22–70	14–34	10–22
Prophyll length (cm)	35–55	18–20	8–17
Inflorescence length (cm)	30–95	25–42	7–18
Rachillae number	39–78	8–18	3–16

Heterospathe elata, a New Record for the New Guinea Islands

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1. *Heterospathe elata* showing the coconut-like habit without a crownshaft. (Photo: Charlie D. Heatubun)

The horticulturally important palm *Heterospathe elata* Scheff. is recorded for New Guinea for the first time on the island of Gag, Indonesia.

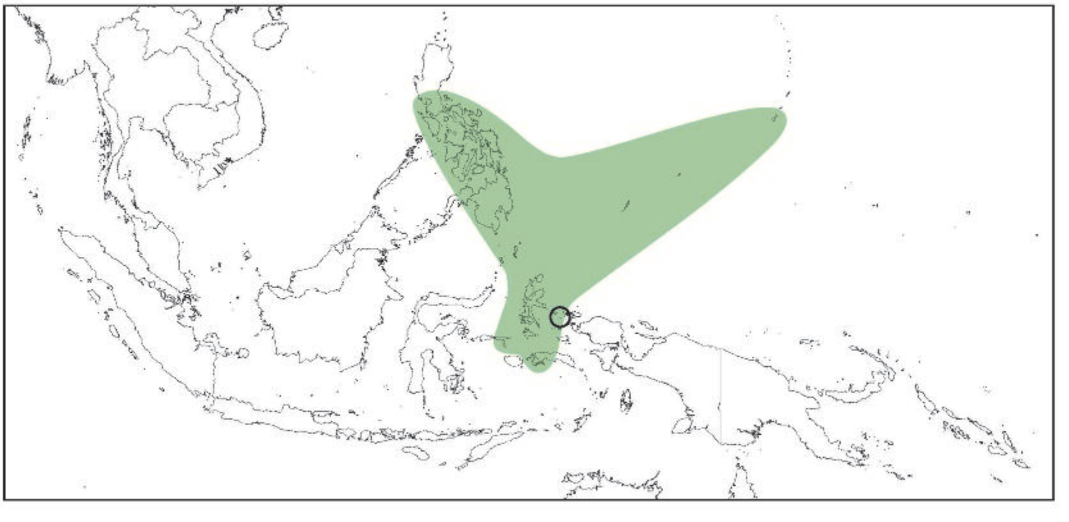
The genus *Heterospathe* (Arecoideae: Areceae) comprises some 39 species of lowland and montane rainforest palms distributed from the Philippines and Micronesia through to eastern Indonesia, New Guinea, the Solomon Islands, Fiji and Vanuatu. During fieldwork by the first author for the Palms of New Guinea project (Baker 2002), three populations (fewer than 20 individuals) of a species of *Heterospathe* were found on the island of Gag, one of the Raja Ampat Islands.

Situated in the Indonesian province of West Papua, the Raja Ampat Archipelago is currently being considered by UNESCO for World Heritage Site listing. Gag is a small island (56 km^2) approximately 150 km north-west of Sorong, the largest town on the Bird's Head Peninsula of mainland New Guinea. Sitting astride the world's largest seam of nickel, the amazing flora and fauna found on the island is under threat from large scale open-cast mining. A more detailed paper will discuss separately Gag Island's environment, including its plant communities and its palms in particular (Heatubun et al., in prep.), but in general, there are two main types of forest based on the underlying geology of the island, namely heath forest on ultramafic soils and rainforest on limestone-rich soils.

2. The inflorescence of *Heterospathe elata*. (Photo: Charlie D. Heatubun)

The *Heterospathe* found on Gag is very rare, occurring scattered throughout the limestone forest and rarely as one or two trees in open grassland near the airstrip and in an old abandoned garden close to a coconut plantation in the north of the island. The palm is solitary, with a slender stem to 10 m high, and has about 17 leaves forming a dense crown that lacks a crownshaft (Fig 1). The leaves are approximately 350 cm long, including the petiole which is 75–100 cm long, with a conspicuously white powdery leaf sheath about 85 cm long. The inflorescence is approximately 150 cm long, emerging from among the leaves, and branching to three orders (Fig 2). The palm is known as *gul ways*

3. Map showing the distribution of *Heterospathe elata* with Gag Island marked with a circle.



in the local language (Gebe dialect), and sometimes local people use the stem for traditional house construction, such as flooring and poles or pillars. This is potentially a cause for conservation concern as so few individuals are known on the island.

Attempts were made to match the Gag specimens at Kew to an existing taxon, and to determine whether or not it may be new. Although the specimens did not match any of the taxa previously recorded in New Guinea, nor any of the descriptions in the literature, it soon became clear that that it was extremely similar to *Heterospathe elata* – a species not recorded previously from New Guinea or its adjacent islands. Most species in the genus *Heterospathe* are endemic to single islands/ groups of islands, whereas *H. elata* is widely distributed, from the Philippines, to Maluku, the Caroline Islands (Palau) and the Marianas (Guam) (Fig 3). The species, the type of the genus *Heterospathe*, was first described by Scheffer in 1876 from material cultivated in Bogor Botanic garden originating from the island of Ambon, relatively close to New Guinea and to Gag Island (see map). *Heterospathe elata* is a canopy palm whereas most other species range from small to medium-sized understory to mid-story palms. Known as the Sagisi Palm, the species is a popular and widely cultivated ornamental, which flourishes in full sun (Jones 1995). According to Fernando (1990), the species is nowhere abundant in the wild, although Moore and Fosberg (1956) reported that the species is considered to be a weed in Guam in several locations, even crowding out native species in ravines.

The Gag island palm displays an intriguing condition that has not been noted in *Heterospathe* before and is very unusual within tribe Areceae. Infructescences produce a mixture of single, bi-, and occasionally tri-lobed fruits, which contain one, two or three seeds correspondingly (Fig 4). From a total of three specimens from Gag Island, one specimen had 10.6% of its fruit with multiple lobes (26 out of 246 fruit), another 11.1% (43 out of 387), and the last specimen 5.3% (16 out of 302). On examining all fruit from all specimens of *H. elata* currently at Kew we found a single cultivated specimen at Kew, from "Lawn O" of Singapore Botanic Garden (*Nur s.n.*) collected in June 1929, and determined by Furtado, with a single bi-lobed fruit. We have no information as to where this specimen originally came from, but the fruit is still attached to a rachilla and indicates that this taxon has the capacity to produce such multi-lobed fruits.

4. The fruits of *Heterospathe elata* – showing development of bi-lobed fruit and the rusty brown indumentum on the rachilla. (Photo: Charlie D. Heatubun)

Two varieties of *H. elata* were described by Beccari, var. *guamensis* and var. *palauensis*. The former was considered to be a synonym of *H. elata* var. *elata* by Moore and Fosberg (1956) on the basis of there being little significant difference between the Guam material and material in cultivation, and their belief that the Guam material may have been introduced historically from the Philippines. Moore and Fosberg considered the fruit size and shape characters used by Beccari to distinguish var. *palauensis* to be "tenuous," but continued to recognize the variety on the basis of specimens bearing more slender rachillae and exhibiting "more strongly cross-rugulose pinnae," compared with var. *elata*. We suspect that these last distinguishing characters are probably also too tenuous, being variable across the many specimens of *H. elata* examined during this work. The curious fruit characters might suggest that the Gag form of *H. elata* merits taxonomic recognition. However, in view of the limited material available and the morphological variation observed across the species, this cannot be justified. Nevertheless, the discovery of this palm on Gag Island represents a significant addition to the New Guinea palm flora.

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Effect of Container Type on the Nursery Growth of Kentia Palms and King Palms

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Palms are amenable to container culture because of the nature of their adventitious, fibrous root systems – all primary roots arise independently from one another at the root initiation zone near the base of the trunk. Nurseries, palm collectors and hobbyists commonly grow palms in containers for future potting-up, sales or outplanting in the landscape. Several new, non-traditional, air-root-pruning container types or designs are available to growers and hobbyists that manufacturers claim enhance growth of shrubs and trees by manipulating soil aeration and root growth to produce a better root system, primarily for outplanting in the landscape but also for potting up into larger containers. In a two-year study at a California nursery, we found that three non-traditional, root-pruning container types produced mixed results but none produced significantly greater root mass, leaf or stem growth and overall quality than a standard, traditional nursery container during production of kentia palms (*Howea forsteriana* (F. Muell.) Becc.) and king palms (*Archontophoenix cunninghamiana* (H. Wendl.) H. Wendl. & Drude). However, one of the air-root-pruning containers appeared to produce a more uniform root system with denser but shorter secondary roots.

In 2007 Sarah Wilcox, co-owner of Keeline Wilcox Nurseries, a long-time grower of kentia palms and other palms and ornamentals primarily for the interior trade, asked Don Hodel for assistance in evaluating three new, non-traditional, root-pruning container types for production of kentia palms from 1-liter containers to approximately 30-liter containers. Two manufacturers promoted these root-pruning containers, stating they enhanced growth of trees and shrubs through their perforated side walls that improved soil aeration and drainage and redirected and air-pruned roots, helping to make a stronger, denser root system for outplanting. In earlier work with non-palm trees, Fitzpatrick et al. (1994) found that mahogany (*Swietenia mahagoni*) grown in root-pruning containers had lower root mass and higher shoot to root ratios compared to trees grown in standard black plastic containers. Similarly, Marshall and Gilman (1998) found that red maple (*Acer rubrum*) grown in root-pruning containers had reduced root mass and fewer roots deflected by the container sidewalls compared to trees grown in standard black plastic containers. Arnold and McDonald (1999) also observed long lateral roots deflected by the walls of standard containers compared to shorter sections of root circling when using root-pruning containers. They also found that seedlings of Chinese pistache (*Pistacia chinensis*) and American sycamore (*Platanus occidentalis*) grown in root-pruning liners had greater height and trunk diameter compared to those grown in standard liners after each was transplanted to larger containers (Arnold & McDonald 1999).

For other woody plant species growth after transplanting from root-pruning or standard containers was similar. For example, Marshall and Gilman (1998) found no growth differences in red maple grown in root-pruning containers compared to standard containers five months after outplanting in the landscape. Similarly, although 0.45-liter root-pruning liners reduced growth of southern live oak

1 (right, top). A non-traditional 11.4-liter nursery container, the RootBuilder® 3 (RB 3) used in the study (D.R. Hodel). 2 (right, middle). A non-traditional 25.4-cm nursery container, the RootMaker® 10 (RM10) used in the study and planted with a kentia palm (D.R. Hodel). 3 (right, bottom). A non-traditional 30.5 cm nursery container, the Accelerator® (NS 12) used in the study. Note the slits in the side wall through which potting soil was lost during irrigation. (D.R. Hodel).

