Food and Agriculture Organization of the United Nations

Red Palm Weevil

Guidelines on management practices

Red Palm Weevil

Guidelines on management practices

Food and Agriculture Organization of the United Nations
Rome, 2020

Required citation:
FAO. 2020. *Red Palm Weevil: Guidelines on management practices*. Rome.
https://doi.org/10.4060/ca7703en

ISBN [978-92-5-132189-8]

This document was prepared by Red Palm Weevil experts with support from FAO technical officers.

Editors

Maged Elkahky

Agricultural Officer, Transboundary Plant Pests
Plant Production and Protection Division
Food and Agriculture Organization of the United Nations
Rome, Italy

Jose Romeno Faleiro

FAO Expert on Red Palm Weevil
FAO Programme on Red Palm Weevil Eradication, Food and Agriculture Organization of the United Nations
Cairo, Egypt

Contributors

Shoki Al-Dobai

Senior Agricultural Officer, Transboundary Plant Pests Team Leader
Plant Production and Protection Division
Food and Agriculture Organization of the United Nations
Rome, Italy

Abdulrahman Saad AlDawood

Professor of Economic Entomology
College of Food and Agriculture Sciences
King Saud University
Riyadh, Saudi Arabia

Moises Fajardo

Independent Consultant on Red Palm Weevil
Canary Islands, Spain

Hassan Y. Al-Ayedh

Professor of Entomology
Life Science and Environment Research Institute, Agriculture Technology National Center
Riyadh, Saudi Arabia

Jose Romeno Faleiro

FAO Expert on Red Palm Weevil
FAO Programme on Red Palm Weevil Eradication, Food and Agriculture Organization of the United Nations
Cairo, Egypt

Josep A. Jaques

Professor of Entomology
Department of Agricultural and Environmental Sciences, Jaume I University
Castelló de la Plana, Spain

Mekki Chouibani

Executive Director
The Near East Plant Protection Organization (NEPPO)
Rabat, Morocco

Michel Ferry

Scientific Director
Phoenix Research Station
Aspe, Spain

Polana S.P.V. Vidyasagar

Senior Consultant/Advisor on Date Palm & Red Palm Weevil
Hyderabad, India

Contents

Preface vii

Abbreviations and acronyms ix

1. Red palm weevil biology 1

1.1 Classification of red palm weevil 1
1.2 Geographical distribution and primary host range 1
1.3 Life cycle 2

2. Red palm weevil integrated pest management and surveillance 5

2.1 Red palm weevil management 5
2.2 Pest surveillance 6

3. Guidelines on visual inspection for early detection of red palm weevil in date palm *(Phoenix dactylifera)* 11

3.1 Introduction 11
3.2 Types of damage symptoms in date palm 12
3.3 Tools used for inspection 18
3.4 Inspection schedules 18
3.5 Marking and labelling of damaged palms 18
3.6 Assessing the degree of damage and indication of next action 19
3.7 Periodic review of the situation 19
3.8 Conclusions 19

4. Guidelines on visual inspection for early detection of red palm weevil in Canary Island palm *(Phoenix canariensis)* 21

5. Guidelines on phytosanitary inspections 25

5.1 Phytosanitary regulations/legislation 25
5.2 Inspection 31
5.3 Control of movement of palms inside countries 33

6. Guidelines on offshoot inspection protocols: preventive methods for planting offshoots from other farms 35

6.1 Transplanting in farms 37
6.2 Nursery management 37
6.3 Other general guidelines for transplanting offshoots 38

7. Guidelines on RPW pheromone trapping with respect to trap design, trap density and servicing 39

7.1 Introduction 39
7.2 Trapping protocols 40

8. Guidelines on mechanical sanitization of infested palms and removal of severely infested palms ... 45

8.1 Objective and approach ... 45
8.2 Step 1: preparation ... 46
8.3 Step 2: sanitation ... 47
8.4 Step 3: waste management ... 56

9. Guidelines on removal and safe disposal of highly infested and damaged palms ... 59

9.1 Introduction ... 59
9.2 Small and marginal farms ... 60
9.3 Medium and large farms ... 63

10. Guidelines on preventive pesticide treatments (sprays/showers) ... 65

10.1 Introduction to preventative and curative pesticide applications ... 65
10.2 Preventive pesticide applications (chemical/natural) ... 66
10.3 The preventive chemical spray (shower) ... 67

11. Guidelines on curative pesticide treatments (chemical trunk injection) ... 71

11.1 Curative pesticide treatments (chemical/natural) ... 71
11.2 Chemical trunk injection ... 71
11.3 Safe application of pesticides ... 76

12. Guidelines on good agronomic practices (including palm density in the field, irrigation, and crop and field sanitation) ... 77

12.1 Good agronomic practices ... 77
12.2 General management recommendations ... 80

Bibliography ... 81

Preface

The red palm weevil (RPW) *Rhynchophorus ferrugineus* Olivier is a major pest of palms in a diverse range of agro-ecosystems worldwide. After gaining a foothold on date palm in the Near East during the mid-1980s, it has spread rapidly during the last three decades. Recent reports of RPW invasion suggest that the pest is establishing in the Caucasian region, where it has been detected on the Canary Island palm in Abkhazia in Georgia, and also in East Africa, where it has been detected on date palm in Djibouti. During 2019 RPW was detected in Bosnia-Herzegovina in Southeastern Europe and also in Bulgaria in the Black Sea Basin.

In March 2017, the Food and Agriculture Organization of the United Nations organized a "Scientific Consultation and High-Level Meeting on Red Palm Weevil Management" and presented a framework strategy for eradication of RPW. Furthermore, the "Rome Declaration" delivered at the end of the meeting called for urgent action to combat RPW by collaborative efforts and commitments at the country, regional and global levels to stop the spread of this devastating pest.

There exist gaps and challenges in almost all the components of the current RPW integrated pest management (IPM) strategy, particularly in relation to early detection of the pest, development and implementation of phytosanitary measures, lack of effective biological control agents in the field and poor participation by farmers in the control programmes, making RPW control and eradication extremely difficult. Although there are several research publications and ongoing research programmes on RPW in many countries, there is an urgent need to intensify RPW research even further to develop user-friendly technologies that would reinforce the current RPW-IPM strategy. Generating data on the socio-economic aspects related to RPW control and enhancing farmer participation in the control programme are other important aspects that need to be considered.

This manual, developed by leading RPW experts, describes the biology and host range of RPW, and presents guidelines for RPW-IPM including surveillance, phytosanitary measures, early detection, pheromone trapping protocols to be adopted, preventive and curative chemical treatments, removal and safe disposal of severely infested palms, and best agricultural practices to mitigate attacks by this lethal pest of palms.

The topics covered in this manual will be useful to all those involved in the day-to-day management of RPW in the field and also to researchers and administrators working to support the RPW-IPM strategy.

Editors

Abbreviations and acronyms

FAO	Food and Agriculture Organization of the United Nations
GIS	geographic information system
GPS	Global Positioning System
IPM	integrated pest management
IPPC	International Plant Protection Convention
ISPM	International Standard for Phytosanitary Measures
NENA	North East and North American
NPPO	national plant protection organization
PFA	pest free area
PFPP	pest free place of production
RPW	red palm weevil
RPPO	regional plant protection organization
SPS Agreement	Agreement on the Application of Sanitary and Phytosanitary Measures
WTO	World Trade Organization

1 Red palm weevil biology

Hassan Y. Al-Ayedh

1.1 Classification of red palm weevil

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Curculionidae

Genus: *Rhynchophorus*

Scientific name: *Rhynchophorus ferrugineus* (Olivier)

Preferred common name: Red palm weevil (RPW)

Other common names: Asian palm weevil, Asiatic palm weevil, coconut weevil, Indian palm weevil, charançon asiatique du palmier (French), Indomalaiischer Palmen-Ruessler (German), picudo asiático de la palma (Spanish), (Arabic) سوسة النخيل الحمراء .

1.2 Geographical distribution and primary host range

Red palm weevil is one of the world's most invasive pests of palms. It is native to Southeast Asia and has spread through the Arabian Gulf and the Mediterranean basin countries. After gaining a foothold on date palm, *Phoenix dactylifera* L., in the Near East during the mid-1980s, RPW has significantly expanded its geographical range during the last three decades.

Red palm weevil has almost 26 primary host palm species (**Table 1**). Reports also suggest, however, that there could be as many as 40 palm species that are hosts of RPW (Save Algarve Palms, 2019).

Table 1. **The primary host species of RPW**

Family	Plant species	Common name
Agavaceae	*Agave americana*	American agave
Arecaceae	*Areca catechu*	Betel nut palm
	Arenga pinnata (synonym *A. saccharifera*)	Sugar palm
	Borassus flabellifer	Toddy palm
	Borassus sp.	Palmyra palm
	Calamus merrillii	Palasan palm
	Caryota cumingii	Fishtail palm
	Caryota maxima	Giant mountain fishtail palm
	Cocos nucifera	Coconut palm
	Corypha umbraculifera	Talipot palm
	Corypha utan (synonyms *C. gebanga*, *C. elata*)	Gebang palm
	Elaeis guineensis	African oil palm
	Livistonia decora (synonym *Livistonia decipiens*)	Ribbon fan palm
	Livistonia chinensis	Chinese fan palm
	Livistonia saribus	Serdang palm
	Metroxylon sagu	Sago palm
	Oncosperma horridum	Thorny palm
	Oncosperma tigillarium	Nibong palm
	Phoenix canariensis	Canary Island palm
	Phoenix dactylifera	Date palm
	Phoenix sylvestris	Silver date palm
	Roystonea regia	Royal Palm
	Sabal palmetto	Cabbage palm
	Trachycarpus fortunei	Windmill palm
	Washingtonia filifera	California fan Palm
	Washingtonia robusta	Washingtonia palm
Poaceae	*Saccharum officinarum*	Sugar cane

1.3 Life cycle

There are several reports describing the life cycle of RPW (Nirula, 1956; Wattanapongsiri, 1966; Avand Faghih, 1996; Abraham *et al.*, 2001). RPW normally takes about three to four months to complete its life cycle. Eggs are laid in cracks and crevices on soft palm tissue by gravid females. Oviposition is often facilitated when adult RPW female weevils are attracted to palm volatiles released from fresh wounds/cuts on the palm. In coconut and date palms, oviposition usually occurs in young palms under 20 years old. There is a weak relationship between *Oryctes elegans* infestation

and RPW infestation in date palm (Al-Ayedh and Al Dafer, 2015). This relationship has also been recorded in coconut (Abraham and Kurian, 1975). RPW can have two generations per year when the temperature reaches above 19 °C (Hussain *et al.*, 2013). In the Canary Island palm and date palms, two or three generations of the pest are completed before the palm is totally collapsed. Depending on temperature, these generations can take place in one single year, but often it requires a minimum of two years (Dembilio and Jacas, 2012).

1.3.1 Eggs

Females lay over 300 eggs over a period of 47 days at 28°C. The whitish-yellow eggs (approximately 2.8 mm long and 1 mm wide) are smooth, cylindrical and have rounded ends. Eggs hatch after two to five days (**Figure 1**).

Figure 1. **Eggs**

Figure 2. **Larva**

Figure 3. **Pupae**

1.3.2 Larvae

Upon hatching from the eggs, the whitish-yellow, legless, newly emerged larvae feed on surrounding soft tissues (**Figure 2**). The larvae keep boring their way towards the centre of the palm trunk, creating feeding galleries as they go. These galleries are filled with frass (chewed-up palm tissue) that has a distinctive odour. The larvae grow up to 5 cm in length and have up to 16 instars in summer. The larval period lasts for 35 days in summer and can extend up to 129 days in winter.

1.3.3 Pupae

The pupal stage requires an average of three weeks. Pupation occurs in an oval, cylindrical cocoon about 38 mm in length and 13 mm wide (**Figure 3**).

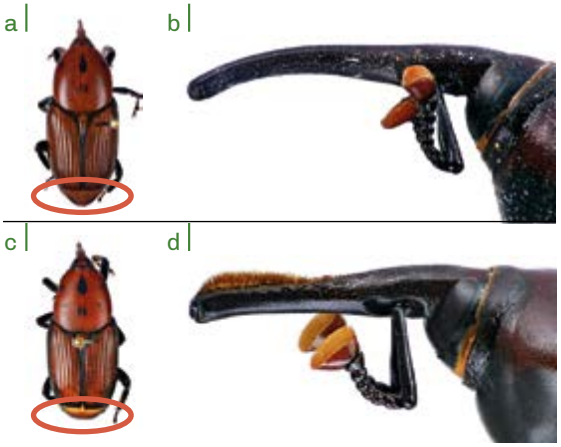


Figure 4. **Female (a, b) and male (c, d) adults are distinguished on the basis of soft hairs on the dorsal side of the snout and abdominal end**

1.3.4 Adults

The newly emerged, reddish-brown, cylindrical weevil has a long, prominent, curved snout. Male and female adults are distinguished on the basis of soft hairs on the dorsal side of the snout. The female weevils lack these hairs on the snout (compare **Figure 4b** and **Figure 4d**). The average longevity ranges from two to three months, during which time they feed on palms, mate multiple times and lay eggs (Murphy and Briscoe, 1999). The average size of adults is about 35 mm long x 12 mm wide (**Figure 4a** and **Figure 4c**). The sex ratio of the weevil population is assumed to be 1:1. However, in various pheromone

(ferrugineol) trapping studies, the captures in traps are dominated by females with a ratio of 1:2 males:females (Vidyasagar *et al.*, 2000; Faleiro, 2006; Vacas, Primo and Navarro-Llopis, 2013; Aldryhim and Al Ayedh, 2015). Adult weevils are predominantly active during the day. Males initiate activity before the females and are capable of long-distance flight. Females in Saudi Arabia have been shown to exhibit two strong peaks of activity from 07.00 to 09.00 hours and from 16.00 to 19.00 hours. The second peak is significantly higher than the first peak. The corresponding male activity has three peaks from 07.00 to 10.00 hours, from 13.00 to 16.00 hours, and from 16.00 to 19.00 hours with no significant differences among the peaks (Aldryhim and Al Ayedh, 2015). Mark–release–capture studies have shown that RPW can fly a distance of up to 7 km over a period of three to five days (Abbas *et al.*, 2006).

Flight mill studies carried out at three different time periods, winter (December), spring (March) and summer (May), in Saudi Arabia indicate that 30 percent of the test weevils failed to fly >1 km. Of those weevils flying >1 km, 55 percent flew >10 km, and five percent of these flyers flew >50 km in 24 hours (Hoddle *et al.*, 2015). Based on similar flight mill studies carried out in Spain, 54 percent of the insects were classified as short-distance flyers (covering <100 metres) and 36 percent and 10 percent were classified as medium- (100 to 5 000 metres) and long-distance (>5 000 metres) flyers, respectively (Àvalos, Martí-Campoy and Soto, 2014). Both Àvalos *et al.* (2014) and Hoddle *et al.* (2015) reported that about 30 percent of RPW adults are non-flyers, which explains the reason for overlapping generations within the same palm.

2 Red palm weevil integrated pest management and surveillance

J.R. Faleiro and Shoki Al-Dobai

2.1 Red palm weevil management

Red palm weevil is managed by employing an integrated pest management (IPM) strategy, the main components of which are: (i) regular inspection of palms to detect infestations, (ii) capture of adult weevils using food-baited pheromone traps (both (i) and (ii) contributing to pest surveillance), (iii) preventive and curative chemical treatments, and (iv) removal/eradication of severely infested palms. These RPW-IPM components are complemented by phytosanitary (quarantine) measures to regulate the movement of planting material, and by capacity building and extension activities. In addition, it has been recommended that hidden breeding sites be removed, particularly in enclosed gardens, that good agronomic practices be adopted in relation to aspects such as field sanitation, palm density, irrigation, and frond and offshoot removal, and that effective biological control agents (fungi and nematodes) that can reach the pest and also be sustained in the field be deployed.

Periodic validation of the strategy based on trap capture data and infestation reports is vital for the judicious use of labour and materials, particularly in an area-wide RPW-IPM programme. In this context, using spatial and temporal maps aided by a geographic information system (GIS) can be useful in helping to identify where best to deploy resources. The Food and Agriculture Organization of the United Nations (FAO) has recently developed an initial beta version of a global RPW monitoring and early warning system to help farmers and national authorities respond to this important transboundary pest on date, coconut and ornamental palms in Africa, Asia and Europe. The system consists of the SusaHamra mobile app for data collection in the field and a GIS-based online global platform for data analysis and mapping.

