Palms

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CONTENTS

FRONT COVER

Digging *Phoenix dactylifera* for transplanting. See p. 72. Photo by D.R. Hodel.

BACK COVER

Dypsis decipiens, Ambohimirahavavy, Itremo, Madagascar. See p. 101. Photo by M. Rakotoarinivo.

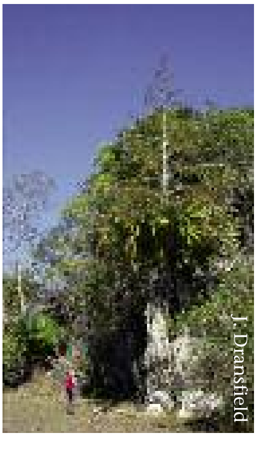
PALM NEWS

A new study by R. Khorsand Rosa & S. Koptur found that ***Mauritia flexuosa*, long thought to be beetle pollinated, is wind pollinated**. When flowers were enclosed in mesh bags, which exclude insects but not wind, the flowers still matured fruits. Flowers covered by paper bags (which excluded both wind and insects) set little fruits. The study was published in the *American Journal of Botany* (100: 613–621. 2013).


S. Zona

Research in biodiesel and sustainable agriculture, especially in Brazil, has fueled interest in ***Acrocomia aculeata* as an underexploited source of tropical oils**. Like the African oil palm (*Elaeis guineenis*), *Acrocomia aculeata* yields two distinct kinds of oils, one from the fruit pulp and another from the seed. The productivity of *A. aculeata* is currently lower than that of African oil palm, but Silva and Andrade (*Journal of Food Process Engineering* 36: 134–145. 2013) believe that *Acrocomia* productivity can be double that of African oil palm if elite cultivars are grown under optimum conditions and the oils are extracted efficiently. Brazilian student Suelen Alves Vianna, who is working on her PhD in genetics, plant breeding and biotechnology at the Instituto Agronomico de Campinas, is studying the taxonomy of *Acrocomia*. She recently spent several weeks at the Montgomery Botanical Center in Miami, Florida, studying *Acrocomia* leaf anatomy.

In Madagascar, *Tahina spectabilis* flowered again in September 2012 and a controlled harvest of seeds was again made in January 2013. Seeds have been available from Toby Spanner at Rarepalmseeds.com and, as before, the sale of seeds has generated income that will go back to the local villagers. We have heard from Xavier Metz that the income will likely to be used to improve the school (built with funds from the first marketed crop of seeds) and improving village wells. Funds will also be spent on improving the firebreak around the *Tahina* site and for administrative costs related to the establishment of a protected area for the palm. It is really heartening to learn that the sale of palm seeds is doing so much not only to conserve the palm in question but also to support the local community and thus reinforce to the community the value of protecting this iconic palm.


J. Dransfield

Recent Advances in Palm Horticulture

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The following eight articles originate primarily from papers presented at the workshop "Recent Advances in Palm Horticulture" that was held at the American Society for Horticultural Science Annual Conference in Miami, Florida, July 30 to August 4, 2012. I initiated, coordinated and moderated the workshop, which was conducted on July 31 and covered a variety of topics within the general categories of nutrition, transplanting and diseases. Presenters were Timothy Broschat and Monica Elliott of the University of Florida and James Downer and I from the University of California. This collection of articles covers some of these presentations but also includes several that were not included in the workshop.

Effect of Leaf Tie-Up and Pre-Plant Storage on Growth and Transpiration of Trans-planted Mexican Fan Palms

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Large palms are often transplanted into landscapes to provide instant, mature plantings with high visual impact. A standard industry practice is to tie up leaves during the transplanting process, removing the ties at a later date or waiting until they disintegrate. Although leaf tie-up purportedly reduces transpirational water loss during transplanting and facilitates handling, recent work is somewhat mixed on whether it is beneficial when transplanting palms (Broschat 1994, Hodel et al. 2003, 2006, 2013b). Also, palms are best transplanted immediately after delivery (Broschat & Meerow 2000) although they are frequently stored at job sites for several days, often exposed to full sun. No studies have examined the effect of pre-plant storage on survival and growth of transplanted palms. Thus, we conducted a study in 2004 to corroborate previous work on leaf tie-up and to examine the effect of pre-plant storage on survival and growth of transplanted Mexican fan palms (*Washingtonia robusta*).

PALMS 57(2): 58–63

Materials and Methods

In July 2004, we purchased 20 Mexican fan palms, each with about three meters of trunk, from a commercial palm grower in the Coachella Valley, a desert area of southern California. The grower delivered the specimens with some leaves already removed and the remainder tied up, to the University of California South Coast Research and Extension Center (UC SCREC), Irvine, which is in the southern coastal plain of California and has a maritime Mediterranean climate. The soil at the Center is a San Emigdio sandy loam with a pH of 7.0, organic matter content of 0.84%, cation exchange capacity of 14.4 meq/100 g., and particle size distribution of 68% sand, 19% silt, and 13% clay. To simulate industry practices, we stored the palms with their tied-up leaves and root balls uncovered and exposed to full sun without irrigation. We planted 10 palms each at three and seven days after delivery (July 26 and 29) (Fig. 1). We removed leaf ties on five palms per storage treatment to create five replications of the two factors (pre-plant storage time and leaf tie-up) arranged in a blocked factorial design. We untied all leaves about 6 months after planting (Feb. 1, 2005) because the twine never disintegrated. The palms were irrigated weekly to moisten the soil to a depth of 30 cm around their root balls. Weeds were removed by hand and with glyphosate herbicide.

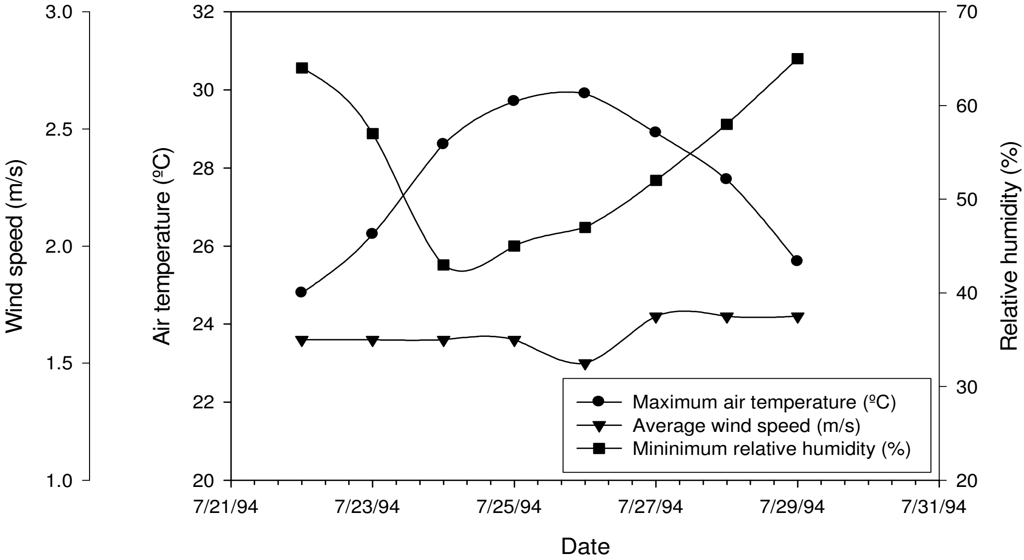
We measured stomatal conductance (leaf transpirational water loss) six times during the first two months and once again at three months after planting with a steady state autoporometer (LI-COR 1600; LI-COR Environmental, Lincoln, NE). At each measurement date, we made three readings from the youngest fully expanded leaf. We also counted the number of brown and new leaves quarterly and summed the totals for one year. Stomatal conductance and number of new and brown leaves were subjected to analysis of variance tests (ANOVA) and means compared using Fischer's Protected Least Significant Difference Test.

A California Irrigation Management and Information System (CIMIS) weather station at UC SCREC (CIMIS Station 75) collected climatic data and recorded real-time daily evapotranspiration data during the study (California Department of Water Resources 2010).

Results and Discussion

The site soil analyses document that the soil chemical and physical properties are near ideal for plant growth. Mostly moderate environmental conditions typical for the site characterized the seven-day, pre-plant storage period (Fig. 2). Maximum daily air temperature started at 25°C, peaked at 30°C, and fell to 26°C after seven days while solar radiation

1. Experimental plot of transplanted *Washingtonia robusta* immediately after planting showing various leaf tie-up treatments, August 2004, UC SCREC, Irvine, CA (D. R. Hodel).



2. Daily maximum air temperature (C), average wind speed (m/s), and minimum relative humidity (%) during seven-day, pre-plant storage period for transplanted *Washingtonia robusta*, 2004, UC SCREC, Irvine, California.

ranges from about 240 to 330 W/m^{-2}. Wind speed averaged about 0.67 m/sec and relative humidity ranged from about 42% to 67%.). Environmental conditions were typical for the site during the four-month post-plant period (Fig. 3). One year after transplanting all palms had survived. Neither storage time nor leaf tie-up affected the number of new and brown leaves (Table 1). Interaction means of leaf tie-up and storage were not significant (data not shown).

Stomatal conductance (transpiration water loss) was similar between tied and untied leaves for all seven sample dates except the last two, Sept. 7 and Oct. 5, when they were 57% and 25% lower, respectively, in untied leaves (Table 2). These data show that leaf tie-up did not reduce transpirational water loss and, indeed, on two dates tied up leaves actually had increased transpirational water loss. Because the main objective when transplanting palms, especially during the

Table 1. Mean number of new and brown leaves of *Washingtonia robusta* after one year after transplanting, 2005, UC SCREC, Irvine, California.

Treatment	New leaves	Brown leaves
Leaves untied	32[z] a[y]	6 a
Leaves tied	31 a	9 a
Tying (P)	*0.93*	*0.07*
3-day storage[x]	32 a	7 a
7-day storage	31 a	8 a
Storage (P)	*0.53*	*0.81*

[z]Number of new and brown leaves were subjected to analysis of variance and means compared using Fischer's Protected Least Significant Difference Test.

[y]Same letters within a column indicate values were not significantly different, $P \leq 0.05$.

[x]Palms were stored without irrigation and with leaves and root balls uncovered and unprotected in full sun prior to planting.

Table 2. Stomatal conductance (mmol ms^{-1}) for newest, fully expanded leaves of transplanted *Washingtonia robusta*, measured seven times after transplanting, July to October, 2004, UC SCREC, Irvine, California.

Date	Tied leaves	Untied leaves
30 July	1.01^{z} a^{y}	0.99 a
6 Aug.	0.87 a	0.92 a
18 Aug.	1.45 a	1.56 a
24 Aug.	3.38 a	3.08 a
31 Aug	2.80 a	2.30 a
7 Sept.	3.45 a	1.47 b
5 Oct.	2.18 a	1.63 b

Date (*P*) <0.0001

Tie-up (*P*) 0.02

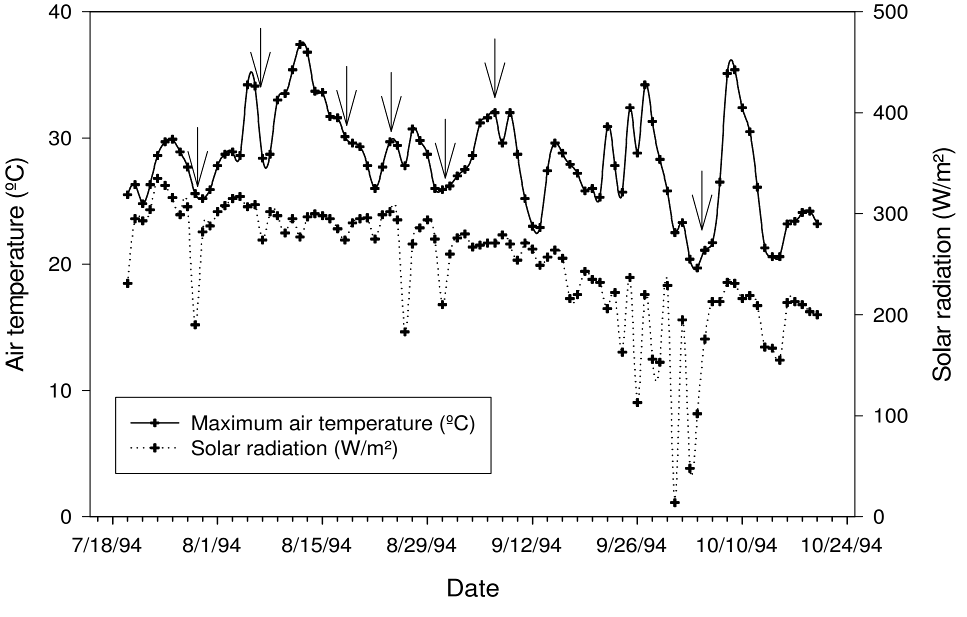
Date × *tie-up* (*P*) 0.03

^{z} Stomatal conductance was subjected to analysis of variance tests (ANOVA) and means compared using Fischer's Protected Least Significant Difference Test.

