Celebrating 60 Years

Palms

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The International Palm Society

Founder: Dent Smith

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CONTENTS

5 **The Singapore Botanic Gardens Palm Collection – Historical Perspective, Representation, Conservation and Direction**
F.F. Merklinger

25 **Pneumatophores on *Acoelorrhaphe wrightii***
S.M Edelman

29 **Flowering of *Carpoxylon macrospermum*, a Critically Endangered Palm, in the Townsville Palmetum, Australia**
J.L. Dowe, R. Lovatt & N. Snajder

41 **Watkins Munro Marin Conservatory, Cairns Botanic Gardens, Queensland, Australia**
J.L. Dowe & D. Warmington

Features

Palm News	4
Obituary	38
Photo Feature	40

The ant-inhabited ocrea of *Korthalsia rostrata*, one of the native species of palm found in Singapore Botanic Gardens. See article by Merklinger, p. 5. Photo by F. Merklinger.

FRONT COVER

Johannesteijsmannia altifrons at Singapore Botanic Gardens. See article by F. Merkinger, p. 5. Photo by F. Merkinger.

BACK COVERS

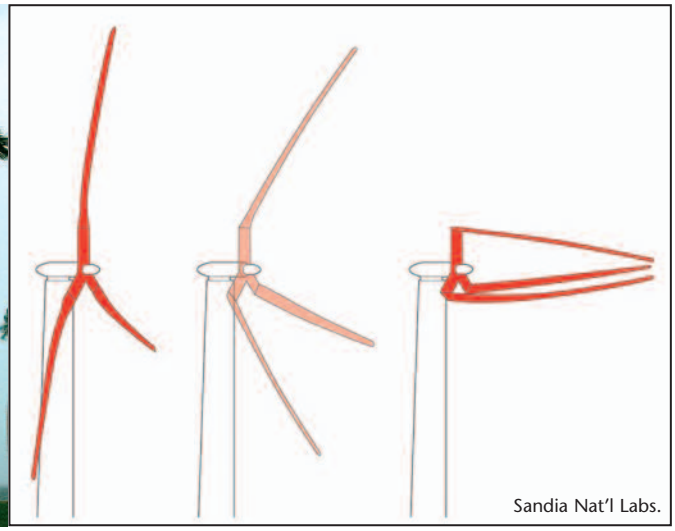
Areca catechu and *Cyrtostachys renda* at Singapore Botanic Gardens. See article by F. Merkinger, p. 5. Photo by F. Merkinger.

PALM NEWS

Of the many herbivores that feed on palms, one of the strangest is the little-known crab, *Labuanium politum* of Singapore, Malaysia and Singapore. **This crab lives in stands of *Nypa fruticans*, coming out only during the darkest part of the night to feed on the leaves of the palm** and remaining hidden among the leaf bases during the day. A recent article (Raffles Bull. Zool. supl. 31: 216–225. 2015) by P.K.L. Ng et al. documents the taxonomy and morphology of this crab and discusses its ecology. It is an obligate arboreal herbivore, with specially adapted legs for gripping and ripping the leaves. The life history of this crab illustrates the interconnectivity of palms and the creatures that live among them. [Photo courtesy of Dr. H.H. Tan, Lee Kong Chian Natural History Museum, Singapore]

Palms were the inspiration for the design of gigantic wind turbines. Sandia National Laboratories, in a partnership of academia and industry, have designed the extreme-scale Segmented Ultralight Morphing Rotor for off-shore deployment, where installation and maintenance are expensive. In order to maximize the energy capture, the designers have built hollow, segmented blades that are more than 650 feet (200 m) long, two and a half times longer than any existing turbine blade. The blades are biomimics, inspired by the way palms move in storms. In excessively high winds, the turbine blades fold to one side (downwind) and redeploy when the wind speeds return to normal, just like the leaves of palms.

Christina Xu



Sandia Nat'l Labs.

The Singapore Botanic Gardens Palm Collection – Historical Perspective, Representation, Conservation and Direction

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1.The avenue of Royal Palms planted in 1950 along office gate road.

A specialized plant collection within a botanic garden often carries a complex historical legacy. At the same time, it can help to shape the future direction of the institution. The palms at the Singapore Botanic Gardens (SBG) constitute a very good example of such a collection, because they have been augmented over many decades, and each major phase of augmentation has left its distinctive mark; furthermore, the collection as a whole has absorbed more than the entire history of the gardens and is still continuing to influence it today.

The development of such a palm collection invokes many dimensions, from planning to collection, from horticulture to arrangement, but three very interesting perspectives ought to be recounted. Firstly, the natural abundance of palms in the Asia-Pacific region, a center of diversity for palms, is impressive. The family has an astonishing diversity of more than 1200 species here. In the botanical region of Malesia alone 50 genera and almost 1000 species of palms have been recorded (e.g., Dransfield et al. 2008, Baker & Couvreur 2012, Heatubun et al. 2014). The hot-wet equatorial climate in Singapore, of course, favors the cultivation of myriad representatives of this essentially tropical plant family. Situated just slightly north of the equator (1°17′N, 103°50′E), Singapore enjoys conditions that promote plant growth: high humidity, a mean average temperature of 28°C all year round, and average rainfall of around 2300 mm annually. How numerous the cultivated palms are in Singapore can be realized from a short bus ride along upper Bukit Timah road from the Botanic Gardens MRT station to the Bukit Timah entrance: as many as 30 genera can be seen!

A second perspective relates to the historical development of the Gardens. Brought to life by an Agri-Horticultural Society with the idea of creating an ornamental pleasure-garden that at the same time should serve local agriculture, the SBG realized that palms had both an ornamental as well as a functional role. Palms even preceded the establishment of the botanic gardens in the form of remnant, cultivated individuals from former days when part of the area served as a plantation. When the Gardens became integrated into the network of British colonial botanic gardens, the exchange of plant material intensified, and more palms were sourced from other parts of the colonies.

The third interesting aspect regards the innovators of the collection, or in this case a series of superintendents, directors and botanists, each contributing to the extension and curation of the collection according to his own interests, personal links, professional enthusiasm or, simply, his general love for plants. I hope to show, over the following pages, how these three areas continue to shape one of the great palm collections of the tropical world.

Singapore botanic gardens in history

The birth of the SBG was in 1859, when a number of wealthy Singaporean residents founded the Agri-Horticultural Society. There had been several attempts previously to establish a garden, though mostly driven by the interest in commercial plantations such as nutmeg cultivation. But as the value of such crops declined, so did the interest in establishing botanic gardens. The name Agri-Horticultural Society suggests a somewhat mixed agenda. Its objectives may be summarized as the development of an experimental garden for the trial of economic crops, while at the same time creating an ornamental pleasure park for the important and wealthy. Its founders were influential business people, and initially the gardens were open only to certain subscribers; this soon changed, however, and all members of society gained access.

The Agri-Horticultural Society acquired the land at the current site and employed Lawrence Niven as its manager on a part-time basis to conceptualize and develop the garden. Niven, from a family of nurserymen, was also managing a local nutmeg plantation. It appears the nutmeg crop had been in decline because of disease, and this may have been Niven's reason for seeking alternative employment (Taylor 2013). Niven started clearing much of what was then secondary growth (previously part of the area had been a gambier plantation – gambier, *Uncaria gambir*, was an important agent for tanning), and the site began to take shape. Soon the space had been neatly laid out with flowerbeds, consciously or not, in a style influenced by the 18th century English Landscape movement, manifesting itself in gently rolling hills and a lake (Taylor 2013). Much of the initial flower cultivation served to provide cut flowers for the garden's subscribers. There was also a patch of natural rain forest, which is still in existence today.

As the garden's developments and expenditures increased, the Agri-Horticultural Society made a proposal in 1874 to hand over the garden to the government. It was argued that by becoming a governmental institution, it could be placed on a "proper scientific footing" (Fox 1889) and be backed up with the necessary financial means.

The government accepted the proposal and what had so far been a nicely laid out park became another link in the network of British colonial botanic gardens. The British had set up botanic gardens in the West Indies (St Vincent) in 1765, Jamaica (1779), Trinidad

2. The male reproductive plant of *Lodoicea maldivica* is growing in the Palm Valley. Its pollen is transferred manually to the female plant in the original Palmetum behind Holttum Hall.

3. Palm Valley with a view toward Burkill Hall 1917.

(1818), and later in the East Indies (with the British East India Company), at Calcutta (1787) and Peradeniya (Sri Lanka) in 1821. By 1837, Queen Victoria's ascension, there were eight such gardens, but at the end of her reign in 1901, this number had grown to more than 100 and included sites in Africa, Australasia, Canada and the Indian Ocean, Hong Kong and the Pacific (McCracken 1997). Regionally two other botanic gardens were of significance: Buitenzorg (today Bogor, Indonesia) founded in 1817 by the Dutch, and Penang (Malaysia) founded in 1884. At the center of this network remained the Royal Botanic Gardens, Kew, training and supplying garden directors, head gardeners and scientists. It was Sir Joseph Hooker, then director at Kew, who recommended the superintendents and directors for the gardens in Singapore.

The first accumulation of palms

From 1875 until 1880, Henry James Murton served as first superintendent of the SBG. Son of a Cornish nurseryman and trained at Kew, Murton arrived in Singapore via Ceylon, from where he already acquired "liberal donations" of plants (Burkill 1918a). Throughout his five years of service in Singapore he maintained regular correspondence with many other colonial gardens as well as Kew, and frequent plant exchanges ensued. It was he who started to turn the well-kept park into a working botanic garden and who first began to accumulate a palm collection. Under him, a herbarium and a library were constructed, and the number of known plant species in the gardens was raised from about 500 to over 1300 (Fox 1889).

