

Palms

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The International Palm Society

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FRONT COVER

The red new leaf of *Chambeyronia macrocarpa*, in cultivation in Kona, Hawaii. Photo by Angela Blakely.

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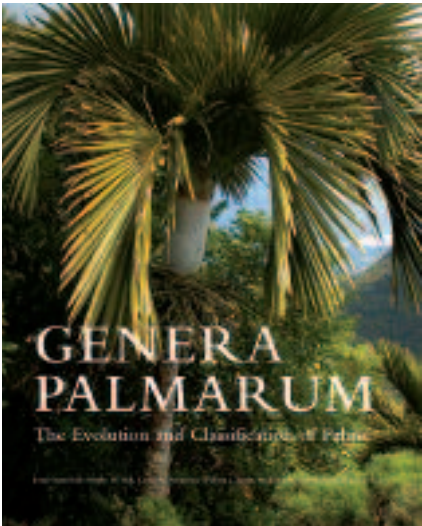
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For Your First Look at the New Edition of *Genera Palmarum* Turn to Page 125.

BACK COVER

A wine-red new leaf of *Welfia regia*, a seen in the wild during this year's Biennial in Costa Rica. Photograph by Angela Blakely. See p. 140.



The red new leaf of *Actinokentia divaricata*, grown and photographed by Angela Blakely.



NEWS FROM THE WORLD OF PALMS

With a certain amount of regret the Editors have decided to terminate the annual compilation of palm literature that appeared in part three of each volume of PALMS. This column has been produced in recent years by Dr. Bill Baker in Kew, whom we thank for his assiduous collation of references. The decision to terminate this feature is based on the fact that modern internet search engines can easily produce listings of recent palm literature, and that those most likely to read the feature in PALMS are almost certainly already using such search engines, making the publication of the feature in PALMS redundant. We shall continue to provide book reviews of recently published palm books.

One of us (JD) has just returned from a short visit to Hawaii where as guest of the Hawaiian Islands Palm Society, I gave a lecture on palm novelties from Madagascar. It was a great opportunity to look at a host of mystery unnamed species of *Dypsis*. First I was taken aback by the astonishing growth rates of palms in Hawaii – even with little or no fertilizer, the growth is mind-boggling, and with fertilizer, many species seem to flower within five years of planting. Examination of some of the unnamed palms has solved a few mysteries, perhaps the most important being that the so-called Madagascar Foxtail is *Dypsis marojejyi*. A lively discussion developed on PalmTalk, with many people contributing their opinions on new determinations, not all in accord with my conclusions.

An extraordinary story has emerged concerning the bertam palm, *Eugeissona tristis*, and penta-tailed tree shrews. Both staminate and hermaphroditic flowers of bertam in Peninsular Malaysia produce copious quantities of nectar that rapidly ferments, and

so when the palm is in flower it has strong alcoholic smell. Frank Wiens and his associates have discovered that the alcohol is attractive to tree shrews and other mammals, who visit the flowers to feed on the alcohol. Amazingly they do not become intoxicated. While visiting the flowers, they also are responsible for the transfer of pollen from anthers to receptive stigmas, thereby pollinating the palm. Wiens' article appears in a forthcoming issue of the Proceedings of the National Academy of Sciences (USA), available at www.pnas.org, along with night-vision video of the tree shrew visiting bertam flowers (listed as Supporting Information). You can listen to an interview with Dr. Wiens at www.npr.org.

The most exciting news from the palm world is the publication last month of the much-anticipated second edition of *Genera Palmarum*. The work revises and expands the first edition to include new discoveries (including new genera), new data and a complete synthesis of the literature that has become available since 1987, when the first edition appeared. The new book, with color maps and illustrations throughout, is co-published by the IPS and the Royal Botanic Gardens, Kew (UK) and the LH Bailey Hortorium. Publishing an important reference work such as this is one of the ways the IPS fulfills the mission of the society and is the tangible result of members' support for the organization. The IPS is the exclusive North American distributor of *Genera Palmarum* (2nd ed.) and has arranged special, members' discount pricing. Order your copy soon (see the Supplement or p. 125 of this issue), as the print run is limited and expected to sell out.

THE EDITORS

GROWING PALMS

Horticultural and practical advice for the enthusiast

Edited by Randal J. Moore

Contents

- 🌴 Recycled Water Quality and Palms: Part I
– Randal J. Moore & Michael Marika



Recycled Water Quality and Palms: Part I

The use of recycled water is increasing as fresh water supplies in many regions become stretched by growing populations and climatic changes. The quality of recycled water for the irrigation of ornamental plants (specifically, palms) plays an important role in determining what can be grown successfully and how irrigation with recycled water should be managed. Water management practices and the concept of recycled water quality are based on the chemical analysis, irrigation methods and environmental factors evaluated in relation to the palms' horticultural requirements.

Many ornamental palms grown in outdoor public spaces are increasingly being irrigated with recycled water. Since many of the conditions under which these palms are grown are not controlled (unlike a greenhouse environment, for instance), additional considerations must be made. They include the soil type, soil amendments, irrigation methods and conditions peculiar to the site.

Water Constituents

In California, the salinity of naturally occurring water is highly variable. Water of low to moderate salinity can be used to successfully produce most types of ornamental palms. A smaller number of palm species are tolerant of water containing higher levels of salts. One way that water picks up additional salts is when it comes into contact with geologic materials—for example, water flowing through limestone increases levels of calcium and bicarbonate. Water in contact with marine sediment is infused with magnesium, sodium, chloride and boron. The major constituents present in all water are: calcium, magnesium, sodium, chlorine, sulfur, carbon bicarbonate and carbonate. The minor constituents present at different levels in various water sources are: potassium, phosphorus, nitrogen, fluorine, boron, and silicon. It is the concentration or proportion of these dissolved materials that determine the suitability of water (specifically, reclaimed water) for irrigation purposes.

Salt Levels and Palm Growth

The Sodium Absorption Ratio (SAR) is a calculated value that indicates the relationship of an irrigation water's sodium content to its combined calcium and magnesium content. SAR is used to determine a soil's potential for permeability problems and the possibility of sodium toxicity

after long-term use of recycled water. Recycled water with a SAR of less than 35 is generally no problem when used to irrigate ornamental palms. It can be problematic, however, in especially fine soils such as clay. If overhead water is applied and absorbed through the leaf or accumulated in the soil, there may also be problems.

Salinity is the total quantity of salts dissolved in water. One way to measure it is by electrical conductivity (EC). A water's ability to conduct electrical current is directly related to the concentration of salts in solution. Pure water is a poor conductor of electrical current, salty water is a good conductor. EC is reported in millimhos per centimeter (mmhos/cm). In California, the salinity of naturally occurring water varies widely. Water of low to moderate EC, up to approximately 1.5 mmhos/cm, can successfully produce most ornamental crops, including most palms. An EC reading of 2.0–3.0 mmhos/cm is approaching a range where some salt sensitive plants, including many palm species, will be damaged. A reading above 3.0 mmhos/cm requires that the salts be removed from the recycled water or washed out of the soil. To leach a soil, water in excess of the amount needed to saturate the soil must be applied at regular intervals. The excess water can carry away the salts.

The pH (reaction) is a measure of how acid or how alkaline (basic) the recycled water or the soil is. It is measured on a scale of 1 to 14, in which 7 is neutral, above 7 is alkaline and below 7 is acid. Most plants, including most palm species, do best in a range from 6.5 to 7.5. The availability of minerals and nutrients to plants is often dependent on the pH. Almost all waters in California are alkaline. It would be unusual to find water, especially recycled water below pH 7.

The total salt level in recycled water is a major concern to growers of ornamental plants including palms, because as the water's salt concentration increases, there is a greater likelihood of salt build-up in the soil. A high salt concentration in the soil reduces the amount of water and nutrients available to the palm. Many palm species are adversely affected by even a modest salt concentration in the soil. High salt concentrations are known to reduce growth. Sometimes the growth reduction is small and may go unnoticed.

If the water contains chloride as a major constituent, the salt concentration will increase as the water evaporates from the soil or is taken up by the palms. Chloride is highly soluble and remains dissolved in the soil. Recycled water that contains sulfates as a main constituent will reach a limited salt concentration when calcium is present, because calcium combines with the sulfate to form gypsum. When a soil dries, water containing bicarbonate as a principal component do not present a salinity problem. Bicarbonate reacts with calcium to form calcium carbonate.

Reclaimed Water in Poway, California

Waste water recycling is used to meet some of the local water requirements in San Diego County, California. Waste water is treated and disinfected to provide non-potable reused water. One of the principal uses is for landscape irrigation in public areas such as parks, lakes and ponds, ornamental fountains, campgrounds, golf courses, parkway medians, community greenbelts, school athletic fields, food crops, nursery stock, dust control and groundwater recharge. It can also be used for some industrial (non-residential) purposes. Currently, about 70% is used for irrigation and 30% is used to recharge groundwater basins.

Since the City of San Diego is heavily dependent upon imported water (about 90% of its water supply), recycled water is increasingly being implemented in its strategy to meet water demands. The North City Water Reclamation Plant is the first large-scale water recycling plant in San Diego. It treats up to 30 million gallons of wastewater daily from northern San Diego communities. Using the latest technological processes, wastewater is treated and purified at the plant. The reclaimed water is then distributed throughout the northern San Diego region via a dedicated pipeline system. Reclaimed pipelines, sprinkler heads, meter boxes and irrigation equipment are purple color-coded to distinguish it as non-potable recycled water.

For purposes of our study, we analyzed the reclaimed water the plant provides to the City of Poway for irrigation use at its business park. The Poway Business Park is a 900-acre development for office, light industrial and large retail businesses. Located on an elevated plateau (or mesa) at the southern city limits, the landscaping is irrigated using reclaimed water purchased from

the North City Reclamation Plant. The poor soil in the business park is comprised of coastal marine clay and rubble with no organic material.

Using a meter that measures both EC and pH, we took several water quality readings within the Poway Business Park and adjacent runoff areas (Figure 1). We sought to evaluate the quality of the reclaimed water for irrigation use on palms in the public landscape areas. For reference, distilled water has an EC of 0.0 and a pH of 7.0. A premixed buffer solution of pH 4.0 $\pm$ 0.01 is used to calibrate the meter. We report the mean of three readings at each location.

The reclaimed water from one of the irrigation valves at the business park had an EC of 1.25 and a pH of 7.9. At these levels, the recycled water could be used on palms and other landscape plants without detrimental effects. However, the soils accumulate salts over time. This condition is exacerbated by voluntary water restrictions that have been imposed to reduce water usage by 20 percent in San Diego County called the "20 Gallon Challenge." Reduction in water use is also leading to less leaching and the possible excess accumulation of salts.

We tested two locations below the Poway Business Park where irrigation water has percolated through the clay soils. Beeler Creek runs about 200 feet (60 meters) below the business park and is primarily comprised of its irrigation runoff. The EC level is 4.0, and the pH is 8.2 (Figure 2). These levels are very detrimental to most palm species and other landscape plants. Only a few palm species can survive marginally in these conditions. Separately, in a 2-acre holding pond found near the stream (which is also fed with some well water), an EC of 4.2 and a pH of 8.0 were recorded. These high readings may be due to summer time evaporation causing an increase in EC levels. The water from Beeler Creek and the holding pond could not be used for the irrigation of most ornamental landscapes.

Turfgrass Field Studies

From 1992 to 1995, the University of California Cooperative Extension performed several field experiments using recycled water. These studies compared the use of recycled water with potable water available in San Diego County and assessed the impact on turfgrass performance. These studies are relevant to palm growers since turfgrass is a reasonably good proxy for palms since both are monocotyledons having fibrous root systems. The performance of turfgrass and palms under similar trials would be expected to be somewhat similar. Three test locations were established in the north, coastal and eastern regions of San Diego County. Two types of turfgrass (a cold and warm season) were tested. The different soil structures at each location were an additional factor with the eastern county location having Diablo clay soil. Irrigation frequency schedules were also tested using infrequent and frequent (daily) irrigation applying the same total water volume.

The studies gave insight into the potential problems that might be encountered when using recycled water to maintain a high-quality landscape. The studies concluded that recycled water can be utilized for irrigation of turfgrass on a wide range of soil types with some consequences as noted. Irrigation frequency was the most significant factor in determining the success of landscapes irrigated with recycled water. This may be due to the type of root system (shallow or deep), drought resistance of the plant and salt tolerance of the plant. Infrequent irrigation using more water per irrigation is more effective in the leaching of salts than frequent irrigation using less water in each application.

Chemical analyses of the water were performed weekly measuring pH, EC, calcium, magnesium, sodium, chloride, nitrogen, bicarbonate and sulfate. Calculations were performed to determine Total Dissolved Solids (TDS) and SAR. Recycled water showed high variability in water quality between locations and sampling dates. The absolute values for salinity (TDS), sodicity (SAR) and toxicity (sodium, chloride and boron) were within acceptable ranges for turfgrass culture.

The chemical analyses showed that the recycled water had higher values for all constituents when compared to potable water. Importantly, recycled water is consistently and considerably more saline than potable water. Approximately 50% to 70% more salts were applied though recycled water than were applied using potable water. The SAR was also higher for recycled water. The studies found that water type did not consistently affect turfgrass quality. Quality scores were based on grass texture, color, growth habit and response to temperature. In some cases, recycled water produced higher quality turfgrass for certain types of grass on certain types of

soil. This was assumed to be due to the higher nitrogen concentrations and warmer temperature of the recycled water.

Chemical analysis of soil extracts determined that water type had no significant impact on soil pH. Soil salinity and sodium concentration, chloride and boron tended to be cyclic in nature. EC values tended to be lowest in Spring due to the leaching from winter rains. EC values were highest at the end of the irrigation season in September or October. Soil salinity and SAR were higher with recycled water but still within acceptable ranges. A reduction in infiltration or soil permeability was a concern but was not observed in the study. Boron levels were significantly increased with recycled water use and could be a long-term concern.

With recycled water, leaching of salts is necessary for the maintenance of acceptable salinity levels in the root zone. Fertilizer rates can be adjusted to compensate for the increased amount of nitrogen present in recycled water. The frequency and amount of irrigation using recycled water should be modified to leach salt accumulation but not nitrates beyond the root zone. Of course, leaching should be performed before fertilizing.

In the past decade since the original field tests were performed, studies on recycled water using chemical analyses of soil extracts continue to be performed in San Diego at selective locations in response to observed poor health of landscape plants in public areas. The main concerns continue to be elevated levels of EC, SAR, sodium, chloride and sulfate measures. In some cases, the test results confirm salt toxicity as diagnosed from symptoms of marginal and tip burning, poor growth performance and yellowing. Other factors can exacerbate the problem of high salinity levels, such as plant diseases, over-watering, under-watering, pests, soil compaction, etc. Often, gypsum is applied to soils with elevated SAR values, and sodium is flushed from the root zone through leaching.

Recycled water will be increasingly used as an alternative water source in arid climates worldwide. The suitability of this water for the irrigation of ornamental palms in public landscapes involves many factors including irrigation schedules, soil structure, palm species to be grown and fertilization. To successfully grow palms using recycled water requires proper management of these factors. – *Randal J. Moore, Poway, California, USA* and *Michael Marika, Park Arborist, City of San Diego USA* 🌴

Beneficial Role of Arbuscular Mycorrhizal Fungi on Florida Native Palms

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Mycorrhizas, the symbiotic associations of roots and soil fungi, are present in Florida native palms collected in the wild. However, the role of mycorrhizas in the growth of these palms is unclear. We studied seedlings of four palms native to the Everglades to see how mycorrhizas affect growth and uptake of phosphorus. Our findings will be helpful in proposed Everglades restoration projects.

The symbiotic fungi are called arbuscular mycorrhizal fungi (AMF) which are common and found in the majority of land plants including cycads, conifers (except the pine family), and most trees and crop plants, including palms. The fungi penetrate and grow inside the roots but are not visible on the root surface with the naked eye. They also do not form large, obvious reproductive bodies (i.e., mushrooms or truffles). Therefore, fungal presence can only be verified after clearing, staining and then observing the roots with a

microscope. Within the root cells, the fungus forms tiny tree-like structures, called arbuscules, which are the places where nutrients and water are exchanged between the two organisms. The fungus cannot make its own food and receives organic nutrients (sugars and amino acids) from the photosynthetic plant. In return, the plant receives mineral nutrients and water through the fungi. Smith and Read (1997) and Wang and Qiu (2006) gave extensive reviews about the general biology of mycorrhizas.



1. Representative plants of *Coccothrinax*, plants unpotted and washed free of soil. Treatments: 1 = no AMF, no microbes; 2 = no AMF, added microbes; 3 = live AMF, added microbes; 4 = no microbes, added 10 mgkg⁻¹ P.

