CURRENT STATUS OF TRAPPING PALM WEEVILS AND BEETLES

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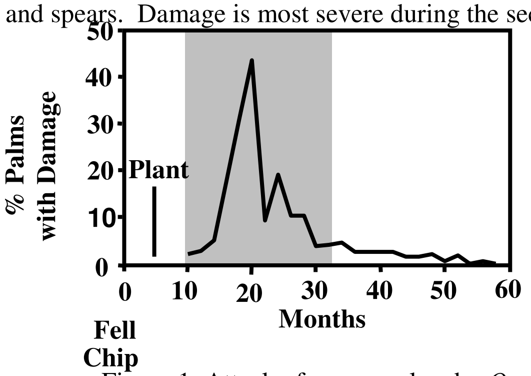
ABSTRACT: *Oryctes rhinoceros* is an economically important problem of young oil palm in South East Asia. Trapping adults using 1 trap / 2 ha lowers damge by over 90% within a few weeks and is competitive with insecticide application. *Rhynchophorus palmarum* is a problem in palmito, coconut and oil palm in Central & South America due to direct larval damage & vectoring of red ring nematode. Pheromone trapping in palmito palm lowers damage by 80% over a year and increases yields by 58%. In coconut trapping of R. palmarum lowers damage by > 80% over 1 year. In oil palm trapping R. palmarum at 1 trap / 5 ha lowers R. palmarum populations and associated damage by > 80% in one year. In the Middle East *R. ferrugineus* infestation of date palm is managed by periodic survey, treatment or removal of infested palms and trapping. There is strong evidence that trapping, in combination with spraying decreases infestation by 64% while smaller scale experiments indicate that trapping alone reduces infestation by 71%. Trapping is most efficient for all palm weevils if aggregation pheromone is combined with food and ethyl acetate. Trapping is made difficult by the requirement for replacement of water & food bait in the traps. This paper reports non-repellant additives that extend the effective life of trap food bait from 2 weeks to 7 weeks. The new additives do not evaporate so that in hot whether traps remain attractive up to 7 weeks without addition of water. This paper also describes tests of repellants that reduce captures of *Rhynchophorus palmarum* in pheromone traps by over 50%. These repellants make possible push-pull strategies to improve management of palm weevils.

Additional Index Words: *Oryctes rhinoceros*, *Rhynchophorus ferrugineus, Rhynchophorus palmarum*, pheromone, kairomone.

Trapping of *Oryctes rhinoceros* in Oil Palm in Malaysia

Commercial oil palm occupies over 4.5 million hectares in Southeast Asia. At ~25 year intervals plantations must be replanted because the height of trees makes harvesting difficult. Replanting generates large volumes of dead palms that, prior to 1990, in Malaysia were routinely burned. In the early 1990's increasing population in the Malaysian peninsula forced a ban on burning and required alternative disposal techniques such as chipping. Since rotting palm trunk is an excellent environment in which *Oryctes rhinoceros* (coconut rhinoceros beetle) breed *Oryctes* populations increased steadily since burning was banned. Adults emerge in areas with an abundance of their preferred host, young palms, to feed on fronds and spears. Damage is most severe during the second and third year after planting (Figure 1)



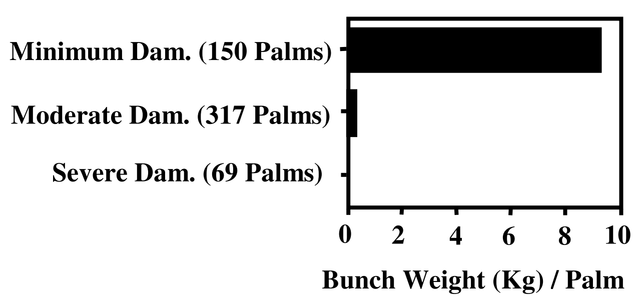
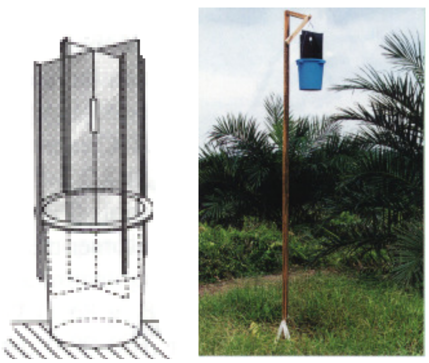


Figure 1. Attack of young palms by *O. rhinoceros* Figure 2. Bunch Wt. (kg) in 2 year old palm.

Severely damaged palms yield almost no bunches during the second and third year while lightly or undamaged palms yield 9-10 kg bunches (Figure 2). To combat *Oryctes rhinoceros* in commercial oil palm is insecticide (usually cypermethrin) application to each palm (144 / Ha) every two weeks during the susceptible period (Gait Fee Chung, Personal Communication). Although a baculovirus is known for

Oryctes rhinoceros its operational use has been restricted because of the difficulty of maintaining viable cultures and of dispersion.

In the early 1990's the author's research group in Canada identified a male-produced an aggregation pheromone for *Oryctes rhinoceros* that was highly attractive to male and female beetles (Hallett et al. 1995). Trap and lure optimization led to the selection of a vane trap mounted above the canopy for trapping this insect (Gait Fee Chung, Unpublished). If the vanes protruded into the trap to within 5 cm of the bottom of the trap then beetles that hit the vanes and fell into the trap could not fly out and dry traps could be used to retain captured beetles (Figure 3, Gait Fee Chung, Unpublished)). Trials by Gait Fee Chung of Sime Darby of Malaysia determined that most *Oryctes* populations could be lowered to below economic thresholds by 1 trap / 2 Ha (Figure 4). Trapping at 1 trap / 2 ha coupled with biweekly servicing makes pheromone trapping of *Oryctes rhinoceros* less expensive than application of insecticide to 288 plants once every 2 weeks Gait Fee Chung, Personal Communication).



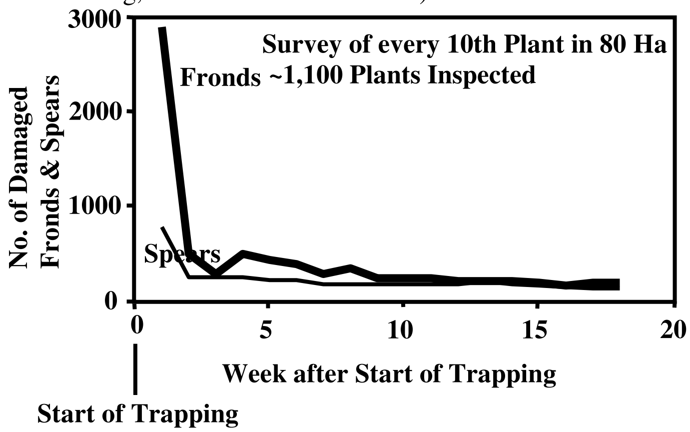


Figure 3. Vane trap for *Oryctes rhinoceros* Figure 4. Reduction in *Oryctes* damage 1 Trap / 2 Ha

Trapping, in combination with removal of breeding sites, occupies a prominent position in the management of *Oryctes rhinoceros* in Malaysia.

Trapping of *Rhynchophorus palmarum* and *Metamasius hemipterus* with the same lure in Palmito Palm in Costa Rica.

The heart of palmito palm (*Bactris gasipaes*, Kunth) is a delicacy in many countries of the world. Increasing demand for dietary fiber continues to fuel demand for palmito heart. Areas dedicated to commercial production in Central and South America in 1996 were about 12,000 Ha of which around 4,000 Ha were in the Atlantic Region of Costa Rica (Anonymous, Min. Agric. & Gran., 1998 Costa Rica).

Palmito palm propagates from offshoots that grow to a harvestable height of one meter in about 3 months. Harvesting discards all parts of the plant except the interior of the stem. In some plantations, competing offshoots are pruned to promote more rapid growth of the remaining offshoots to harvestable size. Harvesting and pruning provide excellent entry points for *Metamasius hemipterus* L. (Vaurie 1966) and *Rhynchophorus palmarum* L. (Couturier et al., 1996; Vásquez et al., 2000). Females of these weevils are attracted to and deposit eggs in cut stem bases. Larvae tunnel the lower stem and rhizome destroying maturing stems.

