Palms

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The International Palm Society

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Corresponding Secretary: Sue Rowlands, 6966 Hawarden Drive, Riverside, California 92506 USA, e-mail palmyview@earthlink.net, tel. 1-951-780-8771.

Administrative Secretary: Larry Noblick, Montgomery Botanical Center, 11901 Old Cutler Road, Miami, Florida 33156 USA, e-mail lnob@montgomerybotanical.org, tel. 1-305-667-3800 ex104.

Treasurer: Randal J. Moore, 15615 Boulder Ridge Ln., Poway, California 92064 USA, e-mail randal.moore@cox.net, tel. 1-858-513-4199.

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Bookstore: Tim Cooke, PO Box 1911, Fallbrook, CA 92088-1911 USA, e-mail books@palms.org

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FRONT COVER

A beautiful young leaf of *Geonoma epetiolata*, the stained-glass palm. See article by Blanco & Martén-Rodríguez, p. 139.

Palms (formerly PRINCIPES)

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Editors: John Dransfield, Herbarium, Royal Botanic Gardens, Kew, Richmond, Surrey, TW9 3AE, United Kingdom, e-mail j.dransfield@rbgkew.org.uk, tel. 44-20-8332-5225, Fax 44-20-8332-5278.
Scott Zona, Fairchild Tropical Garden, 11935 Old Cutler Road, Coral Gables, Miami, Florida 33156, USA, e-mail szona@fairchildgarden.org, tel. 1-305-667-1651 ext. 3419, Fax 1-305-665-8032.

Associate Editor: Natalie Uhl, 228 Plant Science, Cornell University, Ithaca, New York 14853, USA, e-mail nwu1@cornell.edu, tel. 1-607-257-0885.

Growing Palms Editor: Randal J. Moore, 15615 Boulder Ridge Ln., Poway, California 92064 USA, e-mail randal.moore@cox.net, tel. 1-858-513-4199.

Supplement Editor: Jim Cain, 12418 Stafford Springs, Houston, Texas 77077, USA, e-mail palm_dude@pobox.com, tel. 1-281-558-6153.

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The mottled leaves of *Geonoma epetiolata* make it one of the most ornamental species in the genus. See article by Blanco and Martén-Rodríguez, page 139.

BACK COVER

Dead leaves and branches often accumulate among the leaf bases of *Geonoma epetiolata*. See article by Blanco & Martén-Rodríguez, p. 139.

NEWS FROM THE WORLD OF PALMS

The Seventh Annual meeting of the European Network of Palm Scientists (EUNOPS) was held 2–3 June 2007 in Paris, hosted by Dr. Sophie Nadot. The meetings were based in the elegant Amphithéâtre Rouelle of the Museum National d'Histoire Naturelle, situated in the Jardin des Plantes. Palm scientists from throughout Europe presented papers ranging over subjects from taxonomy and ecology to ethnobotany and the great herbarium collections of Odoardo Beccari. The meeting ended with a presentation by Soraya Villalba and a long discussion on the EDIT project. Through a European Union network of European taxonomic establishments known as EDIT (the European Distributed Institute of Taxonomy), a project to place palm taxonomic information on the web has been initiated. The work is being coordinated at the Royal Botanic Gardens, Kew with the collaboration of palm experts from Europe and beyond. The aim of the project is to bring taxonomic information together and deliver it through one portal. It also aims to provide a virtual focus for collaboration among palm scientists and a mechanism for new palm taxonomic research to become available more rapidly in the future. The funding for EDIT runs until 2011. A prototype portal is available at www.palmweb.org that can provide nomenclature, taxonomic descriptions and associated data such as ecology and distribution, as well as images. Currently, Palmweb contains primarily taxonomic content from the Palms of Madagascar. In future, the portal will contain a much wider range of taxonomic content as well as linkages to other on-line sources.

Researchers at the University of Florida have published a paper in the Journal of Agricultural and Food Chemistry (del Pozo-Insfran et al. 2006. 54: 1222–1229.) that reported on the beneficial effects of açai fruit (*Euterpe oleracea*) to health. In this initial study the authors demonstrated that antioxidants in the fruit pulp destroyed human cancer cells *in vitro*. Specifically, extracts triggered an 86% self-destruct response in leukemia cells. The paper cautioned that the study did not demonstrate that açai could prevent leukemia in humans, but nevertheless compounds that have good activity against cancer cells in the laboratory are likely to have beneficial effects in human bodies.

We are pleased to note the formation of the Associação Brasileira dos Amigos das Palmeiras (Brazilian Association of Friends of the Palms), a group to promote palm awareness and horticulture in Brazil. The organization is the first of its kind in Brazil, and we hope it will bring more palms to the attention of the Brazilian people. The organization has a web site, www.amigosdaspalmeiras.org, in Portuguese, French and English.

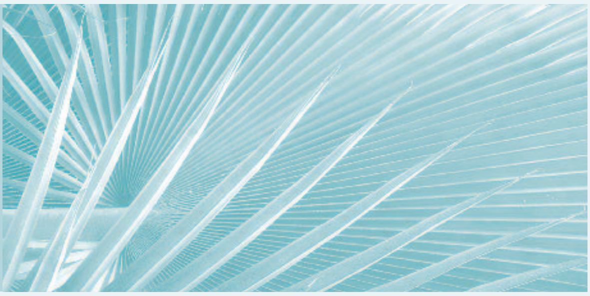
THE EDITORS

GROWING PALMS

Horticultural and practical advice for the enthusiast

Edited by Randal J. Moore

Contents



Management of Falling Fronds

Palms with crownshafts are widely admired for their stately appearance and also for their self-cleaning habit. These palms shed their senescent leaves cleanly in one piece, including the blade, petiole and leaf base.

Most of these self-cleaning palms belong to genera that require tropical or sub-tropical climates. A few will grow well in my warm-temperate climate in San Francisco, California. I grow *Archontophoenix*, *Rhopalostylis* and *Dypsis*. My garden is tiny, only seven meters wide. I have several *Rhopalostylis* palms, some with four meters of trunk below the crownshaft. They present a problem when their leaves fall. *Rhopalostylis* leaves are quite large and heavy, and falling leaves can easily damage smaller plants growing beneath the palms. Also, in my urban garden the leaves can fall over the property line, causing damage to my neighbor's garden.

1. A dead leaf of a *Rhopalostylis sapida* is held in place by an elastic cord. The leaf can then be carefully removed without unfastening the cord so that the cord remains in place.

I have devised a technique to prevent the uncontrolled descent of falling leaves. I use elastic cord to encircle and bind the leaves (Fig. 1). This cord, commonly called "bungee cord," is about 1 cm in diameter and is available at home improvement stores. I loop the cord around the top of the crownshaft, just at the point where the petioles begin (Fig. 2). The length of cord can be secured into a loop by a small metal clamp, called a "hose clamp." The proper amount of tension in the elastic cord should allow a person's closed fist to pass beneath the looped cord.

When the oldest leaf has completely abcissed from the trunk, the leafblade will sag downward, maintaining close contact between the leaf-base and crownshaft. At this time, I use an extension ladder to remove the leaf manually. Standing on


2. Close-up of the elastic cord tied around the crownshaft of a *Rhopalostylis sapida*.

the ladder, I assist the leaf downward toward the ground at a controlled rate. It is not necessary to remove the elastic cord loop. Indeed, it is the loop's support that allows the leaf to move down slowly, rather than falling freely.

One must be very careful in the use of extension ladders. Falls from ladders are a leading cause of injury in the home environment. Do not attempt to this technique unless you are quite comfortable using ladders. Also, this technique will become more difficult as the palms grow taller and the gardener grows older! – *Darold Petty, San Francisco, California USA*

Palm Horticulture in the Rose Hills Foundation Conservatory for Botanical Science, Part II

Light

The Conservatory's light-transmitting structural material is comprised of a laminate sandwiched between two panes of glass. This laminate blocks about 50% of available light and, taking into account a layer of dirt and smog that is present most of the year, yields an interior light level of 4500-4800 footcandles in the most open areas during November. This light level has been generally satisfactory for most species. Exceptions are certain woody plants, especially those trees that thrive in full sun in the tropics.

Among a variety of factors that contributes to outdoor plants being physically stronger and more resilient, the blocking of UV radiation should be given careful consideration for any conservatory project. For this purpose, clear glass is probably the best option. It was rejected in our case due to concerns about cooling capacity during our hot summers. A wide range of glass, polycarbonates and films are available that address both light levels and filtering of non-visible solar radiation.

Air

Presently most air movement in the Conservatory is by convection force and limited ventilation during moderate ambient conditions. When the weather is colder or hotter, ventilation cooling and heating create appreciable drafts and air flow in some areas. However, the air in the middle portion of the Rotunda remains still most of the time. Paddle fans were installed to help move this air.

There is a debate over the need for significant air movement in interior growing spaces. In our building there is no practical way to control micro-environments that may harbor pathogenic fungi and bacteria. One of the major reasons for brisk air movement in production greenhouses is a non-issue for us. Several additional arguments for generating regular air turbulence or air circulation remain, however. One of these is to disrupt the stratification of air by "air mixing." This helps cool or heat air-spaces more efficiently, with the proviso that plants in some areas may be better managed under relatively cool, still air.

A challenge for us is the establishment of taller foundation plantings with strongly anchored root systems. This may be due to a lack of robust air movement (at least periodically) combined with a loose soil-less medium. Lack of wind resistance encourages top growth that may appear healthy and vigorous but with a corresponding root system that is loose and eventually troublesome. Enough air movement to gently ruffle leaves and small branches during the day is sufficient. This is usually achieved with HAF (horizontal air flow) fans. Night-time air movement may be reduced to approximate the cycles in nature.

Pests and Diseases

A variety of pests common to greenhouse-cultivated palms are found in the Rose Hills Foundation Conservatory. They include several species of scale, spider mites and mealybugs. Many of these pests have not yet been identified to genus or species.

Some of these pests arrived from out-of-state on nursery stock, and they are new threats to our collections. For example, the coconut mealybug (*Nipaecoccus nipae*) is common in Hawai'i and feeds on palms and other tropical plants. It is now established in the Conservatory. From another source came trees infested with several species of scale, also new to our collections. Due to resource and schedule constraints, the staff was not able to quarantine any of these plants before they were introduced into the Conservatory. Obviously, the nursery certificates, export/import licenses and apparent health and cleanliness of these plants were not totally effective as protection against imported pest problems.

To date, our primary method of controlling insect pests has been rigorous spraying with a generic insecticidal soap and an emulsifier/surfactant oil mixture. Both ingredients are used at the highest recommended rates on the label and sprayed at high pressure. The forceful spray works in concert with the soap/oil to penetrate the mechanical defenses of insects like scale and mealybugs. It also washes dust and other insect habitat from leaf surfaces.

A program of intense spraying several times per year gives good control, provided that each application is attentive and thorough. Each spray session consists of an initial application followed by second application seven days later and finally a third spraying two weeks after the second. We use a portable electric sprayer, an adjustable spray-pattern nozzle and JMS Stylet™ Oil. Initially, we tried several brands of ceramic hollow-cone nozzles at 28 kgf/cm2 (400 psi) but changed to an adjustable nozzle (TeeJet 5500-series) at 11 kgf/cm2 (150 psi). The coarser spray from this nozzle does not coat surfaces as efficiently but can be adjusted while spraying to reach the taller plants and trees.

Staffing and Volunteers

Current staffing for the Conservatory consists of three full-time positions. A Botanical Technician is responsible for mechanical and systems services. A Conservatory Gardener provides technical horticulture along with the author.

A dedicated team of approximately ten regular volunteers helps make our workload manageable and more enjoyable. This same group of Huntington employees and volunteers also cares for an even larger, more complex collection of plants housed in two large greenhouses. These operations are all under the aegis of the Botanical Division, while a somewhat larger group of Education staff and volunteers works to maintain and develop Conservatory exhibits and signage

The Palms

The following list represents the palms currently planted in the Conservatory. They are arranged into practical groups, with notes on our experiences and impressions of their performance under the conditions described above. In the near term it is likely that there will be small changes to the collection, either by the addition or deletion of species or specimens.

Solitary Feather Palms – *Areca ipot, Asterogyne martiana, Attalea oleifera* (as *A. burretiana*), *Balaka seemannii, Beccariophoenix* sp., *Calyptrocalyx albertisianus, Chamaedorea metallica, Chamaedorea sullivaniorum, Cocos nucifera, Dypsis pusilla, Geonoma* sp. 79327, *Ravenea julietiae, Socratea exorrhiza* – Most of these palms could be described as slow growing under our conditions. All are growing in the Rotunda except the coconut, which is in the laboratory (10°C minimum in winter), and *C. sullivaniorum* (in the Cloud Forest, 11°C minimum in winter). Our young *Cocos nucifera* continues to grow well in a small, raised bed and produces leaves about 2 m long. *Chamaedorea* *sullivaniorum* is in a moist, secluded location and is perhaps too shaded or too cool, as it has only produced one or two leaves per year. It is a male plant (we would like to know about any locally productive females to try to generate a crop of seedlings). One of three *A. ipot* died recently, and the remaining two no longer initiate new stilt roots at the bases of the trunks. Nevertheless, they continue to generate healthy new leaves. In a trio of *A. martiana*, only the youngest, with only 1 m of trunk, continues to grow well. The other two boast trunks over 2 m tall but suffer badly from some form of tip die-back, possibly caused by an attack of anthracnose. Any palm labeled "*Attalea*" probably needs its own conservatory, but this rather obscure species (*A. oleifera*) is among the still-intimidating, mid-sized species. Compensating for its ultimate proportions is the fact that it produces handsome *Cocos*-like leaves and has a slow growth rate. *Dypsis pusilla* is represented by a group planting of four beautiful young specimens in part shade with trunks starting to form. *Ravenea julietiae* has grown well and will be majestic once it develops a trunk; in the meantime, it is very slow growing. By contrast, *S. exorrhiza* grows quickly, though not quite fast enough to outgrow some browning of the leaf tips that is probably the result of salts and high pH water. To help combat this condition we have added a thick layer of long-lived, fibrous peat around the base of the plant, including its impressive stilt roots.