(*Quercus virginiana*) compared to black plastic liners of the same volume initially, growth was similar between the two container types once the trees were transplanted to larger containers (25-liter root-pruning and standard containers) (Arnold & McDonald 1999). Growth in the larger root-pruning containers was also similar to conventional containers for Chinese elm (*Ulmus parviflora*) and velvet ash (*Fraxinus velutina*) (Arnold & McDonald 1999).

Sarah wanted to know if these types of containers would be more beneficial and advantageous for growth of kentia palms than the traditional nursery containers that Keeline Wilcox Nurseries was using. Thus, we conducted a two-year study to determine the effectiveness of these newer, non-traditional, root-pruning containers and compared them to traditional containers in promoting better growth and better root systems for potting up and/or outplanting.

Materials and Methods

We conducted this study from May 2008 to April 2010 at Keeline Wilcox Nurseries in Oxnard, California, using kentia palms grown in 1-liter containers provided by the nursery and king palms grown in 3.8-liter containers provided by ABC Nursery in Gardena, California. Initial overall heights ranged from 0.6 to 1.4 m for kentia palms and 1.2 to 1.7 m for king palms. Initial basal stem diameters, measured at the soil line, ranged from 25 to 40 mm for both species. In May 2008 nursery staff potted the palms singly into seven different containers (four container types and two sizes each for three of the types (Table 1, Figs. 1–3) using their standard kentia palm potting mix: equal parts of sandy loam soil, fine pumice rock, sharp sand, decomposed and nitrogen-stabilized fir bark, and 5 kgs of dolomite lime per cubic m of mix. Keeline Wilcox Nurseries and the container manufacturers (Nursery Supplies, Inc., Orange, CA and Rootmaker Products Company, Huntsville, AL) provided the containers.

We placed the newly potted palms under 50% lath shade (Fig.4) and tagged the newest, fully emerged leaf of each palm for subsequent leaf counts. Nursery staff regularly irrigated the palms as part of their normal irrigation of nearby production plants. We hand weeded the containers as necessary and applied Best Palm Plus 13-5-8 controlled-release, palm-

4. The newly potted palms placed under 50% lath shade (D.R. Hodel).

Table 1. Container characteristics used in evaluation of container types for palm production, Keeline Wilcox Nurseries, Oxnard, CA, 2008–2010.

Project Container Name	Trade Name/ Description	Dimension (H × W top, cm)	Volume (ml)	Manufacturer
KW 10	standard 25.4-cm (10-inch) nursery container	22.9 × 25.4	9700	Nursery Supplies, Inc.
KW 14	standard 35.6-cm (14-inch) nursery container	30.5 × 33.7	22,800	Nursery Supplies, Inc.
NS 12	Accelerator®/ non-traditional 30.5-cm (12-inch) nursery container	22.2 × 30.5	10,000	Nursery Supplies, Inc.
RB 3	RootBuilder®/ non-traditional 11.4-liter (3-gallon) nursery container	29.2 × 26.7	15,453	Rootmaker Products Co., LLC.
RB 5	RootBuilder®/ non-traditional 19-liter (5-gallon) nursery container	39.4 × 29.8	29,661	Rootmaker Products Co., LLC.
RM 10	RootMaker®/ non-traditional 25.4-cm (10-inch) nursery container	24.1 × 27.1	10,750	Rootmaker Products Co., LLC.
RM 13	RootMaker®/ non-traditional 33-cm (13-inch) nursery container	24.8 × 34.3	19,100	Rootmaker Products Co., LLC.

special fertilizer (J. R. Simplot, Boise, ID) at 20 g per palm in April, 2009. At roughly six-month intervals (November 2008, April 2009, December 2009, May 2010) we measured stem diameter and counted leaves produced. At the end of the study in May 2010, we randomly selected six replications, removed the palms from their containers, removed the soil from the roots, examined the roots, clipped them off, dried them at 65° C for five days, and then weighed them.

The experimental design was a randomized complete block with 20 replications. Each replication was a row consisting of two species of palms and seven different containers, all randomized within each row. We analyzed all data using the Mixed Procedure (v. 9.3, SAS Systems, Cary, NC) with the overall error rate for multiple comparisons controlled by Tukey-Kramer adjustment. Because the objective of this study was to compare the new, non-traditional, root-pruning container types with standard, traditional containers, we used container volume and initial palm stem caliper as covariates. This analysis enabled us to separate neatly the effect of container type on palm growth and thus, we report results for only the four container types, regardless of volume.

To examine treatment effects over time, we conducted repeated measures analysis of variance using the Mixed Procedure to address potential autocorrelation for stem calipers, which were measured on the same plants for multiple sampling dates. For this analysis, we selected the Compound Symmetry (CS) covariance model based on measures of relative fit of competing covariance models.

Results and Discussion

None of the three non-traditional, root-pruning container types (RootMaker®, RootBuilder® and Accelerator®) produced significantly more new leaves, greater stem

5 (below, top). The RootBuilder® container tended to produce a more uniform root system with denser but shorter secondary roots (*Howea forsteriana*). 6 (below, bottom). The standard nursery container tended to produce a less uniform root system with fewer but longer secondary roots (*Howea forsteriana*). (D.R. Hodel)

Table 2. Effect of container type on mean number of new leaves, stem caliper, root dry weight, and overall quality of kentia and king palms at Keeline Wilcox Nurseries, Oxnard, CA, May 2010.

Container	New leaves[z]		Stem caliper, mm		Root dry wt, g		Quality, 1–5[y]	
	Kentia	King	Kentia	King	Kentia	King	Kentia	King
Standard	3.1 a[x]	3.2 a	69 a	65 a	452 a	403 a	4 a	3 a
RootMaker®	3.1 a	2.9 ab	69 a	64 ab	337 a	300 a	4 ab[w]	3 a
RootBuilder®	2.4 b	2.7 b	62 b	61 b	520 a	413 a	3 bc[w]	3 ab[v]
Accelerator®	2.4 b	1.8 c	60 b	47 c	406 a	393 a	3 c	2 b
P value	p	p	p	p	0.57	0.13	p	p

p = <0.0001

[z]Total new leaves from May, 2008 to May, 2010.

[y]1=dead, 5=perfect.

[x]Means followed by the same letter within a column are not significantly different at $P<0.05$ (overall error rate controlled by Tukey-Kramer adjustment).

[w]Means for statistical separation were 3.7 and 3.2 for RootMaker® and RootBuilder®, respectively.

[v]Mean for statistical separation was 2.9.

calipers, more root mass or higher quality plants for both palm species than the traditional, standard nursery container (Table 2). Although previous researchers observed reductions in root mass for woody ornamentals using root-pruning containers (Fitzpatrick et al. 1994, Marshall & Gilman 1998, Arnold & McDonald 1999), we found no statistically significant reduction of root mass in either palm species with any of the root-pruning containers. However, an examination of the root systems showed that RootBuilder® containers tended to produce a more uniformly distributed root system and denser but shorter secondary roots than the standard nursery containers (Figs. 5 & 6). These observations are similar to those of other studies with oak species where root pruning encouraged growth of shallow, small diameter roots instead of large diameter roots, resulting in reduced water stress following transplanting (Gilman & Anderson 2006) and better survival compared to trees with unpruned roots (Gilman et al. 2002, Gilman & Anderson 2006). It is unknown, though, whether the uniform and dense root system observed in RootBuilder containers® may afford a planting survival advantage in palms similar to that conferred by root-pruning of oaks. However, studies with other non-palm, woody species generally showed that there was no advantage (Arnold & McDonald 1999, Marshall & Gilman 1998).

RootMaker® was equivalent to the standard nursery container for leaf and stem growth and quality for both palm species. RootBuilder® produced significantly fewer leaves and smaller stem calipers for both species and poorer quality for kentia palms than the standard nursery container but similar quality for king palms as the standard nursery container. Accelerator® produced significantly fewer leaves, smaller stem calipers and lower quality than the standard and RootMaker® containers for both species, and fewer leaves and smaller stem calipers than all other containers for king palms.

Because the new container types with slits and holes in the side walls expose more surface area to evaporation, it is possible they dried out significantly between irrigations scheduled for standard, solid-wall containers. Perhaps this drying accounted for some of the different growth responses but was not quantified in this study. Arnold and McDonald (1999), however, observed that more frequent irrigation was required to prevent wilting in root-pruning containers, possibly resulting in increased water use. We observed that the slits in the sidewalls of Accelerator® containers led to significant soil loss during irrigation, reducing soil mass and moisture, carrying away fertilizer and exposing roots, and was likely responsible for the poorer growth and quality of both species in some instances. Substrate loss was also observed with the Accelerator® prototype root-pruning container (Arnold & McDonald 1999).

Generally, palms in larger containers tended to produce more growth and were of higher quality than those in smaller containers (data not shown). When examining treatment effects over time, we also found no advantages of using root-pruning containers for early leaf or stem caliper growth (data not shown).

One other consideration was that the RootBuilder® containers required assembly, which may be tedious, laborious and time-consuming: side and bottom pieces were pulled together with plastic cinch ties. Also, the assembled RootBuilder® containers have straight sides, unlike the other containers with tapered sides, precluding them from being stacked in a nested fashion to save space.

Conclusions

None of the new, non-traditional container types produced significantly more growth, higher quality palms or greater root mass than the traditional standard container. Although the RootBuilder® containers tended to produce a more uniformly distributed root system and denser but shorter secondary roots than the standard nursery container, these differences did not affect palm growth, overall quality or root mass.

The girdling, kinking or circling seen in woody root systems in container-grown stock generally does not occur in palm roots, which are adventitious, independently arising, and fibrous. Root-pruning containers may, therefore, be less important for development of an optimal palm root system for outplanting than for woody plants, although previous studies with several woody species mostly indicate no advantage to using root-pruning containers, except for some oak species (Gilman et al. 2002, Gilman & Anderson 2006). Whether root system uniformity and density and length of secondary roots in palms impact establishment in the landscape needs to be determined. Other factors, however, such as time of year, planting depth, soil type and porosity, and post-planting care, including irrigation, nutrition, mulching and weed control, likely play a more significant role in successful and rapid establishment of palms in the landscape.

