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Insight in to the management of red palm weevil *Rhyncophorus ferrugineus* Olivier: Based on experiences on coconut in India and date palm in Saudi Arabia

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Abstract

Red Palm Weevil (RPW) *Rhyncophorus ferrugineus* Olivier (Coleoptera: Rhynchophoridae) is a lethal pest of palms distributed in diverse ecological habitats and is reported to attack 17 species of palms in nearly 30 countries. Although, the native home of RPW is South Asia where it attacks coconut, *Cocos nucifera*, during the last two decades it has invaded countries in the Middle East and Europe where it has become a serious threat to the cultivation of date palm, *Phoenix dactylifera*. RPW is a concealed tissue borer difficult to detect. Infested palms detected in the early stage of attack are easy to control with insecticide. However, palms in the late stage of attack do not respond to chemical treatment and often die. Usually palms below the age of 20 years are preferred by the pest.

During the mid seventies RPW has been managed on coconut in India using an Integrated approach, which has been suitably modified to manage the pest on date palm in the Middle East, where in the use of food baited pheromone (ferruginuol) traps play an important role. The pheromone based IPM strategy has been successfully employed to suppress this pest both in coconut and date palm in several countries and comprises of the following major components *viz.* surveillance using monitor traps, mass trapping in endemic pockets, checking palms and locating infestations based on pheromone trap captures, repeat checking of the heavily infested gardens, eliminating hidden breeding sites, clearing abandoned gardens, maintaining strict phyto-sanitary regimes, preventive and curative insecticidal application, implementing quarantine regulations and enhancing human resource capabilities with regard to RPW-IPM through training and extension. It is advocated to implement this strategy through a wide area farmer participatory programme under technical supervision. Although, other IPM options like biological control, host plant resistance and male sterile technique are available, more needs to be done for their exploitation in the field. The use of endoscope, electronic sounding devices and sniffer dogs have been reported to assist in the detection of RPW infested palms and can enhance the efficiency of the above IPM programme. This paper presents an insight in to the management of RPW and describes various aspects of a pheromone based IPM strategy for RPW, based on the experiences of the author during the past decade in coconut and date palm agro- ecosystems.

Key Words: *Rhyncophorus ferrugineus*, date palm, coconut palm, pheromone trapping, IPM

Introduction

Red Palm Weevil (RPW) *Rhyncophorus ferrugineus* Olivier (Coleoptera: Rhynchophoridae) is the most lethal pest of palms and is reported to attack 17 species of palms world wide (Esteban-Duran *et al.*, 1998). Although the home of RPW is South Asia where it attacks coconut, *Cocos nucifera*, only 15 per cent of the coconut growing countries have reported the incidence of RPW. Since the mid nineteen eighties it has caused wide spread damage to date palm, *Phoenix dactylifera* in the Middle East and Europe and has been reported from nearly 50 per cent of date palm growing countries world wide. The quick spread of RPW in the date growing countries of the world, calls for implementing suitable Integrated Pest Management (IPM) strategies for RPW in date palm. The concealed nature of the pest

makes detection of infested palms a difficult task. Usually, palms in the late stage of infestation do not respond to chemical treatment and often die. However, palms in the early stage of attack can be cured with insecticide. RPW usually attacks palms of less than 20 years of age and damage due to RPW may result in one of the following symptoms depending upon the stage of infestation

- (i) presence of tunnels on the trunk and base of leaf petiole.
- (ii) gnawing sound due to feeding by grubs.
- (iii) oozing out of thick brown fluid from the tunnels.
- (iv) appearance of chewed plant tissues in and around opening of tunnels with a typical fermented odour.
- (v) fallen empty pupal cases and dead adults around a heavily infested palm.
- (vi) breaking of the trunk or toppling of the crown in case of severe and prolonged infestation and
- (vii) drying of offshoots in date palm.

In the field, the above damage symptoms can be perceived either through sight, sound (caused by feeding of grubs) or by smelling the typical fermented odour of infested palm tissue. The success of any RPW-IPM programme would lie in the ability of the field staff to detect infested palms in early stage of attack. Infestation detecting aids *viz.* endoscope (Hamad Saad Al-Saad and Mahdi, 2004), sounding equipments to pickup gnawing sound by feeding grubs (Abraham *et. al.*, 1966 ; Soroker *et. al.*, 2004) and use of sniffer dogs (Nakash *et. al.*, 2000) to detect infested palms could play an important role in enhancing the efficiency of the RPW-IPM programme.

Due to the lethal nature of the pest and high value of the crops involved, the assumed action threshold for RPW in coconut and date palm is very low. In small gardens farmers are advised to initiate action even if one infestation is detected, especially when the palms are in the susceptible age group. In big plantations and where RPW-IPM programme is to implemented on a large scale the assumed action threshold would be one per cent infested palms. The challenge in the successful implementation of a RPW-IPM programme would be to maintain infestation levels below 1 per cent in a given operational area, as eradication of this pest is difficult.

