Trapping-a major tactic of BIPM strategy of palm weevils

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Abstract

Several species of curculionid weevils such as *Amerrhinus ynca* Sahlberg, *Cholus annulatus* Linnaeus, *C. martiniquensis* Marshall, *C. zonatus* (Swederus), *Diocalandra frumenti* (Fabricius), *Dynamis borassi* Fabricius, *Homalinotus coriaceus* Gyllenhal, *Metamasius hemipterus* Linnaeus, *Paramasius distortus* (Gemminger & Horold), *Rhabdoscelus obscurus* (Boisduval), *Rhinostomus barbirostris* (Fabricius), *R. afzelii* (Gyllenhal), *Rhynchophorus bilineatus* (Montrouzier), *R. cruentatus* Fabricius, *R. ferrugineus* (Olivier), *R. palmarum* (Linnaeus) and *R. phoenicis* (Fabricius) are associated with palms. Some of these have become a major constraint in the successful cultivation of coconut palm (*Cocos nucifera* L.), date palm (*Phoenix dactylifera* L.) and oil palm (*Elaeis guineensis* L.). *R. ferrugineus* is distributed in over 33 countries and attacks more than two dozen palm species. In the recent past, it has spread to Middle Eastern countries, Mediterranean region of Africa and southern Europe (Spain) causing tremendous economic losses. The yield of date palm has decreased from 10 to 0.7 tons/ha. Coconut palms in India are infested upto 6.9 per cent in Kerala and 11.65 per cent in Tamil Nadu. *R. palmarum* is a major pest of oil and coconut palms in the tropical Americas and, vectors the nematode, *Bursaphelenchus cocophilus* (Cobb) Baujard which causes red ring disease (RRD). Palm losses due to RRD are commonly between 0.1 to 15% which amounts to tens of millions dollars. The status of other species is briefed. The grubs of weevils that develop in the stems, bud, rachis of leaves and inflorescence of cultivated, ornamental or wild palms cause direct damage. Because of the cryptic habitat of the grubs, which act as tissue borer, the management becomes difficult.

Twenty-nine species of natural enemies are associated with palm weevils. The traditional method of controlling palm weevils included sanitation; pesticides and poisoned traps baited with petioles of coconut, stalks of sugarcane, tissues of pineapple or banana fruits.

Kairomones such as pure ethanol or isoamyl acetate have been found as attractive as or even more attractive than natural plant tissue (pineapple vs. isoamyl acetate). Palm weevils (*Rhynchophorus palamrum*, *R. phoenicis*, *R. ferrugineus D. borassi*, *M. hemipterus*, *R. obscurus*, and *P. distortus*) use male-produced aggregation pheromones for intraspecific chemical communication, (4S, 5S)-4-methyl-5-nonanol (ferrugineol) is the major aggregation pheromone for *R. ferrugineus*, *R. vulneratus*, *R. bilineatus*, *M. hemipterus*, and *D. borassi* and a minor component for *R. palmarum*, (5S, 4S)-5-methyl-4-octanol (cruentol), (3S, 4S)-3-methyl-4-octanol (phoenicol) and (4S, 2E)-6-methyl-2-hepten-4-ol (rhynchophorol) are the main aggregation pheromones for *R. cruentatus*, *R. phoenicis*, and *R. palmarum*, respectively. Plastic bucket modified into pheromone trap with synthetic pheromone and synergist (sugar cane stalk or palm petiole or banana fruit) immersed with carbofuran, hung on palms stems at about 1.5-1.7 m above the ground formed a sustained pheromone based trapping system. The sugessions for future management initiatives including areawide trapping, evaluation of trap-palm species and formulation of an international network project are given.

Key words: Palm weevils- *Amerrhinus ynca*, *Cholus annulatus*, *C. martiniquensis*, *C. zonatus*, *Diocalandra frumenti*, *Dynamis borassi*, *Homalinotus coriaceus*, *Metamasius hemipterus*, *Paramasius distortus*, *Rhabdoscelus obscurus*, *Rhinostomus barbirostris*, *R. afzelii*, *Rhynchophorus bilineatus*, *R. cruentatus*, *R. ferrugineus*, *R. palmarum* and *R. phoenicis*; coconut palm, date palm, oil palm, *Oncospernus tigillaria*, *Metroxylon solomenense*, trapping, biointensive integrated pest management (BIPM).

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Introduction

Several species of weevils are closely associated with Palmae (Kalshoven, 1981). Some of the species of weevils (family Curculionidae of order Coleoptera) have become a major constraint in the successful cultivation of coconut palm (*Cocos nucifera* Linnaeus), date palm (*Phoenix dactylifera* Linnaeus) and oil palm (*Elaeis guineensis* Linnaeus). In the recent past, red palm weevil, *Rhynchophorus ferruginus* Olivier has spread to Middle Eastern countries, Mediterranean region of Africa and southern Europe (Spain) causing tremendous economic losses and derailing the economy of some of the countries which are mainly dependent on date palm. In infested areas, the yield of date palm has decreased from 10 to 0.7 tons/ha (Gush, 1997). American palm weevil, *Rhynchophorus palmarum* (Linnaeus) is a major pest of cultivated oil and coconut palms in the tropical Americas (Wattanapongsiri, 1966). Although *R. palmarum* can kill palms through direct attack, its major threat to palm plantations lies in its being the vector of the nematode, *Bursaphelenchus* (*Rhadinaphelenchus*) *cocophilus* (Cobb) Baujard (Cobb, 1922; Tidman, 1951; Hagley, 1963: Martyn, 1953; Griffith, 1967, 1978, 1987) which causes red ring disease (RRD). Palm losses due to RRD are commonly between 0.1 to 15% (Chinchilla, 1988) which amounts to to tens of millions dollars.

Grubs of weevils bore into the palms and eventually make them unproductive. Because of the cryptic habitat of the grubs, which act as tissue borer, the management becomes difficult. The weevils use odor cues to orient to their host plants. The traditional method of controlling palm weevils has been the use of poisoned traps baited with damage tissue of coconut, sugarcane, pineapple, or banana fruits (Morin *et al.*, 1986). In fact, baiting and trapping of adult weevils using a mixture of materials has been considered as one of the best options for lowering the overall population of weevils in a given area. This paper besides discussing the trapping of adult weevils briefly throws light on other aspects of weevils, which could help in devising a sound management strategy for these naferious pests.

Species composition, biography and behaviour of palm weevils

The species of palm weevils recorded are presented in Table 1. Ten species of the genus *Rhynchophorus* are known, of which the greatest part are pests of cultivated palms (Wattanapongsiri, 1966). *Rhynchophorus* spp. is major pests of coconut, oil palm, date palm and sugarcane (Wattanapongsiri, 1966). Grubs that develop in the stems, bud, rachis of leaves, and inflorescence of cultivated, ornamental, or wild palm trees cause damage (Wattanapongsiri, 1966). They adults cause indirect damage to palm trees by vectoring the nematode *Bursaphelenchus cocophilus*, which is responsible for red ring disease (Griffith, 1987).

