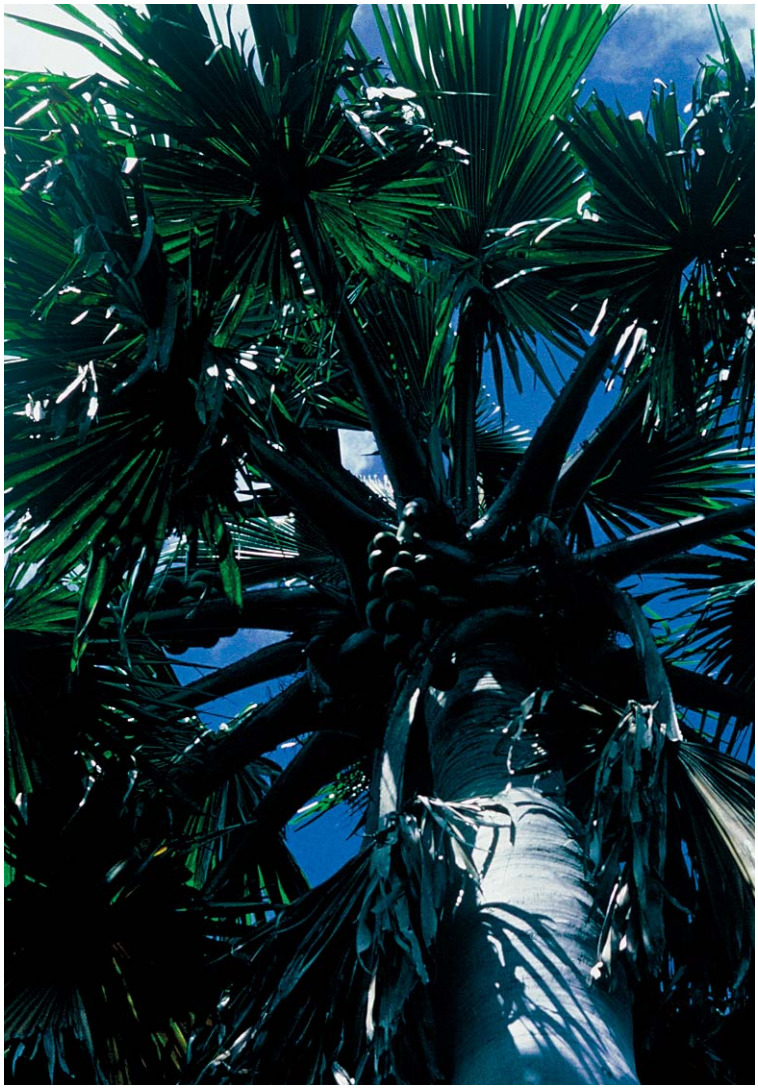
A Re-examination of *Borassus* in Madagascar

ROSS P. BAYTON
School of Plant Sciences, University of Reading, Whiteknights, PO Box 221, Reading, Berkshire, RG6 6AS, UK, r.p.bayton@reading.ac.uk
&
Royal Botanic Gardens, Kew, Richmond, Surrey, TW9 3AB, UK

CALEB OBUNYALI
East African Herbarium, National Museums of Kenya, PO Box 45166, Nairobi, Kenya

AND

ROLLAND RANAIVOJAONA
Herbier, Département Botanique, Parc Botanique et Zoologique de Tsimbazaza, B. P. 4096, Antananarivo 101, Madagascar



1. Female *Borassus aethiopum* growing by the Tana River in Coast Province, Kenya. Photo by J. Dransfield.

Due to the lack of adequate herbarium material, the taxonomic status of the two endemic species of *Borassus* in Madagascar has remained uncertain. This account reports the preliminary conclusions of a study aiming to resolve the issue, utilizing newly-collected specimens from Madagascar and Kenya.

The taxonomy of African *Borassus* L. (Corypheoideae: Borasseae) has been the subject of some controversy since the first African species, *Borassus aethiopum* (Fig. 1), was described by von Martius in 1838. Warburg was one of several authors to disagree with Martius. He sank *B. aethiopum*, recognizing it only as a variety of the Asian *Borassus flabellifer* (Warburg 1895).

However, almost 20 years later, the eminent palm botanist Beccari, published a monograph of the genus, in which he recognized *Borassus aethiopum* and *B. flabellifer* as separate and distinct species (Beccari 1914). In addition, he described a new species, *Borassus deleb*, from the Sudan, and also recognized two varieties within *B. aethiopum*: *B. aethiopum* var. *bagamojensis* from East Africa and *B. aethiopum* var. *senegalensis* from West Africa. In 1986, Dransfield sank Beccari's new species and varieties recognizing only *Borassus aethiopum* Mart. in East Africa (Dransfield 1986a).

The taxonomy of *Borassus* in Madagascar has been no less contentious. *Borassus madagascariensis* was first published by Bojer in 1837, thus predating *B. aethiopum* by one year. However, no type was cited and there was no description of the plant, thus rendering the name illegitimate. In 1907, the French botanists Jumelle and Perrier de la Bâthie described the species as a variety of *Borassus flabellifer*, but later elevated it to species-level in *Palmiers de Madagascar* (Jumelle & Perrier de la Bâthie 1913). They provided a full description of the plant (but no type), and so, inadvertently, validly published the species, which they had attributed to Bojer. This is the reason why *Borassus madagascariensis* (Jum. & H. Perrier) Bojer ex Jum. & H. Perrier revels in such a long author citation!