Such a strategy, if supported with adequate resources and accompanied by systematic planning, good coordination and involvement of all stakeholders, can lead to the eradication of RPW. In most cases, the failure of countries to manage RPW can be attributed to lack of awareness and lack of systematic and coordinated control actions or management strategies that involve all stakeholders, this in turn being related to the available human and financial resources being inadequate to combat the pest. Major components of the RPW-IPM strategy are elaborated in the other chapters of this manual.

2.2 Pest surveillance

Surveillance, both general and specific, are important for the effective control and eradication of RPW. The following guidelines/protocol should be adopted in any RPW surveillance programme.

The International Standards for Phytosanitary Measures (ISPMs) define pest surveillance as "An official process which collects and records data on pest presence or absence by survey, monitoring or other procedures" (ISPM 5 *(Glossary of phytosanitary terms)*). Two kinds of such surveillance are described: general surveillance and specific surveillance (ISPM 6 *(Surveillance)*).

General surveillance is a process whereby information on pests of concern in an area is gathered by the national plant protection organization (NPPO) from various sources. General surveillance aims to:

- support NPPO declarations of pest status;
- provide information on the early detection of exotic pests;
- report to other organizations, such as other NPPOs, regional plant protection organizations (RPPOs) and FAO;
- compile host and commodity pest lists and distribution records.

Outcomes of general surveillance may lead to imposition or lifting of phytosanitary measures based on the results gained, or to the design of specific surveillance if more information about a pest is needed within a geographical region.

Specific surveillance is a process whereby information on pests of concern in an area is obtained by an NPPO over a defined period.

Specific surveillance may be focused on a pest or on a host or commodity. It may include the following types of survey:

- detection survey: to determine if the pest is present (or absent);
- delimiting survey: to establish the boundaries of areas that are considered to be infested by or free from the pest;
- monitoring survey: ongoing survey to verify the characteristics of a pest population.

Specific surveillance results help to:

- support a country's pest status and pest free areas;
- aid in the early detection of exotic pests;
- assist in reporting to organizations such as other NPPOs, RPPOs and FAO.

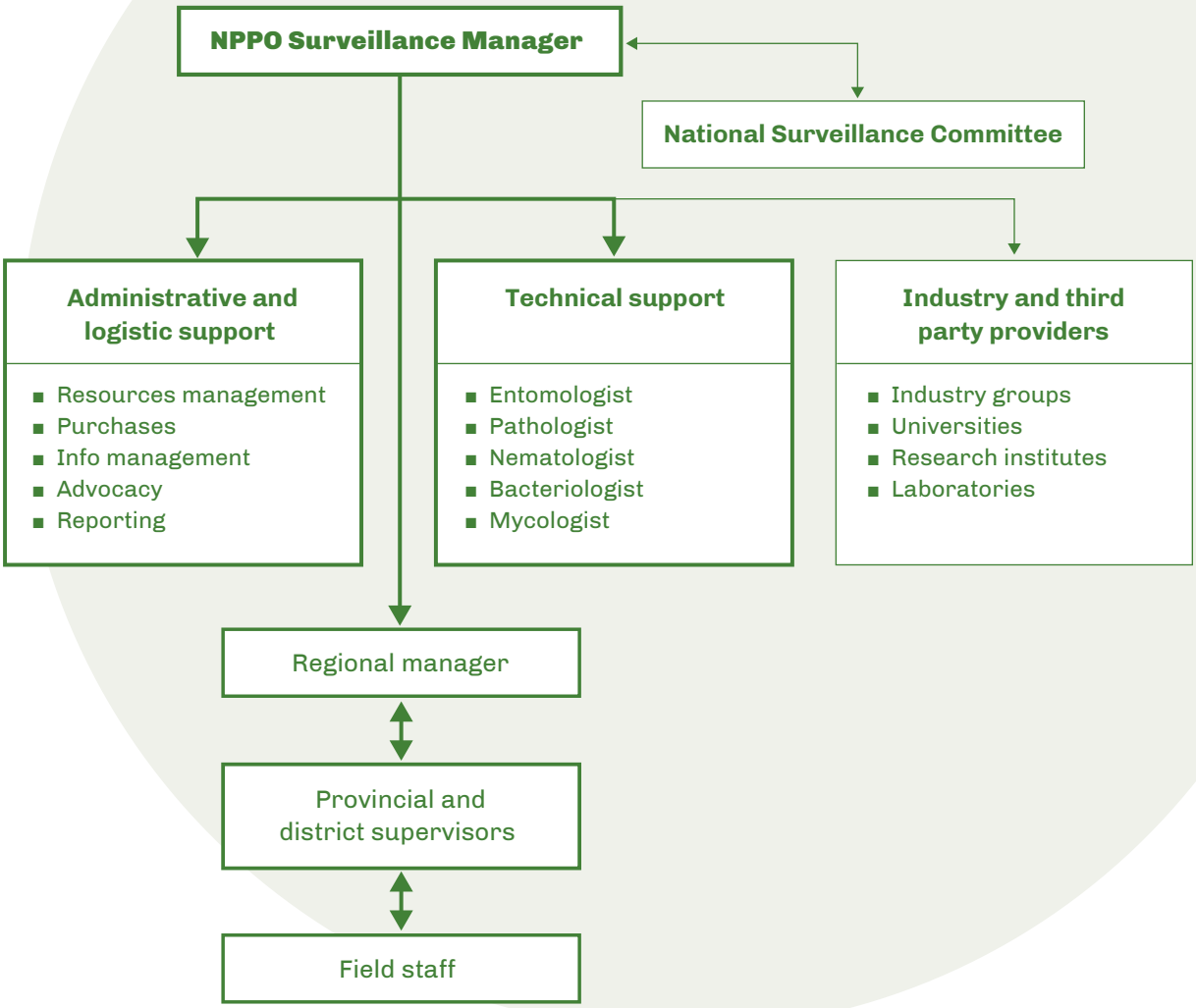


Figure 5. **Example of organizational and management structure for a national pest surveillance programme.**

Source: IPPC plant pest surveillance guide (FAO, 2016)

2.2.1 Organizational arrangements

For a national surveillance programme, an appropriate management structure needs to be established that suits national institutional structures (e.g. **Figure 5**). A national pest surveillance manager, with an appropriate line of command through regional, state, provincial and field staff, should be assigned. The national pest surveillance manager is usually appointed from within the NPPO and may be supported by a national surveillance committee. The main elements of the surveillance programme are administrative support, logistic support and technical support, including technical teams and field teams. Industry and third-party providers, such as industry groups, universities, research institutions and laboratories, can play an indispensable role in ensuring the effectiveness of the programme.

2.2.2 Prior survey considerations

The survey should be conducted at regular intervals, taking into account the temperatures that favour RPW occurrence and development.

Precautions should be taken to prevent the spread of the pest from infested to non-infested areas during the field survey visits. Clothes, personal supplies, survey vehicles and implements should be free of any hitch-hiking insects.

The survey staff should be specialists with sufficient experience and knowledge in the diagnostic characteristics of the pest, its life cycle, and symptoms of infestation.

Permission to enter fields and private properties should be obtained from the owners or relevant authorities before implementing the field visits to these sites.

2.2.3 Survey action plan

Before implementing the survey, a survey action plan should be developed including the following steps:

Survey action plan	
Step 1. Choose a title for the survey and select survey team.	■ Record the title of your survey. ■ Record the names of all personnel involved in the survey (surveyors, survey supervisors, and administrative assistants).
Step 2. Determine the purpose of the survey.	■ Determine and record the purpose of your survey (early detection, delimiting, pest free areas, areas of low pest prevalence, pest management, etc.).
Step 3. Detail the target pest: names, life cycle, dispersal modes, diagnostic characteristics of all pest stages to identify the pest in the field.	■ Record the names of the pest. ■ Record the economic impact of the pest (low–moderate–high). ■ Record the life cycle of the pest and the diagnostic characteristics of each stage. ■ Create any pest information sheets you will use in the field.
Step 4. Detail the host: names, life cycle, distribution, etc.	■ Record the names of the host plant. ■ Record the economic importance of the host plant (low–moderate–high). ■ Record the growth habits of the host plant. ■ Record the likely accessibility of the host if considering a specific survey. ■ Record the regional distribution of the host plant.
Step 5. Detail alternative hosts.	■ Record alternative pest reservoirs.
Step 6. Review any results of surveys conducted in similar conditions, or any other relevant literature, etc.	■ Collect any accessible relevant survey or surveillance plans or reports.
Step 7. Identify the survey area.	■ Record the area for your survey. ■ Provide brief details on the climate, topography and geographical coordinates (Global Positioning System (GPS) coordinates). ■ (area = country, part of a country or parts of several countries).

Survey action plan	
Step 8. Identify the district.	■ Record the district(s) for your survey, clearly identifying each district and providing GPS coordinates.
Step 9. Identify type of survey place, field sites and sampling sites, and number of sampling points.	■ Record the characteristics of places, field sites and sampling sites: – places: e.g. farms, communities, villages, nurseries, ports or markets; – field sites: e.g. fields, plantation lots, private gardens, market stalls; – sampling sites within each place or field site: e.g. quadrats, individual plants, trees, trees with pheromone traps, or crop rows; – number of sampling points: e.g. number of points, offshoots or pheromone baiting traps on an individual tree.
Step 10. Select sites for survey.	■ Calculate and record the number of sites and samples needed, for the level of survey that you intend. ■ Decide the number of samples at each site.
Step 11. Determine sample size required.	■ Determine and record method for choosing places to survey, field sites to survey, sampling sites to survey. ■ Tabulate all possible places, field sites and sampling sites being considered, providing these with individual identifiers. ■ Decide which places, field sites and sampling sites to sample.
Step 12. Determine the timing for survey.	■ Decide on the best time for the survey, considering that this may depend on: – the life cycle of the pest; – the phenology of the pest and its hosts; – the timing of pest management programmes; – whether the pest is best detected on crops in active growth or other stages/conditions. ■ Record the best timing for the survey, detailing the reasons. ■ Record the frequency if the survey is to be performed more than once.
Step 13. Determine what data to collect.	■ Decide if and how you will mark the sites and record an example. ■ Design and include a form for recording data, if appropriate.
Step 14. Determine methods for collecting samples of pests (if required).	■ Determine and record what types of specimens you would collect if the pest is found. ■ Record how you will label the specimens. ■ Record how the specimens will be prepared, treated and identified. ■ Create a list of tools/supplies that you will need to take when surveying.
Step 15. Prepare survey guidance.	■ Prepare a clearly illustrated guide to inspection and sampling in the field, including as appropriate: – visual inspection of plants for different symptoms of damage, presence of different stages of pest, etc.; – use of pheromone trapping and other trapping methods; – collection of samples of the pest for identification/verification as needed.

Survey action plan	
Step 16. Create data storage.	■ Design a spreadsheet or database in which to electronically store the data. ■ Decide how you will create backup copies of the data and how often you will do so.
Step 17. Finalize the team of people involved.	■ Organize information and training for the team. ■ Ensure that personnel involved in surveys are adequately trained, and where appropriate audited, in sampling methods, preservation and transportation of samples for identification, and record keeping associated with samples. ■ Record other people who will be involved in the design, data analysis, pest identification or any other part of the survey.
Step 18. Obtain permission to visit sites and any permits required.	■ Record what sort of permits and permissions will be needed, and who is to seek them. ■ If you find it useful, note the time frames for permission to be obtained. ■ Begin seeking permissions when appropriate.
Step 19. Perform survey: collect data and samples in the field.	■ Conduct the survey using the pre-prepared guidance. ■ Record the site data in the form designed for data collection or electronically through a pre-designed app if available.
Step 20. Analyse data.	■ Store, tabulate and analyse the survey data. ■ Create a map of the pest distribution.
Step 21. Report results.	■ Report the survey results, including at least the following information: – survey title and team members, from step 1; – reason for surveying, from step 2; – background information on the pest, host and sites of interest, including data of any earlier, related surveys (steps 3–6); – survey design methods in detail, including site selection (steps 7–11); – timing of the survey (step 12); – type of data and specimens collected (steps 13 and 14); – how the data were analysed and interpreted (step 20); – conclusions that can be drawn about the survey findings, and how these relate back to the purpose of surveying; – geographical distribution of the pest (including a map, if appropriate) (step 19).

In case of detection of the pest or infested palms, a containment and eradication strategy should be implemented at the earliest possible opportunity.

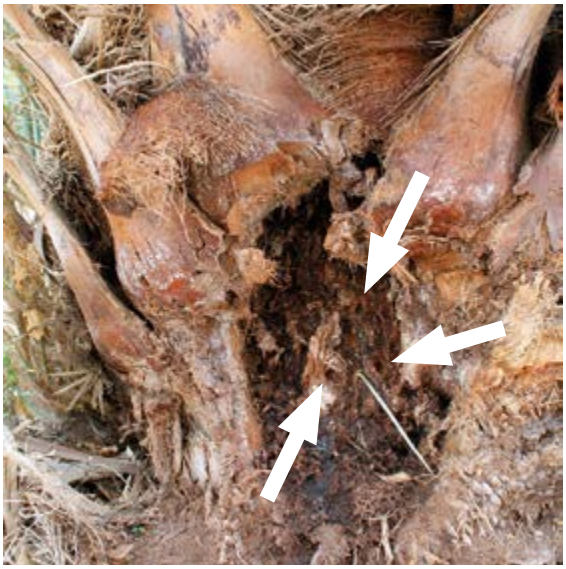
3 Guidelines on visual inspection for early detection of red palm weevil in date palm (*Phoenix dactylifera*)

Polana S.P.V. Vidyasagar

3.1 Introduction

To visually inspect for RPW, it is first necessary to understand how RPW causes damage in date palm, Canary Island palm and other commercially important palms worldwide. After mating, the RPW adult female searches for a suitable host palm and lays tiny eggs inside the soft tissues. The eggs hatch into small apodous larvae inside the host tissues. During feeding with characteristic sounds, the larvae chew up the fibres of the palm with their strong mandibles, this resulting in irregular tunnels (**Figure 6a**). The damage to the host palm is caused mainly by the feeding of one or several larvae. Larval feeding leads to a brown palm ooze mixed with broken wet fibres and other debris (frass), which has a typical fermented "foul" odour. The amount of damage is mainly dependent on the number of actively feeding larvae and the stage of larval instar. If undetected and untreated, the larvae continue to feed, making the trunk hollow. After several moults and considerable time lapse, the larvae transform into a non-feeding stage (pupae) by spinning a fibrous cocoon that serves as a protective cover. The adult weevils emerge from the cocoon after complete development and are free moving or flying. These adult weevils try to seek out new host plants in the nearby vicinity or fly out to new gardens. Due to overlapping of generations, several larvae, pupae and adults can be found within a single infested palm depending on the severity of the infestation (**Figure 6b**).

This chapter discusses various aspects of visual inspection for damage symptoms and their detection at an early stage. A categorization of damage is provided, to facilitate detection of RPW infested palms.



©FAO/Polana Vidyasagar

Figure 6a. **Damaged trunk showing tunnels made by RPW larvae**

©FAO/Polana Vidyasagar

Figure 6b. **Small and large larvae of RPW collected from an infested palm (one Oryctes larva can also be seen, indicated by arrow mark)**

3.2 Types of damage symptoms in date palm

3.2.1 Early infestation and damage

Red palm weevil damage in date palm depends on several factors, such as the age of the palm, agronomic and cultural practices, irrigation methods and, most importantly, the number of infesting stages of the pest present in the palm.

The earliest damage symptom is the oozing of a brown, viscous liquid from the site of infestation (**Figure 7**). In some cases, this ooze also forms a mild froth that drips down the trunk. After a few days the ooze dries up into a flaky substance (**Figure 8**).

Another common symptom is the presence of a small borehole or boreholes from which chewed fibres are expelled. The fibres when fresh are wet and form small lumps called "frass" that have a typical fermented and foul odour.

If you open these wounds, you can see different sizes of boreholes, suggesting the presence of different pest stages inside the palm tissues. The area of damage may range from a few centimetres near the site of observation, in the case of early infestation, to several centimetres in length, extending deep inside and sideways in the form of tunnels, in the case of medium infestation (see 3.2.2). The tissue damage may vary, depending on the tunnelling behaviour of the feeding larvae.

