SYMPTOMS AND POPULATION DYNAMICS OF *RHYNCHOPHORUS CRUENTATUS* (COLEOPTERA: CURCULIONIDAE) IN CANARY ISLAND DATE PALMS

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ABSTRACT

We documented the decline of a 2-hectare Canary Island date palm (*Phoenix canariensis*) nursery caused by the palmetto weevil (*Rhynchophorus cruentatus*) in Dade County, FL. External palm symptoms were defined, divided into nine categories, and representative palms were destructively harvested to assess internal weevil associations. Apparently healthy palms declined and died in a mean of 49 days. At the beginning of the study, 42% of 950 palms appeared healthy but within seven months only 3% were alive. Economic losses were estimated at $285,000-$380,000 for the nursery studied. Palm decline was patchily distributed in the field. The mean palm weevil counts ranged from 0.3 to 223.3 weevils per palm, for healthy to collapsing palms, respectively. Twenty-four weevil grubs were sufficient to kill one mature palm. External symptoms did not allow preventative diagnosis and treatment of internal *R. cruentatus* infestations. By the time that external symptoms were unambiguous, the mean total weevil counts per palm were over 100 with more than 65% as larvae and more than one quarter of these were >2.5 cm in length. Palms in these categories were dying because of irreparable damage to their apical meristems and attempts to save them would have been ineffectual. Thus, phytosanitation (palm removal and destruction) for management of *R. cruentatus* in Canary Island date palms should be implemented as soon as host leaves droop and weevil frass is observed. Growers and buyers of *P. canariensis* in regions where *R. cruentatus* exists should be aware of the potential lethal risk that it poses for this non-native palm. The costs of aggressive phytosanitation at the first symptoms of *R. cruentatus* infestation and prophylactic pesticide treatment at times of pruning, stress, or transplanting should be factored into the predicted cost of production and maintenance of Canary Island date palms in Florida.

Key Words: integrated pest management, palm decline, palmetto weevil, *Phoenix canariensis*

RESUMEN

Documentamos el deterioro de un vivero de 2-hectáreas de palmas datileras Isla Canaria (*Phoenix canariensis*) causado por el gorgojo "palmetto" (*Rhynchophorus cruentatus*) en el condado de Miami-Dade, FL. Síntomas externos de la palma fueron definidos, divididos en nueve categorías, y palmas representativas fueron cosechadas destructivamente para evaluar asociaciones internas de los gorgojos. Palmas aparentemente saludables se deterioraron y murieron en un promedio de 49 días. Al comienzo del estudio, 42% de 950 palmas parecían saludables pero dentro de siete meses solo el 3% estaban vivas. Pérdidas económicas fueron estimadas entre $285.000-$380.000 para el vivero del estudio. El deterioro de las palmas en el campo fue distribuido irregularmente. Cuentas de promedios de gorgojos variaron entre 0,3 y 223,3 gorgojos por palma, de palmas saludables a enfermas, respectivamente. Veinticuatro orugas de gorgojo fueron suficiente para matar una palma madura. Síntomas externos no permitieron diagnosis preventivo y tratamientos de infestaciones internas de *R. cruentatus*. Para el momento en que los síntomas externos eran inequívocos, la cuenta promedio total de gorgojos por palma era sobre 100 con mas de 65% en forma de larva y mas de un cuarto de estos tenían un largo de > 2,5 cm. Palmas en estas categorías morían por daño irreparable a su meristemo apical e intentos para salvarlos hubieran resultado inútiles. Por lo tanto, fito-saneamiento (la practica de remover y destruir las palmas) para administración de *R. cruentatus* en palmas datileras Isla Canaria debería ser implementado en cuanto las hojas del huésped se inclinen y se observen residuos de daño de gorgojo. Vendedores y compradores de *P. canariensis* en regiones donde *R. cruentatus* existe deben estar al tanto de este riesgo potencialmente letal para esta palma no-nativa. El costo de fito-saneamiento agresivo en los primeros síntomas de infestación de *R. cruentatus* y tratamiento de pesticida profiláctico en momentos de podar, estrés, o transplante deben de ser facturados en los costos predichos de producción y mantenimiento de palmas datileras Isla Canaria en la Florida.

The palmetto weevil, *Rhynchophorus cruentatus* (F.) is distributed from the Florida Keys through the coastal regions of the southeastern U.S. including South Carolina and Texas (Wattanapongsiri 1966) and is co-distributed with the sabal palm, *Sabal palmetto* [Walker] Loddiges ex J. A. et Schultes (Woodruff 1967). Although not considered a major pest of palms, *R. cruentatus* has recently reached pest status in several Canary Island date palm (*Phoenix canariensis* Hortorum ex Chabaud) nurseries in southern Florida. Canary Island date palms are a valuable ornamental crop in Florida with retail values of $1,000-4,000 per palm (Anonymous 1997) for large specimen trees.

Adult *R. cruentatus* were first collected from Canary Island date palms from Florida in 1907 and recorded from Dade County, FL in 1909 (Wattanapongsiri 1966). The Canary Island date palm and sabal palm are the most commonly reported hosts for *R. cruentatus* (Giblin-Davis & Howard 1989). Other hosts include saw palmetto (*Serenoa repens* [Bartram] Small), date palm (*P. dactylifera* [L.]), *Pritchardia* sp., *Washingtonia* sp., royal palms (*Roystonea* sp.), coconut palm (*Cocos nucifera* L.), *Latania* sp., *Caryota* sp. (Wattanapongsiri 1966, Giblin-Davis & Howard 1988) and the Florida thatch palm (*Thrinax radiata* Loddiges ex J. A. & J. H. Schultes) (A. G. B. H., unpublished data).