During the mid seventies RPW has been managed on coconut in India using an Integrated approach, (Abraham and Kurian, 1975). The synthesis of the male produced aggregation pheromone by Hallett *et. al.*, 1993 and its subsequent adoption as an IPM tool to manage RPW on date palm and coconut has effectively suppressed the pest in several countries where RPW is a problem (Abraham *et. al.*, 1998; Vidyasagar *et. al.*, 2000; Anonymous, 2004; Soroker *et. al.*, 2005; Faleiro, 2005).

This article presents various aspects of a pheromone based IPM strategy, based on experiences of managing the pest over the last decade in coconut and date palm plantations of India and Saudi Arabia.

Spatial distribution and seasonal incidence

Spatial distribution studies of pest population besides serving as the base for decision making to implement pest management techniques in the field (Bechinski and Pedigo, 1981) is also one of the most important characteristic ecological properties of a species (Taylor, 1984). Insect populations normally follow i) uniform ii) random and iii) aggregated spatial distribution patterns. Distribution studies conducted in Goa, India using pheromone trap captures between August, 1999 and July, 2000 revealed that RPW population was highly aggregated or clumped in nature (Faleiro *et. al.*, 2002) and could have a direct implication on the control strategy has seen in Al-Hassa area of Saudi Arabia, where infestation were observed to occur in clusters due to the aggregated distribution of RPW. Date plantations in the vicinity of such infested gardens were prone to repeated attack by RPW (Anonymous, 1998).

The 40 pheromone traps set through out the State of Goa during 1999 were also used to collect information on the seasonal activity of the RPW in the State. Month wise weevil captures between August, 1999 and December, 2001 showed that weevil activity was high after the monsoon between

October and November, while low adult activity of the pest was noticed during the monsoon between June and July. The weevil captures were female dominated and for every male weevil trapped two female weevils were captured (Faleiro, 2005). In Saudi Arabia the pest is reported to be most active during May with a second peak during November (Anonymous, 1998). The activity of pest was low at the peak of summer and winter during August and February, respectively. Data on weevil captures vis-a-vis infestation in Saudi Arabia indicate that the first adult activity peak of May resulted in the subsequent higher proportion of infestation occurring from June to November. However, the second adult activity peak of November did not result in infestations during the succeeding months from December to May probably due to the adverse effect of the cold winter months had on egg hatch (Anonymous, 1998). Reports from Egypt indicate that the threshold for RPW was in the range of 12-14°C with very low captures between December to January (El-Garhy, 1996).

Study on diurnal activity of RPW using pheromone traps in coconut plantations of Goa, showed that RPW adults prefer to fly between twelve at mid night and six in the morning (Faleiro and Satarkar, 2003).

IPM strategy for RPW

The major components of the IPM strategy against RPW are i) Phytosanitation, ii) Avoid making wounds, iii) Take up preventive insecticidal sprays in endemic pockets, iv) Surveillance (trapping/infestation reports), v) Mass trapping with pheromone traps, vi) Curative chemical treatments, vii) Treat breeding sites, viii) Implement strict quarantine measures and ix) Training and Education. A pheromone based RPW-IPM strategy would involve the following steps.

- ✓ Set monitor traps
- ✓ Implement mass trapping (based on infestation reports and weevil captures in monitors)
- ✓ Check palms around traps recording weevil captures on a weekly basis
- ✓ Treat infested palms (curative control)
- ✓ Eradicate heavily infested palms
- ✓ Take-up preventive insecticidal sprays in and around eradicated/ treated palms.
- ✓ Go in for repeat checking and spraying of palms around traps (50 to 100m) recording high weevil captures and also around gardens where heavily infested palms are eradicated.
- ✓ Implement other components of the regular RPW-IPM programme (phyto-sanitation, quarantine, training and extension, treat breeding sites, watch closed gardens, avoid making wounds etc).

This pheromone based IPM strategy besides successfully combating the pest on date palm in Saudi Arabia (Abraham *et. al.*, 2000; Vidyasagar *et. al.*, 2000) has also been successfully implemented in Israel, Jordan and Palestine (Anonymous, 2004; Soroker *et. al.*, 2005). In coconut a pheromone based IPM strategy was used to suppress the pest in Goa, India (Faleiro, 2005).

Pheromone trapping efficiency

Henry, 1917 was the first to suggest that Kitul palm wood might be effective to trap adult weevils. Later, coconut log traps were effectively used to manage RPW on coconut in India (Kurian *et. al.*, 1979). Further, synthesis of the male produced aggregation pheromone (4methyl-5-nonanol) by Hallett *et. al.*, 1993 formed the basis of RPW management in several countries. Although, 4methyl-5-nonanol is the major component of ferruginol the activity of 4methyl-5-nonanone a minor component as also been demonstrated (Oehlschlager, 1998).

It is imperative to sustain the efficiency of the pheromone traps in the field. The physical and chemical aspects of the ferruginol based-food baited bucket traps were studied in coconut plantations in Goa

through extensive field experiments (Faleiro, 2005). Results pertaining to these studies and those reported from elsewhere are presented below.