1. *Verschaffeltia splendida* (right) and *Aiphanes horrida* (left) growing in the Rose Hills Foundation Conservatory at the Huntington Botanical Gardens.

Finally, a pair of *Beccariophoenix*, supposedly representing a second undescribed taxon, were planted along the upper walkway where they will doubtless outgrow their space in a few years. Shortly after they were planted, acute chlorosis set in until the foliage of one plant was almost entirely yellow. Repeated applications of about 100 ml per plant of Micro-Max™ by hand yielded no results over approximately 6 months. A visiting palm enthusiast from Florida recommended Trachelene™, a specially formulated iron chelate supplement. A similar dose of roughly 100 ml of Trachelene per plant resulted in a near-miraculous and complete return to healthy green leaves on both specimens in 2 or 3 months. However, it is difficult to obtain a supply of Trachelene in small amounts. It would be worth trial experimentation to observe the efficacy of this product on various chlorosis-prone palms and other plants.

Solitary Fan Palms – *Coccothrinax proctorii, Johannesteijsmannia altifrons, Kerriodoxa elegans, Licuala ramsayi, Sabal minor* – Except for the *Kerriodoxa* and *Sabal*, these are adult flowering and fruiting specimens that were purchased as mature foundation plantings. *Coccothrinax proctorii*, with a graceful trunk 5 m tall, produces heavy clusters of near-black fruits. After *Ptychosperma macarthurii*, it is the tallest palm in the Conservatory. The *Johannesteijsmannia* is naturally one of the main attractions in the Rotunda. All of our purchased specimen palms experienced a stressful pre-planting period of high temperatures, high light and low humidity. Underfeeding and under-watering are other probable causes of this stressed growth. Both during and after this period, the least temperamental species in this group was *J. altifrons*. It never produced halting growth or stunted leaves or significant tip die-back. In contrast, *L. ramsayi* has grown well but with subsequently smaller leaf blades and less robust petioles. It will likely exhibit a section of smaller diameter trunk that reflects this transition period. One of the most beautiful of all fan palms, *Kerriodoxa* deserves prominent placement in any collection. It has been a very slow grower for us and this growth rate seems to correlate with its "diving rhizome" seedling morphology, in common with some species of *Ravenea*. *Sabal minor* is a small plant in the upland part of the Carnivorous Plant Bog room.

Clustering Palms – *Basselinia gracilis, Chamaedorea fragrans, Cyrtostachys renda, Geonoma schottiana, Phytelephas* sp. Peru, *Ptychosperma macarthurii, Reinhardtia gracilis, Serenoa repens, Wendlandiella gracilis* – *Cyrtostachys renda* and *P. macarthurii*, were large specimen plants when planted in 2005. The latter is a multi-trunked specimen and, at about 10 m tall, is the tallest plant in the Conservatory. It has grown well but would probably appreciate warmer nights. The same is probably true for *C. renda*, which has suffered from attacks by spider mites and possibly from insufficient humidity. We quickly realized that this eye-catching palm apparently cannot be over-watered, and so it gets more irrigation than other plants in the building. It has been slow to produce healthier and more vigorous new leaves possibly due to insufficient watering and fertilizing and cool nights. Poor water quality is also a factor. *Chamaedorea fragrans* and the rare, *Chamaedorea*-like *Wendlandiella gracilis* are both bushy specimens about 2 m tall. Also met with only infrequently in collections, the ivory nut palms (*Phytelephas*) are represented in the Conservatory by a collection made in Peru. It is a beautiful feather palm with long, upright, graceful leaves suggesting the archetypal rainforest understory. The other species listed here are small specimens.

Rattans – *Calamus caryotoides, C.* sp. (as *C. latifolius*), *C.* sp. Thailand, *Korthalsia laciniosa, Plectocomia elongata* – In spite of the caution required around these formidable palms, we felt that the Rotunda's tall structural columns provide an opportunity to allow the public to see these famous economic plants at close range. The hazard posed by each of these rattans is very real. The rows of curved prickles are sharper and tougher than any cat's claw. But the real hazard lies in the long "whip" or cirrus that is formed as an extension of the leaf tip or the flagellum, formed as a separate maxillary structure. These efficient climbing devices are similarly armed with reinforced, retrorse barbs. For all of this potential horror they are beautiful palms. Our *Korthalsia*, donated by Mr. Donald Hodel, is arguably the most striking palm in the Conservatory. Some of these climbers will likely wear out their welcome sooner than later, as there is probably not enough room for one let alone three rattans in the Rotunda. In the future we hope to somehow add one of our seedlings of the rare *Oncocalamus tuleyi* to the conservatory plantings.

Other Armed Palms – *Aiphanes horrida* (as *A. caryotifolia*), *Cryosophila albida, Salacca magnifica, Verschaffeltia splendida* – Two of these, *Cryosophila* and *Verschaffeltia*, are dedicated to an exhibit showcasing special root adaptations (trunk-borne root spines and stilt roots, respectively). The largest of the three *Verschaffeltia* is over 6 m tall and regularly sets fruit (Fig. 1). The single specimen of *C. albida*, with root spines along its near-white trunk as well as numerous, spoke-like stilt roots near the base of the trunk, is about 4 m tall. In addition to its remarkable trunk and roots, this under-rated palm's broad leaves have a distinct matte cast but are nearly white below. Also heavily armed, *A. caryotifolia* and *S. magnifica* are sited well off the path. Both attract attention with their bold foliage and have not presented any difficulties in their cultivation. We hope to find a suitable location in the Rotunda for a small specimen of the more elegant *Aiphanes lindeniana*.

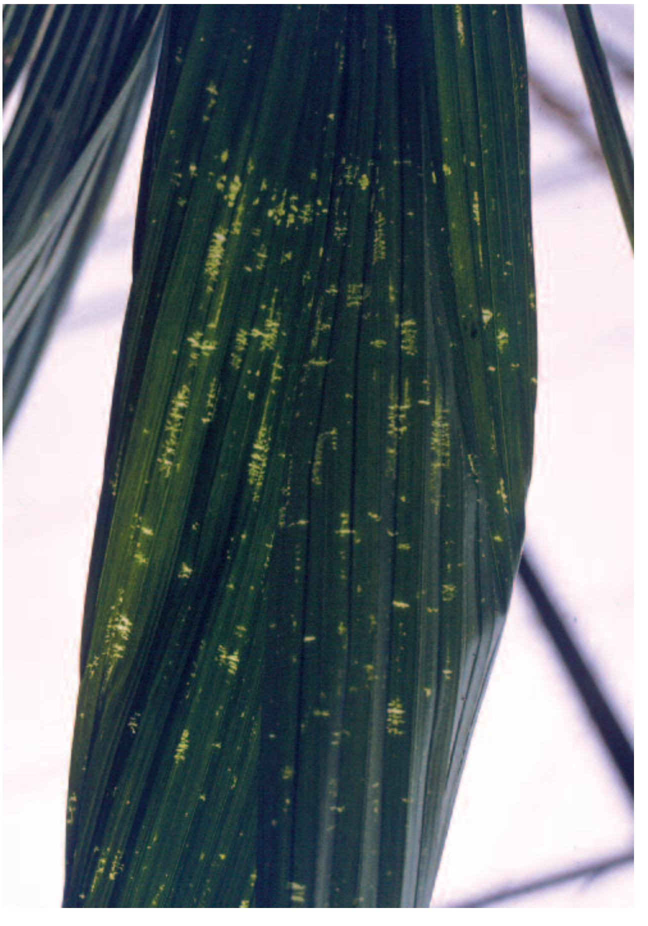
Although the Conservatory is not large enough to house an extensive or representative collection of palms, we hope to eventually have on display a significant number of rare species of known wild origin in addition to important well-known species. Where resources are scarce and space and time are limited, it is not only efficient but appropriate to focus on collections that have value on multiple levels—education, horticulture, research and conservation.

In a botanical garden, both depth and breadth are required to transmit this message to the widest possible audience. Most visitors, while they may not arrive steeped in botanical or horticultural knowledge, appreciate learning about or just observing new and different plants. They recognize that we are the stewards of something special. These considerations acknowledge the value that a varied and dynamic collection of plants has for future generations. – *Dylan P. Hannon, Curator of Conservatory and Tropical Collections, Huntington Botanical Gardens, San Marino, California, USA*

Editor's Note: Part I of Dylan Hannon's account of the Rose Hills Foundation Conservatory for Botanical Sciene appeared in PALMS *51: 7–10. 2007.*

Boron Deficiency Symptoms in Palms

TIMOTHY K. BROSCHAT
*University of Florida,
Fort Lauderdale Research and
Education Center,
3205 College Avenue,
Fort Lauderdale, Florida 33314
USA*



1. Transverse translucent streaking symptoms of B deficiency induced in sand-cultured *Syagrus romanzoffiana*.

Boron (B) deficiency is one of the most common and widespread of all nutrient deficiencies in palms. It occurs in palms growing in high rainfall areas of the tropics, but is also found in palms growing in desert climates (Elliott et al. 2004). Foliar symptoms for most nutrient deficiencies are usually rather specific for a particular species, but those for B deficiency are extremely diverse within a single species, yet vary little among species.

Since B deficiency is a serious problem in the commercial production of coconut (*Cocos nucifera*) and African oil palms (*Elaeis guineensis*), a number of studies have attempted to document the various symptoms associated with this disorder in those species. Several symptoms believed to be caused by B deficiency have never been induced experimentally in sand or hydroponic culture. The purpose of this study was to induce experimentally in sand culture the various symptoms associated with B deficiency. These symptoms will be described and illustrated, with evidence presented linking them to B deficiency.

Materials and Methods

Medium grade silica sand was used for the potting substrate. It was rinsed thoroughly with tap water, soaked for 48 hours in 2N NH_4OH solution, rinsed thoroughly with tap water, soaked for 48 hours in 1N HCl solution, and finally leached with a minimum of 12 liters of deionized water per 4-liter batch of sand. The root balls of one-year old *Syagrus romanzoffiana* and *Phoenix roebelenii* seedlings growing in 1-liter containers were rinsed free of old potting soil prior to planting. The cleaned palm seedlings were transplanted into 4.6-liter plastic containers using the acid washed sand. Twelve replicate palms of each species received 2 liters of nutrient solution containing all essential nutrients except B every Friday, while four additional control palms of each species received 2 liters of the same solution that also contained B. The composition of the nutrient solution used is shown in Table 1. All palms received 2 liters of deionized water per container on Mondays and Wednesdays to prevent a salt buildup in the containers. All palms were grown in an open-sided greenhouse in Fort Lauderdale, FL

2. Tightly fused leaflets in second spear leaf of B-deficient *Syagrus romanzoffiana*.

Table 1. Composition of nutrient solution used to induce boron deficiency symptoms in *Syagrus romanzoffiana* and *Phoenix roebelenii* seedlings.

Element	Source	Concentration (ppm)
Nitrate-nitrogen	Calcium nitrate	150
Ammonium-nitrogen	Ammonium sulfate	150
Phosphorus	Potassium phosphate dibasic	50
Potassium	Potassium phosphate dibasic	
	Potassium chloride	200
Magnesium	Magnesium sulfate	60
Sulfur	Ammonium sulfate	
	Magnesium sulfate	428
Iron	Ferric EDDHA	3
Manganese	Manganese sulfate	2
Copper	Cupric sulfate	0.03
Zinc	Zinc sulfate	0.05
Molybdenum	Molybdic acid	0.01
Chlorine	Potassium chloride	67
Boron*	Boric acid	0.5

*Control (+B) solutions only

3. Chronic B-deficient *Phoenix roebelenii* showing multiple spear leaves with fused leaflets.

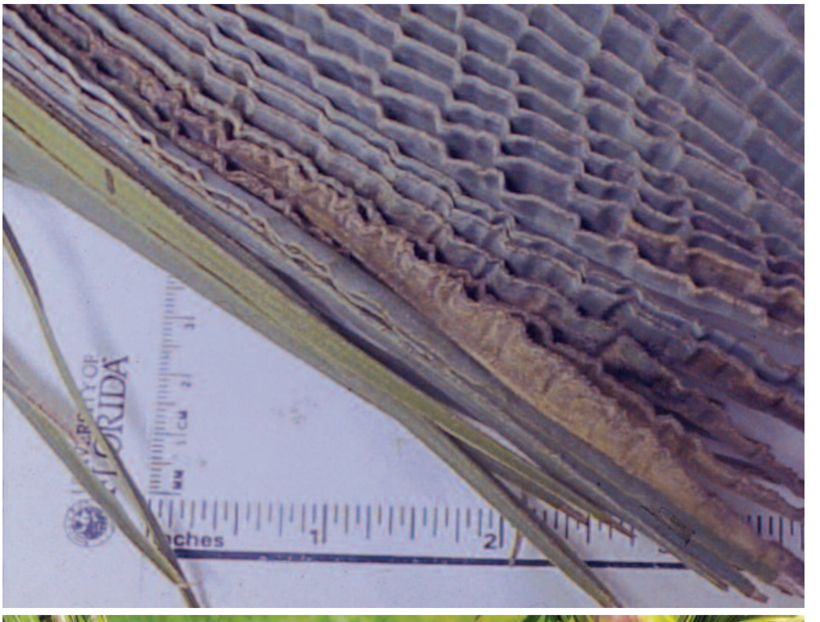
4 (far left). "Hook leaf" in *Cocos nucifera*, a symptom of mild transient B deficiency.
5 (left). Puckered leaflets in *Syagrus romanzoffiana* caused by mild B deficieny.

for two years. Similar numbers of another monocot, *Dracaena marginata,* a species known to be sensitive to B deficiency, were similarly treated for comparative purposes. Boron deficiency symptoms were described and documented photographically as they occurred. No control (+B) palms ever showed any abnormalities in their appearance.