Rhynchophorus cruentatus usually attacks transplanted or otherwise stressed palms but can attack healthy palms. Adults are often attracted to stressed, damaged or dying palms (Wattanapongsiri 1966) and rely on semiochemicals for aggregation (Giblin-Davis et al. 1996a). Mating takes place on the host and eggs are laid deep in the petiole bases, or in wounds. Females lay 207 ± 19 eggs during a 42-day oviposition period (Weissling & Giblin-Davis 1994). Eggs hatch within 64 h and larvae bore into the palm stem. In southern Florida, *R. cruentatus* is mutivoltine and development can take less than 84 days from egg to adult emergence (Giblin-Davis & Howard 1989). Late instar larvae can kill palms by destroying the palm heart (bud) (Giblin-Davis & Howard 1988). Palms are usually asymptomatic until the apical meristem has been damaged. Therefore, weevil presence is usually not detectable until fatal damage and associated rot has occurred, making control efforts ineffective. Males can survive for 87 days and females for 74 days (Giblin-Davis & Howard 1989).

We observed a Canary Island date palm nursery for natural palm mortality caused by *R. cruentatus*. The objectives of this study were to monitor the rate of decline of infested palms and rate of infestation of healthy palms under natural field conditions, and to determine the weevil population dynamics in palms in various stages of decline.

Materials and Methods

Study Site

Sampling and monitoring was conducted from March - October 1997 at a 2-hectare Canary Island date palm field nursery in Florida City, Miami-Dade County, FL. Approximately 90% of the palms at this nursery were planted 10 years ago, and the remaining were planted 5 to 6 years ago. Ten randomly selected, healthy 10-year-old Canary Island date palms were measured at the beginning of the study to give an indication of the size and health of the trees in this nursery for future comparisons. Mean bare stem height was 3.9 cm (range 0-11.4 cm) (measured from the ground to the 'booted' [with attached petioles] portion of the stem) (Fig. 1). Mean bare stem diameter was 42.6 cm (33.0-53.3 cm). Mean booted stem height was 58.4 cm (30.5-81.3 cm) (Fig. 1). Mean maximum booted stem diameter was 56.4 cm (45.7-68.6 cm) (Fig. 1). Mean overall palm height measured from the ground to the top of the spear leaves (unexpanded frond) was 217.7 cm (182.9-251.5 cm) (Fig. 1).

The soil type was 'Krome very gravelly loam' with a plant spacing of 7.9 m × 2.7 m in 0.9 m hilled planting beds. No insecticides were used in the past 6 to 7 years, and no fertilizer or herbicides were applied or palms pruned in the year preceding this study. The surrounding area included avocado (*Persea americana* Mil.) and vegetable plantings with a natural area located just west of the palm field. Native saw palmettos were present in the area but no sabal palms were found nearby. There was a 2-hectare planting of approximately 12-year-old Chinese fan palms (*Livistonia chinensis* [Jacq.] R. Br. ex Mart.) near the study site.

Distribution and Rate of Decline

The site was mapped by assigning each of the 950 living or dead palms a row and tree number. Each palm was surveyed and visually monitored every 1 to 4 weeks for 7 months. We designated nine categories for external palm symptoms. (1) old-dead: crown and stem completely collapsed, often dry and falling apart, fronds completely necrotic (brown) and pithy, palm dead for several months or more; (2) dead: crown and stem collapsed, fronds completely necrotic; (3) recently dead: crown and stem collapsed, spear leaf and 1 to 2 adjacent leaves green, other fronds completely necrotic; (4) crown and stem collapsed but most of the fronds still green; (5) crown collapsing (spear leaf leaning >45°); (6) crown beginning to collapse (spear leaf leaning 5-45°), oldest fronds reclining; (7) 3 to 4 oldest fronds reclining; (8) apparently healthy, weevil frass detectable only after close inspection; (9) apparently healthy, no detectable weevil frass (Fig. 2). Weevil frass is easily detected at or near petiole bases in categories 1 through 7.

Weevil Population Dynamics within Palms

A total of 45 randomly selected palms from differing categories of decline were cut at the soil line with a chainsaw, placed into separately labeled 150-liter plastic containers for transportation to the laboratory and dissected to determine weevil population dynamics. Booted and bare palm stems were quartered with a chainsaw and the remaining tissue was finely sectioned with a sharp, heavy-bladed knife. Completely collapsed and dead palms (categories 3 through 1) were harvested by hand by pulling the crowns and trunks apart in the field. A chainsaw and knives were used as needed. All larvae and adults, as well as empty and occupied cocoons, were removed from dissected palms.

