FEATURE ARTICLE

# Contemporary challenges and future perspectives on the management of red palm weevil

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**Abstract:** After gaining foot hold on date palm in the Middle East during the mid-1980s, the Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* Olivier has spread rapidly in several countries emerging as key pest of palms in diverse agro-ecosystems worldwide. The cryptic nature of the pest makes detection of infested palms difficult. However, palms detected in the early stage of attack respond to curative chemical treatment. RPW is currently managed through a pheromone trap based Integrated Pest Management (IPM) strategy comprising of several components, with varying degrees of success and failure. Each component of the current IPM strategy is besieged with drawbacks and challenges, from lack of quarantine protocols coupled with weak enforcement to check the movement of infested planting material, the non-availability of an efficient, easy to use and cost effective infestation detection device, over dependence on chemical treatments, difficulties in the maintenance and servicing of food baited pheromone traps, labour intensive protocol for the removal and disposal of severely infested palms, lack of effective biological control program , poor farmer participation in the control programs, besides inefficient data collection and reporting for proper monitoring and validation of area-wide RPW-IPM programs resulting in the waste of scarce and precious resources. This paper gives an overview of the status and prospects of managing RPW.

**S**outh Asia is the home of the Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* Olivier (Coleoptera: Curculionidae) where it is a key pest of coconut, but has significantly expanded its geographical footprint since the mid-1980s and emerged as the most destructive pest of palms worldwide (Faleiro, 2006; Giblin-Davis et al., 2013; El-Shafie and Faleiro, 2020). During 2019, RPW was detected in Bosnia - Herzegovina in Southeastern Europe and in Bulgaria in the Black Sea Basin. Recent reports of RPW invasion suggest that the pest is establishing in the Caucasian region where it is detected in Abkhazia on the canary island palm in the Republic of Georgia and from East Africa in Djibouti on date palm. Ecological niche modelling predicts that this pest can expand its range further (Fiaboe et al., 2012). Flight mill studies have demonstrated that RPW has the capacity to fly up to 50 km in a day with flight activity being predominantly diurnal.

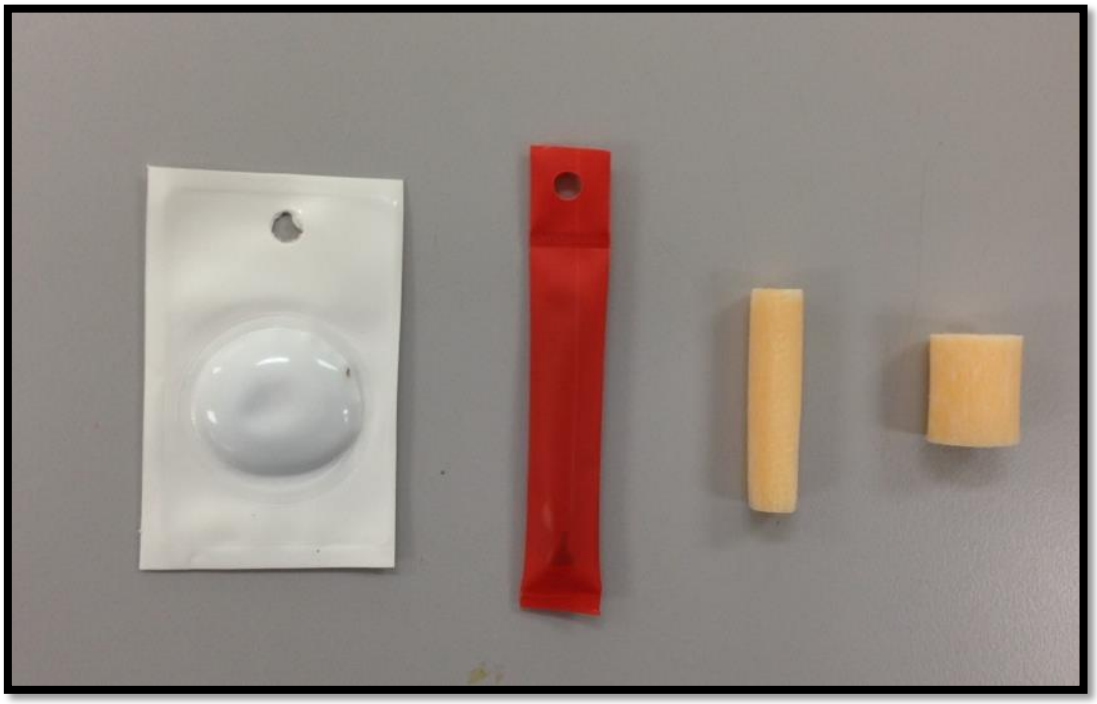
However, a sizeable population is short distance fliers (<100m) which would explain the aggregated/clumped distribution of infestation (Faleiro et al., 2002; Ávalos et al., 2014; Hoddle et al.,2015). Several overlapping generations of the pest may occur inside a single infested palm (Dembilio and Jacas, 2012), which may be due to the