- ✓ Field testing of various trapping densities revealed that, the recommended trap density of 1 trap/ha with ferrolure+ was sufficient to maintain the trapping efficiency of a mass trapping programme. In endemic pockets with heavy infestations an initial trapping density of 2-3 traps per ha could be maintained for 6-12 months, which can be subsequently scaled down to 1 trap/ha. In Al-Hassa region of Saudi Arabia mass trapping of RPW in 4000 ha. date plantation was successfully carried out at a trapping density of 1 trap per 1.5 ha. An initial trapping density of 1 trap per 3 ha was found to be inadequate as, some of the adults from heavily infested palms were not trapped at this density. Between 1994 and 1998 the pest was monitored in the pest free areas of Al-Hassa at a trap density of 1 trap/100ha. (Anonymous, 1998). Depending upon the availability of man power a closer watch could be kept on the pest in such areas by operating at a density of 1 trap for every 10-20 ha.
- ✓ Colour of traps did not significantly influence weevil captures. However, traps with jute sack wrapping registered higher weevil captures. In the United Arab Emirates, specially fabricated plastic traps with a rough exterior surface have now been designed. Hallett *et. al.*, 1999 recorded higher weevil captures in black bucket traps as compared to white traps. Ajlan and Abdul Salam, 2000 recorded superior weevil captures in green reusable bucket traps as compared to white and yellow.
- ✓ Weevil captures were not impaired even when the kairomone (plant volatile) releasing food bait (coconut petiole bits) was not replaced in the trap for one month. However, water in the trap had to be replenished if traps were not serviced beyond 15 days. Reports from Costa Rica indicate that non repellent additives extend the effective life of trap food bait from 2 to 7 weeks without addition of water (Oehlschlager, 2004).
- ✓ Vertical preference for trap heights indicated that highest weevil captures (30.4 weevils per trap) were recorded when traps were placed at a height of 1.0m from the ground. Traps placed at waist height on tree trunks are easy to service as compared to traps set at ground level.
- ✓ Best weevil captures were obtained when traps were serviced (replacing food bait and insecticide solution) every ten days.
- ✓ Carbofuran 3G (0.05%) was found to be most suitable for use in RPW pheromone traps to kill trapped weevils. Carbofuran and carbaryl were found to be effective for retaining captured weevils *R. palmarum* in oil palm plantations in Malaysia (Oehlschlager *et. al.*, 1993). Insecticide free funnel traps have also been reported to be useful in retaining captured weevils (Hallett *et. al.*, 1999).
- ✓ Weevil captures through out the period of study showed that the catches were female dominated. For every male weevil trapped two female weevils were captured. Female dominant captures have also been reported from several countries. This is good from the weevil management point of view, as it is the female weevils that lay eggs which hatch into damage inflicting grubs.
- ✓ Different kairomone-releasing food baits indicated that dates (*khajur*) when used in the pheromone traps gave the highest captures (79.3 weevils per trap), which was at par with sugarcane (54.00) and significantly different from coconut petiole (36.00). However, coconut petiole is the most economical and easily available food bait. Oehlschlager, 2004 has reported that the trapping is most efficient for all palm weevils if aggregation pheromones are used with food bait and ethyl acetate.
- ✓ Food bait quantities (coconut petiole) ranging from zero to 500 g per trap were tested and it was found that coconut petiole at 200g per trap was sufficient to maintain the trapping efficiency.
- ✓ In Goa the field life of the costly pheromone lure (Ferrolure +, 800mg) could be extended for upto five months by setting traps under shade, without impairing the trapping efficiency which

could be maintained even with a low release of 0.48 mg per day. Prevailing weather conditions significantly ($R^2 = 0.46$) influenced the release of pheromone in the field. In Saudi Arabia the same lure was found to have field longevity of 4-5 months (Faleiro *et. al.*, 1999). Release rates of 3 mg for 24 hrs have reported to be superior to lower doses from trials conducted in Indonesia (Hallett, *et. al.*, 1999).

- ✓ Ferrugineol based lures from India, Costa Rica, USA and Holland revealed that pherobank lure, 400mg from Holland was superior to the commonly used ferrolure+ 800mg. The indigenously produced Central Plantation Crops Research Institute (CPCRI, Kerala, India) lure was 50 per cent efficient in attracting the pest as compared to ferrolure+ 800mg. Also, it is essential to use food bait along with the chemical lure in the trap to sustain the trapping efficiency. The lure synthesized by CPCRI Kasargod, Kerala can be economical if available commercially.

It is interesting to note that Chem Tica International, Costa Rica is looking in to the possibilities of finding repellents for *R. ferrugineus*. This holds promise for the future and raises the possibilities of using repellents to deter attack at that portion of the palm which is most vulnerable, besides enhancing the trapping efficiency through push-pull strategies (Oehlschlager, 2004). Laboratory studies conducted on pheromone trap captured RPW adults from coconut and date plantations of India and Saudi Arabia have shown that the female weevils besides being young are also gravid and fertile (Abraham *et. al.*, 2001; Faleiro *et. al.*, 2003). These adult female weevils probably fly out in search of a suitable host for egg laying. RPW food baited pheromone traps therefore curtail the population build up in the field, besides serving as monitors in surveillance programmes.