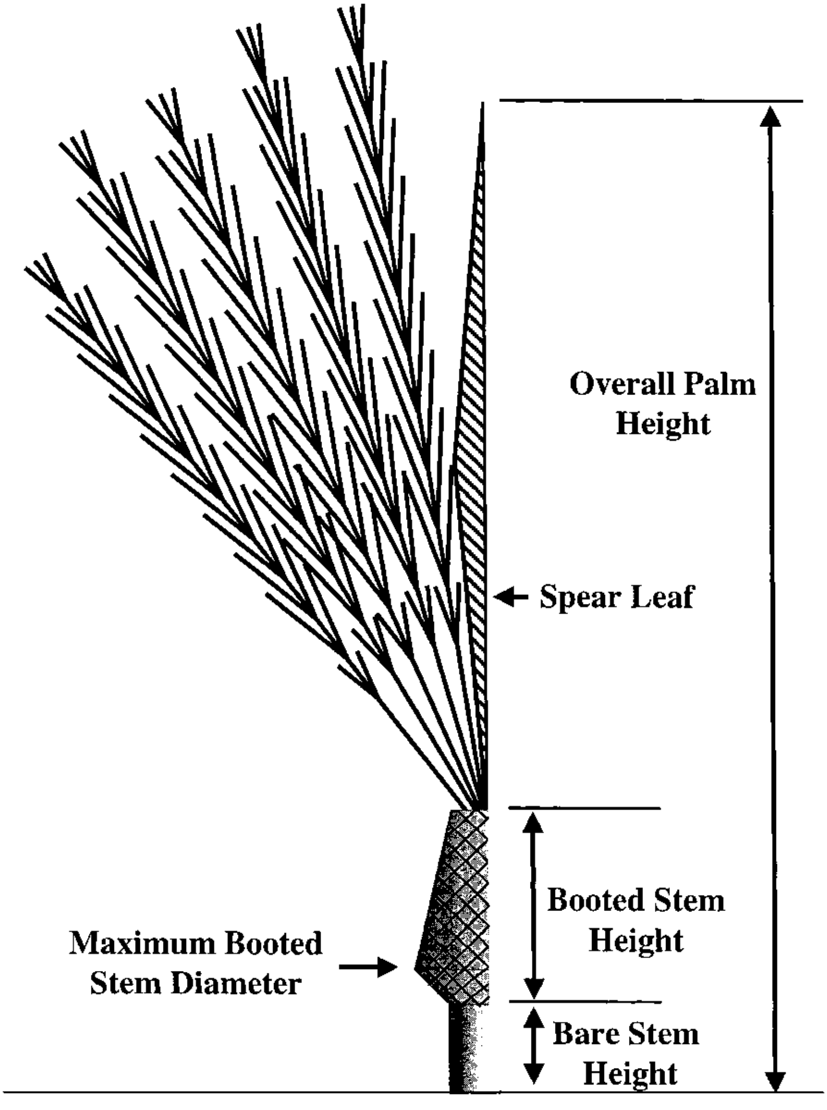

Fig. 1. Schematic drawing of *Phoenix canariensis* showing how various palm size measurements were made.

Larvae were separated by length into two categories, small (<2.5 cm) and large (>2.5 cm). All cocoons were opened to determine the stadium of the weevil (last instar larva, prepupa, pupa, or adult). Adults ready to emerge from the cocoons were sexed. Empty cocoons were counted to estimate the numbers of adults that had successfully emerged. Free-living adults found on dissected palms were also sexed and counted.

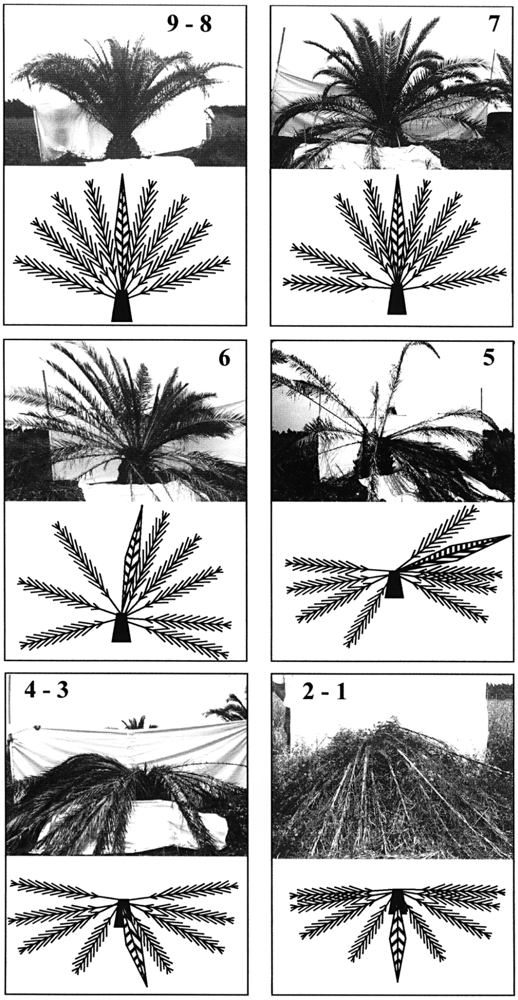

Fig. 2. Photographs and illustrations depicting the various categories of Canary Island date palm decline caused by *Rhynchophorus cruentatus* larval feeding damage. Some categories are pooled together because differentiating symptoms are not visible at this magnification or without color. Categories 9 and 8; (9) Palms healthy, asymptomatic, (8) weevil frass detected in petioles. Category 7; dying, 3 to 4 oldest fronds drooping, weevil frass detected in petioles. Category 6; dying, spear leaf and stem beginning to lean (5-45°), weevil frass detected in petioles. Category 5; dying, spear leaf and stem collapsing (>45°), weevil frass detected in petioles. Categories 4 and 3; (4) dying, spear leaf and stem completely collapsed but crown leaves still green, weevil frass detected in petioles (3); recently dead, spear leaf and 1 to 2 adjacent leaves green, other fronds completely necrotic, weevil frass detected in petioles. Categories 2 and 1; (2) dead, crown and stem collapsed, fronds completely necrotic; weevil frass detected (1); old-dead: crown and stem completely collapsed, dry and falling apart, fronds completely necrotic (brown) and pithy, weevil frass detected, palm dead for several months or more.