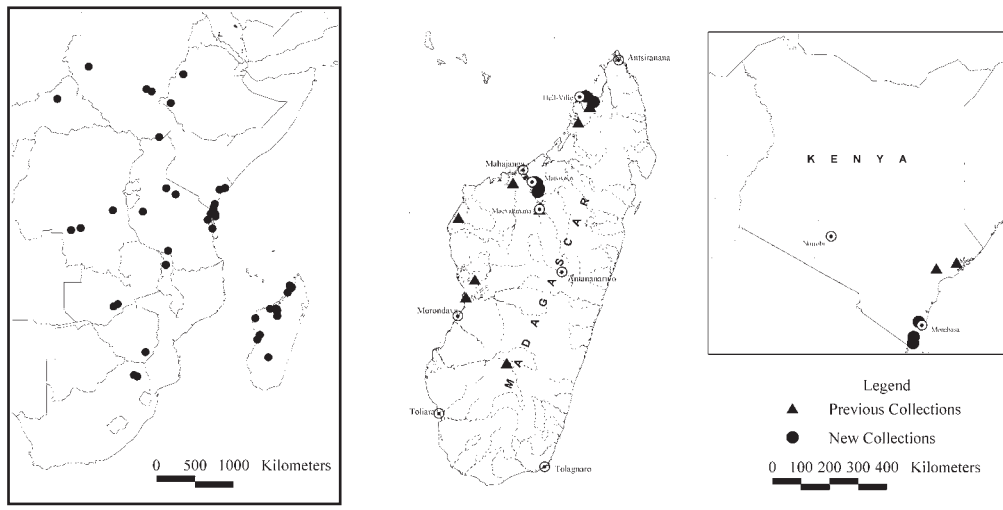
In addition to *B. madagascariensis*, Jumelle and Perrier de la Bâthie described a second endemic species of *Borassus*. The new species, which they named *Borassus sambiranensis*, was restricted to the area between the Sambirano and Ifasy rivers in the north-west of Madagascar (Jumelle & Perrier de la Bâthie 1913).

Palmiers de Madagascar (1913) and the later palm volume of the *Flore de Madagascar et des Comores* (Jumelle & Perrier de la Bâthie 1945) were superseded by *The Palms of Madagascar* (Dransfield & Beentje 1995), which described all of the species and genera of palms on the island, yet *Borassus* remained enigmatic. The limited herbarium material available to the authors allowed for only a preliminary judgment as to the taxonomic status of *Borassus*. In their opinion, there were few morphological characters, which could be used to distinguish reliably either of the Madagascar taxa from *B. aethiopum* in mainland Africa (Dransfield & Beentje 1995).

Taxonomic confusion

Borassus is one of the most widely-distributed of palm genera, and can be found from the Atlantic coast of Africa in the west to New Guinea in the east. The continuing confusion over species delimitation is well demonstrated in the taxonomic history of the African taxa. Species have been recognized, then reduced to varieties, then sunk or recognized again as species, and there are a number of factors that have contributed to this uncertainty. There are considerable logistical problems associated with collecting *Borassus*. All material must be collected from a crown that may be 20 meters or more above the ground. The single

2. Previous herbarium collecions from eastern and southern Africa (left). Collecting sites in Madagascar (center) and Kenya (right).



3 (left). Caleb collecting a DNA sample of *Borassus aethiopum* outside Mazeras town, near Rabai, Kenya. 4 (right). Juvenile specimen of *B. aethiopum* in the Shimba Hills, Kenya. The dark petioles armed with large erose spines are characteristic of the species.

stem is smooth and ventricose with a belly which can reach a girth of over two meters. This prohibits many climbing techniques. The stems of younger, shorter palms are covered in old leaf-bases, which are armed with spines. Where access is possible, the material which is gathered is heavy and difficult to dry in the field. As a final deterrent, *Borassus* is dioecious, and so access must be gained to the crown of another individual of the opposite gender in order to collect complete material of a species.

Throughout much of its range *Borassus* is common, and very few collectors, even those who specialize in collecting palms, will make the effort required to collect a complete specimen of a large, common, widespread palm. Therefore, there are several parts of the range where there are few or no specimens in existence. In particular, Madagascar, West Africa and Indonesia are poorly sampled.

Another problem that has led to confusion in the taxonomy of *Borassus* is the lack of type specimens. The designation of a particular herbarium specimen as 'type' of a name only became obligatory in 1958. Many earlier authors did not specify a type specimen when publishing new taxa and the type must be inferred. The description of *Borassus aethiopum* was based on a specimen collected by Peter Thonning in Ghana but this has since been lost (Hepper 1976). Jumelle and Perrier de la Bâthie did not cite specimens when publishing *Borassus madagascariensis* and *B. sambiranensis* and no suitable material could be found in their collection in Paris.

Collecting in the field

The aim of this study is to assess the status of the species of *Borassus* in Madagascar on the basis of field observations and herbarium material. To that end, an expedition to Madagascar was organized in conjunction with the Parc Botanique et Zoologique de Tsimbazaza in Antananarivo. Fieldwork was completed by RPB and RR in March 2003. Herbarium material of *B. aethiopum* was collected during a prior expedition to Kenya, organized in conjunction with the National Museums of Kenya. This fieldwork was completed by RPB and CO in October 2002. The collecting sites of all specimens are shown in Figure 2.

The major aim of the fieldwork was to collect as much herbarium material as possible. Fieldwork also allows the investigator to observe the plants in the living state, photograph specimens to

5. The Shimba Hills population of *B. aethiopum* near Mivumoni.

6. Secondary school in Mivumoni. The sign shows *B. aethiopum* with the characteristic bulging stem, and two African Fish Eagles (*Haliaeetus vocifer*). The Swahili on the sign translates as "Endeavors bring success."

preserve perishable characters, and to collect additional data on distribution, ecology and conservation status. A secondary aim of the fieldwork was to collect plant samples for DNA extraction and analysis. This is often difficult or impossible to do from preserved herbarium specimens as DNA degrades with age, and with exposure to light and certain chemicals used as preservatives. The DNA samples collected in Kenya and Madagascar form part of a continuing project by RPB to investigate evolutionary relationships in tribe Borasseae.

