Shedding Light on the *Pseudophoenix* Decline

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Pseudophoenix sargentii **and** ***P. vinifera*** **are popular ornamental palms in southern Florida and over the past five years growers have noticed a blackening of the leaf sheath, assumed to be caused by a fungus. In order to understand susceptibility, we created a ranking system to analyze possible susceptibility factors: age, location, provenance and species. All 100** ***Pseudophoenix*** **individuals at Fairchild Tropical Botanic Garden were ranked. The presence of the decline varied with plant age. Older individuals had increased susceptibility and individuals that were not reproductively mature were always asymptomatic. The decline was found in all species except** ***P. ekmanii*****, plants of which were not reproductively mature.** ***Pseudophoenix sargentii*** **was the most susceptible species. Neither provenance nor location in the landscape was a significant factor.**

The Caribbean palm genus *Pseudophoenix* has species found in Florida, the Bahamas, Hispaniola, Dominica, Cuba, Belize, Mexico and Puerto Rico. Species in the genus are widely cultivated in tropical and subtropical climates (Dransfield et al. 2008, Riffle et al. 2012). All *Pseudophoenix* species are solitary palms known for their bottle-like trunks, tough, waxy leaves, narrow leaflets and beautiful green crownshafts of tubular leaf sheaths. The species thrive in porous limestone and sandy soils, such as the soils in southern Florida and at Fairchild Tropical Botanic Garden (FTBG) (Everett 1980).

Pseudophoenix species in southern Florida nurseries, landscapes and at FTBG have been observed to develop a black, moldy crownshaft that leads to a decline in plant health. The decline begins as brown areas on the crownshaft that develop into large, black, sunken cankers in the leaf sheath, resulting in premature senescence of the leaf. Eventually, the individual dies. Researchers have completed preliminary studies that indicate fungal infections are associated with the decline, although it is not known whether these are causal or opportunistic (M. Elliott pers. comm.). Palm growers in south Florida think that copper fungicides prevent the decline but cannot cure infected individuals. If this is substantiated, fungicide would have to be applied continuously in order to protect *Pseudophoenix* plants.

There are four species in the genus *Pseudophoenix* (*P. ekmanii*, *P. lediniana*, *P. sargentii* and *P. vinifera*) (Zona 2002), and all four are found at FTBG. *Pseudophoenix* plants at FTBG and in the horticultural trade come from two main seed sources. Given proper authorization, collectors can collect seed from

Table 1. Distribution of decline by age among all species of *Pseudophoenix* at Fairchild Tropical Botanic Garden. Symptoms of each rank shown in Figures 1–4. There were 23 specimens ≤ 11 yrs, 56 specimens 12–24 yrs, and 21 specimens 25–75 yrs.

	Decline Rank			
Plant Age (yrs)	0	1	2	3
≤ 11	100%	0%	0%	0%
12–24	32%	30%	21%	21%
25–75	10%	10%	43%	38%

Pseudophoenix individuals in native habitats. The individuals that grow from these seeds are thus called wild-collected. Alternatively, growers can collect seeds from plants already in cultivation. The individuals that grow from these seeds are called nursery-sourced individuals.

Although decline has been observed in *P. sargentii* and *P. vinifera* in southern Florida, we do not know whether the other *Pseudophoenix* species are susceptible. We also do not know what factors, such as soil type or seed source, are associated with or might predict susceptibility to decline. The purpose of this study was to provide a standardized description of the progression of the disease and to analyze factors potentially associated with susceptibility to decline.

Materials and Methods

This study was conducted at Fairchild Tropical Botanic Garden, Miami, Florida, USA. *Pseudophoenix* individuals at FTBG are maintained in two main habitats, the uplands and the lowlands. The uplands are characterized by sandy, dry, limestone-based soils and regular irrigation. The lowlands habitat borders a natural mangrove hammock and has mucky, wet soils with no irrigation.

All 100 *Pseudophoenix* individuals in the FTBG collection were sampled on 27 January 2012, and were observed for the presence or absence of decline, degree of decline, age of the individual and origin. The sample comprised 17 *P. ekmanii*, 9 *P. lediniana*, 42 *P. sargentii* and 28 *P. vinifera*.

In order to standardize descriptions of the progress of the decline, we developed a system of ranked classes describing decline severity. Individuals with decline were separated into four ranked classes based on crownshaft discoloration, which increased with severity of decline. The zero rank class showed no signs of decline (Fig. 1), the first rank class showed slight discoloration on the crown shaft (Fig. 2), the second rank class had a brown crownshaft with lesions (Fig. 3), while the third rank class had large black wounds in the crownshaft (Fig. 4). We analyzed the impact of three factors (age, location – as a proxy for habitat and soil type – and whether plants were wild-collected as seeds or acquired as seedlings from nurseries) on the health of the *Pseudophoenix* collection. Analysis of these factors, unless otherwise stated, included only individuals ≥ 12 years old. The addition of this constraint created a sample of 77 Pseudophoenix individuals in total: 6 *P. ekmanii* and included 1 *P. lediniana*, 42 *P. sargentii* and 24 *P. vinifera*. Significance of factors was examined with contingency table analysis.

