

Palms

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The International Palm Society

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FRONT COVER

A male plant of *Borassus madagascariensis* in a field of maize in Madagascar. See article by R. Bayton et al., p. 206. (Photo: R. Bayton)

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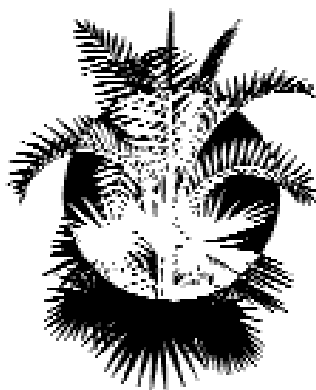
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BACK COVER

The fruits of *Pritchardia viscosa* shine with a sticky natural varnish. Hawaii is the center of diversity for the genus *Pritchardia* and will be the site for the 2004 IPS Biennial and Post Tour. (Photo: J. Dransfield)



NEWS FROM THE WORLD OF PALMS

The Board of Directors of the International Palm Society met in Houston, Texas on 11 Oct 2003. In addition to the usual business of receiving a fully approved financial audit and setting budgetary priorities for the coming year, the Board agreed to redesign the IPS website. The Board hopes to provide visitors to the website with a user-friendly, content-rich site with an enhanced photo gallery and archives of articles from *Principes*/PALMS. A task force will begin assembling specifications for the new website, which the Board hopes will be on-line in the coming year.

Additionally, the Board convened a meeting of the Endowment Committee, which every year receives and reviews grant proposals. The Endowment Fund of the IPS regularly supports educational projects, exhibits, laboratory and field research, and taxonomic studies. This year the Committee funded six projects:

Dr. Larry Noblick of the Montgomery Botanical Center, Miami, Florida, received \$7500 in support of field work in Paraguay and Argentina toward a taxonomic study of *Butia* and *Syagrus*. Dr. Noblick will investigate field variation in two taxonomically confused species of *Butia* and examine a possible new species of *Butia* believed to occur in eastern Paraguay. He also hopes to sort out the identity of a poorly known *Syagrus* in southern Paraguay.

Dr. Mark Brunel, University of the Pacific, Stockton, California, was granted \$2000 toward a molecular study of a population of putative hybrid *Sabal* in Brazoria County, Texas. The palms, long suspected of being hybrids between *S. mexicana* and *S. minor*, have been the subject of scrutiny and debate for many years. Dr. Brunel will use DNA technology to address the question.

Judy duPloy of the Belize Botanic Garden will receive \$2600 for an educational program for school children focusing on Belize's native palms. The Belize Botanic Garden has designed an exciting hands-on exhibit on the uses of palms along with a field trip to the Garden for school children. The IPS is proud to be involved with the program.

Dr. Mónica Moraes, Herbario Nacional de Bolivia, La Paz, is an authority on the palm flora of that South American country. She has been granted \$4500 toward the publication of a taxonomic account of the 78 indigenous palms of Bolivia. The IPS hopes to have copies of this publication available through the IPS Bookstore next year.

Finally, Arlington James, Roseau, Dominica, received \$1924 for field study and monitoring of native palms of Dominica. Just this year, Mr. James wrote an account of his work with *Pseudophoenix sargentii* in Dominica (PALMS 47: 57–61). His new project will produce data on *Coccothrinax babadensis*, two morphs of *Aiphanes minima*, and *Acrocomia aculeata*.

Readers of PALMS also benefit from the Endowment program: Each grant recipient is asked to write an article for PALMS relating to the project funded by the IPS. While we all eagerly await news of the latest palm discoveries from Argentina, Paraguay, Bolivia, Dominica, Texas, and Belize, we can turn to two articles in this issue of PALMS by Endowment grant recipients. Donald Hodel's work with leaf removal and crown tie-up (p. 177) and Ross Bayton's work on the taxonomy of *Borassus* (p. 206) are both the result, in part, of IPS support.

The Editors

Effect of Leaf Removal and Tie Up on Juvenile, Transplanted Canary Island Date Palms (*Phoenix canariensis*) and Queen Palms (*Syagrus romanzoffiana*)

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This study investigates the effect of removing leaves and tying up leaves when transplanting palms. Several combinations of leaf tie up and/or removal during transplanting did not affect establishment and survival of small, juvenile Canary Island date palms (*Phoenix canariensis* Hort. ex Chabaud) and queen palms (*Syagrus romanzoffiana* (Cham.) Becc.). For both species, complete leaf removal resulted in the least amount of new leaf and root growth. None of the combinations resulted in more new leaf or root growth or reduced leaf transpiration rates and leaf water potential than no leaf removal and no tie up. Leaf tie and/or removal appear to offer no benefit to transplanted, juvenile palms provided the root ball and backfill are kept moist.

Palm trees are high-value and increasingly common components of landscapes wherever they can be grown. Large, older specimens are in great demand and command a premium price. Large specimen palms are usually dug and removed from one landscape site or from a commercial nursery field, and then transported and replanted at another site, creating an instant mature landscape.

Specimen palms are easy to transplant when compared to broad-leaved, dicotyledonous and coniferous trees. Only a small root ball is necessary when transplanting most palms because, as monocots, they have an adventitious root system composed of numerous fibrous primary roots that arise independently and periodically from the root initiation zone at the base of the stem (Tomlinson 1990). In California and Southwest USA it is standard industry practice for a root ball to extend from the trunk only about 15–30 cm when transplanting palms up to 20 meters tall with trunks 30–100 cm in diameter. The transplanted palm will grow and reestablish as long as it generates new roots in a timely manner.

Landscape contractors and nurserymen spend considerable resources and labor transplanting

palms since removal of many of the leaves and tying up the remaining ones during the transplant operation are standard industry practices. These practices detract from the esthetic value of the newly transplanted palms but are purported by the landscape industry to reduce water loss and improve reestablishment. There is little research-based information on the effects of leaf removal or tie up when transplanting palms and the benefits of either practice are, thus, largely undocumented. The cost savings and esthetic improvement would be substantial if leaf removal and tie up could be eliminated. The objective of this experiment was to evaluate the effects of leaf removal and tie up on the survival of two commonly transplanted palm species.

Previous Work

Industry tradition and popular literature are replete with accounts of the benefits of leaf removal and tie up when transplanting palms. Broschat (1991) and Costonis (1995) showed that for species like the palmetto palm (*Sabal palmetto*), which usually must generate an entirely new root system when transplanted, complete leaf removal greatly improved survival rates because the practice reduced transpirational water loss.

1 (left). *Syagrus romanzoffiana* prior to root removal. Note tied-up leaves and metal ring to mark 15 cm diameter for root removal. Half leaves removed/tie up treatment [standard industry practice (SIP)]. 2 (right). *Syagrus romanzoffiana*, same plant from Figure 1, after root removal.





3 (left). *Phoenix canariensis*. Co-author Pittenger holds gas-powdered hedge shears used to remove roots. Half leaves removed/no tie up treatment. 4 (right). *Phoenix canariensis*, same plant from Figure 3, six months after root removal and treatment showing new leaf and root growth.

In contrast, Broschat (1994) showed that transplanted pygmy date palms (*Phoenix roebelenii*) had higher new root and shoot growth and survival rates when most or all leaves were left on the palm provided there was sufficient irrigation. He predicted that most other species of palms would probably respond in a way similar to the pygmy date palm rather than to the palmetto palm. Broschat (1994) recommended that leaves should be untied after transplanting because research has shown no benefit from the practice in humid climates. He further suggested that the practice actually promotes disease by decreasing air flow through the canopy. However, he felt there might be some benefit from keeping the leaves tied up for several weeks to reduce transpirational water loss in arid climates.

Removing at least half the leaves and tying up the remaining ones have long been common practices when severing offshoots of date palms (*Phoenix dactylifera*) from the mother tree and planting them out in the field. Growers state that this practice reduces water loss and facilitates handling. Nixon and Carpenter (1978) and Zaid (1999), two of the best known references on this subject,

recommend this practice. Reuveni et al. (1972) reported that less severe leaf removal of offshoots did not improve rooting when planted in the traditional manner, but offshoots retaining all their leaves had higher rooting with overhead misting.

Most recently, Broschat and Meerow (2002) recommended that one-half to two-thirds of the leaves should be removed to minimize transpirational water loss in large, specimen-sized, field-grown palms but did not cite supporting data.

Materials and Methods

We conducted this experiment at the University of California South Coast Research and Extension Center (SCREC) in Irvine, which is in the south coastal plain of California and has a maritime Mediterranean climate. In August 2001 we purchased 30 68-liter (15-gallon), juvenile plants each of Canary Island date palms (*Phoenix canariensis*) and queen palms (*Syagrus romanzoffiana*), one species each from two local growers. Plants within each species were selected for uniform height, leaf number, stem caliper, root growth, and overall quality (Table 1). Plants of

Table 1. Ranges in height from soil line to top of leaves, leaf length, stem diameter, and number of leaves of juvenile, 68-liter (15-gallon) size plants of Canary Island date palms (*Phoenix canariensis*) and queen palms (*Syagrus romanzoffiana*), prior to transplanting, UC SCREC, Irvine, CA, 2001–2002.

Species	Height (cm)	Leaf Length (cm)	Stem Diameter (cm)	Leaf Number
Canary Island date palm	60–75	60–90	14	7
queen palm	180–220	80–110	10	3

both species were free of pests and diseases and had normal green leaves and roots to the sides and bottoms of the containers.

