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CONTROL OF RED RING DISEASE BY MASS TRAPPING OF *RHYNCHOPHORUS PALMARUM* (COLEOPTERA: CURCULIONIDAE)

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Abstract

Rhynchophorus palmarum (L), the American palm weevil, is an important pest of several palm species in tropical America as a vector of the red ring nematode *Bursaphelenchus cocophilus* Cobb. Bimonthly inspections coupled with elimination of red ring diseased (RRD) oil palms (*Elaeis guineensis* Jacq.) failed to reduce infection rates of oil palms in two commercial plantations in Costa Rica. Addition of pheromone-based trapping of *R. palmarum* using trap densities of less than one trap per five hectares lowered RRD in both plantations by over 80% in one year. Continued removal of RRD infected palms and trapping maintained RRD at very low levels over several years. No matter what the initial RRD infection level, trap density or capture rate, areas with high and areas with low RRD infection levels declined to the same low RRD infection level after one year of trapping. An efficient strategy for management of RRD in oil palm is based on an integrated approach where RRD and other diseased (e.g., spear rot) palms are promptly eliminated or properly treated and pheromone-baited traps are used to reduce populations of *R. palmarum*. These strategies are complimented by removal of weevil-infested palms after wind and lightning damage and periodic removal of palms (e.g., coconut palms) in surrounding areas that serve as hosts for *R. palmarum.*

Key Words: American palm weevil, *Rhynchophorus palmaru*m, pheromone trapping, oil palm, red ring disease

Resumen

El gorgojo de la palma americana *Rhynchophorus palmarum* (L), es una plaga de importancia en diversas especies de palmas en América tropical como vector del nematodo del anillo rojo *Bursaphelenchus cocophilus* Cobb. Las inspecciones bimensuales en conjunto con la eliminación de las palmas infestadas con la enfermedad del anillo rojo (RRD, sus siglas en inglés) han fallado en reducir las tasas de infeción en palmas aceiteras (*Elaeis guineensis* Jacq.) de dos plantaciones comerciales en Costa Rica. La adición del trampeo basado en feromonas del *R. palmarum* usando densidades de trampas menores a una trampa por cada cinco hectáreas, efectivamente redujo el RRD en ambas plantaciones en mas de un 80% en un año. La remoción continua de palmas infestadas con RRD y el trampeo mantuvieron el RRD a niveles muy bajos sobre varios años. Sin importar cual fue el nivel inicial de RRD, densidad de trampas o tasa de captura, las áreas con infestaciones altas y las áreas con infestaciones bajas de RRD declinaron su infestación al mismo nivel bajo de infestación de RRD después del trampeo por un año. Una estrategia eficiente de manejo del RRD en cultivo de palma aceitera está basada en un enfoque integral en donde tanto las palmas con RRD como aquellas con otras enfermedades (por ejemplo pudrición del ápice central), son eliminadas o tratadas con prontitud y para reducir las poblaciones de *R. palmarum* vector del RRD se utilizan trampas cebadas con feromona. Esta estrategia es complementada por la remoción también de palmas infestadas de gorgojos después de que ocurran daños ocasionados con el viento o descargas eléctricas, como también con la remoción periódica de palmas (por ejemplo palmas cocoteros) en las áreas que bordean y que sirven como hospederas del *R. palmarum*.

Translation provided by author.

The American palm weevil, *Rhynchophorus palmarum* (L) is a significant pest of cultivated oil (*Elaeis guineensis* Jacq.) and coconut (*Cocos nucifera* L) palms in the Americas through direct attack and as a vector of the red ring nematode *Bursaphelenchus cocophilus*, Cobb (Wattanapongsiri 1966, Fenwick 1968, Blair 1970a, 1970b, Griffith 1967, 1968, 1969, 1987, Hagley 1963, Chinchilla 1988, Chinchilla et al. 1990, Morales & Chinchilla 1990). It is thought that the nematode is transmitted during weevil feeding and oviposition (Griffith 1968, Hagley 1963). Once in the palm the infection may result in two different symptoms. The classical symptom is yellowing of fronds and rapid death of the palm. A second symptom is "little leaf syndrome" which is manifested in stunted growth of fronds. Palms with this manifestation of *B. cocophilus* infection usually

live for many years (Chinchilla, 1988). The ring of darkly colored necrotic tissue observed in the cut cross-sections of stems of palms with classical symptoms of yellowing fronds has given the affliction its common name, red ring disease (RRD).