In the annual report for the SBG from 1876, all plants under cultivation in the gardens by November 1875 are listed, including some 25 genera and 49 species of palms (Murton 1876). This number will vary slightly if we consider current taxonomy, and the list does not include some of the native palms existing on site, such as *Oncosperma*. By the end of his first year of service, however, he already appeared to grow the Double Coconut (*Lodoicea maldivica*) (Fig. 2) and *Stevensonia* palms (*Phoenicophorium borsigianum*), both Seychelles endemics; *Seaforthia elegans* (*Ptychosperma elegans,* N. Australia) and *Kentia* (*Howea*, Lord Howe Island), to name a few. In the annual report for the year 1879, Murton wrote, "The collection of palms has increased by 14 genera and 46 species during the year and some other place must soon be selected for them" (Murton 1880).

The idea of a space dedicated to palms was becoming clearer. By 1879, about 40 genera of palms were cultivated in the gardens. Initially

the palms were planted behind what is today Holttum Hall and referred to as the "Palmetum." This was not the only space devoted to palms; Murton also began to plant palms at the head of a valley, later to become "Palm Valley" (Fig. 3). However, the concentration of palms into "Palm Valley" would come at a later stage.

4. Several specimens of *Attalea* appear to be some of the oldest remaining palms in the Palm Valley.

In 1880, Nathaniel Cantley was appointed superintendent of the SBG. Like Murton, he was recommended by Sir Joseph Hooker and had been trained at Kew before serving as the assistant director of Gardens and Forests in Mauritius. Some of the first changes that Cantley made to the gardens in Singapore included the arrangement of plants into systematic order according to the taxonomic system of Bentham and Hooker. The palm collection established under Murton, partly growing in the Palmetum but increasingly populating the future Palm Valley, was rearranged to reflect the latest taxonomic understanding as outlined in *Genera Plantarum* (Bentham & Hooker 1883). In 1892, James Herbert Veitch learned on a visit to the SBG that the newly established Palmetum was only about six years old (Veitch 1896). This statement confirms that it was Cantley who rearranged the palms accumulated since Murton's time into a space dedicated to palms and the future Palm Valley. Ridley extended the collection of palms commenced by Murton at the head of the valley down into the valley from 1891 onwards (Burkill 1918b).

Cantley spent much time identifying and correctly naming the plants in the collection. He also employed a printer to produce labels for the living collection. The herbarium and the library, which Murton had started, were expanded. These systematic changes to the hitherto rather eccentric collection of plants consolidated the "scientific footing" of the SBG as initially proposed to the government by the Agri-Horticultural Society. Having served within a forestry department before, Cantley was able to increase substantially the number of economically important plants and related trials. He also deserves credit for the establishment of a nursery facility predominantly for ornamental plants, which meant that there was now a dedicated space for plant propagation within the gardens. Unfortunately, Cantley's service was interrupted several times by illness, and he died while on leave in Australia.

The 'finest palm collection in the world'

Henry N. Ridley was appointed as first director of the SBG in 1888. To date, he is still the most famous personality of this garden, not only because of his persistence in promoting *Hevea brasiliensis*, Pará Rubber, as an economically viable crop, bringing him the nickname "Rubber Ridley" among others, but also because he embodied the indefatigable botanist. He collected many thousands of specimens throughout the region and was extremely productive in generating scientific publications. His works included the description of new plant species and writing an entire flora of Malaya, among other classic books about seed dispersal and spices. He also conducted an enormous range of trials with economic plants.

Ridley's interest relating to palms was not only scientific but one centered very much on their usefulness. One of his earliest achievements was the Coconut Tree Preservation Ordinance, an Act that was passed as early as 1890, following his recommendations as outlined in a report to the Royal Asiatic Society (Ridley 1889). Its objective was to control the Rhinoceros beetle, *Oryctes rhinoceros*, in coconut plantations and to prevent its spread to other healthy palms, including those at the SBG, where these insects regularly inflicted damage. A coconut tree inspector was employed to frequent the plantations and fine the owners for not clearing any debris that provided a breeding ground for the larvae of this insect. Ridley wrote in the annual report for 1890, "In the Botanic Gardens, notably at one spot near the office, it was almost impossible to grow any palms at all. Those liable to attack were destroyed often within a day or two of their being planted; a small avenue of the rare and beautiful *Verschaffeltia splendida* by the aviary was perishing tree by tree, till the Act came into force" (Ridley 1891).

Ridley soon started to publish an agricultural bulletin (later to become the *Gardens Bulletin,* see Wong 2012), in which he documented economic plant trials such as his rubber experiments or notes on the cultivation of sago (*Metroxylon sagu*). His article on the oil palm (Ridley 1907), which discussed effective methods of extracting oil from oil palm fruits, undoubtedly intensified the already growing interest in a crop that would become the most important agricultural product of the region, next to rubber. This review of *Elaeis* was based on trees that were planted at the SBG in 1875. Although it appears to be the first introduction of oil palm to Malaya (Anonymous 1958), this planting occurred almost 30 years later than the introduction of oil palm to the Buitenzorg Botanic Gardens (Bogor, Indonesia). Ridley (and subsequent directors) provided oil palm seeds to interested plantation owners in the region, so aiding the establishment of the palm as a major crop, but the origin of many commercial oil palms in Malaya can actually

be traced back to four trees at Bogor that were introduced as early as 1848. The potential of oil palm as a crop was realized very early, but palm oil was imported directly from Africa. There was a growing need for the oil and its derivative glycerine. It was used in soaps and candles (used for heating and light), photography (to preserve film), manufacturing of colors, as a cosmetic and in perfumery (Henderson & Osborne 2000). Commercial explorations by a Belgian company soon started plantations in Sumatra, supplied with seeds from these four trees grown in Bogor. Seed from Sumatran plantations then began to spread to Malaya in 1917 (Henderson & Osborne 2000).

The growing interest in palm oil also led to the exploration of other potential palms yielding oil. For some time around the turn of the 19th century, *Attalea* from tropical America was promoted as an oilseed crop; however, the long time needed by the plants to start fruiting was not anticipated, and plantations of this palm were not deemed economically viable (Burkill 1921). These palms have another interesting connection to the SBG; they were used by the rubber collectors in the Amazon to coagulate and sterilize the rubber by burning the seeds and letting the greasy smoke pass over the rubber (Burkill 1966). Some of the largest palms at the SBG today belong to the genus *Attalea* (Fig. 4).

For the year 1891, Ridley reported the planting of additional palms into the Palmetum, which now comprised 102 genera and 160 species (Ridley 1892). Several species of rattan were introduced into the gardens around the same time, probably in view of the economic value of rattan cane. Ridley also maintained a column in the annual reports where he listed the phenology of rare or particularly interesting plants, such as the flowering of *Korthalsia rostrata* (1900), *Wallichia disticha* (1907) and *Prestoea montana* (1909). Ridley was the first to publish two notes on the palms at the SBG. The first one is an extensive description of palms, a general introduction and horticultural challenges (Ridley 1904). The second is a short list of newly acquired palms (Ridley 1906). In the annual report for the year 1909 Ridley wrote, "Over 200 palms were planted in the Palm Valley. The collection of

5. *Hyphaene dichotoma* in the National Orchid Garden. This plant was already there in the 1920s as part of the Sun Rockery.

palms now is probably one of the largest in number of species of any garden in the world" (Ridley 1910).

In 1910, *Raphia* palms were planted in the economic garden with the intention to use them for fiber production. The same year saw the first recorded flowering of *Licuala grandis* introduced from the island of New Britain, today one of the most commonly used garden palms throughout Singapore. The year 1911 saw the introduction of *Latania commersonii* (*L. lontaroides*), which flowered for the first time in 1920 (Burkill 1921).

While Ridley evidently kept himself occupied, he still exchanged plants and seeds and continued to source plants from overseas, be it through his correspondence with other botanic institutions and growers or from his frequent collecting expeditions throughout Southeast Asia. The herbarium grew to such an extent that it had to be expanded, soon containing a good collection of dried specimens from the entire region.

In 1912, the first *Index of Plants* of the SBG was published (Anderson 1912), containing some 93 genera of palms. The discrepancy between the 102 genera recorded by Ridley a few years earlier and the 93 recorded by Anderson can be explained by the fact that Anderson's catalogue was intended to advertise seed exchange of certain plants, so some immature palms may have been omitted intentionally.

Maintaining and promoting a world class collection

Isaac Henry Burkill succeeded Ridley as director and served from 1912 until 1926. By this time, palm genera from all over the world had found their home in Singapore, and the SBG collection was providing an excellent basis for their study, both botanically and horticulturally. And the acquisition of palms continued. In the annual report dating 1920, Burkill wrote that 27 palms new to the collection had been introduced, while others were starting to flower and fruit, such as *Latania* and *Attalea*.

Frederick Flippance, the assistant curator during 1919–1921, published a guide to the palm collection. This was the first guide to appear since 1906. "In the fourteen years since the last article was written many additions, and it is feared several losses, have to be recorded and accordingly it seemed desirable thoroughly to investigate the collection again" (Flippance 1920a). Surprisingly, in this guide, merely 60 genera of palms are mentioned to be in cultivation. This is in strong contrast to the 102 genera written about by Ridley in 1891, and the 93 genera counted in Anderson's *Index of Plants* (1912). While there is mention of pests such as the Rhinoceros Beetle and the Red Palm Weevil destroying palms (Ridley 1889, 1904; Flippance 1920b), this discrepancy may also be the result of changing palm taxonomy over time, or simply newly introduced palms failing to establish.