On August 14, 2001, we removed the palms from their containers and, using gas-powered hedge shears, clipped back the root balls to 7.5 cm from the center of the stem at its base, resulting in a cylindrical root ball about 15 cm in diameter and 30–38 cm long or deep. We estimated that at least 60% of the roots were removed. The procedure was designed to simulate transplanting palms where typically a large quantity of roots is removed. We immediately repotted each palm in the original container using Scott’s Potting Medium, a peat-vermiculite soil-less potting mixture, and subjected them to one of five treatments:

- All leaves removed
- Half of the leaves removed/tie up [standard industry practice (SIP)]
- Half of the leaves removed/no tie up
- No leaves removed/tie up
- No leaves removed/no tie up (control)

Treatments for each species were replicated six times and the containers with the palms were arranged in a randomized complete block design (5 treatments × 6 replications × 2 species = 60 palms total). Plants were placed in full sun and irrigated twice a week in the summer and once a week in the winter to maintain the soil water content at or near container capacity. The repotting and watering practices are very similar to those the landscape industry in California and the Southwest USA employ when transplanting palms, where sand or other nearly ideal backfill soil is used and trees are irrigated regularly to keep the root ball and backfill moist. No fertilizers or pesticides were applied before or during the experiment. Weeds were removed manually.

We measured mid-day leaf transpiration rate (LTR) and leaf water potential (LWP) of each palm using

a steady-state porometer and a Scholander pressure chamber to provide estimates of plant water loss rate and physiological water status, respectively. We recorded LTRs immediately prior to and after treatments were imposed and at 1, 4, 8, 12, and 25 weeks after treatment (WAT). We recorded LWP at 1, 2, 4, 8, 12, and 25 WAT. Porometer readings and pressure chamber measurements were taken from the abaxial surface of one pinna each of three different leaves per plant and averaged. When canopies were tied up, only exposed outer leaves could be sampled for these measurements.

By late February, 2002, roots were emerging from the bottom of the containers. On March 1, 2002, we removed the palms from their containers, recorded the number of new leaves produced since the start of the trial, and clipped back the root balls to the same size that we had at the start of the project. The new leaves and harvested roots were dried and their weight (mass) recorded.

We subjected data to analysis of variance procedures and compared means for leaf dry mass, root dry mass, number of new leaves, LTR, and LWP using Fischer’s Protected LSD Test.

Results

None of the treatments affected survival. All 60 palms survived and grew enough new leaves and roots to establish successfully. We also observed in both species that many of the severed roots resprouted just proximally of the cut.

Leaf and Root Growth

Canary Island date palms produced significantly more new leaves and new leaf and root mass than did queen palms (Table 2). However, no treatment affected the number of new leaves produced in either species. Also, no treatment resulted in greater new leaf or root mass than in the control (no leaf removal, no tie up) in either species (Table 3). In Canary Island date palms new root mass was reduced when leaves were tied up or when all

Table 2. Summary of randomized complete block statistical effects for two transplanted palms species (*Phoenix canariensis* and *Syagrus romanzoffiana*) and five leaf removal/tie up treatments, UC SCREC, Irvine, CA, 2001-2002.

Treatment	Leaf Dry Mass (g) ^Z	Root Dry Mass (g)	No. New Leaves
Species (S)	***	***	***
Treatment (T)	***	***	NS
S × T	*	**	NS

^Z NS, *, **, *** = not significant and significant at $P \leq 0.05$, 0.01, 0.001 respectively.

Table 3. The effect of leaf removal and tie up on mean new leaf mass, root mass, and leaf number of transplanted Canary Island date palms (*Phoenix canariensis*) and queen palms (*Syagrus romanzoffiana*), UC SCREC, Irvine, CA, 2001-2002.

Treatments	Leaf Dry Mass (g) ^Z	Root Dry Mass (g)	Leaf Number
<i>Phoenix canariensis</i>			
all leaves removed	158C	129B	6.8
1/2 leaves removed, tie up (SIP)	248AB	176B	7.5
1/2 leaves removed, no tie up	251AB	254A	7.0
no leaves removed, tie up	222B	182B	7.0
no leaves removed, no tie up	286A	278A	7.3
LSD, $P=0.05$	56	60	NS
Summary of ANOVA ^Y	**	***	NS
<i>Syagrus romanzoffiana</i>			
all leaves removed	50	36B	1.5
1/2 leaves removed, tie up (SIP)	89	128A	2.0
1/2 leaves removed, no tie up	101	98AB	2.3
no leaves removed, tie up	91	162A	2.2
no leaves removed, no tie up	72	106A	2.0
LSD, $P=0.05$	NS	80	NS
Summary of ANOVA	NS	*	NS

^Z Means within a column followed by the same letter are not significantly different. Means compared using Fischer's Protected LSD Test.

^Y Randomized complete block statistical effects.

^X NS, *, **, *** = not significant and significant at $P \leq 0.05$, 0.01, 0.001 respectively.

leaves were removed (Table 3). New leaf mass in Canary Island date palms was reduced when no leaves were removed but leaves were tied up and when all leaves were removed. In queen palms new root mass was reduced only when all leaves were removed while no treatment affected new leaf mass (Table 3).

Leaf Transpiration Rate (LTR)

Canary Island date palms transpired at significantly lower rates than did queen palms although both species responded similarly to each treatment (Table 4). LTRs declined immediately after application of treatments and transplanting,

recovered to pre-treatment rates by the fourth WAT, then fell below the pre-treatment rates for the duration of the study.

LTRs did not differ among the treatments immediately after they were imposed, but at one WAT and for the remainder of the study, the control had a significantly lower LTR than the SIP.

Over the entire study period LTRs were highest in the SIP. Tying up leaves generally increased LTRs.

We were unable to measure the LTR of the all-leaves-removed treatment until the end of the study (simply because there was no emerged leaf), and it was not significantly different from the other treatments at that time.

Leaf Water Potential (LWP)

Canary Island date palms had significantly higher LWP than did queen palms during the last 18 weeks of the study although both species responded similarly to each treatment (Table 5). None of the treatments affected LWP during the critical period immediately after transplanting. Not until 12 WAT, when plants had begun to reestablish, were there treatment responses. Leaf tie up and complete leaf removal showed greater water stress at 12 and 25 WAT but over the entire study no treatment resulted in lower LWP than in the control.

Discussion

Broschat and Meerow (2000) stated that water stress is one of the most important causes of palm transplant failure. The rationale behind leaf removal and tie up when transplanting palms is that these practices should reduce water loss and prevent drying out of the plant until new roots grow and become functional. The results of our study differ from this theory and contradict recommendations in the popular literature, at least for smaller juvenile palms, because leaf removal and/or tie up did not affect survival of transplanted Canary Island date palms or queen palms. Furthermore, no treatment significantly improved the amount of new leaf or root growth or reduced the LTR and LWP of these species after transplanting. Indeed, the SIP actually had the highest LTR. Our findings suggest that the SIP when transplanting smaller juvenile palms may be unnecessary for optimal leaf and root growth, reestablishment, and survival if the root ball and backfill are kept moist.

In tied-up leaf canopies, outer leaves (the only leaves we were able to measure for these treatments) might have an elevated LTR but inner leaves might have a much lower LTR. If there are about equal numbers of outer and inner leaves,

then tie up would not affect total water loss. Leaf tie up could increase the LTR of leaves on the outside of a tied up crown because the abaxial surface of the leaf is more directly exposed to the sun and wind. Tomlinson (1990) states, and our counts confirm (Table 6), that stomata are most abundant on the abaxial leaf surface in most palms but several genera, including *Phoenix*, have stomata equally numerous on both leaf surfaces. Thus, leaf tie up would expose more stomata to greater light and increased wind.

It should be stressed that increased LTR of the outer leaves in a tied up crown does not mean that these plants lost more total water than those that were untied. Furthermore, the LTR might be irrelevant to water stress when transplanting palms because in our study the LTR in any treatment was not significant enough to increase leaf water potential. Why the SIP actually had the highest LTR in our study is intriguing and certainly bears further investigation.

Transplanted palms need carbohydrates for root and shoot growth. They can obtain carbohydrates from photosynthesis or from starch stored in the trunk, or both. Leaf removal and/or tie up reduce the amount of leaf surface in which photosynthesis can occur. An unstated premise of the rationale behind leaf removal and tie up when transplanting palms is that this decrease in carbohydrate production is temporarily acceptable in order to reduce water loss, and that the palms can use starch stored in the trunk or stem until new leaves are produced. Our findings suggest that when transplanted palms are appropriately irrigated, reducing water loss is not important to their survival and establishment, and reducing leaf surface can actually reduce production of new leaf and root growth.

The findings and interpretation of our work support the earlier work of Broschat (1994). He showed that transplanted pygmy date palms (*Phoenix roebelenii*) had higher new root and shoot growth and survival rates when most or all leaves were left on the palm provided there was sufficient irrigation, but that complete leaf removal was best if the palms were water stressed. Although our results indicate that leaf removal and tie up when transplanting palms, especially small plants with little or no visible trunk or stem, might be unsound horticultural practices, there still are instances when these procedures are helpful. Broschat (1991) and Costonis (1995) showed that for species like the palmetto palm (*Sabal palmetto*), which usually must generate an entirely new root system when transplanted, complete leaf removal greatly improved survival rates. Broschat also

Table 4. The effect of palm species and leaf removal and tie up on mean transpiration rates of transplanted Canary Island date palms (*Phoenix canariensis*) and queen palms (*Syagrus romanzoffiana*) in g cm⁻²s⁻¹, UC SCREC, Irvine, CA, 2001-2002.

Species	Immediate		Weeks After Treatment					
	Pre-Treat- ment ^Z	Post-Treat- ment	1	4	8	12	25	overall
queen palm	4.18A	2.88A	3.61A	4.24A	4.02A	3.14A	1.53A	3.61A
Canary Island date palm	2.71B	2.29B	1.72B	2.82B	3.08B	2.50B	1.23B	2.49B
LSD, <i>P</i> =0.05	0.67	0.39	0.71	0.92	0.60	0.37	0.17	0.42
Treatments								
all leaves removed	—	—	—	—	—	—	1.54	—
1/2 leaves removed, tie up (SIP)	—	2.48	3.47A	4.25	4.35A	3.29A	1.44	3.57A
1/2 leaves removed, no tie up	—	2.44	2.92AB	3.55	3.44B	2.50B	1.30	2.97B
no leaves removed, tie up	—	2.47	2.45BC	3.37	3.60AB	3.12A	1.42	3.00AB
no leaves removed, no tie up	3.44	2.94	1.83C	2.95	2.81B	2.36B	1.21	2.72B
LSD, <i>P</i> = 0.05	—	NS	1.01	NS	0.84	0.52	NS	0.59
Summary of ANOVA ^{Y, X}								
Species (S)	**	**	***	**	**	***	***	***
Treatment (T)	—	NS	*	NS	**	**	NS	*
S × T	—	NS	NS	NS	NS	NS	NS	NS

^Z Means within a column followed by the same letter are not significantly different. Means compared using Fischer's Protected LSD Test.