Acknowledgments

Keeline Wilcox Nurseries donated the kentia palms and some of the containers, allowed us to conduct this experiment at their facility and irrigated and otherwise maintained the research plot. ABC Nursery donated the king palms. Nursery Supplies, Inc. and Rootmaker Products Company, LLC donated containers. We thank an anonymous reviewer whose comments greatly improved this paper. All have our sincere thanks.

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Key to Coconut Cultivation on the American Pacific Coast: the Manila–Acapulco Galleon Route (1565–1815)

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Findings from recent DNA analyses allow a detailed and testable suggestion of when, where and how modern coconut populations first reached Mexico and spread southwards to Peru.

Background

After a decade of work in Jamaica in the 1960s undertaken by Dave Romney, Roger Whitehead and Roger Smith for the Research Department of the Coconut Industry Board, and involving travel in the Caribbean and Central and South America, they were able to describe the distribution of two distinctly different tall coconut populations on the Atlantic-Caribbean and Pacific coasts of America respectively. A world coconut germplasm collection established by the Jamaican team, also in the 1960s, showed that the Atlantic-Caribbean coast coconuts were similar to south Asian and African types; while the Pacific coast coconuts closely resembled named types found in south-east Asia and on some Pacific islands.

A visit to Costa Rica in 1977, at the invitation of ASBANA to advise on coconut hybrid seed production, confirmed the presence of the two coconut populations, and it also stimulated active research into coconut dissemination. The immediate result was to trace the ancestry of the Atlantic-Caribbean type to the return of Vasco da Gama from his first voyage to India and a specific 50 year period, from 1499 to 1549, as the time taken before seedlings propagated from the original introduction were actually planted in America (Puerto Rico). However, the ancestry of the American Pacific coast coconut populations was not resolved because a 16th century account that indicated a pre-Columbian presence had generated different opinions about the origin of *Cocos nucifera*, the relative importance of natural dispersal by floating and human assisted dissemination by boat and even which direction they took across the Pacific!

The possibility that Spaniards returning from the Philippines by the trans-Pacific route would carry coconuts to Mexico, first put forward by Edwin Safford (Lieutenant-Governor of Guam and USDA botanist), was included in a seminal paper on coconut evolution, dissemination and classification that identified the superiority of the south-east Asian and Pacific Coast types, in terms of growth habit, disease resistance, windstorm tolerance, early germination and high nut-water content. Taken on board to supply the crew with fresh, uncontaminated drinking water, any early germinators would be preferentially planted on arrival (Fig. 1). So desirable is this type, it would also have been carried by the coastwise traffic to and from the

1. Early germinators, available for planting.

Peruvian silver mines and planted anywhere between. The result would be to displace other coconut palms, if any were already growing on the Pacific coast of America.

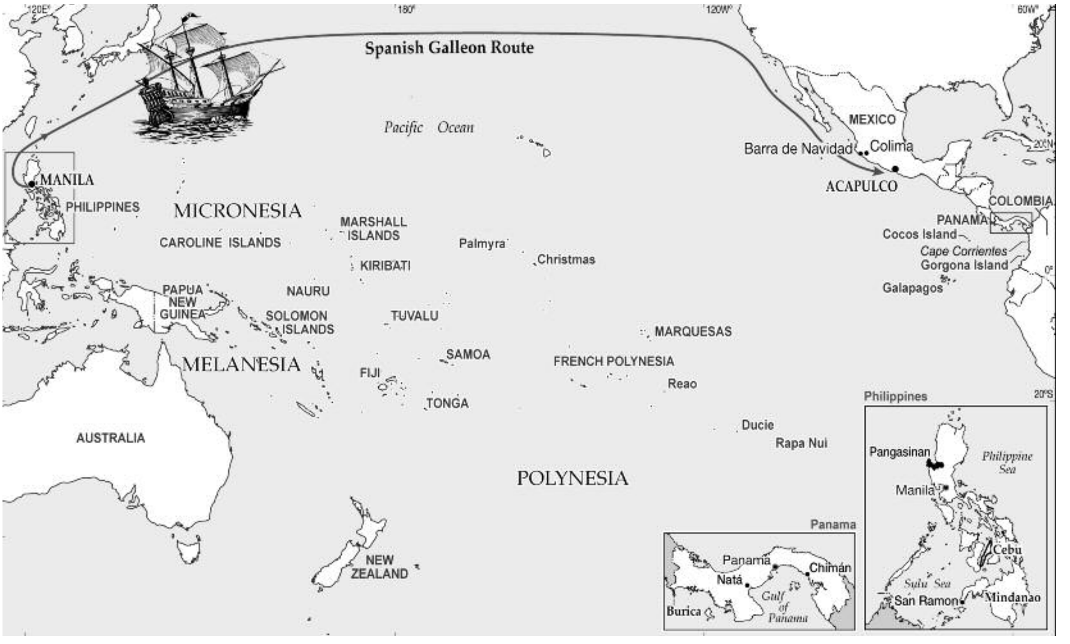
The Tordesillas Treaty of 1494 divided the world outside Europe between Portugal and Spain; Africa and Asia went to Portugal while the "New World" of America and the, as yet unknown, Pacific went to Spain. The treaty effectively prevented Spanish mariners from sailing through Portuguese controlled waters to the Far East until 1580, when both countries were ruled by Philip II of Spain. This meant that for most of the 16th century the conquistadors had no opportunity to see mature, fruit-bearing, coconut palms. They may have heard or read about coconuts and might have seen ripe nuts or even seedlings brought back on Portuguese vessels. When Gonzalo Fernandez de Oviedo y Valdes, a Spanish official historian, learned that "*cocos*" palms were present on the Pacific coast of Panama in 1516 and Alvaro de Guijo, a Panama City resident, sent seed to Mexico in 1539, they may, unintentionally, have misidentified a different palm as just an another sort of coconut. Over the intervening years professional taxonomists have classified some 131 palm species or subspecies as *Cocos*, predominantly from South or Central America, although today they have been assigned to other genera, leaving *Cocos nucifera* as a monotypic genus.

The clue to misidentification was the result of an inquiry from "the American Linnaeus," Elmer Drew Merrill, who was concerned that theorists with "little or no personal experience of the Pacific basin … forget what the situation was in the days of sailing ships, from the fifteenth through the early nineteenth centuries." In a letter to Merrill, in 1952, Paul H. Allen, a botanist respected for his work on economically important species and Central American ecology, suggested that Oviedo may have regarded them as "somewhat aberrant and inferior coconuts" when he wrote "*… I was in the province and headland of Borica* [the present day Burica on the border of Panama and Costa Rica]*, and I ate some of these cocos and carried many with me to Nicaragua, and came to loathe them, and others did as I did and said the same thing as well*." There are people who find coconut kernel indigestible, but it is not usually a group phenomenon, and such an extreme word as "loathe" is an over-reaction and strong evidence that the *cocos* they were carrying were not true *C. nucifera*. Equally thought-provoking is Oviedo's choice of "ate" rather than "drank" as it indicates that, unlike a real coconut, the fruit had little water. The possibility that these were simply over-ripe and germinating is also unlikely because the soft, sweet haustorium (or "apple") inside a germinating coconut is usually considered a delicacy. Most, if not all the rest of Oviedo's account of *cocos* can be found in earlier texts, so his "loathing" is a real-time response that shows he was genuinely, but honestly, mistaken.

Recent genetic data showing a relationship between the Pacific coast coconuts and coconuts in the Philippines confirm earlier findings based on morphometric analyses. For instance Daniel Zizumbo and his colleagues found similarities between Pacific coast coconuts in Mexico and named sorts in south-east Asia and on a few isolated Pacific islands, while Alfonso Vargas of CORBANA and Fabio Blanco particularly compared Pacific coast population in Costa Rica with the San Ramon type in the Philippines. Now, an international team, led by Charles Clement and Daniel Zizumbo, has re-appraised the DNA data and, using the internet to access information about the Manila–Acapulco galleon route that had not been so easily available before, has proposed a detailed and testable suggestion of when, where and how modern coconut populations first reached Mexico and spread southwards to Peru.

Historical knowledge

The Tordesillas Treaty gave Portugal advantageous access for trade from Africa to the Far East, as far as the Moluccas. In 1564, Miguel Lopez de Legazpi, Andres de Urdaneta and Alonso de Arellano mounted an expedition to establish a Spanish settlement in the Philippines to compete with the Portuguese. To avoid sailing through Portuguese waters they set out from Barra de Navidad, Jalisco in Mexico (New Spain). As the expedition navigator Urdaneta set a course for Cebu in the Visayas, where Magellan had landed, some four decades previously. Leaving Legazpi at the settlement in Cebu, Arellano and Urdaneta returned independently to Mexico. Urdaneta reached Acapulco in October 1565 without making any intermediate landfalls, by sailing between 36 and 42°N to avoid the north-east Trade Winds and take advantage of higher-latitude westerly winds (Fig. 2). Arellano, who is thought to have



2. The route of Spanish galleons crossing the Pacific from the Philippines to Mexico.

followed a similar but less well documented route, reached Barra de Navidad in August 1565. Annual voyages started in 1568, and in 1571, the "Urdaneta route" was designated as the preferred route, now commonly called the Manila-Acapulco galleon route. Manila became the premier city of the Philippines (with Legazpi as the first governor), because it already had trade links with China and Japan and, as the northernmost harbor, it was well placed as the departure point for the galleon route. However, on the first occasion in 1565, both Arellano and Urdaneta had sailed from Cebu and not from Manila, and this is significant because there were superior coconuts in that region.

Agricultural knowledge

In 1668 Father Francisco Ignacio Alzina, an agricultural observer who had resided in the Visayas, Philippines, for over 33 years, wrote "*There are very big ones* [coconuts] *which would measure more than one azumbre* [2 liters]." Cebu, in the Visayas, is not far from Mindanao, at the head of the Sulu Sea. When the production of copra became commercially important in the Philippines at the beginning of the 20th century, the coconuts in the San Ramon district of Mindanao were highly regarded; according to the Dean of the Philippines College of Agriculture, Edwin Bingham Copeland, writing in 1914, "*… there are no records from any other part of the world of plantation averages showing such size of nut as those of San Ramon. There was one cutting for the entire plantation at San Ramon in 1905, when the average production was one metric ton of copra from 2800 nuts*." Yet, an almost identical claim was made in an estate company prospectus by William Bardy in the very same year; "G*orgona Island between 3rd and 5th parallel N of Equator 24 miles off Colombia … is famous for producing coconuts of immense size and are of great use to planters as seed nuts. Average yield 82 nuts/tree/year, 1 ton copra/2200 nuts or 1lb copra/nut. This is nearly twice as obtained from the average nut*." Any 20th century connection between Cebu in the Philippines and Gorgona in Colombia has yet to be genetically analyzed.