Trap design and operational tips

Based on experiences of trapping *R. palmarum* in oil palm the size and shape of traps can vary (Oehlschlager, *et. al.* 1993). The early trials in Saudi Arabia during 1994 were carried out with inverted black plastic bucket trap with four windows cut on the sides and a plastic plate fastened to hold the food bait and insecticide soup (Oehlschlager, 1994). These inverted bucket traps though sustaining weevil captures, were not easy to service due to difficulties in untying of the plastic plate attached to the bottom (Anonymous, 1998). Hence, the four window upright bucket model as described below and used extensively in Saudi Arabia and India came into being for the first time in Saudi Arabia.

In this model, a new five litre capacity high density polyethylene bucket with four windows (1.5 X 5 cm²) cut equidistantly below the upper rim of the bucket are used to fabricate the pheromone trap. Jute sack pieces are 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 lure hung to the bucket lid from inside with a piece of wire, the bucket trap contains 200g of a kairomone releasing food bait (dates, coconut petiole, sugarcane etc.) mixed in one litre of insecticide solution (0.05% carbofuran 3G). The palm volatiles released from the food bait act synergistically with ferrugineol released from the pheromone dispenser to attract weevils in to the traps. The insecticide solution kills the trapped weevils. Traps thus prepared are to be numbered and placed under the shade of palm canopy at a height of one meter from the ground to obtain an uniform and sustained release of the chemical in the field.

Using pheromone trap capture data to locate infestations and treat endemic pockets with insecticide sprays can help to judiciously use the resources (men and material), while operating in vast tracts of RPW infested areas. It is therefore essential to number each pheromone trap placed in the field. Such numbered traps can be easily identified and the plantation surrounding this trap can be marked for appropriate IPM action (checking, spraying, etc.)

Pheromone lure -food bait synergism

Adults of *R. ferrugineus* and *R. palmarum* have been reported to be highly attracted to a combination of aggregation pheromone and volatiles secreted by palms (Hallett *et. al.*, 1999, Rochat *et. al.*, 2000). There are several studies to show that attractiveness of the male produced aggregation pheromone of RPW is synergized by adding food to traps (Oehlschlager, 1994, Nair *et. al.*, 2000, Faleiro and Satarkar, 2002). It is essential to maximize synergism between the synthetic pheromone lure and the kairomone releasing food bait used in the trap. This can be achieved by using good and easily available food bait (200-300g) mixed with 1L water containing insecticide/soap. The insecticide/soap would help retain the captured weevils in the trap.

RPW pheromone traps that are not serviced periodically (7-10 days) and go dry due to lack of water may trigger synergism between the synthetic lure and the palms surrounding such a trap. This could make pheromone trapping a counter productive activity, as palms in the vicinity of such a dying/ dead trap could be exposed to RPW. The same inference could be used against the use of dry food baits (just dates without water) which could trigger a “palm- lure” synergism, instead of a “bait- lure” synergism. The later is desirable as it is confined to the trap and would therefore attract the adults into the trap instead of leading them to the palm when the former (palm-lure) becomes active. In order to harvest the advantages of pheromone trapping in a RPW-IPM programme and counter the possible egg laying by weevils arriving to the trap, palms of susceptible age group surrounding a trap (50-100m radius) may be periodically secured with insecticide cover sprays.

Chemical Control

The use of insecticides is vital in the management of RPW both on coconut and date palm. Excessive dependence on insecticide based control strategies can often lead to several drawbacks viz. development of insecticidal resistance in target species, resurgence of pests of minor status to key pests, adverse effect on beneficial non target species and insecticide residues (bio accumulation) in the food chain. The above pheromone based IPM strategy for RPW can play a crucial role in the judicious use of insecticides. In both coconut and date palm, insecticides have been used for both preventive and curative control as a listed below.

Preventive

- Leaf axil filling (coconut)
- Spraying/ Soaking (coconut/ date palm)
- Protecting wounds with insecticide (coconut/ date palm)
- Dipping offshoots in insecticide for quarantine purpose (date palm)
- Soil application (date palm)

Curative

- Trunk Injection (coconut/ date palm)
- Fumigation (coconut/ date palm)
- Root feeding (coconut)

Abraham, 1971 highlighted the importance of treating wounds of palm tissue with insecticide to prevent egg laying by RPW. Periodic leaf axil filling with Benzene Hexa Chloride (BHC) dust + sand helped to repel RPW in coconut. Further, cutting of coconut leaf petioles 1 m away from the leaf base prevented entry of grubs in to the trunk (Abraham, 1989). Spraying/soaking of palms in endemic pockets can help to prevent attack due to RPW. It would be advisable to spray trunks of bigger date palms immediately after removal of petioles to prevent egg laying.