RRD causes a significant economic impact in oil palm. Although RRD is not a problem in plantings under five years, losses increase thereafter and become significant in older stands. Accumulated losses due to RRD and the associated little leaf syndrome can reach 15% or more in commercial plantations (Chinchilla et al. 1990). *R. palmarum* is the only identified insect vector of RRD in oil palm in Central America and other mechanisms of infection such as *via* nematode contaminated knives during pruning or transmission *via* contaminated soil are considered insignificant in comparison to inoculation by the weevils (Chinchilla 1988, Fenwick 1968, Schuiling & van Dinther 1981). *Metamasius* spp. have been suggested as vectors of RRD in Colombia (Silva 1991; Calvache et al. 1995) but *B. cocophilus* infected *M. hemipterus,* the principal *Metamasius* species in oil palm, have not been detected in Costa Rica (Bulgarelli et al. 1998). The rate of red ring infection in Costa Rican and Honduran oil palm plantations is correlated with fluctuations in nematode-infected *R. palmarum* populations (Chinchilla et al. 1990; Morales & Chinchilla 1990). RRD symptoms of frond yellowing are not evident until two to three months after infection and nematocidal treatments at this point have proven fruitless in oil palm (Chinchilla 1988). The most effective strategy to lower the incidence of RRD is rapid elimination of nematode infected palms coupled with reduction of weevil populations through elimination of breeding sites (Chinchilla 1988, Griffith 1987) and trapping of adults (Chinchilla 1988). Treatment of palms with insecticide (Fenwick 1967), removal of red ring-diseased trees and trapping using insecticide-laden palm stem have been considered appropriate phytosanitation practices (Griffith 1969). Trapping has been practiced in the Caribbean since the 1970s (Mariau 1968, Griffith 1969). Most commonly used traps prior to this work utilized insecticide-treated palm stem (Mariau 1968, Griffith 1969, Morin et al. 1986, Chinchilla et al. 1990) or tropical fruits (Delgado & Moreno 1986).

Several years ago we demonstrated that *R. palmarum* are more captured in plastic bucket traps from which are released the male-produced aggregation pheromone and that contain insecticide-laden sugarcane or palm stem (Oehlschlager et al., 1992a,b, 1993b). We subsequently reported that in commercial oil palm plantations bucket traps baited with pheromone and insecticide-laced sugarcane, at a density of 4 traps/hectare, effectively lowered *R. palmarum* populations and new RRD infection (Oehlschlager et al. 1995). In the 38 ha mass trapping site, *R. palmarum* capture rates and RRD declined from initial values by >80% during a one year trial. During the same period RRD in surrounding lots of the same age and material decreased only 10% and the incidence of RRD in the plantation as a whole increased by 20% (Oehlschlager et al. 1995).

This high density trapping experiment was followed by mass trapping in four plots averaging 56 hectares using trap densities ranging from 1 trap/ha to 1 trap/3.5 ha. In all cases initial capture rates declined after two to three months and RRD declined compared to the same period a year previous (Chinchilla et al. 1993).

In the present paper we present results of mass trapping of *R. palmarum* in two large oil palm plantations extending over several years. One site is a 6,514 ha plantation, located in southwest Costa Rica and the site of previous trials. Data from a second 8,719 ha plantation, located in west-central Costa Rica is also included. These studies illustrate the operational use of trapping *R. palmarum* to lower RRD in commercial oil palm that has only been published in preliminary form (Chinchilla et al. 1993).

Materials and Methods

Study Sites

The study was conducted in two commercial African oil palm (*E. guineensis*) plantations near the Pacific Coast of Costa Rica. The Coto plantation is a 6,514 ha commercial oil palm plantation in southern Costa Rica ~10 km from the Pacific coast. The plant age profile of the plantation at the beginning of 1992 was: 1,329 ha of 17-24 year-old palms, 1,265 ha of 12-16 year-old palms, 2,602 ha of 6-11 year-old palms and 1,317 ha of 0-5 year-old palms. The Quepos oil palm plantation is a 8,719 ha commercial plantation in central Costa Rica ~2 km from the Pacific coast. The plant age profile of the plantation at the beginning of 1992 was: 4,333 ha of 17-24 year-old palms, 1,643 ha of 12-16 year-old palms and 2,743 ha of 0-4 year-old palms. The two sites are similar in variety of plant material, plant age profile, size and climate, but Quepos has a more extended dry season.