Age was determined for each individual using accession dates and ancillary information. Individuals acquired as seeds were designated as zero years old on accession date (N = 77); individuals acquired as seedlings were designated as one year old on date of acquisition (N = 17). For three older individuals of *P. sargentii*, accession dates were not available. For these plants, plant height was used as a proxy for age. It was estimated that a one hundred and fifty centimeter tall *P. sargentii* was approximately fifteen years old. Using this approximation, ages of these individuals were estimated. Accession records were used to determine whether plants were wild-collected or nursery-sourced.

Pseudophoenix individuals were mapped to their plot to locate potential hot spots in the garden for the decline. Plants were classified as growing in either upland or lowland areas from these maps.

Results

Decline was found in all of the *Pseudophoenix* species except *P. ekmanii* (Fig. 5). During the course of three months of observation after ranking, two *P. sargentii* individuals, initially ranked as 3, died.

1–4. Symptom ranks (0–3) for *Pseudophoenix* decline. 1 (upper left). Rank 0; individual showed no symptoms of the decline and had a green crown shaft. 2 (upper right). Rank 1; individual was just beginning to show signs of decline and showed slight symptoms of the decline with slight brown or grey tint on the crown shaft. 3 (lower left). Rank 2; individual showed moderate symptoms of the decline and had a brown crown shaft, possibly with a few black lines or spots. 4 9lower right). Rank 3; individual showed severe symptoms of the decline and had large black cankers and the formation of holes in the crown shaft.

Presence of decline symptoms varied with plant age (Table 1). Young plants (≤ 11 years) of *P. sargentii, P. lediniana and P. ekmanii* were asymptomatic. FTBG did not have plantings of *P. vinifera* younger than 12 years, but asymptomatic individuals were found in the younger individuals of this species, whereas older individuals all showed symptoms of decline. Similarly, the only older individual of *P. lediniana* (38 years old) had decline symptoms (Fig. 5). The youngest *P. sargentii* individual to show symptoms for the decline was 13 years old, while the youngest *P. vinifera* individual was 12.

When analyzing older plants (≥ 12 years old) of *P. sargentii* and *P. vinifera,* there was no difference in the presence of decline between upland and lowland plots at FTBG ($\chi^2 = 0.424$, $P > \chi^2 = 0.5152$). A similar lack of significant results was found when the two species were analyzed individually. There was also no difference in the presence of decline between FTBG plants from seeds that were wild-collected or nursery-produced seedlings for *P. sargentii* and *P. vinifera* ($\chi^2 = 0.795$, $P > \chi^2 = 0.3726$). This result for seed/seedling provenance was also non-significant when species were analyzed individually.

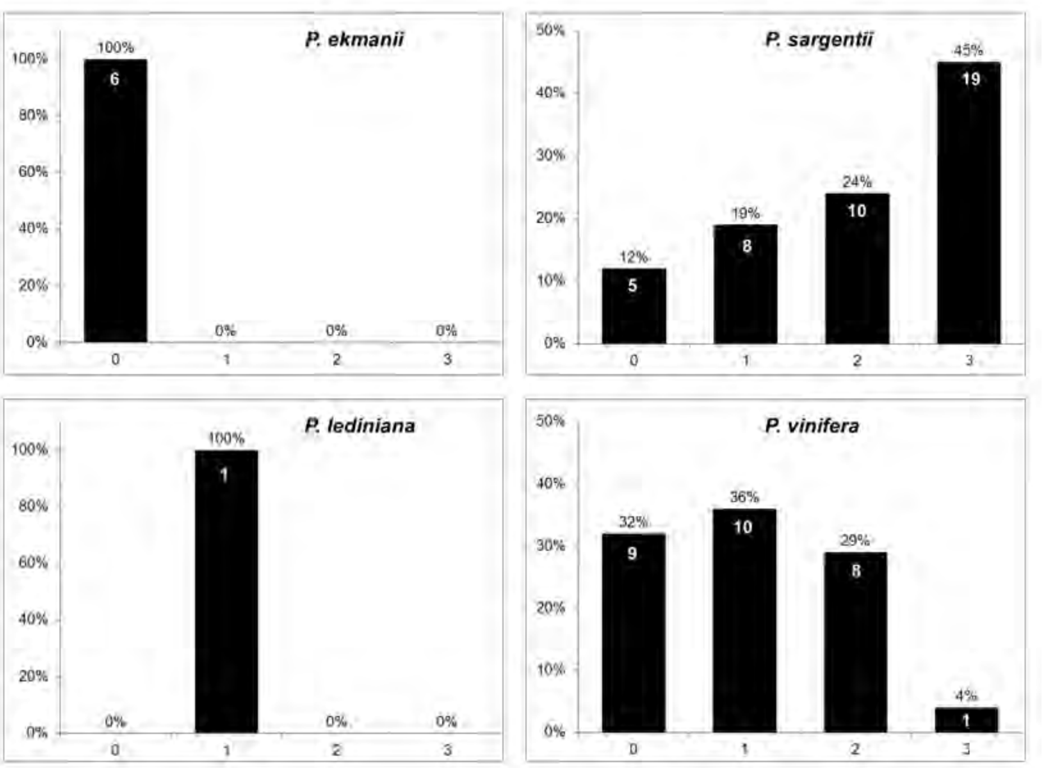
Mature individuals (≥ 12 years old) of *P. sargentii* and *P. vinifera* displayed all stages of decline (Fig. 5), but the two species differed in the severity of decline. The most common rank for *P. sargentii* was 3, while the most common rank for *P. vinifera* was 1 (Fig. 5).