These represented weevils recently emerged from cocoons or weevils that flew into palms before they were harvested.

Temporal Dynamics

We compared the number of weevils and empty cocoons from palms that died before the beginning of this study (categories 1 and 2) with palms that died or were declining during the study (categories 2, 5 and 6) for differences in adult weevil production per palm.

Statistics

Temporal dynamics data were subjected to an analysis of variance (ANOVA) using PROC GLM (SAS Institute 1985) and means were separated by a Duncan's Multiple Range test when the ANOVA was significant at $P < 0.01$.

RESULTS

Distribution and Rate of Decline

Palms declined from category 9 to 3 in a mean of 49 days (±16 SD; range 11-100 days) and from category 7 to 3 in a mean of 31 days (±15 SD; range 8-80 days). Palm decline was patchily distributed throughout the study site (Table 1). When initially surveyed on March 28, 1997 (Julian Date 87), the three middle rows of the site (rows 4, 5 and 6) had the greatest proportion of dead palms (mean mortality 58, 77, 64%, rows 4 - 6 respectively) (Table 1). More dead palms were found near the ends of rows, except for row 5 where dead palms were found throughout the row. In the beginning of this study, 54.7% of all palms were dead, 3.3% were dying, and 41.8% were apparently healthy (Fig. 3). However, seven months later (October 1997; Julian Date 286), the proportion of healthy palms decreased to 3.1% (Fig. 3). Over the same time period, the proportion of dead palms (categories 1 to 3) increased from 54.7% to 88.5%. The proportion of dying palms (categories 4 through 7) was fairlyconstant, with a mean of 9.4% (range 3.3-13.1%) per month. Also, by October 13 (Julian Date 286), almost all of the palms in rows 3, 4, 5, and 6 were dead. No healthy palms were found in row 6 (Table 1).

TABLE 1. PROPORTIONS OF DEAD (CATEGORIES 3 THROUGH 1), DYING (CATEGORIES 7 THROUGH 4), AND HEALTHY (CATEGORIES 9 AND 8) CANARY ISLAND DATE PALMS BY ROW NUMBER FOR MARCH AND OCTOBER, 1997.

	Rows							
March 28, 1997	1	2	3	4	5	6	7	8
% Palms Dead	57.1	43.4	41.6	57.8	73.5	63.8	47.5	56.0
% Palms Dying	4.8	2.8	4.4	2.2	3.8	3.8	2.9	5.0
% Palms Healthy	38.1	53.8	54.0	40.0	22.0	32.3	49.6	39.0
October 13, 1997								
% Palms Dead	85.7	89.5	87.6	94.0	96.2	93.8	82.7	90.0
% Palms Dying	9.5	6.3	6.6	3.0	2.3	6.2	13.7	6.0
% Palms Healthy	4.8	4.2	5.8	3.0	1.5	0	3.6	4.0