Asiatic palm weevils, *Rhynchophorus ferrugineus* and *R. vulneratus* (Panzer) are important pests in South Asia. The Southeast Asian *Oncospernus tigillaria* is a preferred host for breeding of *R. vulneratus* (Wattanapongsiri, 1966). Wattanapongsiri (1966) maintains that *R. vulneratus* is a species distinct from *R. ferrugineus* inspite of the fact that both the species share distribution, life history parameters and host plants (Murphy and Briscoe, 1999) and chemical composition of the pheromones produced (Perez *et al.*, 1995). At best *R. vulneratus* should be considered as colour morph of the same species. Unless other pre- or post-zygotic reproductive isolating mechanisms are discovered, the species should be synonymized with *Rhynchophorus ferrugineus* (Olivier). But the congener *R. bilineatus* differed from them by 10%, suggesting divergence of these lineages about 5 million years ago. Interestingly, this species was originally known as a sub-species of *R. ferrugineus*: *Rhynchophorus ferrugineus papuanus* Kirsch (Kalshoven, I981). In addition to *R. vulneratus* the taxonomic status of Asian *Rhynchophorus* species such as *R. distinctus* Wattanpongsiri, *R. lobatus* Ritsema and others is not clear and some may be conspecific with *R. ferrugineus*.

Table 1. Record of common palm weevils*

Name of the pest	Geographical distribution	Pest status
Amerrhinus ynca Sahlberg (=*Ameris ynca*)	Brazil	Minor / primary
Cholus annulatus Linnaeus	Western hemisphere (Guyana)	Minor / primary
Cholus martiniquensis Marshall	Western Hemisphere (St. Lucia)	Minor / primary
Cholus zonatus (Swederus)	Western Hemisphere	Primary
Diocalandra frumenti (Fabricius) (four-spotted weevil)	Southeast Asia; Oceania; Africa	Minor / primary
Dynamis borassi Fabricius	Colombia	Major
Homalinotus coriaceus Gyllenhal	Brazil; Argentina	Minor / primary
Metamasius hemipterus Linnaeus	Africa; Western Hemisphere; Indonesia (? intercepted)	Minor / primary
Paramasius distortus (Gemminger & Horold) (=*Metamasius inaequalis* Gyllenhal)	Western Hemisphere	Minor / primary
Rhabdoscelus obscurus (Boisduval)	Micronesia and Hawai	Primary
Rhinostomus barbirostris (Fabricius) (bearded weevil)	South America; West Indies	Primary
Rhinostomus afzelii (Gyllenhal)	Africa	Primary
Rhynchophorus bilineatus (Montrouzier) (black palm weevil)	Indonesia; Oceania	Primary
Rhynchophorus cruentatus Fabricius	North America	Primary
Rhynchophorus ferrugineus (Olivier) (Asiatic palm weevil)	South and southeast Asia; Middle East; Oceania; Africa; southern Europe	Major
Rhynchophorus palmarum (Linnaeus) (South American palm weevil)	Confined to New World	Major
Rhynchophorus phoenicis (Fabricius) (African palm weevil)	Widespread in Africa	Major

* Based on Hill (1983) and CABI (2002)

Rhynchophorus ferrugineus may consist of a number of biotype populations each adapted to feeding on a particular group of palm genera. *R.. ferrugineus* specimens collected in India from Arsikere (Karnataka) were different from those collected from Maharashtra and Tamil Nadu showing the biotypic variations. Also variations in the biotic characters (fecundity and sex ratio) of F_1 and F_2, progenies of *R. ferrugineus* (Ramachandran, 1998) were observed. Fluctuation in weather is also believed to influence the insect behaviour and morphology.

Rhynchophorus ferrugineus has a wide distribution as a pest of coconut palm in the South Asian region. There are also evidences of its distribution in the Mediterranean region of Africa besides its report from southern Europe (Esteban-Duran *et al.*, 1998a, b) where it mainly attacks date palm. Report on *R. ferrugineus* was first published in 1891 in Indian Museum Notes (1891/3); later Lefroy (1906) recorded it as a pest of coconut in India, Green (1906) from Sri Lanka and Banks (1906) from the Philippines. Buxton (1920) reported *R. ferrugineus* from Iraq (Mesopotamia) on date palm. But inspite of its report from Iraq, the pest extended its invasion of date palm gardens of Gulf countries only in last two decades. The pest was first recorded in the northern United Arab Emirates (UAE) in 1985, and since then it has spread to almost the entire UAE (Anonymous, 1995; El Ezaby, 1998), Saudi Arabia and Qatar during 1985, Oman and Kuwait in 1993 (Anonymous, 1995). In Iran, it was recorded in Savaran region in 1990 (Faghih, 1996). It was discovered in Egypt at the end of November 1992 in El-Hussinia, Sharquiya region (Cox, 1993). In 1994, it had been captured in the south of Spain (Barranco *et al.*, 1996) and in 1999 it reached Israel, Jordan and the Palestinian Authority Territories (Kehat, 1999). Currently *R. ferrugineus* is distributed in Bangladesh, Bahrain, Cambodia, China, Egypt, India, Indonesia (Sumatra, Java, Kalimantan, Lombok, Sulawesi, Papua province and many of the smaller islands), Iran, Iraq, Israel, Japan (Nokonoshima island), Jordan, Kuwait, Laos, New Caledonia, Malaysia, Myanmar, Oman, Pakistan, Palestinian Authority Territories, Papua New Guinea, Philippines, Qatar, Samoa, Saudi Arabia, Singapore, Solomon Islands, Spain, Sri Lanka, Taiwan (China), Thailand, United Arab Emirates and Vietnam.

In Egypt, *R. ferrugineus* was introduced through importation of offshoots from the United Arab Emirates and in south of Spain from adult palms imported from Egypt (Egypt has been the main source of supply of ornamental adult *Phoenix* palms to satisfy the very substantial demand that exists in all the coastal cities of Spain and, more generally of southern Europe). It might have spread to other countries such as Algeria, Morocco and Mediterranean area. Date palm, *Phoenix dactylifera* and Cannary island date palm, *P. canariensis* are the main crop and ornamental species in the Mediterranean area, but it could also attack some other ornamental palms (Barranco *et al.*, 2000). In infested plantations, yields have been estimated to drop from 10 tonnes to 0.7 tonnes per hectare (Gush, 1997). The cause of the high rate of spread of this pest is human intervention, by transporting infested young or adult date palm trees and offshoots from contaminated to uninfected areas.