Separately, the author was given 100 *Syagus romanzoffiana* seedlings growing in 2-liter containers in a potting mix that exhibited various B deficiency symptoms. Approximately 300 mL of a 125 mg B/L solution of Solubor (a mixture of sodium tetraborate and sodium pentaborate, US Borax, Valencia, CA) were drenched into each pot containing symptomatic seedlings. The seedlings were monitored for recovery from symptoms.

Symptoms of B deficiency

Transverse translucent streaking. This symptom appeared on newly-emerging leaves of all –B replicates of *S. romanzoffiana* and *D. marginata* in our experiment and was the first symptom to appear (Fig. 1). Marlatt (1978) described similar symptoms from a sand culture study using *Dypsis lutescens*. In sand-cultured *E. guineensis*, these streaks are considered to be the earliest stage of B deficiency, and may be either longitudinal or transverse in orientation within a leaflet (Bull 1961, Corrado et al. 1992, Dufour & Quencez 1979, Ollagnier & Valverde



6. Corrugated leaflets in *Butia capitata* caused by mild B deficiency.

7. Crumpled leaf ("Accordion leaf"), a symptom of severe B deficiency in *Heterospathe elata*.

1968, Rajaratnam 1972b). Anatomically, these streaked areas have been shown to be reduced in thickness and lack palisade, and often spongy mesophyll cells (Rajaratnam 1972b). Surprisingly, these fine translucent streaks are rarely, if ever, observed in older palms growing in the landscape.

Fused leaflets. One of the most common symptoms associated with B deficiency in mature landscape palms is a fusion or welding together of leaflets of newly emerging leaves. This fusion can affect leaflets along the entire length of the rachis or it may be restricted to either basal or distal portions of the leaf (Fig. 2). In a chronic state, multiple incompletely opened new leaves may be present within the palm canopy (Fig. 3). Although some *Phoenix* spp. typically display several young leaves of varying lengths, the presence of more than one full-length unopened spear leaf is abnormal and cause to suspect B deficiency.

Leaflet fusion was observed in two *S. romanzoffiana* seedlings grown without B in our sand culture experiment. It has been induced in sand culture in *E. guineensis* (Rajaratnam 1972a, Dufour & Quencez 1979) and *Caryota mitis* (Broschat 1984) and has been attributed to B deficiency in *Cocos nucifera* by

8 (top left). Little-leaf or “fish-bone” symptoms of B deficiency in *Dictyosperma album*. Note that the trunk is also bent in this palm and that it died shortly after the photo was taken. 9 (top right). *Cocos nucifera* showing the truncated leaf tip effects of three temporary B deficiency events during the development of a single leaf. 10 (bottom left). Truncated leaf tip in B-deficient *Pritchardia* sp. 11 (bottom right). Narrow terminal leaflets on B-deficient *Syagrus romanzoffiana* beginning to fall off.

12. Chronically B-deficient *Syagrus romanzoffiana* showing bare rachis tips on all but the youngest leaf. Although B deficiency symptoms affect only young leaves, the symptoms remain visible throughout the life of the leaf as shown here.

13. Chronically B-deficient *Adonidia merrillii* showing little-leaf and trunk bending symptoms.

Manciot et al. (1980), Brunin and Coomans (1973) and Kamalakshiamma and Shanavas (2002).

"Hook leaf." This symptom is best described as an acute zigzag near the tip of palm leaflets (Fig. 4). These leaflet "hooks" are quite rigid and cannot be straightened out without tearing the leaflets. They appear to be symptoms of a mild and transient B deficiency. They may be the only symptom present on a palm, or may be associated with other symptoms. Although we were not successful in inducing hook leaf symptoms in this experiment, Broeshart et al. (1957) and Rajaratnam (1972b) were able to induce this symptom in *E. guineensis* growing in sand culture.

Hook leaf is common in *C. nucifera* and *E. guineensis* and has been attributed to B deficiency by Brunin and Coomans (1973), Manciot et al. (1980) and Ollagnier and Valverde (1968). This author has observed this symptom in *S. romanzoffiana, Washingtonia robusta, Sabal palmetto,* and *Howea forsteriana* growing in Florida landscapes.

Crumpled leaf ("Accordion leaf"). The mildest form of this symptom is a puckering or corrugation within leaflets of newly-emerging leaves (Figs. 5 & 6). In more severe states, new leaves emerge completely crumpled and greatly reduced in size (Fig. 7). Although we successfully induced this symptom in only one *S. romanzoffiana* seedling in sand culture without B, it a common symptom in both

14. Sharply bent petiole on *Syagrus romanzoffiana* caused by a temporary B deficiency during the development of the petiole.

seedling production and mature palms, where it is often associated with other known B deficiency symptoms. This symptom has been described for *C. nucifera* by Kamalakshiamma and Shanavas (2002) and *E. guineensis* by Broeshart et al. (1957) and Corrado et al. (1992). This author has also observed this symptom in *Butia capitata, S. romanzoffiana, Heterospathe elata,* and *Phoenix roebelenii* in container production and in Florida landscapes. Our *S. romanzoffiana* seedlings showing this symptom in container production recovered following a drench with Solubor.

It is important to note that newly-emerging lateral shoots in juvenile *Dypsis lutescens* typically show crumpled leaf symptoms. This condition is caused by the physical pressure exerted upon the new lateral spear leaf as it emerges through the side of the crownshaft. This is normal for this species and perhaps other clustering crownshaft species as well.

Little leaf. New leaves exhibiting this symptom emerge greatly reduced in size, typically with shortened, necrotic-tipped leaflets that are partially fused together (Fig. 8). This symptom is often referred to as "fish bone" in *E. guineensis* (Corrado et al. 1992, Rajaratnam 1972b). In severe cases only necrotic petiole stubs emerge and death of the meristem often follows. Although we were not successful in inducing this symptom in this study, we did observe these symptoms in an earlier sand culture study with *Chamaedorea elegans, Caryota mitis,* and *Howea forsteriana* (Broschat 1984). Marlatt (1978) reported the emergence of small, necrotic leaves followed by bud death in sand-cultured *D. lutescens*. Similarly, little leaf symptoms have been induced in sand-cultured *E. guineensis* (Bull 1961, Rajaratnam 1972b). These symptoms have been documented in B-deficient field-grown *C. nucifera* by Brunin and Coomans (1973) and Manciot et al. (1980). This author has also observed little leaf symptoms on *Dictyosperma album, Adonidia merrillii, Roystonea regia, Dypsis* spp., and *Veitchia* spp. in Florida landscapes.

Leaf tip truncation. Young leaves showing this symptom have tips that are distinctly angular, rather than rounded as in normal leaves (Fig. 9). The identical effect has been achieved by simply cutting the tip of an unopened spear leaf with a shears. When that leaf opens up, the previously folded leaflets will all have their tips truncated, their final length being proportional to the distance of their attachment point from the tip of the rachis. This symptom, therefore, is caused by an acute, but very short duration, B deficiency. Based on growth rates of spear leaves, it appears that deficiencies lasting no more than a day or two are responsible for localized (ca. 1 cm) necroses along the spear leaf axis during its development. Although this localized necrosis and the truncated leaflets that it causes, typically occur at the tip of the leaf, as many as three such necrotic points have been observed on a single *C. nucifera* leaf (Fig. 9). Since it takes about five weeks to produce a single leaf in this species (Broschat 1997), this implies that a short duration B deficiency occurred approximately once every twelve days. Boron is highly leachable through all soil types and B deficiency is usually associated with heavy rainfall and/or irrigation events. Once leaching stops, B release from decomposing organic matter in the soil again provides adequate B for normal palm growth in most environments.

Although leaf truncation is a rather common symptom, it had not previously been induced in sand culture for *E. guineensis* and was only casually mentioned in literature pertaining to B deficiency symptoms in *C. nucifera* (Kamalakshiamma & Shanavas 2002) and *E. guineensis* (Rajaratnam 1972b). In our study we observed this symptom in two *S. romanzoffiana* and two *P. roebelenii* seedlings grown without B. In the latter, we observed that some of the leaflets tips truncated by the B deficiency-induced necrosis fell off after the emergence and opening of the spear leaf. This author has also observed this symptom on *Pritchardia* sp. and *Bismarckia nobilis*, where the entire tip of the fan leaf is truncated with a necrotic edge (Fig. 10).

Bare rachis tip. This symptom had been observed only in mature *S. romanzoffiana*

15. Twisted (epinastic) leaves of *Hyophorbe lagenicaulis* with chronic mild B deficiency.

16. Lateral growth axis of B-deficient *Veitchia joannis* that has forced itself through the lateral wall of the crownshaft's older leaves. This gives the appearance of having a branched stem. 17. Premature fruit drop in *Cocos nucifera* caused by B deficiency.

growing in Florida landscapes. New leaves appear normal when they emerge and open, except that the distal leaflets appear narrower than usual (Fig. 11). Within a month or so these distal leaflets begin to fall off, leaving the distal 20 cm or more of the rachis devoid of leaflets (Fig. 12). We observed this symptom in three *S. romanzoffiana* seedlings in our sand culture experiment grown without B.

Epinasty and trunk bending. Palms in the landscape occasionally are seen to be growing laterally and perpendicularly to the vertical trunk axis (Fig. 13). This symptom has never been mentioned in other studies on B deficiency in *Cocos* or *Elaeis*. We were able to easily induce this symptom in *D. marginata* in sand culture without B in this experiment and in a similar one done about twenty years earlier (Broschat, unpubl. data). This was the first clue that this loss of geotropism in palms was caused by B deficiency. The presence of more typical B deficiency symptoms on most palms showing this bent trunk provided additional evidence linking this symptom to chronic B deficiency. Although we did not induce this symptom in our sand cultured palms, it was observed in about ten *S. romanzoffiana* seedlings in production containers. Treatment of these seedlings with Solubor corrected their growth orientation.

Boron-deficient *E. guineensis* are known to have superoptimal concentrations (about 500 ppm) of indole-acetic acid (IAA), the plant hormone associated with geotropic responses (Rajaratnam 1972b). He found that spray applications of IAA at concentrations of 300 ppm induced little leaf symptoms identical to those of B deficiency. Although most palms showing stem bending grow more or less horizontally, some obviously B-deficient palms actually grow downward, with a twisting of the stem axis as well. Other palms may show sharp bending of the petioles (Fig. 14) due to a temporary B deficiency during petiole development. Some palms may exhibit leaves twisted along the entire length of the petiole and rachis (Fig. 15). These epinastic symptoms appear to be variations on the trunk bending theme and are likely also mediated by excessive auxin (IAA) concentrations.

Some B-deficient palms with crownshafts may appear to have developed a branched crown, but closer examination of such palms has

18. Inflorescence necrosis in *Syagrus romanzoffiana* caused by B deficiency.

19. Boron-deficient *Cocos nucifera* showing multiple and intermediate foliar symptoms.

revealed that the new growth axis has bent sharply and is simply pushing through the base of the crownshaft of older leaf bases (Fig. 16). However, true branching has been observed in two B-deficient *S. romanzoffiana* where other symptoms such as little leaf and epinasty were present on both shoots. Boron deficiency resulted in death of the apical meristem, followed by proliferation of subapical shoots in all B-deficient sand-cultured *D. marginata*. The author has observed these trunk bending and/or epinasty symptoms on *S. romanzoffiana, Roystonea regia, Howea forsteriana, Hyophorbe lagenicaulis,* and *Adonidia merrillii* growing in Florida and California landscapes.

Brittle leaf. Although this symptom is not visible, leaves showing little leaf, crumpled leaf or other symptoms are noticeably brittle. This symptom was apparent on all sand-cultured *S. romanzoffiana* having malformed leaves.

Inflorescence necrosis and premature fruit drop. Necrosis of palm inflorescences has been induced in sand-cultured *Chamaedorea elegans* (Broschat 1984). Floral necrosis and premature nut drop are associated with B deficiency in *C. nucifera* (Kamalakshiamma & Shanavas 2002) (Fig. 17). They also noted that fruits of B-deficient *C. nucifera* were often cracked, had blackened husks, or lacked a shell. They found a strong correlation between copra production and B fertilization rates.