Discussion

The possibility that Urdaneta and Arellano carried coconuts that were planted on their return has previously been discounted because coconuts were not recorded on their list of provisions and their crews were starving and dying on arrival in New Spain. It is hard to believe that a mariner of Urdaneta's experience (the second man to sail round the world) would contemplate making a Pacific voyage without taking fresh coconuts on board at the very last moment – not in the hold or recorded as cargo – but simply on deck for the crew to drink or use when preparing food. In fact, a report by Arellano of cooking oil freezing is strong circumstantial evidence for the presence of coconut oil, but it was previously disregarded as an exaggeration by Europeans not familiar with the remarkable property of liquid coconut oil to become a whitish, crystalline solid at temperatures below 25°C. The average overnight air temperature at 40°N in the Pacific, even in mid-summer, is cool enough for coconut oil to solidify. If coconuts were carried, then the early germination of the San Ramon type, often sprouting at the time of harvesting and exceeding 75% in 105 days, would mean that both Arellano in August or Urdaneta in October could have had plantable seedlings on arrival. Starving seamen would get little to eat and less to drink from germinated seedlings and, even in an extremity, they would know that these represented future food resources if they should make landfall on an uninhabited shore – a very real risk at that time. If they did carry coconuts then the earlier arrival at Barra de Navidad would have given Arellano better planting weather. If they did not carry coconuts they would have learned the value of doing so (as Vasco da Gama did when some of his crew died sailing from India against the prevailing monsoon in 1499). Fresh coconuts would become a priority on future voyages, and Felipe de Salcedo, who had accompanied Urdaneta in 1565, would be a likely candidate on a second return voyage in 1569.

The Barra de Navidad lagoon borders Colima province, which became, and is still today, the center for coconuts in western Mexico. By 1580 skilled Filipino workers, also brought by the Manila-Acapulco galleons, were already tapping flowering palms for tuba (toddy). Indeed, fermenting toddy to produce wine would account for the quick expansion of coconut cultivation in Mexico since it takes only four years from planting until flowering, young palms are easy to climb and tapping is virtually continuous with vigorously growing palms. So it was probably not by chance, that Barra de Navidad became the point of departure for the outward leg of the subsequent Manila-Acapulco galleon voyages. Ocean-going galleons and coastal schooners were built there, and these vessels could routinely carry coconuts for fresh consumption whenever and wherever they went.

At the Philippine end of the trans-Pacific route, for every voyage until the last in 1815, the San Ramon type of coconut would be in demand and might not, at first, be available near Manila. This could be overcome, either by arranging for them to be collected in Mindanao or the Visayas for trans-shipment to Manila or, more easily, by planting them somewhere close to Manila. Therefore it comes as no surprise to learn from Copeland that San Ramon coconuts were in general cultivation in the coast district of Pangasinan province, Luzon, to the north of Manila, which would have been the most convenient location for taking deck cargo on board.

If there had indeed been seedlings from the 1565 Barra de Navidad landing they would be bearing within five to seven years. It would be their year-round production of nuts, rather than the once yearly arrival of unconsumed coconuts from Manila, that would be carried by coastal vessels for consumption on-board. So the coconuts on the American Pacific coast could have come from one or more locations, even on more than one occasion, yet still represent a single genetic San Ramon population, and have a strong founder effect, replacing the indigestible *cocos* that Oviedo and his companions loathed elsewhere on the Pacific coast. Early germinators would be planted at locations like Gorgona Island and would be taken southwards as far as Peru along the Acapulco-Panama-El Callao route, "La Goleta de Lima", established to supply the silver mines with oriental luxuries from China and also with wine. The Hacienda de Apasagualcos, Acapulco, where Urdaneta established a great coconut orchard, was dedicated to the production of coconut wine. The wine trade made coconut important in Mexico centuries before the commercial copra trade made it an agricultural crop in any Central or South American countries, or indeed world-wide.

There is an apparent discrepancy in the currently available genetic data, namely that modern coconut populations in Mexico do not match the modern Panama coast tall data set. The most obvious reason for any discrepancy would be the loss of the original material due to natural causes (fire, flood, hurricane, pest and disease) followed by replanting possibly using non-San Ramon material.

For example, the present day coconut plantations in Mexico received more introductions in the 1930s and were extensively replanted in the 1940s and 50s because the US demand for copra (a raw material for high explosives that could not be met from the Philippines during the Second

World War) had been supplied from Mexico. These 20th Century plantings could account for the mismatch in DNA data between Mexico and Panama. Coconuts in Panama, and elsewhere on the Pacific coast, never had sufficient economic importance to be replanted on the same scale. They closely resemble the Philippines San Ramon-type.

Conclusion

The possibility that coconuts were present on the Pacific coast of pre-Colombian America has yet to be confirmed, but the recent genetic data makes this unlikely by showing that there is little or no possibility that the Pacific coast coconuts could have come from islands in the Pacific, either by floating or in Polynesian canoes. An alternative proposal for a small founder introduction directly from the Philippines to Panama at a remarkably early date – some 2250 years ago – is also difficult to validate. In contrast, a small founder introduction to Mexico in 1565, or soon afterwards, by the Manila-Acapulco route followed by coastwise dissemination south as far as Peru is consistent with established historical records. The difference between modern coconut populations in Mexico and those farther south can also be accounted for by replanting. To help clarify the issue it will be desirable to undertake further DNA testing of the San Ramon populations in Cebu and Pangasinan in the Philippines, the coconuts on Gorgona Island, Colombia and, in Mexico, not only those at Colima but also at the Hacienda de Apasagualcos, Acapulco (if still accessible).

Citations to support statements made in this paper can be supplied on application to Hugh Harries, moderator of the Coconut Time Line at http://cocos.arecaceae.com.

Pseudophoenix sargentii on Mona Island: Conservation Survey and a New Discovery

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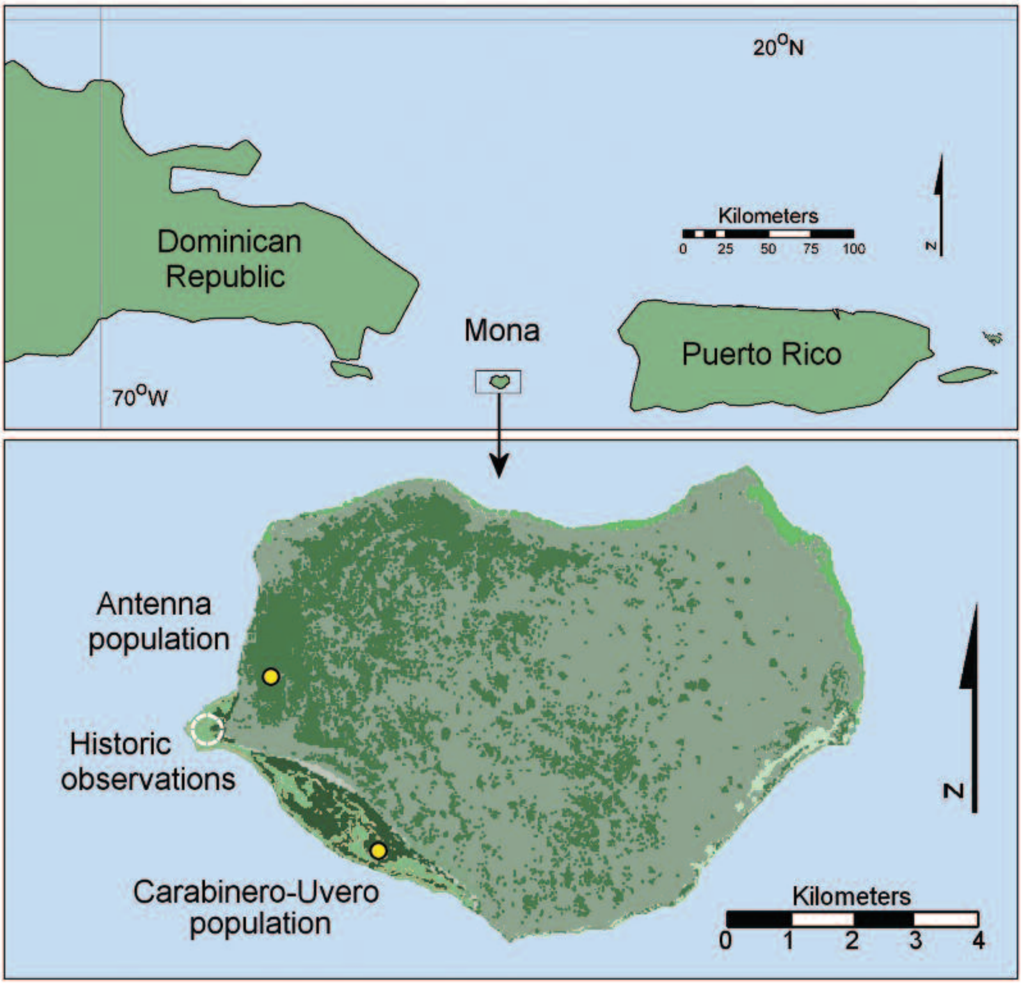
A limited, potentially imperiled and sparsely documented population of *Pseudophoenix sargentii* has been reported from Mona Island, between Puerto Rico and Hispaniola. Literature and specimen review produced a very scant record of this population but suggested decline over many decades. Recently, a second population was located on Mona. Here, we report results from a fieldwork project to survey, map and characterize these populations, to collect seeds for living botanic garden conservation collections and to collect leaflet samples for ongoing conservation genetic research. We are grateful to The International Palm Society for supporting this project.

Pseudophoenix is biogeographically intriguing. Endemic to the Caribbean Basin, the genus occurs mainly in the Greater Antilles, often in isolated populations (Zona 2002). The center of diversity for *Pseudophoenix* is southern Hispaniola, where all four species occur (Henderson et al. 1995, Zona 2002). Three of the four species show fairly narrow distribution. *Pseudophoenix ekmanii*, a strikingly beautiful, exceptionally ventricose palm, is restricted to the Barahona Peninsula and Isla Beata in the extreme southern Dominican Republic (Namoff et al. 2011). This amazing palm was a central highlight of the 2006 IPS Biennial, where IPS members saw the population firsthand in Parque Nacional Jaragua. *Pseudophoenix vinifera* occurs in both Dominican Republic and Haiti. In both countries, *P. vinifera* exists in small and scattered populations (Henderson et al. 1990, Zona 2002). *Pseudophoenix lediniana* is known from a single population in southern Haiti (Zona et al. 2007).