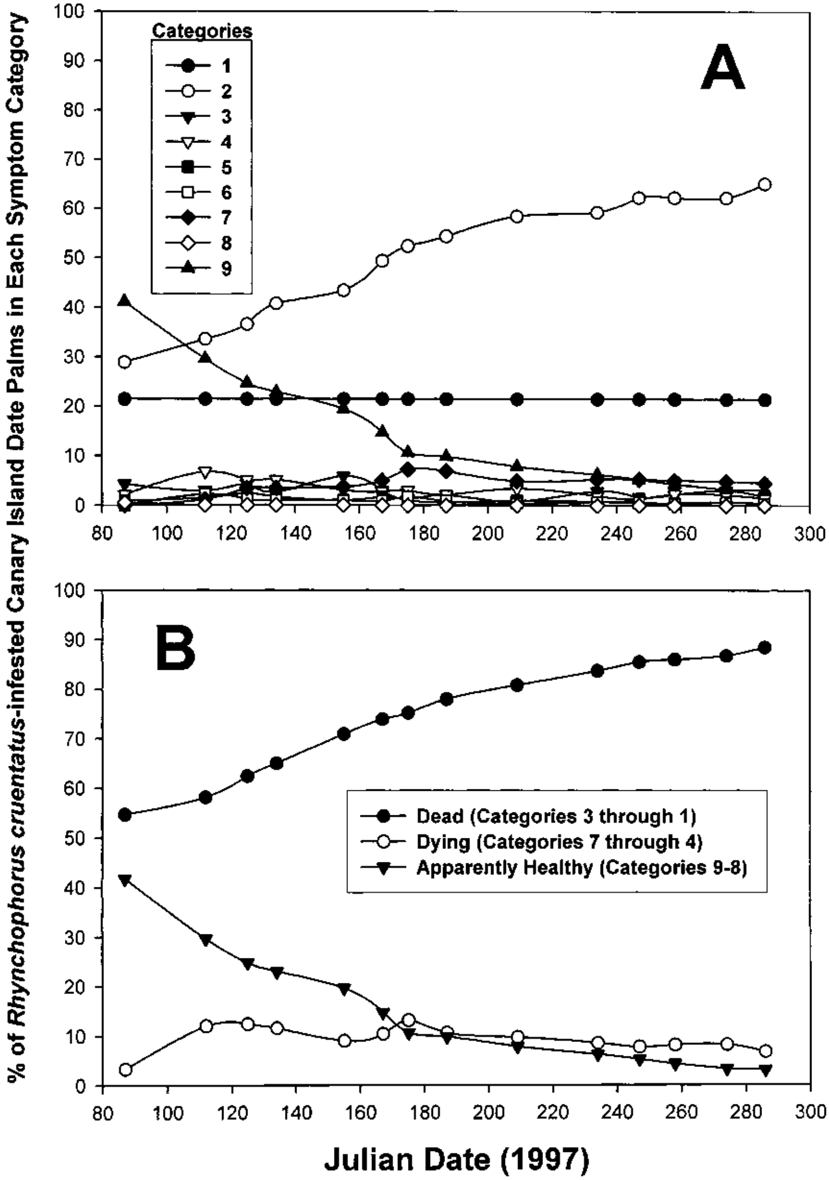

Fig. 3. Plots of the percentage of *Rhynchophorus cruentatus*-infested field-grown Canary Island date palms in each symptom category for each Julian date in 1997 from a nursery in southern Florida. See Figure 2 for descriptions of the symptom categories. A. Palm symptom categories 9 through 1. B. Palm symptom categories consolidated.

Weevil Population Dynamics within Palms

We found that as few as twenty-four *R. cruentatus* larvae were capable of killing a 10-year-old Canary Island date palm. Only two early instar larvae were found in a healthy (category 9) dissected palm with no associated internal damage (Table 2). Adults [1:1 (M:F)] were found within debris collected at the petiole bases of all of the healthy palms surveyed. Palms in category 8, where the palm appears healthy except for larval frass, were rare (Fig. 3) and none were dissected (Table 2). This category was difficult to detect because externally visible frass was normally associated with larger larvae preparing to pupate.

Eighty to 92% of the total live weevils from palms beginning to decline (categories 7 and 6) were larvae and most of these were small (Table 2). As symptoms progressed, the percentage of total live weevils that were pupae and prepupae increased from 11.5% to 38.7% (categories 7 to 3, respectively). Palms categorized as 7, when symptoms were first noticed, had large numbers of weevils (>100 live weevils per palm) (Table 2). The greatest number of weevils recovered was 308 (mostly immatures) in a palm whose crown was just starting to collapse (category 6). On the average, palms with collapsing crowns (category 5) had the most weevils (>200 per palm) (Table 2). Palms with completely collapsed crowns (category 4) also contained large populations of larvae (mean = 113.4 per palm) (Table 2). Recently dead palms (category 3) still had larvae (mean = 29.0 per palm) compared with palms that had been dead for awhile which had less than 1 larva per palm (Table 2). Dead palms (categories 2 and 1) contained mostly empty cocoons (89-99% of the total weevils per palm) (Table 2). Up to two generations of weevils were found within many palms indicating the continued recruitment of adults to infested palms or recidivism. Dead palms had the fewest total weevils per palm (mean = 40.0, 88.3, 75.5; categories 1 through 3, respectively). For all palms, the sex ratio was 1:1 (M:F) for adults inside cocoons.

Temporal Dynamics

Palms that died in the year before this study was started had been infested with a lower ($F = 5.33$; $df = 2,18$; $P = 0.0152$) number of weevils than palms that died during the study (Table 3). A mean of 40.0 weevils per palm was recovered in palms that died before the spring 1997, 88.3 weevils in palms that died during the spring of 1997, and 115.0 weevils in palms that died during the summer of 1997 (Table 3).

The number of empty cocoons within trees served as an estimator of the adult weevil production potential of Canary Island date palms (killed by lethal infestations of weevils) because each empty cocoon represented an adult that emerged. The adult weevil production per palm was related to when the palms were infested. It was a maximum of 148 weevils (mean = 78.5) for those palms that died during the spring-early summer of 1997 (pre-spring 1997 infestation) compared with a maximum of 142 weevils (mean = 105.6) for palms that died during the summer 1997 (spring 1997 infestation) and a maximum of 59 (mean = 39.5) for palms that were infested and died prior to the spring of 1997 (Table 3). Because these observations involved palms that died over the course of 18 months, host size could have been a factor. However, gross comparisons of stem size did not confirm that the trees had grown very much during this time.

Palms (category 6) (Table 3, season of infestation = spring 1997) were selected and some were harvested while others of this cohort were allowed to decline and were subsequently harvested as category 5 and 2 palms at different times in 1997. There was a decrease ($F = 9.35$; $df = 4, 22$; $P = 0.0001$) in total weevil counts as palms declined (Table 3). The mean total weevils per palm in categories 5 and 6 were 223.3 and 183.0, respectively. In contrast, category 2 palms that had been infested at the same time

TABLE 2. MEAN NUMBER OF *RHYNCHOPHORUS CRUENTATUS* DISSECTED FROM FIELD-GROWN CANARY ISLAND DATE PALMS IN SOUTHERN FLORIDA.