It is important to note that lethal yellowing disease (LY) of *C. nucifera* is also characterized by inflorescence necrosis and premature fruit drop (Elliott et al. 2004). The fruits of LY-affected palms will usually show blackening of the calyx end, whereas B-deficient fruits will exhibit only random browning, if any, of immature fruits. Look for other foliar symptoms of either LY or B deficiency to distinguish between these two disorders. This author has also observed floral necrosis on B-deficient *S. romanzoffiana* growing in Florida landscapes (Fig. 18).

Other symptoms. The symptoms described above are by no means the only ones associated with B deficiency in palms. Leaves having abnormally thin leaflets sparsely spaced along the rachis were produced in two of the sand cultured *S. romanzoffiana* without B in this study. On the other hand, Kamalakshiamma and Shanavas (2002) reported that abnormally compact leaves with essentially no distances between leaflets were associated with B deficiency in *C. nucifera*. The symptoms described above are typical, yet symptoms intermediate between two or more of the above symptoms are also commonly observed (Fig. 19). One of the few symptoms associated with deficiencies of other nutrient elements that is not typical of B deficiency is chlorosis. It is also important to keep in mind that while all B deficiency symptoms develop on newly emerging leaves, they will remain on these leaves as they age and are naturally forced down into lower positions within the palm canopy (Fig. 12). Thus, in the case of a transient B deficiency first observed many months following its actual occurrence, the only symptomatic leaf may well be located in the middle or even lower parts of the canopy. Fortunately, none of the nutrient deficiencies that affect older leaves (N, P, K or Mg) show symptoms other than chlorosis, discoloration, or leaflet tip necrosis (Elliott et al. 2004), and thus should not be confused with old B deficiency symptoms.

Acknowledgments

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What's in the Pack? Palm Potpourri Ingredients

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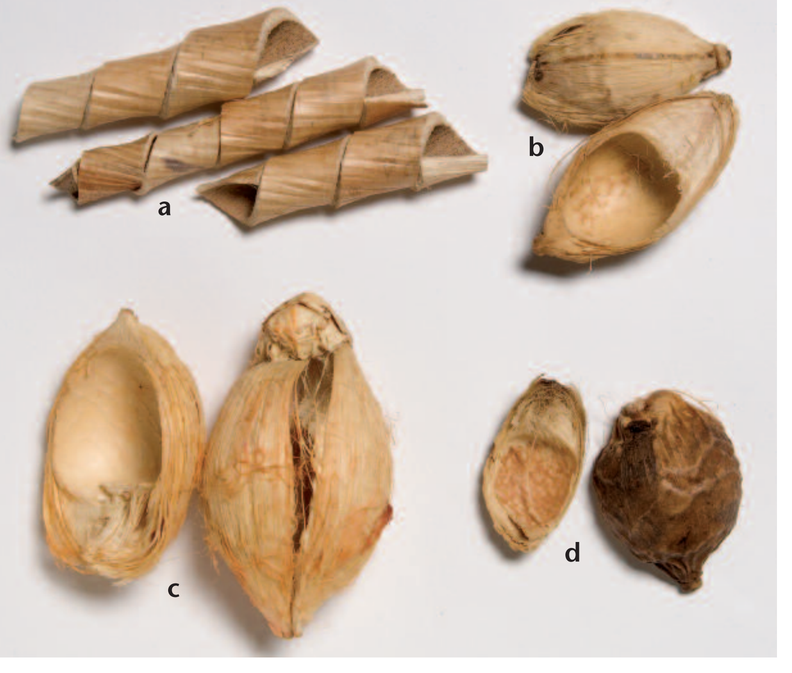


1. *Areca catechu* potpourri items. **a**. leaf sheath fibers (Fiber Curls) EBC-PP 636; **b**. endocarp (Fiber Pod Halves) EBC-PP 109; **c**. endocarp (Bleached Betel Halves) EBC-PP 464; **d**. endocarp with exocarp (Fiber Cup Halves) EBC-PP 305.

Potpourri is big business. Potpourri packs are on sale everywhere, from trendy design shops and luxurious department stores to everyday supermarkets and the humble corner shop. The packs are bursting with botanical products from all over the world, but there is precious little information available as to what species are actually inside. Should we be concerned? Are they harvested sustainably? Might they harbor health risks? This paper looks inside the packs and describes the contribution made by palms.

Traditionally, potpourri was a mixture of dried, naturally fragrant, decorative plant material (especially flowers and petals) that was placed in bowls or pomanders to provide a gentle natural scent in the home. More recently, potpourri mixtures have evolved to include exotic, tropical, dried plant material that looks stunning but needs the addition of fragrances to fulfill the aromatic role. The stylish assortments of plant fragments are sold in packs that are carefully designed for color, texture, fragrance and form. The styles are forever changing to vary with the season, fashion and to encourage continuing demand.

Since 1990 the Centre for Economic Botany at the Royal Botanic Gardens, Kew has worked with companies involved in the design and production of potpourri packs for sale in the United Kingdom. The team has advised on the identification, conservation status and toxicity of nearly 1000 samples. A good proportion (about 6 %) of these involved palms. Samples, however, are often incomplete specimens, frequently fragmented, dyed, bleached and treated in many ways. Even top palm taxonomists have to pit their wits to identify them, and sometimes identifications are tentative. As well as taxonomic expertise, Kew's herbarium, carpological collections and library references have been invaluable. So far, 53 palm potpourri samples have been identified and added to Kew's Economic Botany Collection (EBC). These represent 36 different items from 17 species. (Potpourri samples from the same species are classed as different items if they utilize different plant parts or if the same plant part is shaped differently, e.g. twisted versus straight cut leaves).

Dried decorative botanical material (for both dried flower arrangements and potpourri) used in European markets has also been reviewed by Rohrer (1984), Sprunger and Wieler (1992) and Sprunger (2003). Although there is some overlap between palm taxa represented in these references and Kew's collection, 11 taxa are exclusive to the Kew collection whilst 17 items (including 6 taxa) are exclusive to the cited references. Furthermore, there are many well illustrated catalogues from wholesalers and distributors of dried decorative botanical material available on the internet, many from the U.K., Netherlands, India, Thailand, Australia and U.S.A. Just a few examples include:

Pierce A. Arnold & Son (UK)
www.piercearnold.co.uk,

Decofleur (Netherlands)
decofleur.bulbshop.nl/,

VAC International (India)
vacinternational.com, and

COAST Wholesale Florist (USA)
www.coastwholesaleflorist.com

Usually, product lists provide English names rather than Latin botanical names. Names tend to be loosely descriptive, e.g. King Spear, Palm Medallion, Palm Curly and Arrow Leaves. Only occasionally do they provide a clue to botanical identity, e.g. Uxi Cones, Raffia Bundle, Coco Boat and Coconut Crowns. Wholesalers' catalogues have not been trawled exhaustively for additional palm potpourri, but most items are covered in this paper or in the earlier reviews cited above.

Palm Species Identified in Potpourri

An annotated, alphabetical list of palm potpourri species is given below. The majority of items are illustrated in Fig. 1–6 where their EBC accession numbers and supplier's common names are given. For items not represented in this collection, reference sources are cited.

***Allagoptera arenaria* (M.Gómez) Kuntze.** The Seashore Palm is widely cultivated throughout South America for its sweet, fibrous fruits which are eaten fresh or made into a drink (Haynes & McLaughlin 2000). Infructescences are used as a dried decorative plant material (Sprunger 2003: 185, Sprunger & Wieler 1992: 71).

***Areca catechu* L.** (Fig. 1). Betel Halves, Fiber Pod Halves, Fiber Cup Halves are various names for potpourri components from the endocarp of *Areca catechu* fruits. Frequently these cups are bleached and occasionally they include the exocarp too. They are waste products from the Betel nut trade, the nuts being a popular masticatory stimulant (Plant Cultures 2005). Occasionally curled leaf sheath fibers, Fiber Curls, are also used.

***Attalea speciosa* Mart. (syn. *Orbignya phalerata* Mart.).** The Babassu is one of the most economically important Brazilian palms and wild stands are exploited for multiple uses including oil, flour, thatch, baskets, mats, fermented beverages and palm hearts (IPK 2002). Male inflorescences and infructescence rachises have decorative uses for floral arrangements (Sprunger & Wieler 1992: 57, 116).

Borassus flabellifer **L.** (Fig. 2). The Toddy or Palmyra palm is extensively used for a wide range of purposes in India, northern Sri Lanka and mainland south-eastern Asia (Davis & Johnson 1987, Uhl & Dransfield 1987). It probably contributes the largest number of individual components to potpourri of any plant, palm or non-palm. Leaves may be twisted or their bases cut into spear and fan shapes. In the trade these components are known as Twisted Leaves, Palm Spears and Pammy Leaves, respectively. Husks, also, are cut and made into leaf shapes known as Spear Leaves. The whole perianth (calyx and corolla) without the fruit (Palm Blute) and individual parts of the perianth are used; the latter is sometimes painted gold (Palm Cup Petals). From the fruit, halved fibrous mesocarp (Gyan Pods) and shaved mesocarp are obtained. Additionally, the whole male inflorescence and whole fruit are illustrated as dried decorative material in Rohrer (1984: 22), Sprunger (2003: 186), Sprunger and Wieler (1992: 32, 81). The male inflorescences are sometimes straight and sometimes curled – both make a striking display – and they are also used sliced (Palm Snake, cut).

Brahea dulcis **(Kunth) Mart.** Male inflorescences of the Rock Palm or Sombrero Palm from Mexico and Central America are occasionally used as dried decorative material (Sprunger & Wieler 1992: 32) but the species is more commonly noted for the use of its leaves in hats and for its edible fruits (IPGRI 2000–2006.)

Calamus **spp. and other rattans** (Fig. 3). Although stripped and curled rattan stems are to be found in potpourri (e.g. Curly Thing, probably from *Calamus viminalis* Willd.), rattan species are mainly represented by individual fruits (e.g. *Calamus acanthospathus* Griff., Rattan Seeds and *Daemonorops jenkinsiana* (Griff.) Mart., Cane Fruit) and fruiting branches (e.g. *Calamus andamanicus* Kurz, Andy Cane Berries, *Calamus viminalis* Willd., Canella

2. *Borassus flabellifer* potpourri items. **a**. mesocarp (Gyan Pod) EBC-PP 776; **b**. shaved mesocarp EBC-PP 598; **c**. perianth (Palm Blute) EBC-PP 312; **d**. perianth part (Palm Cup Petal) EBC-PP 770; **e**. male inflorescence (Palm Snake, cut) EBC-PP 689; **f**. husk (Spear Leaf) EBC-PP 767; **g**. part of leaf (Pammy Leaf) EBC-PP 100; **h**. part of leaf (Palm Spears) EBC-PP 679; **i**. leaf parts (Twisted Leaf) EBC-PP 606.

berries with stem and *Calamus longisetus* Griff. (Sprunger 2003: 186, Sprunger & Wieler 1992: 81).

***Caryota urens* L.** (Fig. 4). *Caryota urens* is a multipurpose palm from South and South East Asia. It is an important ornamental species but the trunk yields starch in times of famine. It is tapped for sugar or palm wine, the apex can be eaten cooked and kittul fiber, obtained from the fibrous vascular bundles, is exported from Sri Lanka (CSIR 1950, Flach & Rumawas 1996). For potpourri, the infructescence rachis is bent into a spring shape (Turia Spring or Twig Spring).

***Cocos nucifera* L.** (Fig. 5). The coconut palm, one of the most economically important palm species, provides many different components to the potpourri trade. The majority of items are fruit parts including the endocarp (Coconut Shell), mesocarp and epicarp (Coco Curl or Coco Cut), perianth (Coco Flowers or Coco Heads) and the individual parts of the perianth (Coco Petals). Additionally, curled peduncular bracts known as Maha Curl are most likely to be from the coconut. Rohrer (1984: 13, 20), Sprunger and Wieler (1992: 86, 204) and Sprunger (2003: 186) add two items to this list: whole peduncular bracts and the fruiting stalk with perianth but not fruit.

***Hyphaene compressa* H.Wendl.** (Fig. 4). Fruits of this African species occur in potpourri occasionally (as Palm Seed) despite their importance for food and drink within Eastern African cultures.

***Hyphaene thebaica* (L.) Mart.** The Doum Palm, an African and Arabian species, also cultivated in India and Sri Lanka, is esteemed for many uses. Trimmed leaves, infructescences and infructescence rachises are illustrated as dried decorative material in Rohrer (1984: 12, 13), Sprunger and Wieler (1992: 100, 172) and Sprunger (2003: 186).

***Latania loddigesii* Mart.** The fruits of the Blue Latan Palm, an ornamental fan palm, appear in Sprunger and Wieler (1992: 208) but not in the later volume (Sprunger 2003). Apparently, the red shelled seeds are useful in Christmas floristry. No samples have been received in Kew's potpourri work. This species is a popular landscape plant on account of its blue foliage, especially when younger.

***Mauritia flexuosa* L.f.** (Fig. 4). *Mauritia flexuosa* is an important multipurpose palm in the South American region between the Orinoco and Amazonas (IPK 2002). Potpourri items include fruits (Wood Orange) and male inflorescences (Rohrer 1984: 22 and Sprunger & Wieler 1992: 56).