^{y} Different letters within a row indicate values were significantly different, $P \leq 0.05$.

immediate post-transplanting period, is to keep them well hydrated until a sufficient number of new roots develop, increased water loss through transpiration can reduce hydration, thus stressing transplanted palms and prohibiting or decreasing survival and establishment. Why tied up leaves actually lost more water than untied leaves on the last two dates is unclear but does not appear related to weather conditions. When palms are water stressed, such as the case immediately after transplanting, stomata likely close to prevent or reduce additional water loss; thus, it is not surprising that transpirational water loss was relatively low and stable and did not increase much until four weeks after planting and there

3. Daily maximum air temperature (C) and solar radiation (W/m^2) for four months after transplanting *Washingtonia robusta*, 2004, UC SCREC, Irvine, California. Arrows indicate when we measured leaf stomatal conductance.



were no differences between tied and untied leaves until eight weeks after planting. The last two dates when tied up leaves lost more water than untied leaves were about 8 and 12 weeks after planting. Perhaps by then the palms had begun to establish, develop a new root system, and take up water, increasing their internal reserves and providing them with sufficient water now to transpire or, at least, increase transpiration. Also, the location of a preponderance of the stomates on the abaxial (lower) leaf surface might enhance transpirational water loss in tied up leaves because the abaxial surface of many of the leaves is now vertically oriented and more exposed to solar radiation and wind, two of the most important factors affecting transpiration. Similar to leaf tie-up, storage treatment did not affect stomatal conductance (data not shown).

Conclusions

Our findings corroborate those of Hodel et al. (2003, 2006) that leaf tie-up did not affect growth of transplanted palms and of Broschat (1994) that transplanted pygmy date palms (*Phoenix roebelenii*) had much higher survival rates and growth if some or even all of the leaves were retained as long as the plants were irrigated regularly. They also support those of Hodel et al. (2013a) that leaf tie-up has only a short-term or minimal effect on transpirational water loss. Our somewhat surprising finding was that unprotected storage in full sun with no irrigation for up to seven days did not affect survival and new leaf growth of *Washingtonia robusta*. Rather than a blanket confirmation of this practice, though, this finding is more a testament to the toughness and durability of this species and a consequence of the moderate environmental conditions during the pre-plant storage period. We recommend immediate planting of transplanted palms but if this is not possible then palms should be stored with at least their leaves and root balls protected from sun and wind and irrigated regularly. Leaf tie-up of this species after transplanting is unnecessary outside of the desert areas of California.

Acknowledgments

We thank Tim Broschat and Monica Elliott, who critically reviewed the manuscript.

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Effect of Sand Backfill on Transplanted King, Queen and Windmill Palms

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A standard industry practice in the southwestern United States and in many other places when transplanting palms is to use sand as the sole backfill medium. The justification for using sand is that it promotes better root growth and establishment, and especially for unusually large specimens, it provides better anchorage and stability than native soils. However, in most cases using sand as the backfill medium is an additional, significant expense, and large palms are successfully transplanted in many places without using it as the backfill medium.

Although Hodel et al. (2006) showed that amending the backfill when planting palms directly into native loam or clay soils was not beneficial, there is, unfortunately, no research-based information to refute or support using sand as the sole backfill medium when

1. Palms were trenched on four sides (queen palm) (D. R. Hodel).

transplanting palms. Thus, we designed and implemented a two-year study to determine if this practice was advantageous.

Materials and Methods

We conducted this study at the University of California South Coast Research and Extension Center (UC SCREC) in Irvine, which is in the south coastal plain of California and has a maritime Mediterranean climate. The soil at the Center is a San Emigdio sandy loam with a pH of seven, organic matter content of 0.84%, cation exchange capacity of 14.4 meq/100 g. and particle size distribution of 68% sand, 19% silt and 13% clay. In May, 2008, we dug and transplanted 10 specimens each of king palm (*Archontophoenix cunninghamiana*), queen palm (*Syagrus romanzoffiana*) and windmill palm (*Trachycarpus fortunei*) from one field to another field about 100 m distant at the Center. The palms had 0.5–1.5 meters of trunk and had been planted from 3.9-l (1-gal) containers about seven years earlier. Palms were trenched on four sides (Fig. 1) leaving root balls that extended out from the trunk for about 30 cm and 60 cm deep. Palms were lifted and moved to the new site. Planting holes were 1 × 1 × 1 m.

Five specimens of each of the three species were backfilled with native site soil, and the other five were backfilled with commercially available washed concrete sand. The sand was silica in the form of quartz and composed of particles of varying sizes, ranging from 0.06

Table 1. Mean number of new leaves after one and two years and mean canopy color and survival after two years for king palms (*Archontophoenix cunninghamiana*) transplanted and backfilled with either sand or native site soil, 2008-2010, UC SCREC, Irvine, California.

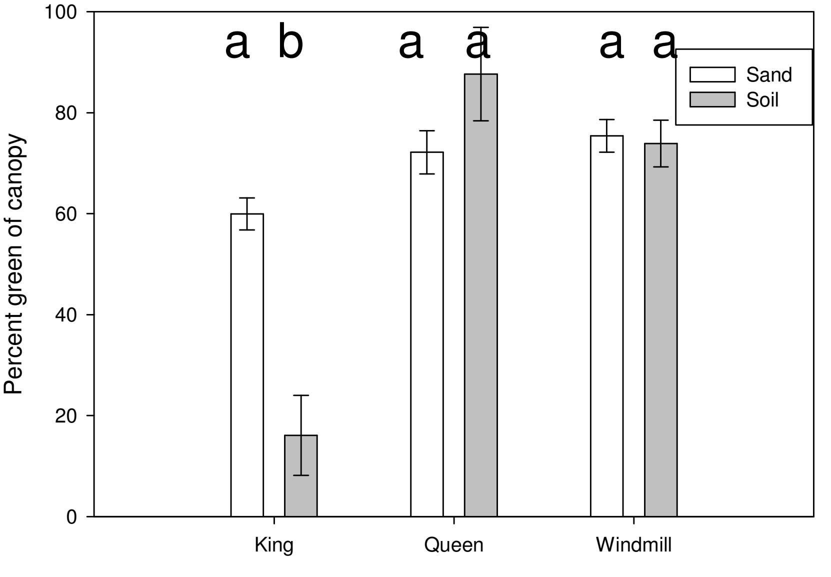
Backfill Treatment	New Leaves (no.)		Canopy Color [z]	Survival (%)
	June 2009	June 2010	June 2010	June 2010
Sand	3	6	2.3	100
Soil	0	1	1.2	40
P value	<0.0023	<0.0023	<0.02	<0.05

[z]1 to 5, 1 = light yellow, 5 = dark green.

2 (left). King palm transplanted and backfilled with sand had more and greener leaves and a higher survival rate (D. R. Hodel). 3 (right). King palm transplanted and backfilled with native site soil had fewer and more yellow leaves and a lower survival rate (D. R. Hodel).

to 0.2 mm (50%), 0.2 to 0.6mm (30%) and 0.6 to 2.0 mm (20%). The palms were spaced five meters distant in rows five meters apart in full sun. The two treatments for each of the three species were replicated five times, and the palms and treatments were completely randomized. Palms were planted at grade, and leaves were not removed or tied up. We marked the newest, fully emerged leaf with red tape to track leaf production. The backfill was well watered in with a hose during the planting process. Using climate data and recorded real-time daily evapotranspiration from a California Irrigation Management and Information System (CIMIS) weather station at the site (CIMIS Station 75) (CDWR 2010), we

4. Percent green canopy of king, queen, and windmill palms transplanted and backfilled with either sand or soil and measured after two years. Analysis of variance included backfill settling as a factor. Different letters within a species denote significant comparisons at $p < 0.05$. Bars are standard error, indicating variability around the mean.



used drip irrigation to irrigate the palms at 80 percent of reference evapotranspiration to maintain the original root ball, backfill and surrounding site soil evenly moist over the course of the study. No fertilizer was applied over the course of the study. Weeds were removed manually.

Every six months for two years we recorded the total quantity of leaves produced up to that time in the study, estimated the percent area of the canopy that was green (alive), and rated the color intensity of that part that was green (1 to 5, 1=light yellow, 5=dark green). We would have preferred to count individual green (alive) and brown (dead) leaves rather than estimate that part of the canopy that was green. However, in most cases individual leaves were not completely green or brown but rather had green and brown portions together on the same leaf, forcing us to estimate percent green canopy. We recorded survival at the end of the study. To address potential autocorrelation of leaf number, percent green canopy and canopy color, which were measured on the same plants for multiple sampling dates, we conducted repeated measures of analysis of variance using the Mixed Procedure (v. 9.3, SAS Systems, Cary, NC) with the overall error rate for multiple comparisons controlled by the Tukey-Kramer adjustment. We selected the following covariance models from four possible ones based on measures of relative fit: Unstructured (UN) for leaf number and Compound Symmetry (CS) for percent green canopy and canopy color.

After one year we noticed that many of the palms had settled from 5 to 10 cm below grade although the root balls were not more deeply covered, while the remaining palms had not settled at all. Thus, if palm root balls settled, we incorporated the settling into the data analysis to determine if either treatment affected the settling and if the settling affected growth significantly.

Results and Discussion

Neither sand nor soil backfill significantly affected growth of transplanted queen palms or windmill palms. Only king palms backfilled with sand grew significantly more leaves after one and two years and had a significantly greener canopy and significantly higher survival rate after two years (Table 1) (Figs. 2 & 3). All species, regardless of backfill treatment, tended to become more yellow over time (data not shown).

Neither backfill treatment affected percent green canopy of any of the three palms unless backfill settling was considered. After 18 months, 10 of the 15 transplanted palms backfilled with soil had settled at least 5 cm, while of the 15 backfilled with sand only one had settled at least 5 cm. Settling was not observed on any other palms regardless of backfill treatment. However, backfill settling affected only king palms significantly, with those backfilled with soil having a lower percent green canopy than those backfilled with sand (Fig. 4).

These data suggest that sand backfill is of somewhat limited value when transplanting palms and largely depends on the species and particular native soil. Where it is beneficial it is probably so because of reduced settling. When backfill material settles, soil aeration is reduced, which decreases nutrient uptake, especially iron, and in turn decreases green color of leaves (Broschat 2004). However, sand backfill might be beneficial when transplanting large specimens because sand has a high bulk density and packs more uniformly and easily than soil, likely providing better anchorage and support.

Acknowledgments

We thank the California Landscape Contractors Association for partially funding this project and Tim Broschat and Monica Elliott, who critically reviewed the manuscript.

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Suitability of Ground Palm Trunk Tissues as a Medium for Growing Potted Plants

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Palms are important and increasingly common features in many tropical and subtropical landscapes. Like all landscape plants, palms are not permanent. They die from senescence, diseases, disorders, trauma, stresses or other natural causes and must be removed. Sometimes changes in landscape plans require removal and disposal of palms. Because of their fibrous nature, palms are generally unattractive to green waste handlers and processors, who frequently discourage or prohibit their entry into municipal green waste streams. Large, heavy, voluminous and bulky trunks of removed palms (Fig. 1) are especially unattractive because they are difficult to process (grind) and, if not processed, are excessively expensive for disposal in ever-decreasing landfills. Also, most municipalities are encouraging or legislating recycling to reduce the volume of material entering the green waste stream. Thus, other disposal options for palm trunks must be considered.