The male and female adults of *R. ferrugineus* are large reddish brown beetles, 30-50 mm in length, generally with longitudinal brightly coloured bands. Adults are very good fliers, can fly up to 1.2 km uninterrupted (Wattanapongsiri, 1966). The female uses its long curved rostrum (a snoutlike projection of the head) for feeding and to bore into the tissue to form a hole in which to oviposit its light-yellow eggs (2.62 mm long and 1.12 mm in width) on the wounds of various origins (pruning or chain saw wounds, lightening damaged or injury caused by rhinoceros beetle or stressed due to any other injury), on spindle, tender leaf, mature stem as well as in the crown, undamaged palms are also attacked (Wattanapongsiri, 1966; Kalshoven, 1981; Murphy and Briscoe,1999). Several eggs are laid together but not in contact, and then the hole is cemented over to protect the eggs. On young, growing date palms, the weevils take shelter under the splitting bark and lay eggs within the newly emerging roots (Abraham *et al.*, 1998). Usually the adults select palms in the nearby vicinity for egg laying probably due to the aggregated spatial distribution of the pest (Faleiro *et al.*, 2002). The males of *R. ferrugineus* produce a pheromone, which causes the weevils to aggregate on damaged trees (Gunawardena and Bandarage, 1995). In general palms of 5-20 years are susceptible.

Table 2. Biography of *Rhynchophorus ferrugineus*

Stage	Duration of development stages in different countries (in days)					
	India*	Indonesia*	Myanmar*	Philippines*	Iran*	Spain **
Eggs per female	127-276	531	300	62-350	62-350	58-243
Incubation period	3-4	3	3-4	3	1-6	–
Larval period	25-61	60-105	30- 105	35 male 38 female	41-78	76-102
Pupal period	18-33	3-17	17-50	1-19 male 2-19 female	5-27	19-45
Duration of life cycle	48-82	60	60-165	45-68 male 45-67 female	57-111	100- 139
Longevity: male : female	50-90 50-90	107 107	- -	63-109 39-72	39-72 20-120	- -

*Adopted from Murphy and Briscoe (1999); **Adopted from Esteban-Duran *et al.* (1998a).

On an average, females are capable of laying 250 eggs (Murphy and Briscoe, 1999), which hatch in three days. On hatching from the eggs, the whitish-yellow young grubs start feeding on soft palm tissue, by making tunnels in the tree crown, upper part of the trunk and at the base of petioles. They can also bore into the trunk of young palms and the decaying tissue of dying palms; Kalshoven (1981) reports that they can develop in the refuse formed during the processing of sago.

The grubs feed within the host, chew the tissue, work back the chewed fibre and seal the tunnel so that entry of any other organism is prevented. They can be found in any place within the palm, even in the very base of the trunk where the roots emerge. In severely infested palms, cavities are formed by the feeding grubs, which weaken the crown of the tree.

The grub is legless, with a swollen median; the head is armed with strong mandibles. They reach a size of more than 40 to 50 mm before pupation. Mainly the grubs damage the palms. The grub stage lasts about two months.

Once mature, the grubs form an oval cocoon (approximately 80 x 35 mm) within the destroyed tissue of the tree. Inside the cocoon, the grub pupates. The thick and strong cocoon protects the tender pupa inside. Pupation occurs generally outside the trunk, at the base of the palms, it could also take place inside the crown. The pupal stage lasts three weeks. Life-cycle is completed in three months.

Rhynchophorus ferrugineus passes over three overlapping generations in a year, all life stages can be present within the same palm tree. Generally the adult weevils present in a palm will not move to another one while they can feed on it. All stages of *R. ferrugineus* are well protected by nature.

The external symptoms of attack include the presence of small holes on the stem, oozing out of brown viscous liquid, extrusion of chewed up fibers, longitudinal splitting of leaf bases, yellowing and wilting of leaves of the inner and middle whorl (Abraham *et al.*, 1998). Later in the infestation process the presence of grubs can be detected through the occurrence of tunnels on the trunk and at the bases of leaf petioles, and through the presence of frass and plant sap, which oozes from these tunnels. When a palm is severely infested, the stem or crown sometimes breaks off the tree. Late detection of the presence of the weevil constitutes a serious problem in the fight against the pest.

Because *R. ferrugineus* is a concealed tissue borer, symptoms of attack at an early stage of infestation are difficult to detect. However, there is a possibility of detecting physiological changes in infested trees (Bokhari and Abuzuhairah, 1992).

In India, 6.9 percent of the coconut palms were infested in Kerala (Abraham *et al.*, 1989) and 11.65 per cent of the young coconut palms (5-10 years old) in Tamil Nadu (Sekhar, 2000). But as mentioned earlier, the date palm yield was reduced by 14 times in areas of its recent introduction.

Rhynchophorus ferrugineus attacks a variety of palms (Nirula, 1956; Lever, 1969; Esteban-Duran *et al.*, 1998a,b; Murphy and Briscoe, 1999) such as betel nut palm, *Areca catechu*; sugar palm, *Arenga pinnata* (=*Arenga saccharifera*); palmyra palm, *Borassus flabellifer*, fish tail palm, *Caryota cumingii*; giant mountain fish tail palm, *Caryota maxima*; *Caryota* sp.; coconut palm, *Cocos nucifera*; burl palm, *Corypha elata*; gibang palm, *Corypha gebanga*; *Corypha* sp.; oil palm, *Elaeis guineensis*; ribbon fan palm, *Livistona decipiens*; *Livistona* sp., sago palm, *Metroxylon sagu*; mangrove palm, *Nypa* sp.; thorny palm, *Oncosperma* sp.; royal palm, *Oreodoxa regia*; Cannary island date palm, *Phoenix canariensis*; Indian date palm, *Phoenix dactylifera*; *Phoenix* sp.; silver date palm, *Phoenix sylvestris*; royal palmetto palm, *Sabal umbraculifera* (=*Corypha umbraculifera*); wind mill palm, *Trachycarpus fortunei* and fan palm, *Washingtoni*a sp. in a wide geographical area, where these are cultivated. It also attacks century plant, *Agave americana* and sugarcane, *Saccharum officinarum* in some countries.

In India, (laboratory studies) coconut culitivar Chowghat Green Dwarf was most preferred for egg laying by *R. ferrugineus* while Malayan Yellow Dwarf was least preferred (Faleiro and Rangnekar, 2001a), hybrid- Tall x Dwarf was most susceptible and Assam Green Tall (Kampura) least (Mazumder, 1995). In Saudi Arabia, the variety `Khalas' was found to be more susceptible to *R. ferrugineus* attack (Anonymous, 1998). In Pakistan, *R. ferrugineus* attacked date palm varieties in the following decending order-Aseel (21.41%) followed by Khurmo (14.5%), Hawawari (14.25%), Karbalain (10.25) and Kupro (6.16%) (Baloch *et al.*, 1994).