Kenya

Borassus aethiopum in Kenya (Fig. 1) is primarily restricted to the humid coastal region, though it has been recorded near the Somali border in the arid north, and on the north shore of Lake Victoria (Beentje 1994). Three collection sites were chosen in Coast Province and these sites varied considerably. The first, Rabai (03°56'S, 39°33'E) (Fig. 3), was dominated by large areas of cultivated coconut and, though inconspicuous, *Borassus* appeared to be numerous. Despite the dense canopy of palm leaves above, several crops

including maize, cassava and pineapple were growing beneath. *Borassus* was generally ignored with the exception of one mature tree in which the trunk had forked producing two crowns. This specimen was venerated by village elders. In Asia, *Borassus flabellifer* is widely cultivated as almost all parts of the palm can be used for some purpose. This did not appear to be the case with *B. aethiopum* in Kenya, and the villagers in Rabai reported that the only useful part of the plant was the old leaf sheaths which made good firewood.

Further south by the Tanzanian border is the Shimoni peninsula (04º36'S, 39º23'E). Here it is possible to see five of Kenya's seven native palm species. *Borassus aethiopum* occurs in the company of *Hyphaene coriacea*, *H. compressa*, *Phoenix reclinata* and *Elaeis guineensis*. Domesticated *Cocos nucifera* is also present. The topography of the peninsula is deceptive. The palms (and *Borassus* in particular) are visible for long distances over the scrub vegetation. However, the terrain is uneven with coral limestone protruding from the soil, and the vegetation is dominated by two-meter tall *Hyparrhenia rufa* grass and introduced *Lantana camara*. A quick stroll towards some nearby palms rapidly becomes an unpleasant three-hour trek.

The third site was in the Shimba Hills although most of the palms lay outside the boundaries of the Shimba Hills National Reserve (Figs. 4, 5). This population is centered on the village of Mivumoni (04º24'S, 39º24'E), which is named after *Borassus* (or *mvumo* in Swahili) (Fig. 6). At this site, *B. aethiopum* grows in small river valleys and on some slopes to an altitude of 300 m. Despite the local connection with the palm, *Borassus* is unpopular. As a wild plant it has evolved several mechanisms which protect it from herbivory and fire damage, including spiny petiole margins and a long cotyledonary axis that buries the seedling in the soil. However, these survival mechanisms also make the palm difficult, if not impossible, to eradicate from agricultural land. The palms are rarely felled as the tough fibrous stem can cause considerable damage to axes and saws. A felled palm trunk is also a significant obstacle in its own right. The population of *B. aethiopum* in the Shimba Hills was the largest of the three populations observed in Kenya.

A fourth population of *B. aethiopum* is known to occur on the Tana River, near the town of Garsen (02º16'S, 40º07'E), and specimens were collected there by John Dransfield in 1975 (Fig. 1). However, the recent civil war in neighboring Somalia has, to some extent, spilt over into this part of Kenya and it was decided not to visit this population for safety reasons.

Madagascar

Borassus in Madagascar is thought to be entirely restricted to the west coast of the island. *Borassus madagascariensis* occurs in several river valleys in Toliara and Mahajanga Provinces while *B. sambiranensis* is restricted to the Sambirano Region in Antsiranana Province. To enable both species to be collected, two excursions were organized – the first to the city of Mahajanga and the second to Ambanja on the Sambirano River.

The last part of the road trip from Antananarivo (Tana) to Mahajanga follows the course of the Betsiboka River. The river, together with the coastal towns of Marovoay and Mahajanga were described by Bojer as the type locality for *B. madagascariensis* (Bojer 1837). The only herbarium material of *Borassus* from this part of Madagascar (collected in 1995 by Dr Larry Noblick of the Montgomery Botanical Center, Miami, USA) was collected near to the coast. Therefore, we were surprised to find a population of *Borassus* in the town of Maevatanana (16º56'S, 46º49'E), some 250 km inland (Figs. 7, 9, 11). The palms could be found growing in gardens and on the street but appeared to be 'tolerated' rather than cultivated. We returned to the town on our journey back to Tana to make a collection.

We found several isolated groups of *B. madagascariensis* along the course of our journey, including at Ankijabe village (16º24'S, 46º46'E) (Fig. 8), Lake Amboromalandy (16º08'S, 46º45'E) and at the Ampijeroa Forestry Station (16º18'S, 46º49'E) of Ankarafantsika National Park. However, the most significant population was in and around the town of Marovoay (16º06'S, 46º41'E) (Fig. 10). *Borassus madagascariensis* (or *dimaka* in the local Sakalava language) was growing in fields and gardens, but also in the center of town. Seedlings could be found growing through cracks in the sidewalk and in abandoned houses. Perhaps the difficulties involved in removing these palms (as discussed earlier) are the reason why they remain in public places. However, none of the sites where *dimaka* was found was free from human interference. Perhaps *Borassus madagascariensis* is a colonizer of disturbed habitats. Another possibility is that local people have influenced the distribution of this palm, though the Malagasy we encountered had relatively few uses for the palm.

Our second excursion took us by plane to the island of Nosy Bé off the north-west coast of Madagascar. From there we went by boat to the town of Ambanja (13º43'S, 48º23'E). Only two modern specimens of *B. sambiranensis* had been collected: one by Dr. George Schatz (Missouri

Table 1. Diagnostic characters for *Borassus* in Madagascar & East Africa.

Character	*B. madagascariensis*	*B. sambiranensis*	*B. aethiopum*
Petiole Color	Yellow along entire length	Yellow-orange distally, brown proximally.	Yellow distally, brown proximally.
Petiole Armature	Spines short (0.1–0.8 cm), erose to serrate (Fig. 18)	Spines long (1.2–2.4 cm), erose (Fig. 18)	Spines long (1.2–2.8 cm), erose (Fig. 18)
Fruit Apex Shape	Pointed.	Flattened or depressed	Flattened or depressed
Fruit Size	16–19 cm long × 15–16 cm diameter	7–13 cm long × 5–11 cm diameter	8–15cm long × 7–11 cm diameter

Botanical Garden) in 1988 near Ambanja; the other by Dr. Henk Beentje in 1992 near Maromandia. However, neither of these sites could be located.