Palm health category[1]	(n)[2]	Mean (±SE) no. weevils per palm								
		Larvae		Pupae		Adults in cocoons		Total live weevils	Empty cocoons[3]	Total weevils[4]
		Small	Large	Prepupae	Pupae	Females	Males			
DEAD										
1	4	0	0.5 (0.5)	0	0	0	0	0.5 (0.5)	39.5 (7.3)	40.0 (7.1)
2	12	0	0.6 (0.3)	0	2.3 (1.0)	3.3 (0.7)	3.6 (0.9)	9.8 (1.0)	78.5 (9.3)	88.3 (10.6)
3	2	0.5 (0.5)	28.5 (26.5)	7.5 (7.5)	14.0 (7.0)	2.0 (1.0)	3.0 (2.0)	55.5 (26.5)	20.0 (15.0)	75.5 (15.5)
DYING										
4	5	44.0 (21.5)	69.4 (21.7)	11.4 (4.6)	19.2 (2.4)	6.4 (0.8)	4.8 (1.6)	155.2 (23.5)	17.2 (5.3)	172.4 (23.4)
5	3	89.7 (15.4)	85.3 (8.5)	10.0 (4.4)	14.7 (5.8)	7.3 (2.3)	10.7 (3.7)	217.6 (20.0)	5.7 (1.5)	223.3 (19.4)
6	3	111.0 (43.8)	51.7 (15.7)	3.3 (1.5)	6.0 (4.0)	3.0 (1.0)	2.3 (0.7)	177.3 (62.5)	6.0 (3.1)	183.3 (62.3)
7	3	62.3 (13.3)	23.7 (10.7)	7.7 (2.3)	4.7 (3.7)	4.7 (4.7)	4.3 (3.3)	107.4 (34.2)	1.3 (1.3)	108.7 (34.7)
HEALTHY										
8	0									
9	7	0.3 (0.2)	0	0	0	0	0	0.3 (0.2)	0	0.3 (0.2)

[1]See Figure 2 for legend.
[2]n = number of palms dissected.
[3]Empty cocoon = emerged weevil.
[4]Total weevils = total live weevils + empty cocoons.

TABLE 3. COMPARISON OF NUMBER OF *RHYNCHOPHORUS CRUENTATUS* DISSECTED FROM DEAD AND DECLINING PALMS INFESTED IN DIFFERENT SEASONS.

Season of infestation	Palm health category[1]	Palms harvested (n)	Mean number (Range) of larvae per palm			Percentage of total weevils[3]	Mean number (Range) of pupae per palm			Percentage of total weevils
			Small	Large	Total[2]		Prepupae	Pupae	Total	
Pre-spring 1997	1	4	0 (0)	0.5 (0-2)	0.5b	1.3	0 (0)	0 (0)	0b	0
	2	12	0 (0)	0.6 (0-3)	0.6b	0.7	0 (0)	2.2 (0-12)	2.3b	2.6
Spring 1997	2	5	0 (0)	0.8 (0-4)	0.8b	0.7	1.0 (0-2)	3.0 (0-7)	4.0b	3.5
	5	3	89.7 (65-118)	85.3 (72-101)	175a	78.4	10.0 (2-17)	14.7 (5-25)	24.7a	11.1
	6	3	111.0 (50-196)	51.7 (26-80)	162.7a	88.8	3.3 (1-6)	6.0 (2-14)	9.3b	5.1

Season of infestation	Palm health category	Mean number (Range) adults in cocoons			Percentage of total weevils	Mean number (Range) of empty cocoons	Percentage of total weevils	Total weevils
		Females	Males	Total				
Pre-spring 1997	1	0 (0)	0 (0)	0b	0	39.5 (25-59)bc	98.8	40.0c
	2	3.1 (0-7)	3.6 (0-9)	6.9b	7.8	78.5 (21-148)ab	89.0	88.3bc
Spring 1997	2	1.0 (0-4)	1.0 (0-4)	4.6b	4.0	105.6 (51-142)a	91.8	115.0b
	5	7.3 (3-11)	10.7 (6-18)	18.0a	8.1	5.7 (3-8)c	2.6	223.3a
	6	3.0 (2-5)	2.3 (1-3)	5.3b	2.9	6.0 (0-10)c	3.3	183.3a

[1]See Figure 2 for legend.
[2]Means in a column followed by a different lower case letter are significantly different according to a Duncan's Multiple Range test.
[3]Total weevils = total live weevils + empty cocoons.

had a significantly lower mean total number of weevils (115.0 per palm) (Table 3) suggesting unknown mortality or other factors. Most of the weevils in category 5 and 6 palms were larvae (78.4 and 88.8%, respectively); whereas, category 2 palms contained 0.7% larvae (Table 3).

Discussion

This study has confirmed that apparently healthy Canary Island date palms are suitable and susceptible hosts for *R. cruentatus* (Giblin-Davis & Howard 1989, Giblin-Davis et al. 1996a,b). This contrasts with most other species of palms that appear to be suitable and susceptible to *R. cruentatus* infestation only after some major stress (Giblin-Davis & Howard 1989). Adult *R. cruentatus* seek harborage between palm sheaths or in rotten parts of the palm, presumably in search of moisture and oviposition sites (Weissling & Giblin-Davis 1993, 1994). *Rhynchophorus cruentatus* may attack healthy Canary Island date palms because of their large and tender leaf bases which may be more semiochemically apparent and easily infested by neonates than the split and hardened petioles of palms such as *S. palmetto* (R. M. G.-D., unpublished data). None of the palms (Chinese fan palm or saw palmetto) in areas next to the study site declined. *Rhynchophorus cruentatus* appeared to be the sole cause of death for all dead or dying Canary Island date palms (922 of 950) observed during this study. In a similar study of 197 six to eight-year-old Canary Island date palms in Indian River County, FL during 1994-1995, 61% died with heavy infestations of *R. cruentatus* (R. M. G.-D. & J. T., unpublished data). At that site, none of the > 100 *S. palmetto* (aged 5 to 10 years old), > 300 *Syagrus romanzoffiana* (Chamisso) Glassman (Queen palm) (aged 5 to 8 years old), > 500 *Aceolorrhaphe wrightii* (Grisebrach & H. A. Wendland) (Paurotis palm) (> 5 years old), > 200 *P. reclinata* N. J. Jacquin (Reclinata palm) (> 5 years old), 214 *Livistonia australis* (R. Brown) Martius (Australian fan palm) (> 5 years old), and > 30 *Washingtonia robusta* H. A. Wendland (Washington palm) (> 5 years old) declined due to *R. cruentatus* infestations during or within 3 years of the study (R. M. G.-D. & J. T., unpublished data).