In the case of older palms, some parts of the crown may be infested but not others (**Figure 9**). In date palm, although infestation usually occurs within a metre from the ground in female date palms, male date palms are usually infested in the crown region, just like the Canary Island palm that is also infested in the crown. In such instances, the leaves above the older leaf whorls are dry, suggesting unnatural drying. When the bases of such leaves are examined carefully, other symptoms of the pest can also be detected. In date palm, dried aerial offshoots visible from a distance are also a symptom of RPW infestation.

Date palms with early RPW infestation can be treated with trunk injection of one of the recommended insecticides and cured.

Early infestation and damage in date palm

©FAO/Polana Vidyasagar

Figure 7. **Fresh brown viscous liquid oozing from the base of a trunk indicating RPW early infestation**

©FAO/Polana Vidyasagar

Figure 8. **Early damage symptoms with dried brown ooze on a trunk showing dripping marks**

©FAO/Polana Vidyasagar

Figure 9. **Dried leaves in a crown, with some damage at the base, indicating RPW damage in the crown**

3.2.2 Medium infestation and damage

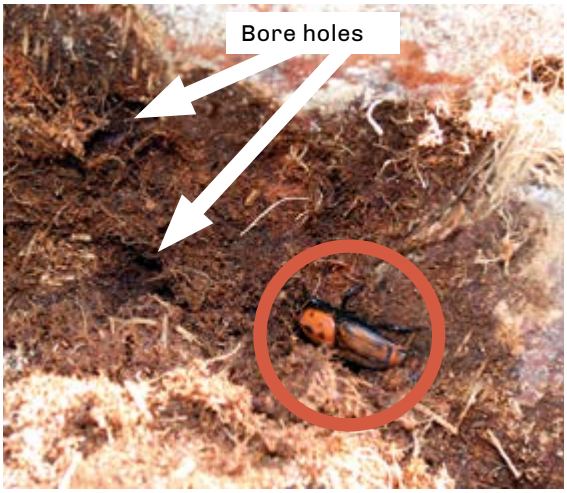
As the feeding larvae grow bigger, more plant tissue is damaged; the resulting tunnels and the proximity of several feeding larvae can cause large cavities (**Figure 10**). An infested trunk may look outwardly normal but have damaged tissues with large cavities (**Figure 11**). On suspicion of damage in such palms, if the external borehole is cut open, chewed-up fibres mixed with ooze and several tunnels running deeper or sideways in the infested palm are noticed (**Figure 12**). Interestingly, the difficult part is to trace the tunnels as they have no pattern and are made in a zigzag fashion. This kind of infestation, where the damage extends several centimetres deep into the trunk and sideways, may be categorized for our convenience as medium infestation. Generally, infestation should only be classed as medium if it does not go beyond 15–25 cm inside the trunk and affects no more than 30 percent of the trunk tissue.

In some palms, easily recognizable external symptoms are manifest owing to the collapse of the old tunnels that opened onto the surface of the trunk. These cavities are variable in size from 15 to 40 cm or more, depending on the severity of damage (**Figure 13**).

Medium infestation can be seen in a young palm of four to five years and in palms with tall trunks. The inspection of such infested palms should be conducted very carefully to avoid missing any fresh damage.

The manifestation of medium damage after opening the wounds is shown in **Figure 14** and **Figure 15**.

Date palms with medium RPW infestation can be treated with trunk injection of one of the recommended insecticides and cured.



©FAO/Polana Vidyasagar

Figure 10. **Damage with holes (white arrows) and an adult near the holes trying to enter (yellow circle)**

©FAO/Polana Vidyasagar

Figure 11. **Young palm with dried frass and chewed fibres showing infestation**

©FAO/Polana Vidyasagar

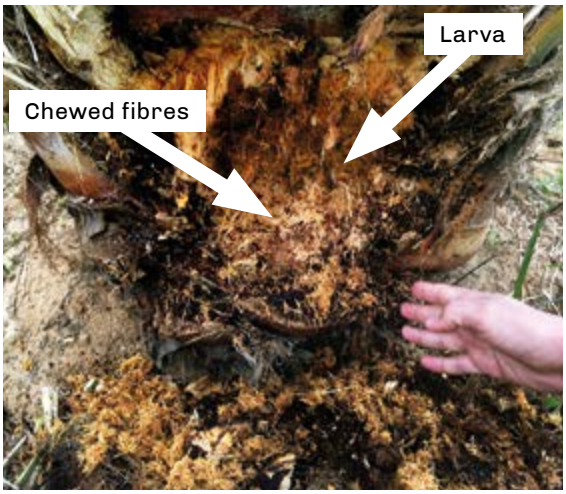
Figure 12. **Soft tissues from trunk scooped out to show damage to fresh tissues**

©FAO/Polana Vidyasagar

Figure 13. **Small holes (white arrows) and chewed fibres indicating RPW infestation**

©FAO/Polana Vidyasagar

Figure 14. **Young palm with 15–25 cm deep damage caused by RPW**



©FAO/Polana Vidyasagar

Figure 15. **Damaged tissues removed to show boreholes, chewed fibres, frass and larvae**

3.2.3 Severe or high infestation and damage

When infestation goes undetected for a long time, the initial injury turns into severe damage that threatens to kill the palm. If a large number of pest stages are present in the palm, the chance of serious damage is greater, as a large number of larvae can actively feed and make internal tunnels without showing any visible symptoms outwardly on the trunk or the leaves. **Figure 16**, for example, shows a young palm with a small hole but no other outward symptoms; when uprooted and removed from the soil, however, a large cavity inside the trunk was revealed (**Figure 17**) with a large number of larvae and pupae. As the cavities inside the trunk coalesce, very soon the areas inside the trunk become hollow. The trunks of such severely damaged palms are likely to break and fall to the ground in heavy winds or storms. The breaking points may be below the crown and at the base near the ground (**Figure 18**).

In many cases, unnoticed damage increases because of the development of one or more generations of RPW inside the trunk of the palm. The resulting continuous damage reaches the point of the tree's growing region and cuts off its supply of nutrients, rendering the palm weak and leading to its subsequent death (**Figure 19**).

If the damage exceeds the radius of the girth of the palm at any given site on the trunk (or more than 30 percent of the tissue in the trunk), it may be classified as a severe case of damage. However, this will be known only after the damage has already occurred (**Figure 20**). In tall palms also, if the infestation occurs in the crown and no action is taken, the damage becomes severe and ultimately the crown of the palm falls to the ground (**Figure 21**).

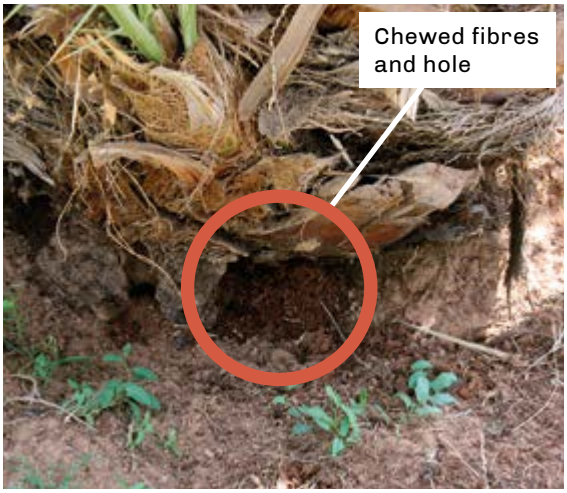
The external symptoms in severely infested palms are easy to identify as the palm is almost dead or is on the verge of death. Such severely infested palms should be removed (eradicated) at the earliest opportunity.

Badly damaged and dead palms should be identified and disposed of properly according to standard protocols. The practice of cutting and burning, or any other practice that is not in conformity with standard protocols, needs to be avoided.

3.2.4 Offshoots

Many farmers allow offshoot development around the mother palms as a source of extra income. However, in neglected farms, the growth of offshoots is not controlled or rationalized by the farmer which makes the detection of RPW very difficult. As a part of the visual inspection, special care should be taken to remove and dispose of any unnecessary offshoots in a safe manner to avoid infestation by RPW.

In offshoots, the main symptom is the drying of the offshoot from the spear leaf or meristem and this is easy to detect. In a poorly managed farm, the offshoots often exhibit damage from RPW infestation. Even if a single central leaf is damaged, either in an aerial offshoot or in a normal offshoot, it is recommended that the infested offshoot/palm be cleaned and removed without any delay.



©FAO/Polana Vidyasagar

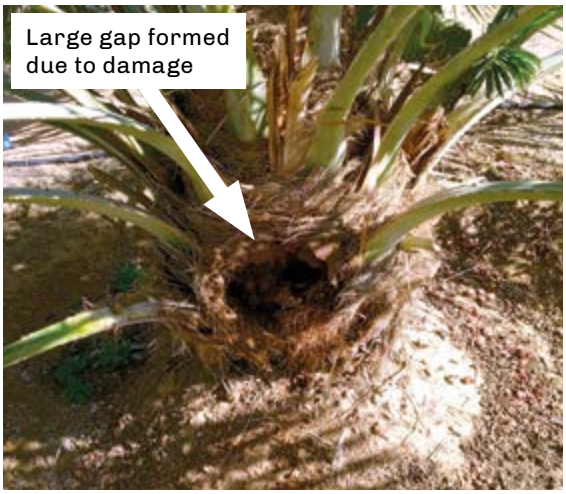
Figure 16. **Young palm showing a small 15 cm hole at the bottom with some chewed fibres**

©FAO/Polana Vidyasagar

Figure 17. **Fresh brown viscous liquid oozing from the base of a trunk indicating RPW early infestation**

©FAO/Polana Vidyasagar

Figure 18. **Young palm exhibiting a deep cavity at the base of the trunk caused by RPW infestation**

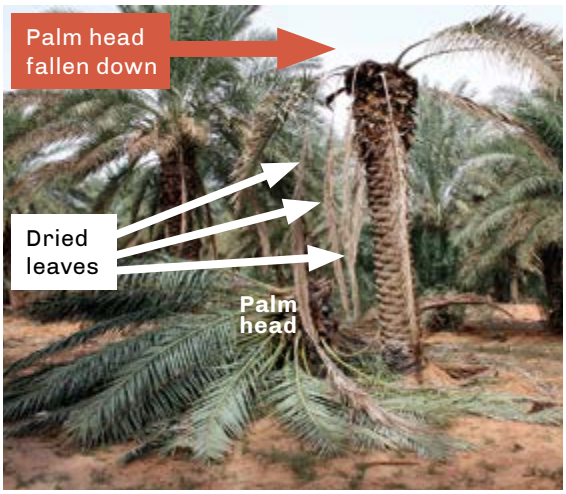


©FAO/Polana Vidyasagar

Figure 19. **Damage caused by RPW in a young palm with a big cavity and feeding holes**

©FAO/Polana Vidyasagar

Figure 20. **Damage by RPW extends on one side of the trunk and runs up to the crown indicating severe damage**



©FAO/Polana Vidyasagar

Figure 21. **Sometimes the infestation on theWcrown is very severe and results in a toppled crown**

3.3 Tools used for inspection

The following tools are required to inspect and examine date palms for RPW infestation:

- screwdriver – 50 cm or longer (**Figure 22**)
- telescopic probe – 50 cm or longer (**Figure 23a** and **Figure 23b**)
- skewer – 50 cm or longer (**Figure 24**)
- gardening gloves – any regular type
- sickle
- machete
- crow bar
- safety barricade tape – red-and-white striped (any kind).

©FAO/Polana Vidyasagar

Figure 22. **Screwdriver**

©FAO/Polana Vidyasagar

Figure 23a. **Telescopic probe, closed**

©FAO/Polana Vidyasagar

Figure 23b. **Telescopic probe, partly extended**

©FAO/Polana Vidyasagar

Figure 24. **Using a metal rod (skewer) in the field to check for infestation**

3.4 Inspection schedules

Every farmer's land is unique, with date palms of different age groups and varieties. It is advisable, therefore, that the farmer makes an inspection schedule that suits his or her needs, integrating this into the normal farm operations.

First of all, the farmer needs to be trained or provide training to workers in the farm on the symptoms of/damage caused by RPW infestation and how to detect and identify RPW infested palms by visual observation. This training may be done through government departments of agriculture or other competent agencies.

The farmer should ideally undertake visual inspection of the farm at regular intervals. Depending on the availability of resources, the visual inspection should be carried out every two months.

3.5 Marking and labelling of damaged palms

For the convenience of operations and tracking the results, it is necessary to mark all palms with numbers. If numbering is not possible, a field plan with rows and columns should be made, especially in farms with a large number of date palms. Starting from one direction, ten rows of palms may be made as one cluster and given a name. Each cluster may comprise 150–200 palms and be defined as one unit. This makes it easier to arrange all palms into several units or clusters. Once this process is completed, the next step is to schedule the visual inspections.

During the inspection, the palms showing damage symptoms should be labelled appropriately for further action (treatment/removal). Generally, a safety barricade tape with red-and-white stripes is used to mark the palm suspected to have RPW damage. This labelling of the tree with safety tape helps the treatment team to locate such palms. This method is also useful after treatment for following up treated palms that may require subsequent treatment. It is recommended where the number of palms is large and the farmer does not live on the farm.

In areas where the technology is available, the palms may be geotagged (for use with GIS), which enables farm managers to develop spatial and temporal maps indicating the intensity or spread of infestations. Such maps are essential for validation of area-wide RPW-IPM programmes.

3.6 Assessing the degree of damage and indication of next action

Based on the visual inspection of palms, a report should be made with clear categorization of palms into healthy palms and damaged palms. The damaged palms should be further divided into groups to receive the recommended type of treatment as soon as possible. The mild- and medium-infested palms should be identified for further treatment and follow-up action as recommended, while severely infested palms should be removed (eradicated). It is important that, after identifying a palm as infested, action to treat it should be taken immediately without further delay to stop the escape of adult weevils and their subsequent dispersal.

3.7 Periodic review of the situation

In order to improve palm health, it is mandatory to periodically review and monitor overall visual inspections done, the treatments imposed on damaged palms and the recovery of treated palms.

By following good agronomic practices and implementing a rigorous inspection schedule of palms for any fresh RPW infestation, it is possible to keep the pest away. In cases where the infestation levels do not come down but show an increasing trend, the farmer should review the management practices used against RPW and consult the competent authority in the region for technical advice.

3.8 Conclusions

It should be kept in mind that prevention is better than cure. If we can identify or detect RPW infestation in the early stages, the recommended control methods can be applied. Thus, the infested palm can be rescued from the attack of this dreaded and hidden pest. Farmers and other stakeholders could also develop their own methods and schedules for early detection and management of RPW. Visual inspection for damage is a part of the overall IPM strategy against this global pest. Proper training in detection methods, advances in knowledge on early detection, and availability of an efficient, cost-effective and user-friendly detection device will go a long way towards the successful control of RPW.

4 Guidelines on visual inspection for early detection of red palm weevil in Canary Island palm (*Phoenix canariensis*)

Josep A. Jaquesr

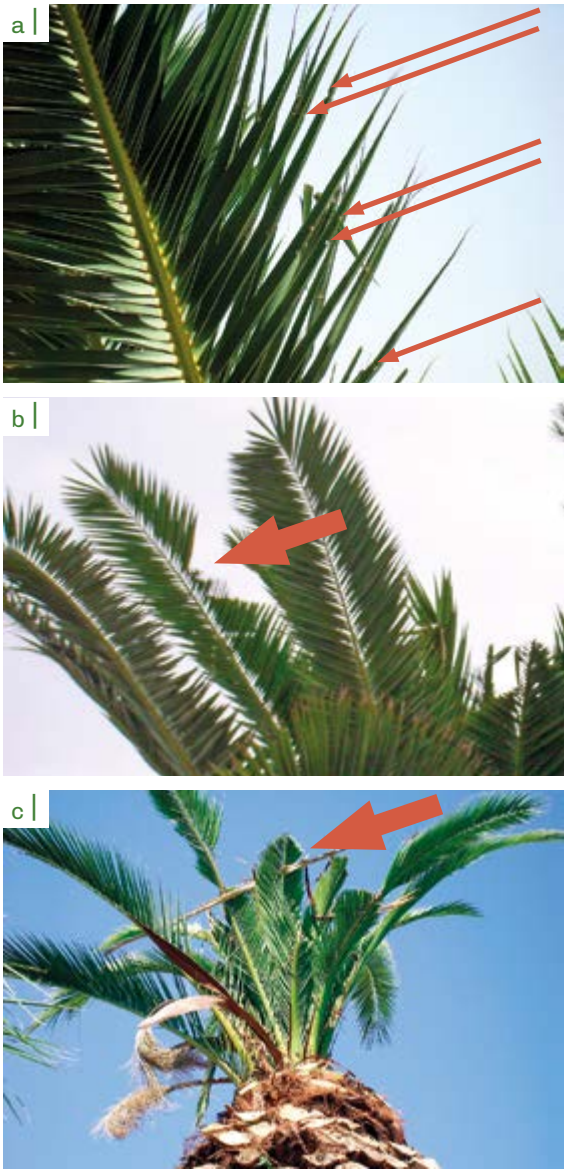
Infestation in *P. canariensis* is usually associated with the crown, where the insect completes its cycle hidden from sight. The tunnelling activities of the insect affect the developing fronds, where symptoms of infestation can be found, and will finally lead to the collapse of the crown and subsequently to the palm death. These cryptic habits mean that visual detection in *P. canariensis* is difficult and most obvious symptoms may not become visible until it is too late for the palm to recover (**Figure 25**).

