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PRESENT MANAGEMENT TECHNOLOGIES FOR RED PALM WEEVIL, *Rhynchophorus ferrugineus* Olivier (COLEOPTERA : CURCULIONIDAE) IN PALMS AND FUTURE THRUSTS

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ABSTRACT : Red Palm Weevil (RPW), *Rhynchophorus ferrugineus* Olivier, has gained the status of a key pest of palms in Asia, Africa and Europe. It is widely distributed in over 20 countries and attacks more than a dozen palm species of which coconut and date palm are of economic importance. In India, the pest has been successfully managed on coconut by employing an Integrated Pest Management (IPM) programme comprising of several tactics. The IPM programme for RPW in coconut has been suitably modified to tackle the pest on date palm in the middle East. At present use of food baited pheromone traps in both surveillance and mass trapping programmes form a vital component of the IPM strategy against RPW.

Assessment of crop loss, search for biotypes if any, behavioral changes of RPW in relation to the changing agro-climatic conditions, influence of environmental factors on the population dynamics, protection given to each-stage of the insect by nature, etc. are some of the important aspects to be studied. Standardization of pheromone trapping methods including use of synthetic food baits, incorporating suitable botanical insecticides in preventive and curative treatments, breeding of tolerant or resistant palm varieties to the pest, introduction of deleterious genes in the pest population, release of sterile male weevils in endemic areas, development of biocontrol techniques, fabrication of a RPW infestation detector, improvement of insecticide application gadgets are necessary for refining the existing IPM programme.

Key Words : IPM, palm, *Rhynchophorus ferrugineus*

INTRODUCTION

The Red Palm Weevil (RPW), *Rhynchophorus ferrugineus* Olivier (Coleoptera : Curculionidae) has a wide distribution as a pest of coconut palm in the South Asian region. In the recent past, the pest has assumed a major role in the pest complex of date palm in middle eastern countries. There are also evidences of its distribution in the Mediterranean

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region of Africa besides its report from Europe. (Esteban - Duran *et al.*, 1998).

Coconut palm (*Cocos nucifera* L.) and date palm (*Phoenix dactylifera* L.) are the economically important species among Palmae attacked by RPW. While coconut yields oil and is considered to be of high utility in the day to day life of millions of people in many parts of the world, date palm is the most common fruit crop providing carbohydrate rich food for millions of people in the middle East. Although the pest is reported on oil palm (*Elaeis guineensis* L), there are no reports to suggest that *R. ferrugineus* is a serious threat to the crop. However, a related species *R. palmarum* is a key pest of oil palm in Latin America. Ever since the appearance of this pest in the middle eastern region in 1985, it has spread to more than ten thousand farms by 1995 and decreased yields from 10 to 0.7 tons/ha in infested areas (Hanounik, 1996). Red palm weevil [illegible] its destructive nature in all places of its distribution. It is a tissue borer having a concealed habitat and hence its management becomes all the more difficult. Till the 1980ss RPW management relied mostly on the use of insecticides.

During the last two decades however, development of pheromone traps has added a new dimension to the Integrated Pest Management (IPM) of RPW. This dreaded pest has been successfully managed on coconut in India using an IPM programme (Abraham and Kurian, 1975; Abraham *et al.*, 1989). This IPM was modified suitably to combat the RPW on date palm in Saudi Arabia taking into consideration the agro-climatic conditions prevailing in the middle East, nature of the date crop and habit of the pest, through research programmes initiated by the Ministry of Agriculture and Water, Kingdom of Saudi Arabia (Abraham *et al.*, 1998), which led to the suppression of the pest in the Kingdom in a short span of four years between 1994 and 1998 (Abraham *et al.*, 2000 a). Though the present IPM has yielded promising results, one should expect that in due course the technology may become less effective as the pest itself tends to change its behaviour to suit the changing ecological and prevailing management practices. This paper besides discussing the distribution and host range of RPW, biotypes, biology and feeding behaviour, status of biocontrol and IPM options currently available to combat the pest, also throws light on thrust areas that need to be studied to refine the existing IPM technology for RPW.