A few adult *R. cruentatus* may initially be found on a palm, but recruitment occurs when male-produced aggregation pheromones and kairomones from stressed, damaged, or dying trees are released (Giblin-Davis et al. 1996a). When healthy and weevil-infested Canary Island date palms in this study were dissected, flying *R. cruentatus* were attracted to the area within minutes of cutting. In most palms, *R. cruentatus* infestations are secondary to some major stress factor such as pruning, transplanting, drought, and/or earlier damage from the West Indian sugarcane borer, *Metamasius hemipterus sericeus* (Olivier) (Giblin-Davis et al. 1996b). However, we found *R. cruentatus* attacking apparently healthy Canary Island date palms that had not been pruned within the past year. The population increase of *R. cruentatus* may have started after hurricane Andrew occurred in August, 1992 causing severe damage to vegetation. Damaged palms at the study site may have provided resources for an increase in the population of this weevil that went unnoticed and became an epizootic. At high densities, *R. cruentatus* may be more of a threat to healthy Canary Island date palms than when present at low densities.

Canary Island date palms are also a suitable host for *M. h. sericeus,* but it does not cause lethal damage (Giblin-Davis et al. 1996b). There was some old *M. h. sericeus* damage and empty cocoons (mean = 3.6 per palm) in the dried petioles of *R. cruentatus*-infested palms in this study. Because of similar chemical ecology, infestation and damage by *M. h. sericeus* can result in the recruitment of the more damaging *R. cruentatus* to palms (Giblin-Davis et al. 1996a).

The symptom categories proposed in this study were ineffective for designating Canary Island date palms that had sub-lethal or potentially lethal internal infestations of *R. cruentatus.* Palms did not react to weevil infestations until there was an accumulation of late instar larvae (>20) (Table 2). As a result, substantial damage occurred before there was any observable manifestation of injury by the palm (Wolfenbarger 1958). The earliest infestation category (8) proved rare and unreliable because of the cryptic nature of *R. cruentatus*. Frass production, the most reliable external symptom of *R. cruentatus* infestation, was not easily observed until palms were classified as category 7. The attached petiole bases of *P. canariensis* obscure visibility making the discovery of frass difficult until large numbers of late instar larvae begin to pupate. Removal of petiole bases before they have completely dried and are ready for abscission to discover *R. cruentatus* is laborious and creates wounds that could attract more weevils.

There are several possible scenarios for category 8 palms where frass was detected before the palm declined. First, an apparently healthy host palm could have been near category 7, but the large number of larvae had not done sufficient damage to critical zones of the palm to induce symptoms. Palms are monocots with large numbers of vascular bundles that connect leaves to roots. Borers can do a lot of random mechanical damage to these vascular elements before enough are destroyed to induce a systemic decline. This would help explain the short time difference between apparently healthy plants (category 9) through death (category 3) (49 days) versus onset of frond reclining (category 7) through death (category 3) (31 days). Second, there might have been a smaller weevil infestation where the weevils had metamorphosized and frass was fortuitously deposited where it could easily be observed. This would explain the long time to death from category 9 through 3 in some palms (range up to 100 days). A palm in this situation, would be the most likely candidate for preventative systemic insecticide treatment, if external symptoms were more reliable and there were proven systemic insecticides available. When a palm in this situation is left untreated, the next generation of adult weevils recruit new weevils or mate among themselves and produce progeny that may kill the palm.

Category 7 was a reliable indicator of a dying palm but some variability existed in the time to death from category 7 through 3 palms (range 8-80 days) suggesting differences in weevil-host dynamics. Fast host death is consistent with a host that was on the verge of severe decline with large numbers of mature weevils when it was rated (Table 2). Slow host death is consistent with a palm that had been structurally compromised by a few weevils allowing for early display of symptoms. The lack of reliability of asymptomatic palms in categories 9 and 8, the similarities of weevil-host dynamics and time to death for categories 7 through 4 and categories 3 through 1 (Table 2), all suggest that the nine categories designated at the start of this study can be consolidated into the following three categories for diagnostic purposes; APPARENTLY HEALTHY (categories 9 and 8), DYING (categories 7 through 4), and DEAD (categories 3 through 1) (Fig. 3).

External symptoms did not allow preventative diagnosis and treatment of internal *R. cruentatus* infestations in *P. canariensis*. By the time that external symptoms were unambiguous (categories 7 through 4), the mean total weevil counts per palm were over 100 with more than 65% as larvae and more than one quarter of these were >2.5 cm in length (Table 2). Palms in these categories were dying because of irreparable damage to their apical meristems and attempts to save them would have been ineffectual. Thus, phytosanitation (palm removal and destruction) for management of *R. cruentatus* in Canary Island date palms should be implemented as soon as host leaves droop and weevil frass is observed.