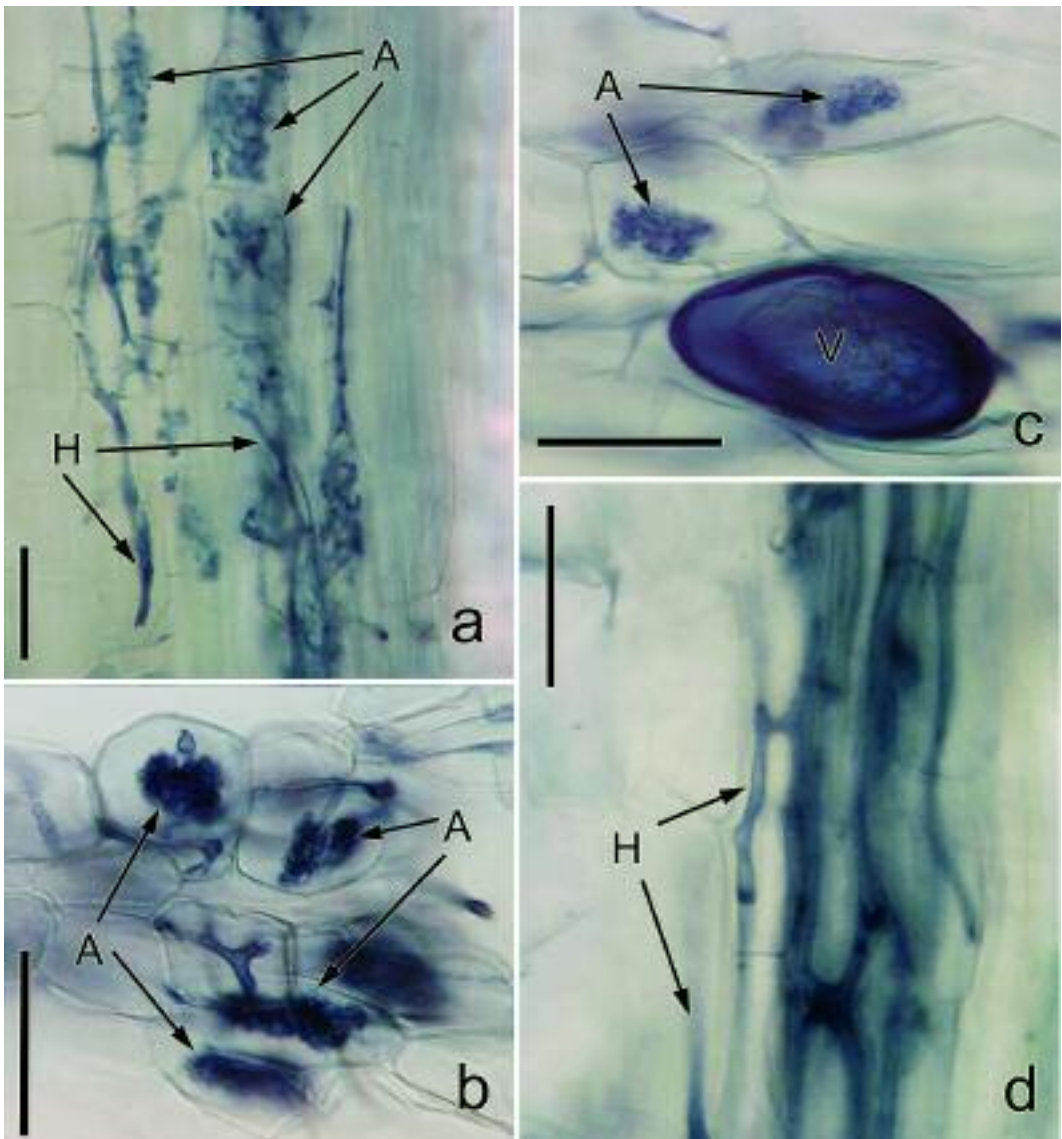
Although no comprehensive surveys of the palm family have been conducted, AMF have been found in every species of palm that has been studied. The first well documented description of a mycorrhiza in a palm and its beneficial effect on palm growth was given for the peach palm (*Bactris gasipaes* Kunth) by Janos (1977). Later, St. John (1988) presented an historical review of AMF in palms. AMF occur in all the three main commercial palms

(African oil, coconut and date) and many wild palm species (reviewed in Fisher & Jayachandran 1999). Since this last review, AMF were reported in wild *Desmoncus* palms (Ramos-Zapata et al. 2006), wild Florida native palms (Fisher & Jayachandran 2005) and old cultivated date palms (Bouamri et al. 2006). But the mere presence of AMF does not tell us about the benefits of AMF for the plant. Although controlled experiments found that

addition of AMF to potted palms increased growth (reviewed later in detail), there have been no experiments with native Florida palms. Here, we report on several experiments with native palms that investigate some of the effects of AMF on palm seedlings that were grown in pots with native soil. This native sandy soil had low levels of phosphorus and other nutrients. We want to know if AMF promote growth and increase the uptake of phosphorus in these palms, similar to the effects of AMF on rare non-palms that were tested on the same native infertile soil (Fisher & Jayachandran 2002).

Our experimental study has practical implications for palms being grown for restoration and for palms growing naturally in the Greater Everglades ecosystem. Native palms are key species in both wetlands and uplands of pine forest and hardwood hammocks of this ecosystem. We need to understand the propagation and cultural requirements of the native palms better to improve their successful outplanting into natural environments. AMF may play an important role in the Everglades, a naturally low phosphorus (P) environment. Additions of P, as from nursery operations, can be

2. AMF in the cortex of ultimate feeder roots of palms. a. Intercellular hyphae and arbuscules in *Sabal*. b. Intracellular hyphae and arbuscules in *Sabal*. c. Vesicle and arbuscules in *Sabal*. d. Intercellular hyphae in *Acoelorrhaphe*. A, arbuscule; H, hypha; V, vesicle. Scale line = 50 μ m.



ecologically disruptive (Fish & Wildlife Service 1999). AMF may be a potential substitute for fertilizers in nursery production of plants used in restorations if native palms respond to AMF.

Materials and Methods

Plants

In the Greater Everglades ecosystem in subtropical Florida, four species of palms are a visible and ecologically important component of the native plant communities. Wetlands have the Everglades or Pauropes palm [*Acoelorrhaphes wrightii* (Griseb. & H. Wendl.) H. Wendl. ex Becc.] and pine rocklands have the silver palm [*Coccothrinax argentata* (Jacq.) L.H. Bailey], the cabbage palm [*Sabal palmetto* (Walter) Lodd. ex Schult. & Schult.f.], and the saw palmetto [*Senecio repens* (W. Bartram) Small]. The last two palms also occur in plant communities transitional between wetland and pine rockland. Urban development, farming and nursery operations have eliminated much of these wetlands and upland communities.

Soil

Soil samples for physicochemical analysis were collected from a pine rockland site containing wild plants of *Coccothrinax*, *Sabal* and *Senecio*. The native pine rockland site had shallow sandy soils over a bed of oolitic limestone. Soil analysis ($n = 3$ at each depth) was carried out by a commercial testing service (A&L Southern Agricultural Laboratories, Pompano Beach, FL 33064). At the 0–5 cm. depth, color was white to gray; pH = 6.8–7.3; weak Bray test = 8 mg kg⁻¹P. At the 5–20 cm depth, color was white to yellow-orange; pH = 7.3–7.4; weak Bray test = 4–8 mg kg⁻¹P.

Soil used to fill pots for greenhouse experiments was dug from 5–20 cm depths and mixed. Soil was sieved through 6 mm mesh to remove stones and large root fragments. The average soil-solution P was 0.002 mg L⁻¹ (SE = 0.0011, $n = 4$), as determined with a water extraction method by Olsen & Summers (1982). The average soil P (weak Bray test) from 0–20 cm depth = 6 mg kg⁻¹.

AMF inoculum

Nurse cultures of mixed native AMF from pine rockland were maintained on pigeon pea and sudan grass in 4 L pots containing fresh, unpasteurized soil from the native habitat of the species of interest. Nurse cultures were at

least 12 wk old before use. The inoculum samples showed heavily colonized root fragments and many AMF spores. Spores collected on the 250 μ m sieve were mostly the genus *Gigaspora* or *Scutelospora*; spores smaller than 250 μ m were mostly *Glomus* spp. Soil and root fragments were mixed well and used as live inoculum (Treat. 3, below). A part of the same inoculum was steam pasteurized for 2 h one time and used as an inoculum control for all treatments without live AMF (Treat. 1, 2 & 4, below). Thus, all treatments received similar additions of organic and inorganic P found in the inoculum.

Experiment

Seeds were collected from wild plants, surfaced sterilized with 1.0% sodium hypochlorite solution for 15 min, rinsed in water, scattered on the surface of inorganic Perlite® medium in plastic pots, and placed under periodic mist watering. Seedlings with one or two green simple leaves (eophylls) were removed from the medium, roots trimmed to 4 cm length (to more easily fit into pots), and transplanted into 5 × 18 cm plastic pots (D40 Deepots™, Stuewe & Sons, Inc., <http://www.stuewe.com>) each filled with 600 g native sandy soil (see description above) that was twice steam pasteurized. Pots, each with one seedling, were grouped by species. Treatments were randomly arranged in frames and grown on benches in a glasshouse under ca. 50% shade. During the growing period, pots were periodically rearranged within and between species groups. Cross contamination was prevented by separation of pots and care in watering.

Four treatments were:

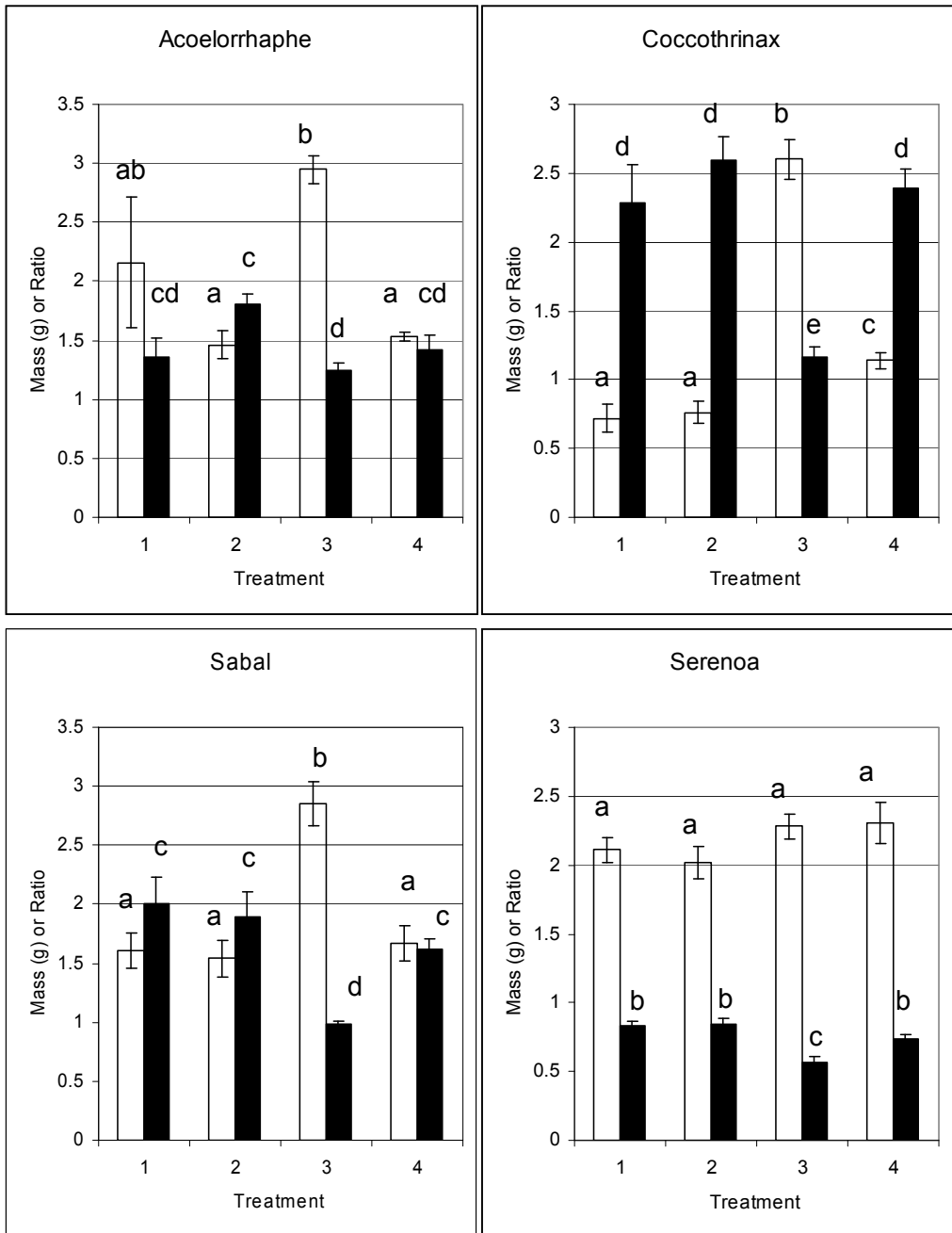
Treatment 1: no AMF; no soil microbes; no P

Treatment 2: no AMF; added soil microbes; no P

Treatment 3: live AMF; added soil microbes; no P

Treatment 4: no AMF; no soil microbes; added 10 mg kg⁻¹ P

Each pot received 20 g of either live or dead inoculum (sterilized). Soil filtrate (containing soil microbes but not AMF) consisted of 30 ml per pot of a soil solution derived from 300 g fresh soil shaken in 2 L distilled water, and filtered through Whatman No. 1 filter paper. Phosphorus addition consisted of five treatments on alternating weeks beginning 3 or 4 wk after transplanting. This brought the



3. Plant dry mass of plants after 12 months for *Acoelorrhaphe*, 16 months for *Coccothrinax*, 12 months for *Sabal*, and 14 months for *Serenoa*. Treatments: (1) no AMF, no microbes; (2) no AMF, with microbes; (3) with AMF; (4) no AMF, no microbes, with added P. Open bar = whole plant dry mass; solid bar = root/shoot ratio. Mean values ($\pm$ SE) given. Statistical comparisons made separately for dry mass and ratio. Bars having the same color and same letter are not statistically different ($\alpha = 0.05$).

total available P additions (in the form of KH_2PO_4) to the pot at 10 mg kg^{-1} (based on 600 g total soil). Hoagland's nutrient solution was prepared without P (Hoagland & Arnon 1950) and 50 mL added periodically to all pots of a species when plants became chlorotic (six

times for *Coccothrinax* and *Serenoa*, four times for *Sabal*, three times for *Acoelorrhaphe*).

There were eight replicate pots per treatment for *Acoelorrhaphe*, *Sabal*, and *Serenoa* and ten replicates pots for *Coccothrinax*. Plants were

harvested after 12 mo (*Acoelorrhaphe*, *Sabal*), 14 mo (*Serenoa*) or 16 mo (*Coccothrinax*), and dry mass of roots and shoots were used to evaluate treatment response. In *Coccothrinax* and *Sabal*, phosphorus content was determined by the dry-combustion and colorimetric method (Solorzano & Sharp, 1980). Ultimate feeder root segments detached during washing (2–6 distal ends) were cleared in KOH, bleached, and stained with trypan blue (Brundrett et al. 1996) to observe AMF root colonization.

Differences among means of dry mass and P concentrations were tested with a one-way ANOVA. Differences between pairs of means were compared post hoc using a conservative Bonferroni test, if the Levene statistic indicated homogeneity of variances, or using a Games-Howell test if variances were not homogeneous using the SPSS Base 10.0 statistical software (SPSS Inc., Chicago, IL; <http://www.spss.com>).

Results and Discussion

Presence of AMF

AMF were present in small ultimate feeder roots (Fig. 1) of plants treated with live, mixed inoculum. All four species contained non-septate hyphae (Fig. 2a, b, d), arbuscules (Fig. 2a–c), and vesicles (Fig. 2c) in the root cortex, although not necessarily in the same root segment. Most commonly, AMF hyphae were intercellular (*Arum*-type morphology) (Fig. 2a), but occasionally intracellular hyphae were observed (Fig. 2b). Roots from other treatments did not show AMF colonization. However, quantitative assessment of fungal colonization could not be done with confidence because of difficulties in clearing roots with lignified epidermis and hypodermis.