Rhynchophorus ferrugineus can breed in a wide range of climates and this is largely because the grubs feed protected within their host palms (Wattanapongsiri, 1966). Several generations can be passed in the same host tree before the tree collapses (Rajamanickam *et al.*, 1995; Faghih, I996). In addition, in the Middle East, the bulk and quick movement of date palm offshoots as planting material has led to the rapid spread of the pest (Abraham *et al*., 1998).

In Goa along the West coast of India the period between September and November coinciding with the decline of the Southwest monsoon was favourable for high activity of the adult weevils. However, *R. ferrugineus* was found to be least active during high rainfall months of June and July (Faleiro and Rangnekar, 2001b). In AI Hassa, Saudi Arabia weevil activity was high during April- May and also during October-November. However, weevil activity was low during August and January at the peak of summer and winter, respectively (Anonymous, 1998).

Rhynchophorus ferrugineus was normally a rare and local insect in south India (Nirula, 1956). Generally, the weevil population is high in managed and commercial plantations than in a natural habitat. In natural habitat the chances of injury are less, natural enemies are protected and ground cover of nectar and pollen bearing plants available which enhances the efficiency of natural antagonist. The excessive use of insecticides is also likely to limit the activity of natural enemies in plantations. The general absence of natural enemies in the date palm plantations in the countries of the Middle East would explain why the *R. ferrugineus* has had a particularly devastating impact in this region.

The basic life cycles of *Rhynchophorus* spp. (Wattanapongsiri, 1966) as well as *D. borassi*, *M. hemipterus*, *R. obscurus* and *P. distortus* are similar. Larvae bore into the palms and after several instars develop into adults in about 2 months (Giblin-Davis *et al.*, 1989, Napompeth *et al.*, 1972, Watananpongsiri, 1966). Larvae of *Rhynchophorus* spp., *D. borassi*, *M. hemipterus*, *R. obscurus* and *P. distortus* appear to inhabit slightly different niches in palms, with *Rhynchophorus* spp. preferring the crown and/or stem (Wattanapongsiri, 1966; Giblin-Davis and Howard, 1989;); *D. borassi* lives in tissues of coconut inflorescence and stem (Gerber *et al.*, 1990; Wattanpongsiri, 1966); and *M. hemipterus*, *R. obscurus* and *P. distortus* petioles and stem periphery, sometimes entering the crown (Giblin-Davis *et al.*, 1996a; Halfpapp and Storey, 1991). The last instar larvae of these weevils move to the petioles or to the rind of the stem to prepare a cocoon from coarse fibers and become a prepupa, pupa, and adult within several weeks (Wattanapongsiri, 1966; Vaurie, 1966). As the borer damage from most of these species accumulates, fermentation volatiles increase and attract more adults.

Rhynchophorus bilineatus is essentially a Melanesian species (Murphy and Briscoe, 1999). However, it has been recorded from Papua New Guinea, Solmon islands, Indonesia (eastern islands and Papua Prvince) and also from Malaysia (Sarawak). It has been recorded from coconut, *Metroxylon armicarum* and *Metroxylon solomenense*. *M. solomenense* is the preferred host for breeding of *R. bilineatus.* In Papua New Guinea grubs of *R. bilineatus* produced on *Metroxylon* palms are considered as delicacy and serve as good source of protein (Mercer and Bukkens, 1997).

Palmetto weevil, *Rhynchophorus cruentatus* is perhaps the largest weevil in North America measuring 1.9 to 3.0 cm (from the tip of the rostrum to end of the pygidium). Adults of *R. cruentatus* vary in color from solid black to almost completely red with a variable black pattern. Males and females can be distinguished by the surface of the rostrum. The rostrum of males is covered with tiny bumps while females have a smoothand shiny rostrum. *R. cruentatus* adults are active fliers and can be found throughout the year in Florida. However, adult activity is usually more noticeable in the late spring and early summer months. When not flying in search of a host palm, adults hide between the leaf bases and stems of healthy palms presumably to conserve water within their bodies. *R. cruentatus* preferred high relative humidity, suggesting that this weevil possesses hygroreceptors to locate moist harborage sites (Weissling and Giblin-Davis, 1993a). Its current distribution range extends from the coastal plains of South Carolina through the Florida Keys, and west into coastal Texas. It is the only species of palm weevil in the continental United States attacking severely wounded and dying trees. Of late it has emerged as a serious pest of stressed nursery and transplanted palms.

The female lays an average of 207 eggs in her lifetime in the bases of leaves or in wounds in a dying host palm. Eggs hatch in about three days. The hatching grubs begin to feed on palm tissue. As they molt (grow) the grubs feed primarily in the soft tissue surrounding the apical meristem.

The grubs are legless and creamy to yellowish in color. Their prominent head is dark brown and very hard. Mature grubs can be quite large, some weighing about six grams.

Grubs of palm weevils are considered a delicacy in some countries.

Mature grubs migrate to the periphery of the stem or petioles and prepare a cocoon from palm fibers. After surrounding themselves with the cocoon, the larvae enter a prepupal stage and then a pupal stage. After a few weeks, an adult emerges from the pupal case and may immediately break free of the cocoon or wait within the cocoon for several days before emerging.

The entire life cycle, from egg to adult, takes about 84 days. Adults may live for several weeks (up to 26 weeks in captivity).

The symptoms of *R. cruentatus* infestation vary, but commonly involve a general, often irreversible decline of younger leaves. In palm species with upright leaves, such as the Canary Island date palm, the older leaves begin to droop during the early stages of infestation but quickly collapse thereafter.

As the infestation progresses, the larval feeding damage by grubs and associated rot is so severe that the top of the palm falls over and grubs, cocoons, and even adults are found within the crown region.

Early detection of weevil infestation is difficult, and treatment even in the early stages of infestation may be too late to save the tree. The abundance of adult palm weevils is affected by seasonal changes.

The primary food source for *R. cruentatus* is stressed or damaged cabbage palmetto palm (*Sabal palmetto*), a palm native to the southeastern U.S. Saw palmetto, *Serrenova repens* is an alternate host and it also sometimes attack other palms such as Cannary island date palm, *Phoenix canariensis;* date palm, *P. dactylifera;* coastal loulu palm, *Pritchardia* sp.; fan palm, *Washingtonia* sp.; royal palm, *Roystonea* sp.; latin palm, *Latania* sp.; coconut palm, *Cocos nucifera*; and fish tail palm, *Caryota* sp. In undisturbed locations, palms are rarely observed with *R. cruentatus* infestations. Trees stuck by lightening have been observed with subsequent weevil infestations.

Rhynchophorus spp. seeks harborage in leaf axils of healthy palms (Weissling and Giblin-Davis, 1993) and moist fermenting garbage (Chittenden, 1902). *Dynamis borassi* usually prefers fresh tissue. In Florida, *R. cruentatus* (Weissling *et al.*, 1994a) and *M. hemipterus* (Peña *et al.*, 1995) are more abundant in spring, before the onset of the rainy season.