In 1923, Caetano Xavier Furtado joined the SBG as assistant botanist, chiefly in charge of naming the living collections and cultivated plants (Kiew 1999). He previously had published studies of an agricultural nature on coconut palms, and soon after arriving in Singapore, he began to study Malayan palms. Four new genera were erected by Furtado: *Cornera, Liberbaileya, Schizospatha* and *Maxburretia* (*Cornera* and *Schizospatha* were subsequently reduced to *Calamus*, and *Liberbaileya* sunk into *Maxburretia*). During several expeditions, including to Kinabalu and Peninsular Malaysia, he studied and collected palms in the field. He also travelled to Europe, where he carried out research in major herbaria in Berlin and London. Furtado studied the extensive living collections at the Bogor Botanic Garden and deposited herbarium vouchers at the SBG herbarium. In order to study the taxonomic accounts, which were often in foreign languages, he learned Italian, Spanish, French and German. He described over 100 species of Malayan palms, mostly in the genera *Licuala, Pinanga, Daemonorops* and *Calamus* (Johnson & Tay 1999). His numerous publications on Malayan palms appeared in the *Gardens' Bulletin Singapore* between 1934 and 1960. During WWII, Furtado continued to work at the SBG along with Edred John Henry Corner and Richard Eric Holttum. After his retirement, Furtado continued to work in the herbarium and studied, among others, the genus *Hyphaene*. Several publications on this genus appeared in the *Gardens' Bulletin*, including a treatment of the Asian species of *Hyphaene* and the publication of *H. dichotoma* from India (Furtado 1970), the only species in cultivation at the SBG (Fig. 5). Furtado's impact on palm taxonomy has not always been realized to the extent it deserved, while personalities like Corner, primarily a fungus specialist, earned a lot of recognition for his inspiring work *The Natural History of Palms* (Corner 1966).

6. The first *Lodoicea maldivica* to reach the fruiting stage was planted in 1961.

Other eminent palm scientists have had an association with the SBG over the years. Odoardo Beccari, for example, regularly corresponded with Ridley discussing information on palms. In honor of Beccari's contribution to our understanding of palms, an avenue of palms described by him was intended to be planted at the SBG (Burkill & Moulton 1921). This intention was realized and "Beccari's palms" were planted below the

7. *Oenocarpus bataua* is producing inflorescences throughout the year.

Sun Rockery (Burkill 1927), which during the 1920s was situated where today the entrance to the National Orchid Garden lies. However, none of these palms exists at this site today. In 1897, David Fairchild was received by Ridley during his travels through the region (Fairchild 1938). Although not primarily a palm scientist, Fairchild left his legacy at the Fairchild Tropical Botanic Garden, Miami, Florida, USA; anyone interested in palms knows the magnificent collection there. Recent years have seen repeated visits by John Dransfield, who has

8. Murton's *Oncosperma tigillarium* planted in 1878.

given much effort to assist palm identification at the SBG. The latest such visit was in October 2014, when two specimens of *Tahina spectabilis* were specially planted by him in a commemorative act. SBG's botanists recently honored Dransfield in *Adonidia dransfieldii* (Wong et al. 2015), a rare Bornean palm with straighter trunks than those of the more commonly planted *Adonidia merrillii*, which usually shows some sinuous trunk development. The SBG will soon plant out the first batch of *Adonidia dransfieldii*.

9 (top). The *Johannesteijsmannia* collection along Maranta Avenue contains some splendid specimens. 10 (bottom). *Sommieria leucophylla* along the Maranta Avenue.

11. *Johannesteijsmannia perakensis*.

Representation

Today the SBG has the largest collection of palms in Singapore besides the recently established Gardens by the Bay and possibly one of the largest collections in the world. There are about 800 individual palms (accessions) in Palm Valley alone. Following the taxonomy as outlined in *Genera Palmarum* (Dransfield et al. 2008), the SBG has 112 genera and 260–300 species, including several yet to be determined. The combination of natural palm diversity in the region, historical acquisition of species through a colonial network of gardens and repeated collecting expeditions throughout SE Asia makes the collections at the SBG world class.

There is a heavy representation of Asia-Pacific palms with 52 genera. Second are palms from the Americas with 32 genera. All six endemic Seychelles palms are in the collection, as well as several genera from Australia, Lord Howe Island, New Caledonia, Madagascar and mainland Africa. Some palms from higher elevations or a more moderate island climates, such as *Howea* or *Rhopalostylis*, can be grown only with great difficulty and usually do not live for very long. Hence the focus has been on Asian, American and African tropical and subtropical species.

Palm Valley is the principal location for palms at the SBG. The arrangement of palms in Palm Valley follows an overall taxonomic arrangement; there are eight clusters (or "islands") of palms, arranged into four subfamilies: along the National Orchid Garden side are two clusters of Arecoideae (characterized by the large clumps of *Oncosperma tigillarium*), one cluster of Coryphoideae (mostly *Arenga, Caryota, Corypha* and *Wallichia*) and Calamoideae with some adult *Mauritia*, *Mauritiella* and *Metroxylon*. Along the rainforest side are two more Coryphoid clusters with *Copernicia, Livistona,* large *Corypha* and a male reproductive *Lodoicea* (Fig. 6) among others. There is also one more Arecoid cluster and the Ceroxyloid cluster, the latter being under development, currently with a mix of species including *Borassodendron machadonis, Calyptronoma occidentalis* and a frequently flowering *Oenocarpus bataua* (Fig. 7). Only recently, young plants of *Ravenea* have been added in an attempt to establish a Ceroxyloideae cluster, reflecting the currently accepted subfamilies (Dransfield et al. 2008). More Ceroxyloid palms are targeted for

12. *Lodoicea maldivica* in 1947.

inclusion in the future, especially the Ivory Nut palms such as *Phytelephas,* a palm that used to be grown at some point in the past. In the center of Palm Valley is a large *Attalea* species (Fig. 4) as well as a mature *Corypha utan*. These are remnant plantings from a time before the Symphony Stage was built, as now they are in the sight line of the stage. The addition of Symphony Stage in the year 2000 has meant that Palm Valley has additionally evolved into an event space. This of course, has considerable implications for the continued management of palms. To maintain this remarkable landscape feature, successional planting is done where possible. This helps to rejuvenate and maintain the palms here, many of which are quite old. Palm Valley is, as such, a major showcase of the SBG grounds, where carefully maintained palm specimens and exhibits, as well as special visitor congregations, will be managed as key aspects. At the same time, important or rare collections are also being planted in different parts of the garden.

In other areas of the gardens, palms are also plentiful, and indeed the huge diversity can only benefit by adopting more than a single concentration at the Palm Valley. The lawn behind Holttum Hall, for example, the original starting point of the Palmetum, is still home to several species including the female *Lodoicea maldivica* (Fig. 6) and a large *Oncosperma tigillarium* (Fig. 8), the latter supposedly established by Murton in 1878. From here, an avenue of *Roystonea* palms planted in 1950, leads toward Maranta Avenue and the Ginger Garden (Fig. 1). Along Maranta Avenue, a significant collection of mostly understory species is cultivated, most remarkably the *Johannesteijsmannia* collection and the New Guinean *Sommieria leucophylla* with its lychee-like fruits (Figs. 9 & 10). Many palms can be seen in the Ginger Garden, including *Drymophloeus, Calyptrocalyx, Dypsis, Areca, Pinanga* and *Roystonea*. *Johannesteijsmannia* palms have also been planted along the drive to the back of Burkill Hall, behind the entrance to the NOG. These may well be the largest cultivated specimens found in any garden; one individual *Johannesteijsmannia perakensis* has a considerable stem attaining an overall height of about 3 m (Fig. 11)!

Lodoicea maldivica, the Coco de Mer or Double Coconut, appears to have been introduced to the SBG on several occasions. It was first mentioned in the Annual Report for the year 1875, where Murton listed it as one of the plants cultivated at the SBG. It is uncertain, however, for how long this plant lived. It also appears that this species was cultivated at various locations throughout the years; a tree planted behind Holttum Hall (possibly the specimen pictured in 1947, Fig. 12) is mentioned in the annual report from 1956 as having been destroyed by the Red Palm Weevil, and another specimen near the Cluny Road entrance was killed by falling branches of another tree (Purseglove 1956). Fortunately, four more seeds were obtained from the Seychelles and were planted in the Palm Valley. In the *Illustrated Guide to the SBG* by Burkill (1927) there is a picture of *Lodoicea* growing on the banks of the [Swan] lake. It seems to be growing well in this habitat although its actual habitat is on the Seychelles on granite bedrock in monodominant stands. In the annual report for 1963 it was stated that "The gardens have for many years been trying to establish plants of the Seychelles Double Coconut (*L. seychellarum*) but have been unsuccessful, the plants succumbing to attack by the Red Stripe Weevil" (Burkill 1964).

The large *Oncosperma tigillarium,* or *Nibung,* growing behind Holttum Hall and supposedly planted by Murton, is one of the largest clumps of this palm at the SBG. However, recent surveys at the bottom of Palm Valley uncovered another specimen, at least three times the size of Murton's. *Oncosperma tigillarium* is native to SE Asia and is found at the inland side of mangrove estuaries. Furtado wrote, "Others like the Nibung made the Malayan civilization possible since its timber was needed not only for the boats but also for the houses, for no other cheap timber was available that could stand salt water and also resist the attack of termites and other destructive organisms" (Furtado 1959).