***Metroxylon sagu* Rottb.** The infructescences of the Sago Palm are useful dried botanical material (Rohrer 1980: 12, Sprunger 2003: 187) especially in decorating candles and balls for Christmas displays (Sprunger & Wieler 1992: 112). They are sometimes partially dyed. Of course, the main use of the sago palm is for the starch, from the trunk, used on an industrial scale for both food and non-food uses (Flach & Rumawas 1996).

***Phoenix* spp.** (Fig. 6). Short lengths of leaves from *Phoenix sylvestris* (L.) Roxb., the Wild Date Palm, from India and Pakistan are used either free (Strip Grass) or tied into bundles (Strip Grass Bundles) or sometimes leaves are woven into Sunny Medallions and used as 'toppers' in potpourri packs. Leaves of the Dwarf Palm (*Phoenix loureiroi* Kunth), an ornamental and fiber species, and infructescence branches of *Phoenix sylvestris* (Date Bunches), are occasional potpourri items as are those of *Phoenix dactylifera* L., according to Rohrer (1984: 12), Sprunger (2003: 159), Sprunger & Wieler (1992: 58, 118).

***Raphia* spp.** (Fig. 4). *Raphia* species are multipurpose palms with uses including raffia fiber, food, oils, soaps and buttons (IPK 2002). *Raphia* fruits are valued in potpourri. Species used include *Raphia farinifera* (Gaertn.) Hyl. (Palm Nut), *Raphia taedigera* (Mart.) Mart. (Uxi Cone) and *Raphia hookeri* G.Mann & H. Wendl. Other *Raphia* potpourri items include the rachis, which can be striking in appearance. Rohrer (1984: 22), Sprunger (2003: 123), and Sprunger and Wieler (1992: 187) illustrate the fruits and rachis of *Raphia vinifera* P.Beauv. Leaves (Raffia bundles) are also are advertized in internet potpourri distributors' catalogues.

***Syagrus* sp.** (Fig. 4). *Syagrus* is a tropical American genus of palm that includes 34 species including *S. coronata* (Mart.) Becc. (Licuri or Ouricuru), the leaves of which produce urucury wax (a carnauba wax substitute). The leaf-like structure at the base of the flower stalk that encloses and protects the flower bud (the peduncular bract) of *Syagrus* sp. (Leaf Husk) occurs infrequently in potpourri samples.

***Trachycarpus fortunei* (Hook.) H.Wendl.** (Fig. 4). The Windmill Palm occurs wild in China and is cultivated for fiber and medicine there;

it is also a popular ornamental. The infructescence (Palma uva) is used in potpourri.

Geographical Origin

There is a wide geographical distribution of palm potpourri species, with a bias towards Asia but Central and Southern America, Africa and the Mascarenes are also represented. Widespread tropical species include *Cocos nucifera* and *Phoenix dactylifera*. *Brahea dulcis* is from Mexico and Central America, and South American species include *Allagoptera arenaria, Attalea speciosa, Mauritia flexuosa, Raphia taedigera and Syagrus*. Those from Asia (largely South and South East Asia) include *Areca catechu, Borassus flabellifer, Calamus* spp., *Caryota urens, Daemonorops jenkinsiana, Phoenix sylvestris, Phoenix loureiroi, Raphia farinifera* and *Metroxylon sagu* with *Trachycarpus fortunei* from China, and *Calamus andamanicus* from the Andaman Islands. *Hyphaene* and some *Raphia* spp. are from Africa (*Raphia hookeri* is West African and *R. vinifera* is a West and West central African species). Although *R. taedigera* occurs from Nigeria to Cameroon, and from NW Colombia and Brazil including Para, the samples in potpourri seem to originate from Brazil. Similarly, *R. farinifera* samples tend to come from India, where it is cultivated (although the species is native to Tropical Africa and Madagascar).

Plant Parts

The vast majority of palm parts used in potpourri come from the infructescence. These include the fruits themselves, fragments of fruits and even whole fruiting branches. Scaly fruits are the most popular (although occasionally large, smooth spherical fruits are used). Rachises without fruits or with just the perianth attached are also used and infructescence fragments occurring in the mixes include the perianth (whole or separated), endocarp, mesocarp and epicarp.

Other palm parts that make an appearance in potpourri packs include male inflorescences (either whole or sliced) and peduncular bracts (whole or curled). Leaves are sometimes used trimmed, twisted, bundled or made into handicraft items; leaf husks can be shaped and leaf sheath fibers curled. Lastly curled rattan stems are occasionally used.

Other than shaping, palm parts are usually just dried and fumigated before use in potpourri, but other treatments include bleaching, dyeing, painting gold and addition of perfumes.

Contribution to Potpourri Designs

Palm parts contribute many varied roles to potpourri mixes. Items with interesting shapes that are sufficiently robust to keep their shapes on mixing are important. The flower-like

3. Rattan potpourri items. **a**. probably *Calamus viminalis* stem (Curly Thing) EBC-PP 765; **b**. *Calamus viminalis* infructescence (Candella on Stem) EBC-PP 69; **c**. *Calamus andamanicus* infructescence (Andy Cane Berries) EBC-PP 218; **d**. probably *Calamus acanthospathus* fruits including seeds (Rattan Seeds) EBC-PP 331; **e**. *Daemonorops jenkinsiana* fruits including seeds (Cane Fruit) EBC-PP 837.

4. Potpourri items from various palms. **a**. *Caryota urens* infructescence rachis (Turia Spring or Twig Spring) EBC-PP 782; **b**. *Raphia farinifera* fruit and rachis (Palm Nut) EBC-PP 313; **c**. *Raphia taedigera* fruit (Uxi Cone) EBC-PP 803; **d**. *Mauritia flexuosa* fruit (Wood Orange) EBC-PP 753; **e**. *Hyphaene compressa* fruit (Palm Seed) EBC-PP 696; **f**. *Trachycarpus fortunei* infructescence (Palm Uva) EBC-PP 406; **g**. *Syagrus* sp. inflorescence bracts (Leaf Husk) EBC-PP 808.

perianth of *Cocos nucifera* and *Borassus flabellifer* have these properties as do the infructescence rachises of, e.g., *Attalea speciosa, Caryota urens, Hyphaene thebaica* and *Raphia farinifera,* the curled leaf sheath fibers of *Areca catechu*, twisted leaf parts and sliced male inflorescences of *Borassus flabellifer,* curled stems of *Calamus* and curled peduncular bracts of *Cocos nucifera*. Other components are more useful for bulking up the contents of the packs without contributing so much to the form element of the designs. They take up dyes and perfumes well and impart color, fragrances and textures to the mixes. The endocarp, mesocarp and perianth fragments of *Areca catechu*, *Borassus flabellifer* and *Cocos nucifera* fall into this category.

Items that form the main visual focus of the potpourri packs are often known as 'toppers'. These are not mixed in the large potpourri mixing drums but are placed in the packs by hand once the main formulation or mix has been made (Hastings 2001). Palms are quite important contributors of toppers to potpourri. Toppers include items such as those handcrafted from leaves of *Phoenix sylvestris*, shaped leaves or husks of *Borassus flabellifer* and *Hyphaene thebaica,* or shiny, scaly, cone-like fruits from *Calamus, Daemonorops, Mauritia* and *Raphia*. These contribute strong design elements as do the large spherical and smooth fruits of *Hyphaene compressa* and the fruits of *Borassus flabellifer.* The halved fibrous mesocarp of *Borassus flabellifer* provides a cup like component. (Large cups are frequently used in potpourri designs, but palms do not contribute many items to this form.) Additionally fruiting branches of *Calamus, Metroxylon sagu, Phoenix* and *Trachycarpus* and fruiting branches with perianth but not the fruit of *Cocos nucifera* and *Borassus flabellifer* may also be included as toppers together with whole male inflorescences of *Attalea speciosa, Borassus flabellifer* and *Brahea dulcis* and bracts of *Syagrus.*

Economic context

The vast majority of palm potpourri items are from economically important palms, many being multipurpose species. It is often material left over from other uses that is used in potpourri. In reality this is unsurprising as sufficiently large quantities of inexpensive material are required to ensure the viability of the potpourri industry.

Infructescence items. Many infructescence parts used in potpourri are by-products of harvesting fruits for food, oil, vegetable ivory, stimulants or even seed for cultivation of ornamentals. For example, *Attalea speciosa* fruits are important sources of seed oil and edible mesocarp flour in Brazil (IPK 2002) and *Caryota urens* seeds are highly valued in horticulture (Flach & Rumawas 1996). Rachises remain after harvesting fruits for these uses. Also *Borassus flabellifer* fruits are valued for the edible gelatinous endosperm, germinated seed, and sugary mesocarp pulp (Davis & Johnson 1987; IPK 2002) and the surplus perianth appears frequently in different guises in potpourri.

Fruit processing can also yield many potpourri items. The endocarp of *Areca catechu* remains after extraction of the masticatory seeds. The endocarp, mesocarp, and epicarp as well as perianth of *Cocos nucifera* are by-products of copra extraction (the dried solid endosperm used extensively in the food, pharmaceutical and cosmetic industries). Of course, not all waste material ends up in potpourri. The endocarp of *Areca catechu* has alternative industrial uses, as a raw material for fibers, hardboard and plastics (van der Vossen & Wessel 2000) and *Cocos nucifera* mesocarp is used in the manufacture of fibers, carpets, baskets, fuel, fertilizer and mulch (Taffin 1997, IPK 2002) as well as appearing as Coco Curls and Coco Cuts in potpourri. The endocarp of *Cocos nucifera* is mainly used for the manufacture of charcoal, ornaments and utensils (IPK 2002) and Coconut Shell potpourri components are a likely waste materials from this manufacture; i.e. by-products of by-products.

Fruits. In contrast to other infructescence parts, the use of palm fruits in potpourri, at first glance, does not seem to utilize waste material but instead competes directly with other uses. For example, *Calamus viminalis* and *C. longisetus* have edible fruits (IPK 2002, Dransfield & Manokaran 1993, respectively) and the endocarp of *Hyphaene compressa* is an important food item in Eastern and North-eastern Africa (Maundu et al. 1999). However, fruits utilized by the potpourri industry are often substandard or surplus to food demands. For instance, fruits from the upper branches of *Calamus* species, are less suited as a food (as they are smaller and less ripe) and more suited to potpourri (as fruits are less likely to be shed from the branches). Similarly, it is smaller, unripe fruits of *Phoenix sylvestris* (Date Bunches) and *Phoenix dactylifera* that are used in potpourri.

The ovoid, scaly, rust-colored fruits of *Mauritia flexuosa,* Wood Orange, can contribute significantly to potpourri designs, as large ball shaped objects are increasingly an important element in potpourri and those with scales, like *M. flexuosa*, seem to be especially favoured. However, *M. flexuosa* fruits are also very important in the diet of some South American Indians and are consumed in many forms (Balick 1988, Padoch 1988, IPK 2002). Nevertheless, *M. flexuosa* is a prolific fruiter, with variation in consumer preference and patchiness in consumption popularity. For example, Balick (1988) described that, for food, darker coloured fruits are preferred and Padoch (1998) noted a high demand in some areas but not in others. This implies that some fruits are surplus to food requirements and available for other purposes such as potpourri.

Fruits of *Raphia* species also have various important food and manufacturing uses (including oil, raphia butter, soap and stearin production (IPK 2002) but they still find their way into potpourri. Their esteem in potpourri may enable a price that competes successfully with these other uses, or the potpourri business, being opportunistic, may seize chances to obtain surpluses when the possibility arises.

Inflorescence parts. In potpourri, male inflorescences of *Attalea speciosa, Borassus flabellifer, Brahea dulcis, Mauritia flexuosa* and *Phoenix* species are usually whole, but in *Attalea speciosa* and *Borassus flabellife*r both whole and sliced inflorescences occur. Slices are used for their circular shape which is a popular element in potpourri designs. Developing inflorescences of *Borassus flabellifer* are tapped for the sugar containing sap used in fresh drinks, wine, vinegar, or palm sugar (IPK 2002). Male inflorescences are largely a waste material.

It is likely that peduncular bracts of *Syagrus* in potpourri utilize the waste material from harvesting the buds for pickles or oil preserved vegetables, but alternative uses for these are also recorded, e.g., *Syagrus romanzoffiana* (Cham.) Glassman is used by artists and in decorations (Noblick 1996). Bracts of *Cocos* *nucifera,* which can be whole (Rohrer 1984, Sprunger & Wieler 1992, Sprunger 2003) or curled (Maha Curl EBC-PP 884) remain after processing for coconut palm products.

Leaves. Leaf potpourri items often utilize material left over from the manufacture of other products. For instance, trimmed leaf bases of both *Borassus flabellifer* (Palm spears and Pammy leaves) and *Hyphaene thebaica* remain after harvesting leaves for the wide range of purposes such as ropes, hats, mats and baskets described in IPK (2002). For *Borassus flabellifer*, fiber is also extracted from leaf bases, petioles and midribs for use in brushes, cordage, weaving and basketry (IPK 2002). Leaves left over from this process are a likely source of Twisted leaves potpourri.

Leaves of *Phoenix sylvestris* are widely used in India and Pakistan for thatching and for products such as mats, fans, baskets, bags, brooms and fishing nets (CSIR 1969). When woven into Sunny Medallions for instance, potpourri provides an additional outlet for this type of Indian handicraft. Potpourri also provides a use for otherwise wasted trimmed leaf ends (Strip Grass, Strip Grass Bundles). Other leaf potpourri items come from the ornamental Dwarf Palm (*Phoenix loureiroi*) better known for mats, hats, baskets and brooms (Brink & Escobin 2003), curled leaf sheath fibers of *Areca catechu* (Fiber Curls) and *Raphia* bundles.