In the case of *M. hemipterus*, West Indian sugarcane weevil, larvae feed for 30-60 days on the interior stalk before pupating in a fibrous cocoon. Adults live 2-3 months and are good fliers (Vaurie 1966). For *R. palmarum*, the American palm weevil, the life cycle is 70-120 days of which the damaging larval stage is 40-60 days (Giblin-Davis et al. 1989). Male-produced aggregation pheromones for both weevil species are known (Perez et al. 1997; Oehlschlager et al. 1992).

Initial experiments conducted in Costa Rica and Honduras in 1995 led to development of a blend of the two pheromones that allowed trapping of both species in the same trap (Chinchilla et al. 1996). These experiments allowed combination lure trapping of both species in palmito palm (Figure 5 & 6).

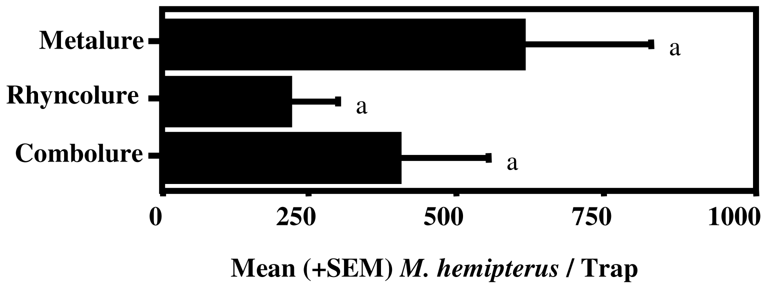


Figure 5. Mean (+SEM) *M. hemipterus* captured in traps baited with sugarcane and 2-methylhept-5-en-4-ol (Rhyncolure), 4-methyl-5-nonanol : 2-methyl-4-heptanol (8:1, Metalure) or a 1:1 mixture of Rhyncolure and Metalure (Combolure). ANOVA (n = 10) gave F = 4.45, p, 0.566 (NS). Means topped by the same letter are equivalent by Bonferonni t-test (P > 0.95).

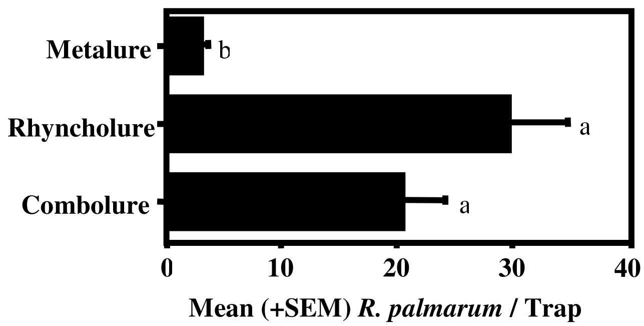


Figure 6. Mean (+SEM) *R. palmarum* captured in bucket traps baited with sugarcane and 2-methylhept-5-en-4-ol (Rhyncolure), 4-methyl-5-nonanol:2-methyl-4-heptanol (8:1, Metalure) or a 1:1 mixture of Rhyncolure and Metalure (Combolure). ANOVA (n = 12) gave F = 8.50, p < 0.05. Means followed by a different letter are statistically different by Bonferonni t-test (P > 0.95).

Commercial palmito is grown under two regimes, one involves harvesting only (non-pruning) while the other involves pruning mats before during growth to encourage the faster growth of only the strongest stems (pruning). Mass trapping in commercial palmito employing both these growing options was carried out using the combination lure for *M. hemipterus* and *R. palmarum.* Traps were set in two 1 hectare plots (1 pruning and 1 non-pruning) using 4 traps / ha. Each trapping plot was separated from other test plots by at least 100 meters and each test plot was at least 100 meters from any border.

Capture rates of *M. hemipterus* in both pruning and non-pruning plots were similar (Figure 7). *M. hemipterus* capture rates declined from September through December and increased from January through March 1997. The highest capture rates occurred in March-April whereas a second population build-up occurred in September 1997. The first population peak corresponded to the end of the dry season in the Atlantic region of Costa Rica and might be attributed to a higher survival rate of *M. hemipterus* pupae in the dry season due to decreased fungal and bacterial action on pupal cocoons. Mass trapping *M. hemipterus* in banana and plantain in this region previously revealed an increase in capture rates during March-April (Alpizar et al. 1998). The peak in capture rates of *M. hemipterus* observed in September 1997 is attributed to the progeny of weevils that emerged in March-April.

Capture rates for *R. palmarum* were much lower than those of *M. hemipterus* at the onset of trapping although after one year of trapping capture rates of both species were similar. Initial capture rates of *R. palmarum* were ~3X higher in the pruned plot than in the non-pruning plot and remained higher for the entire trial. While the capture rates for *M. hemipterus* declined over the trial period capture rates of *R. palmarum* remained rather constant.

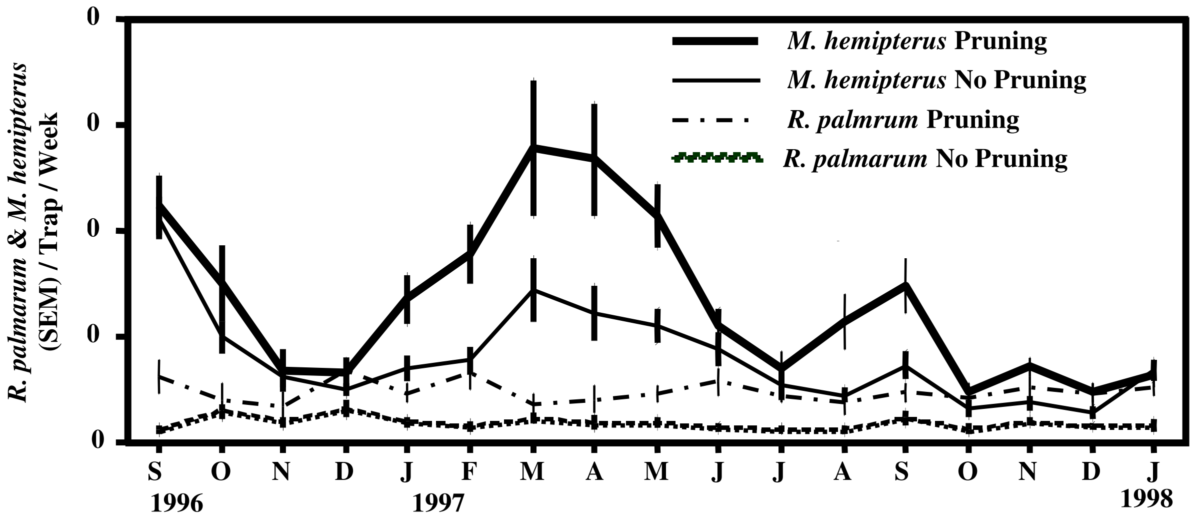


Figure 7. Mean weekly capture of *M. hemipterus* and *R. palmarum* in palmito palm. Four traps were placed in one hectare of palmito palm in which pruning was practiced and four traps were placed in one hectare in which pruning was not practiced. Traps were 4 liter plastic containers with windows cut in the sides and baited with combination pheromone lures and insecticide treated sugarcane.