*Colour Morphs of Rhynchophorus ferrugineus*

fact that part of the population is characterized by 'non-flyers' (Hoddle et al., 2015).

The host range of RPW has also rapidly and significantly increased, from just four palm species in the 1960s to 40 palm species reported in diverse agro-ecosystems (Anonymous, 2013; Giblin-Davis et al., 2013). During March 2017 FAO organized a 'Scientific and High-Level Meeting on the Management of RPW during March, 2017 and through the 'Rome Declaration' called for the urgent need to combat RPW by collaborative efforts and commitments at the country, regional and global levels to stop the spread of this devastating pest.

Several countries are currently working on a wide range of RPW-IPM technologies to address the drawbacks and challenges of the current IPM strategy with ongoing research programs including early detection, phytosanitary measures, new semiochemical techniques involving attract and kill and push-pull strategies, host plant resistance, preventive and curative treatments, biological control, removal and disposal of severely infested palms and data collection using GIS for efficient decision-making that will foster farmer/ homestead owner participation in the management of this deadly pest (Faleiro et al., 2019). Additionally, the socio-economic impacts of RPW need to be assessed



***RPW Pheromone Lure Dispensers***

(Abdedaiem et al., 2017). Furthermore, lack of farmer participation in the control program in several countries is a limitation for the successful management of this lethal pest (AlDobai and Ferry, 2017; Faleiro et al., 2019), Advanced molecular research on RPW (Soffan et al., 2016; Antony et al., 2019), needs to be exploited for strengthening the existing control strategy.

The current RPW-IPM strategy is besieged with several challenges and area-wide programmes are often constrained due to lack of adequate manpower and resources (Ferry et al., 2018). This paper presents the status, challenges and outlines the future perspectives of the RPW-IPM strategy. Following is an insight on each component of the RPW-IPM strategy.

***Semiochemicals:*** The discovery of the male produced aggregation pheromone (ferrugineol) by Hallett et al., 1993 has led to the wide use of food baited pheromone traps.

to monitor and mass trap the pest (Abraham et al., 1998; Hallett et al., 1999; Vidyasagar et al., 2000; Oehlschlager, 2016; El-Shafie and Faleiro, 2017; Al-Saroj et al., 2017; Soroker et al., 2015; Vacas et al., 2014). Pheromone trap captures help in optimizing/prioritizing inspection of palms to detect infestations. Depending on the availability of human resources, palms around traps with higher visual captures should be inspected on priority.

It is of utmost importance to adopt the best trapping protocols with respect to trap design, density, servicing (periodic renewal of food bait), placement, lure attraction etc., for food baited RPW pheromone traps. Adopting sub-standard trapping protocols would adversely impact the trapping efficiency and consequently limit the success of the control program (Faleiro and Al-Shawaf, 2018). Regular trap servicing (replacement of food bait and water) makes pheromone trapping of RPW cumbersome, labour intensive and costly.