One possible option is to use processed palm trunks as a partial or complete substitute for peat moss in many horticultural practices. Many people and organizations in the horticultural industries consider the use of peat moss, which is a common and much prized component of potting and planting mixes and mulches, to be unsustainable because of growing demand, increasing costs, environmental concerns and product inconsistency. Sphagnum peat bogs, the source of most peat moss, regrow slowly after harvesting and are considered sensitive habitats and imperiled fragile environments. The peat moss industry in Great Britain has cut production of domestic peat products (Robertson 1993), and doubts have been raised about the inconsistent quality of many peat mosses (Cresswell 1992).

1. Palm trunks (left background) were processed in a tub grinder that pulverized trunk tissue (D.R. Hodel).

The growth of containerized plants in palm-based media is not unknown to horticulture. Hume (1949) first advocated the use of ground coconut fruit fibers (coir) as a growing medium. Others (Handreck 1994, Meerow 1994) have shown coir or coir dust to have wide horticultural value, perhaps exceeding that of peat moss as a component of container media for some crops. The objective of this study was to determine the effect of processed palm trunks as a media component on the growth of containerized Formosa palms (*Arenga engleri*), queen palms (*Syagrus romanzoffiana*), and the popular bedding plant hybrid impatiens (hybrids mostly from *Impatiens balsamina, I. hawkeri, and I. walleriana*).

Materials and Methods

We conducted this study from 2003 to 2004 at the Ventura Community College Horticulture Department greenhouses in Ventura, California. West Coast Arborists, Inc., a large tree care business in Anaheim, California, processed trunks of four species of palms common to the California landscape that had been removed for various reasons. The species were Mexican fan palm (*Washingtonia robusta*), California fan palm (*Washingtonia filifera*), Canary Island date palm (*Phoenix canariensis*) and queen palm. Trunks were processed in a tub grinder (Fig. 1) that pulverized trunk tissue and then this material was screened in a 1.25 cm trammel screen to produce a consistent particle size product (Fig. 2). Trunks of each species were processed and stored separately. We then mixed the processed palm product of each species separately into a 1:1 (vol:vol) mix with washed plaster sand to produce a growing medium. We potted ten plants of each of the two palm species and the one impatiens, all grown in liners (ca. 4.5 × 4.5 × 8.9 cm) and selected for uniformity in size, vigor and health, into 3.7 L containers using one of six media: the four palm-trunk-based growing media, a commercial palm-growing medium (Sunland Garden Products Inc., Watsonville CA) and a traditional peat-moss-based medium with the same ratio of sand as in the palm-trunk media. Of the ten plants of each of the two palms and the impatiens in each of the three media, we fertilized five with ammonium sulfate (2 g per container) but left the other five unfertilized. We added ammonium sulfate because analysis of the processed palm-trunk product showed that

2. Processed trunk tissues were then screened to produce a product with a consistent particle size (D.R. Hodel).

Table 1. Chemical qualities of various container media and components, including ground palm trunk tissues, 2003 to 2004, Ventura Community College Horticulture Department, Ventura, California.

Medium	Chemical Quality									
	pH	EC	TKN[z]	NH_4	NO_3	P	K	B	Na	Cl
				ppm					meq/L	
					Mixes[y]					
Washingtonia robusta	6.6	4.7	0.08	129	7.0	147	452	0.3	2.2	23.0
Syagrus romanzoffiana	7.4	8.04	0.09	3.8	0.2	54.2	1472	0.2	13.9	49.0
Phoenix canariensis	6.0	9.12	0.04	17.9	0.10	44.7	1013	0.3	8.6	64.6
Washingtonia filifera	5.8	7.21	0.04	13.4	0.1	53.2	661	0.3	2.9	51.1
Peat moss	4.6	1.17	0.08	11.0	11.0	6.2	20.8	0.4	0.9	2.0
Commercial grower's medium	6.4	4.7	0.38	170	118	108	500	0.1	2.6	7.6
Mixed trunk tissue[x]	7.7	5.0	0.018	0.6	31.0	6.0	64	0.6	20.1	14.9
			Pure (100% Source Material)							
Washingtonia robusta	6.3	7.87	1.0	—	—	2247	2362	0.3	3.4	35.0
Syagrus romanzoffiana	7.5	13.35	1.09	31.5	1.5	321.7	3106	0.2	18.4	71.9
Phoenix canariensis	5.9	14.37	0.77	—	—	295.9	2182	0.4	12.2	92.3
Washingtonia filifera	5.7	11.63	0.52	—	—	812.8	1530	0.3	14.2	74.4
Peat moss	4.2	1.56	1.32	—	—	12.7	17.5	0.5	0.4	1.2

Media analyzed at time of planting, February 26, 2004. Missing values are due to lack of sufficient sample.

[z] TKN is total nitrogen by Keldahl digestion method.

[y] Ground, processed trunk tissues or peat moss mixed 1:1 (vol:vol) with washed plaster sand.

[x] Combination of ground, processed trunk tissues of the four palm species mixed 1:1 (vol:vol) with washed plaster sand. Not used in potted palm and impatiens trial.

nitrogen was low (Table 1). Also, the ammonium sulfate would help to compensate for any loss of nitrogen that might occur during decomposition of the processed palm trunk product and allow comparisons between fertilized and unfertilized media.

The University of California Agriculture and Natural Resources Analytical Lab, in Davis, performed chemical and physical analyses on one composite sample taken from several sites in a several cubic meter batch of each of the various processed palm trunk tissues and six media (Table 1). We grew the palms and impatiens for six months, after which we rated them visually on a 1 to 10 scale for quality (overall appearance, color and freedom from insects and disease) and measured height and stem caliper. Data were subjected to analysis of variance tests (ANOVA) and means compared using Fischer's Protected Least Significant Difference Test.

Results and Discussion

Both queen palm and the Formosa palm grew better in the palm-trunk media and the peat-moss-based medium than in the commercial medium although quality and growth of the latter species were low (Table 2). Queen palms produced acceptable to good quality and significantly more growth in the palm-trunk media if fertilizer was added. Formosa palm did not respond to addition of fertilizer, although we observed no nutrient deficiency symptoms or other abnormalities on the

Table 2. Mean quality and growth response of two palms, *Arenga engleri* and *Syagrus romanzoffiana*, when planted in various container media, including ground palm trunk tissues, 2003 to 2004, Ventura Community College Horticulture Department, Ventura, California.

Medium	*Arenga engleri*				*Syagrus romanzoffiana*			
	Quality rating[z]		Stem diameter[y]		Quality Rating		Stem diameter	
	+N	-N	+N	-N	+N	-N	+N	-N
Washingtonia robusta[x]	3.1ab[w,v]	4.1b	6bc	7.4a	6.8a	4.6a	11.1abc	9.4ab
Syagrus romanzoffiana[x]	3.5ab	3.4bc	9.4a	7.7a	6.3a	4.7a	14ab	10.4a
Phoenix canariensis[x]	3.1ab	2.8cd	8.5ab	7.5a	7.3a	2.8b	14ab	7.3bc
Washingtonia filifera[x]	4.2a	2.6d	10.1a	9.6a	6.7a	2.5b	14.9a	5.8c
Peat moss[x]	4.3a	5a	9.1a	8.6a	6.9a	4.4a	9.5c	7.7bc
Commercial medium	2.4b	3.2cd	4.4c	6.8a	6.8a	4.7a	10.8bc	8.9ab
Significance:								
Media	***[u]		***		NS		NS	
+/- N	NS		NS		***		***	
Media × N	**		NS		*		NS	

Planted February 26, 2004; measurements and observations taken October 11, 2004.

[z] Quality: 1 = dead, all leaves necrotic, poorest quality; 10 = alive, all leaves dark green, no diseases or pests, optimal quality.

[y] Measured in mm at the widest portion at the base.

[x] Ground, processed trunk tissues or peat moss mixed 1:1 (vol:vol) with washed plaster sand.

[w] Quality and stem diameter data were subjected to analysis of variance tests (ANOVA) and means compared using Fischer's Protected Least Significant Difference Test.

[v] Means within a column followed by different letters are statistically different according to various significance levels below.

[u] Significance: NS=not significant; *, **, *** significant at 0.5, 0.1 and 0.001 respectively.

palms. Queen palms even responded to addition of fertilizer to the commercial growing medium, which already contained significant amounts of nitrate and ammonium-based nitrogen. This finding that queen palms respond to relatively high levels of nitrogen corroborates earlier work for this species in the landscape (Downer et al. 2007). Impatiens responded similarly to the palms (data not shown). These data suggest that processed palm trunks can be used in media for containerized plants if supplementary nitrogen is added.

Unfortunately, we were unable to control or account for the age of the palms that supplied the trunks in our study. Age of palm trunks could affect their longevity and suitability as a component in a container potting mix. Palm trunk tissues harden and strengthen with age, primarily through cell wall hardening and thickening and increased lignification of tissues (Tomlinson 1990). Thus, trunks of older palms and the proximal portions of those trunks would have harder, more lignified tissues, which could enhance their resistance to microbial degradation, increase longevity as an effective component of a container medium and reduce supplementary nitrogen requirements.

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Effect of Leaf Removal and Tie-Up on Date Palms Transplanted in Extremely Hot, Arid Conditions

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Leaf removal and tie up are standard industry practices when transplanting palms (Nixon & Carpenter 1978, Broschat 1991, Costonis 1995, Zaid 1999, Broschat & Meerow 2000). Recent research findings are somewhat mixed, though, on whether these practices are beneficial. For example, when transplanting juvenile, trunkless specimens of Canary Island date palm (*Phoenix canariensis*) and queen palm (*Syagrus romanzoffiana*) and large, trunked specimens of Mexican fan palm (*Washingtonia robusta*), leaf removal and tie-up did not affect establishment and survival (Downer et al. 2013; Hodel et al. 2003, 2006). Broschat (1994) found a similar response for leaf tie-up when transplanting pygmy date palms (*Phoenix roebelenii*) if they were provided with daily irrigation. However, Broschat (1991) found that complete leaf removal was necessary when transplanting palms like the palmetto palm (*Sabal palmetto*), where all roots cut during transplanting die and the palm must rely solely on stored water in the trunk for survival until a new root system can be produced.

PALMS 57(2): 72–78

The impetus for this study arose when a large supplier of date palms (*Phoenix dactylifera*) for landscape use and a major producer of date fruits for the fresh market stated that he did not feel confident that our earlier work (Hodel et al. 2003, 2006), which showed that leaf removal and tie-up were likely of little value in transplanting palms, was applicable to transplanting mature date palms in extremely hot, arid conditions like those frequently encountered during the summer in the U.S. Desert Southwest. The purpose of this study was to determine the effect of leaf removal and tie-up on survival and quality of mature date palms transplanted in extremely hot, arid conditions.

Materials and Methods

We conducted this study from June 2009 to July 2011 at a date orchard near Desert Center, California (33°42’31.99”N, 115°14’20.25”W), about half way between Indio and Blyth. This location is in the Colorado or low desert, which is characterized by low dew points (10°C), low annual rainfall (75 mm), and high daily maximum summer temperatures (38–42°C) (NWS 2009). Soil at the site is an unclassified desert sand with pH of 6.5 and an EC of 2.0. Twenty-four mature plants of date palm (*Phoenix dactylifera* ‘Halawy’), each with about four meters of trunk and a canopy containing 50–60 leaves, were used in the study.

1. The palms were planted and backfilled with the naturally sandy soil at the site (D.R. Hodel).

The palms were dug on June 30, 2009 (Front Cover) and laid on the ground, where four leaf removal and tie-up treatments were performed. The four treatments were: no leaves removed,

2. The backfill was thoroughly watered in to minimize settling (D.R. Hodel).

3. The transplanted palms were spaced about six meters apart in rows six meters (D.R. Hodel).

no leaves tied up (control); about 60% of the leaves removed, the remainder tied up (standard industry practice); about 60% of the leaves removed, the remainder not tied up; and no leaves removed, all leaves tied up. Leaf removal was accomplished by removing older leaves and shortening the remaining leaves by about half their length before tying them up. We marked the newest, fully emerged leaf with red tape to track leaf production. After digging and performing the treatments the palms remained on the ground for 24 hours with leaves and root balls uncovered, unprotected, and unirrigated to simulate how the palms are typically handled when dug, transported, and replanted into the landscape in this area.