More palms are found scattered throughout the other parts of the gardens, usually as individual, yet often noteworthy, specimens. A clump of the Sago palm (*Metroxylon sagu*) near the Tanglin Gate is of significant size and predates the establishment of the gardens, presumably started when the area was a plantation. Another such leftover from cultivation is the betel nut palm (*Areca catechu,* Fig. 13). Betel nut palms have been cultivated throughout large parts of Asia for centuries,

13. *Areca catechu,* the betel nut palm.

owing to their seeds used as a stimulant (e.g., Flippance 1920c). Used by Niven as an avenue palm in the bandstand hill area, it was later replaced by *Seaforthia elegans* (*Ptychosperma elegans*) by his successor. Today this species can be seen at various places in the gardens, including Heliconia Walk, the Healing Garden and Palm Valley itself. The Healing Garden also contains a number of oil palms, which were planted around the turn of the century. The fringes of the Eco Lake in the Bukit Timah core are occupied by *Metroxylon sagu, Maurita flexuosa* and a large cluster of *Nypa fruticans* (Fig. 14), the last completing the representation of all five subfamilies of palms at the SBG.

The rain forest is home to several rattan species as well as two *Orania sylvicola,* which could have always been there. Undoubtedly the Bayas palms (*Oncosperma horridum*) occurred in the rain forest then, as they do today. Ubiquitous is *Caryota mitis.* Also a number of rattans, notably the large *Plectocomia elongata* as well as *Daemonorops grandis,* have always lived here. These species are equally abundant at the Bukit Timah and the Central Catchment Nature Reserves. *Korthalsia rostrata* has been recorded for the rain forest by Turner (2000);

14. *Nypa fruticans* at the Eco Lake. Ridley stated in 1904 that *Nypa fruticans* would not grow well away from salt mud, however, it grows fine today at the SBG and sets fruit regularly.

however, this species is now difficult to find. General concerns with small fragments of rain forest include the decrease of humidity, possibly affected by increased developments in the surrounding area, and a resulting loss of buffering vegetation. Another issue is the reduction of canopy cover as trees fall and fail to reproduce. The increase in light also favors the establishment of more weedy species in the understory of forest fragments.

Challenges in palm cultivation

Some of the challenges faced in the cultivation of palms at the SBG may briefly be mentioned. The shade requirements, which many species rely upon, cannot always be guaranteed at

Palm Valley or other open sites, thus those species have been given a home in the more wooded environment of the Ginger Garden or along Maranta Avenue, as well as the new Tyersall Learning Forest being established. Successive planting inside the Palm Valley has to be done very selectively, leaving enough room for palm specimens to grow to their full potential so they can be appreciated as landscape features. There are some species that were already mature and flowering at the turn of the century (e.g., *Wallichia* in 1907) but are now represented as very young individuals. Others, such as the *Attalea*, are mature and new recruits have been planted only recently. Hence allowance needs to be made for the large age gap between individual plants, and it will take quite some time for younger palms to catch up. Replacements are carefully chosen and limited to those plants that are going to make a visual impact on the landscape.

The increase in area of the SBG in 1985, when Tan Wee Kiat was the Director, has meant that even more opportunities became available for palms. A good example can be seen at the northern end, where the establishment of *Nypa fruticans* along the edge of the freshwater Eco-Lake has been successful.

Throughout the annual reports, references were made to the various pests that attack the palms at the SBG. Ridley's Coconut Tree Preservation Ordinance was to deal with the Rhinoceros Beetle, but in his preceding reports he also discussed the Red Palm Weevil. Ridley's cure was to locate the beetles by visual inspection and then use barbed wire to impale the insects inside their holes in the palm, at least when dealing with the more obvious Rhino Beetle. During the 1950s, *para*-dichlorobenzene crystals were put into the holes left by the beetles, and the holes then plugged with mud. Preventative measures – collecting the grubs out of compost – were the best control (Burkill 1958). The adult beetles will lay eggs in rotting plant material and dead wood, hence compost heaps represent the ideal food source for the developing larvae. Chemicals were also applied to defend palms against the Red Palm Weevil but to no avail, since "the symptoms of attack are revealed too late to save the plant" (Burkill 1958). Both pests are present today and can cause considerable damage to palms. Pheromone traps are currently employed for monitoring and control of both species at the SBG. Interestingly, the annual reports mentioned palms that were apparently affected by Red Palm Weevil and Rhino Beetle, such as "the avenue of *Verschaffeltia splendida"* mentioned by Ridley, which perished "tree by tree." Today we have several specimens of this palm in the gardens, yet no observation of it being attacked by the insects has so far been made. Equally, the coconut palms have never been observed to be attacked by either Rhino Beetle or Red Palm Weevil. That they do get attacked in other regions of the world has been shown by Hoddle (2015), so possibly the lower density of coconut trees in Singapore today may have drawn the insects instead to other palms, such as *Bismarckia nobilis, Lodoicea maldivica* or *Latania verschaffeltii,* suggesting a hierarchy in the insects' preference that could be density dependent.

The worst pest of palms at the SBG, however, and one for which we do not yet have a cure, are squirrels. These ravenous creatures attack all kinds of palms, especially those with a crownshaft, which they bite through to get to the juicy palm "cabbage." Certain species, *Roscheria melanochaetes* for example, despite being covered in spines, have been difficult to establish outside of the security of the nursery. Constant vigilance and adaptive measures to protect such species are necessary if they are to be included in the collection. We are exploring various methods of such protection including wire mesh cages around small palms. New plantings are usually done at some distance from other palms, reducing "springboard" possibilities for squirrels, but other measures may need to be developed.

Conservation and direction

In the case of the SBG, as for many other gardens, the aspect of a pleasure garden also featured in the reasoning for their establishment. Over the years pleasure merged with economic plant exploration and botanical research as primary objectives. Ridley and others led the SBG toward playing a major role in advancing the region's agriculture, as had been the original objective by the Agri-Horticultural Society. Staff at the SBG advanced the botanical study of palms and made the information available to a wider audience, culminating in Furtado's numerous palm papers in the *Gardens' Bulletin Singapore* and influencing Corner's *The Natural History of Palms* (1966).

In a speech by Holttum in 1984, subsequently published in the *Gardens' Bulletin,* the role of a botanic garden was summarized: "A botanic garden is essentially a museum of living plants.

The word 'museum' is derived from the name of the Greek goddesses of learning and the arts; thus a museum is a place devoted to the pursuit of such studies. A botanic garden is primarily a place where plants are grown for scientific study. But a garden differs from a museum in the fact that the objects in it are living and growing, and thus need the attention of horticulturists. Horticulture is in part applied botanical science: but it is also in part an art, and the aesthetic aspects of horticulture therefore find expression in any garden..." (Holttum 1999).

Over the last three decades, forest cover in large parts of Southeast Asia has disappeared dramatically. Ironically one of the major drivers of deforestation and loss of palm diversity is the exploitation of another palm for commercial use, the oil palm. Since the 1980s the total area of land allocated to oil palm has more than tripled globally, exceeding 14 million hectares in 2007 (Sheil et al. 2009). The understanding of palms, both horticultural and scientific, is thus more important than ever, if this family of plants is to remain as diverse in the region in the future as it is today. The traditional purpose of education and display in botanic gardens has increased once more, to focus on sustainable land use, climate change, public engagement and most importantly, *ex situ* plant conservation and public education. Where horticulture was once evolving around the "aesthetic aspects" of a garden, it must now focus on the applied botanical science – working out practical methodologies such as propagation protocols to facilitate plant cultivation outside their natural habitat, thus preventing them from becoming extinct. Studies have shown that temperate botanic garden collections do not adequately reflect palm conservation priorities because of the lack of genetic diversity represented in their collections, or simply the inability to house such large plants inside a glass house (Maunder et al. 2001). Space constraints are much less a problem in the tropics, where palms can be grown outdoors. In order to encourage the ultimate recovery of threatened palms by means of reintroduction of garden-grown stock, the most effective form of *ex situ* conservation programs have been identified as those that happen in-country (or at least within a region) and are linked with habitat conservation (Maunder et al. 2001). Thus the palm collection at the SBG has a function that far exceeds its mere grandeur; it is a fundamental starting point for *ex situ* conservation.

One priority of the SBG should be the conservation of those palms of the region, which are threatened with extinction, and to build a genetically diverse collection within the gardens. Equally important is the recording of horticultural methods and ecological data such as phenology or pollination behavior. These data could be effectively linked into living collections research and be made available to a wider audience or the scientific community. Such efforts must then be interpreted for the education of the public. Possibilities include, for example, the parallel use of Palm Valley as an event space, where also exists the potential to capture a wide audience, and educate and inspire them about our rich plant life. Our collection strategy now emphasizes assessing and evaluating the current collection in view of conservation purposes, and leading on from this, the planning of a coordinated collecting program, together with regional partners, to continue to study and conserve SE Asian palms. We have now arrived at a point in history, where the repertoire of expertise and intellectual property accumulated over the more than 150 years of SBG's history must be used to lead plant conservation activities more strongly and, at the same time, raise public awareness in our support. And what would lend itself better for such activities than one of the greatest palm collections in the world?

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Pneumatophores on *Acoelorrhaphe wrightii*

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1. Pneumatophores growing around an upright stem of *Acoelorrhaphe wrightii* at Fairchild Tropical Botanic Garden, Miami, Florida, USA. The white pneumatozones are visible.