Disease Surveying

In both plantations periodic visual survey for red ring disease was initiated in 1989 and was continued bimonthly after the beginning of 1990. Each plantation contains palm planted on a 9-m grid at 142 palms/ha. The plantations are divided into approximate 10 ha plots to facilitate management. Inspection was by visual inspection of each 8 rows with the inspector walking through the center. Inspectors recorded the position (section location, row location and location in row) of each palm with early symptoms of RRD. Within 1 week a team of two revisited the infected palm and if they verify RRD infection the palm is poisoned

with 150 mL of MSMA (sodium hydrogen methylarsonate) and left standing to rot. The diagnosis and poisoning protocol are described in Chinchilla (1988) and were conducted as described in earlier studies (Oehlschlager et al. 1995).

Mass Trapping

During 1992 and 1993 traps were 4-liter plastic containers modified to allow weevil entry (Oehlschlager et al. 1993a,b). Each trap contained a slow release formulation (~3 mg/day under field conditions) of 6-methylhept-2-en-4-ol, the aggregation pheromone of *R. palmarum* (Oehlschlager et al. 1992a) and 15 pieces of halved sugarcane stalk ~20 cm long and pre-immersed in Furadan (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) 3% A.I. (Oehlschlager et al. 1993a,b). Weevils were counted and removed bi-weekly at which time sugarcane was renewed. Pheromone lures were renewed at ~3 month intervals when visual inspection showed lures no longer contained liquid.

Between 1994 and 2001 traps were 4-liter containers, modified for weevil entry (Oehlschlager et al. 1993b) containing the pheromone lures and 30 pieces of halved sugarcane stalk 10 cm long immersed for 12 h in Sevin 80 (3% A.I., 1-naphthyl N-methylcarbamate). Trap servicing was as in 1992 and 1993.

Between September and December 1992 traps were placed in those sections of both the Coto and Quepos plantations that were assessed as having RRD infection. Traps were attached to palm trunks at chest height. Traps were not placed in stands younger than 3 years or in stands with no incidence of RRD. Trap density varied according to age of the stands: in 6 to 24 year old stands average trap density was 1 trap per 6.6 ha while stands less than 5 years in age an average of 1 trap/9.5 ha was placed.

Results and Discussion

RRD was first detected as a problem in the Coto oil palm plantation in 1989. In that year, 5,171 of ~800,000 palms were diagnosed with RRD and eliminated. During 1990 and 1991 the only measure undertaken to manage RRD was poisoning or felling of RRD infected palms. If felling was used felled palms were sprayed to runoff with Furadan to kill arriving weevils. During these years the number of RRD infected palms in the plantation approximately doubled each year. An assessment of RRD infection rate versus plant age in the Coto plantation clearly showed infection rates were higher in older stands (Fig. 1). In previous studies it has been reported that, in the Coto plantation, stem traps captured higher numbers of *R. palmarum* when placed in older stands with higher RRD than when in younger stands with lower RRD (Chinchilla et al. 1993). In late 1992, mass trapping of *R. palmarum* in the Coto and Quepos plantations commenced in sections diagnosed with RRD. While optimum trap densities were not determined, in previous smaller trials (Chinchilla et al. 1993, Oehlschlager et al. 1995) it had been found that a trap density as low as 1 trap/3.5 ha was sufficient to significantly reduce RRD in a ~50 ha stand after a few months (Chinchilla et al. 1993). In the present study trap densities in both the Coto and Quepos plantations were higher in older stands with higher rates of RRD infection than in younger stands with lower rates of RRD infection. Capture data from the Coto plantation were analyzed in detail while capture data from the Quepos plantation were not. In spite of the higher trap densities in older stands of the Coto plantation, those traps placed in older stands captured higher numbers of weevils than traps placed in young stands. Since it has been reported that lowering trap density increases capture rates (Chinchilla et al. 1993) it is reasonable to expect that if the trap density had been the same in old and young stands the differences in capture rates would have been greater than presently observed. Throughout the first year of trapping capture rates in the Coto plantation declined from 30 weevils/trap/month to 4 weevils/trap/month, or over 80% (Fig. 2). During the period between 1994 and