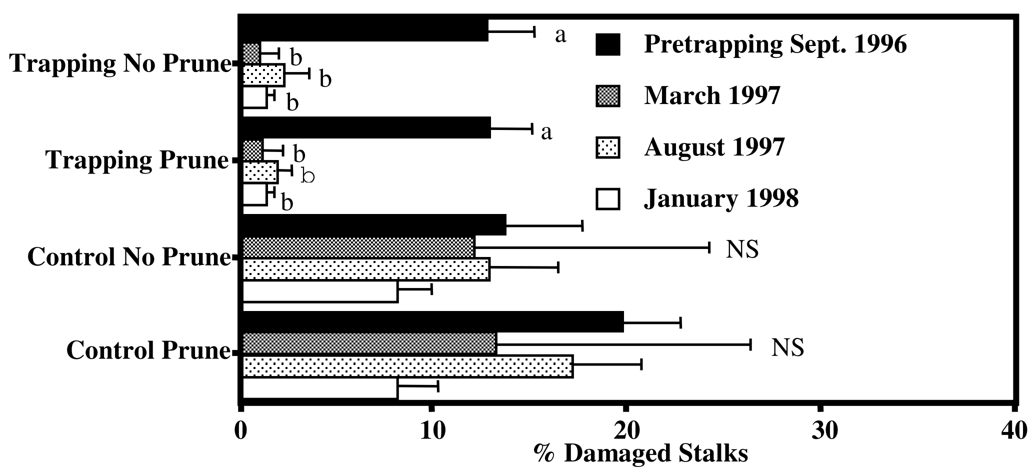


Figure 8. Percent of damaged stalks in palmito palm stalk prior to and after commencement of trapping for *M. hemipterus* and *R. palmarum*. Statistical analysis compares each treatment at different dates and does not compare between treatments. Means followed by a different letter are statistically different by Bonferonni t-test (P > 0.95). Damage was determined by examination of all stalks in 60 bunches (mats) of palmito palm within each 1 Ha experimental plot. This was done by cutting all stalks in each bunch at ground level and examination of each stalk for damage. Variables assessed were, total stalks in each bunch, number of stalks in each bunch with larval damage due to *M. hemipterus* and *R. palmarum* and number of *M. hemipterus* or *R. palmarum* pupae in each stalk.

Weevil damage decreased and yields increased in trapping plots vs control plots (Figure 8 and 9). Because palmito palm grows to maturity in three months and the time between assessments was five to seven months therefore, each assessment after the commencement of trapping was conducted on palmito stalks grown after the commencement of trapping. The first assessment at month seven revealed weevil damage in trapping plots was reduced by >90% compared to pre-trap levels. This occurred even though considerable numbers of *M. hemipterus* continued to be captured in this time period. We conclude, based upon examination of capture rates and damage data that *M. hemipterus* and probably *R. palmarum* entering trapping plots after September 1996 chose the traps over palmito stems. A similar phenomenon was noted during trapping *Cosmopolites sordidus* and *M. hemipterus* in commercial banana (Alpizar et al., 1998).

Yield was assessed on the same dates that damage was assessed (Figure 9). Yields increased dramatically in both trapping and control plots during the trial. After commencement of trapping those plots receiving traps consistently yielded higher numbers of harvestable stems per bunch than control plots without traps.

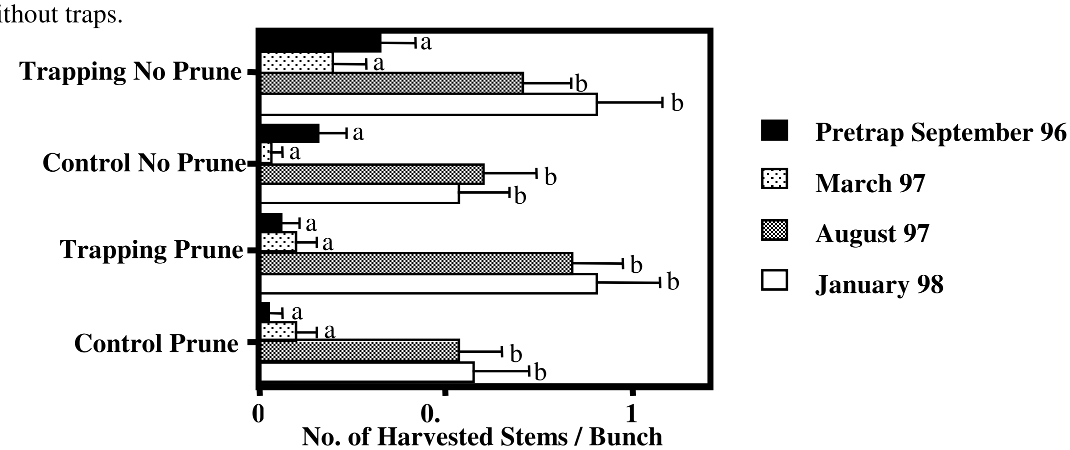


Figure 9. Harvested stems per bunch prior to and after commencement of trapping for *M. hemipterus* and *R. palmarum* (number of stalks harvested from each bunch the week of each damage assessment). Statistical analysis compares each treatment at different dates and does not compare between treatments. Means followed by a different letter are statistically different by Bonferonni t-test (P > 0.95).

Percentage yield increase attributable to trapping was 58% in plots in which pruning was conducted and 70% in plots in which pruning was not conducted. This study has recently been published. (Alpizar et al. 2002).

Trapping *R. palmarum* in coconut

Trapping of *R. palmarum* in coconut palm is also effective. During 2000-2001 the ChemTica group in Costa Rica conducted trapping of this weevil in 50 ha of coconut palm using traps similar to those used in the Coto and Quepos trials. In the coconut palm plantation in which trapping was conducted direct damage by *R. palmarum* larvae was responsible for palm death. A trap density of 1 trap / ha was used in this trial (Oehlschlager and Gonzalez, 2004 Florida Entomologist, Accepted for Publication). Capture rates of *R. palmarum* were initially ~11 / trap / week and did not show a significant decline during the 11 month study (Figure 10). This is in contrast to a > 80% decrease *R. palmarum* capture rates observed in oil palm over 1 year (Oehlschlager et al. 2002).

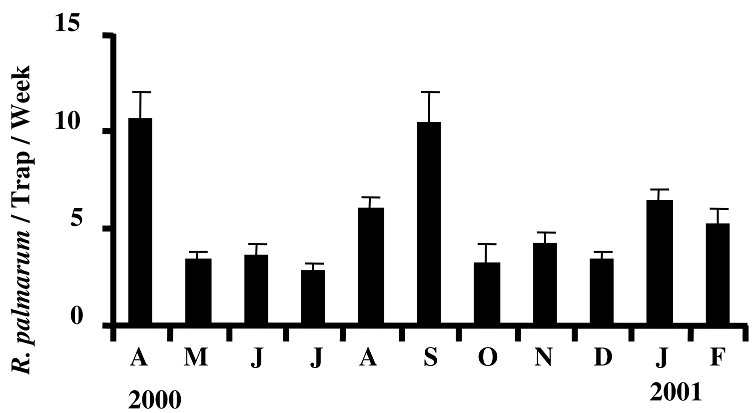


Figure 10. Average of weekly captures (+SEM) of *R. palmarum* in traps baited with pheromone, sugarcane and ethyl acetate April 2000 to March 2001 in 50 ha coconut.

In the current study infested coconut palms were allowed to act as *R. palmarum* breeding sites. Thus, in the coconut palm trial *R. palmarum* capture rates remained high throughout the study. Similarly, rather constant *R. palmarum* capture rates were observed over 26 months of trapping in coconut in Brazil. In the latter case 54 one hundred liter pheromone-sugarcane baited traps were placed around the perimeter of 54 ha of coconut palm infested with *R. palmarum* carrying red ring nematode. Over 97,000 weevils were captured over a 26 month period with no noticeable decrease in capture rate over the entire period (Moura et al. 2000). Despite this the number of RRD infested palms decreased from 206 at the initiation of trapping to 3 within a few months after trapping was started. The most reasonable explanation for a rather constant capture rate accompanied by a declining infestation rate is that weevils immigrating into the plantation as well as those escaping from infested palms preferred traps rather than palms. A similar behavior has been noted in mass trapping of *Cosmopolites sordidus*, the banana corm weevil. In 1 ha plots, using 4 traps / ha capture rates remain high for >8 months while infestations due to this weevil decrease significantly after <5 months (Alpizar et al. 2000).