There was some difficulty in identifying the palm when talking with local people. The name *dimaka* used further south was not always understood and we were often led on long detours only to find the related *Bismarckia nobilis*. Our first encounter with *B. sambiranensis* occurred during one of these detours when we noticed a juvenile palm in an abandoned field (Figs. 12, 13). It had heavily-armed petiole margins and was reminiscent of juvenile specimens of *B. aethiopum* in Kenya. Our local guides described it as *satranbe* which is the Sakalava word for *Bismarckia*. We spent seven days searching for *Borassus* both to the north and south of the Sambirano River. Our only other find was of a pair of male palms hidden within a group of trees.

On our return to Nosy Bé we discovered two very tall adult *Borassus* palms in the center of Hell-Ville town (13°24'S, 48°16'E)(Fig. 14). Both were growing in prime locations with a male tree in front of the mayor's office, and a female tree outside the central police station. This provided our only opportunity to collect material of the female palm, though due to its incredible height, we had to be satisfied with old flowers and infructescences from the ground beneath. An additional bonus was the discovery of a male specimen of *Lodoicea maldivica* flowering in the gardens of a Catholic mission (Fig 15). We were granted permission to make a collection which was fortuitous as no male herbarium material of this species exists at either Kew or Tana.

Collecting Methods

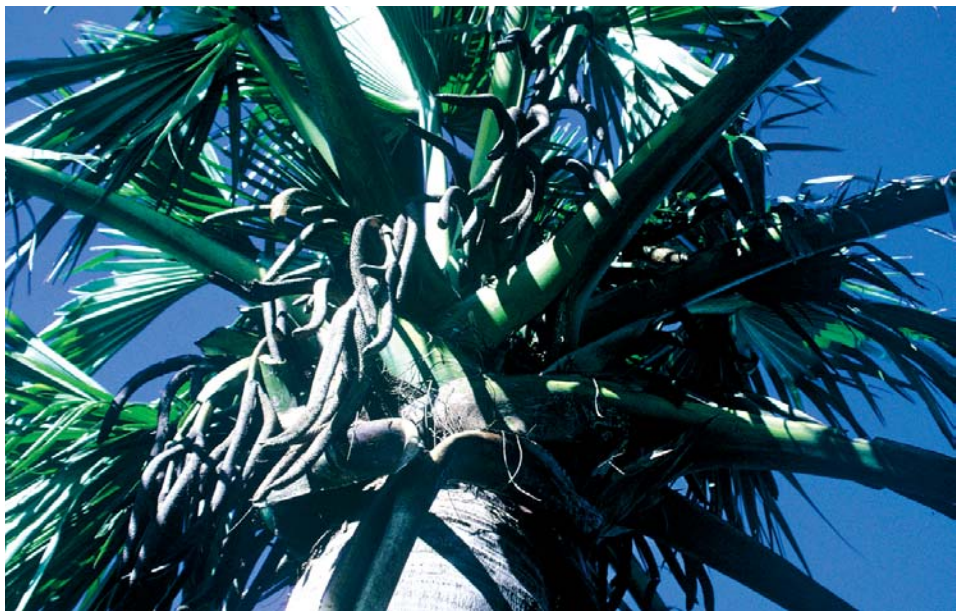
It is essential when making herbarium specimens to collect fertile material, and with many tall palms, dead inflorescences are collected from the ground beneath. However, access to the canopy allows fresh material to be collected and this is preferable when pollen and DNA samples are required. In Kenya, it was hoped that the trees could be climbed using a rope strop and climbing irons (spikes). However, the large belly of the stem precluded access above that level and the hard stem allowed minimal penetration by the spikes. The decision was taken to fell one male and one female tree at each location. There are obvious conservation implications when felling large palms but it was considered that the populations were of sufficient size to allow this. Permission was granted by the owners and the trees for felling were selected by them.

Access to the crown allowed several complete duplicates of each specimen to be produced. The material was preserved using the modified Schweinfurth method (see Dransfield 1986b). Leaf material for DNA extraction was collected from the sword leaf and dried in silica gel. Fieldwork in Kenya coincided with the fruiting season and the many large fruits of the female trees were measured.

The methods employed to collect both herbarium and DNA samples in Madagascar differed considerably from those used in Kenya. Both species of *Borassus* are threatened and are listed by the IUCN (2002). Therefore a different collection strategy was adopted. A ten-meter long pole-saw was used to collect material from the canopy. This necessitated locating smaller adult palms or finding a vantage point, such as a tree or hill, from which the canopy could be reached. Where possible, several duplicate specimens were produced and they were preserved using the Schweinfurth method.

A different approach was required to collect material for DNA extraction as the newer leaves in the center of the canopy were beyond reach. Therefore, root-tips were collected, split longitudinally, and dried in silica gel. The root-tips were often visible emerging from the stem just

7. *Borassus madagascariensis*, a female tree in the town of Maevatanana.