Upward-growing (negatively geotropic) roots were recently observed in both cultivated and wild individuals of *Acoelorrhaphe wrightii*, a rhizomatous wetland palm. Upward-growing roots occur in the vicinity of the rhizomes and arise from horizontal roots. These upward-growing roots usually grow 2–5 cm above the soil surface and are 3–7 mm diameter. They have white bands or sectors that are similar to pneumathodes described on pneumatophores of other palms (Yampolsky 1924). Morphological and anatomical study supports the conclusion that upward-growing roots are pneumatophores.

Pneumatophores are erect aerial roots and are very common in palms growing in swampy conditions (Tomlinson 1990). In swampy conditions, the soil is often waterlogged and deficient in oxygen making it is difficult for roots to respire (Vartapetian & Jackson 1997). In order to overcome this deficiency, some roots are able to project above water surface of flooded soil (Esau 1977). These erect, aerial roots are called pneumatophores and it is presumed that the pneumatophores aid in gas exchange (de Granville 1974, Tomlinson 1990). Pneumatophores are often second order roots that arise from first-order, underground roots (Tomlinson 1990).

Upward-growing roots that resemble pneumatophores were recently found in *Acoelorrhaphe wrightii* (Griseb. & H. Wendl.) H. Wendl. ex Becc., commonly called paurotis or Everglades palm. *Acoelorrhaphe wrightii* grows abundantly around the Caribbean basin, mostly in seasonally or constantly flooded habitats, and is widely cultivated in the tropics and subtropics (Dransfield et al. 2008, Meerow et al. 2001). *Acoelorrhaphe wrightii* is a multi-stemmed palm that creates large, circular clumps through rhizomatous branching. Prolific root formation occurs along the rhizomes.

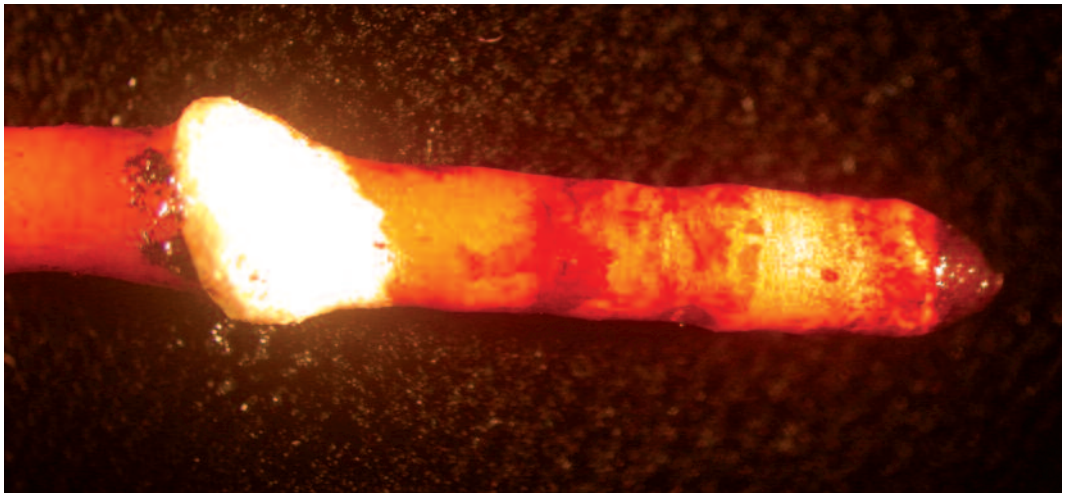
Upward-growing roots were observed on *A. wrightii* first at Fairchild Tropical Botanical Garden and Montgomery Botanical Center, on plants growing in Everglades National Park, and on saplings growing in a mesocosm (large tanks that simulate the Everglades ecosystem on small scale) for a developmental study. These upward-growing roots were found in all observed clumps of *A. wrightii*, both in the wild and in cultivation (Fig. 1). Since they were present in both wild and cultivated individuals these roots are most likely an early adaptation to its wetland habitat that become a typical morphology for the species.

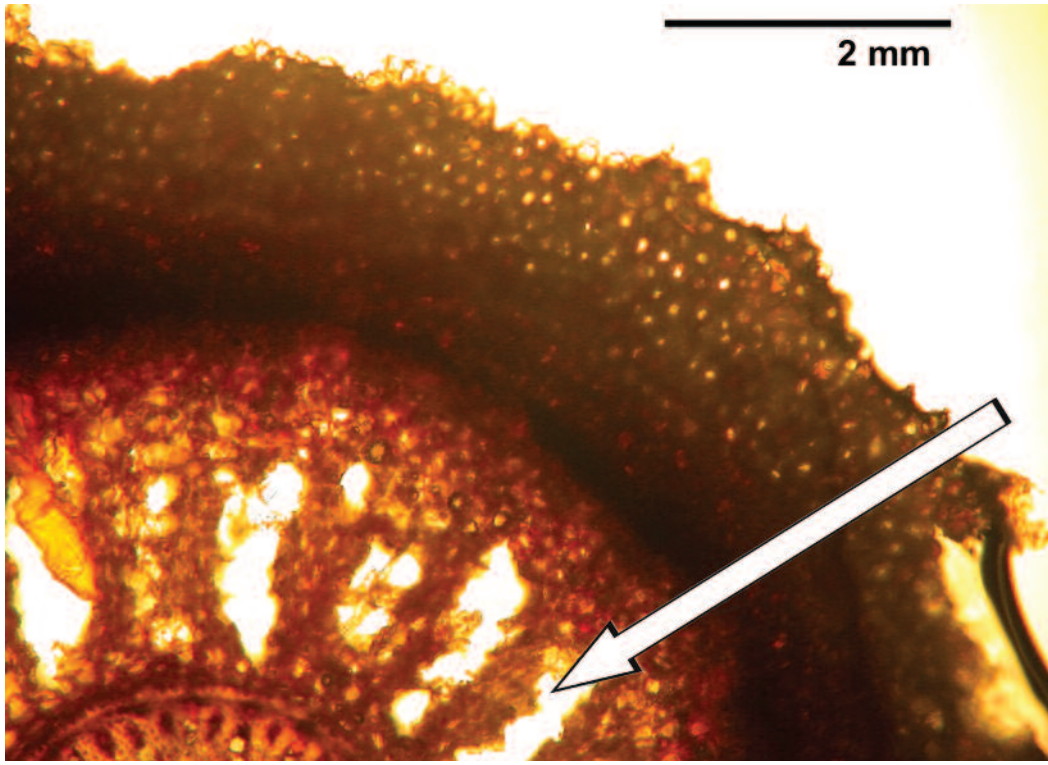
Upward-growing roots are found up to 0.15 m away from the nearest rhizome, mostly on or near the rhizomes. The upward-growing roots initiate from horizontal roots, not directly from the rhizome. Upward-growing roots are commonly between 3–7 mm diameter, which is often smaller than parent roots, and can grow vertically to 2–5 cm above soil level. They have 1–4 white bands or localized sectors that occur around the circumference (Figs. 1 & 2). Upward-growing roots generally do not occur singly, but their density is variable. They are found both sparsely and densely distributed around a rhizome.

Anatomical analysis has shown that upward-growing roots have large air channels (Fig. 4) and pneumathodes (Figs. 2 & 4). The air channels form a longitudinal system that is located in the inner-cortex (Figs. 3 & 4) (Tomlinson et al. 2011). These air channels are aerenchyma tissue and enhance gas exchange in the roots (Tomlinson 1990).

It is not surprising that pneumatophores are present on *A. wrightii* since most wetland palms have this morphological feature and it is common in Coryphoid palms. However, the pneumatophores are very well developed in *A. wrightii*, unlike most Coryphoid relatives. *Serenoa repens*, sister to *A. wrightii*, has second and third-order roots that are upward growing (negatively geotrophic) but do not project

2. A. Pneumatozone (white band) on upward-growing root of *Acoelorrhaphe wrightii*. Root cap to right.



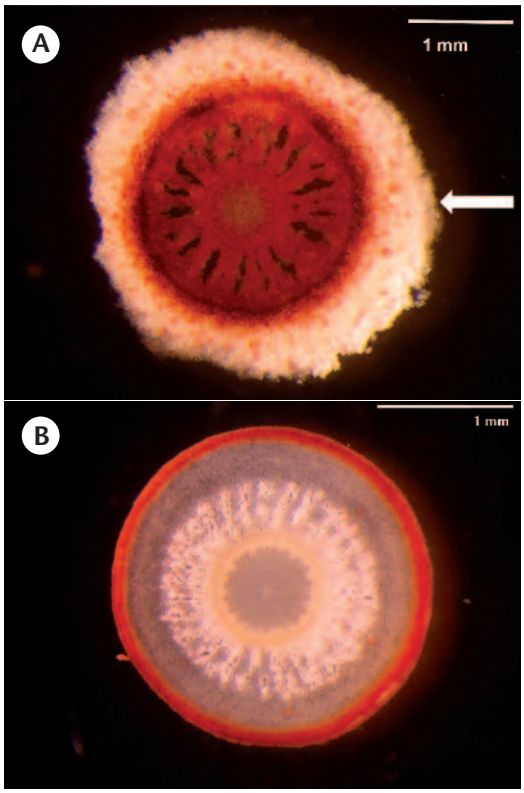


3. Cross-section of upward-growing root. Arrow points to large air channels in the inner cortex; vascular stele occupies interior of root, while loose pneumatozone tissue occurs in the outer cortex and displaces the epidermis.

above the soil (unlike *A. wrightii*) (Fisher & Jayachandran 1999). They do not aid in gas exchange (are not pneumatophoric) but instead have arbuscular mycorrhizal fungi that facilitate nutrient uptake. The upward-growing roots of *A. wrightii* are also quite distinct from other Coryphoid relatives. In most Coryphoid palms, pneumathodes exist in their simplest state as mealy excrescences on the surface of seemingly normal roots (Tomlinson 1990). But, the pneumathodes in *Acoelorrhaphe wrightii* have expanded to create white bands or sectors around the pneumatophore, called pneumatozones (de Granville 1974). Pneumatozones are localized regions on the erect root that have specialized modifications that assist in gas exchange (Jost 1887, Yampolsky 1924). The mealy white bands and localized white sectors on the upward-growing roots of *Acoelorrhaphe wrightii* are similar in morphology to pneumathodes described in *Elaeis* and *Livistona* (Jourdan & Rey 1997, Yampolsky 1924) and resemble the pneumatozones described in *Mauritia flexuosa* (de Granville 1974). The pneumatozones of *A. wrightii* appear to develop from exodermis (under the epidermis) outer cortical region of the root. The outer cortex is parenchymatic in regions of the upward-growing root lacking pneumathodes (Fig. 4). These pneumatozones were observed on first-order roots and well as upward-growing roots.