The American palm weevil, *R. palmarum* is a serious pest on coconut and oil palm in the Neotropical region (Wattanapongsiri, 1966). Weevils attack healthy coconut palms but in oil palm mechanical injury or rot usually precede weevil attack (Chinchilla, 1988). Grubs cause extensive tunneling in the trunk or the whorl (Griffith, 1987). *R. palmarum* is the major known vector of red ring disease caused by nematode, *Bursaphelenchus* (*Rhadinaphelenchus*) *cocophilus* (Cobb) Baujard (Cobb, 1922; Tidman, 1951; Hagley, 1963: Martyn, 1953; Griffith, 1967, 1978, 1987; Gerber *et al*., 1990a; Chinchilla *et al.*, 1993; Oehlschlager *et al.*, 1993a).

In oil palm, infection by other mechanisms such as via nematode carrying harvest knives or soil (Fenwick, 1968) is considered insignificant in comparison to inoculation by the weevil (Schuiling and Dinther, 1981; Chinchilla, 1988). Red ring symptoms become evident after 2-3 months of infection and nematicidal treatments failed to cure the palms. However, low percentage of recuperation with systemic nematicide treatment occurs when symptoms are solely of the little leaf type (Chinchilla, 1988). *R. palmarum* populations appear to peak at the end of the rainy season and throughout most of the dry season in coconut plantations in Trinidad (Hagley, 1963), and in the dry season in oil palm plantations in Brazil (Schuiling and Dinther, 1981), Costa Rica (Morales and

Chinchilla, 1990) and Honduras (Chinchilla *et al.*, 1990).

The African palm weevil *Rhynchophorus phoenicis* causes damage in Africa particularly to young oil palms. Boring by the grub into the crown or root bulb of a young palm causes yellowing of the leaves, while boring close to the growing point is lethal to the palm (Gries *et al.*, 1993).

The silky cane weevil, *Metamasius hemipterus* was accidentally introduced into Dade County, Florida in the early 1980's. It is an important pest of sugarcane, other plants and palms, in the Neotropics (Alpizar, 2002). Adults are attracted to and lay eggs in palm sheaths, petioles, or stems. Within the host, larvae develop into adults in less than two months. The weevil adults appear to be attracted to palms by odors emanating from small wounds created by pruning of leaves. Normally *M. hemipterus* attack is not lethal, but the stress created by the infestation makes the palms susceptible to successful attack by *R. cruentatus*.

Among other species (Mariau, 2002), *Amerrhinus ynca* attacks Brazilian coconuts. Adults are yellow with black points. They lay their eggs in the stems of young palm trees. In cases of severe attack these palms become yellow and break.

Homalinotus coriaceus attacks coconuts in Brazil, between the States of Bahia and Paraiba (Bondar, 1940). The adult is black, and about 20-25 mm long. Eggs are laid at the base of the inflorescence. If the inflorescence is still young, the damage results in rapid and total rot. More often, tunnels are bored in the periphery of the rachis of the inflorescence. This weakens the rachis, which may break when it carries many fruits. Otherwise, the nuts may fall off as a result of insufficient nourishment. The pupal stage is passed in a small excavation made by the larva in the surface of the stem at the base of the rachis. Dwarf coconuts are much more susceptible than talls.

The black adults of South American species, *Rhinostomus barbirostis* are about 30-40 mm long (excluding its very hairy and long rostrum). Being nocturnal, in the daytime they may be found in the grass at the foot of the tree or, more often, in the axils of old leaves (Mariau, 2002). Unlike *Rhynchophorus*, *R. barbirostis* do not need wounds in the stem to lay their eggs, which are often deposited on small uneven parts of the healthy coconut palm. On some of them very great quantities of eggs can be observed, up to more than 100 on a band 10 cm wide. The stem is bored through in all directions, causing a general weakening of the tree, and breakage in case of gusty winds. Attacks may vary between one coconut palm and another. The most serious attacks by these insects have been reported from Brazil, especially from the State of Sergipe. *Rhinostomus afzelii* (Gyllenhal) is distributed in Africa.

Biological control

Studies conducted by various workers in different countries have shown that the community of natural enemies associated with palm weevils includes nematodes, fungi, virus, bacteria, insects and mites (Table 3).

Table 3. Natural enemies of *Rhynchophorus* species*

Species	*R. ferrugineus*	*R. bilineatus*	*R. palmarum*
Nematodes			
Diplogasteridae			
Diplogasteritus sp.			v
Mononchoides sp.	v		v
Entaphelenchidae			
Praecocilenchus ferruginophorus (Rao and Reddy)	v		
Praecocilenchus rhaphidophorus (Poinar)		v	v
Heterorhabditidae			
Heterorhabditis indica (Poinar, Karunakar & David)	v		
Heterorhabditis sp.			v
Steinernematidae			
Steinernema abbasi Elawad, Amad & Reid	v		
Steinernema sp			v
Rhabditidae			
Rhabditis sp.	v		
Teratorhabditis palmarum Gerber & Giblin-Davis	v		v
Bacteria			
Bacillaceae			
Bacillus sphaericus Meyer and Neide	v		
Micrococcaceae			
Micrococcus sp.			v
Pseudomonadacae			
Pseudomonas aeruginosa (Schroeter) Migula	v		
Fungi			
Hyphomycetes			
Metarhizium anisopliae (Metschnikoff) Sorokin	v	v	
Beauveria bassiana (Balsamo) Vuillemin	v		
Insects			
Reduviidae			
Platymeris laevicollis Distant	v		
Forficulidae			
Chelisoches morio (Fabricius)	v		
Staphilinidae			
Xanthopygus cognatus Sharp			v
Sarcophagidae			
Sarcophaga fuscicauda Bottcher	v		
Scoliidae			
Scolia erratica Smith	v		
Tachinidae			
Paratheresia menezesi Townsend			v
Paratheresia rhynchophorae (Blanchard)			v
Mites (ectoparasites?)			
Hypoaspidae			
Hypoaspis sp.	v		
Pymotidae			
Tetrapolypus rhynchophori Ewing	v		
Viruses			
Cytoplasmic polyhedrosis virus	v		
Yeast from the haemolymph	v		

* **Reported by Burkill (1917), Iyer (1940), Nirula (1956), Abraham and Kurian (1975), Moura *et al.* (1994), Rao and Reddy (1980), Peter (1989), Gopinadhan *et al.* (1990), Shamseldean and Abd Elgawad (1994), Bedford (1974), Abbas *et al.* (2001), Ghazavi and Faghih (2002), Bano and Rajendran (2003), Salma *et al.* (2004), Banarjee and Danger (1995), Danger (1997), Hanounik (1998), Bedford (1974),Quezada *et al.(*1969), Prior and Arura, 1985, Poinar (1969).**

A bacterium, *Pseudomonas aeruginosa* was isolated from naturally infected specimens of *R. ferrugineus* collected in Kerala, India (Banerjee and Dangar, 1995). Entomopathogenic fungus, *Metarhizium anisopliae* was isolated from *R. bilineatus* and other beetles in Papua New Guinea (Prior and Arura, 1985). A cytoplasmic polyhedrosis virus (CPV) specific to *R. ferrugineus* (Gopinadhan *et al.*, 1990) and unidentified yeast (Dangar, 1977) were recorded in Kerala, India. Gerber and Giblin-Davis (1990) reported the presence of three nematode species in the bodies of adult *R. palmarum* but their pathogenicity to the weevils was unclear. *Praecocilenchus rhaphidiophorus* was recorded parasitizing *R. bilineatus* in New Britain in 1969 (Poinar, 1969) while *P. ferruginophorus* was recovered from *R. ferrugineus* in India in I980 (Rao and Reddy, 1980).