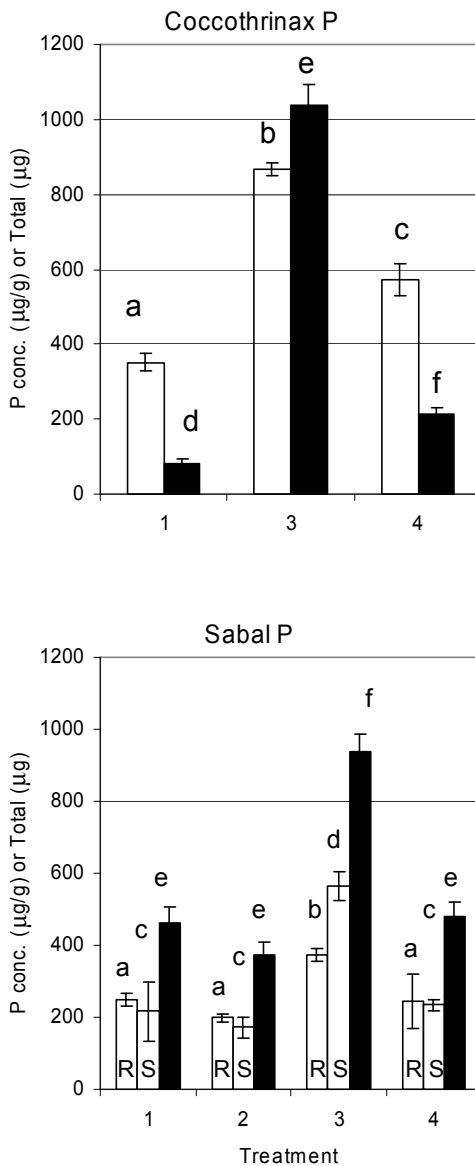
Previous publications have already illustrated AMF in wild collected roots of *Coccothrinax* (Fisher & Jayachandran 2005) and *Serenoa* (Fisher & Jayachandran 1999). In addition, the presence of AMF was reported in roots of six of the eight native Florida palm genera growing in the wild (Fisher & Jayachandran 2005). *Rapidophyllum* was not examined, and *Roystonea* was reported to have mycorrhizal colonization by Zona (1996), which has since been confirmed (J.B. Fisher, unpublished observations). All the major palm crops also have AMF in their roots under field conditions, e.g. African oil palm (Nadarajah 1980), beetle nut (Sengupta & Chaudhuri 2002), coconut (Lily 1975), date palm (Sabet 1940) and peach palm (Janos 1977).

Effects of AMF

The effects of AMF, P and soil microbes on the dry mass (= dry weight) of roots, shoots and the entire plants and on the ratio of root to shoot mass are presented (Fig. 3). Roots and shoots were measured separately to calculate root/shoot ratio. However, for clarity of presentation, only the total plant mass is presented in the graphs. In *Acoelorrhaphe*, AMF (Treat. 3) produced large plants that were statistically different from Treat. 2 and 4, but not different from Treat. 1. For root mass only (not shown in Fig. 3), Treat. 3 was significantly different from Treat. 1, 2 and 4. The root/shoot ratio differed only between Treat. 2 and 3. In *Coccothrinax* (Fig. 3), AMF significantly increased whole plant mass over Treat. 1, 2 and 4. Treat. 4 plants were larger than the control Treat. 1 and 2 but did not equal Treat. 3. The root/shoot ratio in the AMF treatment was significantly smaller than the other treatments. In *Sabal*, AMF clearly promoted whole plant mass over all other treatments, which were not significantly different from one another. Similarly, root/shoot ratio was significantly smallest in Treat. 3. In *Serenoa*, no treatment differences were found in whole plant dry mass, although AMF and added P (Treat. 3 and 4) did significantly increase the shoot dry mass (not shown in Fig. 3). Seedlings of this species are notoriously difficult to transplant (J.B. Fisher, personal experience), and seedlings in this experiment appeared to be stunted in growth for the first few months after planting in pots.

Phosphorus content was determined for two experiments (Fig. 4). *Coccothrinax* had significantly higher P concentration in the shoot tissue of plants with AMF (Treat. 3) and with P (Treat. 4) compared to the soil microbes free control (Treat. 1). The soil level of P (10 mg kg⁻¹) was doubled to 20 mg kg⁻¹ with P added, but this is still low relative to agricultural soils (Brady & Weil, 2002). Moreover, total shoot P was almost five-times greater with AMF than with addition of P. Treat. 2 and root tissues were lost during tissue analysis. In *Sabal*, P concentration of both shoots and roots were significantly greater for the AMF treatment compared to all other treatments. The total plant P was significantly greater in the AMF plants than in those of the other treatments and almost twice that of the P addition.

Working with *Bactris gasipaes* seedlings, Janos (1977) found that inoculated plants grew larger



4. Phosphorus uptake after 12 months for *Sabal* and 16 months for *Coccothrinax*. Treatments: (1) no AMF, no microbes; (2) no AMF, plus microbes; (3) plus AMF, plus microbes; (4) no AMF, no microbes, plus added P. Open bars = shoot P concentration (S) and root P concentration (R); solid bars = total plant P. Mean values ($\pm$ SE) given. Statistical comparisons made separately for shoot, root and total plant. Bars having same color and same lower case letter are not significantly different ($\alpha = 0.05$).

and fewer died than controls growing in native unamended soil free of AMF. However, the difference in size did not appear until after ten months, presumably when nutrients stored in the seed were used up. Later, more varied pot experiments with *B. gasipaes* showed that three

genotypes responded differently to a single species of AMF and added P (Clement & Habte 1995). Some palm genotypes were less dependent on AMF than others, i.e. some grew equally well at higher P levels with or without AMF. When *B. gasipaes* was grown in a field orchard, the results became more complicated and less clear (Bovi et al. 1998). A single plant genotype was used with different levels of fertilization. After five years, roots showed a difference in natural AMF colonization with more colonized at higher N levels. Degree of root colonization also showed an interaction between P and K fertilization.

Rattan palms (*Calamus simplicifolius* Wei, *C. tetradactylus* Hance, *C. tetradactyloides* Hance, and *Daemonorops margaritae* (Hance) Becc.) growing in plantations all had AMF in their roots (Gong et al. 2000). In two species (*C. simplicifolius* and *D. margaritae*), Gong et al. (1995, 2000) found that one year after the addition of AMF, there was an indication of increased shoot dry weight and P uptake both with and without added fertilizer. Unfortunately, replication was limited and differences were not tested statistically. Seedlings of African oil palm (*Elaeis guineensis* Jacq.) were grown for 12 months in non-sterile soil that had natural AMF spores (Sanni 1980). All plants eventually became colonized with AMF, but those inoculated with additional AMF spores were larger, presumably due to greater or more rapid AMF colonization.

Other workers showed more clearly that AMF promoted nutrient uptake by palms. In a more controlled experiment with *Elaeis*, Blal et al. (1990) found that micropropagated plantlets (which unlike seedlings lacked stored nutrients in the seed endosperm) responded to AMF inoculation with greatly increased growth and increased P uptake when grown on two different acidic tropical soils. AMF also promoted growth and uptake of P from two sources of P (rock phosphate and super phosphate fertilizers). In date palm (*Phoenix dactylifera* L.) seedlings, AMF increased plant growth and uptake of P after nine months (Oihabi et al. 1993). Other species of *Phoenix* were also affected by AMF. Two-year-old seedlings of *P. roebelenii* O'Brien inoculated with AMF were larger but did not have significantly higher concentrations of P when they were harvested two years later (Jaizme-Vega & Díaz-Pérez 1999). Seedlings of *P. canariensis* Chabaud were inoculated separately with three different species of AMF (all species of *Glomus*) and grown for one year on a

peat:pine bark substrate in pots (Morte & Honrubia 2002). In unfertilized plants, one AMF species had higher rates of colonization and larger plants than the control or the other two AMF species. In addition, fertilized plants were larger than unfertilized ones. Plants were also analyzed for the concentration of minerals in the shoot tissues. In fertilized conditions, where nutrient levels were presumably less limiting, the AMF increased P only in the shoot. However, in unfertilized conditions, where there was a greater limitation of nutrients, AMF significantly increased the concentration of P, K, Mg, Na and Mn (Morte & Honrubia 2002). Thus, AMF can improve growth and nutrient uptake in palms, especially when soil nutrients limit growth.

The peach palm was considered by Janos (1977, 1996) to be an obligate mycotroph that required a symbiosis with AMF to survive in nature. Yet palms do not always require AMF, especially under high nutrient conditions of ornamental horticulture. Many ornamental palms are grown successfully in sterilized soil or artificial nursery mixes with external input of all required nutrients. Some 20-years-ago, St. John (1988) reviewed the presence of mycorrhizae in palms and suggested that AMF could be beneficial in palm horticulture, possibly when there are problems with nutrient uptake.

Our results with the effect of AMF on Florida native palms are consistent with these previous publications. AMF generally improved growth and increased concentration and total plant P as compared to the AMF-free plants. The addition of soil microbes (Treat. 2) did not significantly affect growth or P concentration over the soil microbes-free control (Treat. 1). Addition of P that doubled the soil P level (from 10 to 20 mg kg⁻¹) increased the shoot P concentration in *Coccothrinax* and *Sabal*. Addition of P increased the whole plant mass of only *Coccothrinax* over the controls (Treat. 1, 2) but was still less than the AMF (Treat. 3). In the other three species, addition of P did not affect plant mass. We have no information on effects of greater additions of P.

The ratio of root/shoot mass is a measure of resource allocation in a plant. In *Coccothrinax*, *Sabal* and *Serenoa*, root/shoot ratios of plants inoculated with AMF were significantly smaller than controls or addition of P (Fig. 3). In *Acoelorrhaphe*, the ratio was significantly different only between AMF and Treat. 2, the control with soil microbes. Colonization by

AMF also lowered the root/shoot ratio in other Florida natives (Fisher & Jayachandran 2002). Such a decrease in root/shoot ratio in AMF plants was found previously in many species (Vaast et al. 1996), although considerable variation in the effect of AMF on root/shoot ratios occurred in other species (Allen 1991, Corkidi & Rincón 1997, Janos et al. 2001).

Significance for Conservation and Restoration

In southern Florida, soils generally have low available P (Myers & Ewel 1990). Phosphorus appears to be a limiting nutrient in coastal and pine rockland soils, as was shown in the native endangered species of *Jacquemontia reclinata* and *Amorpha crenulata* (Fisher & Jayachandran 2002), in which AMF facilitated growth and P uptake. The present results confirm this beneficial effect of AMF in native palms. Arbuscular mycorrhizal fungi (AMF) appear to help native Florida palms gather the low levels of nutrients (and perhaps moisture) found in nutrient poor soils. Palms may require AMF to survive in the wild but not when grown in pots or in the soil of gardens where they are fertilized. This fact may already be obvious to palm growers: most palms grow perfectly well in sterilized soil mixes with added fertilizer. Nutrient deficiencies or poor growth in cultivated palms are commonly related to the extremes of high or low soil pH, temperatures or light intensity, and presumably not a lack of soil microorganisms.

Janos (1996) classified the peach palm as an obligate mycotroph because seedlings would not survive in their natural habitat without AMF, as opposed to facultative mycotrophs which can survive in the absence of AMF. More recently, he clarified the relationship by distinguishing between "response" to and "dependence" upon mycorrhizas (Janos 2007). A species must be grown on a wide range of soil P concentrations to verify these distinctions. Since *Coccothrinax* showed a significant enhancement of growth by P addition (Treat. 4), it may be less dependent upon AMF than the other species which did not respond to this level of P. We have results from only two P concentrations and cannot evaluate these four species for certain. However, *Acoelorrhaphe*, *Sabal* and *Coccothrinax* are definitely responsive to AMF, as shown by increased growth in Treat. 3. Because our AMF-free control plants (Treat. 1 and 2) were small and chlorotic, we suspect that they would not survive, but we do not know for certain. Plants

with additional P (Treat. 4) were healthier. Past experience with growing these four species in a nursery mix without AMF inoculation but with fertilization indicates that they grow well in a high nutrient environment, presumably lacking AMF (unpublished observations). Gemma et al. (2002) suggested that this type of responsiveness to AMF under very low natural soil P levels should be referred to as "ecological mycorrhizal dependency." The four palms can be ranked by their relative responsiveness (called "relative mycorrhizal dependency" by Baon et al. 1993), as determined by the percentage increase in average dry mass of entire plant ([Treatment 3 - Treatment 2]/Treatment 2) based on native soil P concentration. The RMD are as follows: *Coccothrinax* = 241%; *Sabal* = 84%; *Acoelorrhapha* = 47%; and *Serenoa* = 13%. However, because there were different growth periods for the one-time measurement, these rankings are still tentative. The relative ranking is the same if RMD of each species is divided by the number of growing months for that species.

Because P and other nutrients are limiting in natural sites in southern Florida (Myers & Ewel 1990), we assume that natural seedling establishment depends upon AMF colonization. In natural sites occupied by palms, AMF can be expected to be ubiquitous in the roots of most plants and adjacent soil. Thus, any new seedlings that develop will quickly become colonized by AMF. In certain situations, where natural AMF inoculum could be absent or present only in low propagule numbers (e.g., cleared roadsides, sites where top soil was removed, reclaimed urban landscapes or where soil from non-vegetated sources is added, as in canal waste or coastal areas "enriched" with marine dredgings), the resulting soil environment would be similar to the classic low AMF habitats: mine tailings, strip mining disturbance or volcanic eruption (Allen 1991). In such cases, natural seedling establishment could be slowed or prevented by lack of natural AMF colonization. Nursery grown seedlings may lack AMF and successful establishment would require fertilization until AMF colonize the palm. However, use of fertilizers can be an issue in restoration projects in natural areas or preservations. Because the Everglades hammocks and pine rocklands are naturally low P environments (Chen et al. 2000), any use of P fertilizer is a major concern for land managers (U.S. Fish & Wildlife Service 1999). Therefore, acceptance of phosphate fertilization is very unlikely for plants grown

for Everglades ecosystem restoration since P is such a significant pollutant in these habitats (Fish & Wildlife Service 1999). The use of native AMF is an ecologically sound method for conservation horticulture and may be a valuable tool in future restoration plans. AMF inoculation is a non-polluting way to improve growth of native plant seedlings without the need of additional P in situations where natural AMF is limiting growth, including nursery production.

Acknowledgments

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PALM LITERATURE

ORTHO® ALL ABOUT PALMS. Paul Craft, Meredith Books, Des Moines, Iowa. 2008. ISBN 978-0-23604-4. US\$12.95. Softcover. 128 pp.

All About Palms is intended to be an introductory how-to book on palms targeted at an audience primarily of homeowners and landscapers. Because the book is a mass marketed, it carries a low cover price. In addition to bookstores, the book is broadly available in most home improvement centers and even some supermarkets, as well as on-line in booksellers.

The impetus for this book project came on the heels of the success of *An Encyclopedia of Cultivated Palms* (Timber Press, 2003) that Craft co-authored (with Robert Riffle) and that became a standard non-technical reference book on palms. Surprisingly, while there are how-to guidebooks on just about every subject, few (if any) are available about palms. One similar book which appeared recently is *Betrock's Essential Guide to Palms* by David Leaser (Betrock Information Systems, Inc., 2007). Meredith Gardening Books publishes the Ortho® series of do-it-yourself guidebooks and approached Craft to undertake the project.

Paul Craft has the ideal credentials to write this type of reference book about palms. He is an expert horticultural consultant who has worked on many large landscaping projects in Florida and elsewhere. In the past, he was the owner of a wholesale nursery specializing in palms, cycads and exotic ornamentals. Along with his practical experience, Craft is the past-president of the International Palm Society.

All About Palms was released at a book signing event at Fairchild Tropical Botanic Garden in April 2008. In conjunction with the symposium, Craft gave a presentation entitled "Palm That Won't Grow Here." It was essentially the antithesis of his new book in which he related all of his "negative know-how" (what not to do) about growing palms. While the book discusses the methods that are successful for growing palms, knowledge of the multitude of mistakes to avoid is where his years of practical experience are evident.

Given the intended target audience for this book, the first four chapters start out logically with the basics. The first chapter is a "palm primer" that covers at its most basic level palm morphology, taxonomy and even some ethnobotany. It then transitions into the four

basic cultural requirements of light, temperature, soil and water. Again, this is clearly a book for beginners (which we all were at one time).

In the second chapter, Craft accomplishes in just a few pages an explanation of the essentials of landscape design using palms. He explains that, to create a successful garden, one must consider the growth habits and cultural requirements of palms in conjunction with the design objectives of the garden. How many highly-experienced palm gardeners do not heed this type of advice and wind up with a jumbled palm collection with no cohesive design?