Immediately before commencement of mass trapping in coconut palm a survey of palms was conducted in the mass trapping area. We identified and tagged coconut palms with yellowing fronds and verified which of these were infested with *R. palmarum* by a subsequent survey in June 2000. Of the coconut palms initially identified possessing yellowing fronds 49 were eventually confirmed to have died as a result of *R. palmarum* infestation. During the remaining period of the study 4 additional palms were found to be weevil infested (Figure 11). This is a decrease of > 90% in the reduction of infestation and compares favorably with the decrease in RRD achieved in oil palm by trapping *R. palmarum* at trap densities of 3-7 traps / ha (Oehlschlager et al. 2002).

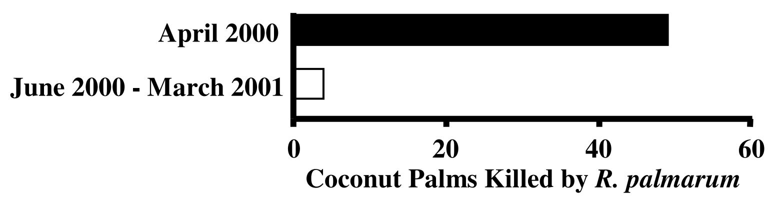


Figure 11. Coconut palms killed by *R. palmarum* in 50 ha of coconut June 2000 to April 2001 in which trapping was conducted.

Trapping *R. palmarum* in oil palm

Weevils of the genus *Rhynchophorus* are also a major problem in oil palm. In Central and South America *R. palmarum* is a major economic problem. Larvae often kill trees and adults carry red ring nematode that is lethal to palms. Prior to 1993 management of this pest was by systematic inspection of palms coupled with cutting and spraying of cut palms with insecticide. This practice did not control red ring infestation carried by the weevil nor did it control direct weevil damage caused by larvae. In the early 1990's the Oehlschlager group (Costa Rica) developed a trap for *R. palmarum* that employed the male-produced aggregation pheromone and insecticide-laden sugarcane or palm. This group, in collaboration with growers, demonstrated that trapping effectively managed both red ring nematode infection and direct larval damage.

An oil palm plantation of ~ 6,000 ha established near Coto, Costa Rica in the mid 1970's was mature by the late 1980's. Red ring nematode infestation (RRD) was first detected in the Coto oil palm plantation in 1989. In that year 5,171 of ~800,000 palms were diagnosed with RRD. These palms were cut and sprayed with Furadan. During 1990 and 1991 the only measure undertaken to manage RRD was elimination of RRD infected palms. During these years the number of RRD infected palms in the plantation approximately doubled each year. In late 1992, mass trapping of *R. palmarum* in the Coto plantation commenced in sections diagnosed with RRD. Traps are plastic containers tied to palms at chest height and are baited with the male-produced aggregation pheromone and insecticide treated sugarcane or palm pieces (Oehlschlager et al., 1993a, Oehlschlager et al. 2002). Decomposition and desiccation of food bait decreases attraction to traps so food bait was replaced every 2-3 weeks. Pheromone and kairomone lures are replaced at 3-4 month intervals. 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 Coto plantation surveys determined that stands with palms older than 17 years were more highly infected with RRD than stands with palms younger than 10 years. Throughout the first year of trapping capture rates in the entire Coto plantation declined from 30 weevils / trap / month to 4 weevils / trap / month, or over 80% (Figure 12). During the period between 1994 and 2001 monthly capture rates were no higher than 2 weevils / trap / month (Oehlschlager et al. 2002).

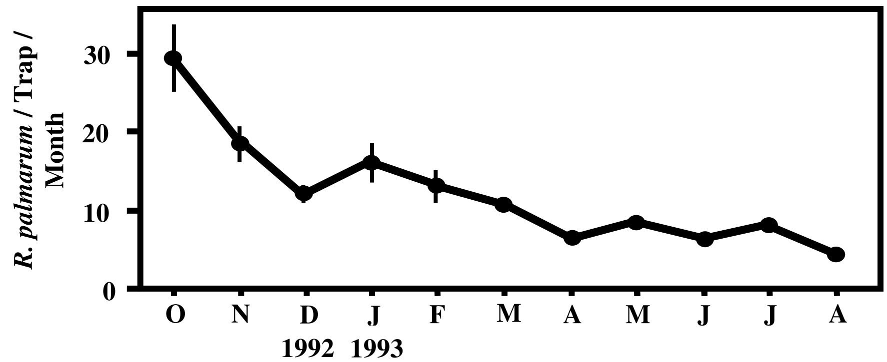


Figure 12. Mean (SEM) capture rates of *R. palmarum* in all pheromone and sugarcane traps in Coto, Costa Rica oil palm plantation 1992-1993.

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 (Figure 13). 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.

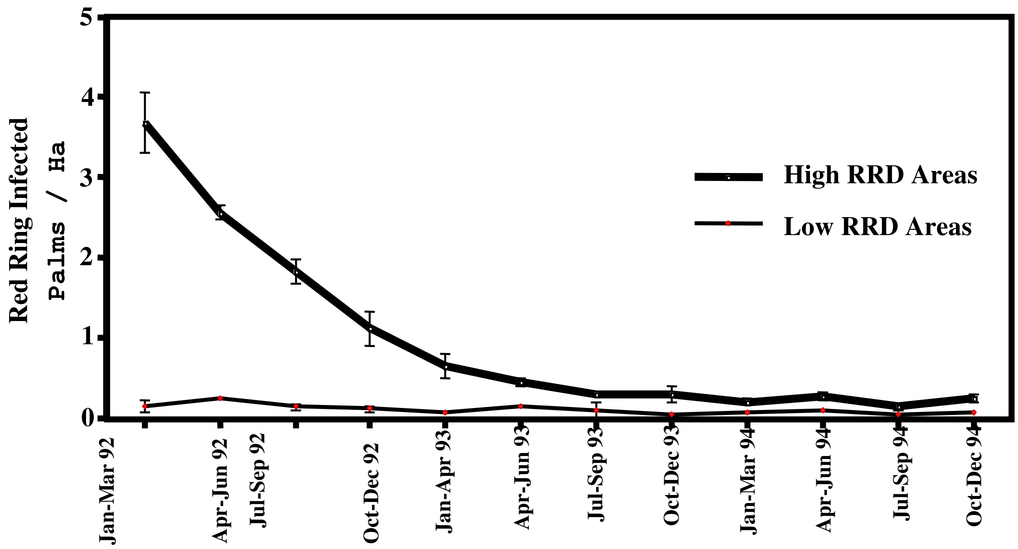


Figure 13. Mean (SEM) RRD infection rates 1992-1994 in areas defined as having high or low RRD in Coto, Costa Rica oil palm plantation. Areas of high RRD had 1992 RRD infection rates > 5.85 palms / ha. Areas of low RRD had a 1992 RRD infection rates < 1.69 palms / ha.

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 (Figure 14). 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.

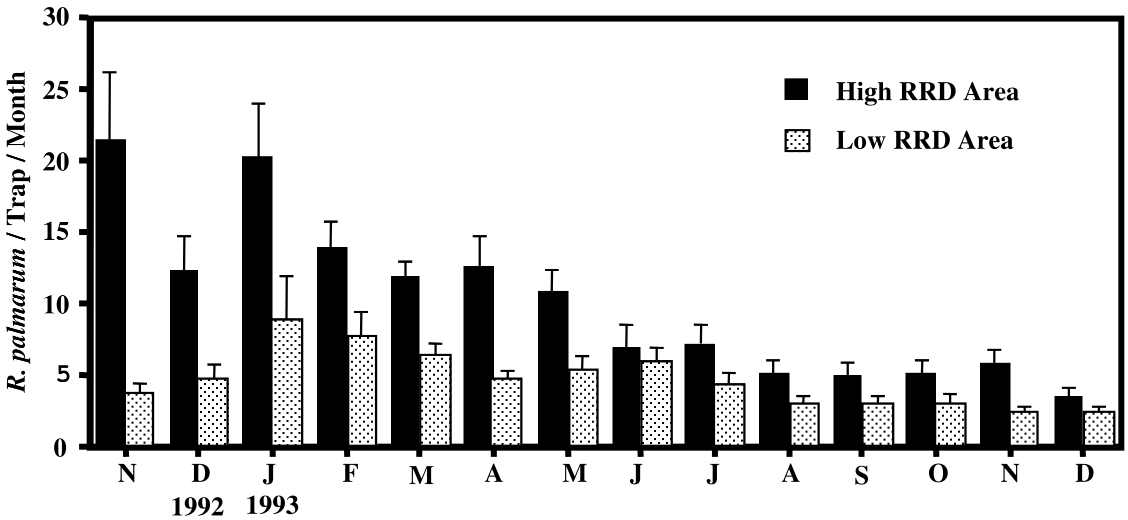


Figure 14. Mean (SEM) capture rate of *R. palmarum* in pheromone and sugarcane traps 1992-1994 in areas in areas defined as having high or low RRD in 1992 in Coto, Costa Rica oil palm plantation as in Figure 13.