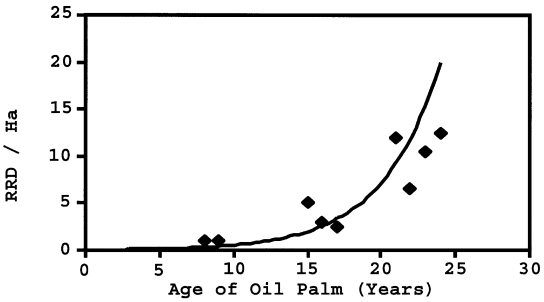

Fig. 1. Red ring disease (RRD) in oil palms of different ages in Coto, Costa Rica plantation in 1992.

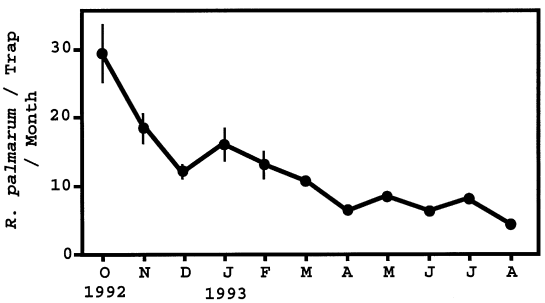

Fig. 2. Mean (SEM) capture rates of *R. palmarum* in all pheromone and sugarcane traps in Coto, Costa Rica oil palm plantation 1992-1993.

2000 monthly capture rates were no higher than 2 weevils/trap/month. Capture rates for the period 1999-2000 is illustrative (Fig. 3).

Although data is not presented a similar trend in capture rates was observed at the Quepos plantation. In 2001 the mean capture rate of traps in the Quepos plantation was 1.13 ± 0.16 weevils/trap/month

To determine if trapping would lead to a faster rate of decrease of RRD infection in stands with high RRD incidence than in stands with low RRD incidence we arbitrarily chose ± 0.5 of a standard deviation of the mean 1992 RRD infection level in the Coto plantation to classify areas in this plantation as possessing either high or low initial RRD infection (Fig. 4). The mean 1992 RRD infection level was 3.77 palms/ha and the standard deviation was 4.16. Areas with 1992 RRD infection rates of greater than 5.85 palms/ha were classified as areas of high RRD infection while areas with infection rates less than 1.69 palms/ha were classified as areas of low infection. When classified in this fashion lots in the Coto plantation covering 1,702 ha were classified as possessing high initial RRD infection while lots covering 2,970 ha were classified as having initial low RRD infection.

Capture rates in lots defined with initially high RRD infection were significantly higher for most months of the trial than capture rates in lots defined with initially low RRD infection rate (Fig. 5). Lots classified initially with high RRD infection had an average trap density of 1/5 ha while lots classified initially with low RRD infection had an average trap density of 1/7.7 ha. No matter what the initial RRD, trap density or capture rates, after one year of trapping all areas are reduced to the same low RRD infection rates and *R. palmarum* capture rates.

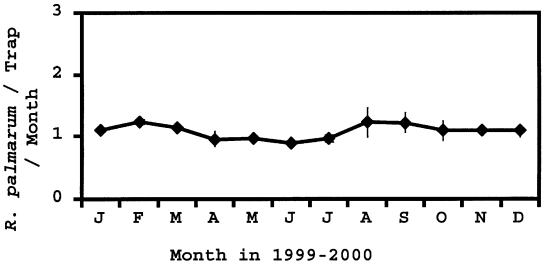

Fig. 3. Mean (SEM) capture rates of *R. palmarum* in all pheromone and sugarcane traps in Coto, Costa Rica oil palm plantation 1999-2000.

The effect of trapping on the incidence of RRD in the plantation is shown in Figure 6. Between 1989 and 1991 RRD management was limited to surveying and eliminating RRD infected palms. In late 1992, traps were introduced throughout the plantation and thereafter RRD incidence level dropped by >90%.

Plantation-wide mass trapping was conducted at a 8,719 hectare commercial oil palm plantation near Quepos, Costa Rica with similar results (Fig. 7).