Scoliid *Scolia erratica* Smith (Burkill, 1917) and furficulid predator, *Chelisochcs morio*- a common predator in the crown of coconuts in Kerala, India were recorded from *R. ferrugineus* (Abraham *et al.*, 1973). Nymphs and adults of the predator consumed 5.3 and 8.5 eggs or 4.2 and 6.7 grubs of *R. ferrugineus*. Staphilinid, *Xanthopygus cognatus* was recorded feeding on *R. palmarum* in Al Salvador (Quezada *et al.*, 1969).

Gregarious tachinid parasitods, *Paratheresia rhynchophorae* (Guimaraes *et al.*, 1977) and *P. menezesi* (Moura *et al.*, 1993) were reported from *R. palmarum*. In oil plantations in Bahia, Brazil, *P. menezesi* parasitised 50% of *R. palmarum*. Mere presence of the parasitoid *P. menezesi* was generally insufficient for controlling serious outbreaks of *Amerrhinus ynca* (Moura *et at*., 1994). Sarcophagid *Sarcophaga fuscicauda* was reported to attack the adults of *R. ferrugineus* in India (Iyer, 1940).

In India, two mite species, *Hypoaspis* sp. and *Tetrapolypus rhynchophori* have also been recorded infesting the adult beetles (Nirula, 1956; Peter, 1989), but the status of these species as parasites is uncertain. Apart from above groups, lizards, toads and birds also feed on adults.

The above account shows that systematic and exensive search for new natural enemies in all the distribution zones of palm weevils is necessary. It seems to be appropriate to conduct more studies on tachinid parasitoids, the efficient one could be established in different countries. Also entomopathogens need extensive studies in different countries.

Management stretegies

Till the 1980s *R. ferrugineus* management relied mostly on the use of insecticides. However, there is now a strong emphasis on the development of integrated pest management (IPM) (Abraham and Kurian, 1975; Abraham *et al.*, 1989; Murphy and Briscoe, 1999) including efficient use of pheromone traps and biological control rather than insecticides alone.

For the management of *R. ferrugineus* in India the recommendations given from time to time incude- surveillance of the pest, avoiding any injury to palm, sealing the injuries with coal tar + carbaryl or slurry of clay or soil prepared with 5 gm carbaryl 50 WP, maintaining plant and field sanitation, when green leaves are to be cut it can be done leaving a petiole length of 120 cm, trapping adult weevils, treating the crown of bud rot diseased or *Oryctes* attacked palms which attract the weevil with a combination of fungicide and insecticide, leaf axil filling with of carbaryl (sevidol 8G) 25g and sand 200g, curative methods include – injection of 0.1% endosulfan/dichlorvos or 1% carbaryl by drilling a downword slanting hole into the stem at about 1.5 m above ground level and pluging with clay (before treating the palm, the nuts are harvested and a waiting period of 45 days observed for next harvest of nuts), log trapping with fermented toddy, mud pot with molasses and placement of pheromone+banana or sugarcane or tender coconut stalk pieces, and finally educating the farmers and agricultural workers on palm weevil management (Abraham and Kurian, 1975); Abraham *et al.*, 1989; Anonymous, 1998; Nair *et al.*, 2002).

In the laboratory 0.1 per cent cypermethrin (Abo-EI-Saad *et al.*, 2001) and 0.2 per cent primiphos methyl or 0.36 per cent oxydemeton methyl (Ajlan *et al.*, 2000) were most effective against *R. ferrugineus*.

The insecticides are administrated into the affected palm tissue as curative treatment. Slanting holes, 2 to 3 cm in diameter and 15 cm deep are made around the affected part using a hollow pointed iron pipe. The insecticide poured into these holes kills the grubs and other stages of the insect inside the trunk (Anonymous 1995). Different insecticides recommended for stem injection to treat *R. ferrugineus* infested palms include pyrocone-E-1% (pyrethrins-piperonyl butoxide combination) (Nirula, 1956), carbaryl-1% (Mathen and Kurian, 1967), 0.2% fenthion (Rao *et al.*, 1973), 0.2 per cent trichlorphon (Abraham *et al.*, 1975), 10 ml of monocrotophos, or the same volume of a combination of monocrotophos and dichlorvos (5 + 5 ml) (Muthuraman, 1984). Injection method was successfully carried out in United Arab Emirates by EI-Ezaby (1997) with carbosulfan, pirimiphos-ethyl and dimethoate. Imidachloprid and fipronil have also shown promise. Root feeding with 10 ml monocrotophos + 10 ml water was also effective in India (Rao *et al.*, 1989; Nair *et al.*, 2002). Carbaryl was effective in Indonesia when applied regularly at two-month interval (Soenardi and Hariadi, 1978).

Phostoxin tablets (aluminium phosphide) applied at a rate of at 0.5-1 tablet/tree were effective in controlling larvae, pupae and adults of *R. ferrugineus* on coconut (Rao *et al.*, 1973). Muthuraman (1984) alternatively used two 3-g Celphos (aluminium phosphide) tablets crushed and placed in holes in date palm. All holes were then sealed with a paste of cement and copper oxychloride to contain the highly toxic phosphine gas released by the tablets. Soaking of the trees with insecticides such as chlorpyriphos, endosulfan, fenitrolthion, diazinon and methidathion has also been attempted.

The technique of multiplication and release of sterile male weevils as first demonstrated by Rahalkar *et al.* (1973) could also play an important role in *R. ferrugineus* management programmes.

Semiochemicals in the management of palm weevils

Observation that adults of *R. cruentatus* were attracted to nitrocellulose lacquer-based automobile paint in Sanford, FL (Bare, 1929) provided a stimulus for research on semiochemicals. Semiochemicals are the chemicals that act as signals between organisms, aggregation pheromones serve as intraspecific transitory signals, whereas kairomones, such as host-plant volatiles, act interspecifically with the receiver benefiting (Dusenbery, 1992). Semiochemicals isolated from *Rhynchophorus* spp. are presented in Table 4.