In *P. canariensis*, where the leaves are cut close to the trunk, it is essential to spray the injured and exposed leaf base with insecticide immediately after the leaf is cut and before the plant tissue dries. This would prevent the wounded leaf base close to the trunk from attracting female weevils for egg laying.

In order to avoid environmental pollution associated with spraying of insecticides through power sprayers, researchers in Saudi Arabia devised an insecticide spray lance without a nozzle that would enable “soaking” of the date palm trunk from the top to bottom with insecticide (Anonymous, 1998). Trunk injection with insecticide (drill-pour-plug) has been recommended by several workers as a significant curative measures to treat infested palms (Nirula, 1953; Abraham *et. al.*, 1975; Abad and Gallego, 1978; Hernandez- Marante, *et. al.*, 2003). Experiences on date palm in Saudi Arabia suggest that depending upon severity of damage, repeated (2-3 times) trunk injection of insecticide is essential to ensure control of infested palm. Coconut palm cavities containing different stages of the pest have been reported to be treated with alluminium phosphide tablets that generate phosphine gas which has fumigant action on the pest. Sealing of all holes is essential to ensure success of this treatment (Lakshmanan *et. al.*, 1972). Application of monocrotophos through root feeding (10ml/palm) diluted with equal amount of water was effective to control RPW in coconut (Ganeswara Rao *et. al.*, 1989). Treating infested palms with alluminium phosphate tablets and application of insecticides through root feeding have their own limitations and are not popular.

Proposed quarantine protocol

Treating date palm offshoots or other ornamental palms with insecticide, prior to being moved/transported would prevent the spread of the RPW through planting material and must be considered as an important component of the RPW- IPM programme that offers the much needed quarantine security against RPW. This, if done under supervision and proper certification would play a major role in preventing spread of the pest to new gardens/regions/countries, while also eliminating the possibility of re-infestation in gardens where RPW has been controlled.

In regions/ countries where planting material is imported from RPW infested areas it is advisable to adopt strict pre- departure (3 months) and post-entry (6 months) quarantine protocols. Palms targeted for sale by nurseries in RPW infested regions/countries should treat (soak/ soil application) such palms with insecticide at 20 day interval for at least 3 months before being shipped/transported. Such treated and certified palms once received by the importing country needs to be closely monitored and treated with regular insecticide treatment before these palms are certified as RPW free and ready for sale. Besides, caging of individual trees with a mesh net (Soroker *et.al*, 2005) by the importing agency could serve as a useful post-entry quarantine protocol, which would restrict the spread of adults if any, besides identifying and eliminating infested material.

Other IPM options

1. Biological Control

Several natural enemies have been reported to attack *R. ferrugineus* in nature (Table 1). Although, Murphy and Briscoe 1999 have highlighted the prospect of biological control as a component of the RPW-IPM strategy, none of the natural enemies enlisted above are known to be applied against RPW

Table 1. Natural enemies of *Rhyncophorus ferrugineus*

Sr. No.	Potential Biocontrol Agents	Scientific Name
1	Insects (Wasp, Earwig)	<i>Scolia erratica</i> , <i>Sarcophaga fuscicauda</i> , <i>Chelisoches moris</i>

2	Bacteria	<i>Pseudomonas aeruginosa</i> , <i>Bacillus sp.</i> , <i>Serratia sp.</i> , <i>B. sphaericus</i> , <i>B. mgaterium</i> , <i>B. laterosporus</i> , and <i>B. thuringiensis</i>
3	Fungus	<i>Beauveria bassiana</i> , <i>Metarhizium anisopliae</i> , and <i>Beauveria sp.</i>
4	Virus	Cytoplasmic Polyhedrosis Virus (CPV),
5	Yeast	-----
6	Entomo-Pathogenic Nematodes (EPN)	<i>Heterorhabditis sp.</i> , <i>Steinernema abbasi</i> , <i>Heterorhabditis indicus</i> , <i>Teratorhabditis palmarum</i> , <i>Steinerema sp.</i> , <i>H. indica</i> , and <i>Rhabditis sp.</i>
7	Birds (Indian tree pie bird and Crow pheasant bird)	<i>Dendrocitta vagabunda parvula</i>

The concealed nature of the pest makes it rather difficult for any biotic factor to influence the population of RPW in the field. However, the search for an effective natural enemy of red palm weevil must go on. Once identified, this natural enemy would need to be conserved in its original agro-habitat, besides being introduced in to alien agro-ecosystems through mass production techniques.

2. Host Plant Resistant (HPR)

Painter, 1951 described plant resistance as the relative amount of heritable qualities that influence the ultimate degree of damage done by the insect. Barranco *et. al.*, 2002 have reported certain palm species to be resistant to RPW in Spain. Reports from Iran suggest that sugar in date palm varieties enhanced growth, daily oviposition and reduced mortality while, calcium was found to inhibit the growth of RPW (Farazmand 2002). The same laboratory has also reported that RPW could not complete its life cycle on wild palm *Nannorrhops ritchiana*, while Mazafati variety of date palm was the most preferred host for RPW.