Likewise, in a 3,300 ha oil palm plantation in Honduras where the most common symptom observed was "little leaf syndrome" trapping reduced RRD by 50% in 2 years, 80% in 3 years and 94% in 5 years (ASD 1999).

A mark-release-recapture experiment conducted in the Coto plantation using 535 marked

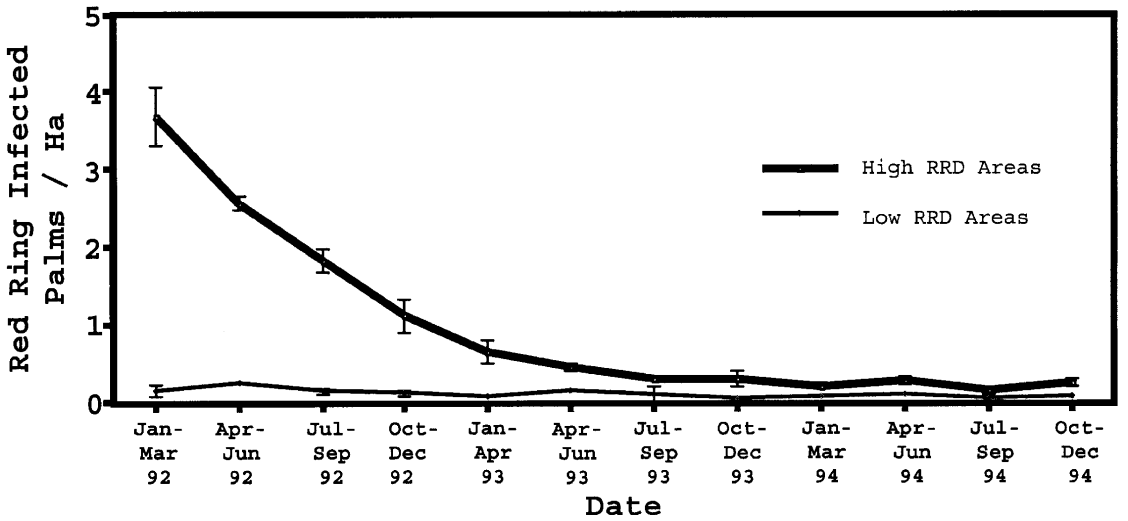

Fig. 4. Mean (SEM) RRD infection rates 1992-1994 in areas defined as having high or low RRD in Coto, Costa Rica oil palm plantation. Areas of high RRD had 1992 RRD infection rates >5.85 palms/ha. Areas of low RRD had an 1992 RRD infection rates <1.69 palms/ha.