For attraction of adult palm weevils (*Rhynchophorus palmarum, R. phoenicis, R. ferrugineus, Dynamis borassi, Metamasius hemipterus, Rhabdoscelus obscurus,* and *Paramasius distortus*) split petioles of different palms such as sugar palm, palmyra palm, fish tail palm, coconut palm, burl palm, gibang palm, African oil palm, oil palm, ribbon fan palm, sago palm, mangrove palm, thorny palm, date palm, palmetto palm and screw pine; cut pieces of sugarcane, aloe and, banana and pineapple fruits were used alone in combination of synthetic kairomones and in combination with different aggregation pheromones.The attractiveness of the plant tissue compounds increased by decomposition of the plant material.

Table 4. Semiochemicals of *Rhynchophorus* spp.

Species	Semiochemical	Reference
Rhynchophorus bilineatus Montrouzier	4S5S-ferrugineol	Oehlschlager *et al.* (1995)
Rhynchophorus cruentatus Fabricius	5me-octan-4-ol 3S4S-3me-octan-4-ol 4S5S-5me-octan-4-ol S-ethyl lactate ethyl isobutyrate ethyl butyrate ethyl alcohol	Weissling *et al.* (1994c) Perez *et al.* (1994) Giblin Davis *et al.* (1994b)
Rhynchophorus ferrugineus Olivier	ethyl acetate 2methoxy-4vinylphenol gamma-nonanoic lactone 4S5S-ferrugineol 5OH ferrugineol 4me-9-5Kt	El Sebay (2003) Gunawardena *et al.* (1998) Gunawardena and Herath (1995) Hallett *et al.* (1993a)
Rhynchophorus palmarum Linnaeus	3me-4OH 2me-4OH acetoin isobutyl acetate 2,3-4diol 2phenylethanol ethyl alchohal ethyl acetate phenol guaiacol veratrole 6-2Kt 9-2Kt 7-2Kt menthone beta-phellandrene ethyl octanoate ethyl acetate E2-6me-hepten-4-ol ethyl alchohal 5Hy 6Ald isopentyl acetate 3me-4OH E2-6me-hepten-4-ol E2-6me-hepten-4-ol	Rochat *et al.* (2000) Jaffe *et al.* (1993) Oehlschlager *et al.* (1992a) Rochat *et al.* (1991b)
Rhynchophorus phoenicis Fabricius	ethyl propionate 3S4S-3me-octan-4-ol 3me-octan-4-ol	Gries *et al.* (1994) Perez *et al.* 1994) Gries *et al.* (1993)
Rhynchophorus vulneratus Panzer	4S5S-ferrugineol ferrugineol 4me-9-5Kt	Hallett *et al.* (1993a)

Fermented sap exuding from dead or wounded palmetto and Cannary islands date palms (*Sabal palmetto* and *Phoenix canariensis*) is highly attractive to *R. cruentatus* (Chittenden, 1902). Attractiveness of chopped, fermenting, *S. palmetto* crown and stem tissue peaks 24-72 hours after cutting, whereas cut surfaces of felled palms remain attractive for 35 days (Weissling *et al.*, 1992). Moist fermenting (stem) tissues from various palm species, fruits, sugarcane, pineapple, and molasses (plus water) are similarly attractive to palm weevils (Diegado and Moreno 1986, Giblin-Davis *et al.*, 1994b). Plant tissues (stem of saw palmetto palm, *Serrenova repens*) or molasses with minimal moisture content are significantly less attractive to *R. cruentatus* and *M. hemipterus*, respectively (Giblin-Davis *et al.*, 1994a, 1996a). Early fermentation volatiles of moist and stressed, damaged, or dying host plant tissues with high sugar content obviously provide olfactory cues to attract palm weevils.

The "palm esters" or plant kairomones such as ethanol, ethyl (S)-(-)-lactate, ethyl acetate, ethyl butyrate, ethyl isobutyrate, ethyl propionate, ethyl acetate, hexanal, isoamyl-acetate, isopentanol and pentane were isolated and evaluated individually, in different mixtures and in combination with different aggregation pheromones. Plant kairomones strongly enhance pheromone attractiveness. Among the volatiles identified, ethanol was shown to be attractive; in addition to isoamyl-acetate (Hagley, 1965), and known to be present in pineapple and banana. Pure ethanol or isoamyl-acetate was as attractive as or even more attractive than natural plant tissue (i.e., pineapple vs. isoamyl-acetate.

Coconut plants contain water, CO2, ethyl acetate, pentane, hexanal, isopentanol, and ethanol. Fruits of pineapple produce ethanol and ethyl acetate (Jaffe *et al.*, 1993). A mixture of 68% ethanol, 27% ethyl acetate, and 5% pentane was found to be as attractive as natural plant tissue. Jaffe *et al.* (1993) observed that ethanol and ethyl acetate in proportion of 70:30, as found in coco plants, was the most attractive two compound mixtures for the weevils. The proportion of ethanol vs. ethyl acetate changed during decomposition of the material, reaching a proportion of 7:3 after three days of decomposition and remained relatively constant up to 9 days. A complex mix of ethanol, ethyl acetate, pentane, hexanal, isolamyl-acetate, and/or isopentanol serve as a short-range orientation cue to fresh wounds on the plant but additional host odor, attracting weevils from a distance is to be discovered.

In most of the countries sugarcane (250 to 500 g) is used as food bait in pheromone traps. In the Middle East, date stem or date fruit itself is the food bait in the traps. In India, banana was efficient food bait (Nair *et al.*, 2000). Coconut toddy is used as food bait in Sri Lanka. It is not possible to get some or all of these natural synergists in all places and during different times of the year. Hence, coconut or any other weevil attractive palm petiole, which is easily available, is commonly used as food bait in pheromone traps in palm plantations. It is also essential to replace the food bait in the trap every week or at nine days interval to maintain the efficacy of the pheromone trapping system.

Historically attracting and killing the weevils formed an important management strategy. A mixture of malt skatole and iso-amyl acetate was significantly better than coconut stem tissue as an attractant for both sexes of *R. palmarum* (Hagley, 1965). In Sri Lanka and Trinidad metal traps filled with coconut petioles were effective in attracting the weevils (Maharaj, 1973). However, in India coconut logs proved more effective than metal traps (Kurian *et al.*, 1979). Coconut logs treated with toddy (1litre), yeast (5g) and acetic acid (5 ml) attracted significantly more number of adult weevils as compared to other food attractants (Kurian *et al.*, 1984).

As mentioned above the early research provided evidence that general fermentation volatiles, such as ethanol, appeared attractive to *Rhynchophorus* weevils (Gunatilake and Gunawardena 1986, Hagley 1965). The recent discovery of aggregation pheromones, which greatly enhance attractiveness of plant tissues, facilitated identification of individual palm kairomones (Giblin-Davis *et al*., 1994b, 1996a, Gries *et al.*, 1994, Jaffé *et al.*, 1993, Perez *et al.*, 1995).