Distribution, host range and seasonal activity

Information on *Rhynchophorus ferrugineus* was first published in 1891 in Indian Museum Notes (1891/3). 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 Mesopotamia (Iraq) on date palm. This pest is distributed in the Tropical Asia from Pakistan to South East Asia. During the last two decades, it has invaded the date palm gardens of Gulf countries. *R. ferrugineus* was reported from United Arab Emirates, Saudi Arabia and Qatar during 1985, from Oman and Kuwait in 1993 (Anonymous, 1995) and from the Republic of Iran in 1992 (Murphy and Briscoe, 1999). The reports on the occurrence of the pest in Egypt in 1992 (Cox, 1993) and Spain in 1993 (Esteban - Duran *et al.*, 1998) are indicative of the spread of the pest to the non-conventional areas.

Adults of RPW are strong fliers. Wattanapongsiri (1966) has reported that they can fly up to 1.2 km uninterrupted. Thus, one of the modes of spread of the pest is by flight. In date plantations of Saudi Arabia and coconut gardens in India it was observed that if one or more RPW infested palms were not detected and treated in time, then new infestations occurred in the immediate vicinity. This shows that 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).

However, the spread of the pest in date gardens from one locality to the other or form one country to another country is mainly through the transportation of planting material *viz.*, off-shoots. The junction at which the off-shoot emerges from the trunk is one of the important sites of egg laying and pest entry. At times young date palms are carried to distant places and transplanted for ornamental or commercial fruit production. These can also be the source of infestation.

R. ferrugineus is specific to plants of the Palmae family and species of palms attacked by RPW are presented in Table 1. It is significant to point out that the host range of the pest has progressively increased from 1956 to 1998, suggesting that RPW is capable of establishing itself in a wide geographical area, where the below mentioned palm species are cultivated.

Abraham *et al.* (1989) found that 6.9 per cent of the palms were infested in an area in Kerala having moderate pest incidence. In Tamil Nadu, Sekhar (2000) reported that 11.65 per cent infestation per hectare in young coconut palms (5-10 years old) resulting in a cumulative loss for 10 years of Rs. 66,000.

Laboratory studies on the ovipositional preference of red palm weevil to different coconut cultivars revealed that Chowghat Green Dwarf was most preferred for egg laying while Malayan Yellow Dwarf was least preferred by the pest (Faleiro and Rangnekar, 2001 a). The coconut hybrid, Tall x Dwarf was also found to be most susceptible to red palm weevil in India (Mazumder, 1995). A large number of date palm varieties are cultivated in the Gulf countries, apart from uncultivated wild varieties growing in the desert areas. In Saudi Arabia, the variety 'Khalas' was found to be more susceptible to red palm weevil attack (Anonymous, 1998). In Pakistan, the highest RPW attack was recorded for the date palm variety Aseel (21.41%) followed by Khurmo (14.5%), Hawawari (14.25%) and Kupro (6.16%) (Baloch *et al.*, 1994).

Knowledge on the varietal resistance or tolerance is necessary for refining the IPM strategy. This will be useful in the breeding programme for resistance in palms against *R. ferrugineus*.

The prevailing weather conditions are known to influence the activity of RPW adults. In Goa along the West coast of India the period between September and November coinciding with the decline of the South- West monsoon was favourable for high activity of the adult weevils. Further, RPW was found to be least active during

Table 1. Host range of *R. ferrugineus* (1956 to 1998)

Sl. No.	Host Palm Species	Reference
1.	*Cocos nucifera, Phoenix dactylifera, Metroxylon sagu* and *Corypha umbraculifera*	Nirula, 1956 a
2.	*Cocos nucifera, Areca catechu, Arenga pinnata, Caryota* sp. *Coelococcus* sp., *Corypha* sp., *Elaeis guineensis, Livistonia* sp., *Metroxylon sagu, Nypa* sp., *Oncosperma* sp. and *Phoenix* sp.	Lever, 1969
3.	*Areca catechu, Arenga pinnata. Borassus flabellifer, Caryota maxima, Caryota cumingii, Cocos nucifera, Corypha gebanga, Corypha umbraculifera, Corypha elata, Elaeis guineensis, Metroxylon sagu, Oreodoxa regia, Phoenix canariensis, Phoenix dactylifera, Phoenix sylvestris, Sabal umbraculifera* and *Washingtonia* sp.	Esteban-Duran *et al.*, 1998

June and July when the rainfall was high (Faleiro and Rangnekar, 2001 b). In Al – Hassa, Saudi Arabia weevil activity was reported to be high during April- May and also during October-November. However, weevil activity was low during August - January at the peak of summer and winter, respectively (Anonymous, 1998).