The effect of trapping on the incidence of RRD in the plantation is shown in Figure 15. 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%.

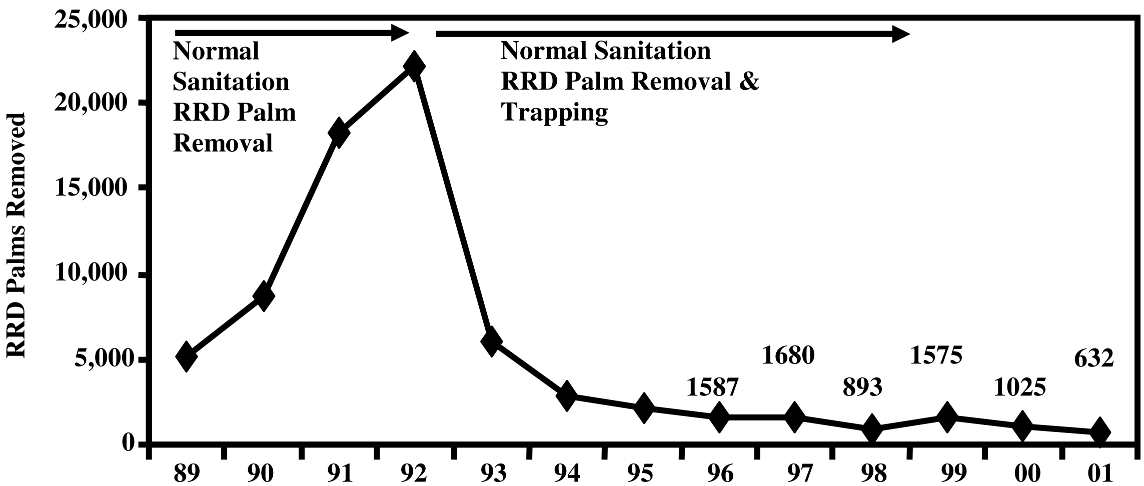


Figure 15. RRD observed in oil palm plantation in Coto, Costa Rica between 1989 and 2001. All palms were inspected bimonthly and infested palms eliminated each year of the study. Pheromone and sugarcane trapping was begun late 1992.

Plantation-wide mass trapping was conducted on 8,719 hectares of commercial oil palm near Quepos, Costa Rica with similar results (Figure 16). Capture rates were initially high but declined to less than 4 weevil / trap / month by 1994. In 2001 the mean capture rate of traps in the Quepos plantation was 1.13 ± 0.16 weevils / trap / month.

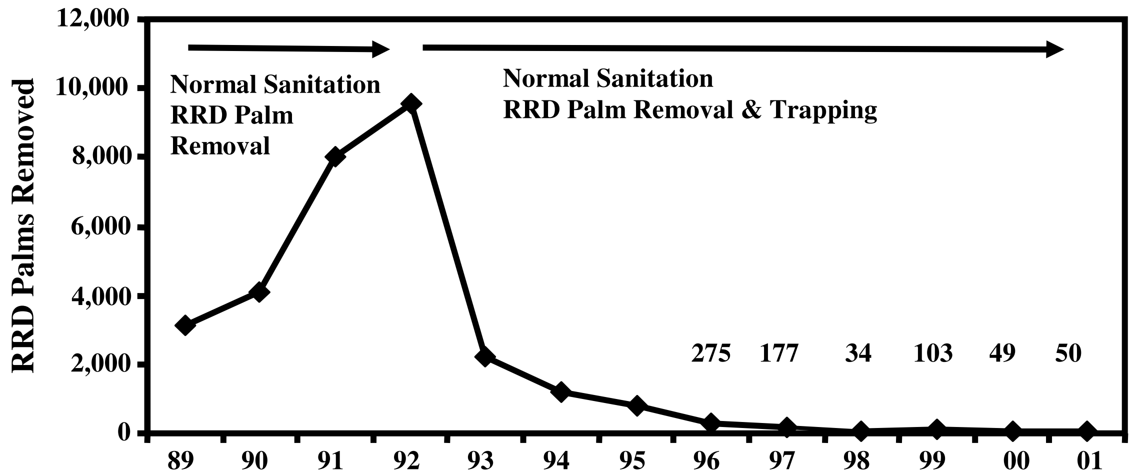


Figure 16. RRD observed in oil palm plantation in Quepos, Costa Rica between 1989 and 2001. Inspection and elimination of infected palms all years. Pheromone and sugarcane trapping was begun late 1992.

In a 3,300 ha oil palm plantation in Honduras trapping *R. palmarum* reduced RRD by 50% in 2 years, 80% in 3 years and 94% in 5 years (ASD, 1999).

Through mark-release-recapture experiments in the Coto plantation in 1991 the initial *R. palmarum* population was estimated at 23-57 weevils per hectare (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.

Trapping, in combination with removal of nematode infected palms, is the principal method by which weevil vectored red ring nematode is managed in oil palm in Central and South America.

Trapping *R. ferrugineus* in date palm

Is trapping effective?

Mass trapping of *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 major study in the UAE between 1996 and 1998 included 1,466 farms containing > 349,000 palms examined the effect of spraying alone and spraying combined with pheromone trapping. A benefit of ~ 30% less infestation appears to be derived from combined use of spray and pheromone traps compared to spray alone (Figure 17).

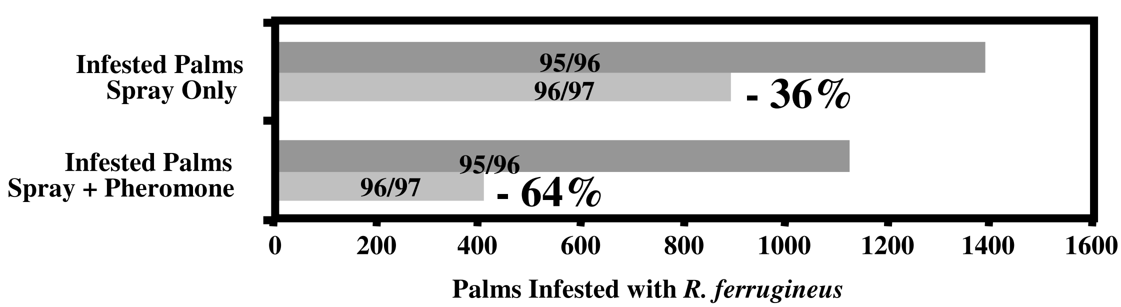


Figure 17. Survey of 1,466 farms in Al-Ain region of UAE between 1994 and 1998. In 1994 farms contained 349,342 palms and had an average infestation rate of 1.9%. In 1995/1996 all farms received chemical treatment and in 1996/1997 45% of the area was treated with chemicals and pheromone traps placed while 55% of the area was treated with chemicals only. In trapping areas in 1996/1997 11,711 weevils were captured. (Ezaby et al., 1998)

It is often argued that traps attract weevils to an area and that not all weevils enter so traps create a situation in which infestation can increase. In the case of *R. palmarum* it has been found that although weevils are attracted to areas where traps are placed that infestation goes down in areas with traps (Oehlschlager et al. 1995). The same situation seems to occur in the case of *R. ferrugineus.* Thus in a recent UAE study in which traps were placed on 6 different farms over one year with no spraying the highest captures resulted in the greatest reduction of infestation (Figure 18, Kaakeh et al. 2001). Interestingly, in this study the average reduction in infestation over all 6 farms from one year to the next was 71%. This suggests that trapping *R. ferrugineus* is as effective as trapping *R. palmarum* and that one can expect approximately a 70-80% reduction in infestation over one year if *R. ferrugineus* traps are maintained well and infested palms are treated to prevent further breeding.