Palm weevils (*Rhynchophorus palamrum, R. phoenicis, R. bilineatus, R. ferrugineus Dynamis borassi, Metamasius hemipterus, Rhabdoscelus obscurus,* and *Paramasius distortus*) use male-produced aggregation pheromones for intraspecific chemical communication (Giblin- Davis *et al.*, 1996a). Males of the palm weevils produce several volatile pheromone related compounds. They are classified as aggregation pheromones since only males produce them but attract both males and females.

Pheromones comprise 8, 9, or 10 carbon, methyl-branched, secondary alcohols. (4S, 5S)-4-methyl-5-nonanol (ferrugineol) (Hallett *et al.,* 1993a) is the major aggregation pheromone for *R. ferrugineus*, *R. bilineatus*, *M. hemipterus*, and *D. borassi* and a minor component for *R. palmarum* (Giblin- Davis *et al.*, 1996a). (5S, 4S)-5-methyl-4-octanol (cruentol) (Perez *et al.*, 1994; Weissling *et al.*, 1994c); (3S, 4S)-3-methyl-4-octanol (phoenicol) (Perez *et al.*, 1994), and (4S, 2E)-6-methyl-2-hepten-4-ol (rhynchophorol) (Rochat *et al.*, 1991b; Oehlschlager *et al.*, 1992a; Jaffe *et al.*, 1993) are the main aggregation pheromones for *R. cruentatus*, *R. phoenicis*, and *R. palmarum*, respectively (Giblin-Davis *et al.*, 1996a). 4-methyl-5-nonanol is the male produced aggression pheromone of *D. borassi* (Giblin-Davis *et al.*, 1997).

For field utilization, nineteen litre capacity plastic bucket was modified by cutting holes in the bottom and entry slots in the sides and top, a device placed to release 3 mg per day of synthetic pheromone, 15 pieces of halved sugar cane stalks that had been immersed in a suspension containing 1.5 cc/l carbofuran, and this bucket hung on palms at about 1.7 m above the ground formed a sustained pheromone based trapping system for *R. palmarum* on oil palm in Latin America (Oehlschlager *et al.*, 1993a). Captured weevils could also be killed by sugarcane stalks treated with other pesticides such as carbaryl and lannate (Oehlschlager *et al.* 1993a) or with soapy water in the bottom of traps (Weissling *et al.*, 1992, 1994b). Based on this experience bucket traps containing pheromone lure and an insecticide treated food bait is widely used to manage *R. ferrugeneus* both in date and coconut plantations (Faleiro *et al.*, 1998). Five litre capacity high-density polyethylene buckets (22cm diameter and 19 cm height) are used as pheromone traps. The lid of the bucket is kept 4 cm raised above the bucket for entry of the weevils. The bucket is wrapped with jute sack to provide grip to the attracted weevils and facilitate their entry in to the trap. The bucket trap is filled one-fourth with synergist bait consisting 100 g mashed banana+2g yeast+2g carbaryl mixed in one litre of water. The pheromone dispenser containing 100 micro litre i.e.78.5mg is placed inside a plastic sachet and suspended at the centre of the bucket with the help of a wire. One is placed at 1.5 m height from the ground level per hectare at strategic places (Abraham and Nair, 2001; Faleiro and Satarkar, 2003; Mayilvaganan *et al.*, 2003). A new pheromone sachet Ferrolure + 800 mg is widely used in surveillance and mass trapping programmes through out the world. In India (Goa) this lure once used in coconut plantations is capable of attracting the pest for five to six months in the field (Faleiro and Rangnekar, 2001c). In Saudi Arabia, field studies on the longevity of pheromone lures revealed that the pheromone (ferrolure 700 mg) exhausted in three months during summer as compared to the winter months when lures lasted for about five months. Also, ferrolure and ferrolure+ (with additive) released the same quantity of the chemical into the environment under shaded conditions, but when traps had to he exposed to sunlight, ferrolure+ lasted longer than ferrolure (Faleiro *et al.*, 1999). In coconut, highest numbers of *R. ferrugineus* weevils were captured in Indonesia when traps were placed at ground level (Hallett *et al.*, 1999). But there are chances of disturbing the traps by ground dwelling predators.

Weevil captures from date and coconut plantations in Saudi Arabia (Al Hassa) and India (Kerala, Goa), respectively have been reported to be female dominated (Abraham *et al.*, 1999; Vidyasagar *et al.*, 2000; Abraham *et al.*, 2000b). Adult female *R. ferrugineus* attracted to pheromone traps in coconut gardens of India were also found to be young, fertile and gravid (Faleiro, 2000; Faleiro *et al*., 2003). This indicates that at present ferrugineol based pheromone traps not only monitor *R. ferrugineus* activity, but also suppresses its build up in the field when used in mass trapping programmes. Continuous mass trapping of *R. palmarum* in oil palm in Costa Rica for 17 months significantly reduced weevil captures from 32.4 weevils per trap to 6.4 per traps (Oehlschlager *et al.*, 1995b). Mass trapping of adults of *R. ferrugineus* together with other management tactics over a period of four years (1994 to 1995) significantly reduced infestation levels in date palm plantations of Saudi Arabia (Abraham *et al.*, 2000a; Vidyasagar *et al.*, 2000).

Conclusions

Weevils are serious pests of coconut palms, oil palms and date palms. *Rhynchophorus ferrugineus* is spreading fast. By now it has invaded more than 31 countries in Asia, Africa and Europe. The main ornamental tall palms planted in the gardens and in the streets of the Mediterranean coast cities are date palms. Thousands of them are imported from Egypt each year directly or indirectly into Spain and other European countries. These palms must have a phytosanitary certificate to assure that the plants are weevil free. *R. ferrugineus* could be also a catastrophe in Elche (Spain) where the date grove has been nominated as a World Heritage Site.

There is a need of determining the correct identity of species and strains of palm weevils by adopting traditional morphometrical and advanced DNA-based fingerprinting techniques. Studies are necessary on crop loss assessment, biotypes, behavioral changes in relation to the changing agro-climatic conditions, population dynamics, natural enemies, innovative pheromone trapping methods including use of synthetic food baits, breeding for pest tolerance or resistance palm, introduction of deleterious genes in the pest population, release of sterile male weevils in endemic areas, development of biocontrol techniques, fabrication of a light portable aquistical detector, improvement of insecticide application gadgets are necessary for refining the existing IPM programme. Particular attention is needed in selecting the best tachinid parasitoids and distributing in different areas, alternate palm hosts distinctly more attractive to weevils, and synthesizing the pheromone locally for distribution to coconut palm, oil palm and date palm producers need encouragement. There is a need for co-operative international network research project for indepth studies on weevils.

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