The upward-growing roots of *A. wrightii* have all the common characteristics of pneumatophores including an upward-growing habit, presence of pneumathodes, pneumatozones and/or pneumatorhiza, and presence of aerenchyma tissue. Pneumatophores are well-documented in a number of other palms: *Livistona australis* (Jost 1887), *Raphia hookeri* and *Phoenix reclinata* (Jeník 2008), *Elaeis guineensis* (Jourdan & Rey 1997, Yampolsky 1924), *Metroxylon sagu* (Flach 1997), *Euterpe oleracea* (de Granville 1974) and *Mauritia flexuosa* (Balslev et al. 2011). Pneumatozones are also present on pneumatophores of *Mauritia*, *Raphia*, *Metroxylon*, *Livistona* and *Phoenix* (de Granville 1974).

Anatomical and morphological work supports the conclusion that the upward-growing roots observed in *Acoelorrhaphe wrightii* are pneumatophores. The pneumatophores, with their pneumathodes, pneumatozones and large air channels, are likely an adaptation to this palm's semi-aquatic environment.



4. Cross-section of upward-growing root in pneumatozone (A) and in region of root without pneumatozone (B). Arrow points to pneumatozone, which forms in the outer cortex of the root; air channels form radiating dark discs in inner cortex.

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Flowering of *Carpoxylon macrospermum*, a Critically Endangered Palm, in the Townsville Palmetum, Australia

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In October 2014, the critically endangered palm *Carpoxylon macrospermum* growing in the Townsville Palmetum, Queensland, Australia, flowered for the first time, an event that had been much anticipated since the species first entered the collection in 1989. We provide a broad outline of the botanical history, cultivation and conservation of this species, as well as details about its occurrence in the Palmetum collection.

The Townsville Palmetum, in Queensland, Australia (latitude 19°S; elevation 25 m above sea level; seasonally dry tropical environment), has one of the largest and most diverse public collections of palms in the world (Dowe 2005, 2011). One of the design criteria for the collection is to display individual palm species in groups or avenues, demonstrating the inherent variability of the species and its landscape/ecological function. Among the many palm avenues in the Palmetum is one composed of the critically endangered species *Carpoxylon macrospermum* H. Wendl. & Drude (Fig. 1). The definition of a critically endangered species is described in the International Union for the Conservation of

Nature and Natural Resources' *Red List* as: *A taxon that is facing an extremely high risk of extinction in the wild in the immediate future* (IUCN 2014). The Palmetum collection holds a large number of threatened, rare or endangered palm species. The value of *ex situ* conservation of such palm species, in particular those species that are threatened through habitat loss, has been examined in regards to public collections, and it has been found that the best outcomes involve a combination of habitat protection and *ex situ* projects (Maunder et al. 2001).

Carpoxylon macrospermum is endemic to Vanuatu, an archipelago of over 80 islands in the southwest Pacific Ocean lying northeast of New Caledonia and west of Fiji. The southern islands of Vanuatu, where *C. macrospermum* occurs naturally, have some of the most altered habitats in the archipelago and have experienced significant forest loss in recent times. Regrettably, there is a local, pervasive attitude that habitat protection is not a viable option in Vanuatu because of the implications of traditional land ownership, and that *ex situ* conservation, such as in the Palmetum and other botanic gardens, may be the only practicable, long-term option for preserving endangered species. Presently, the species is not being actively protected in Vanuatu, and the initial enthusiasm of the 1990s for local conservation has waned (Palm Specialist Group 2015). Therefore *ex situ* conservation of this species has become increasingly important.

As a result of thorough field-work undertaken in 1994 throughout Vanuatu, the known population of *C. macrospermum* at that time was estimated to consist of fewer than 200 mature individuals of which only about 30 mature individuals occurred in undisturbed rainforest in Vanuatu's southern islands of Tanna, Aneityum and Futuna, the majority as cultivated individuals or small groups in villages throughout the whole of Vanuatu (Dowe et al. 1997). The palm is cultivated as it has a number of local uses, though primarily in the fabrication of durable brooms from the dried leaves (Dowe 1996). At one time the species was thought to be extinct (Hodel 1982), but was serendipitously rediscovered whilst one of the authors (JLD) was preparing an

1. The avenue of *Carpoxylon macrospermum* lining the Carl von Martius Way in the Townsville Palmetum, Australia, April 2015. Photo by J.L. Dowe.

account of the palm flora of Vanuatu (Dowe 1989). Because of the palm's rarity it became the subject of a number of conservation projects in Vanuatu (Devoe 1994, Fry et al. 1998), and a program of seed collection and global distribution was established, based at a "village economy" level (Fry et al. 1997). Through those efforts, the species is now relatively frequent in cultivation, in both public and private collections, and has proved amenable to horticulture in tropical climates. It has been flowering and fruiting for a number of years in many locations including Thailand, Hawaii, Florida and Australia.

The habit and flowers of *C. macrospermum* remained unknown to botanists until 1987, as the species was known only by illustrations of fruits and seeds that were collected on the island of Aneityum (also known as Anatom) by the naturalist John MacGillivray in the 1850s. The original diagnosis of the species consisted only of a brief description of the fruit and seed, with an accompanying illustration (Wendland & Drude 1875). The MacGillivray fruits and seeds were later found in the British Museum herbarium (Zona 1995), somewhat as serendipitously as the palm was rediscovered in the wild, when research for a revision of the genus *Veitchia* was being conducted. The fruits and seeds had been incorrectly placed among the *Veitchia* specimens. Based on wild collected specimens, the flowers were first diagnostically described and illustrated in 1989 (Dowe & Uhl 1989), allowing the affinities and relationships of the taxon to be established: *Carpoxylon* is a monotypic genus and its closest relatives are *Neoveitchia* and *Satakentia* (Dransfield et al. 2008). Flowers and fruits of the Palmetum palms are presented here in Figures 2–4.

Carpoxylon macrospermum is the second palm species to grace the long curving pathway in

2 (top). Males flowers of *Carpoxylon macrospermum*. 3 (bottom). Female flower of *C. macrospermum*. Photos by J.L. Dowe.

4. Full-size but immature fruit of *Carpoxylon macrospermum*. Photo by J.L. Dowe.

5 (above). Avenue of *Caryota no* in about 1997, the original palm avenue along Carl von Martius Way. 6 (below). The *Caryota no* avenue after Cyclone Tessi (Category 2) in April 2000. Photos by J.L. Dowe.

the Townsville Palmetum that is part of the Carl von Martius Way since its opening in 1988. The first was an avenue of *Caryota no* Becc., one of the largest solitary-stemmed representatives of that genus. They were planted in 1987, and by 1999 had begun to reach maturity (Fig. 5). Being monocarpic, the flowering palms began to draw on the carbohydrate reserves in their stem for flower and fruit production, slowly weakening the structural integrity of the stems. Consequently, a number of the weakened palms were toppled during Tropical Cyclone Tessi in 2000 (Fig. 6). As the remaining Caryotas in the avenue were showing signs of collapse and deterioration, they were all removed soon after, and the avenue remained palm-less for a number of years.

The first accession of *C. macrospermum* into the Palmetum collection occurred in 1989, with later accessions in 1990, 1992, 1994, all as ungerminated seeds that were collected from cultivated palms in Vanuatu, and in 2006 as established seedlings from a commercial palm business. All individuals from these accessions were correspondingly nurtured as pot plants in the Anderson Gardens Conservatory nursery until large enough to be planted in the ground. The first in-ground plantings occurred in

7 (left). *Carpoxylon macrospermum* in the Palmetum Rainforest section, February 2005. Photo by J.L. Dowe. 8 (right). Same plant of as in figure 7, May 2015. Photo by Nadia Snajder.

February 1995, when four individuals were planted within the Tropical Rainforest Section in the vicinity of the Carl von Martius Way bridge (Fig. 7, Fig. 9, palms 38–41). Although now 25 years old, as of August 2015 (Fig. 8), none of these four individuals has yet to flower. We presuppose that *C. macrospermum* requires exposure to strong sunlight to initiate flowering regardless of age.