^Y Randomized complete block statistical effects.

^X NS, *, **, *** = not significant and significant at *P* ≤ 0.05, 0.01, 0.001 respectively.

noted that most other species of palms will probably respond similarly to the pygmy date palm rather than to the palmetto palm.

Conclusion

Leaf tie up and/or removal did not affect establishment and survival of transplanted, small Canary Island date palms and queen palms when the root ball and backfill were kept moist. Based on our findings and the earlier work of Broschat (1994), the standard industry practice of removing some leaves and tying up the remaining ones seems to be no better than no leaves removed and no tie up when transplanting juvenile palms provided moisture content in the root ball and backfill is maintained near field capacity. No treatment increased survival or new leaf and root growth. While there is less leaf area for transpiration with leaf removal and tie up, transpiration occurs at a higher rate in the outer, exposed leaves.

Little or nothing is gained from leaf removal and/or tie up although these practices greatly reduce the esthetics and function of transplanted juvenile palms. Thus, there is doubt that these standard industry practices are horticulturally sound. Leaf tie up is beneficial only to facilitate moving and minimize damage during the transplanting procedure. Additional work is needed to determine if our findings hold true when transplanting large, mature palms.

Acknowledgments

The International Palm Society partially funded this project from its Endowment Fund.

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Table 5. The effect of palm species and leaf removal and tie up on mean water potential of transplanted Canary Island date palms (*Phoenix canariensis*) and queen palms (*Syagrus romanzoffiana*) in MPa, UC SCREC, Irvine, CA, 2001-2002.

	Weeks After Treatment						overall
	1 ^z	2	4	8	12	25	
Species							
Canary Island date palm	16.3	16.0	16.2	14.0A	17.0A	8.2A	14.1A
queen palm	14.2	15.3	15.0	12.1B	12.9B	7.1B	12.2B
LSD, P=0.05	NS	NS	NS	1.4	1.7	0.6	0.8
Treatments							
all leaves removed	—	—	—	—	—	8.5A	—
1/2 leaves removed, tie up (SIP)	14.9	15.1	15.3	13.3	18.3A	7.9AB	13.9
1/2 leaves removed, no tie up	16.2	15.9	14.5	12.1	12.5B	7.0C	12.2
no leaves removed, tie up	14.1	13.9	15.6	14.1	16.0A	7.6ABC	13.4
no leaves removed, no tie up	15.8	17.7	17.0	12.6	13.0B	7.4BC	13.1
LSD, P=0.05	NS	NS	NS	NS	2.4	0.9	NS
Summary of ANOVA ^y , ^x							
Species (S)	NS	NS	NS	*	***	***	***
Treatment (T)	NS	NS	NS	NS	***	*	NS
S × T	NS	NS	NS	NS	**	**	NS

^z Means within a column followed by the same letter are not significantly different. Means compared using Fischer's Protected LSD Test.

^y Randomized complete block statistical effects.

^x NS, *, **, *** = not significant and significant at $P \leq 0.05, 0.01, 0.001$ respectively.

Table 6. Mean number of stomata per mm² on the adaxial and abaxial leaf surfaces of Canary Island date palm (*Phoenix canariensis*) and queen palm (*Syagrus romanzoffiana*), UC SCREC, Irvine, CA, 2001-2002.

Species	No. of Stomata	
	Adaxial Surface	Abaxial Surface
queen palm	5.5	212
Canary Island date palm	282	270

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Indigenous Management Practices of *Golpata* (*Nypa fruticans*) in Local Plantations in Southern Bangladesh

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1. A *Golpata* plantation in Bagerhat district of Bangladesh



Golpata (*Nypa fruticans*), a familiar palm, growing naturally or in plantations in the coastal areas of Bangladesh (Fig. 1), is gaining increasing importance for its multifaceted uses. Besides growing naturally in the government-owned mangrove forests, it is being grown extensively through private initiatives in plantations established by rural farmers in the coastal areas, especially in the southern part of Bangladesh.

The mangrove palm, *Nypa fruticans* locally named as *Golpata* in Bengali, popularly known as the poor man's tin-sheet, is one of the important non-timber forest products of the tidal estuaries in the coastal belt of Bangladesh (Das et al. 2000). It is a stemless palm with tall erect fronds and underground rhizomatous stem (Shahidullah 2001) possessing an extensive root system, well suited to resist swift running water (Percival & Womersley 1975).

The management of *Nypa* in local plantations is accomplished entirely through the use of indigenous knowledge. *Golpata* is reported to be used mainly for housing, food, fuel, fence-making, medicine, cigarette wrapping, molasses, wine, fishing etc. The kernels of immature fruits are used as food. The juice is used for making molasses, locally called *Gur*, and alcohol. Newly developed shoots are reported to be used as a vermicide. Ash from *Golpata* is used as an analgesic against tooth pain and headache. Dry leaves, petiole, stem wood, fruit residues etc. are used as fuel. In fishing rhizomes of *Golpata* are extensively used, facilitating the fishing net to float over the water surface. Farmers also report that *Golpata* in the river or sea attracts deep-water fish. Bomhard (1964) and Killmann et al. (1989) describe the various ways of using *Golpata* for housing and other important purposes. FAO (1995) and Hamilton and Murphy (1988) describe the tapping of the palm for beverages such as wine or toddy and identify this as an ancient and traditional practice in Pan-Pacific and South and Southeast Asian countries. The present study discusses the indigenous knowledge of local farmers in the southern part of Bangladesh regarding planting pattern, multiplication, development of new plantations, tending operation, harvesting, processing, marketing of *Golpata* and income from it.

In Bangladesh, the natural distribution of *Golpata* is restricted to the Sundarbans, the largest single continuous tract of mangrove forest in the world (Chaudhury & Naithani 1985, Akhtaruzzaman 2000). Throughout the country, the demand for *Golpata* products is much higher than the present production. Shiva (1994) reports that *Golpata* has a great potential for commercial use in housing and medicine in Bangladesh. The role of *Golpata* is invaluable for both the rural and urban livelihood economies of Bangladesh. About 50,000 people living around the Sundarbans depend on *Golpata* and about 80% of houses in the area are made of *Golpata* (Faizuddin et al. 2000a). Although many local people around the Sundarbans plant *Golpata* on their available land, the increased demand for housing and other uses can only be

fulfilled by increasing production through plantation establishment and sustainable management of the wild resource.

The study site

The study area of Bagerhat falls under the old Ganges meander flood plain zone covering the gray silty acid sulfate clay (BBS 1988). The pH of the soil ranges from 7.5 to 8.0 (Faizuddin et al. 2000b). The district has a hot summer and a mild winter. The summer begins from the middle of April and continues till the middle of June. The winter starts from November and continues till February. The maximum and minimum mean temperature during the summer is 35.6°C and 24.6°C, respectively. The maximum and minimum mean temperature during the winter is 27.2°C and 14.6°C, respectively. The level of humidity rises above 95% in the monsoon that commences from the middle of June and continues till the end of September (BBS 1988). The range of annual rainfall recorded in the district is 1640–2000 mm (Siddiqi 2001). Topographical, geological and climatological conditions together make the district prone to severe cyclone occurring in the early part of the summer and the later part of the monsoon. But the district is not seriously affected by these due to the locations of Sundarbans in the south part of the districts that acts as a shelter-belt (BBS 1999).

Materials and Methods

The study was conducted in the district of Bagerhat, in the southern part of Bangladesh, for a three-month period between January to March 2002. *Golpata* is commonly planted surrounding the homesteads of Bagerhat within the tidal coastline.

The study was conducted by interviewing 40 rural household-members and visiting the *Golpata* plantation directly. Data were collected from male heads or other important respondents through a semi-structured questionnaire. The distribution of *Golpata* plantations in the study area was directly observed. The information on multiplication, development of new plantations, tending operations, harvesting, processing, marketing and uses of *Golpata* were gathered.

The data were collected from four villages, two each from the Upazilla (sub-district), namely Bagerhat Sadar and Sarankhola where *Golpata* plantation is a common forestry practice. The name of the villages sampled from Bagerhat Sadar were Saidayllapur and Sayera and from Sarankhola were Rayenda and Soudhkhali.

As nursing and production of *Golpata* plantation are the functions of the land-holding capacity of

Table 1: Distribution of *Golpata* (*Nypa fruticans*) plantations in different sites in the Bagerhat district of Bangladesh.

	Plantation sites (No. of plantations)				Total
	Homestead	Borrow pits	Ditch site	Lower plains of agricultural lands	
Household category					
Landless	5	2	4	7	18
Marginal	7	9	11	6	33
Small	7	3	4	10	24
Medium	2	1	1	4	8
Large	2	0	2	3	7
Total	23	15	22	30	90

Table 2: Production of sap from different aged *Golpata* in the plantations of Bagerhat district of Bangladesh.

Age class	Sap production (ml/shoot/season)
0–4	0
5–8	800–1000
9–12	1500–1900
13–15	1000–1200
>15	600–700

the households, the farmers were stratified into marginal (0.21–0.50 ha), small (0.51–1.00 ha), medium (1.01–2.00 ha) and large (above 2.00 ha) landowners. Out of this stratification, 40 households, 10 households from each village, randomly representing each stratum, were selected.