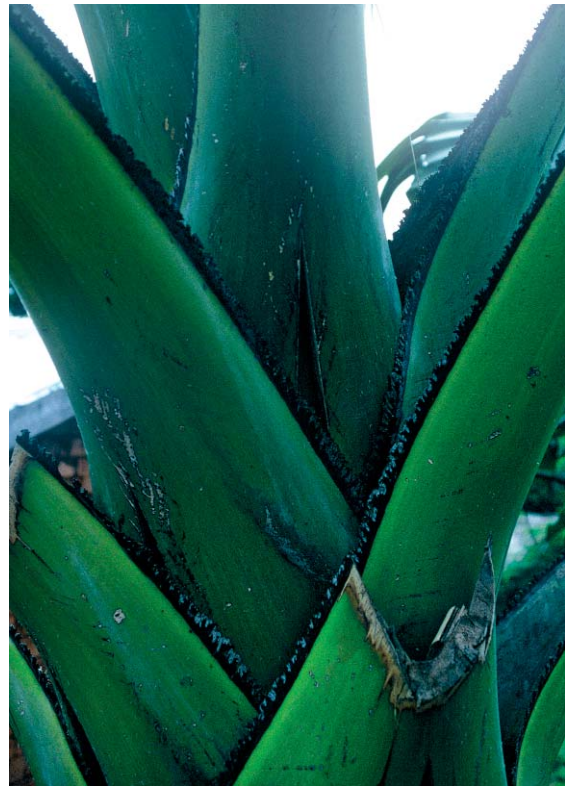
8. *Borassus madagascariensis*, a male tree in flower near the village of Ankijabe.

above the soil surface. In other cases they could be located in the leaf litter, or be found emerging from eroded soil surfaces. Preliminary studies suggest that DNA extracted from roots is not contaminated with foreign DNAs such as those of mycorrhizal fungi.

Preliminary Findings

1. Borassus madagascariensis (Jum. & H. Perrier) Bojer ex Jum. & H. Perrier

Morphology. Massive, solitary dioecious palm to 20 m tall. Old leaf bases remain attached to the trunk until the palm reaches maturity and then they fall away leaving distinctive scars on the stem. Stem is ventricose reaching 80cm diameter at its widest point. There are 16–23 green leaves in the canopy and these are costapalmate with a radius of up to 125 cm. The petiole is yellow in color along its entire length, up to 240 cm long, and 6–9 cm wide at the hastula. The petiole margins are armed with short black spines that are erose or serrated in shape. Each leaf has between 100 and 130 segments and these are 8 cm wide with small brown scales on the surface. Brown indumentum can be found on younger leaves, particularly near the hastulae. The male inflorescence is up to 150 cm long and branches to two orders. The tubular bracts are green and leathery with some brown indumentum. The lower empty bracts have hard,



9 (top left). In the town of Maevatanana, a male *B. madagascariensis* planted in the front garden of the Mayor's office. 10 (top right). A close-up view of the petioles of *B. madagascariensis* showing their yellow color and small marginal spines. This photo (of a juvenile palm) was taken in the town of Marovoay. 11 (bottom right). A juvenile specimen of *B. madagascariensis* growing on the street in the center of Maevatanana.

acuminate apices while the upper bracts have more rounded apices. Inflorescence branches terminate in 1–3 rachillae which are dark brown, up to 40 cm long and 3 cm diameter. Male rachillae are covered in overlapping scales within which are pits containing the male flowers. Male flowers are arranged in a cincinnus with 8–12 flowers, emerging from the pit one at a time. Female inflorescences are unbranched and to 120 cm long. There are 8 empty bracts with brown indumentum and woody acuminate apices. The flower-bearing section of the inflorescence is up to 90 cm long with 7–15 flowers. Female flowers are large and solitary. Fruits are green to yellow in color with a waxy surface. They are up to 19 cm long and 16 cm diameter, and contain 1–3 pyrenes. The pyrenes are also large (8.2–12.1 cm long × 8.6–12.0 cm diameter) and some have a distinctive longitudinal crest.

Distribution. Western Madagascar: Mahajanga and Toliara Provinces. Endemic.

Habitat. Patchy distribution, particularly along river valleys in gallery forest at elevations of 0–60 m above sea level. Along the Betsiboka River occurs primarily in disturbed areas, including farmland, gardens and urban areas.

Ecology. One of the most memorable aspects of collecting *B. madagascariensis* is the noise of birds in and around the canopy. The palm is selected by the Sakalava Weaver bird (*Ploceus sakalava*) that attach their woven grass nests to the tips of the leaflets. The birds nest colonially, and hundreds of old and new nests festoon the palm like pendant Christmas decorations. *Borassus* is particularly suitable as a nest site as the massive solitary stem makes access into the canopy difficult or impossible for land-bound predators and palm collectors alike! Aerial predators are quickly spotted as, at any one time, there are hundreds of birds in or around the canopy.

Nothing is known about the pollination of *Borassus*. In his extensive review of palm pollination studies, Henderson (1986) reports no specific information on the pollination of borassoid palms. Recently, Gerlach (2003) reported that flies (and in particular *Ethiosciapus bilobatus*, Dolichopodidae) were the most likely pollinators of *Lodoicea maldivica*, though geckos could not be ruled out. Observations of *B. madagascariensis* showed that the only insect species attracted to the male flowers was the honeybee (*Apis mellifera*). An indigenous subspecies of honeybee (*A. mellifera unicolor*) has been described in Madagascar but other subspecies may have been introduced (Ratsirarson & Silander 1996). At the time of study, the female trees were in fruit and so there were no female flowers to investigate. Other animal species noted on the male flowers include day geckos (*Phelsuma dubia*) and a chameleon (*Furcifer oustaleti*), although the latter is entirely an insect predator. Gerlach noted that *Phelsuma* geckos fed on both the nectar of *L. maldivica* and on insects visiting the flowers. The inflorescences of *B. madagascariensis* were not observed at night and so nocturnal insects and bats cannot be discounted as potential pollinators.

An additional factor which may influence pollination is the sex ratio. In *B. madagascariensis*, this was observed to be 2 males:1 female. A population of *B. aethiopum* observed by RPB in Malawi had a sex ratio of 1:1, as did three populations of the same species in Ivory Coast (Barot & Gignoux 1999). However, a fourth Ivorian population had significantly more male trees, while the population of *Lodoicea* on Praslin (Seychelles) was shown to comprise 64.3% males. This was attributed to an increased mortality in the female trees (Savage & Ashton 1983).