The palms were planted (Figs. 1 & 2) into a nearby vacant plot on July 1, 2009, spaced about six meters apart in rows six meters apart (Fig. 3). Treatments were replicated six times and the palms were arranged in a randomized complete block design (4 treatments × 6 replications × 1 species = 24 palms total). Each row was a block in which the four treatments were completely randomized. Palms were irrigated thoroughly at planting and then every other day through the summer with about 1,000 l of water applied to each palm at each irrigation event. During the fall and winter irrigation was reduced to about 1,000 l once every two weeks.

For each palm we counted the quantity of new leaves one year after transplanting and estimated the percent of the canopy that was green (alive) and assigned an overall quality rating one and two years after transplanting. Weather data, including maximum temperatures, dew point, and wind speed, were obtained from the National Weather Service weather station in Thermal and reference evapotranspiration data was obtained from the California Irrigation Management Information System station in Indio (Station #200), California, the closest stations that best approximate conditions in Desert Center.

We conducted analysis of variance using the Mixed Procedure (v. 9.3, SAS Systems, Cary, NC) with the overall error rate for multiple comparisons controlled by Tukey-Kramer adjustment. For new leaf growth measured in July 2010, we included the initial number of leaves at transplanting as a covariate. Linear contrasts were conducted to understand the difference between pairs of means (e.g., leaf removal vs. no leaf removal and leaf tie-up vs. no leaf tie-up).

To address potential autocorrelation of percent green canopy and quality estimates, which were measured on the same plants for multiple sampling dates, we conducted repeated measures analysis of variance using the Mixed Procedure with the overall error rate for multiple comparisons controlled by Tukey-Kramer adjustment. We selected the following covariance models from four possible ones based on measures of relative fit: Unstructured (UN) for quality and Compound Symmetry (CS) for brown canopy. Linear contrasts were also conducted for each of these parameters.

Table 1. Average maximum temperatures (°C), dew point (°C), and wind speed (m·sec^{-1}) in July, August, and September, 2009, Thermal, California. (Source: National Weather Service Data, NWS 2009).

July	Maximum	Average	Minimum
Maximum Temperatures	46.7	43.3	37.2
Dew Point	23.9	11.1	-10.5
Wind Speed	11.6	3.1	0.0
August			
Maximum Temperatures	47.8	41.7	37.2
Dew Point	23.3	10.0	-10.5
Wind Speed	14.8	3.6	0.0
September			
Maximum Temperatures	43.3	39.4	33.9
Dew Point	25.0	9.4	-14.4
Wind Speed	13.9	2.7	0.0

Results and Discussion

On June 30, 2009, the day the palms were dug, the maximum temperature was 45.5 °C at the study site. Throughout the next three months of the study (July through September), which are critical for transplant success, maximum daily temperatures averaged well above 39°C, dew points averaged about 10°C, and wind speeds averaged about 3 m·sec^{-1} at the National Weather Service weather station in Thermal, California (NSW 2009) (Table 1). Monthly reference evapotranspiration was 248.6 mm in July, 203.6 mm in August and 169.2 mm in September, 2009 in Indio, California (CIMIS 2009).

After one year, the standard industry practice produced significantly more new leaves than any other treatment and after one and two years had a significantly greater percentage of the canopy that was green than any other treatment (Figs. 4–8) (Table 2). Palms subjected to leaf removal, regardless of tie-up, performed significantly better in all three growth categories than palms with no leaves removed. Palms subjected to no leaf removal, regardless of leaf tie-up, performed the worst, with none

Table 2. Effect of leaf removal and tie up treatments on mean leaf production after one year and percent green canopy and overall quality after two years on transplanted date palms (*Phoenix dactylifera* 'Halawy'), 2009–2011, Desert Center, California.

Treatment	New leaves (no.)[w]	Percent green canopy[x]	Quality[x]
60% of leaves removed, the remainder tied up[y]	10a[z]	83a	4a
60% of leaves removed, the remainder not tied up	4b	54b	3a
No leaves removed, all leaves tied up	0c	15c	2b
No leaves removed, no leaves tied up	0c	12c	1c
P value	<0.0001	<0.0001	<0.0001

[w] Measured one year after transplanting with the initial quantity of leaves at transplanting included as a covariate in the analysis.

[x] 1=dead, 5=optimal. Measured one and two years after transplanting.

[y] Standard industry practice.

[z] Means within a column followed by different letter denote a significant comparison.

4. The experimental plot one year after transplanting (D.R. Hodel).

producing any new leaves and two-thirds (8 out of 12) dying by the end of the first year (no additional palms died after one year).

While both leaf removal and leaf tie-up evaluated separately significantly improved growth compared to no leaves removed and no leaves tied up, leaf removal is more critical than tie-up for successfully transplanting mature date palms in a harsh, hot, arid climate. Linear contrasts indicate that leaf removal had a greater impact on growth than did leaf tie-up, producing more new leaves, a greater percent of the canopy that was green, and a higher quality rating. Estimated least square means differences between leaf removal and tie-up were 7 vs. 3 for leaf production, 55 vs. 16 for percent green canopy, and 2.3 vs. 0.6 for quality. Broschat (1994) showed that pygmy date palms under severe water stress also responded more strongly to leaf removal than to tie-up.

We conclude that leaf removal and tie-up enhance establishment of mature date palms transplanted in extremely hot, arid conditions. Coupled with other work showing that leaf tie-up had little, if any, effect on transplant success (Broschat 1994; Downer et al. 2013; Hodel et al. 2003, 2006), though, we conclude that, in some situations, especially in more moderate climates and where immediate esthetic concerns demand an untied canopy, leaves may be untied after transplanting with little effect on transplant success. For ease of handling and to protect the apical meristem leaves should always remain tied up during the digging, transport, and planting processes but can be untied, where appropriate, after planting.

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5 (top left). After one year palms subjected to the standard industry practice, some leaves removed and the remainder tied up, performed best. 6 (top right). Palms with some leaves removed and the remainder not tied up did not perform as well as those with the standard industry practice although at the end of two years the palms were considered acceptable. 7 (bottom left). Palms with no leaves removed but all leaves tied up performed poorly and either died or were unacceptable. 8 (bottom right). The control, palms with no leaves removed and no leaves tied up, died. (all photos by D.R. Hodel).

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Effect of Leaf Removal and Tie-Up on Water Loss and Estimated Crop Coefficients for Juvenile, Trunkless, Containerized Queen Palms

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Reduction of leaf transpirational water loss is the reported benefit of leaf removal and tie-up, a commonly recommended practice when transplanting palms (Nixon & Carpenter 1978, Broschat 1991, Costonis 1995, Zaid 1999, Broschat & Meerow 2000). Such water loss is important because roots lost or damaged during transplanting are unable to take up water or do so at a much reduced level to replenish water stored in the palm, which is critical to survival when water is unavailable (Holbrook & Sinclair 1992a, 1992b). Recent work is somewhat mixed, though, on whether leaf removal and tie-up are beneficial when transplanting palms.

For example, when transplanting juvenile, trunkless specimens of Canary Island date palm (*Phoenix canariensis*) and queen palm (*Syagrus romanzoffiana*) and large, trunked specimens of Mexican fan palm (*Washingtonia robusta*), leaf removal and tie-up did not affect establishment and survival (Downer et al. 2013; Hodel et al. 2003, 2006). Broschat (1994) found a similar response for leaf tie-up when transplanting pygmy date palms (*Phoenix* *roebelinii*) if they were provided with overhead irrigation. However, Hodel et al. (2013) found that leaf removal and tie-up were beneficial when transplanting date palms (*Phoenix dactylifera*) in sustained, extremely hot and arid conditions and Broschat (1991) found that complete leaf removal was necessary when transplanting palms like the palmetto palm (*Sabal palmetto*) where all cut roots die and the palm must rely solely on stored water in the trunk for survival until a new root system can be produced. Thus, there is some doubt whether leaf removal and tie-up actually reduce water loss or, if so, how critical that loss is to survival and establishment of transplanted palms.

Also, nurseries produce ornamental palms in containers where limited soil volumes require effective water management in order for a grower to realize economical growth without wasting water. Use of evapotranspiration (ET) data can provide irrigation managers with a climate-based tool to help estimate and schedule water applications to crops effectively. This approach requires adjusting available reference ET (ET_O) values by a dimensionless crop coefficient (K_C) to account for unique physiology and water use characteristics of a given crop. A climate-based estimate of a crop's water use over a period of time, known as the crop ET (ET_C), can be derived using the equation:

$$ET_{crop} = K_C \times ET_O$$

Crop coefficients have been derived for many crops that achieve full yield while growing in large fields under excellent agronomic and soil water conditions (Allen et al. 1998), and daily, weekly, seasonal, or annual ET_{crop} (ET_C) values can be calculated for them. Plants growing in containers have limited rooting volumes and their canopies can extend beyond the container surface area, so container production systems violate some of the fundamental assumptions in the $ET_{crop} = K_C \times ET_O$ relationship. Thus, as Burger et al. (1987) and Schuch et al. (1997) pointed out, an ET_C for container-grown plants is difficult to compare with that of field-grown plants. Nevertheless, K_C values have been derived to estimate water needs of several container-grown woody nursery crops, including a few tree species (Beeson 2009; Burger et al. 1987; Schuch et al. 1997), but none has been reported for juvenile, trunkless, container-grown palm species. Holbrook and Sinclair (1992a) reported quantities of water used by container-grown palmetto palms but they did not normalize plant water use to ET_O or the plants' climate-based demand for water.

The objectives of this study were to determine the effect of leaf removal and tie-up on transpirational water loss from juvenile, trunkless queen palms, one of the most common landscape palms in subtropical regions, and to use the measured water loss to estimate K_C values for producing this palm in containers.

Materials and Methods

We conducted this study from July 27 to August 13, 2004 at the University of California South Coast Research and Extension Center (UC SCREC) in Irvine, CA, which is in the south coastal plain of California and has a maritime Mediterranean climate. Thirty juvenile, trunkless queen palms growing in 68-liter (15-gallon), standard nursery containers were used in the study. Selected for uniform height, leaf number, stem caliper, root growth, and overall quality, they were 200–300 cm tall, had five leaves 130–180 cm long and had a basal diameter of 15 cm. They were growing in Scott's Potting Medium (Scotts Miracle-Gro, Marysville, OH), a peat-vermiculite soilless potting mixture, were pest- and disease-free, and had normal green leaves and roots to the sides and bottoms of the containers.

Five leaf removal and tie-up treatments ranging from no leaf removal/no tie-up (control) to complete leaf removal were applied to the palms. Other leaf removal treatments, including the standard industry practice (SIP) (Fig. 1), consisted of removing about two-thirds of the leaf area, and were accomplished through a combination of whole and partial leaves until leaf area was reduced to the desired amount. For the leaf tie-up treatment, leaves present were tied upward using sisal twine to form a tight bunch.

We spaced the palms two meters distant in rows two meters apart in full sun (Fig. 1). The container opening, from the lip to the palm base, was covered with aluminum foil to reduce evaporative water loss from the potting medium (Fig. 1). Treatments were replicated six times and the palms were arranged in a randomized complete block design (5 treatments × 6 replications × 1 species = 30 palms total). Each row was a block in which the five treatments were completely randomized.

Containers were initially irrigated to container capacity, allowed to drain overnight, and then weighed in the morning and then again 24 hours later. The difference in weights between the two weighings would indicate the approximate amount of water lost primarily via leaf transpiration during the 24-hour period. Containers were then irrigated to container capacity again and the process repeated four times, after which we imposed a dry-down period where we weighed them on four consecutive days (three weight differences) without any irrigation until they showed obvious sign of water stress, including drooping and slight color loss of leaves and folding and drooping of pinnae.