Stems. Curled rattan stems (e.g. *Calamus viminalis* (Curly thing)) occasionally occur in potpourri which is just an additional outlet for rattan.

Toxicity

During the course of the potpourri work at Kew, literature-based research reports on the toxicity of potpourri items have been provided to the potpourri companies to assist in risk assessments. Chemical constituents and questions such as the consequences of ingestion and handling have been researched. The potpourri companies are largely interested in acute effects of exposure, such as likely consequences subsequent to ingestion by a child or pet. They are less concerned with chronic effects, e.g. the long terms effects of regularly chewing *Areca* seeds (Betel nut). No palm potpourri items have so far given cause for toxicological concern. Palms in general are of low toxicity and do not feature prominently in the poisonous plant literature. Palms are more likely to give rise to physical injury and infection due to handling of contaminated spikes and thorns (BODD 2006). This is more an occupational hazard than one of concern to potpourri consumers.

Conservation and Sustainable sourcing

Conservation concerns are also reviewed in reports to the potpourri companies to help ensure sources of potpourri items are sustainable. Species are checked against threatened species listings to ensure their use in potpourri is not endangering wild populations. Armed with such information potpourri companies can chose whether to alter or discontinue the use of certain materials. Conservation lists referred to include those of the Convention on International Trade in Endangered Species of wild fauna and flora (CITES), and the global Red Lists of IUCN as well as regional conservation literature. The majority of species contributing palm potpourri ingredients have a wide natural distribution and/or are widely grown. For some species, there are concerns in their native habitat, but these species also tend to be cultivated ornamentals. In these cases, it is most likely that the source of the potpourri material is as a by-product of the horticulture trade. For instance, *Latania loddigesii,* from the Mascarenes is endangered (IUCN category EN C 2a) in its natural habitat (IUCN 2006). It has severely fragmented populations and is threatened with habitat loss or degradation (Johnson 1998). However, it is cultivated widely and is a popular landscape plant. Similarly, *Allagoptera arenaria* is regarded as vulnerable in its native environment of the Atlantic Coastal forest of the east coast of Brazil (Walter & Gillet 1998) but is widely cultivated throughout South America (Haynes & McLaughlin 2000). However, *Calamus andamanicus* from the Andaman and Nicobar Islands in the Indian Ocean is described as vulnerable by Walter and Gillett (1998). In the past, infructescences of *C. andamanicus* have been favored in potpourri over *C. viminalis* as their fruits remain on stems more successfully. This is one example where overexploitation for potpourri purposes should be avoided.

Trade

Modern potpourri trade is sizeable but, it is difficult to provide exact figures for its value and volume. Potpourri related items are often hidden within broader categories defined in the Standard International Trade Classification used in compiling trade statistics. For instance,

5. *Cocos nucifera* potpourri items. **a**. Cocoeae, probably *Cocos nucifera,* inflorescence bract (Maha Curl) EBC-PP 884; **b**. *Cocos nucifera* endocarp (Coconut Shell) EBC-PP 785; **c**. mesocarp and epicarp (Coco Curl) EBC-PP 784; **d**. mesocarp and epicarp (Coco Cut) EBC-PP 586; **e**. perianth parts (Coco Petals) EBC-PP 585; **f**. perianth (Coco Flowers) EBC-PP 646; **g**. perianth (Coco Heads) EBC-PP 22.

retail packs of potpourri are included in a trade class with other room deodorizers. In 2005, UK imports in this class amounted to over £67 million, whilst UK exports were over £76 million pounds. Potpourri packs contributed an unrecorded, but likely high, proportion to this statistic. Similarly, over £4 million of dried foliage and branches and over £8.5 million of dried, cut flowers and flower buds were imported in the UK in 2005. Some, but not all of this, will have been used by the potpourri industry.

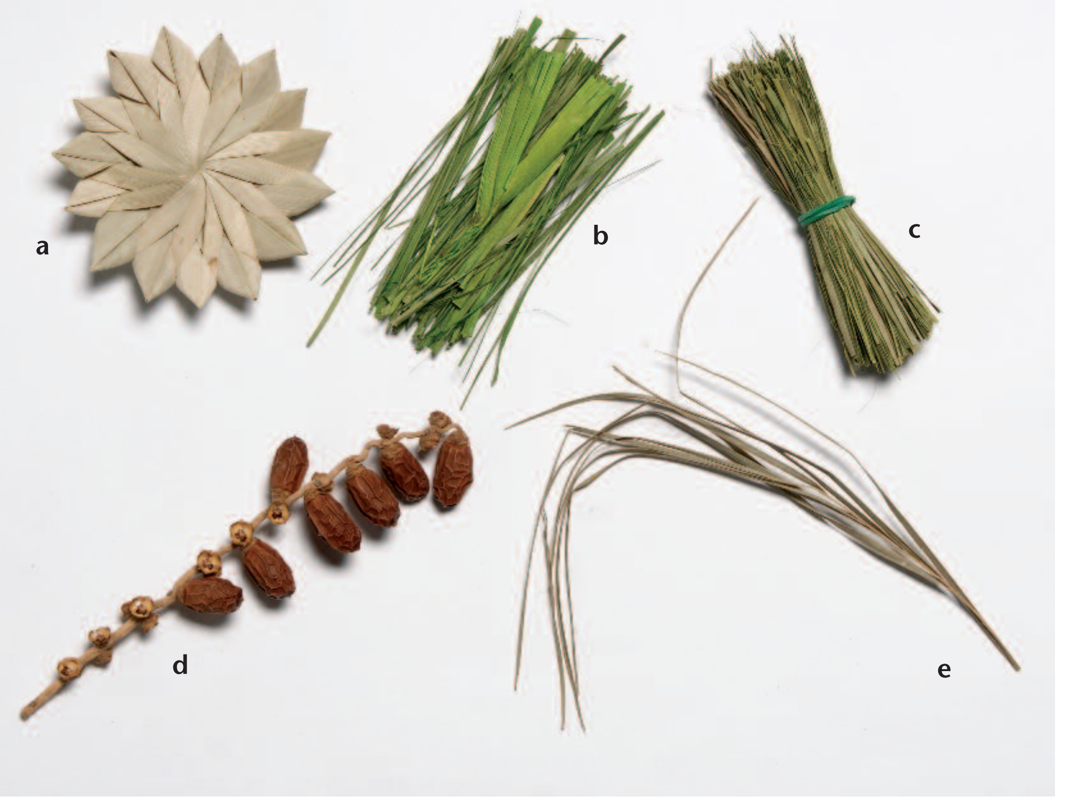
The Netherlands and India were by far the main exporters of raw materials into the UK in 2005 (HM Revenue & Customs 2006). Many other countries are involved but all on a very much smaller scale. Of the two market leaders, India mainly exports dried products whilst the Netherlands usually adds value to the plant material by dyeing, bleaching and preparing it in other ways, but both these countries source material from a wide range of countries.

UK companies either design, source and mix potpourri batches in the UK or, increasingly, design the mixes in the UK, then manufacture them abroad in countries such as Thailand. Although the UK imports “room deodorizers” (the trade category including potpourri packs) from Spain, Hungary, Netherlands, Portugal, France, USA, China, Italy, Germany and Thailand, it is still a net exporter in this category. The main end users of potpourri seem to be concentrated in a few countries. Just over 70% of “room deodorizers” (including potpourri packs) exported from the UK in 2005 were exported to just eight countries (Ireland, France, Italy, Spain, Hungary, Netherlands, Germany and the USA) whilst the remaining 30% or so was exported to over 90 different countries. It is evidently mainly a product for more economically developed countries.

Conclusions

A wide range of palm species from many parts of the globe are used in potpourri. The materials are generally safe for this purpose and the vast majority are from sustainable sources. They mainly represent spin-offs from well established palm based markets that would otherwise be wasted, or at best composted.

It is in the nature of the potpourri industry to be opportunistic, but there are also opportunities for botany as well as industry. Benefits could arise from alerting potpourri companies to potential new sources of material. It is likely that the full potential of palm potpourri has not yet been realized. Many commonly cultivated palms, e.g., the oil palm, *Elaeis guineensis,* are not yet found in



6. *Phoenix* spp. potpourri items. **a**. *Phoenix sylvestris* leaves (Sunny Medallions) EBC-PP 335; **b**. *Phoenix sylvestris* leaves (Strip Grass) EBC-PP 677; **c**. *Phoenix sylvestris* leaves (Strip Grass Bundle) EBC-PP 711; **d**. *Phoenix sylvestris* infructescence (Date Bunch) EBC-PP 579; **e**. *Phoenix* sp. possibly *Phoenix loureiroi* leaves (Dwarf Palm) EBC-PP 886.

potpourri, and some geographical areas, notably Africa, are less well represented than others. This patchiness in representation may also provide opportunities for local communities to play a more prominent and therefore profitable role in the potpourri business.

Significant benefits might also arise from the educational potential of potpourri in promoting a wider understanding of the value of plants. It is possible that the biodiversity, geographical origin and human interest of species represented in potpourri packs could become as much a part of the marketing of potpourri designs as the traditional aspects of colour, texture, fragrance and form. The future may bring packs emphasising various themes such as rainforest products or African fruits, thus raising awareness in consumers of the origins of their room decorations. Some packs may even be devoted entirely to palms!

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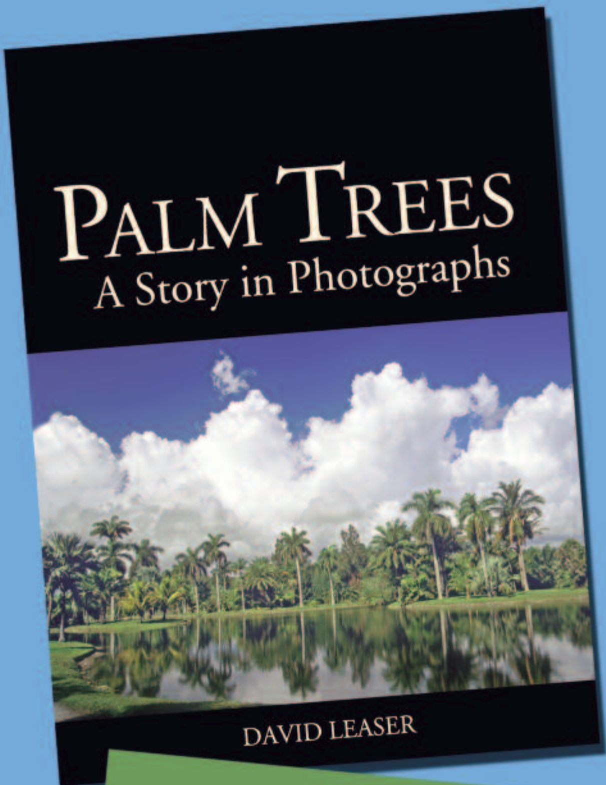

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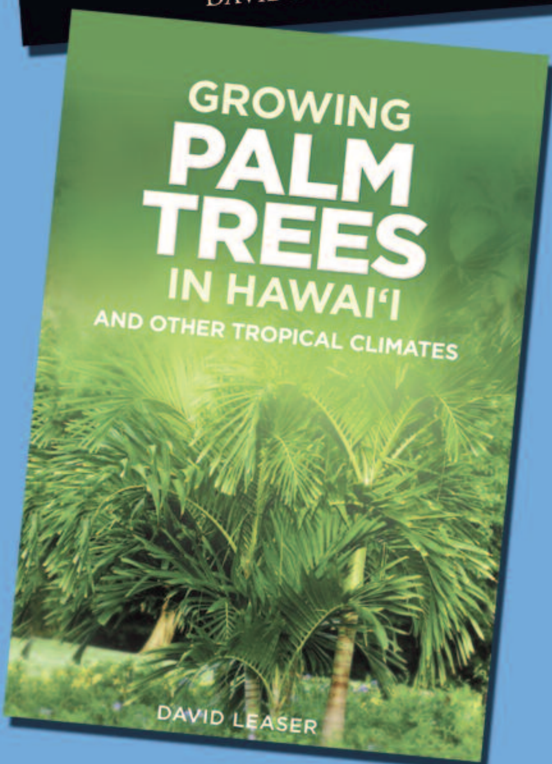

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The Stained-Glass Palm, *Geonoma epetiolata*

Mario A. Blanco
Department of Botany,
University of Florida,
220 Bartram Hall,
Gainesville, Florida 32611
USA
and
Jardín Botánico Lankester,
Universidad de Costa Rica,
Apdo. 1031-7050
Cartago, Costa Rica.
mblanco@flmnh.ufl.edu

and

Silvana Martén-Rodríguez
Behavior, Ecology, Evolution
and Systematics (BEES),
Biology-Psychology Building
144,
University of Maryland,
College Park, Maryland
20742 USA
smartenr@umd.edu

1. *Geonoma epetiolata* in the forest understory, Omar Torrijos National Park, Panama. Note contrasting colors of the expanding new leaf (yellow-purple) and the most recent mature leaf (green), both with substantial mottling.