At present no information is available on seed dispersal of *B. madagascariensis*. The large terrestrial herbivores identified by Zona & Henderson (1989) as dispersal agents for *B. aethiopum* are not present in Madagascar. However, fruit bats in the genera *Pteropus* and *Eidolon* are represented on the island (Garbutt 1999) and have been identified as dispersal agents of palms (Zona & Henderson 1989). It seems unlikely that even the largest of bats could carry the fruits of *Borassus* far from the tree, and the fruits of *B. madagascariensis* may be the largest in the genus. One possibility is that the seeds were dispersed by an extinct animal. Among the mammals, three species of hippopotamus and a number of lemurs have become extinct. The largest of the extinct lemurs, *Archaeoindris fontoynontii*, weighed upwards of 200 kg but has only been found at one site in the central plateau (Garbutt 1999). The three extinct lemurs in the family Archaeolemuridae were smaller, and adapted to a primarily terrestrial life, similar to modern day baboons (Garbutt 1999). The extinct elephant birds (family Aepyornithidae) may also have consumed palm fruits (Dransfield & Beentje 1995). However all theories involving extinct animals remain speculative. Another possibility is that the fruits disperse themselves. Their large size may allow them to travel farther from the tree when they fall. The fruits may be carried by rivers and the sea though no evidence exists to show whether the seeds are damaged by immersion in water. When the close proximity of all populations of *B. madagascariensis* to human settlements is considered, it is impossible to rule out people as seed dispersal agents.

Conservation Status. The largest population of this species was at Marovoay. Although 35 adult palms were observed from the road, local people told us of additional trees further back into the forest. We observed just over 90 juvenile palms although this is probably an underestimate as thick vegetation easily conceals small seedlings. The other populations ranged in size from 17 adults (Maevatanana) to a single adult (Ankijabe). No adults and only four juvenile palms were found at the Ampijeroa Forestry Station. There appear to be few threats to the populations of *B. madagascariensis* in Mahajanga Province. The palms were not exploited for any products and regeneration was obvious and abundant at all sites where more than one adult palm was present. The status of *B. madagascariensis* in Toliara Province is unknown. *Borassus madagascariensis* is listed as vulnerable by the IUCN (2002).

2. Borassus sambiranensis Jum. & H. Perrier

Morphology. Massive, solitary dioecious palm to 20 m tall. Old leaf bases remain attached to the trunk until the palm reaches a certain height and then they fall away leaving distinctive scars on the stem. Stem is ventricose reaching 70 cm diameter at its

12 (top left). Immature *B. sambiranensis* growing in an abandoned field to the north of Ambanja. 13 (top right). A close-up of the petioles of *B. sambiranensis*. The dark color and large petiole spines are characteristic. 14 (bottom left). A large female specimen of *B. sambiranensis* growing in the town of Hell-Ville on Nosy Bé. Though many inflorescences were present, no fruits or pyrenes were found. 15 (bottom right). Rolland standing on the wall of a Catholic mission to collect *Lodoicea maldivica*. This male specimen is in full flower.

widest point. There are 14–22 green leaves in the canopy and these are costapalmate with a radius of up to 117 cm. The petiole is orange to yellow in color near the lamina and becomes dark brown near the trunk. The petiole is 150–190 cm long, and 6–12 cm wide at the hastula. The petiole margins are armed with large black erose spines. Each leaf has 100–110 leaflets and these are 8 cm wide with small brown scales on the surface. The male inflorescence is up to 90 cm long and branches to two orders. The tubular bracts are yellow and leathery with hard, acuminate apices. Inflorescence branches terminate in between 1 and 3 rachillae which are dark brown, up to 35 cm long and 3 cm diameter. Male rachillae are covered in overlapping scales within which are pits containing the male flowers. Male flowers are arranged in a cincinnus with 8–10 flowers, emerging from the pit one at a time. Female inflorescences are unbranched and to 140 cm long. The number of empty bracts is unknown but those collected have woody acuminate apices. The flower-bearing section of the inflorescence is up to 90 cm long with up to 30 flowers. Female flowers are large and solitary. Fresh mature fruits were not seen so color is undetermined. They are up to 13 cm long and 11 cm diameter and contain 1–3 pyrenes. The pyrenes are small, 6.8–8.4 cm long and 6.1–7.1 cm broad.

Distribution. In Madagascar, restricted to the Sambirano region in the north-west (Antsiranana & Northern Mahajanga provinces). Jumelle and Perrier de la Bâthie (1913) reported that the species was found between the Ifasy and Sambirano Rivers and near the northern town of Ambilobe. Despite intensive searching, only one specimen (a juvenile) was found to the north of the Sambirano River (Figs. 12, 13). Jumelle & Perrier de la Bâthie (1945) noted that the species occurs on the island of Nosy Mitsiou but this could not be verified. The specimens found on nearby Nosy Bé were cultivated. Also occurs in the Comoro archipelago on Mayotte (Ludwig 1999).

Habitat. Riverine forest, including disturbed areas, at elevations of 0–50 m above sea level. Also found on disused agricultural land.

Ecology. Due to the comparative rarity of this species, very little is known of its ecology. As with the previous species, it provides nesting sites for colonies of Sakalava Weaver birds. Only two fertile male specimens were observed in the wild and, as with *B. madagascariensis*, honeybees were the only insects visiting the flowers. No other animals were observed in the canopy. There are only four fruits of *B. sambiranensis* in the herbarium collection amassed for this study. They are consistently smaller than those of *B. madagascariensis* but may still be too large for dispersal by any of Madagascar's native animals. It is possible that the fruits may be partially consumed while in the canopy by bats or lemurs, though this would not provide any dispersal. The only large ground-dwelling animal in Madagascar is the bush pig (*Potamochoerus larvatus*) which commonly occurs in disturbed secondary forest and agricultural areas (Garbutt 1999), a habitat it shares with both Malagasy species of *Borassus*. Perhaps this pig, which is known to consume fallen fruit, is a dispersal agent for *Borassus*?