To estimate K_c, the container weight differences from the control treatments only were converted to volumes [1 gram of water = 1 cubic centimeter of water (cm^3)]. Then ET_c was determined using the equation:

ET_c (cm) = volume of water used (cm^3) / container surface area (cm^2), where the container surface area was 1105 cm^2.

Finally, the K_c was derived by the equation:

$$K_c = ET_c / ET_o.$$

A California Irrigation Management and Information System (CIMIS) weather station at UC SCREC (CIMIS Station 75) collected climate data and recorded real-time daily evapotranspiration during the study (CDWR 2010). Mean weights of water lost per weighing interval were calculated, analysis of variance tests (ANOVA) conducted, and means compared using Fischer's Protected Least Significant Difference Test.

Results and Discussion

Daily ET_o during the experiment was about five mm, typical for a midsummer day at UC SCREC (Table 1) (CDWR 2010). All leaf removal and tie-up treatments significantly reduced plant transpirational water loss until the four-day dry down period, which began August 11 (Table 1). After that, among all leaf removal and tie-up treatments, only complete leaf removal reduced water loss, but then only for one day and only compared to the control, after which there were no differences among any treatments. As expected, complete leaf removal resulted in the greatest reduction of water loss.

The dry-down period simulates water deficits that transplanted palms would likely experience because of extensive root loss. Water loss tended to decrease through out the dry-down period, suggesting that the water-stressed palms responded by reducing water loss through some physiological mechanism, such as stomatal closure. Dufrene and Saugier (1993) found that African oil palm (*Elaeis guineensis*) underwent stomatal regulation during periods of moderate water deficit and experienced decreased transpiration with no change in net assimilation, thus producing an increased water-use efficiency. Our findings tend to support the possibility of a similar response in queen palms.

Extrapolating our findings from containerized palms with intact root systems to field- or landscape-grown transplanted palms where most of the root system was removed is difficult. In transplanted palms with much reduced root systems water uptake is typically severely impaired and water stress much greater than with containerized palms with intact root systems that can readily rehydrate following irrigation. Nonetheless, we can conclude that leaf removal and tie-up, which reduced water loss only temporarily, are probably of limited benefit in most situations. However, they are likely beneficial in other instances, for example when transplanting some species in extremely hot, arid conditions where water demands would be exceedingly high or where all a palm's roots die when cut during transplanting. Indeed, as noted earlier, the benefits of leaf removal and tie-up when transplanting palms are somewhat mixed and depend to a great extent on the species and location (local climate factors like temperature and humidity).

The daily calculated K_c values of the control plants ranged from 2.1 to 4.0 (mean 3.1) (Table 1). If considering only the non-dry-down period when the palms were not water stressed, then the values ranged from 3.2 to 4 (mean 3.6). These values primarily reflect only transpirational water loss and, therefore, slightly under represent actual water demand of these palms. However, the values are likely to be mostly accurate relative to container-grown plants because the evaporation component is low due to the reduced surface area of exposed media for plants growing in containers. The average K_c values are comparable in magnitude to those that Burger et al. (1987) and Schuch et al. (1997) developed for several woody shrubs, which generally ranged from about 1.0 to 5.0.

1. Queen palms, showing various leaf removal and tie-up treatments and study lay out. The aluminum foil covering the surface of the containers reduces evaporative water loss (D.R. Hodel).

Although K_c values for container-grown plants do not reflect the true water use characteristics of plant species when grown in the field, and vary considerably due to specific growth stages of the crop, time of year, and location (Burger et al. 1987, Schuch et al. 1997), they can be useful and easy to apply for estimating irrigation needs of plants being produced or maintained in a container system and are another tool to help nursery and irrigation managers schedule irrigations more accurately.

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Table 1. Mean water loss, reference evapotranspiration (ET_o), crop evapotranspiration (ET_c), and crop coefficient (K_c) for each one-day period during the leaf removal/tie-up, water-loss study of juvenile, trunkless queen palms (*Syagrus romanzoffiana*) growing in 68-liter (15-gallon) containers, July to August, 2004, UC SCREC, Irvine, California.

Treatments: Leaf Removal[z]	Leaf Tie-up[z]	7/28	7/30	8/4	8/6	8/11	8/12	8/13	
		Mean Plant Water Loss per Day (kg)							
No[y]	No	2.0a[x]	2.1a	1.8a	2.1A	1.9a	1.4	0.9	
Yes[w]	Yes	0.9b	1.0b	1.1b	1.2B	1.5ab	1.2	0.9	
Yes	No	1.0b	1.2b	1.3b	1.4B	1.5ab	1.3	0.9	
No	Yes	1.1b	1.4b	1.4b	1.5B	1.5ab	1.3	0.8	
Complete	—-	0.3c	0.4c	0.5c	0.5c	0.9bc	0.9	0.8	
Significance[x]		***	***	***	***	*	NS	NS	
		ET_o[v], ET_c and K_c per Day							Daily Mean
ET_o (mm)		5.66	5.21	4.88	4.83	5.63	5.27	3.81	5.04
ET_c (mm)		18.1	19.00	16.29	19.00	17.20	12.67	8.14	15.77
K_c		3.2	3.7	3.3	4.0	3.0	2.5	2.1	3.1

[z] Leaf removal and tie-up were performed according to standard industry practices.

[y] Control.

[x] Mean water losses within a column for the same date followed by different letter are significantly different according to Fisher's Protected Least Significant Difference Test. NS, *, **, *** = not significant and significant at $P \leq 0.05$, 0.01, 0.001 respectively.

[w] Standard industry practice.

[v] Data recorded at California Irrigation Management System Station 75, Irvine, California.

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Effects of Fertilization and Pruning on Canopy Leaf Number and Potassium Deficiency Symptom Severity in *Sabal palmetto*

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Potassium deficiency is the most common nutrient deficiency on landscape palms in the southeastern United States. Early symptoms appear as translucent yellow-orange and/or necrotic spotting on the oldest leaves (Broschat 1990). As the deficiency progresses, leaflet tip necrosis and frizzling develop, which eventually results in premature loss of the leaf (Fig. 1). Deficiency symptoms are most severe on the oldest leaves because potassium is mobile within the palm (Mengel & Kirkby 1982). Under conditions of deficiency, the palm is able to extract potassium from the oldest leaves and translocate it to the newly developing leaves, allowing growth to continue in the absence of sufficient potassium in the soil. Depending on the species and potassium deficiency severity, leaf death occurs from one to three months after necrosis is first observed on a particular leaf. In contrast, natural senescence of healthy, non-potassium-deficient older leaves occurs rapidly, with the oldest leaf being completely green one day, uniformly orange-brown the next day, and completely necrotic by the third or fourth day.

The number of leaves that a palm can support is a function of potassium deficiency severity. For example, the average *Cocos nucifera* in south Florida has a hemispherical canopy with about 13 leaves because of potassium deficiency (Broschat 1997). Potassium-sufficient *C. nucifera* have a full 360º canopy with 26 or more leaves. Similarly, the average *Phoenix canariensis* in south Florida has only about 65 leaves due to potassium deficiency, while potassium-sufficient specimens support canopies of 130 to 150 leaves (Broschat 1997). Severe potassium deficiency can be fatal to palms.

 PALMS 57(2): 84–88

1. The orange discolored and partially necrotic older leaves on these *Sabal palmetto* are caused by potassium deficiency.

Because potassium-deficient older leaves are unsightly, there is a temptation to remove them. However, Broschat (1994) demonstrated that routine removal of potassium-deficient leaves resulted in a net reduction in the number of green leaves in the canopy of *Phoenix roebelenii*. Landscapers often remove some completely green leaves in addition to the unsightly symptomatic leaves believing that they can lengthen the time until they need to re-prune the palm. However, overpruning is known to reduce leaf size and windstorm resistance, in addition to being aesthetically unattractive (Calvez 1976, Chan & Duckett 1978, Mendoza et al. 1987, Oyama & Mendoza 1990). The purpose of this study was to examine the effects of severe pruning and fertilization on canopy leaf number and potassium deficiency symptom severity in *Sabal palmetto*. Our hypothesis was that fertilization would increase canopy leaf number and reduce visible potassium deficiency symptom severity while severe pruning would have the opposite effect.

Materials and Methods

Thirty *Sabal palmetto* having trunks 3 to 4 m tall were transplanted into a Bonneau fine sand soil in Gainesville, FL in 2004. They were spaced about 7 m apart. A similar planting was established on a Margate fine sand soil in Fort Lauderdale, FL in 2005. The root systems of all palms were isolated from each other by installing vertical 60 cm deep polypropylene fabric barriers midway between each palm. Treatments consisting of three fertilizer treatments and two pruning treatments in a factorial design were initiated in 2006.

Table 1. Effect of fertilizer type on number of total and green leaves, percent green leaves, and potassium (K) deficiency score for *Sabal palmetto* in Gainesville, Florida after three years of treatment.

Fertilizer	Total leaves	Green leaves	% Green leaves	K def. score*
None	29	14	57.0	4.40
16-0-8	27	14	57.8	4.25
8-2-12+4Mg	29	14	57.2	4.32

*0=dead, 1=severe K deficiency, 3=moderate K deficiency, 5=no deficiency symptoms. Means were averaged across pruning treatments. All treatment effects were non-significant at *P*=0.05 level.

Table 2. Effect of fertilizer type on number of total and green leaves, percent green leaves, and potassium (K) deficiency score for *Sabal palmetto* in Fort Lauderdale, Florida after three years of treatment.

Fertilizer	Total leaves	Green leaves	% Green leaves	K def. score*
None	15.3	2.0	13.1	3.9
16-4-8	17.3	3.8	22.0	4.0
8-2-12+4Mg	17.0	3.9	22.9	4.1

*0=dead, 1=severe K deficiency, 3=moderate K deficiency, 5=no deficiency symptoms. Means were averaged across pruning treatments. All treatment effects were non-significant at P=0.05 level.

Table 3. Effect of leaf pruning on number of total and green leaves, percent green leaves, and potassium (K) deficiency score for *Sabal palmetto* in Gainesville, Florida after three years of treatment.

Pruning	Total leaves	Green leaves	% Green leaves	K def. score*
Dead only	39 a[1]	14	36.3 b	3.89 b
Severe	18 b	14	78.3 a	4.76 a

[1] Means in a column with a different letter are statistically different at P<0.05. n=15

* 0=dead, 1=severe K deficiency, 3=moderate K deficiency, 5=no deficiency symptoms. Means were averaged across fertilizer treatments.

Table 4. Effect of leaf pruning on number of total and green leaves, percent green leaves, and potassium (K) deficiency score for *Sabal palmetto* in Fort Lauderdale, Florida after three years of treatment.

Pruning	Total leaves	Green leaves	% Green leaves	K def. score*
Dead only	21.3 a[1]	2.3 b	11.5 b	3.67 b
Severe	11.9 b	4.2 a	34.4 a	4.29 a

[1] Means in a column with a different letter are statistically different at P<0.05. n=15

* 0=dead, 1=severe K deficiency, 3=moderate K deficiency, 5=no deficiency symptoms. Means were averaged across fertilizer treatments.

Table 5. Effects of intensive fertilization on number of total and green leaves, percent green leaves, and potassium (K) deficiency score for *Sabal palmetto* in Fort Lauderdale, Florida after three years of treatment.

Fertilizer	Total leaves	Green leaves	% Green leaves	K def. score*
None	22.9 b[1]	5.0 b	22.4	3.91
8-2-12-4Mg	31.9 a	7.6 a	24.8	3.94

[1]Means in a column with a different letter are statistically different at P<0.05. n=15

* 0=dead, 1=severe K deficiency, 3=moderate K deficiency, 5=no deficiency symptoms.