Biotypes

The pest is distributed over a vast geographical zone with wide extremes of agro-climatic conditions and wide host range of palm species. It is therefore possible that biotypes may occur in *R. ferrugineus*. In India a survey conducted by Ramachandran (1991) has revealed changes in morphology and habit from the samples collected from different parts of the country. Insects collected from Arsikere (Karnataka) were different widely from those collected from Maharashtra and Tamil Nadu. This indicates the possibility of the presence of biotypic variations in coconut RPW. Preliminary studies carried out in India on the possibility of breeding natural populations of the pest from different regions of the country revealed variations in the biotic characters (fecundity and sex ratio) of F_1 and F_2 progenies of weevil (Ramachandran, 1998). In the Gulf countries, weather conditions vary drastically between summer and winter. This varying weather influences the development of the insect (El-Garby, 1996). The generations developing during summer vary in many aspects from the ones developing in winter. Thus, changing weather may influence the insect in its behaviour and morphology.

Biology and feeding behaviour

RPW has a wide geographical distribution and its life history has been studied in several countries. Results pertaining to these studies are presented in Table 2.

Table 2. Life history of *R. ferrugineus* from different countries (duration in days)

Character	Country where study was conducted *					
	India	Indonesia	Myanmar	Philippines	Iran	Spain **
No. eggs/female	127-276	531	300	162-350	162-350	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	13-17	17-50	11-19 male 12-19 female	15-27	19-45
Life cycle period	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	– –

*As reported by Murphy and Briscoe (1999). **Esteban-Duran *et al.* (1998).

Red palm weevil is one of the rare insects that is protected by nature throughout its life span. Eggs are laid in holes, which are made on soft tissues using the rostrum. After egg laying, the opening of the hole is cemented by the insect so that no natural enemy or adverse weather can destroy the eggs. On hatching from the eggs, the grubs start feeding on soft palm tissue by making tunnels. The grubs chew the tissue, work back the chewed fibre and seal the tunnel so that entry of any other organism is prevented. Pupation takes place inside the cocoon, which is made out of fibre from the palm tissue. The thick and strong cocoon protects the weak and tender pupa inside. Thus, the pupal stage is also well protected. The only stage moving outside is the adult weevil, Since the exoskeleton of the adult weevil is very thick and hard, it is difficult for the predators to attack the pest. Thus, all stages of the RPW are well protected by nature. A break in this 'chain of protection' is possible only by introducing biocontrol agents which will strengthen the IPM programme. 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 RPW management programmes.

Symptoms of infestation

RPW is a concealed tissue borer, usually infesting young palms with soft tissue below 20 years old. Infested palms exhibit one or more of the following symptoms *viz.*, presence of tunnels on the trunk and base of leaf petiole, gnawing sound due to feeding by grubs, oozing out of thick brown fluid from the tunnels, appearance of chewed plant tissues in and around opening of tunnels with a typical fermented odour, fallen empty pupal cases and dead adults around a heavily infested palm, breaking of the trunk and toppling of the crown in case of severe and prolonged infestation. Besides these symptoms, in infested date palms often exhibit dried suckers (Abraham and Kurian, 1975; Abraham *et al.*, 1998).

Biological Control

Studies conducted by various workers in different countries have shown that several organisms *viz.*, mites, nematodes, fungi, virus, bacteria and insects are associated with RPW (Table 3).

Table 3. Biocontrol agents associated with *R. ferrugineus*

Sr. No.	Biocontrol agent	Reference
1.	*Scolia erratica* (parasitic wasp)	Friedriches, (1913), Burkill (1917)
2.	Family Scoliidae	Clausen (1940).
3.	*Sarcophaga fusicauda* (Calliphorid fly)	Iyer (1940)
4.	*Tetrapolypus rhynchophori* (predatory mite)	Nirula (1956)
5.	*Chelisochus moris* (earwig)	Abraham and Kurian (1975)
6.	*Platymeris laevicollis* (reduvid bug)	Abraham and Kurian (1975)
7.	*Paraecocilenchus ferruginophours* (nematode)	Rao and Reddy (1980)
8.	*Hypoaspis* sp. (mite)	Peter (1989)
9.	*Cytoplasmis polyhedrosis* virus disease	Gopinadhan *et al* (1990)
10.	*Heterorhabditis* sp. (nematode)	Shamseldean and Abd Elgawad (1994)
11.	*Heterorhabditis* sp. (nematode)	Shamseldean and Abd Elgawad (1994)
12.	*Pseudomonas aeruginosa* (fungus)	Banarjee and Danger (1995)
13.	Yeast from the haemolymph	Danger (1997)
14.	*Steinernema* and *Heterorhabditis* (nematodes)	Hanounik (1998)

The above biocontrol agents have not been exploited for practical use in the field and are of academic value. Finding a suitable biocontrol agent and its utilization in weevil management programmes will strengthen the ongoing IPM programme against RPW.