Results and discussion

Distribution of Golpata plantations in the landscape

Within the landscape of the study area, four different sites under *Golpata* cultivation were identified. These were homesteads, “borrow pits”, ditch sites and the lower plains of agricultural land (borrow pits are the pits left after soil is extracted for road building or embankment construction; they fill up with saline water and are thus suitable for *golpata* cultivation). The study revealed that highest number of farms (n = 30) were found in the lower plain of agricultural land followed by homesteads (n = 23), whereas, the lowest number (n = 15) were found along the borrow pits (Table 1). However, the variation in the number of farms among different household categories was easily observed in the study area. All farmers suggested that the production of *Golpata* was higher in lower plain lands where inundation was common and lowest in homesteads, where, of course, inundation is not frequent. This was due to variation of salinity and tidal inundation. This was also supported by Aksornkoae (1987) and Untawale (1987) who reported that salinity and tidal inundation are considered as important requirements for the occurrence of *Golpata*.

The number of plantations was highest in the marginal category of the farmers (n = 33) followed by small (n = 24), landless (n = 18), medium (n = 8) and large (n = 7) as shown in Table 1.

Multiplication within the plantations

The existing plantations were reported to be multiplied through rhizome, viviparous germination and separation of leading shoots. About five to six percent of clumps produced two leading shoots at a time per year instead of one leading shoot. Those two shoots gradually separated from each other at right and left side, respectively and ultimately produced two clumps. This was observed at the periphery of the farm.

Development of new plantations

Soft, muddy and water-logged soils where free access of saline water was available were characteristic of the land used by farmers in selecting sites for *Golpata* plantations. Seed and seedlings, as well as developed seedlings from the viviparous germination were the main planting material. Four different sources of these planting materials were identified and these were floating seeds from water bodies (65%), own material (30%), from neighbors (3%) and from the market (2%). The one-year-old seedlings were generally planted during the rainy season at a spacing of 1.82 × 1.82 m. Farmers reported that if stagnant water conditions lasted 5 or 6 weeks immediately after planting, with the seedlings consequently fully under water, the seedlings would then become rotten. To encourage the establishment

Table 3: Farm size and income of the <i>Golpata</i> planters in Bagerhat district of Bangladesh.					
Farm category	Average farm size (ha)	Frequency	Av. number of leaves harvested/yr (<i>Pon</i> *)	Income/year (Tk**)	Change in income (%)
Landless	0.14	18	22	4667	-
Small	0.3	43	62	12463	16.7
Marginal	0.46	24	91	18833	51
Medium	0.71	8	129	23220	23.1
Large	0.76	7	142	26373	13.57
*1 <i>Pon</i> equals 80 leaves.					
** 1 US \$ = 58 Tk					

of the seedlings, at least 10–12 cm of the seedlings should remain above the water level.

Tending operation

It was reported that the farmers practiced weeding, thinning, removal of diseased or unexpanded leaflets, gap filling at 100%, 65%, 35% and 28%, respectively. Faizuddin et al. (2000b) and Siddiqi (1999) also pointed out such maintenance operations for the acceleration of *Golpata* production in Bangladesh. Gonzales (1979) suggested thinning in order to maintain desired density and Siddiqi (1999) recommended pruning of non-leafy leaflet of *Golpata* for the acceleration of production.

Harvesting

All of the farmers surveyed, irrespective of household category, suggested that the extraction of leaves normally started from the 6- or 7-year old plants within the plantation. A slanting cut, maintaining a 45° angle is used. The cutting height above the ground depends on the planting density. According to the farmers, if the density is high,

cutting is undertaken at 7 or 8 cm above the ground and in case of low density, at 5 or 6 cm. The season of harvesting was January to February as new shoot development begins in March. The reason behind the harvesting season practiced is to allow access to the new leaves for the next month.

Golpata is also much valued for the sweet sap tapped from the stalk of the inflorescence. It was reported that tapping normally commences from the *Golpata* shoots after four years and continues up to 15 years or more. The shoots of 9–12 year old stems are reported to be the highest yielding, providing up to 1500–1900 ml of sap per stem per season. The stems of 15 years or more were reported to yield a reduced sap production (Table 2). The farmers also reported that palms from canals, ditches or riversides gave the highest amount of sap. Tapping began from the first week of December when the fruit begins to mature and turns tan. The stalk of inflorescence was then pulled down and every morning and evening, a thin slice of stalk was removed and sap collected

2. A stack of *Golpata* leaves in Bagerhat district of Bangladesh.



in a container called a *Got*. This was continued up to the next mid March. It was also reported that 1 kg molasses was produced from 7–8 liters of sap. Most of the farmers surveyed were reluctant to tap the stems because of the decline in the quality of leaf production. However, it was observed that 10% of the landless farmers tapped the stems for wine.

Processing

The harvested leaflets are reported to be cut at 5 or 6 cm above the bottom of the rachis. Then, eight leaflets are arranged one after another keeping the apex at one direction. The rachis of accumulated leaflets is then divided into two parts by pulling them in opposite direction. Generally, the operation is undertaken manually (two men) immediately after harvesting. Each of the separated portions was called *dhalis*. Finally, arranging right and left *dhalis* separately, exposing the rachis in a southerly direction for accelerated rapid drying, heaps 0.91–0.95 m high are made. Each side of the heap was fixed by driving two stakes 2.74 m apart and a weight was provided at the top of the heap to make them compact, preventing free air circulation as it promotes the deformation of the leaflets. After 15 days in the heap, the leaflets turned tan in color. Generally they were kept 20–25 days in each heap. A stack of *Golpata* leaves is shown in the Fig. 2.

Marketing

The processed leaves are reported to be the principal product for marketing. Every three to four years, the growers themselves consume a negligible portion of the products for housing purposes and the remainder are sold. Several intermediaries, operating in between the growers and the end users, acted in the marketing of leaves. Generally, the leaves moved from growers through middlemen to wholesalers, to retailers and finally to the end users (Fig. 3). In some cases, the

middlemen sell dried leaves to the retailers or directly to the consumers. However, some retailers had another profitable mechanism to bypass the wholesalers or middlemen, directly buying leaves from the growers. Another important product reported to be sold is *Gur* (molasses), which generally followed a short marketing chain; this product is sold directly to the end-users in villages or in local markets.

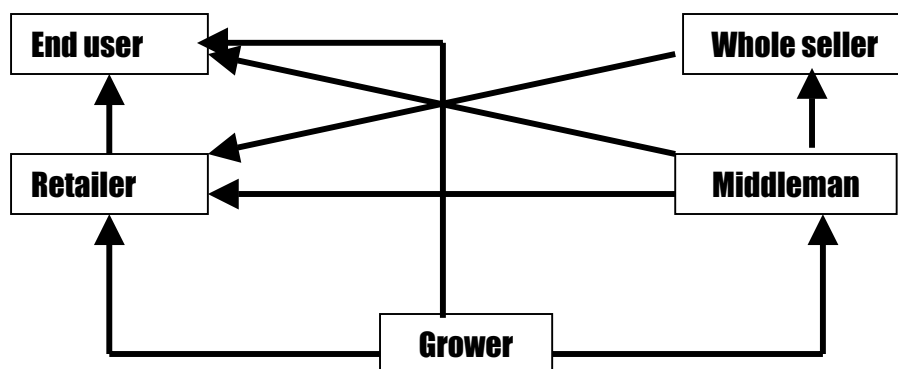
Farm size and income

The study revealed that *Golpata* farm sizes ranged from 0.14 ha to 0.76 ha, gradually increasing with the increase of land holdings. The highest number of farms ($n = 43$) of average size 0.3 ha was observed in small category followed by the marginal category ($n = 24$) of average size 0.46 ha (Table 3). The highest income (Tk 26373 = approx. US\$450) was earned by large farmers and the lowest (Tk 4667 = approx. US\$80) by landless farmer (Table 3). The variation in income among the farmers occurred due to the size of farms and the pattern of their own consumption. It was reported that their own consumption of *Golpata* products by the large farm categories was comparatively higher than the small farm categories. Due to the variation of the farm size, leaf production and sale are varied, which is also reflected in the variation in income of the different farm categories.

Conclusions

Golpata is an important natural resource and the only palm species used for housing in the southern part of Bangladesh. It plays an active role in the contribution to rural livelihoods and to the cultural heritage of the people. Besides solving the housing problem, it also helps to alleviate poverty in the region by providing many people access to the cash economy. The government and NGOs should extend their helping hand providing appropriate technology for cultivation,

3. Marketing channel of *Golpata* products in Bagerhat district of Bangladesh.



management, processing, marketing and utilization incorporating the traditional knowledge described in this paper. Bangladesh has available newly raised coastal lands along the coastal belt and vacant areas in the Sundarbans suitable for *Golpata* plantation (Faizuddin et al. 1998, Siddiqi & Khan 1990) where *Golpata* plantation can be raised, involving local people who already have knowledge of *Golpata* cultivation.

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Studies on the Establishment of Date Palm (*Phoenix dactylifera* 'Deglet Noor') Offshoots. Part I. Observations on Root Development and Leaf Growth

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Date palm cultivars are clones that must be propagated vegetatively, the grower nearly always relying on offshoots (young plants) that arise from the base of the mother palm. We found that offshoots possessing more roots when removed from the mother palm have a greater ability to regenerate a root system and to establish more successfully and rapidly because over two-thirds of all new roots grew from existing cut roots. Leaf extension is a good above-ground indicator of root growth.

This article is the first of two exploring establishment of date palm offshoots. Part II will

appear in a future issue of *Palms* and will address the optimal size for best establishment.

The date palm, *Phoenix dactylifera* L., has long been one of the most important plants of arid, desert areas of northern Africa, the Middle East and southern Asia. Appropriately called "the palm of life," for over 5,000 years it has provided food, ornament and material for shelter, fiber, and fuel in a harsh environment where relatively few other plants are able to grow (Dowson 1982, Nixon & Carpenter 1978, Popenoe 1973, Zaid 1999). Humans have since spread the date palm far beyond its historical range, taking it to nearly all regions of the world where it can be grown. Even in more humid tropical and subtropical areas unsuitable for fruit production, the date palm is widely used as an ornamental palm.