Fertilizer treatments were: 1) no fertilizer (controls); 2) 4.9 g N/m^2 from a 16–4–8 plus Fe and Mn mostly water soluble turf fertilizer (Lesco, Rocky River, OH) applied per palm every three months; or 3) 4.9 g N/m^2 from an 8–2–12–4Mg plus micronutrients controlled-release palm fertilizer (Nurserymens Sure Gro, Vero Beach, FL) applied per palm every three months. Fertilizers were broadcast over a 10 m^2 area surrounding each palm. Half of the palms in each fertilizer treatment were severely pruned once per year by removing all but three of the youngest leaves. The other half had only completely dead leaves removed at that time. The experimental design was completely randomized with five replicate palms per fertilizer/pruning treatment combination. All palms were irrigated twice per week with about 2 cm of water per application using raised rotary irrigation heads. Data were collected once per year just prior to pruning and consisted of counting the number of green, symptom-free leaves and the total number of leaves, as well as scoring the severity of the visual potassium deficiency symptoms on each leaf within each palm canopy. A 1 to 5 scale was used with 1 = severe potassium deficiency symptoms (more than 50% of leaf area necrotic), 3 = moderate potassium deficiency symptoms (20–50% necrotic) and 5 = completely green. This experiment was continued for three years after initiation of treatments. All data were subjected to two-way analysis of variance.

After three years of treatment the results from the first experiment did not support our hypothesis, so a second experiment was set up to test the hypothesis that intensive fertilization of unpruned palms would increase the number of green leaves and total number of leaves in the canopy but would not improve visual potassium deficiency symptom severity until the palm achieved a full 360º canopy. This experiment was conducted in Fort Lauderdale, only on the same block of *Sabal palmetto* used in the first experiment. To prepare the palms for a second experiment, no palms were pruned or fertilized for one year prior to initiating the new treatments. To facilitate treatments, a split plot experimental design was used with 15 replicate palms per treatment. Treatments were 1) no fertilizer (control) or 2) fertilization with 9.8 g N/m^2 from an 8–2–12–4 Mg plus micronutrients controlled-release palm fertilizer (Lesco, Rocky River, OH) applied per palm every six weeks. The fertilizer was broadcast over a 37 m^2 area per palm using a rotary spreader. Palms were never pruned in this experiment. Data were recorded once per year as in the first experiment for three years.

Results and Discussion

No two-way interactions were significant for either site. In the first experiment there were no differences after three years among fertilizer treatments in the number of green leaves, total number of leaves, percent of leaves that were green, and in potassium symptom severity score in either the Gainesville plot or the Fort Lauderdale plot (Tables 1 & 2). These results were unexpected and suggested that either the fertilization intensity was not high enough to significantly affect palm potassium status, the duration of the study was too short, or that the inclusion of pruning treatments in a factorial design was interfering with the fertilization effects.

Predictably, severe pruning significantly reduced the total number of leaves at both sites (Tables 3 & 4). It also resulted in more green leaves in the Fort Lauderdale palms and a higher percentage of leaves that were green at both sites. Severely pruned palms also had significantly less severe visual potassium deficiency symptoms than those having only dead leaves removed. This finding contradicts results obtained in *Phoenix roebelenii* where removal of potassium deficient leaves four times per year resulted in a net reduction in the number of green leaves in the canopy (Broschat 1994). This difference in response may be due to the fact that green leaves were also removed in the present study, resulting in a canopy with fewer leaves than the palm was capable of supporting with its existing soil and plant tissue potassium reserves. Because of the mobility of potassium within palm canopies, these remaining youngest leaves likely had the highest potassium concentrations, well above the threshold concentration for visible symptom expression (Amalu & Omoti 1988, Broschat 1997).

The results obtained from the first experiment suggested that a different model may be required to explain the observed response of potassium-deficient palms to fertilization. Thus, a second experiment was designed to test the hypothesis that intensive fertilization of unpruned palms would increase the number of green leaves and total number of leaves in the canopy but would not improve visual potassium deficiency symptom severity until the palm achieved a full 360º canopy. After three years of intensive fertilization, fertilized palms did, indeed, have significantly more green leaves and more total leaves than unfertilized palms (Table 5). However, fertilization had no effect on the percentage of leaves in the canopy that were green or the severity of the visual potassium deficiency symptoms.

In conclusion, these studies have demonstrated that severe pruning of *S. palmetto* reduces canopy leaf number to fewer leaves than the palm is capable of supporting, and, until canopy leaf number increases to that point, visible potassium deficiency symptoms will not be observed. In the absence of living leaf pruning, application of an appropriate palm fertilizer will gradually increase the number of green leaves and total leaves in the canopy, but will not reduce the severity of visible potassium deficiency symptoms until the palm has reached its maximum genetically-determined canopy leaf number. For most species of palms, that will likely be a 360º canopy. Finally, these experiments point out that elimination of visible potassium deficiency symptoms requires years of intensive fertilization although the canopy will gradually increase in leaf number in the mean time.

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Effect of Fertilizer Nitrogen Source on Susceptibility of Five Species of Field-Grown Palms to *Fusarium oxysporum* f. sp. *canariensis*

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Several Fusarium wilt diseases (FW) attack palms worldwide. The fungus *Fusarium oxysporum* f. sp. *canariensis* causes FW of Canary Island date palm (CIDP, *Phoenix canariensis*). FW is a devastating and fatal disease in California, Florida and many other states and countries where CIDPs are grown. Feather et al. (1979) first described FW of CIDP in California and determined that it was spread in soil and by pruning equipment and was untreatable with fungicides. Because *Fusarium oxysporum* f. sp. *canariensis* is considered a soil-borne pathogen, it is widely recommended not to replant CIDPs in a location where one has died from FW. However, it is thought that other species of palms, even other *Phoenix* species, could be replanted without fear of infection because *F. oxysporum* typically has

strictly host species-specific forms. For example the form of *F. oxysporum* that attacks CIDPs would not attack other species of palms. However, Feather at al. (1989) showed that the form of *F. oxysporum* that attacked CIDPs could also infect and kill seedlings of the date palm of commerce (*P. dactylifera*) although their work was based on artificially inoculated palms grown in containers. Priest and Letham (1996) were unable to corroborate Feather's findings with the date palm of commerce but were able to infect Senegal date palms (*P. reclinata*) with *F. oxysporum* f. sp. *canariensis* and create disease. Also, Howard Ohr (pers. comm.) established that *F. oxysporum* f. sp. *canariensis* could attack and kill California fan palms (*Washingtonia filifera*). Although Ohr's work is unpublished, Summerell et al. (2001) made similar observations in Australia. Thus, the susceptibility of other species of palms to *Fusarium oxysporum* f. sp. *canariensis* needs further study.

Because CIDPs are highly valued as landscape specimens due to their unique and imposing habit, there is a strong desire to maintain their presence in landscapes even after they have succumbed to FW. Indeed, while CIDPs replanted at the same location where one had succumbed previously from FW often die, anecdotal observations show that occasionally they survive. Unfortunately, nothing is known of why some CIDPs survive under these conditions. Keim and Humphrey (1984) showed that nitrate fertilizers increased and

1. *Phoenix reclinata* with Fusarium wilt, 2010, UC SCREC, Irvine, California (D.R. Hodel).

ammoniacal fertilizers prevented FW in the woody shrub veronica (*Hebe* sp.). Both ammonium and nitrate are typically used in palm fertilizers and, thus, perhaps could account for the survival of some CIDPs replanted in soils infested with *Fusarium oxysporum* f. sp. *canariensis*.

An opportune situation was presented to us when in 2004 we planted out 30 CIDPs for a long-term pruning study in a field at the University of California South Coast Research and Extension Center (UC SCREC) in Irvine that 25 years previously had been home to CIDPs inoculated with *Fusarium oxysporum* f. sp. *canariensis* as part of the Feather et al. (1979) FW study. Although the field had been fallow for the intervening 25 years (kept free of all plant growth, including weeds), by 2007 nearly all these palms, which had not yet been pruned, began to show symptoms of FW and over half had died. By 2010 all 30 palms had died from FW. That the pathogen could remain active in a fallow field after 25 years and then infect newly planted CIDPs was remarkable and provided us the opportunity to assess susceptibility of other species of palms and determine if the form of nitrogen in fertilizer could affect susceptibility to FW.

Materials and Methods

In 2008 we initiated this study in the same field inoculated with *Fusarium oxysporum* f. sp. *canariensis* at the UC SCREC in Irvine where the 30 CIDPs had previously died from FW. We planted out 25 palms each of five species grown in 3.8 L (one-gallon) containers: *Phoenix canariensis, P. dactylifera* (seedlings of 'Deglet Noor'), *P. reclinata*, *P. roebelenii* (pygmy date palm) and *Washingtonia filifera*. Each palm was selected for uniformity in size, growth, vigor and health. We established the experiment in blocks with five replications. Each block was subdivided into five sub-blocks, each of which contained one palm each of the five species and was fertilized with one of five fertilizer treatments: untreated, ammonium sulfate, calcium nitrate, calcium-ammonium nitrate and Best Palm Plus [13(4.8 ammoniacal nitrogen, 8.2 urea nitrogen)-5-8-2.8(Mg), complete, controlled-release, palm-special fertilizer, J. R. Simplot, Lathrop, CA]. Fertilizers were applied to the soil surface and lightly incorporated into the soil around the newly planted palms to supply 0.454 kg of actual nitrogen per palm. After one year the same amount of fertilizer was applied again. Irrigations were scheduled to provide 80% of reference evapotranspiration for the site. The experiment was a two-factor, factorial, randomized complete-block design.

We determined palm growth by initially marking the newest leaf and then counting subsequent leaves produced and measuring palm volume every six months: length × width × height. Each symptomatic palm was tested for presence of *Fusarium oxysporum* f. sp. *canariensis*. Petioles of dying or dead trees were washed and soaked in 10% household bleach for five minutes and rinsed in sterile water. Using flame sterilized knives and pruning shears, petioles were opened and tissue pieces were placed on acidified ¼ strength Difco (Becton, Dickinson and Co, Sparks, MD) potato dextrose agar (10 g PDA and 10 g agar with 1 ml lactic acid/L deionized water). Cultures were incubated at 24C and allowed to grow for up

Table 1. Susceptibility of field-grown *Washingtonia filifera* and four species of *Phoenix* to *Fusarium oxysporum* f. sp. *canariensis*, 2009-2012, UC SCREC, Irvine, California.

	P. canariensis	*P. reclinata*	*P. roebelenii*	*P. dactylifera*	*Washingtonia filifera*
Number Dead Palms^z	25	12	0	0	14
Percent Probability of Death^y	100	44.6	0	0	56.0
P value	0.009	0.009	0.009	0.009	0.009

^{z} Number of palms out of 25 for each species that died and tested positive for *Fusarium oxysporum* f. sp. *canariensis*.

^{y} Percent probabilities of death due to *Fusarium oxysporum* f. sp. *canariensis* were made with a binary logistic regression model that had significant Chi Square values (χ^2=98.786; six degrees of freedom).

to ten days or until colonies containing macroconidia typical of *Fusarium oxysporum* were identified. *Fusarium oxysporum* f. sp. *canariensis* were verified using PCR methods and primers (Plyler et al. 1999). Total number of dead palms due to *Fusarium oxysporum* f. sp. *canariensis* was recorded at the end of the trial. Data were subjected to two-way analysis of variance (ANOVA), and probabilities of death due to *Fusarium oxysporum* f. sp. *canariensis* were made with a binary logistic regression model.

Results and Discussion

All palms established well except for two *Phoenix dactylifera* that died after planting, likely from inadequate irrigation; they tested negative for *Fusarium oxysporum* f. sp. *canariensis*. The remaining palms all established and began to produce new growth. FW symptoms and mortality were first noted in 2009 on *P. canariensis* followed by *P. reclinata* (Fig. 1) and *Washingtonia filifera*. By the fall of 2012 all *P. canariensis* and about half the *P. reclinata* and *W. filifera* had died (Table 1). None of the *P. roebelenii* or remaining *P. dactylifera* died. Fertilizer treatment did not significantly affect mortality. Similarly, fertilizer treatment did not affect growth of any species except *W. filifera*, which responded positively and equally to any fertilizer (data not shown).