Integrated pest management strategy for RPW

In coconut RPW has been managed using an IPM programme as recommended by Abraham and Kurian (1975); Abraham *et al.* (1989). The major components of this IPM programme in coconut are surveillance of the pest, maintaining plant and field sanitation, trapping adult weevils, preventive chemical treatment of wounds, treating the crown of bud rot diseased or *Oryctes* attacked palms which attract the weevil, with a combination of fungicide and insecticide, filling the leaf axils of young palms with a mixture of insecticide and sand, curative chemical treatment of infested palm, cutting and burning of severely infested palms, discouraging the making of wounds on the stem and cutting of leaves at a distance of one meter away from the leaf base, and educating farmers and agricultural workers on palm weevil management. This IPM programme first developed and tested on coconut was modified and successfully used to manage RPW on date palm in the middle East (Abraham *et al.*, 1998). The IPM programme for date agro-ecosystem in the middle East revolves around the use of food baited pheromone traps in surveillance and mass trapping programmes. Examining palms to detect RPW infestation specially around pheromone traps recording consistent weevil captures, locating hidden breeding sites, plant and field sanitation, preventive and curative chemical control, adopting quarantine measures to restrict the transport of infested palm suckers and training and education for large scale weevil management are the important components of the IPM programme in date plantations. Recently, Nair *et al.* (2002) has evaluated and recommended an IPM module for red palm weevil in coconut comprising of (i) removal of infested palm, (ii) curative treatment of palms involving treatment of infested palm with 1% carbaryl 50 WP as topical injection using injection funnel or with 10 ml monocrotophos 36SL given as root feeding and (iii) pheromone trapping of adult weevils. This module resulted in substantial reduction of infestation in the field.

Major components of IPM strategy currently used to combat RPW are discussed below.

Surveillance

Detecting the presence of weevil in the plantation is imperative. This can be achieved by taking up periodic surveys for spotting infestation. Manual examination of palms utilizing the symptoms of infestation is commonly used to detect the pest. However, it is very difficult to detect infested palms because of the hidden nature of the pest and due to the delayed expression of the symptoms. Food baited pheromone traps can be used to monitor weevil activity, especially in the areas where the pest is not known to exist. Once detected, further management strategies are to be initiated.

Preventive chemical treatment

Adult weevils hide during the day time in the leaf axils and also lay eggs there. Mathen and Kurian (1966) recommended filling of leaf axils of young coconut palms with five per cent BHC or chlorodane plus sand mixture as a preventive control measure. Entry of the pest in to the palm through the crown, trunk and collar region in date palm was prevented by taking up prophylactic insecticidal treatments of 0.1 per cent endosulfan or carbaryl @ 5 to 10 L per palm in Saudi Arabia (Anonymous, 1998). Insecticide when sprayed on the crown, is absorbed by the matted fibre of the palm and is retained in the leaf axil. Further, treatment of the trunk and the collar region prevents egg laying in the cracks, crevices and cut surface, in these areas. In vast plantations, preventive treatments can be restricted to the palms in the vicinity of an infested area. Recently, Abo-El-Saad *et al.* (2001) assessed the comparative toxicity of four pyrethroid insecticides in the laboratory, which revealed that 0.1 per cent cypermethrin was most effective against all stages of *R. ferrugineus*. Further, laboratory evaluation of certain organophosphorus insecticides by Ajlan *et al.* (2000) indicated that either primiphos-methyl at 0.2 per cent or oxydemeton-methyl at 0.36 per cent is sufficient to kill larval and adult stages of the RPW within three days.

Sealing of wounds

Making of any wound on the trunk of the palm should be discouraged, as it is to these wounds that the female weevil gets attracted for egg laying. Often weevils take shelter inside the split bark and lay eggs on the emerging new root zone. These entry points are to be sealed by applying slurry of clay or soil prepared with 5gm carbaryl 50 WP (Anonymous 1998). The four important points of RPW entry into date palms are (i) junction of offshoot on the stem where the eggs are laid, (ii) deep wounds caused on the palm trunk while removing the offshoot which attract weevils for egg laying, (iii) base of the palm where the bark cracks and (iv) freshly cut petiole ends.