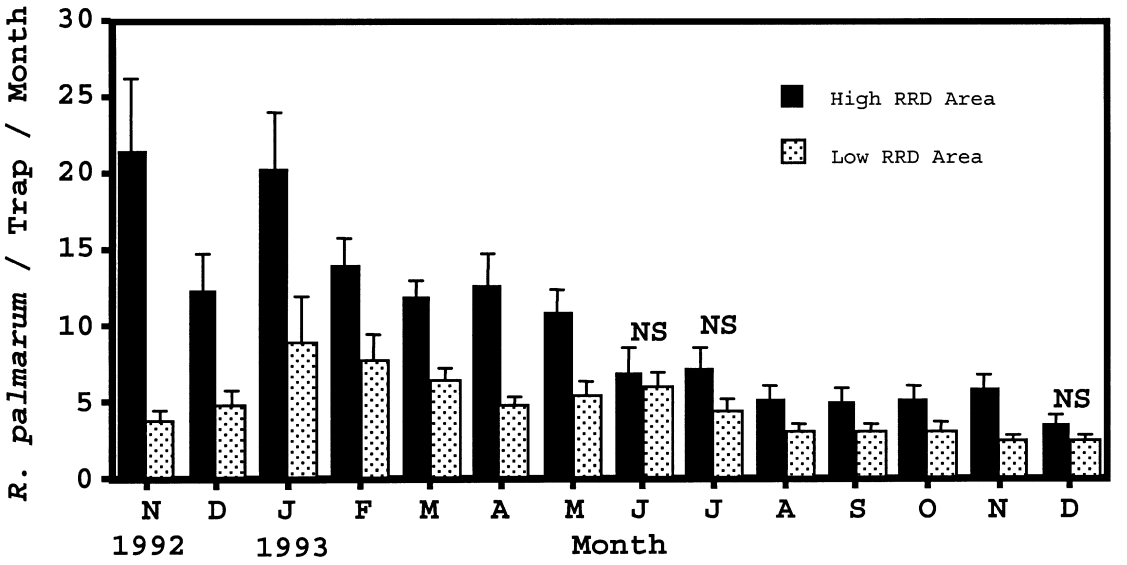

Fig. 5. Mean (SEM) capture rate of *R. palmarum* in pheromone and sugarcane traps 1992-1994 in areas defined as having high or low RRD in 1992 in Coto, Costa Rica oil palm plantation as in Figure 4.

weevils and traps located over 78.5 ha yielded a population estimate of 23-57 weevils per hectare in late 1991 (Chinchilla et al. 1993). During the period April 1991-September 1992 an estimated 123,000 weevils were captured in trap optimization and mass trapping experiments (Oehlschlager et al. 1993b, Chinchilla et al. 1993, Oehlschlager et al. 1995). Plantation-wide mass trapping captured another ~80,000 weevils to the end of 1993. The approximately 200,000 weevils removed by trapping during 1991-1993 corresponds to ~30 weevils/hectare. During the same period new RRD infection decreased from ~22,000 in 1992 to ~5,000 palms in 1993. If one attributes the observed lowering of RRD to removal of ~200,000 *R. palmarum* and uses data from a previous study that estimated ~4% of *R. palmarum* in this plantation are infected with the nematode (Chinchilla et al. 1990) then removal of ~8,000 nematode-infected weevils may have resulted in infection of 17,000 less palms between 1992 and 1993. Thus, one nematode-infected weevil may infect an average of 2 palms. This estimate is supported by the observation that once a RRD infected palm is located within an oil palm plantation it is often observed that within 27 m-36 m of the infected palm three to four RRD infected palms will be found. These latter palms often

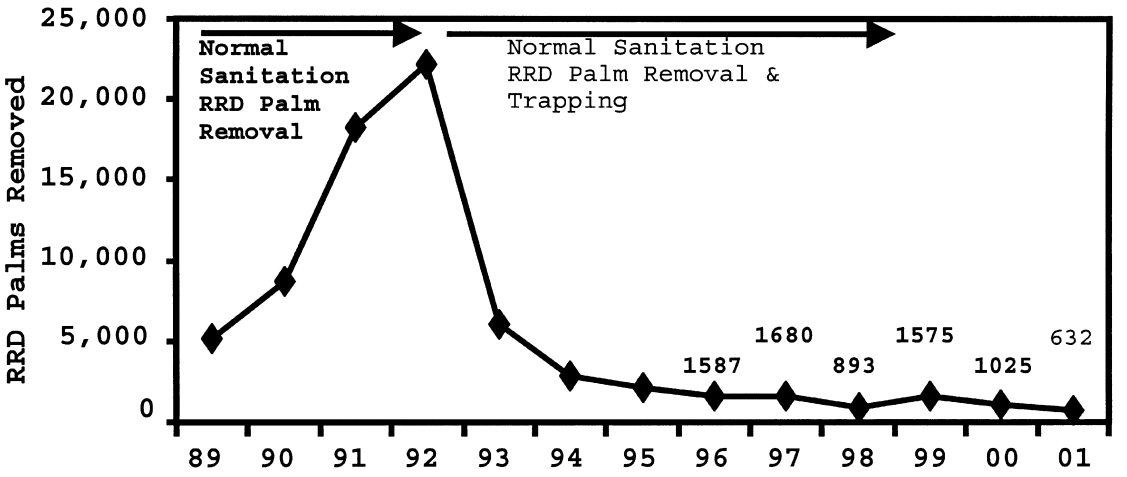

Fig. 6. RRD observed in oil palm plantation in Coto, Costa Rica between 1989 and 1994. Inspection and elimination of infected palms all years. Pheromone and sugarcane trapping was begun late 1992.