The practical information on planting and maintaining palms is in the third chapter. It covers a long list of basic horticultural topics: Buying a containerized palm, planting it, staking, fertilizing and mulching, watering, pruning, frost protection and seed germination (probably advanced for a beginner's how-to book).

The final introductory (fourth) chapter covers pests and diseases. Craft restricts the list of pests to the most common and controllable: mealy-bugs, aphids, scale and mites. Discussing fungal problems and control can be complicated even for the professional, so Craft mostly avoids delving too deeply and discusses a few lethal problems that do not have any treatment options. He also gives brief attention to environmental and cultural problems. The comment that closes this chapter is an indictment on palm collectors in zone denial: "It's natural for gardeners to try to extend the growing range of plants they like, but trying to grow palms unsuited to your climate can be frustrating."

The remainder of *All About Palms* contains the requisite directory called the "Gallery of Palms." It covers 175 species of palms presented alphabetically by scientific name on 49 pages, or about 40% of the total book length. In addition, there is a much shorter "Palmlike Plant Gallery" some compatible plants such as cycads, tree ferns, pandanus, dracaenas and such. The Gallery section gives a short general description, some horticultural requirements and landscape uses. A common name is provided for every species, even though many probably did not have a common name before publication of this book. Palm hardiness based on a minimum temperature is a tricky guideline since a major factor is the duration of the cold period.

Photo Feature



This wonderful mosaic of a date palm was probably constructed in the 13th century. It forms one wall of the treasury (Kubbet al-Kazneh or Beit al-Hal) of the Umayyad Mosque in Damascus, Syria. (Photo: Ralph W. Dransfield).

Ecological Factors Affecting the Spread of *Rhynchophorus ferrugineus* (Red Palm Weevil) in Eastern Sicily

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The red palm weevil, *Rhynchophorus ferrugineus* (Oliv.) (RPW), is one of the most damaging pests of *Phoenix canariensis* Chabaud. It is native to southern Asia and occurs in many countries of the Mediterranean Basin, such as Egypt, Spain and Israel (Ferry & Gomez 2002). This paper describes the ecology of the weevil in Sicily.

Female palm weevils (Fig. 1) lay eggs in the axils and petioles of new leaves or in wounds caused by pruning or wind damage. The larvae burrow into the petioles and reach the terminal bud of the palm where they complete their life cycle. Tunneling and feeding by the larvae debilitate the infested trees, which die as a consequence of the build up of numerous generations attained by the insect (Ferry & Gomez 2002). Common symptoms of weevil infestation include leaf chlorosis, drop of green leaves that are no longer supported by the bored axils and collapsed canopy (Fig 2). Larval feeding activity and tunneling produce a typical sound that can be heard and detected

with bio-acoustical devices. Infested trees can die in 4–6 months.

In Italy, *R. ferrugineus* was first detected in October 2004 in a palm nursery near Pistoia (Tuscany) (Sacchetti et al. 2006). In the following year, RPW spread to other regions in southern and central Italy including Sicily, where it was detected mainly in old *P. canariensis* palms growing along the eastern coast of the island (Longo & Tamburino 2005, Conti et al. 2006, Longo 2006).

RPW adults detected in Sicily are reddish with a very long rostrum; females average 31.8 mm long and males 30.1 mm. Different prothoracic

spots of diagnostic significance characterize the Sicilian populations (Longo 2006). In Sicily, RPW life stages have been found in the leaf axils and inside the terminal bud of the palm, but not inside the stem. The pupa is protected by a 47.5 mm long cocoon, consisting of palm fibers (Longo 2006). A phoretic mite, *Centrouropoda almerodai* Wisniewski & Hirschmann, has been found associated with adults of the populations studied (Longo & Ragusa 2006).

In many countries where the pest is considered of economic importance non-chemical and chemical approaches have been adopted to manage it. Non-chemical phytosanitary measures such as the removal of insect-infested palm material and wound protection with mastic are useful in suppressing the insect populations and preventing oviposition. The chemical approach, including the application of various chemical formulations, has resulted in inconsistent results and requires frequent chemical applications (Ferry & Gomez 2002). In Italy, pyrethrum and rotenone are registered for use on ornamentals in public sites, but their efficacy is very low. Chlorpyrifos and carbaryl, well known for their effectiveness, are restricted insecticides that are registered for use under special situations such as palm plantations or nurseries. The aim of this work was to determine i) the effect of ecological factors on the progression of RPW infestations

in several sites in eastern Sicily, and ii) the population dynamics of the insect using an aggregation pheromone trap technique.

Materials and Methods

Survey and detection of RWP

A preliminary survey by visual inspection was initiated immediately after the first detection of RPW in a Sicilian historical town (Acireale), in the fall of 2005 (October) and was concluded in the spring of 2006 (May). The survey included heavily infested sites and bordering areas in botanical parks, downtown gardens and historic villas. 1140 *P. canariensis*, 81 *Washingtonia filifera*, 58 *P. dactylifera*, 50 *Howea forsteriana* and 6 *Chamaerops humilis* in 162 sites were visually inspected in an area encompassing about 150 km² in Catania province. These areas were surveyed again by visual inspection, in summer (July–September 2006) and fall (October–December 2006). Data collected during the three surveys were compared in order to assess the progression of the infestation over the year. Palms with symptoms were visually inspected, sometimes with the help of a lifting device and checked for the presence of larvae and cocoons. All trees were ranked for tallness with the aim of determining whether plant height was a predisposing factor to insect infestation and damage. For conciseness, all the homogeneous sites were grouped together and presented as

1 (left). Adult *Rhynchophorus ferrugineus*. 2 (right). *Phoenix canariensis* severely infested by Red Palm Weevil.



composite sites in Table 1 and Figs. 1–3. A few observations on chemical spray applications, where such programs have been implemented, are also reported.

Monitoring insect populations with pheromone traps

Since RPW adults are attracted by a male aggregation pheromone consisting of ferrugineol and minor components (Soroker et al. 2005), we placed pheromone traps in two different composite sites for monitoring the population dynamics of the insect. One of these sites (Acireale) was undisturbed, whereas the other (Acicatena) underwent chemical management. The pheromone used was Tripheron (Pheromone Trap System). Traps consisted of a 3-liter plastic bucket, covered with rough jute bag and containing the pheromone and an emulsion of water and mineral oil (Longo et al. 2007). No food baits were added because the traps were intended for monitoring the presence of RPW adults and not for mass trapping. The pheromone was changed every 3 months. Traps were hung at 2–3 meters on the palm trunks from May 2006 to January 2007. They were checked weekly.

Results

Survey and detection of RPW

The results of our survey by visual inspection indicate that *P. canariensis* palms are the only host of RPW in Sicily. No RPW were observed on *W. filifera*, *P. dactylifera*, *H. forsteriana*, or *C. humilis*. Male palms are usually more infested than females, which however, are also seriously damaged by the pest. Taller palm trees were more seriously infested than shorter ones (7.72 vs. 6.74 m in 2006). At the beginning (November 2005) of the first survey (October 2005–May 2006), the percentage of infested palms was highest at Acireale (Table 1 and Fig. 1). The percent of infested palms during this survey was variable at the other sites (Table 1). At the end of the first survey in May 2006 and beginning of the second survey in July 2006 we did not notice any increase in the number of infested palms compared to that recorded in November 2005. The cold temperatures during winter and spring time had an adverse effect on the biological activity of the insect and prevented further spreading of the infestation (Figs. 2, 4). However, a total of 71 trees were damaged by the weevil in 2005,

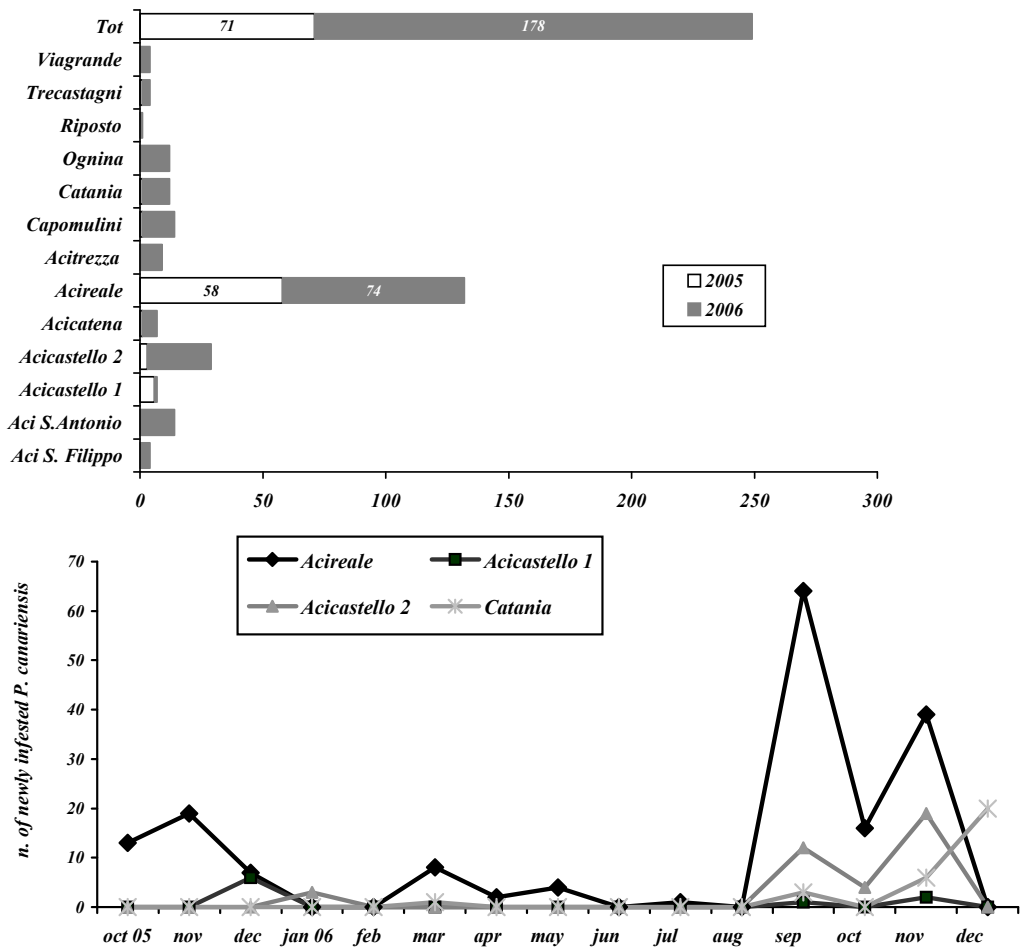
Table 1. Sites surveyed and percent of Canary palms infested by *Rynchophorus ferrugineus* during three different periods (2005–2006), in Eastern Sicily. Nr = not recorded.

Composite sites	Sites examined	No. trees examined	% infested (2005)*	% infested (2006-I)**	% infested (2006-II)***
Aci S. Filippo	5	31	0	12.9	16.0
Aci S. Antonio	7	59	0	23.7	Nr
Acicastello 1	4	59	10.17	6.8	15.0
Acicastello 2	17	130	2.31	20.8	29.9
Acicatena	4	20	5.0	35.0	46.7
Acireale	56	312	18.13	39.7	47.5
Acitrezza	9	24	0	37.5	Nr
Capomulini	3	39	2.56	35.9	73.9
Catania	33	128	0.78	9.38	14.7
Ognina	11	228	0	5.3	Nr
Riposto	4	67	0	1.5	Nr
Trecastagni	4	23	4.35	17.4	Nr
Viagrande	4	8	0	50	Nr
TOTAL	162	1140	6.23	21.07	30.4

* monitoring from Oct. 2005 to May 2006;

** monitoring from July 2006 to September 2006

*** monitoring from October 2006 to December 2006



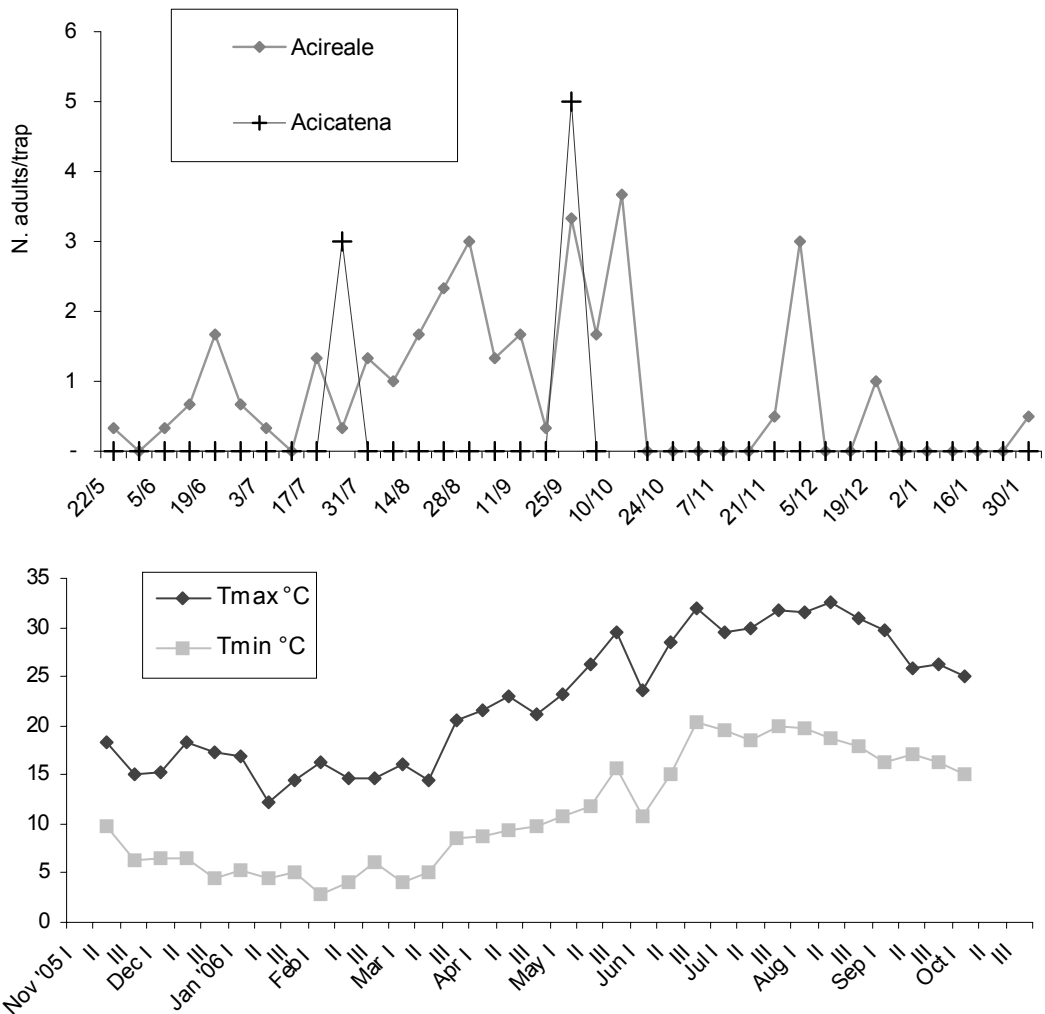
1 (top). Cumulative number of *Rhynchophorus ferrugineus*-infested Canary palms observed during three different surveys (2005–2006), in Eastern Sicily. 2 (bottom). Progressive number of newly infested trees observed from October 2005 to December 2006, at four sites in eastern Sicily.

mainly in the warm period of October–November (Table 1, Fig. 1). The number of infested palms increased dramatically in the summer 2006 (August) at all sites. The high summer temperatures favored the pest activity and its damage. The spread of the insect infestation resumed in July–August 2006 and peaked in September 2006 (Fig.2). Another minor peak occurred in November at the time of the third survey (October–December 2006) (Fig. 2). The highest infestation was again recorded at Acireale site (Table 1). During the infestation peaks young, mature larvae, pupae and adults were observed on the terminal crown of the infested palms. A total of 178 trees sustained RPW damage in the latter survey with a total final incidence of 30.4% of infested palms (Fig.1 and Table 1). Our visual inspections indicate that, generally, some pyrethroid and organophosphate

applications in winter 2005 and spring 2006, had some positive effects and favored sprouting of new vegetation by the infested palms. We suspect that these treatments only suppressed insect populations to levels undetectable by visual inspections. However, in the following autumn the same trees were infested again and died, indicating that the suppression effect of these insecticides is not persistent and repetitive chemical applications are needed to avoid insect population increase.