Conservation Status. During our fieldwork in the Sambirano region, it was extremely difficult to locate *B. sambiranensis*. Herbarium specimens have been collected from only six locations in the north-west of Madagascar. Beentje reports that he found a population of 15 adult plants with some regeneration (in Dransfield & Beentje 1995). However during our recent trip, only a single juvenile and two male trees were found in the wild. *Borassus sambiranensis* is listed as endangered by the IUCN (2002).

3. Borassus aethiopum Mart.

Morphology. Massive, solitary dioecious palm to 20 m tall or more. Old leaf bases remain attached to the trunk until the palm reaches maturity and then they fall away leaving distinctive scars on the stem. Stem is ventricose reaching 90 cm diameter at its widest point. There are 18–27 green leaves in the canopy and these are costapalmate with a radius of up to 190 cm. The petiole is yellow in color near the hastula, and becomes darker towards the trunk. Petiole is up to 220 cm long, and 4–9 cm wide at the hastula. The petiole margins are armed with large black erose spines. Each leaf has 80–120 leaflets and these are 10 cm wide with small brown scales on the surface. Brown indumentum can be found on younger leaves, particularly near the hastulae. The male inflorescence is up to 150 cm long and branches to two orders. The tubular bracts are yellow and leathery with some brown indumentum, and have hard, acuminate apices. Inflorescence branches terminate in 1–3 rachillae which are dark brown, up to 50 cm long and 3 cm diameter. Male rachillae are covered in overlapping scales within which are pits containing the male flowers. Male flowers are arranged in a cincinnus with 8–14 flowers, emerging from the pit one at a time. Female inflorescences are unbranched and to 160 cm long. There are 7–9 empty bracts with brown indumentum and woody acuminate apices. The flower-bearing section of the inflorescence is up to 96 cm long with 10–28 flowers. Female flowers are large and solitary. Fruits are orange to brown in color with a waxy surface. They are up to 15 cm

long × 10 cm diameter with a sunken or depressed apex, and contain between one and three pyrenes. The pyrenes have a variable shape and are 6.9–10.9 cm long and 5.8–10.5 cm broad.

Distribution. Sub-Saharan Africa. In the East, recorded from the Central African Republic, Democratic Republic of Congo, Kenya, Malawi, Mozambique, Rwanda, South Africa, Tanzania (including Pemba & Zanzibar), Uganda, Zambia and Zimbabwe. Pascal & Labat (2002) report a population of *B. aethiopum* at Pointe Saziley on Mayotte (Comoro Archipelago). This is probably the Mayotte population of *B. sambiranensis* reported by Ludwig (1999).

Habitat. Patchy distribution, particularly along river valleys in gallery forest at elevations of 0–1200 m above sea level. Locally abundant.

Ecology. *Borassus aethiopum* is widespread in tropical Africa and dominates the plant communities in which it occurs. Several animal species exploit this palm and its relatives. As in Madagascar, weaverbirds attach their nests to the palm leaf segments. In Kenya, only the Village Weaver (*Ploceus cucullatus*) was observed utilizing *B. aethiopum* as a nest site, although other Kenyan weavers including the Spectacled Weaver (*P. ocularis*), Golden Palm Weaver (*P. bojeri*) and African Golden Weaver (*P. subaureus*) frequently nest in palms. Other Kenyan birds which select *Borassus* as a nest site include the Red-necked Falcon (*Falco chiquera*), African Palm Swift (*Cypsiurus parvus*) and Collared Palm Thrush (*Cichladusa arquata*).

While the pollination strategy of *B. aethiopum* remains unknown, there has been considerable speculation as to the method of seed dispersal. Though there have been no documented studies which examined the subject thoroughly, several observations of animals feeding on the fruits have been made. These animals include elephants, baboons and three bat genera (Zona & Henderson 1989). Dransfield (1986a) reported that lions may eat the fruits of *B. aethiopum* while McGrew et al. (1988) speculated that chimpanzees may also eat the fruit. It is unclear to what extent these animals provide effective seed dispersal. Burtt & Salisbury (1929) found germinating *Borassus* pyrenes in the dung of elephants in the Singida District of Tanzania. This remains the only record of effective animal-mediated seed dispersal in this palm. Other possible methods of dispersal include water (*B. aethiopum* is common in riverine forest and floodplains) and man.

Conservation Status. *Borassus aethiopum* is not listed by the IUCN although some populations are declining (Davies & Pritchard 1998). The three populations of *B. aethiopum* examined in Kenya are large with regeneration occurring. However, none of these populations is within a protected area and effective seed dispersal may also be curtailed. While baboons are present at all three sites, elephants (probably the most effective animal dispersal agent) are absent. Elephants are present within the Shimba Hills National Reserve but are contained within the park by a fence and thus have no access to the large *Borassus* population outside.

Discussion

The fieldwork described here allowed new herbarium material of African *Borassus* to be collected, adding considerably to that already available. It is hoped that in the near future a phenetic analysis of the morphology of these specimens will provide conclusive proof as to the taxonomic status of *Borassus* in Madagascar and East Africa. In addition a fieldtrip to Burkina Faso, currently in preparation, will allow herbarium specimens of West African *Borassus* to be collected and included in the analysis. However, it is now possible to present some preliminary conclusions of the morphological study.

There are two taxonomic questions which must be considered. Firstly, can *Borassus madagascariensis* and *B. sambiranensis* be differentiated from each other? Secondly, can either species be distinguished from *B. aethiopum* in mainland Africa?