One species, *P. sargentii*, is also known from the Bahamas (Correll and Correll 1982), Turks and Caicos, Dominica (James 2003), extreme eastern Cuba, far northern Belize (Noblick 2009), Yucatán and Quintana Roo, Mexico (Duran & Franco 1992), Navassa Island, Isla Saona, and in the Florida Keys (Lippincott 1992). Thus, *P. sargentii* has the widest distribution of the genus. Perhaps due to this wide distribution with some significant disjunctions, many Caribbean island populations were described as separate species, subspecies, or varieties. The most recent revision of the genus placed a number of these

1. Location of *Pseudophoenix sargentii* populations on Mona Island. Historic observations at Sardinera come from Little et al. (1974) and Woodbury et al. (1977); the Carabinero-Uvero Population is documented by Hernandez (1994) and *Proctor 49505* (FTG); the new population (Antenna) is presented here. Basic vegetation types (see text) are adapted from Martinuzzi et al. (2008).



2. *Pseudophoenix sargentii* at the Antenna population. The flagging is used for census work. Compare to Figure 3. (photo: P. Griffith)

disjunct island *Pseudophoenix* populations into synonymy under *P. sargentii* (Zona 2002).

This project is focused on one such disjunction of *P. sargentii,* present on the island of Mona,

3. A group of adult *P. sargentii* at the Carabinero-Uvero population. Only one adult palm of 22 was in fruit in late January 2012. Compared to the palms in Figure 2, these appear taller (average of 4.5 m), much thinner (average of 16 cm diameter), and have a less robust crown of leaves, (average of 9 per plant). (photo: E. Santiago-Valentín)

between Puerto Rico and Hispaniola (Fig. 1). This location is of very limited size, of considerable conservation concern and of great phytogeographic interest. Only one other population of *P. sargentii* is located further southeast, on Dominica; the species is not known from other Lesser Antillean Islands and does not occur on the main island of Puerto Rico.

Conservation Concerns

Isolated populations of *Pseudophoenix* are often imperiled. For example, *P. lediniana* exists in a single population of fewer than 50 individuals, and seedling recruitment does not appear to be increasing this number (Zona et al. 2007). Two other species, *P. vinifera* and *P. ekmanii*, appear to have a reduced overall census, perhaps from prior destructive harvest of sap to produce an alcoholic beverage (Zona 2002, Namoff et al. 2011).

Pseudophoenix sargentii has recently been categorized as a species of Least Concern (Zona et al. 2007), as the species is relatively widespread. Many of the populations of *P. sargentii* are imperiled, however. Perhaps the best example is on Navassa Island, where a single wild individual remains (Zona 2002). One other well-known example concerns the individuals in Florida, which were once more widely distributed (Ledin et al. 1959) but were subsequently reduced to a single population on Elliot Key (Lippincott 1995). Careful, sustained work has succeeded in reestablishing some populations in Florida (Maschinski & Duquesnel 2006).

Pseudophoenix on Mona Island has also a very limited distribution, but conservation concerns in this case differ from other *Pseudophoenix* populations. Unlike many habitats, Mona Island benefits from a high level of protection and management as a Nature Reserve. Lack of permanent human settlement on Mona also greatly reduces the risk of human-mediated extirpation, although Acevedo-Rodríguez and Strong (2005) noted that seedlings of these palms have been sold in Puerto Rico and St. Croix. One possible threat to the Mona population is predation by feral goats and pigs (Cintrón 1991). Recent analysis of feral goat diets did not recover *P. sargentii* as goat forage (Melendez-Ackerman et al. 2008).

Past Records of *Pseudophoenix* on Mona

The earliest botanical exploration of Mona did not find *Pseudophoenix* (Britton 1915), and for the next half century, the palms were not known to occur on the island (Little 1955, Little & Wadsworth 1964).

In 1969, this journal reported R.O. Woodbury's discovery, which appears to be the first printed record of the species on Mona (Read 1969). The earliest published census (Little et al. 1974) reported a single individual. Woodbury et al. (1977) stated that Little's (1974) observation was made before 1968. However, in 1968, Woodbury observed three palms but found these three palms dead in 1974 and suggested that this was by human actions (Woodbury et al. 1977). This observation prompted Little (1978) to pronounce the Mona population extirpated. Apparently no specimens were made but careful reading places these localities in the coastal lowland near Playa Sardinera (Fig. 1), on the western tip of the island.

In the 1980s, botanist José L. Vivaldi re-discovered this species on Mona by chance from the air during a routine Departamento de Recursos Naturales y Ambientales of Puerto Rico (DRNA) flight. The site of this population is near Playa Uvero, in a coastal lowland forest in southern Mona. Since that discovery, efforts

4. An example of a dead palm at the Carabinero-Uvero site. Over the years, notes on this site (Hernández 1994; Acevedo & Strong 2005) suggest a decline in the number of healthy adult palms. (photo: P. Griffith)

5. *Pseudophoenix sargentii* in fruit at the Antenna site. All four adults were in fruit in late January 2012. (photo: E. Santiago-Valentín)

have been made to document and manage this colony of palms for conservation. First, DRNA biologist José Rosario erected an exclosure (i.e., exclusion fence) to keep feral pigs and goats from the largest adult plants. In 1986 Gerardo Hernández (DRNA) counted 32 adult palms, 6 dead palms and a single juvenile (Hernandez 1994). That year, Hernández expanded the exclosure to protect more of the palms, and carried out selective removal of canopy branches that shade the base of adult palms. Hernández added measures to deter climbing and flying granivores in 1991 and 1992, which allowed him to collect and germinate many seed for establishment at selected lowland sites on Mona (Hernández 1994). Two herbarium specimens from this population collected in 1989 (*G.R. Proctor 45905*: FTG, SJ) documented 26 mature trees, all about 6 m tall.

The most recent account (Acevedo-Rodríguez & Strong 2005) also reported 26 mature trees of 6 m height, and thus appears to have followed the information from *Proctor 45905* (cited therein).

A New Discovery

In 2009, José Sustache and Eugenio Santiago were made aware of a potential new population of *Pseudophoenix* on Mona Island, on the plateau near Playa Sardinera, which was found by Miguel Bonet (a DRNA Ranger) while hiking off-trail. Mr. Sustache verified this observation, confirming these palms were *P. sargentii*, and performed the first census of the new population in April 2009, counting 4 adult and 8 juvenile palms. Scouting for *Pseudophoenix* and monitoring for phenology was then added to routine fieldwork on Mona. This is the first population of *Pseudophoenix* reported from the dogtooth limestone plateau of Mona Island.

Need and Objectives

As detailed above, very little information characterizing this unique island population of *P. sargentii* is currently available. Given the inconsistent depth and variation in these reports, the need for an up-to-date census is evident: were the early reports incomplete? Did, perhaps, the population go through a bottleneck in the 20th century, with the remaining palms descended from few survivors? And, are the most recent reports still accurate?

Pseudophoenix can benefit from *ex situ* conservation through botanic garden collections, an important part of re-establishment efforts. As slow-to-germinate, slow-growing palms, *Pseudophoenix* species are not highly suited for the conventional nursery trade, although it is difficult to find a more visually striking genus. Indeed, near extirpation of *P. sargentii* in Florida is largely due to past demand for the prized ornamentals. Cultivating *P. sargentii* from seed has been successfully performed by botanic garden conservation workers, but these efforts require a long-term view and significant commitment of resources (Maschinski & Duquesnel 2006). Developing *P. sargentii* populations from Mona Island will advance the conservation of this distinct population, and will help fill a phytogeographic gap in botanic garden collections where they can be of great utility to the research community and to the visiting public. Finally, ongoing conservation genetic research on *Pseudophoenix* (Namoff et al. 2010, 2011) would benefit greatly by the sampling of the Mona Island population.

Thus, in support of botanic garden living collections, conservation genetic research and basic phytogeographic and conservation assessment of *Pseudophoenix sargentii*, fieldwork on Mona Island was planned. The objectives were to:

Collect herbarium specimens of *Pseudophoenix sargentii* for FTG and UPR

Collect seed of *P. sargentii* for living collections at MBC, UPR and FTBG.

Collect leaflet samples of *P. sargentii* for conservation genetic research, from each individual in the population.

Map, census, assess and characterize the population, for age, size and recruitment.

The Current Fieldwork

Based on *Pseudophoenix sargentii* herbarium (JBSD, FTG and UPR) and living collections (MBC and FTBG), we expected flowering late in the calendar year and mature fruit in January or February. No flowering was observed in 2009 and 2010, perhaps due to unusually cold conditions or reduced rainfall. Finally, in 2011, inflorescences were observed, and in December 2011, a few mature fruit and abundant developing fruit were observed. With conditions thus lined up for a fruitful project, we travelled to Mona Island on January 20–23, 2012.

Here, we document the two native populations of *Pseudophoenix sargentii* on Mona, one occurring between Playa Carabinero and Playa Uvero ("Carabinero-Uvero") and one located near the DRNA radio communication antenna on the Mona Plateau (Fig. 2). These populations are growing in different vegetation associations, show different gross morphology and also appear to have differential reproductive success. Additionally, we report on the progress of initial *inter situ* (i.e., reintroduction to historical sites and other suitable locations) work in the 1990s (Hernandez 1994)

The Carabinero-Uvero Population.

As observed in the late 1980s, the Carabinero-Uvero population had 32 living adult palms in 1986 (Hernandez 1994) and 26 in 1989 (*Proctor 49505*: FTG). Survey by Mr. Sustache in April 2009 counted 20 living adult palms and 15 dead palms. One of these palms has been toppled and the growing tip has reverted upward, perhaps within the last 5 years. No flowers, fruits or seedlings were observed in 2009.

Survey in January 2012 counted 22 adult palms (Fig. 3), with quite a few dead palms also noted (Fig. 4). A single adult palm here was in fruit, and seeds were collected from this individual. Two seedlings were observed. Specimens (*Griffith 367*) are deposited at UPR and FTG.

The Antenna Population.