The bait and trap free technique of attract and kill has been used to curtail the emerging adult RPW population (El-Shafie et al., 2011; El-Shafie and Faleiro, 2020). The dry Electrap$^{TM}$ is another service-less RPW dry trap that works without the food bait/water (Al-Saroj et al., 2017). Smart traps capable of recording and transmitting weevil capture data on a 24x7 basis have been developed (Aldhryhim and Al-Ayedh 2015) but have yet to be deployed on a large scale in control programmes. Spotta-UK offer IoT based field validated smart trapping technology against RPW (https://www.spotta.co/agriculture).

Recently high boiling repellents tumerone, vanillin, nepetalactone and cinnamic acid were found to collectively induce a high degree of stimulo-deterrence against RPW with a trap shutdown of 83.8%. RPW repellents need to be tested to protect fresh injury sites on palms and also in devising a broader RPW semiochemical mediated control strategy by deploying the above repellents as non-host volatiles in the field in conjunction with pheromone (ferrugineol) traps in area-wide push-pull RPW control programs (Faleiro et al., 2022).

***Detection of infested palms:*** Although advanced techniques such as detecting chemical signatures, acoustic detection, use of infrared cameras, thermal imaging, satellite imaging/IoT etc., are being researched upon (Pugliese et al., 2018; Mankin, 2017; Soroker et al., 2017), farmers have to rely on visual (manual) inspection to detect an RPW infested palm. Here, regular

45-day interval inspection of date and coconut palms in the susceptible age group of less than 20 years old is vital to break the cycle of the pest by locating an infested palm before adults emerge. In the Canary Island palm, infestation occurs even in older palms and is usually confined to the crown where early detection becomes extremely difficult.

***Chemical treatments:***

***Preventive:*** Preventive chemical treatments should only be carried out in farms with high weevil activity as gauged from high infestation and removal of infested palms / high trap captures / high seasonal activity. Treat all fresh wounds especially the wounds on palm immediately after frond and offshoot removal (Faleiro,2006; Dembilio et al., 2015; Al-Dosary et al., 2016; Milosavljević et al., 2018). Commonly used insecticides for preventive treatments: imidacloprid, thiamethoxam, avermectin, abamectin, chlorpyrifos, phosmet. Some of the insecticides are being phased out and need to be used with caution. It should be borne in mind that regular, periodic, and preventive insecticide treatments are often unnecessary and excessive, which would have negative impact on the environment as a whole.

***Curative:*** Palms in the early stage of attack recover with insecticide treatment (Ferry and Gomez, 2014; Aldawood, et al., 2013; Gomez and Ferry, 2019). We need to go for the simple diffusion method by cleaning the palm around the infested site on the palm, drilling 4-6 slanting holes 20cm deep at an angle and pouring insecticide solution into each of the holes. Treat the palm again after 15 days. Once the palm recovers and infestation is close to the ground, cover the treated site with soil to facilitate rooting. Commonly used insecticides for curative treatments: imidacloprid, thiamethoxam, avermectin, abamectin. Several pressure injectors are available in the market, which should be used with extreme caution (not > 2bar pressure) to avoid rupture of palm tissue that can lead to death of the treated palm. Only limited number of stem injections may be carried out in ornamental palms, while prohibiting stem injection on a preventive basis in palms grown as food crops (Ferry and Gomez, 2014).

***Removal of severely infested palms:*** Severely infested palms often harbor adult weevils and must be removed (eradicated). Such palms disperse adult weevils in the field that initiate new infestations. In many countries shredding machines are used to destroy severely infested palms. In-situ (on farm site) removal and disposal of severely infested palm tissue by cutting into small pieces (20x10 cm) and soaking with insecticide is recommended (Ferry, 2017). In countries where removal of severely infested palms is outsourced to private agencies, bureaucratic procedures in issuing work

orders to contractors often result in delays which in turn leads to the spread of the weevil.