In USA commercial date fruit production began in the late 1800s and is still an important component of desert agriculture in southern California and Arizona (Albert & Hilgeman 1935, Johnson et al. 2002, Karp 2002, Nixon & Carpenter 1978). Since the late 1970s and continuing to the present, steady economic growth and subsequent real estate boom in the south-western and southern United States have fuelled an unusually strong and steady demand for large landscape palms.

Mature date palms are highly desirable landscape subjects because they are plentiful, relatively inexpensive, uniform in size and habit, and highly ornamental. Dug out of date groves in California and Arizona, the palms are transported for outdoor landscape planting within these states as well as to southern Nevada, Texas, and Florida, and sometimes even for indoor use elsewhere.

Most date growers have found it more profitable to sell date palms for landscape use, once they attained a desired height of 8–10 meters of trunk, than to continue to grow them solely for fruit production (D. Young & W. Geissler pers. comm., Karp 2002). Planted about 50 palms per acre (0.4 ha.), the palms begin to produce harvestable fruits after three to five years, steadily increasing to full production at 15–20 years. Growers can annually net US \$500–1,000 per acre at full production. However, they can net about US\$50,000 per acre when the palms have reached the desired height and are harvested and sold for landscape use, usually in 20–25 years (D. Young & W. Geissler pers. comm., Karp 2002). Indeed, much of the recent expansion of date palm acreage in California and Arizona is due as much, if not more, to the demand for the palms for landscape use than it is to demand for fruit production (D. Young & W. Geissler pers. comm.).

Thus, date palm production in California and Arizona is an unusual agricultural commodity because it is one of the few crops that actually

generates cash income (fruit production) to help defray production costs for 20–25 years until the palms attain a harvestable and saleable size (landscape use). For additional income during this time, growers can sell offshoots, small palms arising from the base of the mother palm that can be removed and planted to generate new palms.

Because date fruit production is dependent on named clones, for example 'Deglet Noor,' 'Medjool,' 'Zahidi' and 'Barhee,' growers can only propagate new palms vegetatively by tissue culture or by removing offshoots and planting them, which is the dominant method of propagation. Demand for offshoots is high and, depending on the variety, they can cost as much as US\$100 to \$300 each (D. Young & W. Geissler pers. comm.). This high value has prompted a rash of thefts of recently planted offshoots from fields in date growing regions of southern California and Arizona.

Propagation of date palms from offshoots frequently yields variable and disappointing results. A 50–80% survival rate for date palm offshoots is considered normal although some growers have reported successful establishment from as low as 10% to as high as 90% (D. Young & W. Geissler pers. comm.). After offshoots are removed from the mother palm, they are directly planted into the field where the new grove will be established. Furrow or flood irrigation is provided to maintain adequate soil moisture until the offshoots establish.

Successful establishment of date palm offshoots is dependent on regeneration of a new root system and leaf growth. Workers have cited many factors responsible for the success or failure of offshoots to establish and survive (Table 1). The purpose of our work was to observe the response of root systems and leaf growth of several date palm offshoots after removal and replanting and to determine which aspects might be critical in their successful establishment and in directing future research.

Materials and methods

A date grower in Indio, California removed 12 offshoots of *Phoenix dactylifera* 'Deglet Noor' from mother palms in a commercial date grove on 14 July 1999 and provided them for this study. The offshoots were positioned low on the mother palm at the soil line. Following standard industry procedures, skilled laborers dug soil away from the base of each offshoot and removed all leaves except for the 12 newest ones, which were then tied tightly together. During digging each offshoot's roots were cut to about 2–10 cm long.

Table 1. Factors cited in literature as responsible for the success or failure of offshoots to establish and survive.

<u>Factor</u>	<u>Literature</u>
variety (clone)	Drummond 1919; Nixon & Carpenter 1978; Zaid 1999
age/size	Albert 1926; Aldrich et al. 1945; Bader & Al-Yasiri 1986; Bader & Hummadi 1987; Cride, 1926; Dowson 1982; Drummond 1919; Hilgeman 1951; Nixon & Carpenter 1978, Reuveni et al. 1972; Toutain 1966; Wertheimer 1956; Zaid 1999
quantity of offshoots on mother palm	Aldrich et al. 1945
presence of roots	Albert 1926; Aldrich et al. 1945; Crider 1926; Furr 1966; Nixon & Carpenter, 1978; Wertheimer 1956
position on mother palm	Drummond 1919; Crider 1926; Dowson 1982; Gupta & Godara, 1984
leaf pruning	Albert 1926; Dowson 1982; Drummond 1919; Furr 1966; Reuveni et al. 1972; Zaid 1999
removal technique	Dowson 1982
planting technique	Albert 1926; Al-Mana et al. 1996
humidity	El-Hamady et al. 1992; Reuveni et al. 1972
temperature	Reuveni et al. 1972
soil moisture	Aldrich et al. 1945; Al-Mana et al. 1996; Bader & Al-Yasiri 1986; Furr 1966; Zaid 1999
plant growth regulators	Al-Mana et al. 1996; Bader & Al-Yasiri 1986; El Hodairi et al. 1992; Reuveni et al. 1972; Reuveni & Adato 1974
carbohydrate content	Reuveni et al. 1972; Reuveni & Adato 1974
time of year	Albert 1926; Bader & Hummadi 1987; Dowson 1982; Drummond 1919; Furr 1966; Reuveni et al. 1972; Zaid 1999

Using a sledgehammer, the workers drove a heavy, broad-bladed chisel between the offshoot and mother palm, cutting their connection. Once the offshoot was free, they cut the tied up leaves at a common point, removing about the upper half of their length, and cut off the remaining leaf bases of old or removed leaves, reducing the diameter of the offshoot base by 3–7 cm. At this point the offshoot had little or no soil around the roots and was ready for immediate planting in the field.

Prior to replanting, we recorded the height (distance) from base to the cut tip of the longest leaf, diameter of the base at its widest point, number of cut roots, number of leaves present, and the number of leaves removed at digging for each offshoot.

We planted the offshoots on the same day at the University of California, Riverside in UC potting mixture No. 2 (1 part peat moss and 1 part sand) in standard 50-liter (15 gallon) plastic nursery containers. We set them in the container so that the area where the roots originated from the stem was 20–25 cm below the potting mixture surface. Tomlinson (1990) termed this area the root initiation zone (RIZ). This depth is slightly shallower than that of the standard industry practice, which normally calls for planting the offshoot so that the area where roots originate from the stem is about 25–50 cm below the surface of the field soil. Planting depth is mostly dependent on the size of the offshoot; the larger the offshoot the deeper it is planted. Deeper



1. Co-author Dennis Pittenger holds offshoot No. 5, which had no root growth or leaf extension.

planting supports the offshoot in an upright position until new roots grow. Leaves remained tied up for the duration of the study. We placed the containers with potted offshoots in an unheated greenhouse for the duration of the 12-week study.

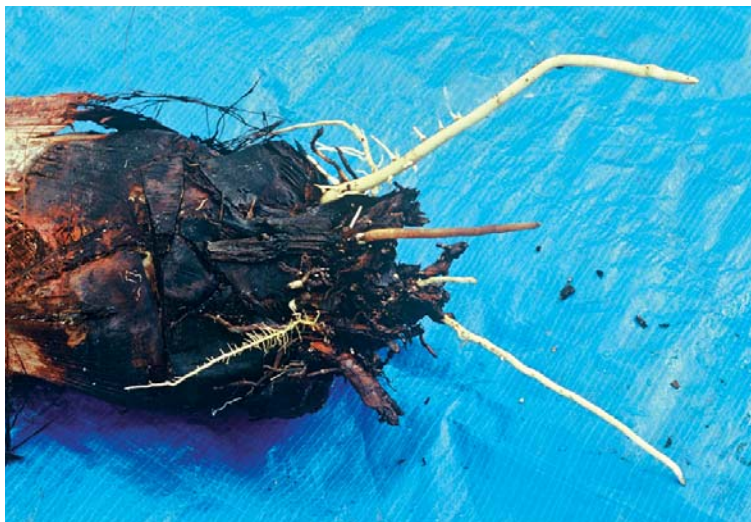
Immediately after planting we hand-irrigated the offshoots thoroughly to bring the potting mixture to container capacity. A drip irrigation system provided water for the duration of the study.

Irrigation rates for each container were 2 liters per day for the first 2 weeks, then 2 liters 4 days a week for 6 weeks, then 2 liters 3 days a week for 2 weeks, and finally 2 liters 2 days a week. These schedules maintained the media at or near container capacity.

We continuously fertilized the offshoots through the irrigation system using a commercial fertilizer with N-P-K analysis of 21-5-20 at 300 ppm of N. During the study, night air temperatures in the greenhouse ranged from 15 to 21°C while day air temperatures ranged from 27 to over 38°C. Temperatures exceeded 38°C on 40 days with an estimated maximum temperature of 41°C. We recorded soil temperatures periodically using a thermometer placed 15 cm deep near the center of the container. Morning (0800–1000 hours) soil temperatures ranged from 23 to 25°C while afternoon (1300–1600 hours) temperatures ranged from 33 to 35°C.

Light levels inside and outside the greenhouse averaged 1000 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{sec}^{-1}$ and 1600 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{sec}^{-1}$ respectively, indicating that about 63% of available light was entering the greenhouse. We did not record relative humidity in the greenhouse but did use a Mee® fog/fine mist system for greenhouse cooling and humidity control for the first two weeks after planting. Pad and fan cooling was used throughout the duration of the study.