The *C. macrospermum* avenue was established in two phases, with 24 individuals planted in 2004, and another ten individuals in 2006 (Fig. 9, palms 1–34). The substrate conditions along the length of the avenue are variable with regard to soil compaction, irrigation reach and water penetration into the soil. Accordingly, there has been considerable variation in growth rates and robustness of individuals in the avenue (Fig. 1). Two individuals were replaced in 2006/07 after they perished of an unknown cause. In 2014, another two were replaced when they succumbed to what was diagnosed at the time as palm weevil infestation and fungal attack respectively. In addition, another three individuals were planted in the nearby "Pandan Wangi Gully," thus bringing the total of individuals in the Palmetum to 41 (Fig. 9, palms 35–37).

An examination of Table 1 indicates that the palms in the shaded Tropical Rainforest Section (Fig. 9, palms 38–41), planted in 1995, had considerably less biomass than those in the open environment of the avenue, planted in 2004/2006, despite being in the ground for about nine years longer. The average height of the four Carpoxylons in the Tropical Rainforest Section is 595.5 cm (the avenue is 664.5 cm); the average DBH of the group is 44.5 cm (the avenue is 64.7 cm) and the average basal diameter of the group is 131 cm (the avenue is 170.4). This extrapolates to a comparative biomass increase of about 21% in the avenue individuals compared to those in the shaded Tropical Rainforest Section. Horticulturally, this suggests that optimal growth for the species is best achieved in open sunny environments.

As of May 2015, five individuals in the avenue had flowered, and two of these had produced mature fruits. An examination of the data in Table 1 indicates that the flowering individuals had all reached a height of at least 700 cm and the tallest to 852 cm. The average height of the avenue palms is 664.5 cm. It appears that there is an optimum height at which Carpoxylons begin to flower, this being about 700 cm or

9. Aerial view showing the locations of *Carpoxylon macrospermum* in the Townsville Palmetum. Numbers refer to 'Individual' column in Table 1. Map prepared by R. Lovatt and Asset Management Services, Townsville City Council.

Table 1. Dimensions, planting history and flowering/fruiting of *Carpoxylon macrospermum* in the Townsville Palmetum, recorded May 2015. See Figure 9 for locations of individual palms.

Individual	Clear trunk [cm][1]	Crownshaft + leaves[cm][2]	DBH[3]	Basal diam. [cm][4]	Year planted[5]	Flowered/ fruited[6]
1	107	337	>DBH: 53	131	2004	
2	335	500	67	184	2004	
3	180	422	70	179	2004	
4	392	458	71	185	2004	Fl/Fr
5	177	383	60	171	2004	
6	310	477	76	174	2004	Fl
7	158	345	56	147	2004	
8	140	414	66	169	2004	
9	102	331	44	144	2004	
10	0	240	0	49	2014	
11	136	354	80	186	2004	
12	293	427	64	184	2004	
13	171	380	79	185	2004	
14	247	522	67	183	2004	
15	149	332	52	152	2004	
16	218	477	64	172	2004	Fl
17	180	441	62	164	2004	
18	310	542	71	184	2004	Fl
19	218	486	66	178	2004	
20	327	569	70	184	2004	Fl/Fr
21	256	404	63	171	2004	
22	422	570	71	177	2004	
23	245	492	64	171	2004	
24	88	460	>DBH: 53	150	2004	
25	245	392	65	170	2006	

greater. It is also evident that those individuals that have flowered are growing on the more exposed side of the avenue, in locations where overhead shading, cast by *Samanea saman* (raintrees), is less than in other locations along the avenue (Fig 9, *S. saman* indicated).

The Carpoxylons in the Palmetum have proven hardy to moderate drought and temperatures occasionally dropping to 10°C, although better suited to an increased watering regime and quarterly applications of fertilizer. The species displays no major nutrient deficiencies or tendency for any pest problems. As with the entire palm collection, the *Carpoxylon* avenue receives an annual application of palm weevil borer spray.

Ideally, *ex situ* conservation programs should attempt to include as broad as possible sampling of genetic diversity of the subject species. It is known that all the plants of *C. macrospermum* in the Palmetum were collected from cultivated specimens, though from a number of parent palms in different localities. The origin of the parent palms of the cultivated individuals is not known, but it is highly suspected to be from nearby cultivated palms, thus suggesting that genetic diversity may be limited. This proposal was confirmed by Dowe et al. (1997), who examined the genetic diversity within 19 collections of both cultivated (n=15) and naturally occurring individuals (n=4) and concluded that diversity was extremely low within the cultivated samples but higher in the natural samples. It would be advantageous to collect representatives from the entire known range of *C. macrospermum*, both natural and cultivated individuals, to have a truly representative *ex situ* collection.

The flowering and fruiting of *C. macrospermum* in the Townsville Palmetum represents a

Table 1. continued.

Individual	Clear trunk [cm][1]	Crownshaft + leaves[cm][2]	DBH[3]	Basal diam. [cm][4]	Year planted[5]	Flowered/ fruited[6]
26	134	450	56	163	2006	
27	147	394	52	153	2006	
28	211	476	64	179	2006	
29	93	443	>DBH: 48	140	2006	
30	99	443	59	146	2006	
31	0	213	n/a	46	2014	
32	50	427	>DBH: 45	121	2006	
33	36	368	n/a	120	2006	
34	82	367	42	127	2006	
35	0	190	n/a	34	2014	
36	0	287	n/a	51	2014	
37	0	189	n/a	51	2014	
38	62	423	>DBH: 38	105	1995	
39	158	382	43	128	1995	
40	190	470	48	145	1995	
41	243	454	49	146	1995	

[1] From ground-level to the attachment of the crownshaft.
[2] From base of the crownshaft to the highest vertical extent of the leaves.
[3] DBH = diameter at breast height; >DBH being that the measurements were taken below breast height, which in this case was set at 137 cm.
[4] Basal diameter was measured 2–4 cm above ground-level.
[5] Does not indicate age; it is the year in which the individual was planted in the ground.
[6] These individuals first flowered in October/November 2014.

significant milestone in the history of the collection and is a demonstration of the relative ease with which this species can be grown in botanic gardens and induced to flower and fruit in a moderate time frame with normal levels of maintenance and care. Under the Palmetum conditions, flowering has occurred within ten years of planting. The other Carpoxylons known to have flowered and fruited in other areas of the world also occur in tropical climates, in Hawaii, Thailand and southern Florida. Growth rates and horticultural adaptation to sub-tropical or warm temperate climates is presently not known.

If the shortcomings in genetic representation are considered, the collection of *C. macrospermum* in the Palmetum represents an integral part of the *ex situ* conservation of the species, as records have been kept related to collection, propagation and cultivation. The value of the Palmetum collection is inherently important for conservation of the species, considering the current situation in Vanuatu.

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Jean-Christophe Pintaud (1960–2015)

Henrik Balslev

"Death is a thief," as the African proverb says. Just last year, death stole one of the most eminent palm scientists, Jean-Christophe Pintaud, researcher at the Institute de "Recherche pour le Développement" (IRD). JCP, as he was affectionately called, was a palm-lover ever since he was a boy, when he used to sell seeds of *Washingtonia robusta* to make some extra pocket money. His love of palms was contagious, spreading quickly to people who took the time to listen to him, from students to scientists. Jean-Christophe had me hooked on palms after our first meeting back in 2001. He was what I call a true naturalist, a rare breed of person nowadays who has an encyclopedic knowledge of the natural world from botany to astronomy. Jean-Christophe had an acute sense of observation, a vital quality for a palm researcher, in my view. He knew palms inside out, from the ecosystem they lived in to the DNA molecules that made them. He was also very much involved in getting palm people from different fields to work together, being one of the founders of the

European Network of Palms Specialists (EUNOPS) that has met every year for the past 14 years.

Jean-Christophe undertook his university studies first at the de Université de Nice-Sophia Antipolis in southern France, then at the Université de Toulouse and finally at the Universities of Paris-Jussieu et Paris-Orsay where he graduated in Ecology in 1993. During his masters, he studied the ecology of palms in the far away and isolated island of New Caledonia where he spent four months in 1994. He then had the opportunity to return there as a Technical Volunteer between 1994 and 1996 where he continued his studies the ecology of New Caledonian palms. From 1996 to 1999 he undertook his PhD entitled "Phylogeny, biogeography and ecology of New Caledonian palms," for which he received great honors. This led to the publication of the important and still central piece of work "Palms of New Caledonia," co-authored with Don Hodel in 1998, in which they described five new species endemic to the island. During his post doctoral years he expanded his expertise by learning techniques of molecular biology at the Royal Botanic Gardens, Kew (UK) and the University of Washington (US). It is during that time that he first travelled to Ecuador and discovered the huge diversity of Neotropical palms.

In 2000, Jean-Christophe was recruited at the IRD, where he, naturally, initiated a research program on Neotropical palms. He always took multidisciplinary approaches to the study of palms, using molecular biology, phylogeny, anatomy, phytochemistry and taxonomy to answer the questions at hand. He was mainly interested in understanding patterns in speciation across the region using large species complexes such as *Astrocaryum* or the subtribe Bactridinae as models. He lived in Ecuador from 2003 to 2007, where he undertook numerous field trips collecting and observing. These trips, of course, allowed him to gain an incredible and unique understanding of palm species of the region. He had a deep understanding of the taxonomy and ecology of complex palm genera such as *Astrocaryum*, *Attalea* and *Bactris*. In parallel, he was also interested in the economic value of palms and started programs on the origins of domestication and genetic dynamics of certain economically important species such as *Bactris gasipaes* (the only truly domesticated palm of the Neotropics), *Oenocarpus bataua, Euterpe edulis* and several *Ceroxylon* species. More recently he was involved in a new project looking at domestication genetics of the pacaya palm (*Chamaedorea tepejilote*). He was also deeply involved in understanding the genetic diversity and domestication origins of the date palm (*Phoenix dactyliefera*), and numerous subsequent publications have slowly unraveled the complex history of the important palm. His research in date palm genetics earned him the distinction of "Cavaliere delle Palme" in 2008 by the *Phoenix*-dominated town of San Remo in Italy. Finally, Jean-Christophe continued his long lasting interest in New Caledonian palms, undertaking more in depth phylogenetic studies mainly of the subtribe Archontophoenicinae.