Curative treatment

Curative treatment of an infested palm is done by administering insecticide into the affected palm tissue. 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 will kill the grubs and other stages of the insect inside the trunk (Anonymous 1995). Different insecticides recommended for stem injection to treat RPW infested palms are presented in Table 4.

Table 4. Insecticides effective for stem injection to treat *R. ferrugineus* infested palms.

Sl. No.	Insecticide	Reference
1	1 per cent pyrocone-E (pyrethrins-piperonyl butoxide combination)	Nirula (1956 b)
2	1 per cent carbaryl	Mathen and Kurian (1967)
3	0.2 per cent trichlorphon	Abraham *et al.*, (1975)
4	10 ml monocrotophos + 10 ml water (root feeding)	Rao *et al.*, (1989)

Pheromone trapping

Trapping RPW adults using suitable attractants formed an important component of the IPM strategy prior to the synthesis and availability of pheromone lures. Hagley (1965) reported that 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*. Maharaj (1973) reported that metal traps filled with coconut petioles were effective in attracting the pest in Sri Lanka and Trinidad. However, in India coconut logs proved more effective than metal traps (Kurian *et al.*, 1979). Further, Kurian *et al.* (1984) found that coconut logs treated with toddy (1 L), yeast (5g) and acetic acid (5 ml) attracted significantly more number of adult weevils as compared to other food attractants.

Hallett *et al.* (1993) identified and synthesized the male produced aggregation pheromone "ferrugineol" (4-methyl-5-nonanol) for red palm weevil. Further, Oehlschlager *et al.* (1993) designed a pheromone based trapping system. Food baited pheromone traps are widely used for monitoring weevil activity, to assess the population levels of the pest and also to mass trap the adult weevils. Pheromone trapping is currently a key component of RPW management programmes, both in date and coconut plantations (Abraham *et al.*, 2000 and Faleiro *et al.*, 2002). Weevil captures from date and coconut plantations in Saudi Arabia and India, respectively have been reported to be female dominated (Abraham *et al.*, 1999; Vidyasagar *et al.*, 2000; Abraham *et al.*, 2000), which is desirable in any IPM programme, as it is the females that lay eggs which hatch into damage causing grubs. Different components of pheromone trapping for RPW are discussed below.

Trap design

Bucket traps with pheromone and insecticide treated sugarcane has sustained pheromone based trapping system for *R. palmarum* on oil palm in Latin America (Oehlschlager *et al.*, 1993). Based on this experience bucket traps containing pheromone lure and an insecticide treated food bait is widely used to manage RPW both in date and coconut plantations (Faleiro *et al.*, 1998). Five litre capacity high density polyethylene buckets with four windows (1.5 X 5 cm) cut equidistantly below the upper rim of the bucket are used to fabricate the pheromone traps. Jute sack pieces are usually stuck with adhesive to the outer surface of the trap to provide grip to the attracted weevils and facilitate their entry in to the trap. Besides, a new pheromone sachet, hung to the bucket lid from inside with a piece of wire, the bucket trap contains kairomone releasing food bait mixed in one litre of water. The food volatiles released from the bait act synergistically with ferrugineol released from the pheromone sachet to enhance weevil captures (Hallett *et al.*, 1993; Faleiro and Chellapan, 1999).

Placement of traps

In coconut, highest numbers of *R. ferrugineus* weevils were captured in Indonesia when traps were placed at ground level (Hallett *et al.*, 1999). However, the authors (unpublished data) have found that hanging traps at a height of 1 to 1.5 m was most suitable for obtaining high weevil capture in India. It has been recommended to place traps on the date palm at 1.5 m height from the ground level (Abraham *et al.*, 1998). The recommendation of placing traps at 1.5 m was made based on the study conducted in Costa Rica on oil palm for trapping *R. palmarum* (Oehlschlager *et al.*, 1993). El-Garhy (1996) placed traps at 3 m height on date palm for trapping *R. ferrugineus* in Egypt. Faleiro *et al.*, (1998) recommended the setting of food baited pheromone traps under the shade of palms to extend the longevity of the lure (ferrolure) and also to obtain a uniform release of the chemical in the field