Monitoring insect populations with pheromones traps

The patterns of weevil captures in pheromone traps were similar at the two composite sites (Acireale and Acicatena) (Fig. 3). Although very few adults/trap were captured during the monitoring program, seven apparent population peaks were recorded at the



3 (top). Captures of *Rhynchophorus ferrugineus* adults in pheromone traps in undisturbed (Acireale) and chemically treated (Acicatena) sites in Eastern Sicily, 2006. 4 (bottom). Maximum and minimum temperatures (°C) in Acireale recorded during this study (data supplied by the Extension Service Office of Acireale).

undisturbed site (Acireale). Only two peaks were observed at the treated site, Acicatena, where several chemical treatments were applied in July–September, slowing down insect development and adult migration. The adults were captured both in the presence and in the absence of evident declining symptoms on the palms in proximity to the traps. However, in some weeks, no captures occurred even in the presence of high infestation symptoms.

Discussion

Since October 2005, when *R. ferrugineus* was first detected in Sicily, the pest rapidly spread over large areas of the island. The fast spread of the insect may be due to the accidental introduction of new RPW sources with infested

or contaminated palms that are used in many sites for landscape purposes. The insect, in the monitoring period (October 2005–December 2006), has infested exclusively *P. canariensis*. The patterns of new infestations and adult captures indicate that, in Eastern Sicily, a strong reduction of adult activity occurs in winter and spring as a consequence of the low temperatures recorded in these two seasons. Then, a long period of time is required by the weevil to increase its populations, which reach damaging levels near the end of summer in September–October. Higher infestation rates were observed in the tallest palms compared to the shorter ones. Pheromone traps were not always effective in monitoring the insect population dynamics. In some cases they failed to detect RPW adults before the damage

occurred to the palms. Adult capture was not always in synchrony with the expression of symptoms by the palms. Only on two occasions, in September and November 2006, were two simultaneous peaks of captures and number of newly infested palms noticed. The numerous peaks of adult captures over the survey period could be assigned to overlapping generations of RPW populations.

Our visual inspections suggest that the application of organophosphates or pyrethroids resulted in an effective control of the pest only when the spray applications were repeated frequently and particularly on trees slightly infested. This kind of management strategy is not sustainable in urban areas as well as private gardens and villas because of the environmental and health risk that these treatments pose.

The implementation of rigorous phytosanitary measures is the most promising approach to manage this pest. Under the environmental conditions of Sicily, extensive surveys and the immediate elimination of the newly infested trees at the first insect detection, after the period of decreased activity of the pest in winter and early spring, can suppress drastically the insect populations and the damage to palms in the summer season. Extensive survey and insect monitoring are crucial for the success of this phytosanitary strategy.

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Seed Predation of *Attalea dubia* (Arecaceae) in an Island in the Atlantic Rainforest of Brazil

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The palm *indaiá* (*Attalea dubia*) is endemic to the Atlantic rainforest of Brazil, and is important as a food source for the local fauna. This paper investigates aspects of seed predation and seed dispersal on a 15,100 ha island in southeastern Brazil.

The post-dispersal seed predation of arboreal tropical species is very high, varying from 75 to 90 percent (Howe et al. 1985, Schupp 1988a, b) and it is even higher close to mother trees (Janzen 1971, 1972). Seed predation depends on seed size, seed nutritional compounds (Osunkoya 1994, Fox & Mousseau 1995, Campbell 2002, Scherer & Romanowski 2005)

and on the combined effects of density and distance from the mother plant (Janzen 1970, Burkey 1994, von Allmen et al. 2004). These are the main factors that determine the recruitment of new individuals (Janzen 1971) and contribute to the maintenance of plant diversity (Janzen 1970, Connell 1971, Augspurger 1983).

Rodents and insects that specialize in seed predation usually forage closer to mother plants (Janzen 1970, 1972, Howe et al. 1985, Traveset 1990, Peres et al. 1997). Rodents often remove and scatter-hoard seeds for later consumption (Forget 1990, Donatti 2004) and, as a result, some seeds can germinate if the rodent forgets the seeds it caches. This behavior makes the rodents important seed dispersers (van der Wall 1992); the scatter-hoarded seeds show a higher survival and germination rate in comparison to seeds left in the soil (Smythe 1989, Forget 1990, Forget & Milleron 1991, Asquith et al. 1999, Silva & Tabarelli 2001).

Forest fragmentation, poaching and palm harvesting are the main factors that negatively affect fruit-eating mammals (Johns 1988, 1991, 1992, Peres 2000). In impoverished (defaunated) areas that completely or partially lose their herbivores, seed dispersers or seed predators, there is a decrease in seed removal (Asquith et al. 1999, Guariguata et al. 2000, Wright et al. 2000, Forget et al. 2001, Galetti et al. 2006), as well as a decrease in seed dispersal and predation by vertebrates (Wright et al. 2000, Bleher & Bohning-Gaese 2001). The consequences of defaunation then, are increases in the seedling density and survival below the parent tree, resulting in decreases of plant diversity in the long term (De Steven & Putz 1984, Dirzo & Miranda 1991, Wright & Duber 2001, Wright 2003, but see Asquith et al. 1997, Roldan & Simonetti 2000 for different results).

The Atlantic rainforest of Brazil is considered a very highly endangered biome and the areas in southeastern Brazil are the most disturbed (Dean 1996). The vertebrate-dispersed plant species (representing 86% of trees in the Atlantic forest, Campassi 2006), such as palms, can suffer in the absence of herbivores, seed predators and dispersers (Donatti 2004, Galetti et al. 2006). According to Galetti et al. (2006), 45% of all palm species dispersed by scatter-hoarding rodents in the Atlantic rainforest may face problems in population recruitment due to defaunation effects, i.e. the loss of seed dispersers. The population crash of palms may have strong cascading effects on the whole community (Peres 2000).

Palms are important because they present a low fruiting synchrony, unlike other vertebrate-dispersed plants (Terborgh 1986, Peres 1994, Galetti 1996), and also because of the high energy value of their fruits (Zona &

Henderson 1989). Bruchid beetles depend on palm seeds because they thrive on the nourishment of the seeds during a large part of their life cycle (Johnson & Romero 2004). These beetles may use 60 to 90 percent of all fruits found beneath the mother plant, mainly in the beginning of the fruiting season (Forget et al. 1994, von Allmen et al. 2004).

We investigated the seed dispersal and predation of the Atlantic forest endemic palm, the indaiá *Attalea dubia*: (1) the importance of seed predators; (2) the selection of bruchid beetles *Pachymerus* sp. and rodents on the pyrene size; (3) the proportion of seed predation by beetles in the pyrenes with one or two seeds; (4) the variables that affect seed predation and (5) the seed dispersal of scatter-hoarding rodents. The pyrenes are structures that comprise the endocarp and the seeds in palm fruits.

Materials and Methods

Study site. The study was carried out at Ilha do Cardoso (25°03'S; 47°53'W), Cananéia, São Paulo, Brazil. Observations on seed predation were made in May 2003 and on seed removal in September 2003. The climate is subtropical and the annual rainfall can exceed 3,000 mm. The area is 15,100 ha and has many forest formations, from beaches to highland forests (Noffs & Baptista-Noffs 1982). The diversity of mammals and birds in the Ilha do Cardoso is high, including important seed dispersers of palm trees, e.g. *Attalea dubia*, such as squirrels (*Sciurus ingrami*) and agoutis (*Dasyprocta leporina*) (Bernardo & Galetti 2004). However, the island suffered intense poaching that resulted in the extinction of the jaguar (*Panthera onca*) and the tapir (*Tapirus terrestris*) in the past and nowadays is threatened by Mbya Indians (Olmos et al. 2004).

Study species. The indaiá palm *Attalea dubia* occurs in secondary forests and in open and disturbed areas (Henderson et al. 1995). The individuals have one stem from 15 to 25 meters high and a diameter of 20 to 30 cm. The fruits are fleshy, with a fibrous mesocarp and a hard endocarp, and generally contain only one seed (Reitz 1974). The pyrenes are 23.0 ± 2.5 mm in diameter and 38.4 ± 3.5 mm in length ($n=307$). Lorenzi (1996) indicated that this species can bear fruits all year round, yet predominately during spring and summer.

Seed predation. We evaluated the importance of the seed predation by bruchid beetles and rodents by collecting all the pyrenes found

within a 3 m radius from the mother palm beneath nine *Attalea dubia* palms. The pyrenes were visually classified as: **intact**, when there were no signs of seed predation; **preyed on by beetles**, when entry or exit holes of larva or adults were present (the entrance hole is much smaller than the exit hole, but can still be easily identified), **preyed on by rodents** when we found teeth marks in the endocarp (Cintra 1997, Wright et al. 2000, Wright & Duber 2001); and **germinated**, when the root in the germinative hole was present. To verify the effect of the density of pyrenes beneath the mother palm on the proportion of seed predation, we used a Spearman correlation test.

All pyrenes collected were opened for an examination of the seed condition and were classified in the same four categories: intact, for no sign of predation; preyed on by beetles, when the pyrenes presented a larva or an adult inside them; preyed on by rodents; and germinated, when no seeds were found inside the pyrenes and these did not present entry or exit holes. The difference between the apparent evaluation of the pyrenes (visual) and their real state (when we opened them) was analyzed using a Chi-square test.

In order to test if the predators selected the pyrenes for size, we measured the diameter and the length of all pyrenes that we collected. We compared the measurements between predated pyrenes by rodents and beetles using an ANOVA (one factor) and Multiple Comparisons (Tukey).

The following variables were examined around the mother palm from which we collected the pyrenes, because they could have some effects in the proportion of seed predation. We then used a Multiple Regression Analysis (Stepwise) to relate these variables with the proportion of seeds preyed on by rodents and beetles:

Number of adult palms of *A. dubia* within a 10 m radius of the mother plant;

Distance from the closest adult of *A. dubia* (maximum distance: 20 m);

Average canopy cover (percent) at four points (N, S, E, W), 3 m distance of the mother palm;

Average leaf litter depth at four points (N, S, E, W), 3 m distance of the mother palm;

Number of fallen trunks with a breast high diameter of more than 5 cm., within a 5 m radius of the mother plant;

Number of juveniles of *A. dubia* with a breast high diameter of more than 10 cm., within a 10 m radius of the mother palm;

Distance from the closest treefall gap (maximum distance: 20 m.).

Seed removal and fate experiment.

Fruits of *A. dubia* were collected from ten individuals, the pulp was removed manually and the seeds were inspected for insect infestations. Only the uninfested seeds were exposed to the animals. Pulp consumers are not likely to remove seeds without pulp; therefore, only the interactions between the rodents and the seeds were investigated to measure the seed removal, dispersal and predation of *A. dubia*. All seeds received an individual code for identification.

We observed the fate of the seeds through this system of marking: by attaching threads to the seeds we observed their fate by using a modified version of the spool and line method (Donatti 2004). Each seed was threaded with a line spool that was placed inside a small box, allowing the line to unroll easily when the seed was removed. Ten of these boxes (each one with one seed attached) were fixed in one palm stem that represented one experimental station. Each experimental station was located beneath a randomly selected fruiting palm. We worked with 10 experimental stations. Palms closer than 50 m of other selected palms or within 10 m of other conspecific adults were not selected for the experiment. Due to the fast removal of seeds during the pilot study using other species of palm trees (Donatti 2004), we searched the area and followed the threads to locate the seeds after seven days. The seeds were placed on the forest floor, just after the period of fruit fall (December 2002 to February 2003).

Each spool line was 35 m long; this length was based on previous work, which showed this distance to be the maximum that rodents usually disperse seeds (Forget 1990, Peres et al. 1997, Forget et al. 2000, Pimentel & Tabarelli 2004, but see Hallwachs 1986). Intact seeds were defined to be seeds not removed from the experimental stations. Removed seeds were categorized as either dispersed or preyed upon. Dispersed seeds were separated into two subgroups: seeds dispersed in the litter (seeds removed but left in the litter) or scatterhoarded seeds (buried or found beneath the leaf litter). Seeds totally or partially destroyed were considered preyed upon by rodents.

Results

Seed predation. We collected 900 pyrenes beneath nine individuals of *A. dubia*, with the follow apparent (visual) predation: 41.9% were intact, 48.9% showed signs of predation by beetles, and 3.2% were empty and did not present any sign of predation. Rodents preyed on only 5.9% of the pyrenes. However, these animals may carry seeds far from the mother plant (Forget 1990, Forget & Milleron 1991), suggesting that this data might be an underestimate.

We found a positive correlation between the number of pyrenes collected and the number of pyrenes preyed upon ($r_s=0.883$; $p=0.002$), which means that we found more seed predation in palms that presented a high availability of seeds. We also compared the apparent (visual) evaluation of pyrenes with the true evaluation (actual state when we opened the pyrenes): in a random sample of 247 pyrenes out of the 900 collected, we found that 18.6% were classified in a different state when opened. We found a difference between the apparent evaluation and the real evaluation of the pyrenes that we analyzed ($\chi^2=30.205$; $p=0.000$).

Seed predators selected the size of pyrenes: The vertebrates preyed on pyrenes with the largest diameter ($F=6.128$; $p=0.002$) while beetles prefer the ones with the largest length ($F=13.25$; $p=0.000$). In relation to the number of seeds inside the pyrenes, 96% of the pyrenes that we opened had one seed and 4% had two seeds. In relation to pyrenes with two seeds, 33.3% of them had one seed preyed upon by beetles, while the other remained intact; 50.1% had both seeds intact and 16.6% had both preyed upon.

We found a negative relationship between the distance from the closest adult of *A. dubia* and the proportion of seed predation by beetles beneath the mother palm ($F=7.17$; $p=-0.032$); i.e., the predation by beetles is higher within a shorter distance between palms. We did not find any relationship between the variables that we measured and the seed predation by vertebrates.

Seed removal and fate experiment. There was no seed removal after seven days, suggesting that seed removal by rodents in the study site had little role in aspects of seed dispersal and predation, at least in the period observed. A similar experiment with *Astrocaryum aculeatissimum* using the same period of seed

exposure had 36% of removal (Donatti 2004, Galetti et al. 2006).

Discussion

We found that beetles are the most important seed predators of *Attalea dubia* at Ilha do Cardoso. This may be because beetles are more specialized (Janzen 1980), while rodents can feed on a variety of different food resources (Paschoal & Galetti 1995, Silvius & Fragoso 2003). Nevertheless, squirrels (*Sciurus ingrami*) that are considered the main seed predator and disperser of the palm *Attalea dubia* (Voltolini 2004), are uncommon on Cardoso Island (Bernardo & Galetti 2004). Understanding the impact of vertebrates and invertebrates on seed predation is important because vertebrates can adversely impact the populations of invertebrates close to the mother plant (Herrera 1989, Traveset 1992). Our data indicate that the low rate of predation and absence of seed removal by rodents or other large seed dispersers (such as tapirs) can contribute to the high rates of seed predation by beetles beneath the mother plants.

Janzen (1970) suggested that the seed mortality increases with the proximity of a reproductive adult, and this relation was also clear in several other studies (Wilson & Janzen 1972, Wright 1983, Schupp 1988b). Our data indicate that predation by beetles is higher in areas with more availability of seeds and also in palms that have close conspecific adults.

In five apparently intact pyrenes, we found either larva or adult beetles. It is possible that the fibers covering the pyrene hide the holes made by this invertebrate because there is a high growth of fibers in pyrenes that suffered damage (C.E. Steffler, personal observation). Some pyrenes proved to be intact regardless of the obvious small holes in their endocarps. These data echo the consideration brought up by Pires (2006) that it is important to open the pyrenes for a clear understanding of their real state, but few studies have done this (Wright et al. 2000).

Besides the selection in the pyrene size by beetles (Fox & Mousseau 1995, Campbell 2002, Scherer & Romanowski 2005), Westoby et al. (1992) showed that rodents prefer the largest seeds. In the case of scatter-hoarding rodents, they can be limited by the weight of the pyrenes. Our data show that the pyrenes selected by beetles have the largest diameter while the ones selected by rodents have the largest length, indicating that this preference

may occur because rodents can better handle pyrenes with this shape.

Even though most of the pyrenes of *Attalea dubia* have only one seed (Reitz 1974, Voltolini 2004, this study), pyrenes with two seeds have the highest chance of escaping predation (Bradford & Smith 1977) because they are only partially attacked. Our data agree with these findings because 33.3% of the pyrenes with two seeds were just partially predated, meaning that fruits with more than one seed do not always have all seeds attacked by beetles. The presence of two or more seeds per fruit can be a strategy for escape of predation (Bradford & Smith 1977, Scherer & Romanowski 2005). Therefore, the combined effects of the behavior of rodents and the high seed predation by beetles can be a consequence of pyrene size in this species.

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ZONA, S. AND A. HENDERSON. 1989. A review of animal-mediated seed dispersal of palms. *Selbyana* 11: 6–21.