The nearest landmark to this newly found population is the DRNA radio communication antenna, thus we refer to this group of palms as the "Antenna Population." Survey in both 2009 and 2012 found 4 adult plants; none of these were in flower in 2009, but all 4 had fruit in 2012 (Figure 5). Eight juvenile plants (i.e., individuals with trunks, distichous leaf arrangement and not reproductively mature) were located along with a number of seedlings. No evidence of any dead palms has been observed. Five separate accessions of seeds for living collections were made, one from each adult palm, and a mixed collection from ripe fruits collected under the group of adults. Specimens (*Griffith 365*) are also deposited at UPR and FTG.

Propagated offspring.

Two offspring from *inter situ* efforts were observed at Sardinera at two exact sites recommended by Hernandez (1994). These plants, offspring from the Carabinero-Uvero population, are now juveniles with around 20 cm of clear trunk and leaves 2.5 m long after nearly 20 years of growth (Fig. 6). About an additional dozen plants have been planted

6. One of the propagated *P. sargentii* planted near the DRNA Facilities at Sardinera. The first records of *P. sargentii* on Mona (Little et al. 1974) come from this general area, but were at one time extirpated. Reestablishment efforts on Mona began in 1992 using seed from the Carabinero-Uvero site (Hernandez 1994). Note the characteristic distichous leaf arrangement for juvenile *P. sargentii*. (photo: P. Griffith).

throughout the sandy coastal vegetation along Playa Mujeres, near Sardinera. These are also offspring of the Carabinero-Uvero population.

Comparing the Populations

Habit is noticeably different between the two groups and consistent within each. The Carabinero-Uvero palms are an average of 25% taller, much thinner, hold fewer leaves and produce fewer inflorescences than the Antenna palms. The Antenna palms are strikingly ventricose (Fig. 7), with shorter, stouter trunks – double the diameter of the Caravinero-Uvero population – topped with more leaves and more inflorescences. Comparison of Figures 2 and 3 shows these differences and their consistency within each population.

The two sites also have some obvious habitat differences. The Carabinero-Uvero site is located near sea level (ca. 5 m) on the Sardinera Plain, with sandy carbonate soil (Gonzales et al. 1997), while the Antenna site is on the Mona Plateau (48 m elevation), on dogtooth limestone. Associated vegetation differed between the sites. The Antenna site (on the plateau) is in semideciduous dry limestone

7. *Pseudophoenix sargentii* from the Antenna population, showing the pronounced ventricose trunk character presented in all four adult plants in the population. The palm pictured has a diameter of 41 cm at the widest point. From left to right are Francisco-Ortega, Griffith and Sustache. (photo: E. Santiago-Valentín)

woodland, with moderate canopy cover, while the Carabinero-Uvero site is in a mature semideciduous forest with mostly closed canopy (Marinuzzi et al. 2008).

The strongly swollen trunks of the Antenna population are notable and are the largest yet reported for *P. sargentii* (Read 1968, 1969; Zona 2002). Prior workers described other taxa which included this character (*P. insignis* for example; Cook 1923). Read's (1968, 1969) keys do not make use of trunk characters, but the arching inflorescences seen in all Mona Island *Pseudophoenix* place the plants within Read's concept of *P. sargentii* ssp. *saonae*. Zona's (2002) revision of the genus presents the significant problems with recognizing segregate taxa of *P. sargentii*, and his treatment brings a number of these island taxa into synonymy. Thus, both populations of the Mona Island palms fit the modern concept of *P. sargentii*, given the petioled leaves and divaricating inflorescence rachillae. However, the prominent trunk swelling places the Antenna population significantly outside the range of trunk characters presented by Zona (2002), who reports cylindrical stems up to 25 cm dbh. Furthermore, the trunks of the Antenna population differ greatly from Read's (1968) report that *P. sargentii* trunks are "always enlarged at the base, then narrowed above."

One difference noted from the census data appears to be differential survivorship of the two populations. Available notes from the Carabinero-Uvero population (1986 through present) suggest an ongoing decline of mature adults, limited flowering and very limited recruitment of seedlings, whereas the information from the Antenna site suggests a very healthy population (albeit with few individuals), with good evidence of recruitment in the long and short term. If these trends continue, we may expect expansion of the Antenna population and further decline of the Carabinero-Uvero palms, perhaps to extirpation.

A thorough study of the palms on Dominica was also reported in this journal (James 2003), and that report showed some interesting parallels with the Mona populations. Firstly, a number of the *P. sargentii* palms on Dominica were also reported to have swollen trunks (James 2003), the largest one reaching 31 cm in diameter. Furthermore, the subpopulation with most reproductive output was also the population with most ventricose trunks, as also found in Mona.

With a native population of *P. sargentii* on adjacent Isla Saona, one possibility is that differences in the two populations seen on Mona are the result of two separate, but relatively recent introductions from Saona. Past introductions with few founders, population expansions, declines and perhaps extirpations may have occurred on Mona, and the differences seen between the groups on Mona may also be influenced by the circumstances in founding each population.

Although the demographic records are limited, taken together they suggest that some ecological change in the coastal lowlands has created less favorable conditions for the Carabinero-Uvero population, which appears to have fallen by nearly half over the last four decades. The nature of that change is outside the scope of this paper, but we offer recommendations to improve conditions for the Carabinero-Uvero palms below. In contrast, the apparent long term success of the Antenna population indicates that conditions have been very favorable to its health over the same period.

Moving Forward: Conservation and Research Recommendations

This project has produced a number of outcomes thus far. First, here we summarize what is now known about the census, health and distribution of *Pseudophoenix* on Mona Island, including the discovery of a new population of morphologically distinct palms. Also, documentation has been formalized through museum collections which include census information. Additionally, leaflet samples of each adult and subadult observed have been collected and prepared for population genetic analysis. And, a significant number of seeds has been accessioned for living collections at the Jardín Botánico at UPR, MBC and FTBG (Fig. 8). These outcomes correspond to the initial goals of the project.

Pseudophoenix sargentii on Mona occurs in two very limited populations – the Antenna population is morphologically distinct and limited to four reproductive adults, while the Carabinero-Uvero population appears to be in long-term decline. Thus, continued investigation and management of these palms is essential. Here, we present our recommendations for continued work to advance the understanding and conservation of the palms on Mona.

Continue current management.

Mona Island enjoys a very high level of protection, monitoring and management as a Reserve under the purview of the DRNA. Also, unlike many protected sites, Mona is also isolated as an island with no permanent residents and very limited human impact. This situation is ideal for the native *Pseudophoenix* populations, given the history of anthropogenic removal elsewhere (Zona 2002). Careful management of feral animal populations (especially pigs) underway by the DRNA is essential to the health of the *Pseudophoenix*, as well as other native plants on Mona (Cintrón 1991). We highlight the success of these current management conditions in keeping these palms in good health when many other *Pseudophoenix* populations are imperiled by human use and non-native herbivores.

Maintain exclosure at the Carabinero-Uvero site.

This action, initiated by Mr. Rosario and continued by Mr. Hernández in the 1980s, has helped limit predation by nonnative herbivores, and also to help produce abundant seed in past years. The current exclosure fence requires repair. Also, expansion of the exclosure may be undertaken to include all of the adult palms at Carabinero-Uvero. Measures to exclude granivores (introduced rats) have been previously successful in increasing seed production (Hernández 1994), and continuing this as possible will be helpful.

Selectively thin canopy at Carabinero-Uvero site.

The exclosure fence, as well as an additional exclosure surrounding the area of the Carabinero-Uvero site, has succeeded in limiting herbivory, and thus some of the Carabinero-Uvero palms are currently in dense canopy shade. Selectively removing canopy branches that shade the base of adult palms may encourage seedling recruitment.

Further develop and distribute living collections.

Maintaining living conservation collections of palms is essential to an integrated conservation strategy. Seed produced from both sites appears to be sufficient for distribution to other living collections beyond those mentioned here. Several botanic gardens in the Caribbean (for example, Jardin Botánico Rafael Moscoso, Dominican Republic), as well as other conservation entities, have ideal conditions to support these unique palms. As seeds germinate and living collections are established at MBC, FTBG and UPR, surplus palms can be distributed to other plant collections. Maintaining these palms at multiple gardens can ensure long-term preservation of this important material.

Perform targeted aerial survey for additional populations.

Despite its conspicuous, unique charisma, *Pseudophoenix* went undetected on Mona for over 50 years – on an island area of less than 60 km^2. This highlights the difficult logistics of fieldwork on the island – limited trails, difficult scrub vegetation, high temperatures, lack of surface water and limited shade complicate access to the interior of the Mona Plateau. Given that both populations currently known were discovered well away from access trails, we recommend targeted aerial survey for further individuals and populations. The vegetation association in which the Antenna population occurs is dominant on the western half of the Mona Plateau (Martinuzzi et al. 2008), and perhaps deliberate flights over this area would spot further populations. Surveys scheduled in January and February, when fruits are turning red, may be most productive.

Continue and expand inter situ outplantings on Mona.

As recommended previously (Hernandez 1994), propagating and establishing plantings of *Pseudophoenix* from both sites would be helpful for conservation management. We further recommend carefully managing the provenance data from these outplantings, given that two populations are now known, and also known to have different characteristics. Establishing plants derived from Antenna and Carabinero-Uvero in separate locations on Mona will help preserve the distinctiveness of these groups. Given that the DRNA has recently constructed a small greenhouse to develop research and conservation on the plants of Mona Island, this is an ideal opportunity to continue an active *inter situ* conservation program.

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8. Fruits and seeds of *P. sargentii* from the Antenna population. The fruits can contain one, two, or three seeds, and mature from green through orange to red. (photo: E. Santiago-Valentín)

for managing the seed accessions; Larry Noblick for providing guidance on palm characters; Ericka Witcher for assistance with maps; and the DRNA Cuerpo de Vigilantes for hospitality and support in the field. This project was partially funded by a CREST Grant (NSF- HRD 0734826) to Univ. of Puerto Rico. This is contribution number 224 from the Tropical Biology Program of Florida International University and number 5 of the Herbarium of the University of Puerto Rico Botanical Garden. We especially thank and dedicate this paper to the biologists, managers, and DRNA staff involved in the protection of Mona Island, especially to Gerardo Hernández, Miguel A. Nieves, Gaspar Pons, José Rivera, and José Rosario for their work to manage and conserve these palms. The palms they planted on Mona in the 1990s are healthy, but demonstrate the slow growth of this species – which prompts the old saying: *The best time to plant a tree was twenty years ago. The second best time is today.*

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Heterospathe barfodii, a New Species from Papua New Guinea

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1. *Heterospathe barfodii* in type locality, showing habit (Photo: Anders Barfod).