Geonoma epetiolata **is the only neotropical palm that exhibits substantial leaf mottling. This article provides a summary of its biology and conservation, some observations of natural populations and a discussion of the ecological role of leaf mottling.**

Palm leaves display a great morphological diversity; however, leaf color in most species is uniformly green. Color variation occurs in some species, in which the sheaths and petioles are red or orange (e.g., *Areca vestiaria*, *Cyrtostachys renda*), the adult leaves are covered with a bluish-gray bloom (e.g., *Brahea decumbens*, *Bismarckia nobilis*), the lower leaf surface is almost completely white (*Cryosophila* and *Arenga* spp.), or the new expanding leaves are bright red (e.g., *Actinokentia divaricata*, *Welfia regia*, *Calyptrocalyx* spp.). However, few species normally have truly variegated leaves.

In almost all palms with naturally variegated leaves, the variegation is expressed as mottling (roundish dark spots on a lighter background, or vice-versa; Dransfield 1974, Tucker 1992). This type of leaf variegation is well exemplified by various species of *Pinanga* and a few species and varieties of *Licuala*, both of them Asian and Malesian genera. But perhaps the most vividly colored foliage among variegated palms belongs to the Tropical American *Geonoma epetiolata*, the Stained-Glass Palm.

Described less than 30 years ago (Moore 1980), *G. epetiolata* remains relatively unknown despite its attractive foliage (Fig. 1). The few accounts of this species in the literature mention the unusual leaf pigmentation very briefly (Henderson et al. 1995, Ellison & Ellison 2001, Grayum 2003, Riffle & Craft 2003). The original description mentioned only the red or purple lower surface of the leaves (Moore 1980). Only recently has some information about this species become available online (Gray 2006).

Distribution and habitat

The Stained-Glass Palm occurs in a few sites in Panama and Costa Rica. In Panama, populations are known from the provinces of Coclé, Colón, San Blas, and Veraguas. It is said that the type population north of Santa Fe de Veraguas has been extirpated by unscrupulous collectors, but this has not been verified by us. In Costa Rica, the Stained-Glass Palm is restricted to a narrow band of premontane rain forest that includes the northeastern part of Braulio Carrillo National Park and three adjacent private reserves. We have seen *G. epetiolata* in three locations: the private reserves Rara Avis and Terra Folia in Costa Rica, and in Omar Torrijos National Park in Panama (Fig. 2).

All known populations of *G. epetiolata* occur on the Caribbean slope at 300–1500 meters above sea level. In Braulio Carrillo National Park in Costa Rica, at least 37 other palm species, including eight species of *Geonoma*, occur at the same elevational band (Chazdon 1987).

Annual precipitation is very high at all the locations where *G. epetiolata* occurs. In Rara Avis private reserve for example, annual rainfall averages 6 to 7 meters, and more than

2. Caribbean slope of Cerro Calvario in Omar Torrijos National Park, Panama, one of the sites where the Stained-glass Palm occurs. Note the red, lateritic soil exposed by the dirt road.

3. New leaves are almost completely devoid of chlorophyll while expanding.

10 meters were recorded in 1997. This precipitation falls aseasonally throughout the year, although there are occasional dry spells. Even between rains the sky is almost always overcast. Consequently, the understory is generally very dark. The plants grow in the understory of primary forest on poor lateritic soils, but with abundant leaf litter on the soil surface.

Vegetative morphology

Plants of *G. epetiolata* have solitary brown stems that can (rarely) reach 2.5 meters in height, but most plants in a population are juveniles less than 1 meter tall. The diameter of the stem is 1–1.5 cm. About five to twelve leaves can be present at once, and the largest ones reach 60 cm in length. The leaves are undivided, cuneate-oblanceolate in shape, and are bifid to almost one-fourth of their length (Figs. 1 & 3). Each bifurcation is acute at the tip, but when the leaves have not expanded completely the margins can be folded under, which creates the false impression of a rounded tip with an acuminate apex. The blades taper gradually towards the junction with the stem, where they form a short fibrous sheath without a connecting petiole (thus the specific epithet). The leaves are pleated between the veins, which run at a narrow angle relative to the midrib.

The leaves can be quite narrow, up to five times as long as wide. The type collection (*Dressler 4777*) has these narrow leaves. This seems to be an extreme of the variation, however, and

4. Only the youngest leaf shows the red underside. Notice three inflorescences, one with fruits.

the leaves can be proportionately wider, up to 2.5 times as long as wide; variation in leaf proportions has also been noticed by other observers (see Gray 2006). When fully expanded, young leaves appear wider than mature ones. During preparation of herbarium specimens the leaves seem to become somewhat narrower, probably because the plications become more pronounced after drying.

The most remarkable feature of the species is the beautiful color pattern of its foliage (Front Cover, Figs. 1 & 3). Young leaves are pale yellow with green veins, and marked with prominent red purple blotches over the upper surface. Frequently, but not always, the lower surface is flushed with red purple. The expanding leaves stand more or less erect, and when illuminated from behind they appear really luminous, like a pane of stained glass (thus the common name). Only the youngest leaf in each plant has these bright colors. Young leaves of *G. epetiolata* are similar to those of *Pinanga veitchii* (see back cover of Principes 34(2), April 1990), but the spots are red purple instead of brown.

As soon as they mature, the leaves turn into a beautiful light emerald green, and the spots change from purple to dark green (Fig. 1). The texture of the upper leaf surface is not smooth but micropapillate, which gives it an opaque, velvety appearance. This combination of colors and texture make the mature leaves look like a thick pane of green sanded glass with dark stains at the opposite side. The red color frequently disappears from the underside of very old leaves, or from most mature leaves in plants exposed to bright light (Figs. 4).

Chazdon (1991) detected a correlation between plant size and degree of leaf complexity among species of *Geonoma*. Species with short stems tend to have small, undivided leaves, while taller species have progressively larger leaves with more divisions. Furthermore, for species with bifid (undivided) leaves, small leaves are more efficient than large ones in terms of shade tolerance (Chazdon 1986). *Geonoma epetiolata* fits this pattern well, as it is one of the smaller species in the genus. Its undivided, epetiolate leaves form something like a funnel, and dead vegetable matter frequently accumulates among the leaf bases of large individuals (Back Cover). Raich (1983) studied this phenomenon in *Asterogyne martiana*, another short understory palm with undivided leaves and very short petioles; he hypothesized

5. Few male flowers are produced per day on each spike.

the impoundment of debris is an adaptation to increase the quantity of nutrients available to the plant. When it rains, nutrients from the decomposing debris leach to the base of the stem and toward the roots.

Reproductive structures and phenology

Plants of *G. epetiolata* become reproductive at approximately 10 years of age (based on the average rate of leaf production and counts of leaf scars in the smallest reproductive plants seen). The unbranched inflorescences are borne from the leaf axils, and they can persist on the stem after the subtending leaf has fallen. One of us studied the reproductive biology of *G. epetiolata* in Costa Rica (Martén & Quesada 2001), and found that the spikes take from three to seven months to elongate completely after they emerge from their enclosing bract and prophyll. The rachis can reach 40 cm in length, and is held more or less erect at first (Fig. 4). Each spike starts with a male phase, and produces one to three staminate flowers per day for up to six months (Fig. 5). After all staminate flowers are spent the inflorescence enters the female phase (13 to 28 days), during which up to 25 pistillate flowers are produced each day. This extended flowering period per inflorescence is among the longest recorded for any palm species.

Each plant produces new inflorescences continuously, so that spikes in male, female and various fruiting stages often co-occur on the same plant. The plants are self-compatible, and they can be successfully fertilized with their own pollen (Martén & Quesada 2001). However, because staminate and pistillate flowers are present on different inflorescences at any given moment, even self pollination has to be mediated by a pollinating agent.

Neither staminate nor pistillate flowers produce any nectar, and very few insect visitors were observed. Among these were weevils, drosophilid flies and stingless bees; none of them could be positively identified as a true pollinator. From 1020 flowers marked, only 13% initiated fruit and 75% of these aborted prematurely. Some abortions were caused by weevil predation (Martén & Quesada 2001).

After fertilization, the ovary swells and turns from yellow to green. The fruits ripen after five to nine months and turn dark purple. They are subglobose, about 0.6 cm in diameter. No animal dispersers were observed during the two-year phenology study, and many fruits simply fell to the ground after an average of 54 days on the inflorescence (Martén & Quesada 2001). This suggests that gravity is the main form of fruit dispersal, but it is likely that frugivorous birds also disperse some fruits. This low seed dispersal capability might explain why populations of *G. epetiolata* are so restricted geographically.

De Nevers and Grayum (1998) found that the populations east of El Copé (central-western Panama, where Omar Torrijos National Park is located) have female flowers with digitate staminodial tubes, whereas those to the west (including the Costa Rican one) have crenate staminodial tubes. Both morphs co-occur in El Copé. The degree of staminodial tube lobing in female flowers is taxonomically important in *Geonoma*, but this seems to be the only difference among eastern and western populations of *G. epetiolata* (de Nevers & Grayum 1998).

Why the leaf colors?

The micropapillate leaf texture and the abaxial anthocyanin layer on young leaves might represent adaptations to maximize the capture of photosynthetically active radiation (PAR) in the dark forest understory. Lee et al. (1979) demonstrated that the abaxial anthocyanin layer present in the leaves of many tropical understory plants reflects most of the PAR that has traveled through the leaf uncaptured by the photosynthetic pigments back into the mesophyll. *Geonoma epetiolata* grows in extremely low light environments, so its red leaf undersides are adaptive in this respect.

The abaxial layer of anthocyanins might also protect the photosynthetic pigments from the negative effects of ultraviolet radiation during the formation of the new leaf (Gould 2004). However, this is unlikely to explain leaf coloration in an understory specialist such as *G. epetiolata*. An alternative explanation is that anthocyanins protect new leaves against fungal infections and insect herbivores (Coley & Barone 1989, Gould 2004).

Mottled leaves, even when attractive to the human eye, probably have the opposite desired effect: they can serve as camouflage. Most large mammal folivores of the forest floor (e.g., deer, tapirs, etc.) are color blind, and the mottling might hide the leaves from their sight by "breaking" their outline, so they "blend" with the background (Stone 1979, Givnish 1990, Tucker 1992) (Fig. 6). Another possibility is that the spots make the leaves appear diseased or senescent. In fact, most plants with naturally mottled foliage are short herbs of the forest understory, where they are more susceptible to defoliation by grazing mammal herbivores (Givnish 1990). All species of *Pinanga* with mottled leaves are understory palms; the species with the most strikingly mottled leaves in the genus, *P. veitchii*, is a very short plant, and larger species of *Pinanga* that have mottled leaves as juveniles loose some of the mottling intensity after they grow tall. However, several epiphytes, notably some bromeliads, also have mottled or fenestrated foliage. Benzing and Friedman (1981) found that the dark spots on these bromeliads have higher concentrations of chlorophyll and likely have higher photosynthetic rates than the surrounding "pale" areas of the same leaf. They suggested that the patchy distribution of chlorophyll on the leaf optimizes the nutrient economy of the plant in a nutrient-poor environment and improves the light harvest of plants with multi-layered canopies in exposed situations. This hypothesis is also an unlikely explanation for the mottling in *G. epetiolata*, which occurs in the dark forest understory. Benzing and Friedman (1981) did not explicitly consider the potential role of leaf variegation as camouflage or disease mimicry as a defense against herbivory.

Most palms with mottled foliage tend to turn uniformly green when exposed to increased light levels (Tucker 1992). This provides further support for the understory camouflage hypothesis, because the mottling would be ineffective as camouflage in open areas, although Ferrero (2006) reported that the strongly mottled *Licuala mattanensis* can tolerate full sun. The camouflage hypothesis,

6. New leaves of *G. epetiolata* are very attractive to the human eye because of their colors (left). The same photograph in grayscale (right), approximates the vision of a color-blind mammal herbivore; notice how the mottling "breaks" the outline of the leaf and makes it harder to see against the background.

therefore, still awaits rigorous experimental testing (Allen & Knill 1991).

It is puzzling that no other neotropical understory palms have substantial leaf mottling (lowland populations of *Chamaedorea tuerckheimii* have a subtle mottling), while this phenomenon is more widespread among Malesian palms. Almost all of these, however, belong to the genus *Pinanga* (Dransfield 1974), which suggests this trait evolved only a few times among them.

Cultivation

The Stained-Glass Palm has never been common in cultivation, and has the reputation of being difficult to grow. A few small plants are grown successfully at Lankester Botanical Gardens in small pots with an organic mix and a generous layer of mulch on top. They should be kept under intermediate temperatures and high humidity and be watered daily. A couple of plants are in cultivation in the Atlanta Botanical Garden, where they are doing well planted in a highly organic mix designed for epiphytes. The species is reportedly in cultivation also in the Harold L. Lyon Arboretum (University of Hawaii at Manoa) and in a few private collections (Gray 2006).

In order to preserve the beautiful mottling and red undersides of the leaves, the plants should never be exposed to bright light, as already mentioned above. A few days of bright light (not even direct sunlight) will cause the leaves to turn almost uniformly green, and the affected leaves will not revert to the normal mottling even if the plant is returned to a shadier place (R. Determann, personal communication). Dransfield (1974) suggested that a nutrient-poor substrate could increase the intensity of the variegation in species of *Pinanga*, but this does not seem to be a requirement for *G. epetiolata*. Plants grow very slowly; populations in Costa Rica produce a new leaf approximately every three to six months (S. Martén-Rodríguez, unpublished data).