About the Covers

The stunning images on the covers and table of contents page come to us from IPS member Angela Blakely of Hawaii. Angela wrote, “Growing up in inland Southern California and seeing the same old landscape palms – *Phoenix canariensis*, *Syagrus romanzoffiana*, *Washingtonia robusta* – over and over again, I never paid much attention to the colors of palms. For me they were always green. When I later learned that *C. macrocarpa* has a red emergent leaf, my first response was disbelief! My second was, ‘Where can I get my hands on one?’ The red new leaf of *C. macrocarpa* was a revelation. From the moment I laid eyes on that red leaf I was transformed into an enthusiast.” She went on, “As an artist, I am drawn to the intense colors of tropical foliage... Many of the palms with red emergent leaves are so eye-catching that they have really inspired me to share their beauty through my photography.” Angela now lives in Hawaii, on the Big Island, where, as she said, “a whole new colorful world of palm options is open to me.”

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Actinokentia divaricata (Table of Contents, p. 107) is another of Angela’s favorites, along with the “Mad Fox,” *Dypsis marojejyi*. Of the latter, she wrote, “Its changing beauty reminds me of

a sunset. As the new frond just barely starts to open, some parts catch the light and almost glow a brilliant orange, especially on overcast days. At first, the leaf shifts from orange-red to red. After the leaf opens fully, it changes to a burgundy color. As it matures, it becomes increasingly purple. Eventually the sunset ends, and it finally fades to green.” Angela has posted a number of her beautiful images of red new leaves on PalmTalk, but we cannot resist one last image (below), that of the new leaf of *Calyptrocalyx lauterbachianus* with contrasting bright green stripes on the leaflets.

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– THE EDITORS



New Species of *Licuala* (Palmae) from Vietnam

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Eleven new species of *Licuala* from Vietnam are described and their relationships discussed.

Licuala contains about 137 species (Govaerts & Dransfield 2005), occurring from Bhutan and northeastern India throughout southern and southeastern Asia and into the western Pacific (Vanuatu). The two main centers of diversity are the Sunda Shelf in Peninsular Malaysia and Borneo with about 80 species, and the Sahul Shelf on the island of New Guinea with about 40 species (Saw et al. 2003).

The most recent taxonomic treatment of the Indochinese species is that of Gagnepain and Conrard (1937), based on previous works by Beccari (1910, 1933) and Magalon (1930). Gagnepain and Conrard recognized ten species from Vietnam, and subsequently two more were described by Burret (1940, 1941) and one by Barfod and Borchsenius (2000). Of these, we currently recognize ten species for Vietnam – *L. bracteata* Gagnep., *L. calciphila* Becc. (with

its synonyms *L. fatua* Becc., *L. tonkinensis* Becc. and *L. tomentosa* Burret), *L. dasyantha* Burret, *L. glaberrima* Gagnep., *L. hexasepala* Gagnep., *L. paludosa* Griff., *L. radula* Gagnep., *L. robinsoniana* Becc., *L. spinosa* Thunb. and *L. taynguyensis* Barfod & Borchs.

Recent field work in Vietnam, and study of herbarium material at A, AAU, FI, HN, HNU, K, LE, MO, NY, P, SYS and VNM (herbarium acronyms from Holmgren et al. 1990; VNM is the acronym of the Institute for Tropical Biology in Ho Chi Minh City), has shown that the genus is more diverse in Vietnam than previously suspected. We estimate that at least 30 species occur there, including previously described species. Unfortunately, several undescribed species are represented by fragmentary specimens, and their description awaits further field work, particularly in the

plateau regions of south-central Vietnam (Kon Tum, Play Ku, Dac Lac, Da Lat plateaus). In this paper, 11 new species are described, those for which there are adequate, recently-collected specimens. We follow the terminology of Saw et al. (2003) in describing these new species.

Notable among Vietnamese *Licuala* is the large number of dioecious and dimorphic species, a condition previously considered rare in the genus (Saw et al. 2003, Henderson et. al. 2007). Of the estimated 30 species of *Licuala* in Vietnam, approximately one-third are thought be dioecious and dimorphic, including the previously described *L. calciphila*, *L. dasyantha* and *L. hexasepala*, as well as four species described here (*L. acaulis*, *L. centralis*, *L. magalonii* and *L. manglaensis*). These dioecious

species are characterized by a central segment that is usually split to the apex of the costa, the costa with an abaxial "gland," reduced, dimorphic inflorescences with only one or a few partial inflorescences, scarcely developed floral stalks, small flowers, clustered staminate flowers and solitary pistillate flowers, staminate flowers with gibbous sepals and non-versatile anthers, pistillate calyces splitting at or after anthesis into 6 lobes, very short styles and globose fruits with reflexed perianths.

Licuala acaulis Henderson, N. K. Ban & N. Q. Dung **sp. nov.**, a speciebus ceteris generis *Licualae* habitu dioecio, segmentis viridibus 26–32 et perianthio pistillato glabro differt. Typus: Vietnam. Da Nang City: Hoa Vang District, Ba Na-Nui Chua Nature Reserve, road

1. *Licuala atroviridis*, showing inflorescence and flowers with pedicelliform calyces.



to summit, 16°00'N, 108°01'E, ca. 500 m, 19 Apr 2007, A. Henderson, Nguyen Quoc Dung, Nguyen Canh & Le Van Bo 3302 (Holotypus: HN! Isotypi: K! NY!).

Stems solitary, to 0.4 m tall, diameter not known, often short and subterranean. Leaf number and leaf sheaths not known; petiole length not known, the entire length with widely spaced, recurved, brown thorns to 0.5 cm long; blades to 108 cm wide, split into 26–32 segments, these with straight sides; costa terminating at base of split of the middle segment, with a “gland” abaxially; middle segment only slightly wider than the others, split almost to the base of the blade (to costa apex) into 2 lobes, these ca. 50 cm long, ca. 5 cm wide at the apex; segments scarcely indented at the apices. Plants dioecious. Inflorescences to 50 cm long, recurved below the leaves after anthesis; prophylls 25 cm long; peduncles 30 cm long; rachis 6–25 cm long with 1 partial inflorescence, this branched to 2 orders, subtended by a swollen, densely brown tomentose bract splitting laterally; staminate rachillae ca. 21 on each partial inflorescence, 20–30 cm long, 1.5–2.5 mm diam., densely covered with brown, felty tomentum, floral stalks scarcely developed; pistillate rachillae 9–16, 8–13 cm long, 2.5–3 mm diam., tomentum and floral stalks similar to those of the staminate rachillae; staminate flowers 6 mm long; calyx 2.5 mm long, tubular, gibbous, 3-lobed at the apex, glabrous; corolla 4.5 mm long, split for two-thirds its length into 3 valvate petals, glabrous; stamens 6; staminal ring scarcely developed; filaments free for 1.6 mm; anthers 0.5 mm long, oblong, dorsifixed, non-versatile; pistillate flowers solitary, spirally arranged; buds 8–10 mm long, ellipsoid; calyx 4–4.5 mm long, cupular, briefly 6-lobed at the apex at anthesis, glabrous; corolla 6–8 mm long, split for about two-thirds its length into 3 valvate petals, glabrous; staminal ring scarcely developed, with vestigial filaments, anthers absent; pistil 3–3.5 mm long including a 1 mm long style, glabrous. Fruits not known.

Local names and uses: *la non*. No uses recorded.

Distribution and habitat: Endemic to central Vietnam near Da Nang City, on steep slopes in primary, evergreen, broad-leaved, wet forest at 500 m elevation.

Notes: The specimens cited here will not key in either Gagnepain and Conrard (1937) or Magalon (1930), and this species was

apparently unknown to these authors. Among the dioecious Vietnamese species, *Licuala acaulis* is similar to *L. dasyantha* in inflorescence and floral morphology. Both species have inflorescences which curve down after anthesis, thick, fleshy rachillae 1.5–5 mm diam., and pistillate calyces briefly 6-lobed at the apices at anthesis. However, the leaves of the two are quite different, with those of *L. acaulis* having 26–32 green segments with the middle segment only slightly wider than the others, and *L. dasyantha* having 5–10 mottled light and dark green segments with the middle segment much wider than the others. The pistillate perianth of *L. acaulis* is glabrous and that of *L. dasyantha* is densely covered with felty, brown hairs.

Additional specimens examined. VIETNAM.

DA NANG CITY: Hoa Vang District, Ba Na-Nui Chua Nature Reserve, road to summit, 16°00'N, 108°01'E, ca. 500 m, 20 Apr 2007, Henderson et al. 3309 (HN, NY).

Licuala atroviridis Henderson, N. K. Ban & N. Q. Dung, **sp. nov.**, a speciebus ceteris generis *Licualae* habitu monoecio, inflorescentiis partialibus rachillis glabris praeditis, floribus glabris, calycibus pedicelliformibus, differt. Typus. Vietnam. Da Nang City: Hoa Vang District, Ba Na-Nui Chua Nature Reserve, road to summit, 16°00'N, 108°01'E, ca. 500 m, 19 Apr 2007, A. Henderson, Nguyen Quoc Dung, Nguyen Canh, & Le Van Bo 3303 (Holotypus: HN! Isotypi: K! NY!). (Fig. 1.)

Stems solitary, to 0.3 m tall, 14 cm diam., covered with persistent leaf bases, often short and subterranean. Leaves 23; leaf sheaths not known, extended above the petioles into 20 cm long ocreas; petioles 135 cm long, 0.5 cm wide near the apices, the proximal ca. half with widely spaced, recurved thorns to 0.5 cm long; blades 82–115 cm wide, split into 22–28 segments, these with straight sides; middle segment not wider than the others, not split, petiolulate, 46–55 cm long, 4.5–5.5 cm wide at the apex; indentations leading to adaxial folds 0.8 cm deep, those leading to abaxial folds 0.5 cm deep, indentations deeper on lateral segments. Plants monoecious. Inflorescences 71–100 cm long, erect among the leaves; prophylls 33–38 cm long; peduncles 40–62 cm long; rachis 6–11 cm long, with 1 or 2 partial inflorescences, these branched to 1 order, subtended by a tubular, glabrous bract; rachillae 7–9 on each partial inflorescence, 12–16 cm long, 2 mm diam., glabrous, the



2. *Licuala bachmaensis*, leaf showing deep indentations and middle few segments remaining joined at their apices.

floral stalks giving them a bumpy appearance; flowers solitary or paired, when paired the pedicelliform base longer in one flower of a pair; flower buds 6–9 mm long, club-shaped; calyx 5–7.5 mm long including a 2–4 mm long pedicelliform base, tubular, briefly 3-lobed at the apex, glabrous; corolla 3–4 mm long, split for two-thirds its length into 3 petals, the apices remaining together but the margins opening to give lateral slits, glabrous; stamens 6; staminal ring 0.5 mm long; filaments free for 0.5 mm; anthers oblong, dorsifixed, versatile; pistil 1.5–2 mm long including a 0.5 mm long style, glabrous. Fruits not known.

Local names and uses: *la non*. No uses recorded.

Distribution and habitat: Endemic to central Vietnam near Da Nang City, on steep slopes in primary, evergreen, broad-leaved, wet forest at 350 m elevation.

Notes: The specimens cited here will not key in either Gagnepain and Conrard (1937) or Magalon (1930), and this species was apparently unknown to these authors. It differs from all other monoecious Vietnamese *Licuala*, except *L. glaberrima*, in its inflorescences with glabrous rachillae and glabrous flowers with

pedicelliform calyces. *Licuala atroviridis* differs from *L. glaberrima* in its 1 or 2 (versus ca. 5) partial inflorescences, and longer pedicelliform calyces (2–4 mm versus 1 mm).

Additional specimens examined. VIETNAM.

DA NANG CITY: Hoa Vang District, Ba Na-Nui Chua Nature Reserve, road to summit, 16°00'N, 108°02'E, ca. 350 m, 19 Apr 2007, *Henderson et al.* 3300 (HN, NY), *Henderson et al.* 3310 (HN, NY), 4 Jul 2002, *V. X. Phuong* 4847 (HN).

Licuala averyanovii Henderson, N. K. Ban & N. Q. Dung, **sp. nov.**, a *L. spinosa* rachillis brevioribus atque floribus solitariis differt. Typus. Vietnam. Kon Tum: Sa Thay Dist., Sa Son commune, Chu Mon Ray Nature Reserve, 14°25'N, 107°44'E, 600–700 m, 28 Apr 2000, *L. Averyanov et al.* VH 5799 (Holotypus: HN! Isotypus: MO!).

Stems to 2 m tall, branching and diameter not known. Leaf number not known; leaf sheaths not known; petioles to 300 cm long, 1.5 cm wide near the bases, 0.6–0.7 cm wide near the apices, almost the entire length with widely spaced, recurved, yellowish-brown thorns 0.5–0.7 cm long; blades to 120 cm wide, split into 22–26 segments, these with straight sides; middle segment only slightly wider than the others, not split, 50–63 cm long, 3.5–4.5 cm wide at the apex; indentations leading to adaxial folds 0.5 cm deep, those leading to abaxial folds 0.2 cm deep, indentations deeper on lateral segments. Plants monoecious. Inflorescences not known in their entirety, erect among the leaves; prophylls and peduncles not known; rachis not known in its entirety, with at least 6 partial inflorescences, these branched to 1 order, subtended by tubular, inflated bracts briefly split at the apices; rachillae 2–5 on each partial inflorescence, 3.5–11 cm long, 2–2.5 mm diam., densely covered with short, golden-brown hairs, with prominent floral stalks giving the rachillae a bumpy appearance; flowers solitary, spirally or irregularly arranged; flower buds 4.8–5 mm long (post-anthesis), bullet shaped; calyx 2.5–3 mm long, tubular, briefly 3-lobed at the apex, densely to moderately covered with golden brown, appressed hairs; corolla 3 mm long, split for almost half its length into 3 valvate petals, these remaining erect, densely hairy as the calyx; stamens 6; staminal ring 1–2 mm long, fused to corolla; filaments free for 0.5 mm; anthers 0.8 mm long, oblong, dorsifixed, versatile; pistil 3 mm long including a 1 mm

long style, glabrous. Fruits 0.9–1 cm long, 0.6–0.7 cm diam., ellipsoid, with perianth appressed to base of the fruit, color not known.

Local names and uses: None recorded.

Distribution and habitat: Endemic to south-central Vietnam in Kon Tum, in primary, wet, broadleaf, closed, evergreen, mountain forest on granite at 700–900 m elevation.

Notes: The specimens cited here will key in Gagnepain and Conrard (1937) and Magalon (1930) to *Licuala spinosa*. *Licuala averyanovii* is similar to *L. spinosa* but differs in its shorter rachillae (3.5–11 cm long versus 20–40 cm long), and solitary rather than clustered flowers. It also occurs in a different habitat. *Licuala averyanovii* occurs in primary, wet, broadleaf, closed, evergreen, mountain forest on granite at 700–900 m elevation whereas *Licuala spinosa* occurs in open, wet places, often associated with mangroves or in disturbed habitats, at low elevations.

Additional specimens examined. VIETNAM.

KON TUM: Sa Son, Chu Mon Ray Nature Reserve, 14°25'N, 107°44'E, 28 Feb 2000, *Harder et al.* 4560 (MO); Dak Gle, Dak Mon, 27 Mar 1978, *Bien* 563 (HN); Dak Gle, 23 Mar 1978, *N. H. Hien* 266 (HN).

Licuala bachmaensis Henderson, N. K. Ban & N. Q. Dung, **sp. nov.**, a speciebus ceteris generis *Licualae* incisuris profundis ad plicaturas adaxiales ducentibus, segmentis mediis paucis ad apices vestri adhuc coalitis, ovulis pilosis differt. Typus. Vietnam. Thua Thien-Hue: Phu Loc Distr., just outside Bach Ma National Park, 16°15'N, 107°52'E, ca. 50 m, 12 Apr 2007, *A. Henderson, Nguyen Quoc Dung, Nguyen Canh, & Le Van Bo* 3254 (Holotypus: HN! Isotypi: K! NY!). (Fig. 2.)