Abandoned and neglected plantations also harbor the pest and have to be closely monitored for incidence of RPW by intensive inspection campaigns. Farmer cooperation to assist in tackling the pest in neglected gardens should also be sought through persistent awareness programs. The technique of attract and kill is suited for such plantations.

***Assessing the control program:*** GIS based models can be developed to validate the strategy at periodic intervals based on trap captures and infestation reports (Massoud et al., 2012; Fajardo et al., 2017). This helps to judiciously use the resources where most required. FAO has proposed real time data base and web portal for the management of RPW at the local, national and NENA Region. Furthermore, a mobile app for android and iOS smart phones to record geo-referenced data at the field location on a standard form needs to be developed. FAO has made initiatives in this regard both at the regional (NENA) and global levels by developing the web based RPW platform to present the RPW maps and analyse data through the '*SusaHamra*' mobile application (Yaseen, 2018; Cressman, 2019).

***Phytosanitation/Quarantine:*** Keep a strict watch on movement of planting material (offshoots/palms) for both farming and landscape gardening so that only treated and pest-free material is allowed to be transported within national boundaries (Faleiro, 2006; FAO, 2019). Although regulations/decrees to regulate the movement of palms for planting exist in several countries, implementing the decree in letter and spirit is often lacking (FAO, 2019; Balijepall and Faleiro 2019). In this context some European Union (EU) guidelines that could be useful are: delimitation of survey and demarcated areas, three monthly official inspections of palm nurseries, annual crop declaration, application of phytosanitary treatments, registration of planting material movement and use of plant passport to monitor trade of palms. Developing certified palm propagation programs (certified seed), through tissue culture would go a long way ensuring the propagation of pest free material.

***Palm resistance to RPW:*** Although some preliminary research has characterized palm cultivars in term of tolerance/susceptibility to RPW (Dembilio et al., 2009; Alayedh, 2008; Faleiro, 2014), host plant resistance has not been fully studied and exploited. Farmers still cultivate their preferred commercial cultivars, which are often the most susceptible to RPW. Efforts should be put in developing handy screening techniques to identify resistant cultivars and parental

material for use in breeding programs. Molecular markers associated with resistance to RPW need to be developed and used in breeding programs for the development of resistant cultivars. Advanced molecular techniques such as RNAi could hasten the utilization of host plant resistance against RPW (Al-Dosary et al., 2016).

***Protecting fresh wounds:*** Frond and offshoot removal call for immediate treatment of wounds on the palm to mask the emitting palm volatiles and avoid the gravid female weevil getting attracted to these sites for oviposition.

***Impact of irrigation/In-groove humidity:*** High in-groove humidity is known to attract and harbor adult weevils (Aldryhim and Al-Bukiri, 2003). With flood irrigation water touches the trunk at the ground which encourages adult weevils to oviposit in the collar region of such palms, resulting in new infestations. Build-up of in-groove humidity is accelerated by dense planting coupled with flood irrigation and inadequate drainage.

***Biological control:*** The rapid trans-continental distribution and expansion in host-range of this invasive pest demands urgent attention to explore the most effective and efficient approach to protect date palms in a sustainable manner. Conventional control measures, such as mass pheromone trapping and insecticide application via both injection and spray have not given satisfactory results. Therefore, target-oriented and eco-friendly sustainable approaches should be explored for the management of this pest. The current RPW-IPM program could be significantly strengthened if biological control agents (Mazza et al., 2014) could be delivered to the target site and sustained in the field. Laboratory and semi-field cage studies showed the possibility of infecting RPW adults with *Beauveria bassiana* using pheromone traps (Hajjar, 2015). Reports from Spain suggest that the entomopathogenic nematodes (EPN) (*Steinernema sp)* (Dembilio et al., 2010) and the entomopathogenic fungi (EPF), *Beauveria bassiana* (Gűerri-Agulló et al., 2011) are promising in the field.