Figure 25. **Late symptoms of RPW infestation: although the initial infestation may have started a minimum of three months before, early symptoms may remain undetected for the untrained observer; the final collapse of the palm can take as little as one week**

However, early symptoms can be clear to the trained eye, especially if an inspection window has been previously cut for regular survey (**Figure 26**). These early symptoms include the presence of holes in the fronds (**Figure 27a**), which may look "chewed" (**Figure 27b**) and may be broken (**Figure 27c**). Further damage can lead to the absence of new fronds (**Figure 28a**) and to the wilting/dying of already developed fronds (**Figure 29**) which will later lead to an asymmetrical crown (**Figure 30**) which will eventually collapse (**Figure 25**). During this time, frass (**Figure 28b**) and even insect exuviae and cocoons can be observed. Furthermore, a pungent odour can also be perceived.

©FAO/PikuRed

Figure 26. **The cutting of an inspection window, comprising a triangular area extending from the top of the crown down to the base of the canopy (about 50 cm long) where fronds have been removed, may facilitate the observation of early symptoms of infestation**



©FAO/Josep A. Jaques

©FAO/Josep A. Jaques

©FAO/Josep A. Jaques

Figure 27. **Early symptoms of RPW infestation in Canary Island palm: damage inflicted by larvae on fronds developing in the crown result in the fronds becoming (a) perforated, (b) chewed, or (c) broken when unfolded**

©FAO/J.J. López-Calatayud

©FAO/J.J. López-Calatayud

Figure 28. **The tunnelling activities of RPW larvae may lead to the absence of new fronds in the canopy (a), and frass may be found on unfolded fronds (b)**

©FAO/Josep A. Jaques

Figure 29. **Already developed fronds may wilt/die as a consequence of damage made by RPW larvae in the internal tissues of the crown, which may result in the crown looking asymmetrical**

©FAO/Josep A. Jaques

Figure 30. **The crown becomes asymmetrical because of continuous damage on the developing fronds, and once this stage is attained, the collapse of the palm may take only a matter of days**

©FAO/PikuRed

5 Guidelines on phytosanitary inspections

Mekki Chouibani

5.1 Phytosanitary regulations/legislation

According to Article IV.3 (a) of the International Plant Protection Convention (IPPC), "each contracting party shall make provision, … for the distribution of information … regarding regulated pests and the means of their prevention and control."

This means that countries should update their legislation, if needed, to prevent introduction of RPW through imported palm trees, with appropriate notification of such changes to the IPPC Secretariat and in accordance with the World Trade Organization (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement). This notification is aimed at providing greater transparency. Regulations/legislation may encompass the following elements:

- **Regulated pest list:** In those cases where RPW is not included in the regulated pest list, NPPOs should update their pest quarantine list with notification to the IPPC Secretariat, RPPO and WTO (SPS notification).
- **Import permit:** The import permit will allow NPPOs to evaluate the risk by knowing in advance the origin of palms and the place of plantation. If necessary, NPPOs can advise applicants on the requirements for compliance. All importers should know the required information about the import, and provide this to the regulatory authorities, before the importation takes place.
- **Registration of importers:** NPPOs should keep a register of all importers (growers, nurseries, dealers, etc.) and establish a database on importation and destination of palms. (This information is useful for risk management.)
- **List of RPW hosts** to cover all susceptible hosts (Aracaeae). (See Table 1 for host range of RPW.)
- **Phytosanitary requirements** relating to:
  - importation (to achieve the **appropriate level of protection** for the country)
  - nurseries
  - movement of palm trees within the country.

5.1.1 Phytosanitary import requirements

These should include the following:

- the point of entry (through which palm trees should be imported);
- the prohibition of importation of palm trees from a particular origin (infested area/countries), if required;
- the obligation of all stakeholders entitled to import palm trees to be registered and authorized by their NPPO (such stakeholders – growers, nurseries, dealers, etc. – should be mapped by the NPPO of the importing country);
- the import requirements to be met by exporting countries regarding ornamental and date palms.

The phytosanitary actions to be implemented in the case of non-compliance with import requirements should also be established.

Ornamental palms (Figure 31)

Only palm trees originating from recognized nurseries should be imported. Nurseries should be authorized, certified, mapped and regularly inspected by the NPPO of the exporting country. All ornamental palm trees to be exported should:

- have a trunk diameter of less than 5 cm at the base of the trunk;
- be secured to maintain their integrity from the nursery to the port or airport;
- be protected by a mechanical structure (mesh net structure that does not allow entrance of RPW) or by chemical treatment.

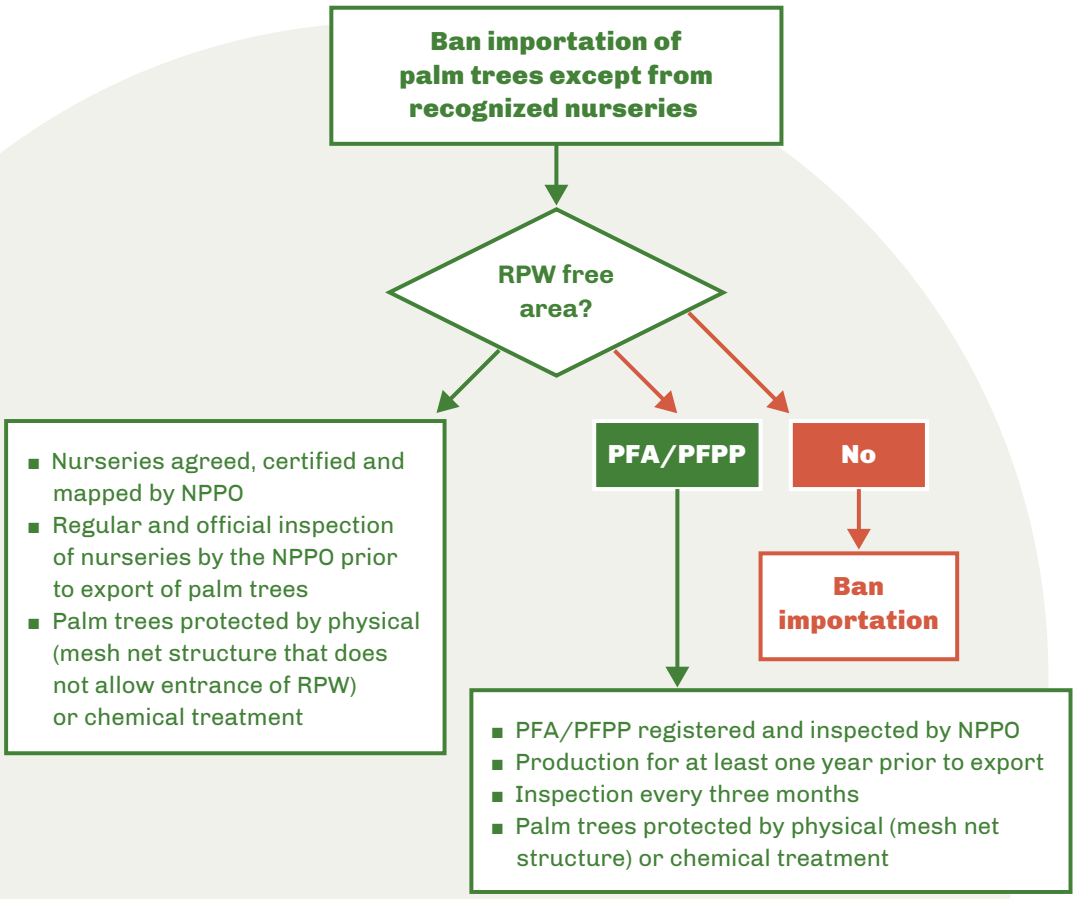


Figure 31. **Phytosanitary measures required for importation of palm trees**

Additional phytosanitary measures are needed where the palms are being exported from an RPW infested area.

Additional phytosanitary measures for infested areas

NPPOs of exporting countries should take the following actions in relation to an infested palm tree or trees:

- Define and map a demarcated area (**Figure 32**), consisting of an:
  - infested zone where the presence of RPW is confirmed (according to the biology of RPW, the infestation level over the course of the year and the specific distribution of susceptible hosts); and
  - a buffer zone extending at least 10 km beyond the boundary of the infested zone.
- Draw up and implement an action plan for the demarcated area, to mitigate the risk of RPW. This may include: intensified survey around the infestation and tracing back of any related plant material in the case of a new outbreak; immediate destruction or, where appropriate, treatment/mechanical sanitation of the infested palms; and/or application of chemical treatments in the immediate vicinity of the infested palms to prevent any spread of RPW during the destruction or sanitation actions.
- Localize the nurseries in relation to the infested area (using GIS and mapping).
- Agree (authorize), certify and map the nurseries.
- Conduct official annual surveys for the absence of RPW on palm trees.
- Implement a traceability system for all palm trees in this area (incorporating a plan of production lots and the storage area, an inventory of lots, invoices for purchase and sale, and the date of entry of palms into insect proof structures).
- Regularly update all these data (if needed) and make them available to the importing country upon request.
- The demarcated area will be declared free from RPW if, during three consecutive years, RPW has not been detected.

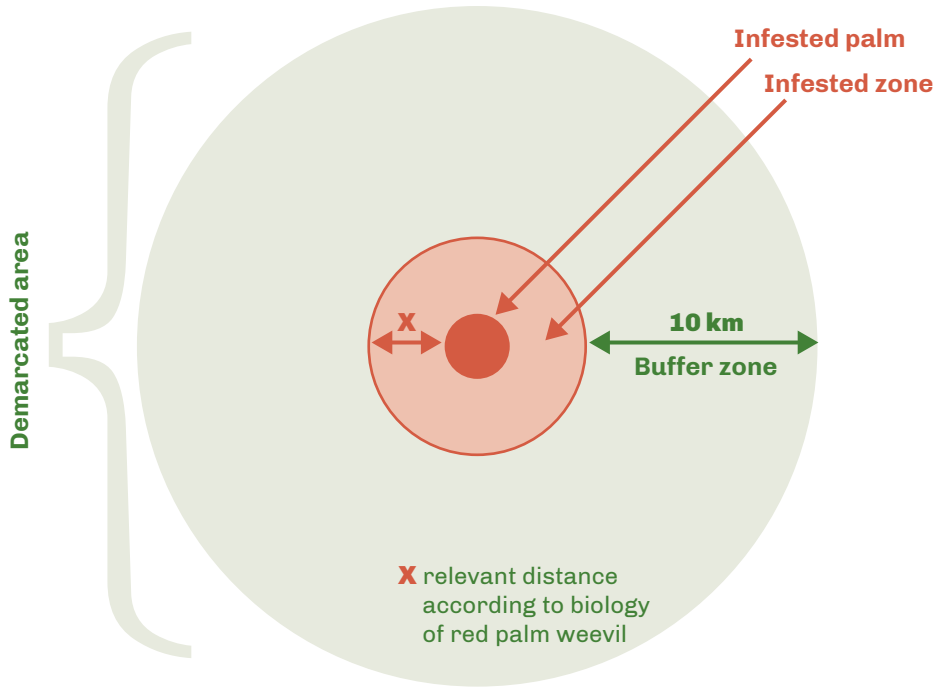


Figure 32. **Demarcated area with buffer zone and infested zone**

Prior to exportation of palms, the area should be inspected so that an additional declaration can be made in the phytosanitary certificate that the palm trees being exported have a base diameter of less than 5 cm, are well protected and meet all of the following conditions:

- they have originated from a pest free area (PFA), established officially by the NPPO of the exporting country according to ISPM 4 *(Requirements for the establishment of pest free areas)* and officially maintained accordingly, or from a pest free place of production (PFPP), established according to ISPM 10 *(Requirements for the establishment of pest free places of production and pest free production sites)* (including a buffer zone) and officially maintained accordingly;
- there have been no introductions of palm in that PFA or PFPP during the last three years;
- there have been no infested palms and no captures of RPW in traps for the last three years;
- the place of production has been inspected regularly (every three months) prior to the exportation.

Date palms

The only date palms imported should be those propagated *in vitro* in test tubes by laboratories that are officially certified to propagate such materials.

Laboratories propagating plant materials should:

- identify the mother tree from which the starting plant material is taken to ensure varietal identity and its authenticity (the starting material being taken during fruiting in autumn);
- localize geographically (using GIS) the mother tree and label it, under the supervision of the NPPO (each mother plant should be marked with the year, sampling area and serial number, and the labelling should allow it to be distinguished from any other mother plants within the same parcel plan);
- notify the NPPO when material is introduced to the laboratory (*in vitro* plant laboratory);
- set up a traceability system whereby individual plantlets can be traced during the various stages of multiplication, acclimatization and seedling rearing to guarantee the varietal authentication.

To help ensure traceability at the propagating facility, records should include a plan of production lots and the storage area, an inventory of lots, invoices for purchase and sale, and the date of entry into insect proof structures.

The nursery in the importing country should have adequate facilities for acclimatization and development of imported *in vitro* plantlets (acclimatization should be done at the imported country level).

The nursery should declare the quantity of *in vitro* plants imported and their origin.

The imported palm trees should be secured in RPW-proof quarantine facilities for one year.

The imported palm trees should be inspected bi-annually by the NPPO of the importing country.

In infested countries, nurseries should be located far from the infested area.

In the case of offshoots, only domestic movement (i.e. movement within the country where the offshoots were produced) should be permitted, as offshoots could be the pathway of RPW introduction or dissemination. Importation should be banned. Offshoots should be procured from identified healthy parent palms under the supervision of the NPPO (**Figure 33**). The parent palms should be mapped (using GIS). The NPPO should inspect all offshoots and issue a movement certificate when needed.

©FAO/Ait Chit Mustapha

a. **Identification of a healthy parent tree (registration by serial number, number of offshoots, area, year, etc.) (notification to NPPO)**

Localization (GIS, mapping)

©FAO/Berrichi Mohamed

b. **Selection and removal of offshoots under supervision of NPPO**

Treatment of offshoots (dipping in relevant chemical solution)

©FAO/Berrichi Mohamed

c. **Rearing offshoots in a protected area in the nursery (regular inspection by NPPO)**

Developing of offshoots in protected area in the authorized and certified nursery

Figure 33. **Selection of offshoots (or starting material for propagation)**

5.1.2 Nurseries entitled to trade RPW free palms (Figure 34)

"Nursery" means any location where nursery stock is grown, propagated, stored, or sold; or any location from which nursery stock is distributed directly to a customer. "Nursery stock" means any plant for planting, propagation or ornamentation.

Nurseries should be officially registered, mapped and given approval to operate by the issuance of a *certificate of registration or license*. The *stock certification* of the nursery acknowledges the authenticity, quality and commitment of the nursery towards phytosanitary regulation.

Nurseries should regularly notify the NPPO of available palm trees. They should implement a traceability system (trace back and trace forward) to verify supplies and sales (plan of production lots, storage area, inventory lots, invoices for purchase and sale, date of entry into the structure) and make data available to the NPPO.

Nurseries should submit a detailed parcel plan (showing plots of different species of palms and their location) to the NPPO. Each plot should be labelled individually or in groups by species (as appropriate) and isolated from the others.

Nurseries should be inspected at least three times a year. The NPPO should issue a **nursery stock certificate** and a **movement certificate** when needed.