Because no *Phoenix dactylifera* died from FW we feel confident in advocating this species as a replacement for *P. canariensis* that have died from FW. This finding is consistent with those of Priest and Letham (1996), who found *P. dactylifera* not to be susceptible to *Fusarium oxysporum* f. sp. *canariensis*. Also, we are able to corroborate Ohr (pers. comm.) and Summerell et al. (2001) that *Washingtonia filifera* is susceptible to *Fusarium oxysporum* f. sp. *canariensis*, at least under our experimental field conditions. We stress that we have never seen or verified *W. filifera* or *P. reclinata* dying from FW in the landscape, a fact that is somewhat puzzling because there is certainly ample opportunity for FW to spread from infected *P. canariensis* to these two species because the three species are frequently planted together in California. We also show that *Fusarium oxysporum* f. sp. *canariensis* can remain viable in fallow soil for at least 25 years and still infect some species of newly planted palms, which verifies the recommendation not to replant *P. canriensis* and other susceptible species of palms into the same site where a palm has died from *Fusarium oxysporum* f. sp. *canariensis*.

While not significant at the end of the study, the interaction of palm species and fertilizer source produced a few interesting results. Fertilizers containing nitrate were associated with more deaths from *Fusarium oxysporum* f. sp. *canariensis*, contradicting the results of Keim and Humphrey (1984) for *Hebe* sp., suggesting that another study is needed using more replication to verify the possible significance of this finding.

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Palm Phytoplasmas in the Caribbean Basin

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Lethal yellowing (LY) of *Cocos nucifera* and numerous other palm species is the dominant phytoplasma disease occurring in the Caribbean Basin. However, the phytoplasma strain that causes LY is not the only one affecting palms in this region. This review briefly discusses what are phytoplasmas, how they are identified and classified, and which palm phytoplasma strains are present in the Caribbean Basin and where they have been detected.

Palm diseases caused by phytoplasmas can now be found throughout the humid tropics, but this review is limited to the phytoplasma diseases occurring on palms in the Caribbean Basin. However, defining the Caribbean Basin is difficult, and there appears to be no definitive definition. Therefore, for the purposes of this review, we use the following (Wikipedia 2012):

> "The Caribbean Basin is generally defined as the area running from Florida westward along the Gulf coast, then south along the Mexican coast through Central America and then eastward across the northern coast of South America. This region includes the islands of the archipelago of the West Indies. Bermuda is also included within the region even though it is in the west-central Atlantic, due to its common cultural history created by European colonization of the region, and in most of the region by the presence of a significant group of African descent."

Phytoplasmas

Phytoplasmas are unculturable, cell wall-less bacteria that belong to the class Mollicutes (Kirkpatrick 1992, Lee et al. 2000, Bai et al. 2006, Bertaccini 2007). These very small bacteria alternate passage between plant and insect hosts, in which they propagate and persist. Phytoplasmas inhabit phloem sieve tubes of their plant hosts and depend on transmission from plant to plant by phloem-feeding insect vectors of the order Hemiptera, primarily leafhoppers, planthoppers and psyllids (Weintraub & Beanland 2006). This pathogen group is associated with over 1000 plant diseases, causing a wide variety of symptoms and potentially plant death. However, some plant species are tolerant of phytoplasmas and therefore show mild or no symptoms. Because phytoplasmas are nutritionally fastidious, and thus far unculturable, their taxonomic characterization is limited mainly to molecular-based methods.

Before a comprehensive classification for phytoplasmas was devised, phytoplasmas were often named according to primary plant host and main symptom they caused. The shortfall of this system was that molecularly distinct phytoplasmas that cause the same symptoms were usually assigned the same name. Murray and Schleifer (1994) proposed the '*Candidatus*' system for assigning binomial names to incompletely described prokaryotes. This system was adopted for genus and species descriptions of phytoplasmas for taxonomic purposes (IRPCM 2004). An alternative scheme for identification and classification of phytoplasmas based on restriction fragment length polymorphism (RFLP) analysis of 16Sr RNA gene and ribosomal protein gene sequences has been widely used also (Lee et al. 1998, Seemüller et al. 1998, Martini et al. 2007, Wei et al. 2007). According to the most recent classification scheme (Wei et al. 2007), phytoplasmas may be differentiated into 28 major groups, known as 16Sr groups, with numerous sub-groups or strains within some of the major groups. Using the species concept, two phytoplasma strains are the same species if they share at least 97.5% of their 16S rRNA gene (IRPCM 2004, Harrison et al. 2011). However, if two such strains (that share more than 97.5% of their 16S rRNA) are vectored by different insects, or have different hosts or behave differently in the same host, or are molecularly distinct based on DNA hybridization tests or can be differentiated by serotyping or polymerase chain reaction (PCR) assays, then these two strains warrant separate '*Ca*. Phytoplasma species' designations.

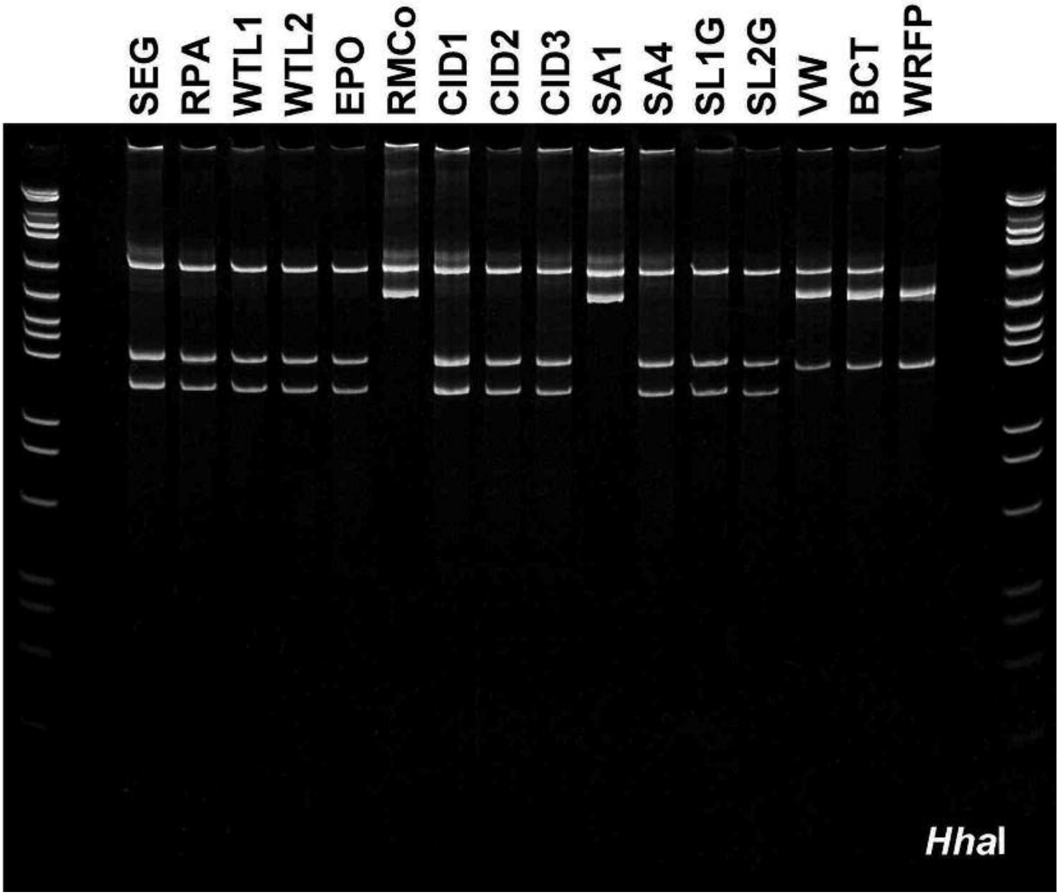
Sampling and Detection of Palm Phytoplasmas

Because phytoplasmas are unculturable, molecular methods are currently used to detect and identify them in tissues of affected palms. While immature leaf bases are usually the most reliable tissue for detection of phytoplasmas, the most common non-destructive method for obtaining samples from palms for phytoplasma detection uses trunk tissue (Oropeza et al. 2011, Harrison et al. 2013). With this method, a wood drill bit is heated with a blow torch to eliminate any contaminating DNA, cooled with water and then used to drill into the palm trunk. As the drill bit is moved in and out of the trunk, internal trunk tissue shavings are collected in a self-sealing plastic bag; approximately 3 grams of material is required. For palms that retain their old leaf bases, it is important that the drill bit is sufficiently long to obtain trunk tissue and not old leaf base tissue.

DNA is extracted from this trunk tissue and then used for nested PCR assays (Harrison & Oropeza 2008, Harrison et al. 2013). In general, the primers used for the first PCR are phytoplasma universal primer pair P1/P7 (Smart et al. 1996)), and primer pair LY16Sf/LY16Sr is used for the second PCR (Harrison et al. 2002). These primer pairs amplify group 16SrIV phytoplasma strains in a relatively group-specific manner (Harrison & Oropeza 2008). Detection specificity is enhanced by using primer pair P1m/LY16-23Sr followed by primer pair LY16Sf2/LY16-23Sr2 (Harrison et al. 2008). The resulting PCR products are viewed by agarose gel electrophoresis. Positive results, which indicate that a group 16SrIV phytoplasma has been detected, are then subjected to enzymatic digestion using specific restriction enzymes that "cut" the DNA. Products of the restriction digests are separated by nondenaturing polyacrylamide gel electrophoresis (Fig. 1) (Harrison et al. 2013). While the PCR products are sequenced for supporting information, the fragment patterns resulting from RFLP analysis provide unequivocal visual evidence about phytoplasma identity.

Group 16SrIV phytoplasmas

Group 16SrIV phytoplasmas cause lethal yellowing (LY), LY-like and lethal decline symptoms on palms. This group of phytoplasmas is commonly referred to as the Coconut Lethal Yellows Group. Based on symptom description, some of the diseases they cause, such as LY, have been known for more than one-hundred years in the Caribbean Basin. While symptoms vary among palm species and even among cultivars within a species, there are common elements that aide in field diagnosis of these diseases. Initial symptoms include flower necrosis and premature fruit fall. In *Cocos nucifera* (coconut palm), these symptoms can be detected all year because *C. nucifera* flowers and fruits all year. With other palm genera, such as *Phoenix*, these initial symptoms are unreliable because the palm only flowers and fruits once each year. Another early symptom is premature chlorosis and necrosis of the oldest leaves. For most



1. Visualization of the fragment profiles following endonuclease digestion of phytoplasma rDNA products amplified from symptomatic palms infected with a group 16SrIV phytoplasma. RMCo and SA1 represent the pattern obtained for strain A. SEG, RPA, WTL1, WTL2, EPO, CID1, CID2, CID3, SA4, SL1G and SL2G represent the pattern obtained for strain D. WRFP represents the pattern obtained for strain F. VW and BCT represent the pattern obtained for a co-infect of strains A and F. SA1 and SA4 are samples from two different *Phoenix canariensis* located in Manatee County, Florida, USA.

palm species, there is progressive discoloration of the leaves from the bottom to the top of the canopy, with the spear leaf being the last leaf to die. With *Phoenix, Sabal* and a few other genera, the spear leaf dies prematurely, prior to the youngest leaves dying.

Early reports in the Caribbean Basin of mortality of palms due to yellowing symptoms were made in the Cayman Islands (1834), Cuba (1870s) and Jamaica (1870s) (Fawcet 1891, De La Torre 1906, Johnston, 1912, Martyn 1945, Nutman & Roberts 1955, Ollagnier & Weststeijn 1961, Maramorosch 1978, McCoy et al. 1983). After these first records, palm lethal yellows were also reported in the Dominican Republic (Ciferri & Cicarone 1949, Schieber & Hichez-Frias 1970), Haiti (Leach 1946), Bahamas (Leach 1946) and Florida in the USA (Martinez & Roberts 1967, Thomas 1979). Other outbreaks were also reported in the Yucatán Peninsula of Mexico (McCoy et al. 1983, Cardeña et al. 1991), Belize (Escamilla et al. 1994, Harrison & Oropeza 1997), Guatemala (Mejía et al. 2004) and Honduras (Ashburner et al. 1996). The most recent observations of palm lethal yellows have been in Antigua (Gordon 2012) and St. Kitts & Nevis (Myrie et al. 2006, Myrie et al. 2012).