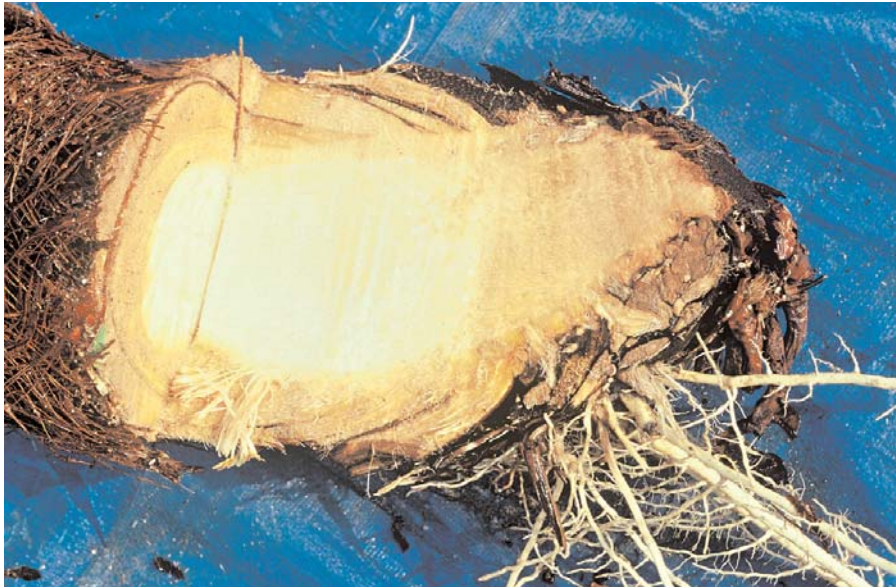
After 12 weeks we removed the offshoots from their containers and recorded their leaf extension (height). Using a high-pressure water jet to remove the potting mixture, we traced all new roots to their origin and recorded the number of new first order-roots originating from the stem and the number of new first-order roots originating from



2. Offshoot No. 10 had little root growth.



3. Offshoot No. 3 had significant root growth. Note mass of numerous secondary roots growing up to the surface. These may function for additional gas exchange in wet or saturated soils.



4. Offshoot No. 8 had a large, well developed RIZ broadly rounded proximally.



5. Offshoot No. 11 had a small, poorly developed RIZ lacking roots.

Table 2. Diameter at base, number of leaves (Lvs.), leaf extension (Ext.), number of cut roots, and number and origin of new roots of 12 date palm offshoots, University of California, Riverside, 1999.

Off-shoot	Base Diam. (cm)	No. Lvs.	Leaf Ext. (cm)	No. Cut Roots	Number and Origin of New Roots			
							Cut	Cut
					Total	RIZ	Face	Roots
1	18.0	20	45.1	30	22	6	1	15
2	20.7	24	77.5	35	37	16	3	18
3	21.7	28	76.2	40	50	7	0	43
4	23.9	20	27.4	29	9	3	0	6
5	23.7	20	6.9	17	0	—	—	—
6	21.1	23	26.7	28	4	3	0	1
7	25.4	24	64.8	30	18	6	0	12
8	25.8	33	38.1	43	26	5	0	21
9	21.0	25	24.1	29	16	1	0	15
10	18.0	20	11.4	17	6	1	0	5
11	27.0	16	0.0	23	0	—	—	—
12	18.3	22	45.0	35	27	9	3	15

Table 3. Mean, median, and range of base diameter, number of leaves, leaf extension, and number of cut roots of 12 date palm offshoots, University of California, Riverside, 1999.

	Base Diameter (cm)	No. Leaves	Leaf Extension (cm)	No. Cut Roots
Mean	22.1	23.9	36.9	29.6
Median	21.7	22.5	32.8	29.5
Range	18–27	16–33	0–77.5	7–43

roots cut during removal from the mother palm. Of roots originating from the RIZ, we distinguished between those that originated from the uncut and undamaged surface and those that originated from the margin of the cut face (the flat, wounded surface made when the chisel cut the connection to the mother palm). We did not count second- and third-order roots. We cut the bases of six offshoots transversely and longitudinally to observe where and how new roots originated.

Results

We summarize the data for each offshoot in Tables 2 and 3. Mean base diameter was 22.1 cm with a range of 18–27 cm, while mean leaf extension was 36.9 cm with a range of 0–77.5 cm. All offshoots except one had leaf extension, some even before

we planted them. Mean leaf number at planting was nearly 24 (23.9) with a range of 16–33 while the mean number of cut roots was nearly 30 (29.6) with a range of 17–43. Median values were nearly the same as the means except for the leaf extension, which was 32.8.

Of the 12 offshoots, Nos. 5 (Fig. 1) and 11 showed no root growth and little or no leaf extension. They were desiccated and we considered them to be dead. Nos. 4, 6 and 10 (Fig. 2) showed little root growth and relatively short leaf extension and had not established successfully but were not yet dead. The remaining offshoots had significant root growth and leaf extension (Fig. 3).

New roots were white and round and numbered 0–50 per offshoot with a mean of about 18 (17.9).

The longest new primary roots were 30–45 cm long and reached the bottom of the container where they were directed laterally. New roots originating from cut roots were numerous and about 3 or 4 mm in diameter, while those originating directly from the offshoot stem were fewer and larger at 4–7 mm in diameter.

Roots originating from cut roots often appeared a few centimeters from the point where the cut root attached to the stem. It was not possible to see their points of origin without removing the potting medium, leaf bases and other tissue on the surface of the stem. Gage (1901) and Broschat and Donselman (1990a) documented branching or resprouting of damaged or cut palm roots for related species, *Phoenix paludosa* Roxb. and *P. reclinata* Jacq. respectively, while Peebles (1936) documented the same phenomenon for the date palm. Secondary, tertiary, and quaternary roots were present and, in the most developed root systems, typically were growing toward the soil surface (Fig. 3). Tomlinson (1990) suggested that these upward growing and proliferating roots, characteristic of most palms naturally growing in or near wet or saturated soils, such as swamps, bogs, marshes, and ponds, function as sites for additional gas exchange.

All offshoots that survived and displayed good root development, such as Nos. 2, 3 (Fig. 3) and 8 (Fig. 4), had large, broadly rounded proximally, well developed and defined RIZs nearly around the entire perimeter although they were thin or briefly interrupted at the point of attachment with the mother palm (the cut face). These offshoots also had more roots when initially removed from the mother palm. In longitudinal section, these RIZs were broadly rounded at the proximal end

where root initiation was concentrated and pointed at the distal end where shoot (leaf) growth originated. They were lighter in color than the surrounding tissue, bore ample root initials and roots, and decreased abruptly in diameter proximally but gradually in diameter distally.

In contrast, offshoots that had little or no root growth, such as No. 11 (Fig. 5), had small, poorly developed RIZs, which in longitudinal section tapered gradually at the distal and proximal ends. There were few root initials and little or no root growth.

In the 12 offshoots we observed a high ratio of new roots originating from cut roots compared to those originating from the RIZ. We summarize the mean, median, range and percent of new roots by origin (Table 4). A total of 215 new roots were produced, with a mean of nearly 18 (17.9), a median of 17, and a range of 0–50. Of those new roots, over two-thirds, 151 (70.2%), originated from cut roots while only slight more than one-fourth, 57 (26.5%), originated from the RIZ. Only 3.3% of new roots originated from the margin of the cut face, indicating the damage the RIZ sustained in this area during digging and separation from the mother palm. The mean, median, and range of new roots originating from cut roots are 15.1, 15, and 1–43 respectively; from the RIZ they are 5.7, 5.5, and 1–16 respectively; and from the margin of the cut face they are 0.7, 0, and 0–3 respectively.

Discussion

Although the study was not replicated, our observations indicate that shape and size of the RIZ, probably both functions of age but not necessarily of size of the offshoot, may affect the

Table 4. Mean, median, range and percent of new roots by origin of date palm offshoots, University of California, Riverside, 1999.

	Origin			
	Total	RIZ	Cut Face	Cut Roots
Number of Offshoots	12	10	10	10
Number of Roots	215	57	7	151
Percent	100	26.5	3.3	70.2
Mean	17.9	5.7	0.7	15.1
Median	17.0	5.5	0.0	15.0
Range	0–50	1–16	0–3	1–43

6. Offshoot No. 12 had new roots originating from cut roots only a few centimeters from the stem (lower left). Note presence of root initials and how original roots pushed out from the RIZ (bottom).



7. Cut root of offshoot No. 3 resprouted into three roots.



ability of the date palm offshoot to establish successfully. Offshoots with larger, well defined, and more broadly rounded RIZs produced more roots than those with smaller, poorly defined, and more slender RIZs. More importantly they had more roots when initially removed from the mother palm.

Wertheimer (1956) recognized the importance of the shape of the offshoot being round to establish successfully. Broschat and Donselman (1990b) linked diameter of the stem to development of

the RIZ and regeneration of palm root systems in *Phoenix roebelinii* O'Brien and *Chamaedorea elegans* Mart. They reported that regeneration of root systems in these palms is dependent on the presence of the RIZ, and noted that the RIZ does not develop and become active until the stem has reached its maximum diameter and begins to elongate vertically.

We observed that the RIZ develops and becomes active at a much earlier stage in date palm offshoots, well before the offshoot stem attains its

maximum diameter and begins to elongate vertically. We suspect that the RIZ must attain a critical minimum size to ensure sufficient regeneration of a new root system but that this critical size is only loosely correlated with offshoot stem diameter. Certainly, this critical size is independent of the offshoot stem attaining its maximum diameter and then elongating vertically because none of the offshoots were anywhere near their maximum diameter yet all but three regenerated healthy, extensive root systems enabling them to establish successfully and quickly.

Most important was the ability of existing roots to resprout, sometimes with two to five additional roots each (Figs. 6, 7), after they were cut during removal from the mother palm. This discovery contrasts dramatically with Crider (1926), Dowson (1982) and Nixon and Carpenter (1978), who reported that most cut roots of date palm offshoots die, but it confirms the findings of Peebles (1936). The large percentage of new roots originating from cut roots also differs from Broschat and Donselman (1984, 1987, 1990a), who reported that roots of other palm species cut less than 15 cm from the stem rarely survive. Because over two-thirds of all the new roots grew from existing cut roots, offshoots possessing more roots when they are initially removed from the mother palm have a greater ability to regenerate a new root system. Such offshoots have larger, better defined, and more broadly rounded RIZs. Aldrich et al. (1945), Crider (1926), Furr (1966), Nixon and Carpenter (1978), Wertheimer (1956) and Zaid (1999) recognized the importance of a well developed root system prior to removal from the mother palm for successful establishment of offshoots but they did not associate it with the ability of existing roots to resprout and continue to grow once cut. Our work suggests that offshoots with 29 or more existing roots should establish successfully while those with 23 or fewer might die or take much longer to establish.