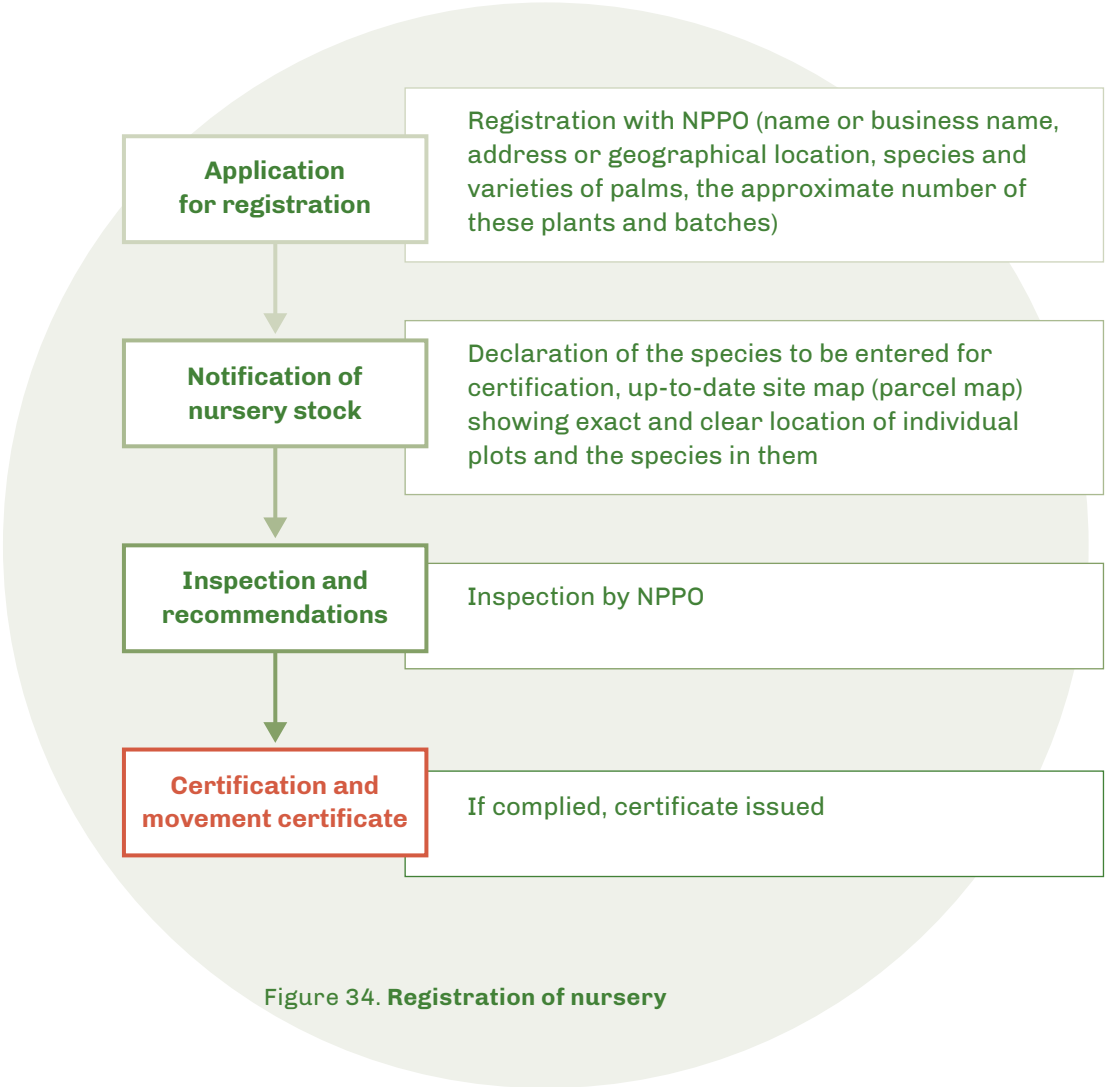


Figure 34. **Registration of nursery**

5.1.3 Movement of palms

The movement of palms (at national or international level) from an infested area is the main pathway by which the pest is spread. All movement of nursery stock plants should be regulated. NPPOs should supervise these movements and issue a movement certificate when needed.

With respect to offshoots from an RPW free area within a country, the NPPO should identify the parent palm trees and inspect them regularly. Offshoots should be removed under supervision of the NPPO, treated (dipping in insecticide solution) and protected from infestation. The NPPO should issue a movement certificate if the phytosanitary requirements are met.

5.2 Inspection

5.2.1 Inspection at borders (point of entry) (Figure 35)

Countries should implement strict phytosanitary measures to ensure that only pest free and certified plant material is imported. Inspection at borders, according to ISPM 23 *(Guidelines for inspection)*, will help to verify compliance of the imported consignment with phytosanitary import requirements.

Step 1: Documentation review

The inspector should examine all documents associated with the imported palm trees, including the import permit if applicable and other relevant documents, for completeness, consistency, accuracy and validity (authenticity of the phytosanitary certificate, additional declaration, etc.).

If the document package is not complete, the inspector should contact the importer to obtain the missing information or documents.

If the documents are complete and comply with the phytosanitary import requirements, the inspection should proceed to the next step.

Information needed to proceed to the physical inspection:

- number or weight of containers or units of material (this should match the information in the import documents);
- location of the consignment;
- scientific or common name of palm trees to be inspected;
- origin of the palm trees (where they were grown or harvested);
- size of consignment;
- type of consignment (commercial or non-commercial);
- destination indicated;
- end use indicated.

Step 2: Preliminary visual examination (physical inspection)

The inspector should verify that the palm trees' identity, integrity and condition are in accordance with the accompanying documents. The available information (species, varieties, size, etc.) should match the phytosanitary certificate and import permit.

The inspector should also verify that other palm tree species, not included in the accompanying documents, are not added or substituted at the last minute.

If more detailed examination is necessary to confirm compliance, the inspection should proceed to the next step.

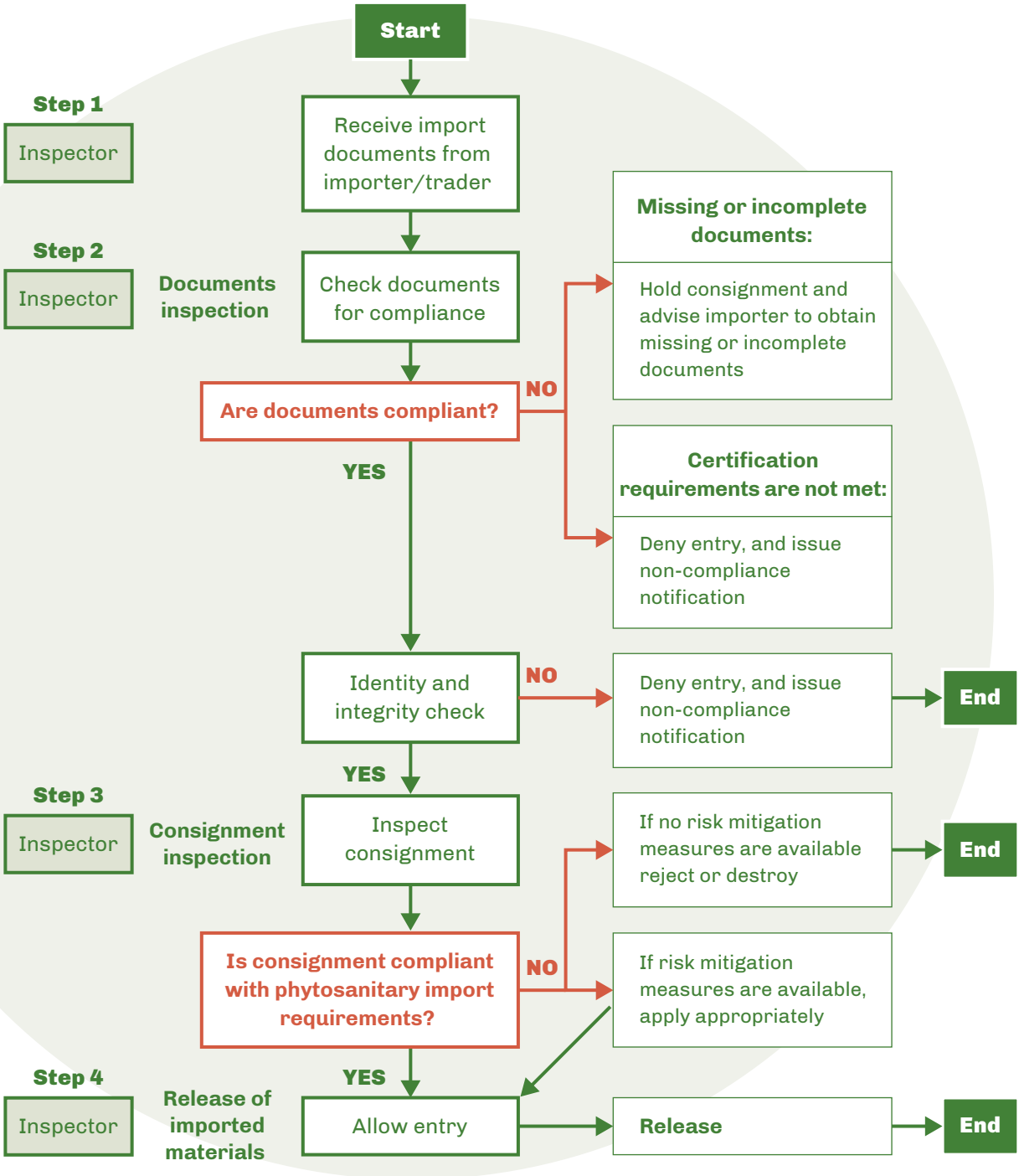


Figure 35. **Import verification chart**

Step 3: Detailed visual examination (physical inspection)

The inspector should:

- verify whether the palm tree species or variety complies with the accompanying documentation
- validate the number or weight of containers or units
- verify that the base diameter is less than 5 cm
- select palm tree units to be inspected as samples
- take samples if needed (according to ISPM 31 *(Methodologies for sampling of consignments)*).

The inspector should then make the appropriate decision:

- detention if further information is required;
- release of the palm trees if compliance requirements are met;
- return of the infested palm trees to the country of origin if no compliance, with care to be taken to prevent RPW spread or destruction;
- destruction of any infested materials detected.

Any non-compliance should be reported to the exporting country and RPPOs.

5.2.2 Inspection of nurseries

Nurseries entitled to produce, to sell or to resell palm trees should:

- be declared to the NPPO of the country in which the nursery is located;
- be registered and mapped (with GIS);
- declare at the beginning of the season their expected production or the quantity they intend to import;
- provide a parcel plan showing separate individual lots by species to facilitate inspection at any time;
- ensure the traceability of palms (trace back and trace forward);
- maintain palm trees in RPW-proof quarantine facilities for one year.

NPPOs should:

- regularly inspect the nurseries at least three times a year;
- control imported palms for a period of three years;
- issue a movement certificate for palm trees to leave the nursery.

5.3 Control of movement of palms inside countries

The movement of plant material is the main pathway for entry and/or spread of RPW. To avoid any further potential spread of RPW, movement of palm trees within countries should be regulated.

No palm tree should leave a nursery without a **movement certificate** issued by the NPPO. They should be protected physically (with nets) or chemically (by use of insecticide).

A total ban on movement of date palm offshoots, date palm trees not propagated from tissue culture, and ornamental palm trees of more than 5 cm base diameter, constitutes the best solution in countries where RPW has not been eradicated.

Movement of palms into and out of pest free areas could be authorized under the same conditions as the ones proposed for importing palms. Movement of palm trees into and out of infested areas should be totally prohibited, except where the trees have been previously inspected, treated before transport and maintained in RPW-proof certified nurseries for at least one year. The traceability of these palms should be established for a period of three years.

6 Guidelines on offshoot inspection protocols: preventive methods for planting offshoots from other farms

Polana S.P.V. Vidysagar

To deal with the situation of accidental entry of adult weevils when offshoots are transported, a simple method is presented below and summarized in **Figure 36**. This method may be followed for any farm and may be further refined, based on field conditions, to make it easy to adopt.

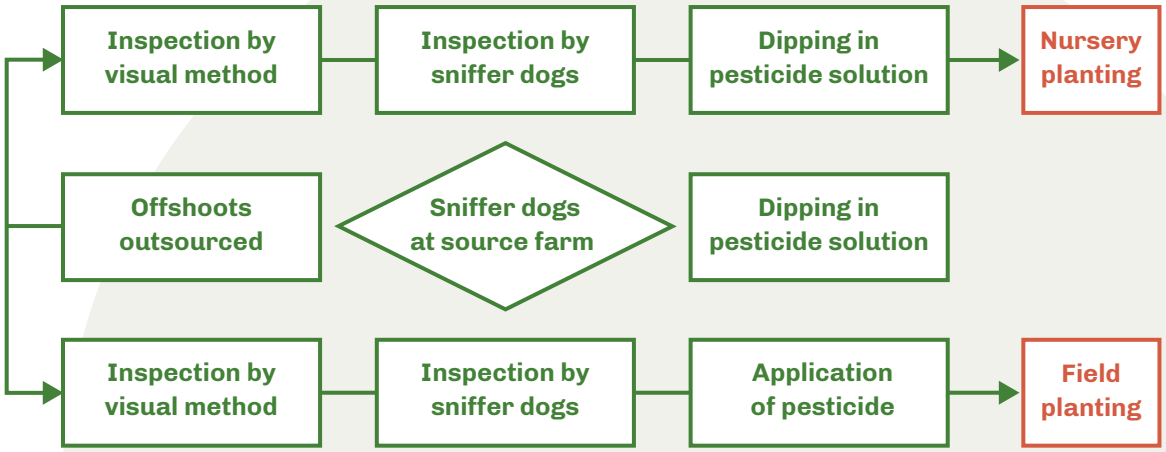


Figure 36. **Flow chart showing the process of offshoot treatments**

©FAO/Polana Vidyasagar

Figure 37. **Visual inspection at the source farm**

©FAO/Polana Vidyasagar

Figure 38. **Visual inspection of offshoots at the destination farm**

©FAO/Polana Vidyasagar

Figure 39. **Checking the offshoots with sniffer dogs for any hidden RPW infestation or stages**

©FAO/Polana Vidyasagar

Figure 40. **Dipping offshoots in pesticide solution before planting**

©FAO/Polana Vidyasagar

Figure 41. **Transplanting in the field after treatments**

6.1 Transplanting in farms

The procedure is as follows:

1. A visual inspection of offshoots for any suspected symptoms of RPW or other pests should be made at the time of loading onto the truck at the source farm (**Figure 37**). Only healthy, pest- and disease-free material should be chosen to be loaded for transport. Upon arrival, the offshoots may be stopped near the destination farm and another physical check may be carried out (**Figure 38**).
2. If trained sniffer dogs are available, they may be pressed into service to check all offshoots thoroughly before the truck is allowed to enter the farm premises. It is difficult for the dogs to sniff and identify any infested plants after application of pesticides, as the strong odours of the chemicals distract them. Hence, it is highly recommended that, if sniffer dogs are used, this should happen before any chemical spraying is undertaken (**Figure 39**).
3. At the entrance point of each farm, a thorough spray with a mixture of recommended insecticide and fungicide may be given. This is done to prevent any escapes of pests and diseases.
4. After bringing the truck to the transplanting site, each offshoot is unloaded from the truck and at this stage it is recommended that the bole or roots be dipped up to the growing point of the offshoot in a recommended pesticide solution (2 ml of pesticide per litre of water) (**Figure 40**). Depending on the recommendation by local authorities, pesticides such as deltamethrin, fipronil, diazinon or beta cyfluthrin may be used.
5. After preparing the planting basins, transplanting the offshoots (**Figure 41**) and installing irrigation lines, a granular pesticide with systemic action may be applied to the basins. This application gives protection against any hidden stages of pests inside the small trunk and also prevents any foliar pests. It will also protect the offshoots from soil pests.
6. Three to four weeks after transplantation, offshoots should be treated with a granular application (20 to 25 g/plant) of imidacloprid (Confidor®), which is a systemic insecticide. Additionally, a broad-spectrum fungicide (Bayfidan®) could also be sprayed.

By following the above method, RPW and other pests can be controlled in young, newly transplanted offshoots brought from outside.