The two tachinid parasitoids are: (i) *Billaea menezesi* (Townsend) reported more than 25 years ago in the South of Bahia/Brazil, where parasitism rates of up to 72% on *Rhynchophorus palmarum* (L.) have been registered (Moura et al., 1993); and recently, (ii) *Billaea rhynchophorae* (Blanchard) (Diptera: Tachinidae) reported from oil palm and a native palm species, *Attalea funifera* Mart (Moura et al., 2006). Considering the extremely high parasitization rates registered in Brazil and the observed parasitism of five different genera of palm weevils, the parasitic flies could be a promising complement to the currently employed RPW control methods.

However, before beginning attempts of large-scale introduction, there is a need to do a proof of concept of these tachinid parasitoids to demonstrate their capacity to parasitize RPW successfully.

***Extension and capacity building programs:*** Regular dissemination of the latest information on RPW-IPM among officials, plant protection personnel, extension agents and farmers through capacity building programs and also electronic and print media is essential for the successful control of this pest (FAO, 2019).

***Farmer participation in RPW control:*** Farmer participation and cooperation is vital for any IPM program to succeed (Yu and Leung, 2006). Efforts need to be made to ensure farmer participation in the control programme. The challenge is to enhance the involvement of farmers in the control of RPW in their farms, especially in the GCC countries and keep state support/participation in the program to the bare minimum (FAO, 2019).

**RPW control implemented through private companies:**

Area-wide RPW-IPM programs are being outsourced to private companies in some countries. Here the lack of experienced staff to oversee operations in the field is a major constraint. Furthermore, it is essential for the Government authorities to efficiently supervise, monitor and evaluate the control program implemented by the private company, on a regular basis. Inadequate supervision will result in waste of precious resources, besides proliferation of the pest. Efficient control of RPW in the field calls for maintaining continuity of the field operations. Often in countries where RPW control is entrusted to private agencies, there is a delay in providing necessary inputs (pheromones, insecticides, etc.) and also in finalizing the tender/quotation for the subsequent period before the expiry of the on-going tender. Any break in the control operations will dilute the success achieved and result in the spread of the pest.

**New FAO initiatives against RPW**

Based on the recommendations of the "*Scientific Consultation and High-Level Meeting on Red Palm Weevil Management"* held in Rome during March 2017, FAO has initiated two major projects against RPW during 2018 i) FAO Programme on Red Palm Weevil Eradication for the NENA region and ii) FAO Global RPW management platform.

The regional initiative aims to support efforts/programs of countries in the NENA region to contain the spread and eradication of RPW. The key outputs of the project revolve on governance, monitoring, scientific research, capacity building and coordination of RPW control response coordinated across

countries and the region. The program aims to boost ongoing research on the applicable approaches of biological control, innovative detection and studies on socio-economic impacts (Yaseen, 2018).

The global FAO project on RPW monitoring and early warning system aims to address critical shortcomings in the field for effective monitoring and efficient management of RPW; to systematically collect standard geo-referenced data. The data collection system consists of a mobile App and GIS- based online system combined with remote sensing imagery for data analysis and mapping (Cressman, 2019). FAO, 2020 gives a detailed account on the guidelines of RPW management.

**Conclusion**

Although RPW is a difficult pest to control, there have been success stories in isolated pockets reported from different countries (Hoddle et al., 2013; Al-Dosary et al., 2016). In the recent past, Mauritania and the Canary Island have reported successful containment and eradication of the pest (FAO, 2019). However, the RPW control programs have not been fully successful (FAO, 2019). There is still need to devise efficient, cost effective and farmer friendly early detection tools, besides deploying efficient biological control agents that can be sustained in the field and addressing issues facing application of quarantine measures. There is also an urgent need to further intensify RPW research to develop user friendly technologies with respect to early detection, phytosanitary measures, semiochemical techniques, preventive and curative treatments, biological control, removal of severely infested palms, data collection and decision-making tools that will foster farmer/homestead owner participation in the management of this deadly pest. The effects of the RPW and the measures required to eradicate and control it are having significant impacts on the palm tree populations and landscape in affected areas. In addition to the direct economic losses related to production losses caused by RPW, there are economic losses related to the measures and resources to prevention and control the RPW (chemical and non-chemical). This calls for studies to be carried out on the socio-economic impacts due to RPW. Furthermore, several new RPW-IPM tools (RPW detection sensors, pesticides, injectors, semiochemicals, smart traps, microwave devices etc.) are available in the market, but need proper validation. The current RPW-IPM program offers hope and as witnessed in the Canary Islands of Spain, and Mauritania. Though challenging, with proper planning and coordination supported by adequate resources (human and material), it is possible to successfully control this dreaded pest of palms.