Stems solitary, to 1.5 m tall, 15 cm diam., covered with persistent leaf bases, often short and subterranean. Leaves 20; leaf sheaths not known; petioles 160–177 cm long, 0.6 cm wide near the apices, almost the entire length with widely spaced, straight, dark brown thorns to 0.5 cm long; blades 122–127 cm wide, split into 12–18 segments, these with straight sides; middle segment not split, petiolulate, not wider than the others, 63–64 cm long, 12–13 cm wide at the apex, the middle few segments remaining joined at their apices; indentations leading to adaxial folds 14–20 cm deep, those leading to abaxial folds 0.5 cm deep, indentations not deeper on lateral segments. Plants monoecious. Inflorescences to 340 cm

long, erect above the leaves; prophylls 17 cm long; peduncles and rachis not known in their entirety, with to 11 partial inflorescences, these branched to 1 order, each subtended by a tubular, glabrous bract briefly split at the apex; rachillae 5–11 on each partial inflorescence, 13–33 cm long, 0.8 mm diam., densely covered with golden-brown hairs, with floral stalks giving the rachillae a bumpy appearance; flowers solitary or in groups of 2 or 3; flower buds 2 mm long, depressed-globose; calyx 2 mm long, briefly 3-lobed at the apex, densely covered with brown hairs; corolla 1.5–1.8 mm long, split for one-half to one-third its length into 3, triangular petals, densely covered with appressed, silvery-brown hairs; stamens 6; staminal ring 0.5 mm long; filaments free for 0.1 mm; anthers 0.4 mm long, oblong, dorsifixed, versatile; pistil 1 mm long including a 0.5 mm long style, the ovules sparsely hairy near the apices. Fruits 1 cm long, 0.5 cm diam., ellipsoid, with perianth appressed to base of the fruit, red at maturity.

Local names and uses: *la non*. The leaves are used to make rain coats.

Distribution and habitat: Endemic to central Vietnam in Quang Nam and Thua Thien-Hue, on slopes of mountains in broad-leaved, evergreen, primary closed forest on sandstone, shale, or granite rock, to 1150 m elevation, persisting in disturbed areas and grown in villages.

Notes: It is not clear that either Magalon (1930) or Gagnepain and Conrard (1937) were aware of this distinctive species, and it will not key in either work. It is distinguished from all other Vietnamese monoecious *Licuala* by its unique combination of leaves with deep (14–20 cm long) indentations leading to the adaxial folds, middle few segments remaining joined at their apices, and hairy ovules.

Additional specimens examined. VIETNAM. QUANG NAM: Cu Lao Cham, 28 Mar 1987, *Anon* 403 (HN, LE). THUA THIEN-HUE: Phu Loc Distr., just outside Bach Ma National Park, 16°15'N, 107°52'E, ca. 50 m, 21 July 2007, *Henderson & N. K. Ban* 3449 (HN, NY); Route number 1, Hai Van Pass, 16°13'N, 108°05'E, ca. 100 m, 21 Jul 2007, *Henderson & N. K. Ban* 3450 (HN, NY); Phu Loc Distr., Bach Ma National Park, S slope of Bach Ma mountain below Hai Vong Dai Peak, Khe Su, 16°11'N, 107°51'E, ca. 1150 m, 20 Apr 2003, *V. V. Dung* HLF 1185 (HN).

Licuala bidoupensis Henderson, N. K. Ban & N. Q. Dung, *sp. nov.*, a *L. spinosa* floribus



3. *Licuala cattiensis*, showing partial infructescence with 1 rachilla and fruits with the perianth appressed to base.

spinosis corollis glabris praeditis differt. Typus. Vietnam. Lam Dong: Lac Duong District, Bi Dup-Nui Ba National Park, road from Da Lat to Dac Lac, montane forest, 12°11'N, 108°22'E, 1200 m, 1 Jun 2007, *A. Henderson, Bui Van Thanh, Ton Thien An, & Duong Thanh Tuyet* 3419 (Holotypus: HN! Isotypi: K! NY!).

Stems clustered, with basal shoots and two main stems, to 2.5 m tall, 3.3–4.5 cm diam., rough with persistent leaf bases. Leaves 10–21; leaf sheaths 8–17 cm long, extended above the petioles into 30–43 cm long ocreas; petioles 98–127 cm long, 0.7 wide near the bases, 0.5 cm wide near the apices, the proximal ca. half with widely-spaced, recurved thorns to 0.3 cm long; blades 77–87 cm wide, split into 21–25 segments, these with straight sides; middle segment not wider than the others, not split, briefly petiolulate, 37–47 cm long, 3.8–4 cm wide at the apex; indentations leading to adaxial folds 0.5 cm deep, those leading to abaxial folds 0.2 cm deep, indentations deeper on lateral segments. Plants monoecious. Inflorescences 150–176 cm long, erect above

the leaves; prophylls and peduncles not known; rachis ca. 100 cm long, with 7–8 partial inflorescences, these branched to 1 order, subtended by tubular, glabrous bracts briefly split at the apices; rachillae 7–14 on each partial inflorescence, 12–14 cm long, 1.2–1.5

mm diam., sparsely covered with brown hairs, with floral stalks giving the rachillae a bumpy appearance; flowers solitary; buds 3.5–4 mm long, ellipsoid; calyx 2 mm long, briefly 3-lobed at the apex, sparsely covered with brown hairs; corolla 3 mm long, split for ca. half its

4. *Licuala centralis*, showing habit and leaves split into numerous, more or less equal segments.



length into 3 valvate petals, glabrous; stamens 6; staminal ring 1 mm long; filaments free for 0.2 mm; anthers 0.6 mm long, oblong, dorsifixed, versatile; pistil 2 mm long including a 1 mm long style, glabrous. Fruits ca. 1 cm long, ellipsoid, with perianth appressed to base of the fruit, red at maturity.

Local names and uses: None recorded.

Distribution and habitat: Known only from Lam Dong in Bi Dup-Nui Ba National Park in montane forest on steep slopes, at 1200 m elevation.

Notes: The specimens cited here will key in Gagnepain and Conrard (1937) and Magalon (1930) to *Licuala spinosa*. *Licuala bidoupensis* differs from this and other monoecious Vietnamese *Licuala* by its hairy, non-zigzag rachillae, branched partial inflorescences, and solitary flowers with glabrous corollas.

Additional specimens examined. VIETNAM. LAM DONG: Lac Duong District, Bi Dup-Nui Ba National Park, road from Da Lat to Dac Lac, montane forest, 12°11'N, 108°22'E, 1200 m, 1 Jun 2007, *Henderson et al.* 3420 (HN, NY).

Licuala cattienensis Henderson, N. K. Ban & N. Q. Dung, **sp. nov.**, a *L. radula* segmentis lateralibus strictis praeditis, rachillis non flexuosis, pilis sparsis, brevissimis glandulosis tectis differt. Typus. Vietnam. Dong Nai: Cat Tien National Park, road along Dong Nai river, 11°26'N, 107°26'E, 150 m, 28 May 2007, *A. Henderson, Bui Van Thanh, Vu Van Duy, Nguyen Ngoc Quynh, & Phan Van Phuc* 3407 (Holotypus: HN! Isotypus: NY!). (Fig. 3)

Stems solitary or with basal shoots, to 2 m tall, 4 cm diam. Leaves 18; leaf sheaths not known in their entirety, extended above the petioles into 20 cm long ocreas; petioles 136 cm long, 0.4 cm wide at the apices, with widely-spaced, recurved, thorns; blades 80 cm wide, split into 12 segments, these with straight sides; middle segment not wider than the others, not split, not petiolulate, 46.5 cm long, 6.5 cm wide at the apex; indentations leading to adaxial folds 0.5 cm deep, those leading to abaxial folds 0.3 cm deep, indentations deeper on lateral segments. Plants monoecious. Inflorescences 120 cm long, erect among the leaves; prophylls and peduncles not known; rachis 50 cm long, with 2–4 partial spicate inflorescences, subtended by tubular bracts; rachillae 1 on each partial inflorescence, 16–22 cm long, 1.5–2 mm diam., covered with scattered, very short, glandular hairs, with prominent floral

stalks giving the rachillae a bumpy appearance; flowers not known, borne in pairs. Fruits 0.8 cm long, 0.6 cm diam., globose to ellipsoid, with the perianth appressed to base of the fruit, ripening from green to yellow to bright red.

Local names and uses: *la toi*. No uses recorded.

Distribution and habitat: Endemic to southern Vietnam in Dong Nai, in lowland rainforest in flat areas near rivers at low elevations.

Notes: In Gagnepain and Conrard (1937) the specimen cited here keys to *Licuala radula* (it will not key in Magalon (1930) and *Licuala radula* was not known to him). *Licuala cattienensis* differs from *L. radula* in its segments which have straight sides (versus curved) and rachillae which are not zigzag and are covered with scattered, very short, glandular hairs (versus zigzag and densely covered with golden brown hairs). It also differs in habitat. *Licuala cattienensis* occurs in lowland forest at low elevations in flat areas near rivers in Dong Nai; *L. radula* occurs on steep slopes in montane forest more than 500 km to the north, in Thua Thien-Hue.

Licuala centralis Henderson, N. K. Ban & N. Q. Dung, **sp. nov.**, a speciebus ceteris generis Licualae habitu dioecio, segmentis folii 13–26, segmento centrali vix quam aliis latiore differt. Typus. Vietnam. Da Nang City, Hoa Vang District, Ba Na-Nui Chua Nature Reserve, road to summit, 16°00'N, 108°02'E, ca. 350 m, 19 Apr 2007, *A. Henderson, Nguyen Quoc Dung, Nguyen Canh, & Le Van Bo* 3299 (Holotypus: HN! Isotypi: K! NY!). (Fig. 4.)

Stems clustered, to 5 m tall, 2–4 cm diam.. Leaves 9–13; leaf sheaths 14–19 cm long, extended above the petioles into 12 cm long ocreas; petioles 82–127 cm long, 0.6–0.7 cm wide near the bases, 0.4–0.5 cm wide near the apices, the proximal ca. quarter with widely spaced, recurved, black or brown thorns to 0.5 cm long; blades 63–99 cm wide, split into 13–26 segments, these with straight sides; costa terminating at base of split of the middle segment, with a 'gland' abaxially; middle segment only slightly wider than the others, split almost to the base of the blade (to apex of costa) into 2 lobes, these 40–45 cm long, 4.5–8 cm wide at the apices; indentations leading to adaxial folds to 0.5 cm deep, those leading to abaxial folds 0.2 cm deep, indentations deeper on lateral segments. Plants dioecious. Inflorescences to 65 cm long, erect

among the leaves; prophylls 15 cm long; peduncles 35 cm long; rachis 17 cm long, with 2–4 partial inflorescences, these branched to 2 orders, subtended by flat, densely brown tomentose bracts not splitting except apically; staminate rachillae 5–14 on each partial inflorescence, 9–17 cm long, 1 mm diam., moderately covered with brown, felty hairs, scarcely bumpy, spine-like at the apices; pistillate rachillae similar, to 2 mm diam.; staminate flowers solitary or in pairs; buds 2.7–3 mm long, bullet-shaped; calyx 1.5–2.5 mm long, glabrous (or with scurfy brown tomentum at the bases), shallowly lobed at the apex; corolla 2.5–3 mm long, glabrous, split to the base into 3, valvate petals; stamens 6; staminal ring 0.2 mm long around base of pistil; filaments free for 0.5 mm long; anthers 0.5 mm long, oblong, dorsifixed, non-versatile; pistillate flowers solitary; buds 2–3.5 mm long, oblong; calyx 1.5–2 mm long, cupular, 3-lobed at the apex with each lobe splitting again as the fruits develop and becoming 6-lobed, glabrous or with scurfy brown tomentum at the base; corolla 1.5–2.7 mm long, split almost to the base into 3 valvate petals, these reflexed at and after anthesis, glabrous; staminal ring 0.2 mm long at base of pistil, with vestigial filaments, anthers absent; pistil 1 mm long including a 0.3 mm long style, glabrous. Fruits 0.6–0.8 cm diam., globose, with reflexed perianth, whitish at maturity.

Local names and uses: *la non*. The leaves are widely used in the manufacture of hats.

Distribution and habitat: Endemic to central Vietnam in Ha Tinh, Khan Hoa, Kon Tum, Ninh Thuan, Quang Binh, Quang Nam, Quang Tri, and Thua Thien-Hue and near Da Nang City, in broad-leaved, evergreen, closed forest on steep slopes on shale, sandstone, or limestone rocks, and persisting in secondary forest, at low elevations.

Notes: In Magalon (1930) the specimens examined here key to *Licuala spinosa* and in Gagnepain and Conrard (1937) to *L. paludosa*. *Licuala centralis* differs from both those species in being dioecious. Among dioecious Vietnamese species it differs in its erect inflorescences (versus curved down below the leaves in *L. acaulis* and *L. dasyantha*), lack of dense black tomentum on sheaths and petioles (versus with black tomentum in *L. hexasepala*), and 13–26 leaf segments with the central one scarcely wider than the others (versus 3–11 segments with the central one wider than the others in *L. calciphila*, *L. magalonii*, and *L.*

manglaensis). *Licuala centralis* bears a close resemblance to the Chinese *L. hainanensis* Henderson, Guo & Barfod, differing in its densely brown tomentose (versus sparsely tomentose) partial inflorescence bracts, and whitish (versus orange or red) fruits.

Additional Specimens examined. VIETNAM.

DA NANG CITY: Hoa Vang District, Ba Na-Nui Chua Nature Reserve ("Mount Bana"), 15 Jun 1927, *Clemens et al.* 3356 (A, NY, P); "Annam: col de Nuages, près Tourane," 17 Sep 1923, *Poilane* 8022 (P). **HA TINH:** Vu Quang District, Vu Quang National Park, road from Park Headquarters to Border Army Post, 18°20'N, 105°26'E, ca. 100 m, 17 Jul 2007, *Henderson & N. K. Ban* 3428 (HN, NY), 18°19'N, 105°22'E, 18 Jul 2007, *Henderson & N. K. Ban* 3434 (HN, NY); Huong Son Distr., Son Kim Commune, Rao Bun, 18°23'N, 105°15'E, 300–400 m, 4 May 2004, *P. K. Loc* HAL 5112 (HN); Huong Son Distr., Rao An-Ngam, 18°21'N, 105°13'E, 900–1150 m, 15 May 1998, *N. T. Hiep* VA540 (HN, MO); Huong Son Distr., Nga Doi, 18°29'N, 105°13'E, 19 May 1998, *N. T. Hiep et al.* VA753 (HN, MO); 2.6 km from Cat Bin to Khe Gat, 21 Jan 1990, Newman 226 (AAU). **KHANH HOA:** Nhatrang, montagne de Dong Bo, 5 Mar 1922, *Poilane* 2720 (P); Nhatrang, 19 May 1922, *Poilane* 3444 (P); Hui Han Heo près de Nhatrang, 5 Oct 1922, *Poilane* 4913 (P); Annam: La Mere et l'Enfant, province Nhatrang, 4 Nov 1922, *Poilane* 5016 (P); Annam, km 25 route de Nhatrang a Ninh Hoa, *Poilane* 8255 (P). **KON TUM:** Kon Plong Distr., Hieu Commune, Mang La, 14°39'N, 108°25'E, 21 Apr 2000, *Averyanov et al.* VH5462 (HN); *Averyanov et al.* VH5492 (HN, MO). **NINH THUAN:** Ninh Hai District, Nui Chua National Park, near summit of mountain, near 11°48'N, 109°10'E, ca. 800 m, 27 Jul 2007, *Henderson & Ninh Khac Ban* 3470 (HN, NY); Ninh Hai District, Vinh Hai Commune, E slopes of Nui Chua, 11°43'N, 109°08'E, 800–900 m, 27 Mar 2004, *Regalado et al.* HLF 4201 (HN), 28 Mar 2004, *Regalado et al.* HLF 4313 (HN). **QUANG BINH:** Minh Hoa District, 72 km NNW of Dong Hoi, Yen Son village, 17°40'N, 105°57'E, 450–500 m, 17 Apr 1997, *Averyanov et al.* VH4766 (HN, K, MO); Rung Dong San, Dong Hoi, 10 Feb 1979, *V. V. Duic* 15A (HN); Phong Nha Ke-Bang National Park, road near park entrance, 17°34'N, 106°18'E, ca. 20 m, 5 Apr 2007, *Henderson et al.* 3222 (HN, NY); *Henderson et al.* 3227 (HN, NY); Phong Nha-Ke Bang National Park, west branch of Ho Chi Minh trail, 17°28'N, 106°19'E, ca. 600 m, 6 Apr 2007, *Henderson et al.* 3229 (HN, NY);

Henderson et al. 3230 (HN, NY), V. X. Phuong 4265 (HN). QUANG NAM: Nam Giang district, Thanh My, no date, *Cuong 10* (HN). QUANG TRI: massif de Dong Che, no date, *Poillane 11323* (P). THUA THIEN-HUE: Bach Ma National Park, ca. 8 km from the summit, 16°13'N, 107°51'E, ca. 530 m, 13 Apr 2007, Henderson et al. 3274 (HN, NY), 11 Mar 1997, Boyce 1176 (K), 28 Apr 2003, N. T. Hiep et al. HLF1399 (HN), 22 Apr 2003, V. X. Phuong et al. HLF1286 (HN); A Luoi, 7 Sep 1980, N. K. Khoi 243 (HN).