6.2 Nursery management

In general, date palm nurseries are maintained for date palm offshoots of high value, which are not ready for direct transplanting. In such cases, the method described below should be followed, for the protection and safety of the offshoots:

1. Before the offshoots are loaded at the source farm, a thorough visual inspection should be done to ensure that there is no infestation. This should be done regularly.
2. After the offshoots are brought to the farm entrance at the new site, another round of visual inspection should be done.

3. Next is inspection by trained sniffer dogs. This can be done in farms where a squad of trained dogs and handlers are available (**Figure 39**). The dog squad do the sniffing and any suspicious material should be kept aside and further checked. Only the healthy offshoots should be allowed inside the farm for pot planting in the nursery.
4. The offshoots should be drenched with a combination of insecticide and fungicide.
5. At the time of unloading at the nursery, each offshoot should be dipped in the recommended pesticide (2 ml pesticide per litre of water; pesticides used include deltamethrin, fipronil, diazinon, beta cyfluthrin or any other recommended pesticide as per the guidelines of the local authorities) (**Figure 40**).
6. After dipping, the offshoots should be planted in pots kept inside a net house or greenhouse.
7. Offshoots should be sprayed with pesticide once per month.
8. One month after planting in the pot, the offshoots should be treated with one application of granular pesticide for better plant protection.
9. Monitoring of offshoots for any pest or disease should be continued on a regular basis.

By following these procedures, the risk of importing any weevil or pest accidentally can be reduced, and any hidden pests can be killed.

6.3 Other general guidelines for transplanting offshoots

As described above, offshoots should be treated with an insecticide and a fungicide during transplantation to avoid insects and fungal attacks during this sensitive period. Care should be taken when mixing an insecticide with a fungicide, to make sure that they are compatible.

Deltamethrin (Decis®) is a recommended preventive insecticide for offshoot treatment, at a dose of 2 ml per litre (**Figure 41**). Tebuconazole (Folicur®) with its broad-spectrum and systemic action can be used and mixed with deltamethrin (they are compatible); the recommended dose for tebuconazole is 430 g/ha (0.8 g per litre).

Pesticides should be applied by soaking the bole region (date palm offshoots) or crown region (ornamental palm offshoots) well, so that any hidden adult weevil is killed.

As described above, three to four weeks after transplantation, offshoots should be treated with a granular application (20 to 25 g/plant) of imidacloprid (Confidor®), which is a systemic insecticide. Additionally, a broad-spectrum fungicide (Bayfidan®) could also be sprayed.

Every three months, a preventive insecticide should be applied, as part of the RPW-IPM programme.

7 Guidelines on RPW pheromone trapping with respect to trap design, trap density and servicing

J.R. Faleiro

7.1 Introduction

After synthesis of the RPW male-produced aggregation pheromone ferrugineol during the early 1990s, food-baited pheromone traps have been used both to monitor RPW in surveillance and in mass trapping programmes. Weevil captures in RPW pheromone traps are known to be female dominated. Usually, an average of two female weevils are captured for every male weevil trapped, which is desirable as female weevils captured by RPW pheromone traps are mostly young, gravid and fertile. Such captures in mass trapping programmes of the pest help to curtail the build-up of the RPW population in the field. Pheromone trapping by itself accounts for only part of the adult population in the field and therefore mass trapping must be combined with other IPM tactics for the programme to be successful (regular inspection of palms to detect infested palms, preventive and curative chemical treatments, removal of severely infested palms, phytosanitary measures, etc.).

It is vital to adopt the best trapping protocols, both to ensure high weevil captures and also to eliminate the possibility of attracted weevils posing a threat to palms in the vicinity of the trap. Substandard trapping protocols may result in weevils not entering the trap due to weak bait–lure synergy. The best RPW pheromone trapping protocols for adoption in the field are summarized below.

7.2 Trapping protocols

7.2.1 Trap design

The four-window (4 cm diameter) bucket trap (5–10 litre capacity) with no openings on the lid to prevent entry of rain water is widely used to trap RPW. The lid of the trap is secured to the bucket with a piece of wire. Black-coloured, dome-shaped traps capture more weevils compared to the bucket traps. However, although the dome trap is as efficient as the bucket trap, the time taken to service the dome trap could be more and for operational ease it may be more convenient to use the bucket trap, especially in an area-wide operation where several hundred traps are in the field.

Black- and red-coloured traps have been found to capture more weevils than RPW pheromone traps of other colours. The rough outer surface of the trap is also known to facilitate weevil entry into the trap.

7.2.2 Food baits and kairomones

Incorporating food bait into RPW pheromone traps is vital to generate bait–lure synergy, which is essential to sustain the trapping efficiency. A food bait high in sugar content ensures higher weevil captures. Several food baits have been reported for use in RPW pheromone traps. However, dates (100–200 g/trap) generate the best bait–lure synergy, resulting in better weevil captures.

Ethyl acetate (kairomone) dispensers enhance captures when combined with the food bait in RPW pheromone traps; however, this component could also significantly increase the cost of an area-wide mass trapping programme.

Co-attractants based on fermenting compounds, such as ethyl acetate and ethanol, could improve the attractant level of ferrugineol and potentially replace non-standardized natural kairomones in RPW trapping systems.

7.2.3 Water in the trap and trap servicing (renewal of food bait and water)

It is essential to add water (1–2 litres/trap) and mix the food bait in the water, to ensure fermentation of the food bait (dates) and generate optimum bait–lure synergy. The food bait, if placed in a separate container inside the trap, often does not generate the optimum level of bait–lure synergy as the lack of water in the container will limit fermentation of the food bait (dates) and deter the weevils from entering as they prefer a moist environment. It is recommended that 100–200 g of dates be added in one trap.

It is essential to service the pheromone trap (renew the food bait and water) once every 7–15 days. Weevil captures may also be recorded during servicing. In a mass trapping programme where traps are set at a density of 1 trap/ha, the servicing team (car with driver and labour) can service 50 traps/day. In a surveillance programme where traps are set at 1 trap/km, the servicing team can service 30 traps/day.

Recently, service-free pheromone trapping options for RPW (attract-and-kill/dry trap based on electromagnetic radiation) have been developed and these are discussed below.

7.2.4 Insecticide in the trap

Adding a small amount (1 g) of non-repellent insecticide to the water in the trap prevents escapes of trapped weevils.

7.2.5 Lure and lure longevity

Among the wide range of commercial lures available on the market, it is recommended that the most attractive lure that is long lasting be used. During the winter the best lure would have a field longevity of three to four months, while in summer a good lure would need to be replaced every two to three months provided the traps are set in shade.

Exhausted lures should not be discarded in the field. They should be taken to a suitable disposal location and buried deep in the ground.

7.2.6 Trap placement and trap density

To ensure better lure longevity, traps should be set under the shade of the palm/tree canopy. RPW pheromone traps should be placed on the ground with around half of the bucket trap inserted into the soil. Traps should not be placed on or near young palms.

In monitoring/surveillance programmes a trap density of one trap for every km is recommended, while in mass trapping programmes a trap density of 1–4 traps/ha can be adopted depending on the intensity of the pest in the field. However, often it is not possible to enhance the trap density beyond 1 trap/ha due to the increasing cost and labour required to service the traps. In this case, service-free trapping options could be pursued.

7.2.7 Service-free trapping options

The need to regularly service RPW pheromone traps (i.e. to renew food bait and water in them) is the main constraint to sustaining an efficient RPW-pheromone trapping programme. Currently, the service-free RPW-pheromone trapping options that are available are: (i) "attract-and-kill" and (ii) the dry trap based on electromagnetic diffusion of semiochemical signals (http://www.unido.it/award2017/electrap/), which is a dome-shaped dry trap that is used without food and water. These service-free trapping options have been tested in Saudi Arabia and found to be efficient. Both systems have a field longevity of three to four months. In the case of attract-and-kill, one to two dollops (3 g) per palm or 200–400 dollops/ha should be used, depending on the intensity of the pest in the field, while in the case of the dry trap, a trap density of up to 4 traps/ha could be maintained. Currently, commercial attract-and-kill products are made of a flowable gel/paste containing 15–30 percent ferrugineol and

five percent cypermethrin. All safety precautions (wearing of gloves, mask, footwear, etc.) should be complied with while applying RPW attract-and-kill formulation in the field. In the case of allergic reaction or coming into direct contact with the product, further application should be stopped, immediate medical assistance sought, and the manufacturer contacted.

Unlike the food-baited bucket trap that should be set under shade, the electromagnetic based dry trap must be exposed to sunlight. In both the service-free systems, it is essential to also maintain the traditional food-baited pheromone trap at a minimum density of 1 trap/ha, to obtain regular data on weevil captures during trap servicing. This would need to continue until such time that a "smart" dry trap is available that could automatically transmit data on weevil captures on a 24/7 basis.

7.2.8 Data collection, validation and decision making

For efficient and judicious use of resources (labour and materials), it is essential to record weevil captures when the trap is serviced every 7–15 days. These data can be used to periodically validate area-wide RPW-IPM programmes, develop plans to inspect palms around traps recording high weevil captures, and mobilize localized preventive chemical treatments in the hot spots. Smart traps have recently been designed to automatically record the number of weevils captured on a 24/7 basis and could significantly assist in performance analysis of area-wide RPW control programmes. A dry smart trap, if developed, would be ideal and would eliminate both the need to periodically renew the food bait/water and the manual collection of data on weevil captures.

Other technological developments are also underway. For example, GIS could be used to georeference the traps and to develop periodic spatial and temporal maps to gauge the efficiency of the RPW-IPM strategy, based on weevil captures in pheromone traps. In this context, FAO has recently developed an initial beta version of a global monitoring and early warning system to help farmers and national authorities respond to RPW (see Chapter 2).

Several aspects of pheromone trapping are illustrated in **Figures 42 to 49**.

©FAO/Romeno Faleiro

©FAO/Romeno Faleiro

Figure 42. **Fermenting dates mixed in water in RPW pheromone traps: essential for good bait–lure synergy**

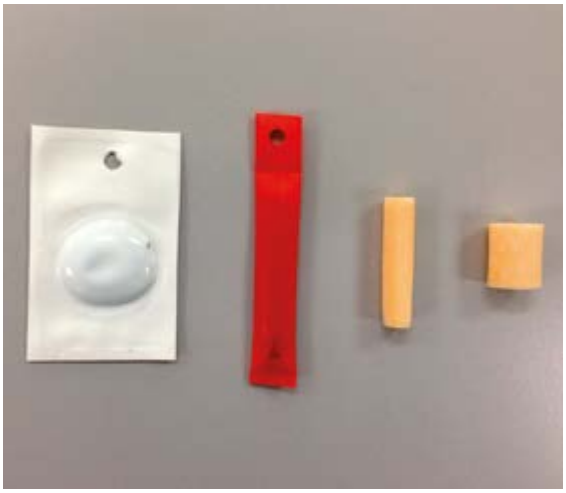
©FAO/Romeno Faleiro

©FAO/Romeno Faleiro

Figure 43. **Poorly maintained RPW pheromone traps**

©FAO/Romeno Faleiro

Figure 44. **Recording weevil captures during trap servicing**



©FAO/Romeno Faleiro

Figure 45. **Commercial RPW pheromone lures**

©FAO/Romeno Faleiro

Figure 46. **Attract-and-kill (HOOK-RPW™) dollop on date palm**

©FAO/Romeno Faleiro

Figure 47. **Attract-and-kill (Smart Ferrolure™) dollop on date palm**

©FAO/Maged Elkahky

Figure 48. **A dry RPW pheromone trap (Electrap™)**

©FAO/Romeno Faleiro

Figure 49. **Dead weevils at the base of an Electrap™**

8 Guidelines on mechanical sanitization of infested palms and removal of severely infested palms

Michel Ferry

This chapter may be used as a reference protocol for the practical field training of trainers or of farmers during workshops that are organized to ensure the proper execution of mechanical sanitation and to promote its use.[1]

8.1 Objective and approach

The objective of mechanical sanitation is to eradicate RPW. It does not mean that the infested palm itself must be necessarily eradicated. It depends on the seriousness of the infestation. When the RPW infestation is very deep and the sanitation operation could result in too big a hole in the trunk, it is recommended that the infested palm be eradicated (removed).

Infested palms can be sanitized either by mechanical sanitation or by injection of an insecticide into the stipe (trunk for palms). The farmer can perform the mechanical sanitation with his or her usual manual tools. It is very important that the entire mechanical sanitation intervention is done in the same location as the infested palm is situated to minimize the risk of RPW spreading and to reduce the efforts and costs.

[1] This mechanical sanitation protocol is designed for infested date palms, but is also recommended for *Phoenix canariensis* when infestation has started in the trunk area (for palms of less than two to three metres trunk height). However, for P. canariensis when infestation has started in the crown, a different protocol should be adopted.

The type of mechanical sanitation protocol will differ according to the degree/extent of infestation in the palm. The degree/extent of infestation may be categorized as follows:

- Early or medium infestation – The RPW infestation has been detected based on early symptoms: presence of dry leaves in the offshoot or the mother palm, dry offshoot, chewed fibre, oozing, galleries or chewed petiole bases easy to pull, cocoons.
- Severe infestation – The RPW infestation has been detected too late, with an advanced degree of infestation: trunk deeply damaged, crown leaves drying, head bending, and other advanced damage.

Aspects of mechanical sanitization are illustrated in **Figures 50–72**.

8.2 Step 1: preparation

The following preparations should be made:

1. Register the Global Positioning System (GPS) coordinates of the infested palm or, at least, an address that will allow the palm to be located later, for instance on Internet-based maps and virtual globe images. The global RPW monitoring and early warning system currently under development by FAO (see Chapter 7) will be useful in this regard.
2. If no trap is present within a radius of 25 metres, install an RPW pheromone bait trap, although only when the proper maintenance of the new trap can be assured. Register the GPS coordinates of the new trap.

©FAO/Michel Ferry

©FAO/Michel Ferry

Figure 50. **Offshoot pruning for deep inspection**

3. Severely prune all leaves of offshoots and mother palm that can be considered an obstacle in accessing the suspected infested area. This process will also facilitate a deep inspection for other potential places of infestation. (Caution: offshoot pruning does not mean offshoot removal; offshoot pruning means pruning the leaves.) A manual tool specifically designed for such pruning could be used to facilitate this task.
4. Soak the infested palm with a neonicotinoid or equivalent insecticide to kill all the adult weevils that could be present in cocoons or hidden at the base of the petioles, the base of the offshoot fronds, or the base of the mother palm fronds. Soaking should be applied up to two metres trunk height. This treatment should be applied immediately after detection to avoid any RPW spreading before sanitation. The nozzle of the sprayer should be removed to target and soak the correct places. (Remark: this treatment is also necessary when chemical injection sanitation is applied, as injected insecticide does not reach and kill the weevils inside the cocoons or the adults that are hidden at the base of the petioles).

©FAO/Michel Ferry

Figure 51. **Insecticide treatment by soaking targeted zones**

5. Soak all the palms around the infested palm, within a radius of 20 metres, with a neonicotinoid or equivalent insecticide to kill all the adult weevils that could have been previously attracted by the infested palm and that could be attracted by the sanitation operation.
6. Eliminate all the vegetation and obstacles below the infested palm, so that there is a clean area in which to implement the intervention (allowing easier movement of personnel and implements).

8.3 Step 2: sanitation

The procedure in this step depends on the symptoms detected on the infested palm.

8.3.1 First case: the infestation symptom is a drying offshoot

The offshoots constitute the main "entrance door" for RPW into date palm. While inspecting the offshoots, the farmer should look for partially or totally dry offshoots (even the very small ones), offshoot fronds or petiole bases that are easy to pull, chewed fibre, and other symptoms of possible infestation. The inspection of offshoots when they are present constitutes one of the first tasks of the inspection protocol. It often allows infestation to be detected at a very early stage.

When infestation has been detected in an offshoot, the following procedure should be applied:

1. Prune all the leaves of the infested offshoot, cutting the petioles as low as possible.
2. Inspect carefully the petiole bases of the cut leaves to be sure that there are no galleries or cocoons.
3. If a cocoon is found, open it. If it contains an RPW, crush it immediately. If the cocoon is empty, register this information. Empty cocoons mean that from this infested palm, new weevils have emerged and perhaps infested neighbouring palms, making it necessary to intensify inspection of all palms in the area.

4. If there is a gallery at the base of a petiole, cut the petiole in two parts to ascertain that there is no adult hidden inside.

5. Cut off the infested offshoot with a cutting tool (axe, crowbar with flat cut, chainsaw, etc.). Locate and scrape the galleries to eliminate the larvae and to reach its bottom.