Offshoot size may be important for resprouting of cut roots, though. Al-Mana et al. (1996), Reuveni et al. (1972) and Reuveni and Adato (1974) concluded that the larger offshoots have more stored carbohydrates for energy for root growth, higher levels of root-promoting substances, and lower levels of root-inhibiting substances than smaller offshoots.

We believe previous investigators may have mistaken many resprouted cut roots for new roots originating from the RIZ. We found that cut roots often resprout within a few centimeters of the stem (Fig. 6) and might appear to be new roots

from the RIZ. All roots must be traced to their origin to determine whether they originate from cut roots or the RIZ.

Offshoots with at least 30 cm leaf extension and 29 existing roots established most successfully. Those with at least 22 green leaves when removed from the mother plant generally grew more roots. Although some leaf extension occurred even before the offshoots were replanted, offshoots with at least 24 cm leaf extension are probably successfully established.

Conclusions

The RIZ must attain a critical minimum size and shape, both of which are unknown and directly immeasurable, for the offshoot to have enough existing roots to regenerate a sufficient number of new roots to establish and survive. The number of roots existing at the time an offshoot is removed from the mother palm appears to be most important, with 29 or more roots being optimal. Future work should be directed to determine which external indicators might be useful in determining when the offshoot and RIZ have attained the minimum size, optimal shape, and optimal number of roots for removal from the mother palm.

Protecting existing cut roots of date palm offshoots from damage when digging, transporting, and replanting is important because these are the sources of the majority of newly regenerated roots necessary for successful establishment. One might surmise that root pruning offshoots prior to removal from the mother palm would be beneficial. However, any newly sprouted roots would be susceptible to damage during the removal and replanting process. In all cases it is advisable to maintain a root ball at least 15 cm out from the perimeter of the offshoot to protect the existing cut roots and the RIZ.

Acknowledgments

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Studies on the Establishment of Date Palm (*Phoenix dactylifera* 'Deglet Noor') Offshoots.

Part II. Size of Offshoot

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Date palm offshoots 10 to 35 cm in diameter have the highest survival rates. Offshoots this size probably have more roots when initially removed from the mother palm, more stored carbohydrates to provide energy for root growth and increased levels of naturally-occurring, root-promoting substances.

This article is the second of two exploring establishment of date palm offshoots. Part I (Hodel & Pittenger 2003) had an introduction discussing the background and importance of the date palm industry and the critical practice of propagating date palms from offshoots.

Date palm cultivars are clones that must be propagated vegetatively, nearly always relying on offshoots (young plants) that arise from the base of the mother palm. Researchers have reported many factors responsible for the success or failure of date palm offshoots to establish and survive (Hodel & Pittenger 2003). Size was frequently mentioned as an important factor; the literature generally stated that rooting is low in small offshoots and rises with increasing offshoot size

to a point above which there is no additional advantage. The objective of our work was to determine the optimal offshoot size (diameter) for best establishment.

Previous Work

There is no research-based information correlating offshoot diameter with establishment and survival. The information that does exist is anecdotal. Albert (1926), Albert and Hilgeman (1935), Bader and Al-Yasiry (1986), Dowson (1982), Drummond (1919), Nixon and Carpenter (1978), Reuveni et al. (1972), Toutain (1966) and Zaid (1999) reported that offshoots of a wide range of sizes, weights, and ages will root and establish successfully. Reported sizes ranged from about 13 to 41 cm in base diameter, weights from about 2



1. Newly planted date palm offshoots used for this study, February, 1998, Indio, California.

to 41 kg, and ages from 3 to 12 years. Optimal ranges reported also varied greatly but were about 20–36 cm in diameter, 10–30 kg, and three to five years of age (Table 1). Growers in California usually select offshoots 10–45 cm in diameter at the widest point.

Researchers typically focused on offshoot weight rather than base diameter, but weight has major disadvantages. It is nearly impossible to weigh an offshoot still attached to the mother palm, and weights do not necessarily reflect the water content of the offshoot or how many leaves and leaf bases were removed prior to weighing. Measuring the diameter of the offshoot base is less problematic but can still vary depending on whether the measurement was taken at the widest point or elsewhere. The widest point of the offshoot base when attached to the mother palm is usually concealed below the soil, further complicating diameter measurements. Albert (1926), Drummond (1919), and Zaid (1999) have attempted to correlate diameter of the base at the widest point with weight after leaf removal (Table 2).

Materials and methods

A commercial date grower in Indio, California permitted us to use a field that was newly planted

in February, 1998 with 500 offshoots of *Phoenix dactylifera* 'Deglet Noor.' Workers had planted offshoots about three meters apart in rows about five meters apart in the field in full sun the same day that they were removed from the mother palm (Fig. 1). They placed the offshoots so that the roots were 20 to 45 cm below the soil surface, backfilled with the unamended soil removed when making the planting hole, and flood irrigated the field thoroughly. Field soil at the site was a fine sandy loam, and regular irrigations maintained it near field capacity during establishment.

Using a completely randomized experimental design, we collected data along five transects encompassing 117 offshoots, two diagonals from the four corners of the rectangular field and three randomly selected rows running the length of the field. We recorded diameter at the soil surface, height from the soil surface to the tip or highest point of the newest emerging leaf (leaf extension) (Fig. 2), and survival for each offshoot in the transect immediately after planting and every six months thereafter for two years. Successful offshoot establishment is dependent on new root growth (Hodel & Pittenger 2003); thus, we selected offshoot leaf extension and an increase in stem (offshoot) diameter because they are indicative of root growth (Hodel & Pittenger 2003; Tomlinson, 1990).

Data were subjected to ANOVA and mean separations using Fischer's Protected LSD Test. Offshoot diameters we measured and recorded are about 5–10 cm less than the actual widest diameter of the offshoot because, whether planted in the field or still attached to the mother palm, the widest point of an offshoot is below the soil surface. Because the offshoots varied greatly in initial height, we report the percent increase in leaf extension rather than the simple numerical increase.

Results

Offshoots 10–25 cm in diameter had significantly greater increases in diameter than those 25 cm or larger in diameter, and offshoots less than 20 cm in diameter had significantly greater increases in leaf extension than those 30 cm or larger in diameter (Table 3). Clearly, the larger the offshoot diameter the smaller the percent increase in leaf extension (Table 3). Although more than half the offshoots survived across all the size categories, those 10–35 cm in diameter had survival rates of 83 to 95 percent while those 35 cm or larger in diameter had a survival rate of only 74 percent (Table 3).

Discussion

Our findings show that date palm offshoots with initial base diameters at the soil surface from 10 to 25 cm had the greatest increases in leaf growth and base diameter and high survival rates (>83%). However, offshoots with initial base diameters from 25 to 35 cm had equally high survival rates but had smaller increases in leaf growth and base diameter, suggesting that they establish more slowly than the smaller offshoots. Only offshoots with initial base diameters greater than 35 cm showed lower survival rates (74%). These findings generally agree with accounts in the literature (Albert 1926, Albert & Hilgeman 1935, Bader & Al-Yasiry 1986, Dowson 1982, Drummond 1919, Nixon & Carpenter 1978, Reuveni et al. 1972, Toutain 1966, Zaid 1999).

Several related factors are probably responsible for better establishment and survival of date palm offshoots with base diameters from 10 to 35 cm, rather than smaller diameters. Reuveni et al. (1972) reported that carbohydrates stored in the offshoot, which provide the energy for root growth, and unnamed, naturally occurring, root-promoting and root-inhibiting substances, which control the initiation of root growth, are critical factors. Generally as offshoots increase in size they contain increased amounts of carbohydrates and root promoters and decreased amounts of root inhibitors. Later, Reuveni and Adato (1974)



2 . Same date palm offshoots pictured in Figure 1 but two years later in February, 2000, Indio, California.

concluded that it was the root inhibitors rather than the root promoters that are primarily responsible in initiating root growth. Rooting ability is positively correlated with carbohydrate content and negatively correlated with root inhibitor content. The larger the offshoot is the greater the carbohydrate content and the smaller the content of root-inhibiting substances.

More recently, Al-Mana et al. (1996) concluded that naturally occurring rooting co-factors (substances) are probably responsible for initiation of offshoot root growth. These co-factors, thought to be phenolic compounds, may encourage rooting by protecting root-promoting hormones or auxins, like indoleacetic acid (IAA), from destruction by oxidizing enzymes. In the case of IAA the enzyme is IAA-oxidase.

Work with several auxins has tended to support the position that rooting co-factors or substances play a critical role in initiating date palm offshoot rooting. Bader and Al-Yasiry (1986), Gupta and Godara (1984) and Reuveni et al. (1972) reported that applications of indolebutyric acid (IBA) increased rooting of date palm offshoots. In contrast Reuveni et al. (1972) reported that naphthaleneacetic acid (NAA), gibberellic acid (GA),

Table 1. Absolute and optimal ranges of size (base diameter at widest point), weight (after leaf removal), and age of offshoots for successful rooting and establishment as reported in the literature (Albert 1926, Albert & Hilgeman 1935, Bader & Al-Yasiry 1986, Dowson 1982, Drummond 1919, Nixon & Carpenter 1978, Reuveni et al. 1972, Toutain1966, Zaid 1999).

	<u>Diameter (cm)</u>	<u>Weight (kg)</u>	<u>Age (years)</u>
Absolute range	13–41	2–41	3–12
Optimal range	20–36	10–30	3–5

Table 2. Offshoot base diameter correlated with weight as reported in the literature.

Diameter (cm)	12–15	15–20	20–25	25–35
Weight (kg)	4.5–6.8	6.8–13.6	13.6–22.7	22.7–40.8

Table 3. Mean increase in base diameter, mean percent increase in leaf extension, and percent survival of date palm offshoots in six size classes, Indio, California, 1998-2000.