Licuala ellipsoidalis Henderson, N. K. Ban & N. Q. Dung, **sp. nov.**, a *L. paludosa* atque *L. spinosa* segmentis folii paucis, rachillis brevibus, fructibus ellipsoideis differt. Typus. Vietnam. Kon Tum: Kon Plong Distr., Hieu Commune, Mang La Forest Enterprise, 14°39'N, 108°25'E, 1100–1200 m, 24 Apr 2000, Averyanov et al. VH 5698 (Holotypus: HN! Isotypi: K! MO!).

Stems not known, palms to 1 m tall. Leaf number and leaf sheaths not known. Petioles 37–56 cm long, 0.3–0.4 cm wide near the bases, 0.2 cm wide near the apices, without thorns or the basal ca. half with widely spaced, straight, brown thorns to 0.5 cm long; blades 22–32 cm wide, split into 4 segments, these with straight sides; middle segment wider than the others, split for about half its length into 2 lobes (but not split to the apex of the costa), these 20–24 cm long, 4–4.5 cm wide at the apices; indentations leading to adaxial folds 1 cm deep, those leading to abaxial folds 0.2 cm deep, indentations not deeper on lateral segments. Plants monoecious. Inflorescences to at least 30 cm long; prophylls, peduncles, and rachis not known in their entirety; rachis at least 30 cm long, with 3 partial inflorescences, these branched to 1 order, subtended by swollen, tomentose bracts; rachillae 2–8 on each partial inflorescence, 3.5–5 cm long, 0.9–1.2 mm diam. (thickening in fruit), densely covered with branched, wooly, brown hairs, the prominent floral stalks giving the rachillae a bumpy appearance; flowers solitary or paired; buds 4 mm long, club-shaped; calyx 3 mm long, deeply 3-lobed at the apex, tomentose; corolla 3 mm long, split for almost its entire length into 3 valvate petals, densely covered with appressed, silvery hairs; stamens 6; staminal ring 0.5 mm long; anthers oblong, dorsifixed, versatile; pistil 2 mm long including a 1 mm long style, glabrous. Fruits 1.2–1.5 cm long, 0.6 cm diam., ellipsoid, with the perianth appressed to base of the fruit, color at maturity not known.

Local names and uses: None recorded.

Distribution and habitat: Central Vietnam in Kon Tum in primary, broad-leaved, closed, evergreen forest on sandstone slopes at 1100–1200 m elevation.

Notes: The specimen cited here will not key in Magalon (1930) or in Gagnepain and Conrard (1937). *Licuala ellipsoidalis* is a distinctive species in its leaf splitting. In most dioecious species of *Licuala*, the central segment of the leaf is split into 2 lobes, and the base of the split coincides with the apex of the costa. There is a distinctive “gland” at the apex of the costa on the abaxial surface in all these species (except in *L. manglaensis*, which has a non-split central segment). In most monoecious species of *Licuala* the central segment is not split, but often petiolulate, with the petiolule representing the costa of the leaf. The only exceptions to this in Vietnam are *L. ellipsoidalis*, *L. paludosa*, and *L. spinosa*, in which the central segment is split, but not to the apex of the costa. In these species, the costa continues into one of the two lobes, and there is no abaxial “gland.”

Licuala ellipsoidalis differs from *L. paludosa* and *L. spinosa* in its 4 (versus 6–19) leaf segments, 3.5–5 cm long (versus 12–40 cm long) rachillae, and its 1.2–1.5 cm long and 0.6 cm diam. ellipsoid (versus 0.6–0.8 cm diam., globose) fruits.

Licuala longiflora Henderson, N. K. Ban & N. Q. Dung, **sp. nov.**, a speciebus ceteris monoeciis Vietnamensibus generis *Licualae* floribus elongatis differt. Typus. Vietnam. Ninh Thuan: Nui Chua National Park, near summit of mountain, near 11°48'N, 109°10'E, ca. 800 m elevation. 27 Jul 2007, A. Henderson & Ninh Khac Ban 3471 (Holotypus: HN! Isotypi: K! NY!).

Stems solitary, to 3 m tall, 4 cm diam.. Leaf number not known; leaf sheaths 12 cm long, extended above the petioles into 12–14 cm long ocreas; petioles 80 cm long, 0.7 cm wide near the bases, 0.4 cm wide near the apices, the proximal ca. half with widely spaced, recurved, brown thorns to 1 cm long, these sometimes bifid apically; blades to 80 cm wide, split into 19–29 segments, these with straight sides; middle segment only slightly wider than the others, not split, petiolulate, 35 cm long, 3.5 cm wide at the apex; indentations leading to adaxial folds 2 cm deep, those leading to abaxial folds 0.5 cm deep, indentations not deeper on lateral segments. Plants monoecious.



5. *Licuala magalonii*, habit showing leaves split into 3 or 4 segments, the middle one much wider than the others and deeply split into 2 lobes.

Inflorescences to 250 cm long, erect above the leaves; prophylls ca. 20 cm long; peduncles 114–116 cm long; rachis 40–67 cm long, with 7–8 partial inflorescences, these branched to 1 order, subtended by tubular, glabrous bracts; rachillae 1–7 on each partial inflorescence, 4–10 cm long, 0.7–0.8 mm diam., densely covered with golden-brown hairs, with

prominent floral stalks to 2.5 mm long giving the rachillae a bumpy appearance; flowers solitary; buds 6.5–7.5 mm long, ellipsoid; calyx 6 mm long including a 1–2 mm long pedicellate base, 3-lobed at the apex, ciliate, densely covered with golden-brown hairs; corolla 5.5–6 mm long, split for 4 mm into 3 non-valvate petals, densely covered with

appressed, golden-brown hairs; stamens 6; staminal ring 1.5–3 mm long, free from corolla; filaments free for 0.8 mm long; anthers ca. 3 mm long, oblong, dorsifixed, versatile; pistil 10 mm long including a 8.5 mm long style, glabrous. Fruits immature, with perianth appressed to base of the fruit.

Local names and uses: *la non duc*.

Distribution and habitat: Endemic to Nui Chua National Park in Ninh Thuan, in lowland forest on steep slopes at 800 m elevation.

Notes: These specimens will not key in Magalon (1930) or in Gagnepain and Conrard (1937), and this species was apparently not known to these authors. It differs from all other monoecious Vietnamese species in its elongate flowers.

Additional Specimens Examined. VIETNAM. NINH THUAN: Ninh Hai District, Vinh Hai Commune, NEE slopes of Nui Chua mountain, 11°43'N, 109°08'E, 800–950 m, 31 Mar 2004, *Regalado et al. HLF 4420* (HN).

***Licuala magalonii* Henderson, N. K. Ban & N. Q. Dung, sp. nov.**, a speciebus aliis dioeciis generis *Licualae* rachillis tenuibus, vaginis petiolisque viridibus, segmentis folii 3, inflorescentiis non dimorphicis et segmento medio fisso differt. Typus. Vietnam. Da Nang City: Hoa Vang District, Ba Na-Nui Chua Nature Reserve, 20 Apr 2007, *A. Henderson, Nguyen Quoc Dung, Nguyen Canh, & Le Van Bo 3304* (Holotypus: HN! Isotypi: K! NY!). (Fig. 5.)

Stems solitary or clustered, to 1.5 m tall, 2–2.5 cm diam., sometimes short and subterranean. Leaves 6–12; leaf sheaths 14–15 cm long, extended above the petioles into 10 cm long ocreas; petioles 16–56 cm long, 0.6–0.8 cm wide near the bases, 0.5–0.6 cm wide near the apices, the proximal ca. half with widely spaced, recurved, brown thorns to 0.2 cm long; blades 44–48 cm wide, split into 3 or 4 segments, these with straight sides; costa terminating at base of split of the middle segment, with a 'gland' abaxially; middle segment much wider than the others, deeply split (to apex of costa) into 2 lobes (sometimes not split), these 33–41 cm long, 13–20 cm wide at the apices; indentations leading to adaxial folds 1 cm deep, those leading to abaxial folds 0.2 cm deep, indentations deeper on lateral segments. Plants dioecious. Inflorescences to 54 cm long, erect or arching among the leaves; prophylls 11.5–18 cm long; peduncles 26–45 cm long; rachis 0–(14) cm long, with 1–(2)

partial inflorescences, these branched to 2 orders, subtended by tubular, tomentose bracts; staminate rachillae 9, 10–14 cm long, 1–1.5 mm diam., moderately covered with brown, felty hairs, scarcely bumpy; pistillate rachillae 2–7, 4.5–15 cm long, 1.5 mm diam., scarcely bumpy; staminate flowers borne in clusters; buds 3–3.5 mm long, oblong; calyx 1.5–2.7 mm long, gibbous, 3-lobed at the apex, glabrous; corolla 2.5–3 mm long, split for ca. two thirds its length into 3 petals, glabrous; stamens 6; staminal ring 0.5 mm long; filaments free for 0.5 mm; anthers 0.5 mm long, oblong, dorsifixed, non-versatile; pistillate flowers solitary; buds 2.5–3.5 mm long, oblong; calyx 1.5–2 mm long, 3-lobed at the apex with each lobe splitting again as the fruits develop and becoming 6-lobed, glabrous; corolla 2–2.5 mm long, split for 1.5 mm into 3 petals, these spreading horizontally as the fruits develop, glabrous; staminal ring vestigial; pistil 1.5 mm long including a 0.2 mm long style, glabrous. Fruits 0.9 cm long, 0.7 cm diam., irregularly globose, with reflexed perianth, color at maturity not known.

Local names and uses: *cay la ma ca, la non, la non nham*.

Distribution and habitat: Endemic to central Vietnam near Da Nang City and in Thua Thien-Hue, in primary, broad-leaved, evergreen, closed, montane forest on steep slopes on granite rocks, at 1000–1500 m elevation.

Notes: The first known specimen (*Magalon 6*) of this species was identified by Magalon (1930) as "*Licuala ternata* ou *L. triphylla* Griff." *Licuala ternata* is now considered a synonym of *L. triphylla*, a monoecious species from Peninsular Thailand, Peninsular Malaysia and Borneo. Gagnepain and Conrard (1937) mistakenly identified *Magalon 6* as *Licuala hexasepala*, a species otherwise known only from the southern part of Vietnam.

Licuala magalonii differs from all other dioecious Vietnamese species in its slender, 1–1.5 mm diam. rachillae (versus 1.5–5 mm diam. in *L. acaulis* and *L. dasyantha*), more or less green sheaths and petioles (versus with dense, black tomentum in *L. hexasepala*), leaves with 3 or 4 segments (versus 13–26 in *L. centralis*), non-dimorphic inflorescences (versus dimorphic in *L. calciphila*), and split middle segment (versus non-split in *L. manglaensis*).

Additional specimens examined. VIETNAM. DA NANG CITY: Hoa Vang District, Ba Na-Nui

Chua Nature Reserve, 20 Apr 2007, *Henderson et al.* 3305 (HN, NY), May-Jul 1927, *Clemens & Clemens* 4444 (NY, P), Jan-May 1927, *Squires* 203 (NY); "Mt. Bana, environs Tourane" [Da Nang City, Hoa Vang District, Ba Na-Nui Chua Nature Reserve], 24 Jan 1940, *M. Magalon* 6 (ITB, P). THUA THIEN-HUE: Bach Ma National Park, no date, *T. P. Anh* 107 (HN); 27 Oct 2004, *Anon* 4 (HN), 13 Apr 2007, *Henderson et al.* 3268 (HN, NY), 26 Apr 2003, *N. T. Hiep et al.* HLF 1336 (HN), 4 May 2003, *N. T. Hiep et al.* HLF 1623 (HN), 30 Jan 1990, *Newman* 177 (AAU, K), *Newman* 179 (AAU, K), 18 Apr 2003, *V. X. Phuong et al.* HLF 951 (HN).

Licuala manglaensis Henderson, N. K. Ban & N. Q. Dung, **sp. nov.**, a speciebus ceteris generis *Licualae* habitu dioecio et segmento rhomboideo centrali non fisso differt. Typus. Vietnam. Kon Tum: Kon Plong Distr., Hieu Commune, Mang La Forest Enterprise, 14°39'N, 108°25'E, 1100–1200 m, 16 Apr 2000, *Averyanov et al.* VH 5201 (Holotypus: HN! Isotypus: MO!).

Stems to 1 m tall, diameter and branching not known. Leaf number not known; leaf sheaths 8–10 cm long, extended above the petioles into 6–7 cm long ocreas; petioles 33–38 cm long, 0.4–0.5 cm wide near the bases, 0.2–0.3 cm wide near the apices, the proximal ca. half with widely spaced, straight, brown thorns to 0.7 cm long; blades 20–24 cm wide, split into 5 segments, these with straight sides; middle segment wider than the others, not split, rhomboidal, the costa continuing to the apex of the middle segment, 14–17 cm long, 9–11 cm wide at the apex; indentations leading to adaxial folds 0.8–1.5 cm deep, those leading to adaxial folds 0.3–0.4 cm deep, indentations not deeper on lateral segments. Plants dioecious. Inflorescences to 75 cm long, erect among the leaves; prophylls 14.5 cm long; peduncles 57 cm long; rachis absent, partial inflorescence 1, this branched to 2 orders, subtended by tubular bracts; staminate rachillae 12–15 on each partial inflorescence, 7–10 cm long, 0.6–0.7 mm diam., densely covered with short, whitish-brown hairs; pistillate rachillae number not known, length, diameter, and hairs similar to staminate; staminate flowers borne in groups of 2 or 3; buds 1.2–1.5 mm long, globose; calyx 1 mm long, tubular, shallowly 3-lobed at the apex, densely covered with spreading, whitish-brown hairs; corolla 1–1.2 mm long, glabrous, split completely to the base into 3, valvate petals; stamens 6; staminal ring absent;

filaments 0.2 mm long, fused to the base of the vestigial pistil; anthers oblong, 0.5 mm long, dorsifixed, non-versatile; pistillate flowers solitary; buds 1.7 mm long, globose; calyx 1.5 mm long, 3-lobed at the apex, densely covered with spreading, whitish-brown hairs; corolla 1 mm long, split completely to the base into 3 valvate petals, glabrous; staminal ring absent, 6 vestigial filaments at base of petals; pistil 0.5 mm long including a 0.2 long style, glabrous. Fruits ca. 0.8 cm diam., globose, with reflexed perianth, color at maturity not known.

Local names and uses: None recorded.

Distribution and habitat: Endemic to southern-central Vietnam in Kon Tum, on steep slopes in primary, evergreen, broad-leaved, wet forest at 1100–1200 m elevation.

Notes: *Licuala manglaensis* is dioecious. All other dioecious species of *Licuala* known from Vietnam have the central segment split. In *L. manglaensis*, however, the central segment is not split and has a rhomboid shape, although the costa is well-developed and reaches almost to the apex of the central segment. The staminate flowers, with the petals split completely to the base, scarcely developed staminal ring, and very short filaments inserted at the base of the vestigial pistil, are also distinctive.

Additional Specimens Examined. VIETNAM. KON TUM: Kon Plong Distr., Hieu Commune, Mang La Forest Enterprise, 14°39'N, 108°25'E, 1100–1200 m, 23 Apr 2000, *Averyanov et al.* VH 5614 (HN, MO).

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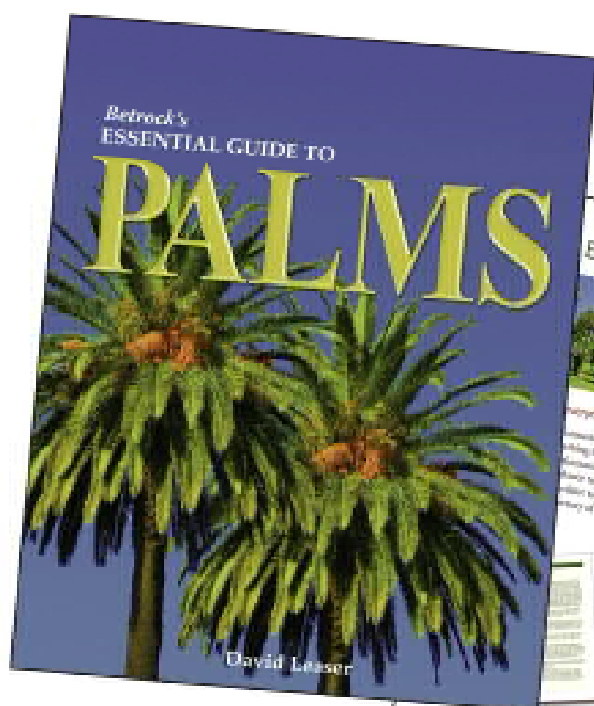
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