6. Observe carefully the cut area on the mother palm side. You may find one of the following two possibilities:
   a) The tissues of the cut area are intact (without any gallery, rot or chewed tissue) so there is no need to inspect deeper. The palm sanitation process is finished. Cover the wounded zone with clay (or equivalent) and/or soak it with a systemic insecticide. Soak the sanitized palm up to two metres height with an insecticide to kill all the weevils that could have been or will be attracted by the odours (palm tissue volatiles) produced by the wounded tissues. For the management of the wastes, see step 3.
   b) The tissues at the cut area are not intact; the mother palm is infested. Go to the second case.

8.3.2 Second case: the infestation symptom is not a drying offshoot but the larvae have passed from the offshoot to the mother palm

In this case, the farmer needs to progressively eliminate the infested zone with a cutting tool. After cutting off each portion of the infested area, the depth of the remaining galleries, chewed or rot zones should be inspected with a knife (or equivalent). When eliminating the non-infested tissue around the infested tissue, care should be taken to remove just the minimum necessary to operate the cleaning. All the galleries should be located and scraped to the bottom to eliminate the larvae.

During this progressive chopping and cleaning process, one of the following two possibilities may be found:

a) You rapidly reach an intact zone: there is no need to cut deeper. The sanitation is finished. Cover the wounded zone with clay (or equivalent) and/or soak it with a systemic insecticide. Soak the sanitized palm up to two metres height with an insecticide to kill all the weevils that could have been attracted by the odours (palm tissue volatiles) produced during the operation. For waste management, see step 3.

b) You discover that the trunk is deeply rotten and chewed by the larvae: it is useless to continue. This palm could recover from a deeper sanitation, but its yield will be affected, and it could be at risk of falling down in the future. Go to the third case.

©FAO/Michel Ferry

Figure 52. **Infested offshoot**

©FAO/Michel Ferry

Figure 53. **Young infested offshoot**

©FAO/Michel Ferry

Figure 54. **Cutting all the leaves of the infested offshoot as low as possible**

©FAO/Michel Ferry

Figure 55. **Cocoon at the base of a petiole**

©FAO/Michel Ferry

Figure 56. **Cocoon control**

©FAO/Michel Ferry

Figure 57. **Cutting off the infested offshoot with a manual cutting tool**

©FAO/Michel Ferry

Figure 58. **Cutting off the infested offshoot with a chainsaw**

©FAO/Michel Ferry

Figure 59. **Cutting off to reach the base of the offshoot**

©FAO/Michel Ferry

Figure 60. **Inspected the cutting area with knife to check the depth of the infestation**

©FAO/Michel Ferry

Figure 61. **Non-infested tissue at the base of the offshoot**

Figure 62. **Sanitation of the infested zone detected by the presence of cocoon, petiole easy to pull, chewed fibres or oozing (linked with aerial roots when in high position)**

©FAO/Michel Ferry

©FAO/Michel Ferry

Figure 63. **Progressive and careful elimination of the infested tissues**

©FAO/Michel Ferry

Figure 64. **Sanitized palm**

©FAO/Michel Ferry

Figure 65. **Too deeply infested palm, better to be eradicated**

8.3.3 Third case: palm detected too late with very advanced infestation

In this case, it is usually better to eradicate (remove) the infested palm. The principle of the protocol for this type of infested palm is to separate and manage differently the infested part and the non-infested part of the palm to save a lot of effort and time while ensuring the necessary eradication of a severely infested palm.

The non-infested part does not present any phytosanitary risk and should be processed as for usual green wastes. See step 3.

For the infested part, the main concern will be to locate and eradicate the free adult weevils and the cocoons that perhaps had not been reached by the insecticide treatment conducted in step 1. Regarding the eggs and larvae, they do not present any risk, as they will die quickly due to drying of the tissues. To accelerate this drying, the infested parts of the palm should be cut into small pieces. The management of the infested wastes is described in step 3.

How to differentiate between the infested parts and the non-infested parts

At the beginning of the sanitation process, it is not possible to establish the limits of the infested area of the palm. However, they will be established during the process, allowing the infested parts to be easily and safely separated from the non-infested parts.

First, some important biological aspects should be taken into consideration: a palm is destroyed by RPW when the movement of sap stops, either because the vascular system has been totally collapsed by the larvae in the infested portion of the trunk or, when the attack starts at the crown, the terminal bud is destroyed and the leaves dry. When the palm is dead, the larvae will not survive for long because they feed from sap and not by ingesting palm tissues. Consequently, the extension of the infested zone stops rapidly when the palm is dead.

The limits of the infested zone will differ according to the initial place of infestation and will be indicated by the state of the palm at the moment of sanitation:

- If the initial place of infestation is an offshoot or a place in the trunk and if the mother palm fronds are still green, it can be concluded that the infestation is limited only to a portion of the trunk. It is often the case that the fronds of a tall mother palm dry severely. Dried fronds are due to the destruction of the whole vascular system of a portion of the trunk caused by the larvae, that leads to prevention of sap movement. So usually, if the fronds are still green, it can be concluded that the top part of the trunk and the crown are not infested. When the infestation of the trunk is very severe, the palm falls down.
- In less frequent cases, when the initial place of infestation is the mother palm frond bases, the palm will rapidly collapse, the leaves will dry and consequently the infestation will not usually extend much below the upper part of the trunk.

©FAO/Michel Ferry

Figure 66. **Possible limits of the infestation zone**

©FAO/Michel Ferry

Figure 67. **Only the upper part of the trunk and the bases of part of the fronds are infested**

The sanitation process

To ensure the most efficient sanitation, the following procedure should be adopted:

1. Cut off the fronds. The RPW larvae do not infest the expanded leaves, except in some cases the petiole bases (and sometimes the small central fronds). Be careful not to interpret wrongly symptoms at the frond level: the larvae live only inside the palm tissues; the symptoms at the frond level correspond to damage produced by the larvae when the fronds were still inside the heart of the palm. The fronds (except in some cases the petiole bases) can be considered as ordinary green waste material and can be put aside after their pruning. See step 3 for their processing. Check carefully the base of each frond and if the presence of galleries or cocoons is observed, cut the bases into small pieces and crush the RPW present in the cocoons.

2. Cut through the trunk at the level of the zone where infestation has been detected. Then, chop it in small pieces above and below this zone until a non-infested area is reached. When you reach a non-infested area above and/or below the infested area, move apart the corresponding non-infested part of the trunk. The non-infested part can remain in place or be removed. These non-infested trunk portions will be processed as normal waste material (see step 3).
   - If using a chain saw, cut the trunk into slices of around 20 cm in thickness. In these cases, it is better, if the palm is not too tall, to cut it progressively in slices from the top until the infested area is reached, rather than cutting near the base for the palm to fall down. The non-infested slices (intact tissue) are put aside. See step 3 for their processing.

©FAO/Michel Ferry

Figure 68. **Fronds, after control of their bases, are placed aside and processed as normal green waste**

©FAO/Michel Ferry

Figure 69. **Cutting the trunk of an infested palm into small blocks with a chain saw**

©FAO/Michel Ferry

©FAO/Michel Ferry

©FAO/Michel Ferry

©FAO/Michel Ferry

Figure 70. **Cutting an infested palm into small pieces until a non-infested area is reached**

During the operation, as the initial insecticide treatment (step 1) could not have reached all the cocoons and adults, careful attention should be paid in the infested trunk portion to locating and eradicating all possible cocoons at the petiole bases or between them, and adults that could be hidden inside the chewed and rotted tissues. When larvae have reached the base of the trunk, cocoons can sometimes be present at the soil level around the trunk base: the soil surface should be inspected and the RPW found in any cocoons should be crushed.

8.4 Step 3: waste management

Very complicated, expensive and unsafe methods of eradicating infested palms have usually been proposed and applied due to common but invalid knowledge on some characteristics of RPW biology.

To safely and efficiently manage the eradication of infested palms or the removal of the resulting waste after mechanical sanitation, two very important aspects of RPW biology should be taken into consideration:

- As already mentioned, the RPW larvae feed from the sap and not from the palm fibres. They are not xylophagous and consequently they will die very quickly in drying tissues.
- The females will not lay eggs in such tissues. Instead, they lay their eggs in living tissue that they can reach by digging small and shallow holes with their rostrum.

These biological characteristics of RPW have two essential consequences regarding the management of the waste:

- Waste arising from infested parts, when cut into small pieces and spread to dry, will not present any risk even if it still contains eggs or larvae because these pest stages will die quickly in such tissues.
- Drying waste arising from non-infested parts does not provide suitable egg lying sites for the females (even if the females can be attracted by this material).

These two points allow a very simple, efficient and safe procedure to be established, and explains the importance of differentiating and separating the non-infested parts from the infested parts in step 2.

Waste arising from non-infested parts: this should be considered and processed as normal green waste. Nevertheless, adults can be attracted by this material. So, it is recommended that this material be soaked with insecticide as described in step 2.

Waste arising from infested parts: during step 2, these materials are cut into small pieces. In step 3, they just need to be spread out on the ground to facilitate their drying. As they can attract adults, they should be soaked with insecticide after spreading.

©FAO/Michel Ferry

Figure 71a. **Drying waste arising from non-infested parts**

©FAO/Michel Ferry

Figure 71b. **The females lay their eggs in live tissue that they reach after digging with their rostrum a hole of a few mm in depth; successful oviposition in drying tissue will never occur**

©FAO/Michel Ferry

Figure 72a. **Waste arising from infested parts, cut into small pieces, is spread out to dry**

©FAO/Michel Ferry

Figure 72b. **Larvae feed on sap that they extract from the palm fibrous tissue after chewing it; they cannot survive on drying tissue**

9 Guidelines on removal and safe disposal of highly infested and damaged palms

Polana S.P.V. Vidyasagar

9.1 Introduction

When the RPW infestation is very high and damaged tissues are beyond any reasonable recovery, it is always recommended that such palms be removed carefully. If the infestation is not detected and the pest stages grow inside the palm, the trunk becomes completely tunnelled, leading to the trunk becoming a hollow structure. On many occasions, the external symptoms may look moderate but only upon excavating the wound would it be clear that the damage is severe and warrants immediate removal of the palm. The reason why such badly damaged palms need to be removed from a garden or farm is to prevent the dispersal of emerging adult weevils and further spread of the pest to new and healthy palms within the garden or farm, or to other gardens and farms.

In many cases, due to a lack of understanding and knowledge about the pest, many farmers simply cut down the damaged palm and throw it outside the farm. This is a very bad practice and does not eradicate the pest. Some farmers cut the tall palm into two or three pieces and burn them within or outside the garden. Again, this is not the correct method of removal and destruction of the pest. The burning of large pieces of trunks does not kill the larvae or cocoons hidden inside the trunk or crown of the palm. Instead, the damaged palm should be disposed of safely and it is suggested that the procedure outlined in this chapter is adopted.

The procedure is as follows:

1. Identify the badly infested or damaged palms and make a marking on all such palms detected inside a farm (**Figure 73**). After detection, mark all such palms with a distinct colour tape or spray paint, or a specific number of straps.
2. After identification of badly damaged palms, initiate the removal process as soon as possible. Otherwise, the adults from these infested palms will make their way to healthy palms in the vicinity, making the task much more difficult.
3. As a prophylactic measure, soak, drench or shower the palm crowns and also the trunks and bole regions with a recommended pesticide.

Then proceed as follows, depending on the size of farm.

9.2 Small and marginal farms

Farmers with fewer palms need not wait for their Agriculture Department to bring their equipment and remove the palms. Instead, they can do the removal and disposal themselves safely without affecting their other healthy palms:

1. With the help of a chain saw, crowbar, axe, sickles, and other tools cut the palm into pieces approximately 60 cm long, after removal of all leaves. These trunk and crown pieces need then to be further split and cut in the middle to expose the inner tissues. Make the pieces as small as possible before they are carried to a dumping place that may be a pit or any area assigned by the Agriculture Department (**Figure 74**, **Figure 75** and **Figure 76**).
2. After dumping the palm pieces in the pit, apply pesticide thoroughly and leave it for a day. Any living stages of the insect, which crawl out, will thus be killed due to contact with the insecticide (**Figure 77**, **Figure 78** and **Figure 79**).
3. After 24 hours, the infested palm pieces in the pit may be set on fire under controlled conditions and with proper permission from the Fire Department authorities.
4. Once the plant tissues are burnt down, close the pit with soil or sand.

The above procedure is applicable in individual farms with very few, highly infested palms. However, in farms that are large and infestation levels are very high, the relevant regulatory authorities need to be informed for the eradication of the damaged palms.

©FAO/Polana Vidyasagar

Figure 73. **Highly infested palm ready for removal**

©FAO/Polana Vidyasagar

Figure 74. **Using a chain saw, the palm is cut from the base**

©FAO/Polana Vidyasagar

Figure 75. **Using crowbars, the palm is moved for cutting into small pieces**

©FAO/Polana Vidyasagar

Figure 76. **Leaves are cut and then the trunk is cut into small pieces**

©FAO/Polana Vidyasagar

Figure 77. **Spraying the damaged tissues removed from the infested palm, before burning**

©FAO/Polana Vidyasagar

Figure 78. **Leaf bases and some tissues from a damaged palm, heaped together to be sprayed with insecticide and then burned**

©FAO/Polana Vidyasagar

Figure 79. **Spraying to sanitize the area near a treated palm**

©FAO/Polana Vidyasagar

Figure 80. **Trunk pieces are loaded into a covered truck with a pulley to facilitate easy transport**

©FAO/Polana Vidyasagar

Figure 81. **Dumping ground of damaged palm trunk pieces brought from different gardens**

©FAO/Polana Vidyasagar

Figure 82. **The trunk pieces are shredded into very small bits and dumped in a square**

9.3 Medium and large farms

The regulatory authorities with their trained staff can follow the above procedure but with some variations and improvements (**Figure 74**, **Figure 75** and **Figure 76**).

Some departments have established palm shredding centres in different locations on a permanent or temporary basis. These centres are located in remote areas with the least population of palms, but logistically work well within limited areas.

These centres are equipped with heavy machinery called "palm shredders" and these machines can shred large pieces of trunks or large crowns into smithereens in minutes and can shred hundreds of palms in a day.

Even if such machines are available in the region, the basics of removal and disposal remain the same. The identified palms are cut into reasonably sized pieces, loaded into covered trucks and transported to the shredding machines (**Figure 80**). These infested palm pieces are shredded immediately to avoid any weevil escapes (**Figure 81** and **Figure 82**).

A large amount of plant waste or pith-like substance will be generated as a result of the process. This can be periodically recycled, adhering to the relevant regulatory policies in force.

It is advisable to apply pheromone trapping all around the shredding location to catch and kill the weevils attracted to the freshly cut plant tissues or escapes from the infested palm parts brought to the location.

The gardens around the shredding locations or mass dump areas should be closely watched and monitored to avoid any flare-up in fresh infestations.

In the case of completely neglected farms where the pest is active, it is recommended that all palms be removed in a systematic manner, observing all the protocols described here.

The competent authorities with the help of heavy machinery can do mass removal of palms, using bulldozers, loaders, covered trucks, and other similar vehicles. Since awareness about RPW has reached every corner of the globe, it is a rarity to have such mass removals or large-scale infestations in any region.

By following the methodology described above, infested palms can be safely disposed of without spreading the pest.

©FAO/PikuRed

10 Guidelines on preventive pesticide treatments (sprays/showers)

Moisés Fajardo

Management of RPW in the field involves several control measures, and preventive and curative pesticide treatments form a major component of RPW-IPM strategies. This chapter gives an introduction to these treatments, followed by detailed protocols on preventative chemical treatment; Chapter 11 describes curative chemical protocols. These preventative and curative protocols can also be used for application of biocontrol agents in the management of RPW.