Laboratory studies with six coconut cultivars from India, revealed that the cultivar, Malayan Yellow Dwarf was least preferred by RPW for egg laying. While, maximum number of eggs were laid in Chowghat Green Dwarf (Faleiro and Rangnekar, 2001).

Thus, there exists a good possibility of inducing resistance to RPW in both date palm and coconut through classical plant breeding and modern biotechnology techniques. This IPM component must be pursued as a long term IPM option in the fight against RPW.

3. Male Sterile Technique (MST)

The feasibility of using the sterile insect technique against RPW was evaluated for the first time by Rahalkar *et. al.*, 1973. Irradiation of male weevils with a dose of 1.5 K rad, 1 to 2 days after emergence from cocoons induced sterility to the extent of 90 per cent. During 1974 sterile male weevils were released in large scale field trials in 400 ha coconut plantations of Kerala, India, comprising nearly of 20,000 young palms with a damage level due to RPW of 6.4 per cent. Follow up studies made with females collected from the experimental areas using coconut log traps showed that viability of eggs laid by these weevils was 70 per cent (Anonymous, 1974). This was probably due to the fact that the female weevils had already mated with normal males inside the infested palms itself before flying out for egg laying. Recent studies (Krishnakumar and Maheshwari, 2004) have shown that when irradiated males when replaced by normal males, egg hatch increased from 7.04 to 67.19 per cent. The concealed nature of the pest and the opportunity for female weevils to mate with normal males in the field limits the success of this technique.

Conclusion

Managing RPW both in coconut and date palm is an intricate task that needs a complete understanding of the pest, the host and the eco-system. With the management options currently available a pheromone based IPM strategy offers a practical and sustainable option in both coconut and date palm. Wide area farmer participatory pheromone based, RPW-IPM programmes can effectively suppress the pest if implemented under proper supervision. Early detection of infestation in the field is vital for the success of such a programme. Developing, standardizing and implementing plant quarantine protocols are essential to check the movement of RPW in to new areas within a given eco-system and also from one ecological habitat to another, besides preventing re-infestation of areas where the pest has been already controlled. Finding effective natural enemies of RPW, coupled with the introduction of host plant resistance can go a long way in strengthening the existing RPW-IPM programme.

References

- Abad, R.G. and Gallego, V.C. 1978. Chemical control of Asiatic palm weevil through the drill-pour-plug method. Paper presented at the *Ninth Ann. Con. Pese Control Counc. Philipp.*, PICC, Manila. May 2-6.
- Abraham, V.A., K. Mathen and Kurian C. 1966. Aids to Detect Red Palm Weevil infestation in coconut palm. *Cococnut Bull*, **20** (7):145-146.
- Abraham, V.A. 1971. Prevention of red palm weevil entry in to coconut palms through wounds. *Mysore Journal Agril. Sci.*, **5** :121-122.
- Abraham, V.A. and Kurian, C. 1975. An integrated approach to the control *Rhynchophorus ferrugineus* F. the red weevil of coconut palm. *Proceedings, 4th Session of the FAO Technical Work Party on Coconut Production Protect Processing*. Kingston, Jamaica, September 14-25.
- Abraham, V.A., Abdullakoya, K.M. and Kurian, C. 1989. Integrated management of red palm weevil (*Rhynchophorus ferrugineus* Oliv.) in coconut gardens. *Journal of Plantation Crops*. **16** (Supplement): 159-162.
- Abraham, V.A., Al-Shuaibi, M.A., Faleiro, J.R., Abozuhairah, R.A. and Vidyasagar, P.S.P.V. 1998. An integrated Management approach for red palm weevil, *Rhynchophorus ferrugineus* Olivier -A key pest of date palm in the Middle East. *Agricultural Sciences*, **3** :77-83.
- Abraham, V.A., Faleiro, J.R., Al-Shuaibi, M.A. and Prem Kumar, T. 2000. A strategy to manage red palm weevil *Rhynchophorus ferruginous* Oliv. in date palm *Phoenix dactylifera*. Its successful implementation in Al-Hassa, Kingdom of Saudi Arabia. *Pestology*, **24** (12): 23-30
- Abraham, V.A., Faleiro, J.R., Al-Shuaibi, M.A. and Abdan, S. 2001. Status of Pheromone trap captured female red palm weevil from date gardens of Saudi Arabia. *Journal of Tropical Agriculture*, **39** : 197-199.
- Ajlan, A.M. and Abdulsalam, K.S. 2000. Efficiency of pheromone traps for controlling the red palm weevil *Rhynchophorus ferruginous* (Olivier) (Coleoptera: Curculionidae), under Saudi Arabia conditions. *Bull. ent. Soc. Egypt Econ. Ser.*, **27** (109).
- Anonymous, 1974. Annual report Central Plantation Crops Research Institute, Kerala, India.
- Anonymous, 1998. Final report of the Indian Technical Team (Part A), - Red palm weevil control project, Ministry of Agriculture and Water, Kingdom of Saudi Arabia, pp 1-65.
- Anonymous, 2004. The Middle East Red Palm Weevil Programme, July 1998 to June, 2004 (Final report) published by The Peres Center for Peace, Israel, 62pp.
- Barranco, P., Pena, J. A. Dela, Martin, M.M., Cabello, T. 2002. Host rank for *Rhynchophorus ferrugineus* (Olivier, 1790) and host diameter. (Coleoptera: Cuculionidae). *Bolentin de Sanidad Vegetal, Plagas*, **26** (1): 73-78.