An extraordinary new species of *Heterospathe* from Papua New Guinea, which is already established in cultivation under an incorrect name, is described here for the first time.

We first became aware of this puzzling, slender palm with a striking silvery-white crownshaft when it featured on the cover of the *Field Guide to Palms in Papua New Guinea* (Barfod et al. 2001) identified as "*Rhopaloblaste* sp." Anders Barfod from Aarhus University had found and collected the palm with Roy Banka (PNG Forest Research Institute) and John Dowe (James Cook University) in 2000 in a relatively remote area of Milne Bay where it grew along a roadside on the edge of disturbed forest (Fig. 1). Through research for a revision of *Rhopaloblaste* (Banka & Baker 2004), we realized that this palm did not fit well within this genus, for example in its inflorescence with elongate, rather than short peduncle and persistent, rather than caducous prophyll (Figs. 2 & 3). At that time, we decided that the species most closely conformed to *Heterospathe*, except for one confounding fact – it had a conspicuous crownshaft, a feature unknown in any other species of that genus (Baker & Dransfield 2006, Dransfield et al. 2008).

In 2008 John Dransfield visited the nursery of Jeff Marcus in Hawaii and was shown a palm cultivated under the name *Heterospathe glauca* (Scheff.) H.E. Moore (Figs. 4 & 5). *Heterospathe glauca* is an enigmatic species described in the 19th century as *Ptychandra glauca* Scheff. and not collected in recent years. Only a few herbarium specimens are known from Bacan and Ternate islands in Maluku, Indonesia, and from cultivation in Bogor and Singapore Botanic Gardens. The most recent specimen was collected by John Dransfield in Bogor Botanic Garden from the last cultivated plant, which was struck by lightning during a storm in 1971. Its re-discovery in cultivation would certainly have been significant.

As part of a revision of *Heterospathe* for the Palms of New Guinea project (Baker 2002, Trudgen & Baker 2008), we compared specimens and photographs of the plants cultivated by Jeff Marcus with an extensive range of material from relevant herbaria and concluded that the cultivated palm is the same as the palm collected by Barfod and colleagues in Milne Bay, Papua New Guinea. We also found that the species does not match the specimens, type description and illustration of *H. glauca* (Scheffer 1876). The staminate flowers of *H. glauca* are more robust and have many more stamens than those of the unidentified palm (Fig. 6), 24 or more in the case of the former and just 6–9 in the latter. Similarly, *H. glauca* bears large, globose fruits "the size of a rifle ball" (Scheffer 1876) up to 17 mm in diameter, whereas the unidentified palms bears similar but much smaller spherical fruits which are 7–9 mm in diameter (Fig. 7).

2. *Heterospathe barfodii* in type locality, showing maroon infrafoliar inflorescences (Photo: Anders Barfod).

3. Roy Banka with inflorescence of *Heterospathe barfodii* (Photo: John Dowe).

From the specimens and images available to us, it remains uncertain whether or not *H. glauca* has a crownshaft, like that of the unidentified palm.

It is clear that the unidentified palm is in fact an undescribed species, which we publish here as *Heterospathe barfodii*, in honor of the collector of the first specimen, Anders Barfod, and his contribution to New Guinea palm taxonomy and exploration. Using DNA methods, we have confirmed that the species is indeed a member of the genus *Heterospathe*, despite its unusual morphology, which means that the concept of the genus has to be broadened to account for the presence of a crownshaft in rare instances.

Quite how the species became established in cultivation is unclear. Jeff Marcus obtained seed from former IPS President Donn Carlsmith in 1990. It has been distributed widely since this time throughout the USA and North Queensland, Australia, but from whom

4. *Heterospathe barfodii* growing at Floribunda Palms and Exotics, Hawaii (Photo: John Dransfield).

5. *Heterospathe barfodii* growing at Floribunda Palms and Exotics, Hawaii, showing crownshaft, inflorescence and developing infructescence (Photo: Jeff Marcus).

Carlsmith obtained his material remains a mystery. Several individuals of the new palm were observed by JD in 2008 in the Robert and Catherine Wilson Botanical Garden at the Las Cruces Biological Station, in southern Costa Rica, where they were unnamed and lacked provenance (Fig. 8). We speculate that they could have originated from the same source as

Donn Carlsmith's plants – perhaps an early distribution of seed from Papua New Guinea via the Palm Society Seed Bank. It appears to be a faster grower in cultivation than other *Heterospathe* species.

Unfortunately, the name *Heterospathe glauca*, which seemed so appropriate for this species with its startling glaucous crownshaft, cannot be used, but perhaps this will inspire palm experts to track down the true *H. glauca*, which is so poorly known and perhaps even threatened in its native Maluku.

Heterospathe barfodii L.M. Gardiner & W.J. Baker, **sp. nov.** Type: Papua New Guinea, Milne Bay Province, along the Kabawawa highway, March 2000, *Barfod et al. 4539* (holotype K!; isotypes AAU!, LAE, BRI, CANB). Fig. 9.

Medium, solitary palm. **Stem** erect to (2–)8 m tall, 7–10 cm in diam.; leaf scars 1–2 cm wide; internodes 3–10 cm (up to 17 cm in juvenile stem); green to dark brown but upper few internodes covered with white farinaceous indumentum. **Leaves** 7–9 in crown; sheaths 55–67 cm long, forming a well-defined crownshaft, pale green, covered with dense, thin farinaceous white indumentum with scattered, minute, pale brown, white-edged scales; petiole 20–40 cm long, concave adaxially, bright green, indumentum as for sheath; rachis 205–240 cm long, 10–12 mm wide at midpoint; leaflets 38–56 per side, borne 4 cm apart (along mid-section of leaf), regularly arranged, in a single plane, held horizontally with tips drooping slightly, narrowly to broadly linear, leathery, singlefold but apical leaflet pair sometimes multifolded and partially joined, tapering to bifid apices, bright green, concolorous, red-brown or whitish medifixed ramenta to 5 mm long scattered on abaxial surface of proximal portion of midrib and secondary veins, transverse veinlets conspicuous, proximal leaflets 39.5–49 cm long, 1.2–2.1 cm wide, middle leaflets 67–78 cm long, 4–5.5 cm wide, distal leaflets 22–23.5 cm long, 1.5–2.4 cm wide. **Inflorescence** 68–99 cm long, infrafoliar, branched to 3 orders, branches spreading, deep maroon at anthesis; prophyll 25–34 cm long, 5–7 cm wide, opening apically, persistent, covered with white farinaceous indumentum; peduncular bract similar to prophyll, caducous or persistent, exserted from prophyll, insertion ca. 14 cm from base of the peduncle, enclosed within prophyll; peduncle 32–33 cm long, 20–22 mm wide; rachillae 14–36 cm long, 2.5–3 mm in diam., with ca. 6 triads per 1 cm, rachilla bracts minute to 1 mm, triangular; all inflorescence axes sparsely covered with floccose to lanate brown to pale brown indumentum, diminishing along branches. **Staminate flower** 2.9–3.7 mm long, 2.7–3.3 mm in diam. in bud, ovoid; 7.5–8.4 mm in diam. and deep maroon at anthesis; sepals 3, imbricate, thick, triangular, 1.1–1.5 mm long, 1.0–1.7 mm wide; petals 3, 3.0–4.0 mm long, 1.7–2.4 mm wide, valvate, triangular; stamens 6–9, 4.2–5 mm long; filaments 3–3.5 mm long, 0.4–0.5 mm in diam., fused at base for 0.4 mm to form a ring around pistillode, white, inflexed; anthers 1.2–1.9 mm long, 0.6–0.9 mm wide, medifixed; pistillode 1 mm long, 0.8 mm in diam. at base, conical, minutely

6. Staminate flowers of *Heterospathe barfodii* on rachilla at anthesis (Photo: John Dransfield).

7. The fruits of *Heterospathe barfodii* (Photo: John Dowe).

trifid. **Pistillate flower** immature, bud ca. 4.9 mm long, ca. 2.7 mm in diam., globose-ovoid, deep maroon; gynoecium ca. 2.1 mm long, ca. 0.9 mm in diam., perianth imbricate. **Fruit** 1 cm in diam., spherical, surface striate, red when mature; perianth cupule clasping; stigmatic remains subapical; endocarp thin bony, dark brown; occasionally bilobed with two developed carpels or one developed and one partially developed carpel. **Seed** 7 mm in diam., spherical, pale brown; endosperm ruminate; embryo basal.

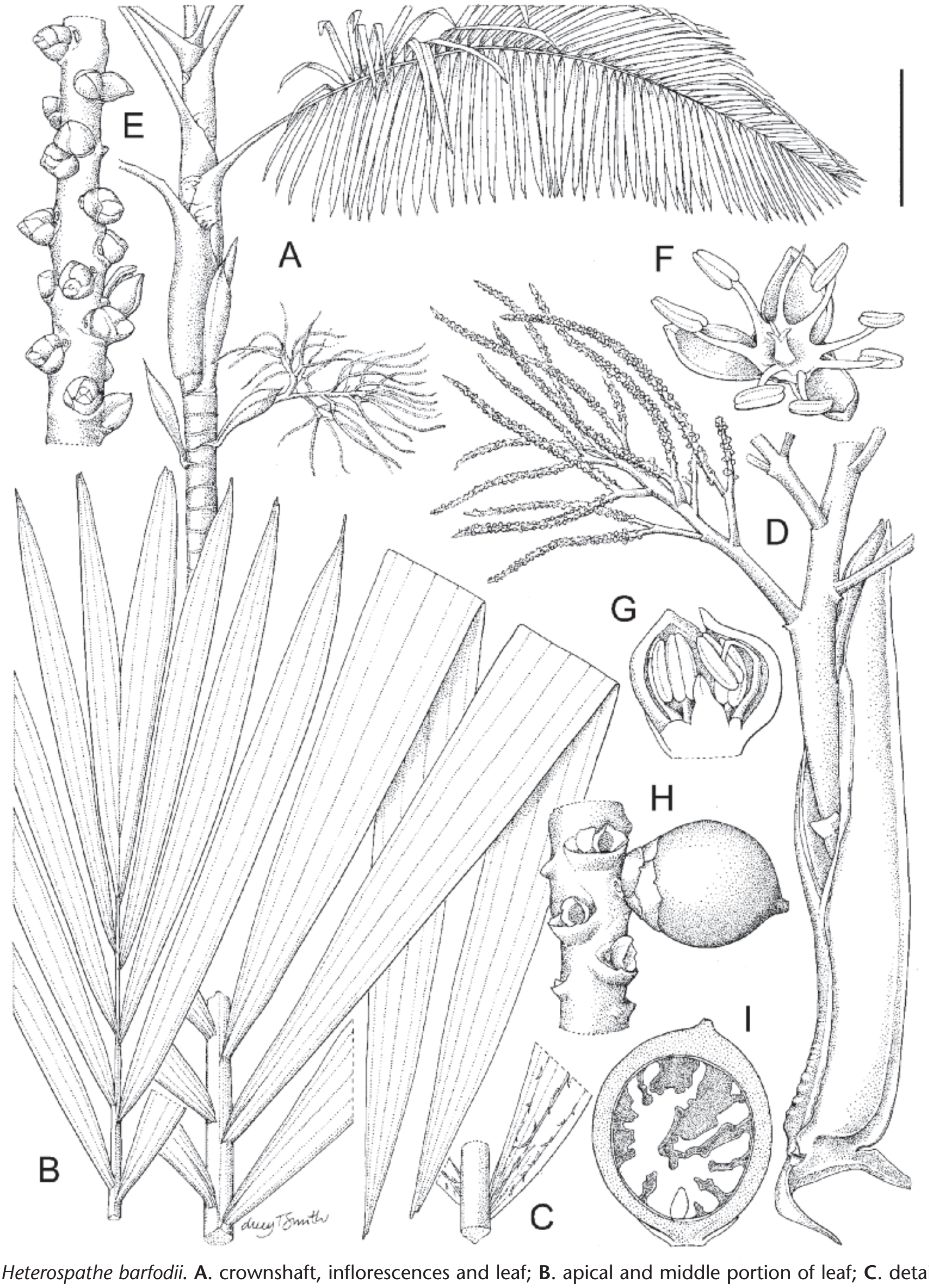
Distribution: Known only from one wild-collected specimen, from the lowlands of mainland Milne Bay Province, Papua New Guinea.