In *The Palms of Madagascar*, Dransfield & Beentje (1995) described three characters which could be used to distinguish *B. madagascariensis* from *B. sambiranensis*. Firstly, the pistillate rachilla of the former species is shorter than that of the latter. However, newly collected material has shown that *B. madagascariensis* can have a pistillate rachilla of up to 90 cm long as in *B. sambiranensis*. It does appear that *B. sambiranensis* has a greater number of female flowers (ca. 30, compared with 7–20 in *B. madagascariensis*, Dransfield & Beentje 1995) though only two female rachillae of this species have been collected. The third character, fruit size, together with the correlated character of pyrene size, also appears to distinguish the two Malagasy species from each other (see Table 1). Jumelle & Perrier de la Bâthie (1913) and Beccari (1914) both noted the large black spines on the petiole margins of *B. sambiranensis* and these distinguish that species from *B. madagascariensis*, which has very small petiole spines (Fig. 16).

While it appears that both Malagasy species of *Borassus* can be distinguished from one other, it is also necessary to compare these species with *B. aethiopum*. Beccari (1914) suggested that *B.*

16. Petiole sections collected from African *Borassus*. From left to right: *B. sambiranensis* (*Bayton & Ranaivojaona 53*), *B. aethiopum* (*Bayton & Obunyali 14*) and *B. madagascariensis* (*Bayton & Ranaivojaona 46*).

sambiranensis was very similar to *B. aethiopum* var. *bagamojensis* (described from East Africa), while *B. madagascariensis* was said to resemble *B. deleb*. *Borassus deleb*, together with the varieties of *B. aethiopum* described by Beccari were later sunk into that species by Dransfield (1986a). Dransfield & Beentje (1995) noted that there were few characters which could be used to separate the Malagasy taxa from *B. aethiopum*, and cited a greater number of leaves in the canopy, a shorter costa, fewer empty bracts and fruit of ca. 12 cm × 14 cm in that species.

It is apparent from Table 1 that few characters exist to distinguish *B. sambiranensis* from *B. aethiopum*. When encountered in the field, the two taxa are indistinguishable. Particularly striking is the similarity in the petiole armature. Almost none of the morphological differences enumerated by Dransfield and Beentje (1995) was applicable as the measurements for *B. sambiranensis* fell within the range of variation exhibited by *B. aethiopum* in East Africa. The fruits of *B. sambiranensis* are very small, but such small fruits exist in *B. aethiopum*, and this was confirmed using the morphological data collected from the female trees felled in Kenya. The only other slight difference noted in the field was the orange-yellow color of the distal section of the petiole in *B. sambiranensis*, compared with the yellow-green color found in *B. aethiopum*. In the original description of Jumelle and Perrier de la Bâthie (1913), the petiole is described as being golden. However, colors can be difficult to interpret as they can vary with light intensity, and the color has been lost in most old herbarium specimens. The preliminary assessment is that *B. sambiranensis* should be placed in synonymy with *B. aethiopum*.

Borassus madagascariensis, on the other hand, possesses several characters which distinguish it from *B. aethiopum*. The petiole margins are armed with small spines less than 1 cm long. These spines can be erose, such as is found in *B. aethiopum*, or can be serrated like a fine-toothed saw. The petiole itself is yellow-green in color along its entire length. This feature is most noticeable near the stem where the green base of the petiole contrasts with the gray stem. In *B. aethiopum*, the petiole tends to become darker in color towards the stem. For comparison, see Fiugres 4, 10 and 13.

The fruits of *B. madagascariensis* are the largest in the genus and have a pointed apex. This contrasts with the slightly smaller, squat fruits of *B. aethiopum* which typically have a sunken or depressed apex. There was some overlap in size between the fruits of *B. madagascariensis* in the herbarium and those of *B. aethiopum* measured in the field. This could be due to the fact that the herbarium specimens are dried and may have shrunk during the process. However, it is possible that larger fruits of *B. aethiopum* exist. A pyrene was collected in the Central African Republic (*J. M. Fay s.n.*) measuring 10.9 cm long by 10.5 cm wide. No other material was collected and so the identity of this species could not be verified but only *B. aethiopum* has been recorded in the CAR. The fruit, which would have contained between one and three of these pyrenes, must have been very large.

The characters described above, and particularly the petiole armature, can be used to recognize *Borassus madagascariensis* both in the field and in the herbarium. It could be that this species is derived from *B. aethiopum,* and indeed preliminary results from the molecular study show that the two species are sister taxa. However, it appears to be distinctive enough to warrant continued recognition as a species.

The preliminary results published here await confirmation using morphological and molecular

analyses. If they are confirmed, then nomenclatural changes will follow.

Acknowledgments

RPB thanks his supervisors Dr. Barbara Pickersgill (Reading), Dr. John Dransfield and Dr. Bill Baker (RBG Kew) for their support and advice. RPB thanks the International Palm Society and the Central Florida Palm Society for funding the trip to Madagascar, and the South Florida Palm Society for funding the trip to Kenya. In addition, RPB acknowledges the continued financial support of the Natural Environment Research Council (NERC). RPB and RR thank Hélène Ralimanana, Solofo Rakotoarisoa and Dr. Adam Britt (RBG Kew) for their help in Madagascar. RPB and CO thank Dr. Henk Beentje, Dr. Aaron Davis, Dr. Kaj Vollesen (RBG Kew), Quentin Luke, Dr. Muthama Muasya and Dr. Siro Masinde (EA) for their help in Kenya. Many thanks to the Myles family for taking care of RPB in Nairobi. We thank the herbaria that supplied us with specimens for this project: AAU, BH, BM, FTG, K and P. Many thanks to Justin Morat for constructing the maps. Last but not least, many thanks to Sue Mott, Carole Raynor, Christine Bradshaw and Anne Davis in the School of Plant Sciences at the University of Reading.

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