- Bechinski, E.J. and Pedigo, L.P. (1981) Population dispersion and development of sampling plans of *Orius insidiosus* and *Nabis* Spp. In Soyabeans. *Environ. Entomol.*, **10** : 835-841.
- El-Garhy, M. E. 1996. Field evaluation of the aggregation pheromone of the red palm weevil, *Rhynchophorus ferrugineus* in Egypt. *Brighton crop protection conference: Pest and diseases*, **3** : 1059-1064.
- Esteban - Duran, J., Yela, J. L., Beitia Crespo, F. and Jimenez Alvarez, A. 1998. Biology of red palm weevil, *Rhynchophorus ferrugineus* (Olivier) in the laboratory and field, life cycle, biological characteristics in its zone-of introduction in Spain, biological method of detection and possible control. (Coleoptera: Curculionidae: Rhynchophorinae) *Boletin-de-Sanidad- Vegetal*, **24** :737-748.
- Faleiro, J. R., Al-Shuaibi, M.A., Abraham, V.A. and Prem Kumar, T.1999. A Technique to assess the longevity of the pheromone (Ferrolure) used in trapping the date red palm weevil, *Rhynchophorus ferrugineus* Oliv. *Agricultural Sciences*, **4** (1): 5-9.
- Faleiro J. R. and Rangnekar, P.A. 2001. Ovipositional Preference of Red Palm Weevil *Rhynchophorus ferrugineus* Oliv. to Coconut Cultivars. *Indian Coconut Journal*, **32** (6): 22-23.
- Faleiro, J. R., Kumar, A. J. and Rangnekar, P.A. 2002. Spatial distribution of red palm weevil, *Rhynchophorus ferrugineus* Oliv. (Coleoptera: Curculionidae) in coconut plantations. *Crop Protection*, **21**(2): 171-176.
- Faleiro J. R. and Satarkar, V. R. 2002. Sustaining trapping efficiency of red palm weevil, *Rhynchophorus ferrugineus* (Olivier) pheromone traps by periodic replacement of food baits. National Seminar on Resources management in plant Protection during twenty first Century. Hyderabad, India, 14-15, November .
- Faleiro J. R., Rangnekar, P.A. and Satarkar, V. R. 2003. Age and fecundity of female red palm weevils *Rhynchophorus ferrugineus* (Olivier) (Coleoptera : Rhynchophoridae) captured by pheromone traps in coconut plantations of India. *Crop Protection*, **22** : 999-1002.
- Faleiro J. R. and Satarkar, V. R. 2003. Diurnal activity of red palm weevil, *Rhynchophorus ferrugineus* Olivier in coconut plantations of Goa. *Insect Environment*, **9** (2): 63-64.
- Faleiro J. R. 2005. Pheromone technology for the management of red palm weevil *Rhynchophorus ferrugineus* (Olivier) (Coleoptera : Rhynchophoridae) –A key pest of coconut, *Technical Bulletin* No.4, ICAR Research Complex for Goa.40pp.
- Farazmand H. 2002. Investigation on the reasons to food preference of Red Palm Weevil *Rhynchophorus ferrugineus* Oliv. *Applied entomology and Phytopathology*, **70** (1): 11-12.
- Ganeswara Rao, A., Ramamohana, Rao, P., Ramamohana, Rao, T. and Laxminarayana, K. 1989. Studies on the effect of root feeding of systemic insecticides in the control of red palm weevil, *Rhynchophorus ferrugineus* Fab. In coconut. *Indian Coconut Journal*, **19** (9): 12-16.
- Hallett, R.H., Gries, G., Borden, J.H., Czyzewska, E., Oehlschlager, A.C., Pierce H.D., Jr., Angerilli, N.P.D and Rauf, A. 1993. Aggregation pheromones of two Asian palm weevils, *Rhynchophorus ferrugineus* and *R. vulneratus*, *Naturwissenschaften*, **80**: 328-331.
- Hallett, R. H., Oehlschlager, A.C. and Borden, J.H. 1999. Pheromone trapping protocols for the Asian palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae). *International Journal of Pest Management*, **45** (3): 231-237.
- Hamad Saad Al-Saad and El Fatih Mohamed Mahdi 2004. Endoscope: a potential diagnostic tool for Red Palm Weevil infestation. Date Palm regional Workshop on Ecosystem based on IPM for Date Palm in Gulf Countries UAE University, Al-Ain, UAE, 28-30 March, pp89-93.
- Hernandez-Marante, D., Folk, F., chez, A. And Fernandez-Escobar, R. 2003. Control of red palm weevil (*Rhynchophorus ferrugineus* Olivier) using trunk injections and foliar sprays. *Boletin de sanidad Vegetal, Plagas*, **29** (4): 563-573.
- Henry, G. M. 1917. The coconut red weevil, *Rhynchophorus ferrugineus* Trop. Agric. Peradeniya, **48** (4): 218-219.