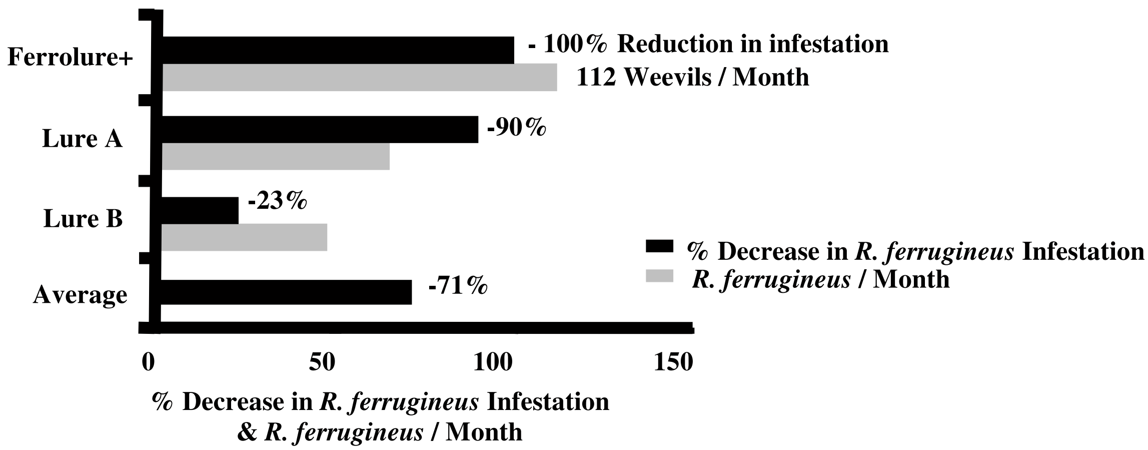


Figure 18. Trapping *R. ferrugineus* at 6 farms in UAE with 3 different lures. Infestation from first year in which spray only was used to second year in which trapping only was used (Kaakeh et al. 2001).

Trapping of *R. ferrugineus* in date palm over 2 years in India resulted in a 75% decrease in captures suggesting a significant decrease in population (Figure 19, . Muralidharan et al. 1999). No damage assessment was made in this study. The decrease in capture rate observed in this study was very similar to the reduction in capture rate observed in Costa Rica for *R. palmarum* trapping in oil palm (Chinchilla et al. 1993, Oehlschlager et al. 2002).

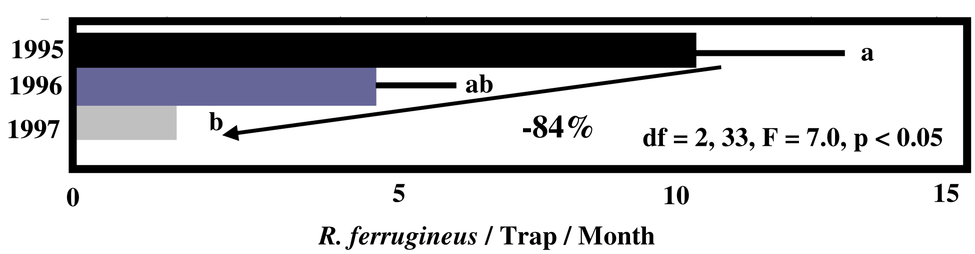


Figure 19. Average capture of *R. ferrugineus* in 5 date palm gardens in 4 villages in northern India ANOVA (n = 12) gave df = 2, 33, F = 7.0, $p < 0.05$. Means followed by different letter are significantly different, Bonferonnit t-test, $P > 0.95$.

Since female *R. ferrugineus* are the primary target of trapping it is often debated as to whether trapping removes young females with high egg laying potential or old females with low egg laying potential. Dr. Falerio of the Goa, Research Station in India conducted an extensive study of female *R. ferrugineus* captured in pheromone traps (Falerio, 2000). In his experiment he removed female *R. ferrugineus* daily from traps and placed them alone with only other females or placed them in contact with males also captured in the traps. The captured female *R. ferrugineus* were then allowed to feed and oviposit on sugarcane for the rest of their life. The results indicated that trapped females held separately from males after capture laind an average of 208 eggs during the rest of their life. Since Wattanapongsiri, 1966 reports that wild females lay an average of 127-376 eggs during their lifetime these results indicate that young, gravid females are captured by pheromone traps. Thus, trapping is predicted to have a major effect on egg laying potential of the population.

Palm weevils are present in most plantations in relatively small numbers and have a relatively long life (Wattanapongsiri 1966). These characteristics allow mass trapping to be an efficient management technique since 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.

Since palm weevils are strong flyers traps can be widely spaced and trapping is expected to be more efficient than spraying for weevil management.

Kairomones in Pheromone Traps:

In the early 1990's it was shown that addition of ethyl acetate to pheromone / sugarcane baited traps increased capture of *R. palmarum* (Jaffe et al. 1993). In 1992 the ChemTica group also determined that ethyl acetate increased by 50-100% the attraction of *R. palmarum* to pheromone traps and spent considerable effort trying to find additional attractants that might further increase attractiveness (Chinchilla, Oehlschlager and Gonzalez, unpublished). Since palm weevils are attracted to wounds of palms that are several days old and fermentation of trap bait food increases attraction it is logical that ethanol might increase capture rates to pheromone / sugarcane baited traps. In 2001 ChemTica examined a report that combination of ethyl acetate and ethanol improves attraction of *R. palmarum* to pheromone / sugarcane traps more than ethyl acetate (Rochat et al. 2000). In several experiments (Figure 10) ethanol did not increase attraction to pheromone / sugarcane baited traps more than ethyl acetate nor did ethanol synergize ethyl acetate. These experiments further confirmed a 50% increase in capture of *R. palmarum* in pheromone / food baited traps that additionally emit ethyl acetate.

To date the best attractant for *R. palmarum* is the combination of pheromone, food and ethyl acetate (Figure 20).

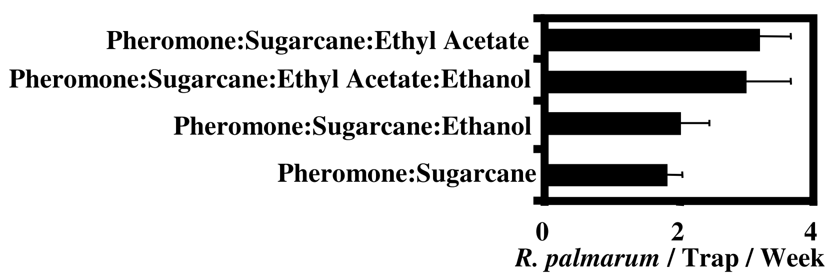


Figure 20. Test conducted May 17-30, 2000 using traps made from 20 liter white plastic buckets with four 5 X 8 cm slots near the top for insect entry. One liter 1% lannate was added to each trap at start of test and 500 mL after the first week. Treatments were fresh sugarcane and ethyl acetate:ethanol lure; fresh sugarcane and ethyl acetate lure; fresh sugarcane and ethanol lure or fresh sugarcane (control). Weevils were counted and removed after first week at which time trap positions rerandomized. ANOVA (n = 20) revealed no significant differences between treatments.