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**Dr. Jose Romeno Faleiro**: *Dr. Faleiro is internationally renowned for his work on red palm weevil (RPW), with deep insight on both the control and research of this key pest of palms. His work on RPW goes back to nearly three decades when he was deputed during 1993 by the Government of India/ICAR as a member of the Indian Technical Team on RPW to the Ministry of Environment, Water and Agriculture in Saudi Arabia where he worked for a period of five years until 1998 in the Al-Hassa oasis of Saudi Arabia at the Directorate of Agriculture, implementing an area-wide strategy to control RPW. Dr. Faleiro has led Research Projects on RPW in India (Indian Council of Agricultural Research) and Saudi Arabia (Food and Agriculture Organization of the UN and King Faisal University). These projects generated valuable data on RPW involving repellents, GIS, host plant*

*resistance, attract & kill, pheromone technology, etc. Several of these findings are widely used to manage RPW in date palm and other palm based agro-ecosystems. Dr. Faleiro has also widely published his research on diverse aspects of RPW in internationally renowned peer reviewed Journals besides writing book chapters and presenting invited talks on RPW in several countries. His publications are widely cited. Since 2008, he has completed numerous consultancy assignments for FAO and other international organizations on RPW in different date producing countries including Egypt, Iraq, Libya, Mauritania, Morocco, Republic of Georgia, Saudi Arabia, Sudan, Tunisia, UAE, and Yemen. Dr. Faleiro delivered a lead talk on the management of RPW during the "Scientific Consultation and High-Level Meetings on Red Palm Weevil Management", organized by FAO and CIHEAM, Italy, 29-31 March, 2017. He has been a resource person on IPM for FAO, ICARDA and Michigan State University, USA. In recognition for his work on RPW in the date palm sector, Dr. Faleiro received the prestigious "Khalifa International Date Palm Award" during 2015 in the "Distinguished Figure" category from the Government of the United Arab Emirates as a lifetime achievement award.*

**Dr. Mustapha El Bouhssini**: *Dr. El Bouhssini earned his PhD in entomology from Kansas State University (KSU) in 1992. He started his research career as entomologist at the Dryland Research Center (INRA-Morocco) before joining the International Center for Agricultural Research in the Dry Areas (ICARDA) in 1996. Dr. El Bouhssini has been an Adjunct Faculty at KSU, Entomology Department since 2005. He joined Mohamed VI Polytechnic University on in 2021 as Professor of Entomology and Program Lead, Biodiversity and Plant Sciences. His major research focus has been on Integrated Pest Management (IPM) of key pests of cereals, food legumes, date palm and cactus. Dr. El Bouhssini has made exceptional contributions to the development of IPM options that are increasingly used and scaled out particularly in the West Asia, Central Asia, and North Africa regions. Dr. El Bouhssini has been the recipient of several awards that have recognized his achievements in the scientific field of entomology. Major awards include the 2021 Grand Prix Hasan II for Invention & Agronomic Research, category of Advanced Sciences and Technologies, the 2018 Lifetime Achievement Award in plant resistance to insects from the International Association of Plant Resistance to Insects, the 2014 Distinguished Scientist Award from the International Branch of the Entomological Society of America, the 2014 Distinguished Alumnus Award from the Kansas State University Department of Entomology and the 2007 International Plant Protection Award of Distinction from the International Association for the Plant Protection Sciences.*