Geonoma seeds have a reputation for being difficult to germinate, and those of *G. epetiolata* are no exception. Several attempts to propagate the species in Costa Rica have consistently resulted in disapointingly low germination, although rigorous experiments to test the effects of different environmental conditions and scarification treatments have yet to be carried out. Ellison and Ellison (2001) reported that seeds of this species can germinate within two to three months of planting, but gave no details about treatment.

Conservation status

The conservation status of *Geonoma epetiolata* has not been assessed before. Johnson (1996) listed this species in his Appendix 3 (Endemic palms with unknown conservation status) as being restricted to Panama, although as already said, it also occurs in Costa Rica.

At least in the two populations we have seen, the Stained-Glass Palm is locally abundant and protected within national parks and private reserves. Seedlings are not uncommon and there seems to be good recruitment. The condition of the other Panamanian populations is unknown to us. Habitat loss through deforestation is always a concern, given that there are so few known populations.

Like some other ornamental palms, the Stained-Glass Palm is threatened by collection of seedlings and adult plants for the horticultural trade (Johnson 1994). The owners of the private reserves in Costa Rica where the Stained-Glass Palm occurs are well aware of its presence, and they look after the population. Illegal collectors have been discovered on a few occasions. Given the slow growth rates of these palms and their low fruit set, any decrease in their populations can threaten the long term survival of the species.

Chazdon (1987) recommended seed germination studies for several ornamental palms in Costa Rica (including *G. epetiolata*) for propagation purposes, as a sustainable alternative to collection of plants from the wild. Johnson (1996) suggested that nurseries for propagation of ornamental palms should preferentially be established as close as possible to their natural populations, so the local people can acquire an appreciation of the palms, perceive a benefit from their presence in nature and feel compelled to protect them.

The area of occupancy of *G. epetiolata* in Costa Rica is estimated to be 50 km^2 (Martén & Quesada 2001), and the known populations in Panama probably occupy less than 150 km^2 altogether, taking into account the likely loss of habitat through deforestation. The extent of the species as a whole is likely declining. Given these circumstances, *G. epetiolata* should probably be listed as Vulnerable according to the IUCN Red List criteria (Johnson 1994, IUCN 2001).

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Evaluating *Chamaedorea alternans*

CHRISTINE D. BACON
Department of Biology, New Mexico State University, Las Cruces, New Mexico 88003, USA
current address:
Program in Molecular Plant Biology, Colorado State University Ft. Collins, Colorado 80523 USA

1. Los Tuxtlas Biological Station is home to 11 palm species.

Chamaedorea alternans is endemic to Veracruz, Mexico. Delimitation from the related widespread _Chamaedorea tepejilote_ distributed from southern Mexico to western Colombia is assessed in this paper.

Understanding species limits has been a problem for systematists working in many plant groups, including palms. First of all, there are several different species concepts that apply to plants, each having a different philosophical basis. Second, classification of plants can be inherently difficult because of hybridization and polyploidy, plastic phenotypes and variable morphology, as well as technical issues including field collection and herbarium work. In certain groups of palms, systematists have only partial knowledge of species variation. Molecular evidence has improved research from classic morphological studies in many cases because of its power in resolving difficult taxonomic problems.

An example where species-level taxonomic confusion prevails is in the genus *Chamaedorea*. *Chamaedorea* has traditionally been a difficult group in which to work due to issues with dioecy, sympatry and complex morphological variation (Hodel 1992).

One example of historical confusion in *Chamaedorea* that has received particular attention is that of *Chamaedorea alternans* H.Wendl. and *C. tepejilote* Liebm. These two species are sympatric in the Los Tuxtlas Biological Station in Veracruz, Mexico, where *C. alternans* is endemic and listed as a threatened taxon. *Chamaedorea tepejilote* is morphologically variable and is distributed from southern Mexico to western Colombia. This article will review recent work involving the assessment of species boundaries between these species using molecular markers and supporting evidence from morphological characters (Bacon & Bailey 2006). Lastly, the aim is also to illustrate how problems in taxonomy can impede conservation efforts for threatened and endangered taxa.

La Estación Biología Tropical Los Tuxtlas (Fig. 1) is located at the northern limit of the tropical rainforest ecosystem, in the state of Veracruz, between 150 and 700 m (492–2296 ft.) in altitude. The Los Tuxtlas region is phytogeographically interesting as elements of Caribbean, Central American, and mainland Mexican flora mix in a relatively restricted geographic area. Annual rainfall averages 450 cm (177 in.), and the mean annual temperature is 24ºC (75ºF). The substrate in the preserve is volcanic in origin. A detailed account of the Los Tuxtlas field station can be found in Gonzalez Soriano et al. (1997).

Although the Los Tuxtlas area has been largely deforested for pastureland, the station itself encompasses some areas of virgin tropical rain forest that contain approximately 820 vascular plant species (Ibarra-Manriquez & Sinaca-Colin 1987). Of the 11 species of palms found within the preserve, six are members of *Chamaedorea* (*C. alternans*, *C. elatior, C. ernesti-augusti*, *C. oblongata*, *C. pinnatifrons*, *C. tepejilote* and *C. woodsoniana*) and five are from other genera (*Astrocaryum*, *Bactris*, *Geonoma*, *Reinhardtia* and *Desmoncus*). All palms in Los Tuxtlas are subcanopy plants that do not exceed 10 m (32 ft) in height.

Some of the past debate over the recognition of *Chamaedorea alternans* appears to be caused by the paucity of quality herbarium specimens. Many botanical collections lack informative characters that would facilitate positive identification, and therefore numerous collections are likely misidentified. At the herbarium at the Los Tuxtlas Biological Station, specimens have been annotated numerous times and generally alternate between designations.

The debate has impacted some recent and older ecological studies on *Chamaedorea* that have recognized just one species, *C. tepejilote*, rather than both (Oyama & Dirzo 1988, Pompa et al. 1988, Oyama 1990, Oyama & Mendoza 1990, Oyama 1991, Oyama & Dirzo 1991, Oyama et al. 1992, Oyama 1993, Gonzalez Soriano et al. 1997), while others have accepted *C. alternans* as distinct from *C. tepejilote* (Otero-Arnaiz & Oyama 2001). If the latter classification is accurate, then the former approach has mixed divergent species within studies designed to address intraspecific variation.

It is also likely that the great morphological variation found across the range of *Chamaedorea tepejilote* has confused past comparisons with *C. alternans*. Given that *C. tepejilote* is a widespread and poorly understood taxon, the pertinent comparisons are from those *C. tepejilote* that occur in sympatry with *C. alternans*. Based on field observations of *C. tepejilote* outside of this region, future research on this species may demonstrate that this taxon, now understood to be highly variable, will warrant splitting it into additional taxa.

The lack of a consensus on the status of *Chamaedorea alternans* has implications that reach beyond basic taxonomy. The Los Tuxtlas region has been largely devastated by deforestation over the last 20 years (e.g., Dirzo & Garcia 1992). While the Mexican government currently treats *C. alternans* as a threatened taxon, the uncertain taxonomic status of *C. alternans* puts the putative species in a delicate position with regard to its conservation status. Thus the ongoing debate and confusion over *C. alternans* has direct impacts for conservation in southern Mexico.

In a review of the literature, a number of systematists have in fact recognized *Chamaedorea alternans* as a distinct taxon from *C. tepejilote* (Hemsley 1885, Standley 1920, Burret 1933, Glassman 1972, Hodel 1992, Quero 1992, Govaerts & Dransfield 2005). Taxonomic treatments recognizing a single highly variable *C. tepejilote* are primarily attributable to Ibarra-Manriquez (1988) and Henderson et al. (1995).

2. *Chamaedorea alternans* has multiple inflorescences at the node.

Using data derived primarily from field observations, Hodel (1992) concluded that *Chamaedorea alternans*, which was first described by the German botanist Hermann Wendland in 1880, represents a taxon distinct from *C. tepejilote*. He distinguished *C. alternans* primarily by the presence of white leaf sheaths with distinct venation and multiple inflorescences at a node (Fig. 2). More recently, Henderson et al. (1995) addressed the status of *C. alternans* using observations from available herbarium specimens. They concluded that specimens that were identified as *C. alternans* were insufficiently distinct from those of *C. tepejilote*. Subsequently, they treated all representatives of this group as *C. tepejilote,* a name that has nomenclatural priority over *C. alternans*.

The goal of this study (Bacon & Bailey 2006) was to investigate whether *Chamaedorea alternans* and *C. tepejilote,* as morphologically defined by Hodel (1992), are genetically distinct in the Los Tuxtlas region, meaning they are behaving as separate species. Populations of both putative species were analyzed using Amplified Fragment Length Polymorphism (AFLP) markers (Vos et al. 1995). AFLP is a highly sensitive method for detecting DNA polymorphisms. AFLP data can be informative at and below the species level, and these data have been useful in addressing species complexes in several plant groups.

A total of 249 samples of leaf material suitable for AFLP was collected (127 of *Chamaedorea tepejilote* and 122 of *C. alternans*). Upon AFLP analysis (Bacon & Bailey 2006), the samples separated into distinct clusters that closely correspond to the morphologically defined *C. alternans* and *C. tepejilote* (*sensu* Hodel 1992). AFLP analysis provides results that are consistent with genetic differentiation between species and shows no evidence of gene flow occurring between taxa, suggesting that they are distinct under most currently accepted concept of species.

Taxonomically useful characters that were previously unused in the classification of the two species of *Chamaedorea* were noted in the field by Bacon (Bacon & Bailey 2006). These include *Chamaedorea alternans* having a solitary, single-stemmed life form, larger fruit and seed size, as well as delayed fruit maturation and possibly flowering time, compared to *C. tepejilote*. In contrast, *C. tepejilote* has multiple stems and has smaller fruits and seeds, which mature earlier than *C. alternans*. These morphological characters support the differentiation of *C. alternans* and *C. tepejilote* as distinct species.

Apparent ecological differentiation was also observed between the species. In general, *Chamaedorea alternans* is common in the eastern half of the reserve in association with well-developed soils. In contrast, *C. tepejilote* is nearly absent from the eastern portion of the reserve but dominates the rocky forests in the western half. It is important to note that the morphological and ecological characters of *C. tepejilote* in this study apply only to individuals within the Los Tuxtlas field station. There appears to be considerable morphological variation in *C. tepejilote* across its greater distribution, but nowhere does it approach *C. alternans* in similarity.

Evidence supporting the distinctiveness of *Chamaedorea alternans* from *C. tepejilote* is important for both conservation biology and ongoing research on these taxa. Our results (Bacon & Bailey 2006) demonstrate *C. alternans* should remain a priority for conservation biology in southern Mexico. *Chamaedorea alternans* is found within a rapidly disappearing type of vegetation, and it is not currently known to exist outside of the Los Tuxtlas region. Recognition of this species should create an impetus for its conservation and the proper management of this area.

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Compiled by
William J. Baker,
Herbarium, Royal Botanic Gardens, Kew, Richmond, Surrey,
TW9 3AE, UK

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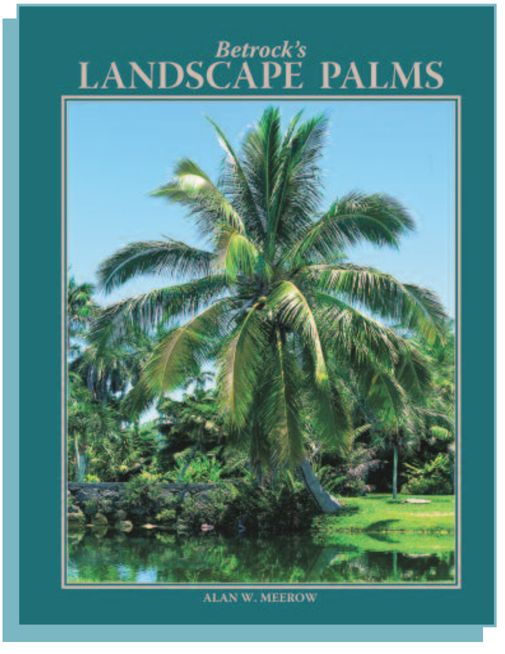

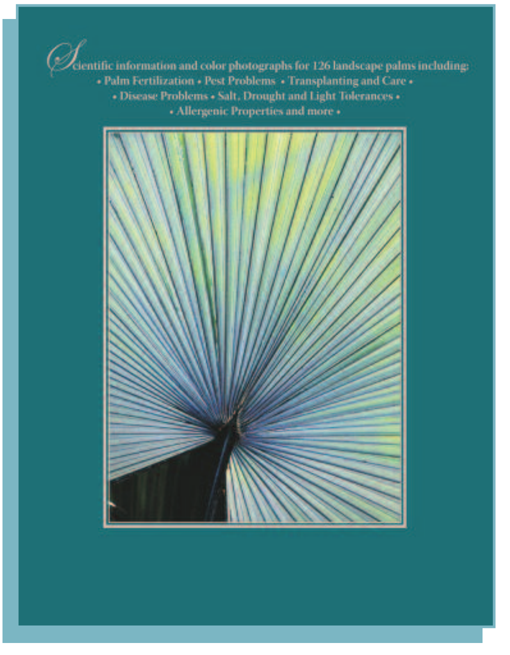

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