In July 1997 ethyl acetate was proven increase attraction of *R. ferrugineus* to pheromone traps by 2.6X in the UAE (Anwar and Oehlschlager, CTI Technical Bulletin, 1997 and Oehlschlager, 1998). In August of 1997 addition of ethyl acetate to pheromone traps increased captures by 5X in an Egyptian experiment (Oehlschlager, 1998, Figure 21). In September 1997 ethyl acetate along with several extracts of different palm species and palm tissue were given by CTI to the GCC-AOAD project in the UAE for evaluation. The results of these evaluations suggested that ethyl acetate alone was the preferred kairomone and that no additional attraction was derived from inclusion of palm tissue extract. French workers have published work (Rochet et al., 2000) that suggested kairomones and pheromone alone were as attractive as food (sugarcane) and pheromone for *R. palmarum*. In Costa Rica the ChemTica group has repeated the

French work with much attention to detail and report that the French work is not reproducible and that the blend (best blend H) of kairomones reported is no more attractive to *R. palmarum* than ethyl acetate alone (Oehlschlager and Gonzalez, 2004, Florida Entomologist, Accepted for publication). At the current time the most attractive kairomone for *Rhynchophorus* species is ethyl acetate and its attractiveness has not increased by addition of either natural extracts of palm nor additional synthetic kairomone candidates for either of *R. palmarum* nor *R. ferrugineus*.

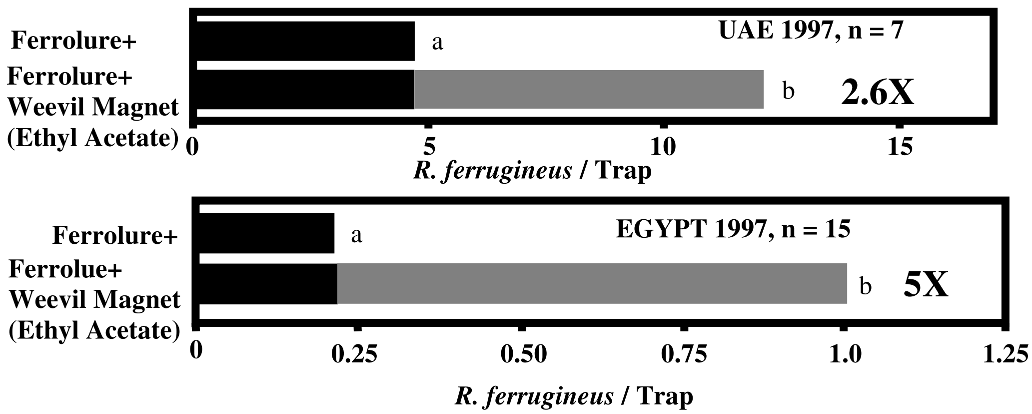


Figure 21. Increase in capture of *R. ferrugineus* to pheromone / food traps containing lures emitting the kairomone, ethyl acetate. One experiment conducted in UAE (Aswar and Oehlschlager, ChemTica Technical Bulletin) and a second experiment conducted by G. Moawad and Y. El Sebay, PPRI, in Egypt, 1997 (Oehlschlager, 1998). ANOVA on both experiments revealed significant differences between treatments, Bonferonni t-test, P > 0.95.

Traps loose attractiveness when they become dry. What to do about the problem?

Replacement of food bait due to decomposition and desiccation is a major part of the work of trapping *R. palmarum* and *R. ferrugineus*. In Costa Rica in the dry season food bait becomes dry and unattractive after 2 weeks while in the wet season decomposition renders food bait unattractive due to decomposition after 3-4 weeks. Claims that artifical food bait can be constructed from chemical odors (Rochat et al., 2000) are not borne out by field experiments (Oehlschlager and Gonzalez, 2004 Florida Entomologist, accepted for publication). Water is an essential ingredient of traps since a primary method of retaining weevils in traps is for them to feed on insecticide-laden wet food (*R. palmarum*) or drown (*R. ferrugineus*). In the GCC region food bait in traps often dries out within a few days and traps loose their ability to retain attracted *R. ferrugineus*.

ChemTica conducted several experiments to extend the useful life of trap food bait (*R. palmarum* traps) by addition of inexpensive materials that retard the evaporation of water, are not repellant to the weevils and are not toxic to humans. Figures 22 and 23 show typical results with one such "Trap Extender". The Extender does not evaporate so traps containing it do not get dry. The Extender is not toxic to humans and is relatively inexpensive. The Extender prolongs the useful life of sugarcane baited traps until at least 7 weeks. In Figure 22 after 4 weeks traps with the Trap Extender are still more attractive than 2 week old traps with water. Traps with Trap Extender were still attractive and contained liquid after 10 weeks.

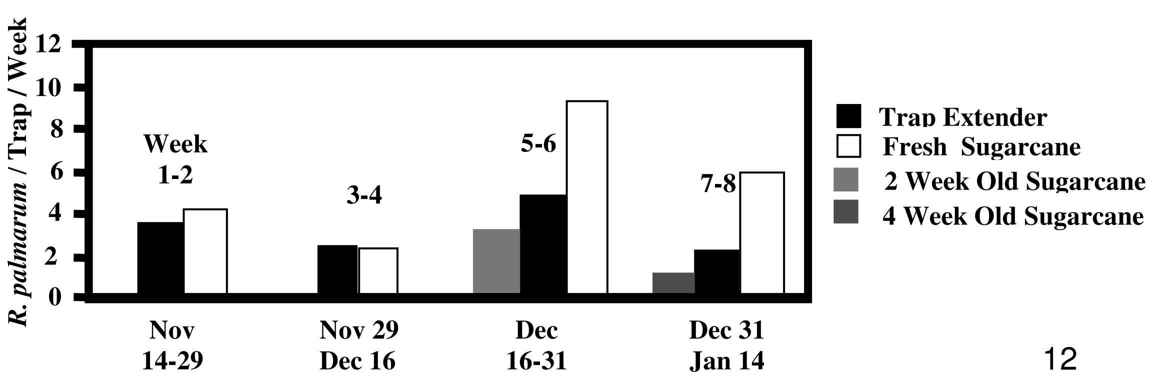


Figure 22. Experiment set up November 14, 2000. All traps contained commercial pheromone lures (ChemTica). Treatments were traps baited additionally with fresh sugarcane in 750 mL of water containing 0.13% Lannate (New Sugarcane); 2 week old sugarcane in 750 mL of water containing 0.13% Lannate (2 Week Old Sugarcane); 6 week old sugarcane in 750 mL of water containing 0.13% Lannate (6 Week Old Sugarcane) and fresh sugarcane, ethyl acetate lures in 750 mL of water with 20% Trap Extender and 0.13% Lannate placed November 14, 2000 (Traps with Trap Extender). Ten traps of each treatment were placed. Means of capture are presented. ANOVA on data collected November 29 (n = 9-11), December 16 (n = 9-10) and January 14 (n = 9-10) indicated no significant differences between treatments. ANOVA (n = 8-10) on December 31 and Feb 1 (n = 9-10) indicated traps containing new sugarcane were significantly more attractive than other treatments.

In Figure 23 traps prepared with Trap Extender January 14, 2001 remained attractive 7 weeks until March 8, 2001. At this time point traps containing Trap Extender were still almost as attractive as freshly prepared traps.

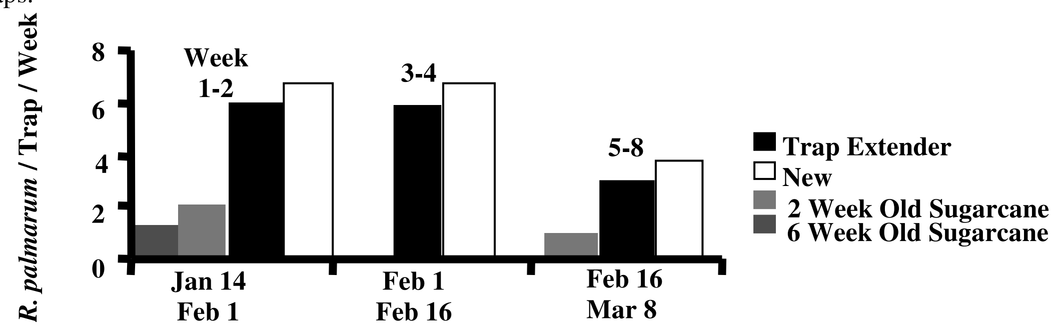


Figure 23. Experiment set up January 14, 2001 all traps contained commercial pheromone lures (ChemTica). Treatments were traps baited additionally with fresh sugarcane in 500 mL of water containing 0.13% Lannate (New Sugarcane), 2 week old sugarcane in 500 mL of water containing 0.13% Lannate (2 Week Old Sugarcane), 6 week old sugarcane in 500 mL of water containing 0.13% Lannate (6 Week Old Sugarcane) and fresh sugarcane, ethyl acetate lures in 750 ml of water with 50% CTI Trap Extender and 0.13% Lannate placed January 14, 2001 (Traps with CTI Trap Extender). Ten traps of each treatment were placed. Means of capture are presented.