Habitat: Lowland tropical rainforest vegetation at about sea level. The type locality is an open grassy area at the side of a dirt road through the forest

Vernacular name and uses: There are no known records of local names or uses for this palm.

8. Row of mature *Heterospathe barfodii* trees at Las Cruces Biological Station, Costa Rica (Photo: John Dransfield).

Conservation status: This palm meets the criteria for threat category Critically Endangered (CR B1ab(i,ii, iii, iv, v), C2(ai, aii), D; IUCN 2001) as it is only known from a small population at a single location, and therefore its extent of occurrence is estimated to be less than 100 km^2. Similarly, the area of occupancy is estimated to be less than 10 km^2, the palm is only known from one location, and the population size is suspected to number



9. *Heterospathe barfodii*. **A**. crownshaft, inflorescences and leaf; **B**. apical and middle portion of leaf; **C**. detail of leaflet underside showing ramenta; **D**. inflorescence showing prophyll; **E**. buds on portion of rachilla; **F**. open staminate flower; **G**. staminate bud in section; **H**. fruit on rachilla; **I**. fruit in section showing ruminate seed. Scale bar: A = 50 cm; B, C, D = 8 cm; E, H = 1 cm; F = 5 mm; G = 3 mm; I = 7mm. A-I from *Marcus 1*. Drawn by Lucy T. Smith.

fewer than 50 mature individuals as no other individuals were seen (A.S. Barfod, personal communication). The type locality is a disturbed forest edge, along the side of a dirt road – by definition individual plants in this location are vulnerable, and the area is under threat from logging, mining and oil palm plantations. Therefore the population of this species is likely to decline unless conservation action is taken.

Additional specimens examined: Cultivated: United States of America, Hawaii, Floribunda Palms and Exotics, June 2009, *Marcus 1* (K!).

Notes: The genus *Heterospathe* Scheff. is defined by a combination of characters that occur in other genera of tribe Areceae, rather than by any unique synapomorphies: "leaf sheath splitting to the base, interfoliar inflorescences (at least at anthesis), peduncle longer than the rachis, peduncular bract longer than the prophyll, prophyll persistent, and peduncular bracts persistent" (Norup et al. 2006). *Heterospathe barfodii* shares most of these characters. Although *H. barfodii* has a distinct crownshaft with the outermost leaf sheaths remaining largely tubular, it appears that the oldest sheath is at least partially open with fibrous margins, a condition that can be observed on inner leaf sheaths of other species of *Heterospathe*. It would appear that the possession of a crownshaft is a matter of degree in *Heterospathe*. The fact that the inflorescences are infrafoliar in *H. barfodii* is most likely related to the physical constraints imposed by a well-defined crownshaft.

As noted by Norup et al. (2006), the combination of a crownshaft and persistent prophyll, as is found in *Heterospathe barfodii*, occurs elsewhere in tribe Areceae only in *Dransfieldia*, *Drymophloeus*, *Roscheria* and some species of *Dypsis*. Of these, *H. barfodii* most closely resembles a robust *Dransfieldia*, on account of its crownshaft, infrafoliar inflorescence, elongate peduncle and persistent prophyll. However, *Dransfieldia* is a much more slender palm, with slim, bullet-shaped staminate buds well-spaced along the rachillae (unlike the relatively crowded arrangement of ovoid buds along the rachillae in *H. barfodii*), more stamens (up to 19) and an inner whorl of erect stamen filaments (the filaments all being inflexed in *H. barfodii*). *Dransfieldia* is also restricted in geographic distribution to the far-western Papua province in Indonesian New Guinea. We have generated DNA sequence data for the two low-copy nuclear genes PRK and RPB2 from the cultivated material of *H. barfodii*, integrating these into the recent arecoid dataset of Baker et al. (2011) and re-analysing the data following their methods. The resulting molecular phylogeny places the species firmly within the genus *Heterospathe*, and although the sampling of New Guinea taxa is incomplete, resolves it in a clade with two other New Guinea taxa, *H. delicatula* H.E. Moore and *H. elegans* subsp. *humilis* (Becc.) M.S. Trudgen & W.J. Baker. In this revised analysis, *Dransfieldia* remains quite distinct from *Heterospathe*.

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Ravenea glauca in Andringitra, Madagascar

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1. *Ravenea glauca* "palm forest."

The two main populations of *Ravenea glauca* are strikingly different in general appearance. The population from the type locality is illustrated in this article.

Andringitra is a major mountain massif in the southern part of Madagascar and Pic Boby, its highest point, at 2658 m elevation, is the tallest mountain south of the capital, Antananarivo. It can be seen from afar, dominating the spectacular inselberg scenery to the east of Route Nationale 7 near Ambalavao as one travels by road to the far south. The eastern slopes of the Andringitra massif receive the benefit of moisture-laden air from the Indian Ocean and are clothed with significant remaining stands of submontane and montane rain forest. The upper reaches of the massif consist of rocky barrens with scattered heath vegetation dominated by species of *Erica* interspersed with

2. *Ravenea glauca* in abundance in a boulder field. Note the spherical crown, glaucous leaves and stiff more or less erect leaflets.

bare rock, small lakes and streams that rapidly flood after heavy rain. Most of the central core of the massif lies within the boundaries of a national park, the Andringitra National Park. To the west, there is a significant rain shadow effect and in the lower reaches of these western slopes most of the vegetation has already been modified into anthropogenic grassland, frequently burned by local villagers. The spectacular inselbergs carry cliff vegetation composed of Cyperaceae, succulent species of *Euphorbia, Pachypodium* and *Xerophyta*. These inselbergs such as Tsaranoro have become popular with rock climbers and paragliders. In some areas patchy semi-evergreen woodland survives, home to significant populations of the ring-tailed lemur (*Lemur catta*). Above all, the western approaches to the Andringitra massif are spectacularly beautiful.

Ravenea glauca has been recorded from scattered localities in the southern part of Madagascar, either from the western slopes of Andringitra or from the Isalo massif. The type specimen, *Perrier 13649*, was collected on the western slopes of Andringitra at 1200–1800 m elevation in 1921. However, the most convenient place to see the palm is in the much more accessible sandstone gorges of the Isalo National Park, about 200 km southwest of Andringitra. Here the palm grows in fragments of riverine rain forest deep within the narrow gorges, and my own knowledge of the palm in the field is based on these populations.

Photographs of the Andringitra population were shown to me by Adam Britt in 2004 and seemed to show a rather different palm. Instead of the rather delicate slender stemmed palm of Isalo with its dark green leaves, the Andringitra palm looked much more robust, stocky and with curved glaucous leaves (Back Cover).

Ravenea glauca is locally abundant in the western approaches to Andringitra at elevations of about 500–1000 m. A few scattered individuals can even be seen a bit lower among the huge boulders at the foot of the granite wall of Tsaranoro, but it is higher and further away that it occurs in most abundance. To the side of the main rock faces of Tsaranoro among boulder fields it is so abundant that it seems appropriate to call the vegetation "palm forest" (Figs. 1 & 2).

In 2010 I had the opportunity finally to see the palm in Andringitra. I was on holiday with my wife and friends and so was in no position to be able to make collections. Nevertheless there are good collections from this general area – seeing the palm in the field was almost as important as making any collections.

The route up to the palm forest involved climbing steeply through grassland towards the southern end of the precipices of Tsaranoro. Even early in the morning it felt unbearably hot as we toiled up the steep path. Once we reached the precipices and skirted along their base, the vegetation became much more interesting, with a wealth of succulent plants. We had to cross a dry gulch with fragments of closed evergreen forest and here we found *Dypsis albofarinosa*. This species was described by Don Hodel from cultivation, and so it was immensely satisfying to see it in the wild. It is a slender clustering species with very much the habit of *D. baronii* and *D. lutescens* but with intense gleaming white crownshafts.

Shortly after this we began to meet *Ravenea glauca*. The path then led steeply upwards into the col between Tsaranoro and the next mountain, and we were soon in the midst of palm forest, dominated by beautiful *Ravenea glauca*.

Ravenea glauca here dominates the vegetation on a steep rocky hillslope, occurring singly or in dense groupings, mostly in full sun at the edge of small-leaved evergreen forest. Trunks show much evidence of damage from burning.

In the Isalo gorges, *Ravenea glauca* is a more slender palm, with a hemispherical crown of bright green, not glaucous leaves. The leaves are only slightly arcuate with leaflets held horizontally or slightly curved. In contrast the Andringitra palms are more robust and stockier, have spherical crowns of glaucous, strongly arcuate leaves and the leaflets are held stiffly in a V, more or less porrect to the rachis. These rather striking differences will be the subject of further study aimed at investigating whether the two populations represent separate species.