The map of all *Pseudophoenix* individuals and their rank showed no hot spots in the garden for the decline.

Discussion

The decline severity ranking system presented here allowed us to analyze the decline's association with other factors and could be useful for documenting the progress of this disease over time. While this decline can lead to death, the decline is very slow to develop and time between initial symptom development and death appears to take years, not months. Many individuals with severe symptoms continue to produce viable seeds.

5. Distribution of decline ranks among individuals ≥ 12 years old for *P. ekmanii*, *P. vinifera*, *P. sargentii* and *P. vinifera* at FTBG. Data are percent of sample for each species at each rank, while white numbers within the bars are the number of individuals given each rank.



6. A picture from the Fairchild Tropical Botanical Garden archives taken in 1992 of a *Pseudophoenix sargentii individual with discoloration on the leaf sheaths.*

Decline was found in three of the four *Pseudophoenix* species. The two main factors found to be associated with progress of the decline were age and species of the individual. This study found no evidence that severity of decline was based on whether seeds were wild-collected vs. nursery-generated or on habitat and treatment after planting. Examination of older pictures of *Pseudophoenix* individuals found in the FTBG archives showed that the condition was present at least for the past 20 years and has only been recognized more recently, over the past 5 years (Fig. 6).

Pseudophoenix lediniana, *P. sargentii* and *P. vinifera* all showed symptoms once individuals were reproductively mature, and Table 1 suggests that with an increase in age, the symptoms increase in severity. No reproductively immature individual showed symptoms of decline. Although no *P. ekmanii* individuals showed decline, none of them was reproductively mature, consistent with the observation that juvenile palms are more resistant. Since the age of reproductive maturity differs for each of the species, however, age alone cannot predict susceptibility.

The trend for increased severity with age was exaggerated for *P. sargentii* individuals. Older individuals of this species may have been infected for a longer period than younger individuals by the agent(s) causing the decline. This increased exposure time could have resulted in the increased severity, although we do not know whether there is some factor associated with aging, such as a decline in vigor, a decreased growth rate or an increased allocation to reproductive effort that caused increased severity in older plants.

In southern Florida *P. sargentii* has been in cultivation for longer than the other three species and has the largest *ex situ* population. The heightened infection rate of *P. sargentii* could thus be a result of its historical popularity and use in southern Florida, which has produced both more and older individuals in the landscape. With increased popularity, cultivation, and exposure of *P. lediniana* and *P. vinifera*, the severity and number infected for these species will likely increase.

Since individuals decline slowly overtime, the use of preventive measures before the decline is observed are thought to be necessary in order to maintain healthy plants. Preventive measures common among palm horticulturists include but are not limited to hydrogen peroxide treatment poured directly in the bud or copper fungicide spray applied to the leaf bases. Neither of these techniques, however, have been tested or proven to be effective, so additional research for control measures is needed. Other suggestions to lessen decline in cultivated plants include increasing seed propagation only from asymptomatic individuals, possibly creating a stronger, less susceptible population.

More research needs to be completed in order determine the pathogen and to find treatments that are more effective and affordable. Two of the four species are considered to be critically endangered (IUCN 2012) and thus are of special concern. Evaluation of populations and the progress of the decline outside of FTBG and in other parts of the Caribbean will further increase our understanding of the threat posed by this decline throughout these species' native and cultivated ranges.

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