Can repellants be found to lower palm weevil attack on palms?

A recent study in the UAE and Oman defined the location of attack of *R. ferrugineus* on date palm (Khalifa et al. 2001). As shown in Figure 24 attack is highly concentrated very near ground level. This is expected since attack often accompanies offshoot removal or damage at ground level. The highly localized nature of *R. ferrugineus* attack raises the possibility of using repellants to deter attack on that portion of the palm that is most susceptible to attack. Most repellants deter insects only at close range and then can be expected to function only over short ranges.

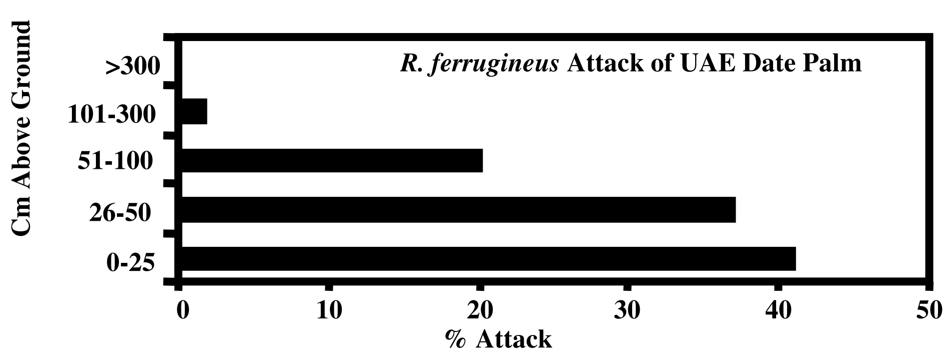


Figure 24. Survey of 1,325,574 Palms in UAE 1998-2000 of which 2,296 were infested. (Khalifa et al, 2001)

Because of the highly localized nature of *R. ferrugineus* attack ChemTica has been investigating repellants for *R. palmarum* with the assumption that this is a good test species for *R. ferrugineus*. The strategy compares capture efficiency of pheromone / food baited traps with pheromone / food baited traps additionally releasing candidate repellants. This approach allows a rapid screening. Rapid screening is necessary because there are over 9,000 compounds reported to be repellant to different insects. ChemTica has narrowed the search by eliminating any compound that has been reported both as a repellant and an attractant and currently has ~ 30 candidates. Repellants are an important strategy for the management of several species of bark beetles. In management of Mountain Pine Beetle (*Dendroctonus ponderosae*) trees are baited with pheromone lures to induce beetles to attack trees in timber stands selected for cutting. Simultaneous baiting of surrounding stands with repellants increases the efficiency of the bait-tree beetle concentration strategy. Similar strategies of push – pull are used for management of the Southern Pine Beetle (*Dendroctonus frontalis*) and the Douglas Fir Beetle (*Dendroctonus pseudotsugae*).

In trials conducted to date two potent repellants for *R. palmarum* have been discovered. In Figure 25 release of one of these, Repellant A, from highly attractive pheromone / sugarcane / ethyl acetate baited traps decreases capture rates by over 50%. In Figure 16 a similar test of known repellants of other insects is shown. While it could be argued that alpha-pinene would mask the odor of palm trees with that of a non-host pine tree this candidate is not repellant. Likewise, leaf alcohol has been reported to be repellant to many species of insects but is not repellant to *R. palmarum*.

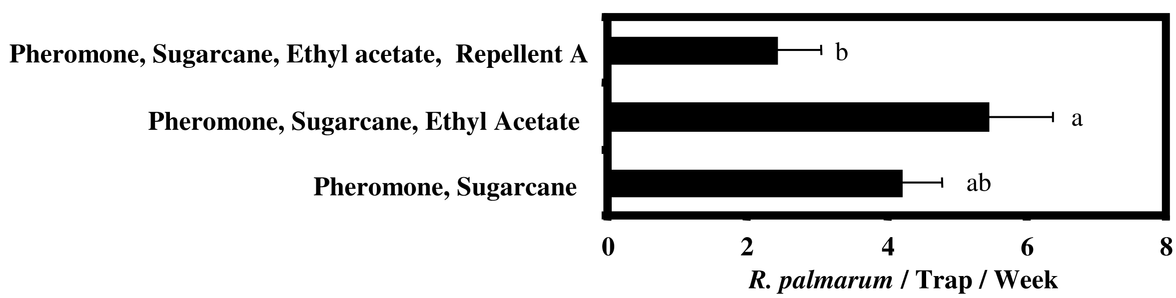


Figure 25. Experiment conducted November 14-29, 2000 in 50 ha of commercial coconut palm in Costa Rica. Treatments were pheromone and sugarcane in 750 mL 0.13% Lannate; pheromone, sugarcane, ethyl acetate with 750 mL water containing 0.13% Lannate and pheromone, sugarcane, ethyl acetate, and Repellant A with 750 mL water containing 0.13% Lannate. ANOVA (n = 8-10) gave $p < 0.05$. Means followed by different letter are significantly different by Bonferonni t-test, $P > 0.95$.

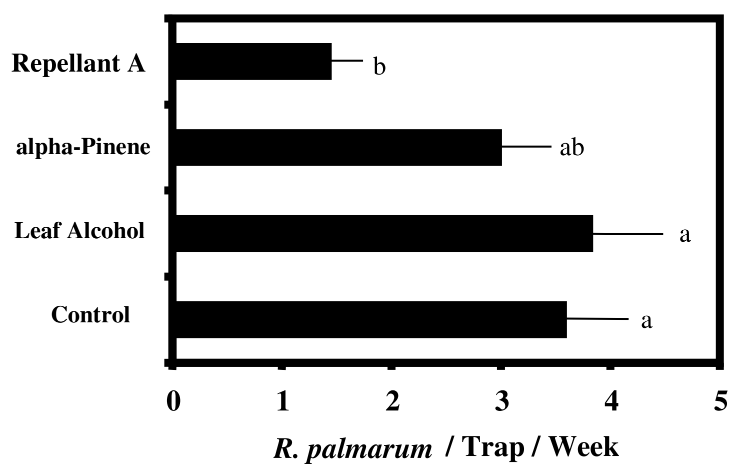


Figure 26. Experiment conducted May 31-June 13, 2000. All traps contained pheromone lures, ethyl acetate:ethanol (1:1) lures and fresh sugarcane immersed in fresh sugarcane 1 liter of 0.25% Lannate. Repellant candidate traps additionally contained slow release devices containing the indicated candidate repellants. Weevils were counted and removed June 6 at which time trap positions were re-randomized. Analysis determined no differences in capture rates on June 6 and June 13 allowing combination of

captures for June 6 and 13. ANOVA (n = 17-20), df = 3, 72, F = 4.62. Means followed by different letter are significantly different by Bonferonni t-test, P > 0.95.

Present Status

In Central and South America trapping is well established in the management of problems associated with *R. palmarum*. Current management of *R. palmarum* involves removal of infested palms and trapping. No synergistic combination of pheromone with other biological agents such as *Beauvaria bassiana*, entomolopathogenic nematodes or viruses has been developed. In the Middle East trapping of *R. ferrugineus* is well established in the management of weevil populations. Trapping is used in combination with regular survey and treatment of infested palms. Biological agents (fungi) are under investigation and show promise. Effective trapping of all palm weevils requires the use of pheromone, food and ethyl acetate. No synthetic chemical combination has been found to be as effective as natural food as a synergist for any palm weevil pheromone.

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