Food baits in traps

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 a study conducted in India, banana was an efficient food bait (Nair *et al.*, 2000). Coconut toddy is used as food bait in Sri Lanka. It is not possible to get date, sugarcane and toddy in all places and different times of the year. Hence, coconut petiole, which is easily available, is commonly used as food bait in pheromone traps in coconut plantations. It is also essential to replace the food bait in the trap every week to maintain the efficacy of the pheromone trapping system

Choice of insecticide in pheromone traps

Abraham (1987) found that dust of BHC 50 per cent @ 2 g/trap was suitable for adding to coconut log traps. Weevils when caught in pheromone traps are killed by the presence of insecticide in the food bait mixture. Oechlschlager *et al.* (1993) recommended 0.1 % lannate for use in pheromone traps. At present in India either 0.1% carbaryl 50 WP or 0.03 per cent carbofuran 3G are used (Faleiro and Satarkar, 2002; Abraham and Nair, 2001).

Longevity of Pheromone lure

Ferrolure + 800 mg is widely used in surveillance and mass trapping programmes through out the world. Studies conducted in western India in coconut plantations of Goa have shown that this lure once used is capable of attracting the pest for five to six months in the field (Faleiro and Rangnekar, 2001 c). 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 be exposed to sunlight, ferrolure+ lasted longer than ferrolure (Faleiro *et al.*, 1999).

Age of Pheromone trapped weevils

It is essential to know the age and also the reproductive status of pheromone trap captured RPW adults so as to judge the impact of pheromone trapping on the over all build up of the pest population, especially in mass trapping programmes. Pheromone trap captured female weevils collected from date plantations of Al Hassa in Saudi Arabia were found to be young, gravid and fertile (Abraham *et al.*, 2000 b). Female RPW adults attracted to pheromone traps in coconut gardens of India were also found to be young, fertile and gravid (Faleiro, 2000). This indicates that at present ferrugineol based pheromone traps not only monitor RPW activity, but also suppress 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 weevil per trap to 6.4 per traps (Oehlschlager *et al.*, 1995). Mass trapping of RPW adults together with other management tactics over a period of four years between 1994 to 1995 significantly reduced infestation levels in date palm plantations of Saudi Arabia (Abraham *et al.*, 2000a and Vidyasagar *et al.*, 2000).

Attraction of RPW to ferrugineol based pheromone lures

The most widely used ferrugineol based pheromone lure in RPW management programmes is manufactured by Chem Tica Natural, Costa Rica, which is commercially available as ferrolure and ferrolure+ (with additive). However, Agrisense, UK, Calliope, France and ISCA Technologies, USA have also synthesized ferrugineol based pheromone lures for attracting RPW. Results on the weevil attracting potential of different ferrugineol based lures in date plantations of Al-Hassa, Saudi Arabia, indicated that high release lures obtained from Chem Tica Natural, Costa Rica attracted twice as many weevil, as compared to low release formulation of Chem Tica. Further, ferrolure and ferrolure + were equally effective in attracting the pest. Both were however at par with Agrisence lures from UK but ferrolure+ was superior to Calliope formulation from France (Faleiro *et al.*, 2000). In coconut too, it was found that the Costa Rican formulation was superior to Agrisense formulation from UK (Faleiro and Chellapan 1999).

The above IPM strategy for RPW as yielded positive results in both coconut and date plantations but may become less effective in due course of time as the pest itself could change its behaviour to suit the changing ecological and prevailing management practices. In view of this, the following areas of work are suggested to refine the existing IPM practices.

Future thrusts

Red palm weevil, the most dreaded pest of coconut and date palm is at present managed by a IPM strategy comprising of several tactics (Abraham *et al.*, 1998). This IPM strategy is largely based on the use of pheromones and insecticides. Advancement of existing IPM technology is necessary to make it more effective, ecofriendly and acceptable to the user. Assessment of crop loss, possibility of biotypes of the pest existing in different agro- ecosystems, population dynamics and effect of environmental factors on the pest population, special care by nature given to each stage of the insect are factors to be studied for refining the current technology. Minimizing the use of insecticide for preventive as well as curative treatments, incorporating botanical insecticides in the IPM programme, standardizing and refining pheromone trapping techniques including development of synthetic food bait for pheromone traps, breeding palms for tolerance or resistance to the pest, introduction of deleterious genes in the pest population, release of sterile male weevil in endemic areas, developing biocontrol techniques for RPW management, fabrication of an early infestation detector, improvement of insecticide application gadgets are suggested for further studies to refine the existing IPM programme.

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