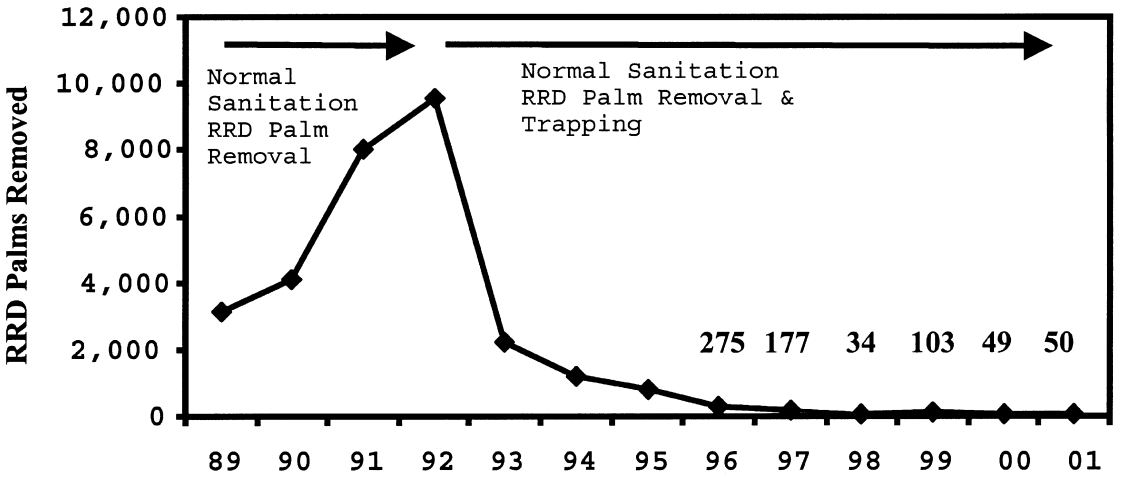

Fig. 7. RRD observed in oil palm plantation in Quepos, Costa Rica between 1989 and 1994. Inspection and elimination of infected palms all years. Pheromone and sugarcane trapping was begun late 1992.

have less severe symptoms than the initially detected RRD palm (Chinchilla, pers. obs.).

Recently, it has been reported that trapping *R. palmarum* in coconut palm significantly reduced RRD infection. The remarkable feature of this study was that throughout the entire 2.3-year trapping period capture rates for *R. palmarum* remained high and unchanged from initial values. By contrast, RRD was reduced to less than 5% of the initial value within the first year of trapping (Moura et al. 2000). A logical interpretation of this result is that although *R. palmarum* continued to be generated in or drawn to the trapping area arriving weevils preferred traps over coconut palm.

Mass trapping of related species *R. ferrugineus* is widely practiced in the Arabian Peninsula where it is a major problem in date palm. Management of *R. ferrugineus* relies on frequent inspection of palms to detect infestation, treatment of infested palms by injection of insecticide or removal, periodic spraying and trapping (Abraham et al. 1998). A large study (>340,000 palms) in the United Arab Emirates demonstrated that year-to-year these techniques decreased infestation rates by 64% (El Ezaby et al. 1998). When trapping was eliminated from the regime year-to-year infestation reduction was only 36% (El Ezaby et al. 1998).

Trapping *R. ferrugineus* in date palm groves in India led to a 84% decline in capture rates over two years (Muralidharan et al. 1999). Presumably this corresponds to a decrease in population as was assumed for *R. palmarum* in the current study.

Characteristics of palm weevils that allow mass trapping to be an efficient management technique are their relatively small numbers and long adult life (Wattanapongsiri 1966). Thus, capture of low numbers can significantly impact future populations and a significant proportion of an adult population can be captured over the long period they are susceptible to pheromone and food traps.

Another characteristic that allows mass trapping to be an efficient management technique is the fact that palm weevils are strong fliers. This allows traps to be widely spaced and has made trapping more efficient than spraying for weevil management.

The current strategy for management of RRD in oil palm in tropical America is based on an integrated approach. Within oil palm plantations regular inspections are made to detect and eliminate *R. palmarum* and RRD infected palms as well as those with damage that would render them susceptible to weevil attack. These conditions are commonly wind and lightning strike damage as well as spear rot. Because *R. palmarum* is a strong flyer and prefers coconut palm, wild in most regions of tropical America, regular surveys of areas surrounding oil palm plantations are made to detect and remove *R. palmarum* and RRD infected coconut palms. When these measures are complimented with pheromone and food trapping to reduce populations of *R. palmarum* within the oil palm plantations effective control of RRD is achieved.

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