The most striking aspect of JCP's research was his ability to build long lasting and solid collaborations with South American institutes in for example Colombia, Ecuador or Peru, as well as in other countries such as Algeria, Tunisia, Pakistan and Djibouti. He was appointed invited professor at the Pontificia Universidad Católica del Ecuador and honorary professor at the Universidad National Mayor San Marcos and Universidad Nacional Toribio Rodríguez de Mendoza, both in Peru.

His involvement with other institutes is reflected in the vast number of students he has trained and supervised, especially from South America, northern Africa, Pakistan and Europe. Most of these now have permanent positions in their universities or institutes of origin. Jean-Christophe has been a scientific mentor to many of the new generation of palm researchers, including myself, and his premature disappearance has robbed the next generation of palm students of his passion, skills and kindness. Jean-Christophe described himself recently as a "fous de palmier," but I think he was more than that; he lived through palms. We lost a friend, a colleague and mentor, and he will be greatly missed.

Thomas Couvreur

Photo Feature

Nephrosperma van-houtteanum, in fine fruit, photographed in Mauritius by IPS member Urmas Laansoo from Estonia.

Watkins Munro Martin Conservatory, Cairns Botanic Gardens, Queensland, Australia

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1. Front view of the Watkins Munro Martin Conservatory, September 2015.

Watkins Munro Martin Conservatory in Cairns, Queensland, Australia, was opened in September 2015. The design of the structure uses a *Licuala ramsayi* leaf as its inspiration. The conservatory houses a substantial collection of rare plants featuring understory tropical palms, aroids, bromeliads, cycads, ferns, *Nepenthes*, pandans and orchids.

On 4 September 2015, the Watkins Munro Martin Conservatory (Fig. 1) at the Cairns Botanic Gardens, Queensland, Australia, was officially opened by the Mayor of Cairns, Councilor Bob Manning OAM. The new conservatory replaces two adjoined structures,

which had previously occupied the site – the Munro Martin Fernery and the George Watkins Orchid House. Both of these structures were modest and inadequate to display the gardens' growing collection and provide the best experience to the increasing number of visitors. After many cyclones, and the impact of tropical conditions on building materials, the orchid house and fernery were, by the late 1990s, starting to show signs of structural breakdown, which would necessitate their complete rebuilding. Their replacement was

2 (top). Internal view of the Watkins Munro Martin Conservatory, with *Licuala cordata* in the foreground. 3 (bottom). The roof is supported on steel girders, the longest to 20 m. The central pillar (in left of picture) is offset at an angle of about 5° to give the effect of a *Licuala* leaf.

Table 1. Palm species in the Watkins Munro Martin Conservatory, Cairns Botanic Gardens, Queensland, Australia, in September 2015.

Arenga caudata
Arenga hookeriana
Calyptrocalyx hollrungii
Calyptrocalyx laxiflorus
Calyptrocalyx micholitzii
Calyptrocalyx multifidus
Calyptrocalyx pachystachys
Calyptrocalyx yamutumene
Calyptrogyne ghiesbreghtiana
Carpoxylon macrospermum (at entrance outside)
Drymophloeus sp. 'Patipi'
Dypsis pinnatifrons
Dypsis poivreana
Geonoma macrostachys (as *G. atrovirens*)
Geonoma epetiolata
Geonoma sp. [0120127]
Heterospathe trispatha
Hydriastele sp. 'Halmahera'
Hydriastele beguinii
Hydriastele cariosa
Iguanura sp. [0140031]
Iguanura spectabilis
Licuala cordata
Licuala mattanensis
Licuala orbicularis
Licuala platydactyla
Licuala ramsayi
Licuala sallehana
Licuala sp. 'pre-ati'
Licuala triphylla
Licula malajana
Linospadix albertisianus
Pinanga aristata
Pinanga chaiana
Pinanga disticha
Pinanga maculata
Pinanga ridleyana
Pinanga simplicifrons
Pinanga tomentella
Reinhardtia latisecta
Rhapis excelsa
Sommieria leucophylla

first suggested by the Friends of the Botanic Gardens in 2001. A concept plan was developed and funded by the Friends; however, because of budget constraints, no action could be taken. A master plan for the Botanic Gardens precinct placed priority on the provision of infrastructure such as a new Visitor Centre; however, in 2013 the Conservatory was successful in securing funding in the capital works program and Cairns Regional Council called for design concepts. The brief was to build a structure on the same footprint as the existing fernery and orchid house with some encroachment allowable into the nursery area to increase the overall size and function. The Conservatory was designed by Queensland-based architects, Gordon Gould Ipson.

Cairns Botanic Gardens are situated about 5 km north-west from the city center in the suburb of Edge Hill, and are administered and funded by Cairns Regional Council which is a local government entity. The area was originally developed as a recreation reserve in the 1870s, and the first ornamental gardens were created on the site in the 1890s (Dowe 2015). Since being officially designated as a Botanic Garden in the 1960s, the Gardens have grown into Australia's premier tropical public garden (Dowe 2011). The Gardens are among the most visited places in the city of Cairns, receiving about 300,000 visitors per annum, and are a major hub for cultural events in the city's calendar. There are a number of discreet gardens within the precinct, including Flecker Gardens (named after Hugo Flecker [1884–1957], surgeon, radiologist and naturalist in Cairns) in which the new conservatory is sited, the Fitzalan Garden (named after the gardener, Eugene Fitzalan [1830–1911], who originally developed the site in the 1890s), Centenary Lakes (establish in 1975 to celebrate the Cairns City Council centenary), and the Gondwanan Heritage Garden (which has an emphasis on the flora of Australia's Wet Tropics). Flecker Gardens is listed as a State Heritage Place on the Queensland State Heritage Register because of its historic, aesthetic and social values (EHP 2015). Approval was therefore required from the Queensland Department of Environment and Heritage Protection for the demolition of the fernery and orchid house and the construction of the new Conservatory.

The Munro Martin Fernery was constructed around 1968 after the Munro and Martin families donated money and a fern collection

4. Group of mature *Sommieria leucophylla*.

to the Gardens. The fernery was designed by Vince Winkle who was then the Director of Parks and Gardens 1967–82 (George 2009). A small pond at the entry and a circular pathway through a spectacular display of tropical plants was the highlight and memory of the Munro Martin Fernery for many people. The George Watkins Orchid House was constructed in 1991 and named in memory of George Ernest Watkins, a local businessman and orchid fancier. The Watkins' family donated his collection of orchids and anthuriums and the orchid house was built on part of the nursery space to showcase the orchid collection. Until this time orchids were also displayed in the Munro Martin Fernery, which was rapidly filling with rare plants as the collection grew.

The Cairns climate is tropical-monsoonal, with an annual rainfall of about 2000 mm (80 inches), and average temperature range 21–29°C (70–85°F]) (Weatherzone 2015). The Conservatory, therefore, does not require any heating but has an internal irrigation system

5. One of the group of flowering *Licuala sallehana*, with *Iguanura spectabilis* in the upper left.

that supplements natural rainfall. The area covered by the conservatory is about 650 m², the lowest roof point is at 4 m, the highest roof point to about 8 m and the internal volume is about 3900 m³. The Conservatory structure is based on the outline of the leaf of *Licuala ramsayi*, when viewed from above, and is almost circular (Fig. 2). A central pillar (the

6. *Licuala mattanensis*.

petiole) is off-set at an angle of about 5°, and supports 17 roof sections (the leaflets). Apart from the central pillar, the internal space is otherwise pillar-free. The primary roof supports are long metal girders, the longest to 20 m (Fig. 3). The roof is composed of three types of materials: 1) perforated aluminum panels with a shade rating of ca 50%; these act as

7. *Geonoma atrovirens*, a name now placed in synonymy with *G. macrostachys* (Henderson 2011).

walkways for maintenance, 2) tensioned shade-cloth with a shade rating of ca. 75%, and 3) a semi-clear waterproof membrane, Hiraoka PVDF 11, which was installed to enable controlled watering of the *Nepenthes*, tassel ferns and orchid collections, which are situated beneath these particular roof sections. The external walls are held on outward sloping

8. *Calyptrogyne ghiesbreghtiana*.

piles, which support the roof girders, and wall sections are covered with tensioned shade-cloth. The plantings are arranged in more or less discreet plant groups, including understory palms (Figs. 4–9; Table 1), aroids, bromeliads, ferns, *Nepenthes* and orchids, amongst others. A winding pathway loops through the garden beds and there is a 20 m^2 pond, almost in a

9. *Licuala orbicularis* (front) and *Hydriastele beguinii* (back).

central position, that displays emergent aquatic aroids and submerged plants. Plant name signage is unobtrusive, mainly limited to the species name but there are a few elaborate signs that include information such as geographical origin and family, and a few interpretive panels about the individual plant groups and butterflies. Local butterfly species

are an additional feature; the pupae are purchased from certified breeders in the area and released upon emergence into the Conservatory.

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The Watkins Munro Martin Conservatory is a major national contribution to the cultivation and display of rare tropical plants. In particular, the management protocol allows for regular rotation and additions to the display of understory tropical palms, of which the Cairns Botanic Gardens holds a globally significant collection.

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