- Krishnakumar, R. and Maheshwari, P. 2004. Evaluation of mating behaviour of irradiated and normal adults of red palm weevil. *Insect Environment*, **10** (2): 94-96.
- Kurian, C., Sathiamma, B., Sukumaran, A. S. and Ponnamma, K. N. 1979. Role of attractants and repellents in coconut pest control in India. Paper presented at the 5th session of the FAO technical working party, Manila.
- Lakshmanan, P.L., Subba Rao, P.V. and Subramaniam, T.R. 1972. A note on the control of the coconut red palm weevil, *Rhynchophorus ferrugineus* with certain new chemicals. *Madras agric. Journal*, **59**: 638-639.
- Murphy, S.T. and Briscoe, B.R. 1999. The red palm weevil as an alien invasive: biology and the prospects for biological control as a component of IPM. *Biocontrol News and Information*, **20** (1): 35-45.
- Nair, S.S., Abraham, V.A. and Nair, C.P.R. 2000. Efficiency of different food baits in combination with pheromone lures in trapping adults of red weevil *Rhynchophorus ferrugineus* Oliv. (Coleoptera: Curculionidae). *Pestology*, **24**(6): 3-5.
- Nakash, J., Osam, Y. and Kehat M. 2000. A suggestion to use dogs for detecting red palm weevil (*Rhynchophorus ferrugineus*) infestation in Date Palm in Israel. *Phytoparasitica*, **28** (2):153-154.
- Nirula, K.K., Antony, J and Menon, K.P.V. 1953. The red palm weevil and its control. *Proceedings 40th Sessn. Indian Sci. Cong.* pp147-148.
- Oehlschlager, A.C., Chinchilla, C.M. and Gonzalez, L.M. 1993. Optimization of a Pheromone-Based Trap for the American palm weevil, *Rhynchophorus palmarum*. *PORIM International Oil Palm Conference*, Kuala Lumpur, Malaysia, September 1993.
- Oehlschlager, A.C. 1994. Use of pheromone baited traps to control red palm weevil in the Kingdom of Saudi Arabia. Submitted to Ministry of Agriculture, Kingdom of Saudi Arabia, 17pp.
- Oehlschlager, A.C. 1998. Trapping of the date palm weevil, *Proc. FAO Conference Workshop on date palm weevil (Rhynchophorus ferrugineus) and its control* (Cairo, Egypt).
- Oehlschlager, A.C., 2004. Current status of trapping palm weevils and beetles. Date Palm regional Workshop on Ecosystem based on IPM for Date Palm in Gulf Countries UAE University, Al-Ain, UAE, 28-30 March, pp64-83.
- Painter, R.H. 1951. Insect resistance in crop plants. The MacMillan Co., New York, USA.
- Rahalkar, G. W., Harawalkar, M. R., Rananavare, H. D., Shantaram, K and Gopal-Ayengar, A. R.1973. Laboratory studies on radiation sterilization of red palm weevil (*Rhynchophorus ferrugineus* Oliv.). *J. Plant Crops*, **1**: 141.
- Rochat, D., Nagnan – Le Meillour, P., Esteban-Duran, J.R., Malosse, C., Perthuis, Morin, J.P. and Descoins, C. 2000. Identification of pheromone synergist in American Palm Weevil *Rhynchophorus palmarum* and attraction to related *Dynamis borassi*, *J. Chem. Ecol.* **26**: 155-188.
- Soroker, V., Nakache, Y., Landau, U., Mizrach, A., Hetzroni, A. and Gerling, D. 2004. Utilization of Sounding methodology to Detect Infestation by *Rhynchophorus ferrugineus* on Palm offshoots. *Phytoparasitica*, **32** (1):1-3.
- Soroker, V., Blumberg, D., Haberman, A., Hamburger-Rishard, M, Reneh, S., Anshelevich, L., Harari, A.R. 2005. Current status of red palm weevil infestation in date palm plantations in Israel. *Phytoparasitica*, **33** (1): 97-106.
- Taylor, L.R. 1984. Assessing and interpreting the spatial distribution of insect populations. *Annu. Rev. Entomol.*, **29**:321-357.
- Vidhyasagar, P.S.P.V., Al- Saihati, A.A., Al-Mohanna, O.E., Subbei, A.I. and Abdul Mohsin, A.M. 2000. Management of Red Palm Weevil *Rhynchophorus ferrugineus* Olivier. A serious pest of date palm in Al-Qatif, Kingdom of Saudi Arabia. *Journal of Plantation Crops*, **28** (1): 35-43.