Weevil populations during the present study were high in the late spring and early summer of 1997 (a total of 3,016 *R. cruentatus* and 3,043 *M. h. sericeus* adults were captured and killed in semiochemical-baited traps [5 traps per hectare] over the course of the seven month study [unpublished data]). We hypothesize that the populations expanded in 1997 because of significant increases in the number of empty cocoons harvested in spring of 1997 from category 2 palms compared with category 1 palms from pre-spring 1997 (Table 3). The lack of chemical control and/or phytosanitation were the most likely factors responsible for the weevil population increase. Additionally, the semiochemicals released from dying palms and adult weevils may have recruited more *R. cruentatus* from surrounding areas into the site. Even though >3,000 *R. cruentatus* were mass-trapped from the site, the within field populations of *R. cruentatus* did not decrease enough during the summer to prevent most of the palms at the site from being destroyed by this weevil. Adult weevil density estimates for the entire site were 34,390 (417 palms with 78.5 empty cocoons per palm, category 2; 57 palms with 20.0 empty cocoons per palm, category 3; 30 palms with 17.2 empty cocoons per palm, category 4) between April - May 1997 (Fig. 3 and unpublished data). Therefore, the mass trapping efforts removed about 9% of *R. cruentatus* adults present. We speculate that the *M. h. sericeus* that we trapped were recruited from other sites because we did not find any immatures in dissected palms. The only phytosanitation done at this site was the removal of palms for dissection and represented about 5% of the total suggesting that semiochemical-based mass trapping was ineffective for small field plot control of *R. cruentatus* without aggressive concurrent phytosanitation, especially during a weevil epizootic. Replicated studies are needed to verify the usefulness of mass trapping in small and large stands of Canary Island date palms. Care should be taken when implementing mass trapping in small plots of highly susceptible palms, such as Canary Island date palms, because pheromone could call more weevils into a site.

The theoretical *R. cruentatus* yield for this site for 1997 was 82,696 adult weevils (522 palms, mean = 64.1 weevils per palm; 428 palms, mean = 115.0 weevils per palm). Loss to this grower was estimated at $285,000-$380,000 (based on the number of palms per hectare and a $300-$400 wholesale price for this size palm). Growers and buyers of *P. canariensis* in regions where *R. cruentatus* exists should be aware of the potential lethal risk that it poses for this non-native palm. The costs of aggressive phytosanitation at the first symptoms of infestation by *R. cruentatus* and prophylactic pesticide treatment at times of pruning, stress or transplanting (Giblin-Davis & Howard 1989) should be factored into the predicted cost of production and maintenance of Canary Island date palms in Florida. To prevent the spread of *R. cruentatus* populations, Canary Island date palms shouldn't be transplanted from sites with an epizootic because early weevil infestations are not easily diagnosed and stressing of palms can call in colonizing weevils before removal from the nursery.

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REFERENCES CITED

ANONYMOUS. 1997. PlantFinder, wholesale guide to foliage and ornamental plants, Aug. 15. Betrock Information Systems, Hollywood, FL. Pp. 165-166.

GIBLIN-DAVIS, R. M., AND F. W. HOWARD. 1988. Notes on the palmetto weevil, *Rhynchophorus cruentatus* (Coleoptera: Curculionidae). Florida State Hort. Soc. 101: 101-107.

GIBLIN-DAVIS, R. M., AND F. W. HOWARD. 1989. Vulnerability of stressed palms to attack by *Rhynchophorus cruentatus* (Coleoptera: Curculionidae) and insecticidal control of the pest. J. Econ. Entomol. 82: 1185-1190.

GIBLIN-DAVIS, R. M., A. C. OEHLSCHLAGER, A. PEREZ, G. GRIES, R. GRIES, T. J. WEISSLING, C. M. CHINCHILLA, J. E. PEÑA, R. H. HALLETT, H. D. PIERCE, JR., AND L. M. GONZALEZ. 1996a. Chemical and behavioral ecology of palm weevils (Curculionidae: Rhynchophorinae). Florida Entomol. 79: 153-167.

GIBLIN-DAVIS, R. M., J. E. PEÑA, AND R. E. DUNCAN. 1996b. Evaluation of an entomopathogenic nematode and chemical insecticides for control of *Metamasius hemipterus sericeus* (Coleoptera: Curculionidae). J. Entomol. Sci. 31: 240-251.

SAS INSTITUTE. 1985. SAS user's guide: statistics, 5th ed. SAS Institute, Cary, NC.

WATTANAPONGSIRI, A. 1966. A revision of the genera *Rhynchophorus* and *Dynamis*. Dept. of Agricultural Science Bulletin, Bangkok 1:1-328.

WEISSLING, T. J., AND R. M. GIBLIN-DAVIS. 1993. Water loss dynamics and humidity preference of *Rhynchophorus cruentatus* (Coleoptera: Curculionidae) adults. Environ. Entomol. 22: 93-98.

WEISSLING, T. J., AND R. M. GIBLIN-DAVIS. 1994. Fecundity and fertility of *Rhynchophorus cruentatus* (Coleoptera: Curculionidae). Florida Entomol. 77: 373-376.

WOLFENBARGER, D. O. 1958. Palm insects and their control. Principes 2: 107-112.

WOODRUFF, R. E. 1967. A giant palm weevil, *Rhynchophorus cruentatus* (Fab.), in Florida (Coleoptera: Curculionidae). Florida Dept. of Agriculture Division of Plant Industry, Entomology circular no. 63.