Initial Base <u>Diameter (cm)</u> ^Z	Mean Increase Base <u>Diameter (cm)</u> ^{Z,Y}	Mean Percent Increase <u>Leaf Extension</u> ^{Y,X}	Percent Survival (No. Survived/ <u>No. Measured</u>)
10–15	5.3 a	178 a	95 (35/37)
15–20	5.4 a	157 a	92 (12/13)
20–25	5.2 a	142 ab	83 (15/18)
25–30	0.3 b	123 ab	92 (12/13)
30–35	1.3 b	121 b	92 (12/13)
>35	0.8 b	76 c	74 (17/23)
LSD, <i>P</i> = 0.05	2.7	38	
Summary of ANOVA ^W	***	***	

^Z At soil surface; actual base diameters are 5 to 10 cm greater; see explanation in text.
^Y Means followed by the same letter are not significantly different; *P* = 0.05; completely randomized design.
^X Calculated as: (overall height change/initial height) × 100.
^W *** = significant at *P* ≤ 0.001.

and several other compounds did not increase rooting. However, Al-Mana et al. (1996) reported that NAA did increase rooting of date palm offshoots.

The factors responsible for decreased survival of the largest offshoots are not as clear. Perhaps their larger size creates a lower root-to-shoot ratio, which makes them more susceptible to desiccation prior to sufficient new root growth, or perhaps other growth-inhibiting substances are produced in larger quantities

Conclusions

Offshoots with base diameters of 10 to 35 cm at the soil line when still attached to the mother

palm are at their optimal size for removal and replanting. Offshoots this size probably have more roots when initially removed from the mother tree, a critical factor because over two-thirds of all new roots on an offshoot arise from preexisting roots cut and severed during removal (Hodel & Pittenger 2003). Also, offshoots this size have more stored carbohydrates to provide energy for root growth and increased levels of naturally-occurring, root-promoting substances. Offshoots smaller than 10 cm diameter likely have fewer existing roots, smaller amounts of stored carbohydrates, and smaller levels of root-promoting substances. While offshoots larger than 35 cm diameter may have more roots and higher levels of carbohydrates and root-promoting substances, their large size and

heavy weight make removal, handling, and planting more difficult and problematic. Future work might investigate the causes of lower leaf and root growth and survival rates with these larger offshoots. Perhaps it is simply their lower root mass to shoot ratio that is responsible for the reduced growth and survival.

Acknowledgments

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A Re-examination of *Borassus* in Madagascar

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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. (Coryphoideae: 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!

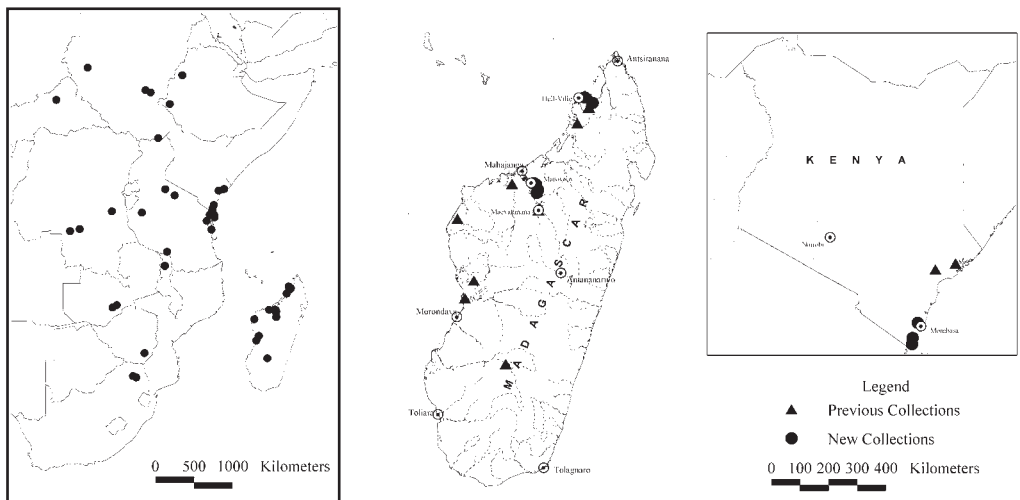
In addition to *B. madagascariensis*, Jumelle and Perrier de la Bâthie described a second endemic species of *Borassus*. The new species, which they named *Borassus sambiranensis*, was restricted to the area between the Sambirano and Ifasy rivers in the north-west of Madagascar (Jumelle & Perrier de 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 collections 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 (04°36'S, 39°23'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 (04°24'S, 39°24'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 (02°16'S, 40°07'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 (16°56'S, 46°49'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 (16°24'S, 46°46'E) (Fig. 8), Lake Amboromalandy (16°08'S, 46°45'E) and at the Ampijeroa Forestry Station (16°18'S, 46°49'E) of Ankarafantsika National Park. However, the most significant population was in and around the town of Marovoay (16°06'S, 46°41'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 (13°43'S, 48°23'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	<i>B. madagascariensis</i>	<i>B. sambiranensis</i>	<i>B. aethiopum</i>
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.



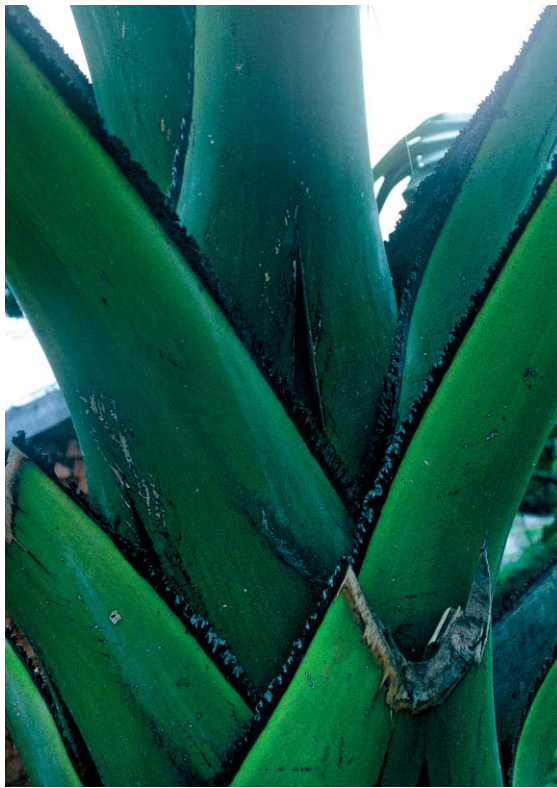
above the soil surface. In other cases they could be located in the leaf litter, or be found emerging from eroded soil surfaces. Preliminary studies suggest that DNA extracted from roots is not contaminated with foreign DNAs such as those of mycorrhizal fungi.

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 $\times$ 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. aethiopicum* 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).

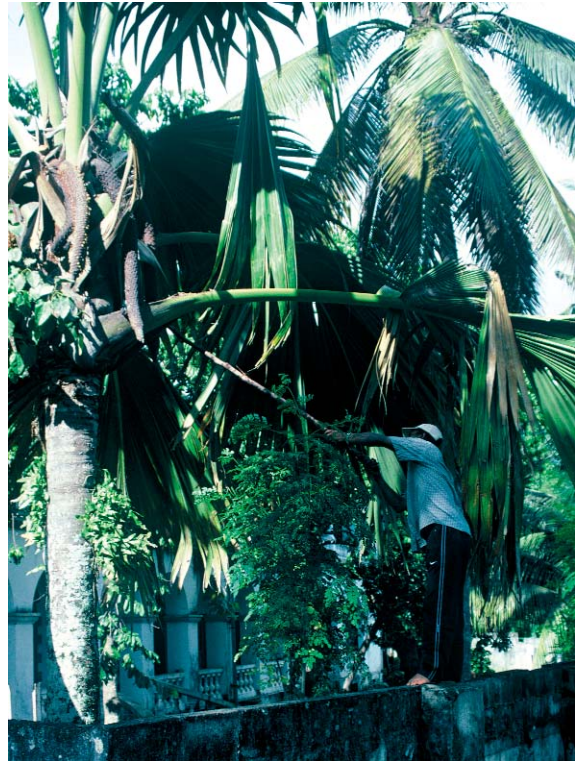
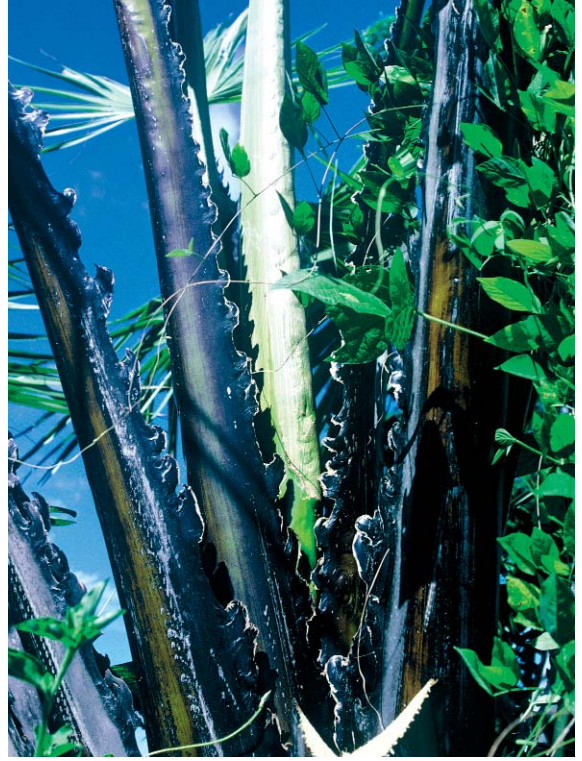
At present no information is available on seed dispersal of *B. madagascariensis*. The large terrestrial herbivores identified by Zona & Henderson (1989) as dispersal agents for *B. aethiopicum* are not present

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 $\times$ 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 chiqueira*), 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. Burt & 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 & Obunyal 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 Figures 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

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