Most lethal yellowing disease reports cited above were made on *Cocos nucifera*. In Florida and Jamaica, LY epidemics killed most of the 'Jamaican Tall' variety of *C. nucifera* from the 1970s until the 1990s. However, in Florida, where palms are a dominant element in the landscape, numerous palm species have been documented to be affected by LY (Harrison & Jones 2004). During the late 1970s, McCoy et al. (1980) reported on a disease epidemic

2. Current Caribbean Basin locations of five strains in the 16SrIV phytoplasma group.

caused by a LY-type phytoplasma occurring on *Phoenix canariensis* (Canary Island date palm) and *P. dactylifera* (date palm) in the Brownsville and Rio Grande Valley in southern Texas. In 2002, Harrison et al. reported detecting a 16SrIV phytoplasma in *P. canariensis* in Corpus Christi, Texas. Symptoms on *P. canariensis* resembled those reported previously by McCoy et al. (1980). Later records of LY-type diseases on palms were made on *P. canariensis, P. dactylifera, P. sylvestris* (wild date palm), *Syagrus romanzoffiana* (queen palm) and *Washingtonia robusta* (Mexican fan palm) in west-central Florida (Harrison et al. 2008). A lethal decline of *Sabal palmetto* was also recorded in west-central Florida in 2008 (Harrison et al. 2009). This latter report was the first time that a phytoplasma disease was documented for a palm native to the Caribbean Basin, although a recent study completed in the Yucatán peninsula of Mexico has expanded this list (Vázquez-Euán et al. 2011).

Occurrence of 16SrIV sub-group phytoplasmas in the Caribbean Basin

Subgroup 16SrIV-A

This subgroup is the strain that causes the palm disease commonly referred to as lethal yellowing (LY). Early reports of this disease were made prior to the use of molecular classification schemes, but subsequent studies have confirmed the pathogen in most of these countries. Lethal yellowing has been observed on *Cocos nucifera* in Antigua, Bahamas, Belize, Cayman Islands, Cuba, Dominican Republic, Guatemala, Haiti, Honduras, Jamaica, Yucatán Peninsula of Mexico, St. Kitts & Nevis and Florida (USA). In Florida, subgroup 16SrIV-A strains have been detected as far north as Polk county in 40 palm species (see Harrison & Jones 2004 for partial list) but never in a palm species native to the Caribbean Basin. However, recent studies in the Yucatán peninsula of Mexico detected this subgroup in *Cocothrinax readii* (thatch palm), *Sabal mexicana* and *Thrinax radiata* (thatch palm), three species native to the Caribbean Basin (Narváez et al. 2006; Vázquez-Euán et al. 2011).

Subgroup 16SrIV-B

This strain has been detected in *Acrocomia aculeata* (grugru palm) and *Cocos nucifera* in Honduras (ca. 150 km from the Atlantic coast) (Roca et al. 2006) and *C. nucifera* in Mexico's Yucatán Peninsula (Harrison & Oropeza 1997).

Subgroup 16SrIV-C

While this phytoplasma subgroup has not been detected in the Caribbean Basin, it is noted here, lest readers feel we do not know the alphabet. It is known to cause a lethal disease of *Cocos nucifera* in East Africa (Hodgetts et al. 2008). However, this strain illustrates the problem with using the classification scheme of Wei et al. (2007), which relies on RFLP analysis of a 1.25 kb fragment of the 16Sr gene, a relatively short fragment. When analysis of a larger portion of the 16Sr gene sequence is conducted, this strain represents a phytoplasma that is phylogenetically distinct from other group 16SrIV phytoplasmas group and from strains affecting *C. nucifera* in western Africa (Tymon et al. 1998).

Subgroup 16SrIV-D

Confirmation of this strain did not occur until early 2000s, when Harrison et al. (2002) determined that the phytoplasma disease affecting *Phoenix canariensis* in Corpus Christi, Texas was caused by a subgroup 16SrIV-D strain. Symptoms observed at that time resembled those on *P. canariensis* and *P. dactylifera* during an epidemic in the Brownsville and Rio Grande Valley in southern Texas during the late 1970s (McCoy et al., 1980). Although no phytoplasma DNA existed from that time period, subsequent surveys in Texas have detected this strain in Bexar, Cameron, Hidalgo, Kleberg, Nueces and Willacy counties in Texas occurring in *Phoenix canariensis, P. dactylifera* and *Sabal palmetto* (Ong & McBride, 2009).

As noted previously, this strain was subsequently detected in west-central coastal Florida when *Phoenix* spp. and then *Sabal palmetto* began dying with LY-like symptoms (Harrison et al. 2008, 2009). To date, subgroup 16SrIV-D strains have been identified in Florida in eight palm species: *Phoenix canariensis, P. dactylifera, P. reclinata, P. roebelenii* (pygmy date palm), *P. sylvestris, Sabal palmetto, Syagrus romanzoffiana,* and ×*Butiagrus nabonnandii* (*Butia odorata* × *S. romanzoffiana*). To date, *Phoenix* spp. have been most widely affected in Florida with confirmed cases of diseases in Charlotte, Duval, Highlands, Hillsborough, Indian River, Lake, Lee, Manatee, Orange, Palm Beach, Pinellas, Polk and Sarasota counties. Both subgroup16SrIV-A and 16SrIV-D strains induce the same symptoms on *Phoenix* palms. Therefore, subgroup 16SrIV-D strains may occur in other Florida counties too, but until its presence has been confirmed in affected palms, it is not counted as an actual occurrence. For *S. palmetto*, detection of infected palms has been limited to Charlotte, DeSoto, Hardee, Hillsborough, Manatee, Polk and Sarasota counties in Florida.

In a recent study conducted in the Yucatán peninsula of Mexico, subgroup 16SrIV-D phytoplasmas were detected in *Pseudophoenix sargentii* (buccaneer palm), and in both *Sabal mexicana,* and *Thrinax radiata*, palms native to this area (Váquez-Euán et al. 2011). What was most notable about the observations of *S. mexicana* is that only 5 of 18 phytoplasma-positive palms died during the course of the 18-month study period. However, it was also noted that the number of green leaves on affected palms varied due to phytoplasma infection, with *S. mexicana* supporting 14.3 leaves on healthy palms but only 9.8 leaves on infected palms. Subgroup 16SrIV-D phytoplasmas were also recently detected in Puerto Rico in *Carpentaria acuminata, Caryota mitis* (clustered fishtail palm) and a *Roystonea* sp. (royal palm) (Rodrigues et al. 2010; sequences deposited in GenBank by N. Harrison). More information is needed from Puerto Rico regarding this strain, hosts and symptom expression.

Subgroup 16SrIV-E

This subgroup strain has only been detected in localized outbreaks of disease among *Cocos nucifera* on the southern coast of the Dominican Republic (Martinez et al. 2007). The phytoplasma is more closely related to strain 16SrIV-B than it is to strain 16SrIV-A.

Subgroup 16SrIV-F

In the process of surveying for 16SrIV-D phytoplasma in west-central Florida, Harrison et al. (2008) detected another, previously unknown 16SrIV subgroup phytoplasma, subsequently labeled strain F. It was detected in two *Washingtonia robusta* and in two *Phoenix dactylifera*. So far, subgroup 16SrIV-F strains have not been detected in any other palm samples even though numerous other palm samples have been received from the general vicinity of these palms. Interestingly, the two *P. dactylifera* were also co-infected with subgroup 16SrIV-A phytoplasmas, which highlights the importance of using RFLP analysis in addition to DNA sequencing to separate and identify phytoplasmas.

Summary

While the focus of palm phytoplasma diseases in the Caribbean Basin has always been on lethal yellowing of *Cocos nucifera* caused by subgroup 16SrIV-A strains, we now know that: 1) at least four more 16Sr IV subgroup strains occur in this region (Fig. 2); 2) the same palm species can be infected by multiple strains (e.g., *Phoenix canariensis* is susceptible to both strain A and strain D); 3) mixed infections of strains in the same palm are possible; and 4) infection by these phytoplasmas may not always cause the palm to die. The latter observation is especially intriguing, as it may mean many more palms, especially palms native to the Caribbean Basin, are hosts to phytoplasmas but either remain asymptomatic or the mild symptoms are largely overlooked because they were presumed to be due to another biotic or abiotic problem. Much is yet to be learned about these diseases in palms and in their insect vectors.

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Palm Conservation in Itremo, Madagascar

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1. Population of *Dypsis decipiens* in a narrow depression and deep valley at Antsirakambiaty, Itremo Protected Area. The species inhabits humid rocky sites on steep slopes or narrow depressions throughout the grasslands or on forest margins.

The authors describe efforts to conserve two iconic Madagascar palms.

Palms are highly characteristic of the east of Madagascar with about 91% of the 195 currently described species inhabiting the eastern lowland rainforest. In other parts of the island, palms, although few in numbers of species, can be conspicuous and even charismatic, especially when they form homogeneous populations across the landscape. This is the case in Itremo protected area, a rocky massif composed of quartzite, mica schist and marble extending through 244 km^2 and located at about 70 km west of Ambositra in the Central High Plateau of Madagascar. With only three species recorded locally (*Dypsis ambositrae*, *D. baronii* and *D. decipiens*), the local palm flora is not rich but the visitor is immediately struck by the abundance of palm trees in the landscape.

Dypsis baronii is widespread but the other two species are both threatened with extinction according to the IUCN Redlist. On the one hand, *D. decipiens* (Back Cover), Endangered, is known to occur sporadically in the Highlands between Andilamena and Ambohimahasoa. Outside Itremo, this species is quite rare as populations are usually small. In contrast, *D. decipiens* dominates the

2. Fires are one of the major threats to the regeneration of the population of *D. decipiens*. Almost all seedlings and juvenile plants are destroyed by fire on the grassland every year at the end of dry season (August through October). Photo: G. Ratovonirina.

landscape in Itremo with individuals abundant in valleys and along riverbanks (Fig. 1). A counting of palm crowns using Google Earth across the area revealed that there are at least 2700 mature trees of *D. decipiens* in Itremo. In spite of such density, this palm is highly threatened in Itremo. Annual grassland firing for cattle-grazing, for deterring migratory locusts or for preventing bandit attacks, severely affects the population structure as seedlings are killed and eliminated by burning and trunks are sometimes consumed by fire (Fig. 2). If such practices continue, it is expected that the population of this species will decline progressively. On the other hand, *D. ambositrae* (Fig. 3), Critically Endangered, is regionally endemic, restricted to Ambositra and Itremo area. In total, fewer than 50 mature individuals are estimated for this species in the wild; about 20 of them are in the gallery forest of Itremo. The main threat for this species in Itremo is forest logging as this causes habitat degradation and disturbs the growth and regeneration of this species.

These two species are endemic to the High Plateaux and play a key role in the ecosystem mainly by preventing erosion and participating in the water cycle; the loss of the two species will undeniably have an impact on the ecology and on the local economic balance. Residents around Itremo massif are mainly farmers and any change in the water availability or the soil structure in their fields may have a negative impact on their income, and consequently have a knock-on effect on conservation. In response, the Conservation Leadership Programme (CLP), a partnership of four organizations (BirdLife International,

3. *Dypsis ambositrae* emerging from the canopy of gallery forest, Antsirakambiaty, Itremo.

Conservation International, Fauna & Flora International and Wildlife Conservation Society) decided to support the effort of the Royal Botanic Gardens, Kew in the research and the conservation of the palms of Madagascar. CLP is funding a one year project to start the restoration of these species, for awareness-raising of the importance of palms in the ecosystem and finally for ecological surveys of the wild populations. Specifically, the project works firstly with the local community for restoring the wild populations by collecting seeds, building a local nursery and for assuring the transfer of the produced seedlings from the collected seeds back into the wild; secondly for providing environmental education to children by encouraging them to respect the environment and to adults by increasing their awareness of the ecosystem in general and of any risk related to the destruction of the environment; thirdly by studying the population trends of the two species, including population genetics and niche modeling under current ecological conditions and the potential effects of climate change. The expected results for this one-year project are to increase the involvement of the local community in the protection of the two species and to develop their interest in a balanced environment.

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