10.1 Introduction to preventative and curative pesticide applications

Pesticide application is considered to be the most commonly used and effective method for management of RPW. Registered pesticides – either insecticides or combinations of insecticide and acaricide – are used in preventive and curative treatments of palms against RPW. As a preventive measure, the palms are sprayed using high-powered sprayers, with the pesticide applied slowly through central leaves to give a thorough coverage to the entire palm tree. The preventive treatments can be repeated as needed depending on local infestation status, especially during peak periods of RPW activity (April–June and September–November). As a curative treatment, the pesticides are commonly applied as both spray (shower) and trunk injection on infested palms. For trunk injections, points are marked around the palm trunk, either in a spiral manner or at the base of the trunk depending on the pesticide used and the infestation pattern; at each point a hole is then drilled at an angle of 30–45° using a drill machine equipped with a brad point drill-bit (8 mm in diameter). A biodegradable microinjection plug is placed into the drilled hole to act as a barrier, thereby restricting any backflow of the pesticide. The pesticide is delivered into the trunk immediately after drilling using a suitable delivery system, these including the tree microinjection gun, the passive method (gallon), the low-pressured method (balloon) and injection machines. Treated

palm trees should be examined regularly to evaluate the efficacy of the treatment. The most commonly used pesticides against RPW in the Near East and North Africa (NENA) region are imidacloprid 20% SL, chlorpyrifos 48% EC, thiamethoxam 25% WG, abamectin 8% EC, emamectin benzoate 4% ME, lambda-cyhalothrin 5% EC, and Bio-Weevil™ (a mix of essential oils).

It is essential to use these pesticide treatments judiciously. Like all control operations, preventive and curative treatments (chemical or natural) should also be supported by a GIS-based data collection and management system.

10.2 Preventive pesticide applications (chemical/natural)

Preventive pesticide applications are currently either carried out using chemical products or products that have a natural origin. They have two purposes:

a) to kill the hidden adult weevils at the bases of the leaves;

b) to protect the palms by killing adult female weevils and early stages of the pest.

Preventive pesticide applications should be applied either by showering/soaking targeted zones of the palms or by injection (for ornamental palms only). To ensure the efficiency of the preventive pesticide treatments and to minimize both hazards to human health and the environmental impact of this treatment, the following points should be followed:

- A range of pesticides should be tested and registered against RPW for each country.
- Attract-and-kill products may be registered as a preventive semiochemical treatment.
- There is a need for further testing to validate the efficacy of natural products against RPW.
- There is a need for further testing of recommended doses and frequency of treatments for each registered pesticide against RPW to ensure proper use in field operations.
- Preventive pesticide treatments should be applied only to palms within the delimited infested area and according to a specific schedule that has been established based on an evaluation of the trap captures and infestation reports.
- When applying pesticide by showering/soaking, the pesticide solution should be targeted to the base of the leaves of the crown (ornamental palms of more than two metres in height) and inner leaf whorls, the trunk up to a height of two metres, and offshoots (the latter for date palms and small ornamental palms).
- For ornamental palms, if pipes are attached to deliver pesticide showers to leaf bases in the crown, the pipes will need shifting periodically.
- Although injection treatment of ornamental palms may be used for preventative purposes, it should not be considered as a routine technique as it creates permanent wounds. It should be applied only a limited number of times and only as part of a programme designed to obtain quick eradication of the pest (for more information on the pesticide injection process, see Chapter 11).

10.3 The preventive chemical spray (shower)

10.3.1 Purpose

The objective of preventative chemical spray is to eliminate the pest stages that are found in the most superficial part of the palm tree: pupae, adults and newly hatched larva.

This procedure should be included in an RPW control and eradication programme. It is recommended that it be carried out within both field-by-field IPM and area-wide IPM (synchronized throughout the affected area):

- **Field-by-field IPM:** This is usually done by a worker from the RPW management programme. It requires two kind of treatments:
  a) Periodic: The goal would be to perform an annual treatment of all palm trees in the affected zone. The frequency of this measure depends on the budget.
  b) Guided treatment (more important): It is recommended that all palm trees within a 100 metre radius of the traps with the greatest weevil captures (the top 25 percent of traps) be treated. This treatment could be coordinated or alternated with trunk injection.

- **Area-wide IPM:** Treatments are performed by the farmer. An intensive information and awareness campaign aims at involving the farmers in the control programme. Treatment should be organized and synchronized across the area. It should be carried out during the peak activity periods (April–June and September–November). In this case, all farmers will treat their palms for a month. In order to achieve maximum coverage of the treated area, the success of the treatments should be evaluated and the information used to achieve improvements during the subsequent years. It is recommended that the campaign be repeated once every year.

10.3.2 Scope

The application of chemical sprays covers all actions from the delimitation of the treatment area at the start of the process, through to entry of the treatment records onto the database at the end of the process.

10.3.3 Reference documentation

All relevant information should be kept as a reference, including the pesticide label and information on legislation regarding chemical products, the target pest (red palm weevil) and the palm crop of the country.

10.3.4 Methodology

Area determination

Based on the data of weekly captures in traps, visual inspection reports, and/or reporting from farmers, the team leader for the RPW management programme should determine the areas that need to be treated during the following week. The treatment should include all palm trees within a radius of 100 metres of the traps with the highest weevil captures. The planning for the target area should be on a weekly basis.

Prior notice

The famer/owner should be informed by the team leader well in advance about the need to carry out the treatment, the location of the palms to be treated, the products to be used, and the treatment day. All arrangements need to be coordinated with the farmer in order to facilitate the labour for the treatment.

©FAO/Moisés Fajardo

©FAO/Moisés Fajardo

Figure 83. **Preparing spray solution and carrying out preventive treatment of the Canary Island palm**

Solution preparation

Operators should have a valid license for basic level application of chemical products and adopt all required safety procedures. Practices adopted should comply with legal regulations concerning safe systems of work for chemical treatments. While the team member prepares the solution (**Figure 83**), another worker should perform a visual inspection on the palm trees to be treated. The solution should be prepared according to the instructions on the product label, and the products should be authorized for use on palm trees. Some of the most commonly used pesticides and biological agents against RPW in the NENA region are imidacloprid 20% SL, chlorpyrifos 48% EC, thiamethoxam 25% WG, abamectin 8% EC, emamectin benzoate 4% ME, lambda-cyhalothrin 5% EC, and biological agents (entomopathogenic nematodes and fungi).

The pH of the water should be tested, and the need for a pH regulator product (buffering agent) should be determined. The ideal pH is usually between 5.5 and 6.5.

Spraying process

The sprayer should be set to shower mode at low pressure without nozzle and 15–20 litres of the solution should be used to treat each palm tree.

For date palms, the sprayer should be directed to the lower area of the trunk, from a height of 1.5 metres from the ground, with special attention given to the offshoots contact area.

The treatment must be applied in a uniform way to guarantee the proper delivery of the solution. Several passes should be made through the same area with the jet at a different position, to guarantee entry of the solution in the offshoots production area.

It is much better to use two treatment hoses, if is it possible.

At the end of the treatment, all used spraying pumps should be cleaned by adding clean water into the empty solution tank (about 25 litres) and running the motor until the tank is empty.

When treating ornamental palms in urban areas, the following points should also be taken into consideration:

- The target area for the treatment in the case of Canary Island palm is the crown.
- Place beacon tapes around the perimeter surrounding the palms to be treated in order to avoid damage to third parties. The area to protect in this way will depend on the maximum drift of the chemical treatment and the dimensions of the palm tree.
- Place pedestrian crossing signs on pavements that are close to the work area.
- Place appropriate traffic signs and cones around where the vehicle is during the treatment in the street (**Figure 84**).
- When treating large Canary Island palm trees, it might be necessary to use an elevator with a platform (**Figure 85**).
- Once the chemical treatment has been completed, place an information poster on the dangers of the treatment in a visible place (**Figure 86**). Any treatment should be registered in the database.

10.3.5 Supporting information resources

A database, map and mobile application for collecting data should be used for ease of reference.

©FAO/Moisés Fajardo

Figure 84. **Preventive chemical treatment against RPW in an urban area**

©FAO/Moisés Fajardo

Figure 85. **Truck mounted elevator with platform to treat the crown of the Canary Island palm**

©FAO/Moisés Fajardo

Figure 86. **Canary Island palm labelled after preventive chemical treatment**

11 Guidelines on curative pesticide treatments (chemical trunk injection)

Abdulrahman Aldawood

11.1 Curative pesticide treatments (chemical/natural)

Treating RPW infested palms in the early stages of infestation (i.e. early infestation and medium infestation) ensures recovery of the palm from attack by this lethal pest. It is important to develop a protocol for the rational use of curative pesticide applications, especially with regard to trunk injection. This chapter provides guidance on trunk injection. Curative sprays are included in the protocols of mechanical sanitization and the proper and safe removal and disposal of infested palms at the farm/site level (Chapter 8 and Chapter 9).

These guidelines are intended as a field reference for RPW management programme personnel, plant health personnel at the relevant government department, and others concerned with developing RPW control programmes.

11.2 Chemical trunk injection

11.2.1 Purpose

Chemical trunk injection as a curative treatment is highly recommended if the affected part is estimated to be less than 30 percent of the trunk of the infested palm. The aim of the management programme in this case is to chemically treat mild to moderate damage, targeting different RPW stages that can be found in both the superficial and the internal parts of the palm trunk. This treatment aims to control existing infestation and avoid new infestation.

11.2.2 Responsibilities of personnel

To guarantee the efficient chemical control process, all members of the RPW management team should carry specific responsibilities as follows.

Programme director

The programme director should have the responsibility for the overall implementation of the procedures. This includes, for example, the following tasks:

- distribution of work between teams (through periodic meetings at the beginning of each week), taking into consideration for each affected area the number of palm trees, the proportion of these that are damaged, and the apparent rate of expansion of the infestation;
- oversight of the teams on the ground and creation of the appropriate atmosphere for the workers by providing the required supplies;
- oversight of employees, evaluation of their performance, and solving the problems facing field teams;
- oversight of the management of affected areas according to the level of infestation and the development of appropriate plans and programmes;
- oversight of efforts to raise awareness and provide guidance to farmers in the affected areas regarding the seriousness of this pest and how to deal with it;
- elimination of obstacles faced by the teams, associated with uncooperative farmers or owners of closed or neglected farms;
- preparation of periodic reports of the completed tasks, clarifying the negatives and positives;
- ensuring that, following the results of the daily fieldwork, the teams concerned are provided with the necessary information about the appropriate action to take, according to the nature of the infestation (a copy stored on the computer and copies to the treatment teams, the spraying teams, the injecting teams, and the removal teams (if any)).

Team leader technicians

The team leader technician should be responsible for delimitation of the treatment area, ensuring proper execution of tasks by workers, coordination with farmers and organizing supply to workers of all the materials necessary for the injection treatments.

Workers

The chemical injection treatment should be performed by workers operating in pairs. They should report any requirements (e.g. for supplies) and problems, if any, to the team leader. These pairs of workers treat infested palms marked for treatment by the detection team (e.g. with one strap, or with a distinct colour tape or spray paint) with the type of treatment required (spraying or injection of infested palms). A palm in an advanced stage of infestation requiring eradication (removal) will have been marked differently (e.g. with two straps or a different colour tape or paint).

All personnel

All those involved in the treatment procedures should be responsible for making suggestions for the improvement of these procedures.

11.2.3 Reference documentation

All relevant information should be kept as a reference, including the pesticide label and information on legislation regarding chemical products, the target pest (red palm weevil) and the palm crop of the country.

11.2.4 Methodology

Attention should be focused on ensuring that trunk injection is targeting pupae, adults and larvae found in tunnels. An equipment list for chemical treatments is provided as Table 2.

Area determination

According to the results of weekly trapping data, visual inspection team reports, or reports from farmers, the programme director in cooperation with team leader technicians should determine the areas to be treated during the following week. Infested palm trees should be treated as a priority without delay. There should be weekly planning of these actions.

Prior notice

The farmer/owner should be informed by the team leader well in advance about the need to carry out the treatment, the location of the palms to be treated, the products to be used, and the treatment day. All arrangements need to be coordinated with the farmer in order to facilitate the labour for the treatment.

Work procedure

All treatments on the same farm are done on the same day. Prior to applying treatment, the infestation level should be assessed (**Figure 87**) to determine what action to take:

- If the affected palm tissue is less than 30 percent of the trunk of the tree, mark the palm (e.g. with one strap) for shower spraying or trunk injection (**Figure 88**).
- If more than 30 percent of the trunk has been affected, mark the palm (e.g. with two straps) for removal, make an entry on the daily work form to identify the palm for removal, and refer the matter to the removal (eradication) team. This form should be handed from the spray/injection team worker to the team leader technicians.

Solution preparation

Operators should have a valid licence for basic level application of chemical products and adopt all required safety procedures. Trunk injection procedures should comply with legal regulations concerning safe systems on work for chemical treatments. While one team member prepares the solutions for trunk injection, the other should perform a visual inspection on the palm trees to be treated. The solutions should be prepared according to the instructions on the product label, and the products should be authorized for use on palm trees.

The pH of the water should be checked, and the need for a pH regulator product (buffering agent) should be determined. The ideal pH is usually between 5.5 and 6.5.

Solution application

Before starting the injection process, the following points should be considered:

- To ensure that the pesticide spreads in the trunk of the palm within a short period of time, the irrigation of treated palms should be stopped for a week before injection.
- The injection process should be avoided at least two months before harvesting time in the case of date palms. If RPW infested date palms have to be treated within two months of harvest, then all fruit (dates) should be harvested and discarded.

The injection process should then be performed as follows:

1. After determining the damaged area on the trunk, mark several points for drilling around the palm trunk, either in a spiral manner or at the base of the trunk, depending on the pesticide used, the infestation pattern, and the height of the infested palm. For the spiral method, mark four to six holes, depending on the height of the palm trunk; these should be at intervals of 50 cm apart from ground level to no higher than one metre from the meristematic area of the infested palm, to avoid the pressure of the pesticide injection directly affecting the meristematic area. For injections into the base of the trunk (which depends on the product being used), mark four holes.
2. At each point, drill a hole at an angle of 30–45° using a drill machine equipped with a brad point drill-bit (with a length of 40–50 cm and diameter of 8 mm) (**Figure 89**).
3. Immediately after drilling, administer the trunk injection using a suitable injection delivery system that delivers the required chemical through the drilling holes into the palm trunk (**Figure 90** and **Figure 91**). Suitable delivery systems include the tree microinjection gun, the passive method (gallon method), the low-pressured method (balloon) and injection machines. If possible, the system should have multi-injection hoses, with enough hose for four palms at the same time. The injection pressure should be between one and two bars, so that an injection rate of 1.5 litres per linear metre of infested palm height is delivered. This amount is calculated through the reservoir of the injection device.
4. After completion of the injection, insert a biodegradable microinjection plug into the drilled hole to act as a barrier, thereby restricting any backflow of the pesticide.
5. After finishing all treatments, rinse the solution tank with water (about 25 litres) to get rid of all deposits, and then allow the water to drain away until the solution tank is empty.
6. Examine treated palm trees regularly to evaluate the efficacy of the treatment.
7. Register all treatments on a database.

©FAO/Abdulrahman Aldawood

Figure 87. **Visual detection method in action**

©FAO/Abdulrahman Aldawood

Figure 88. **Labelling with one clear strap indicating palm needs injection treatment**

©FAO/Abdulrahman Aldawood

©FAO/Abdulrahman Aldawood

Figure 89. **Starting injection method by drilling holes**

©FAO/Abdulrahman Aldawood

Figure 90. **Injection method in action**

©FAO/Abdulrahman Aldawood

Figure 91. **Post incection treatment of date palm**

11.3 Safe application of pesticides

To ensure the safe application of pesticides, the following principles apply:

- Operators of injection and spray equipment should receive suitable training before handling and applying pesticides.
- Pesticides should only be transported and stored in their original transport container and packages.
- The selection of appropriate and suitable spray/injection equipment is essential for the safe and effective use of pesticides.
- Pesticides should only be used if the application is economically justified.
- All pesticides should be used strictly in accordance with the recommendations on the pesticide label.
- The use of personnel protective equipment is essential for protecting the health of operators.
- Empty pesticide containers should never be reused by users and should be disposed of safely.
- If any worker develops any pesticide exposure symptom, he or she should go directly to a medical care provider with the product label.

Table 2. **Chemical treatments equipment list**

Tool group	Tools	Use
Machinery and equipment	Transport vehicle	Transporting workers, tools and products
	Spraying pumps, hoses, products, injection equipment, drills hoses	Pesticide application
	Tools (repair kit)	Maintenance
	Chemical products	Control
	pH meter	
Individual equipment	Personal protection equipment	Individual safe protection
Others	Mobile data-input device	Registration of actions taken
	Labels	Follow-up actions
	Cameras	Documentation

12 Guidelines on good agronomic practices (including palm density in the field, irrigation, and crop and field sanitation)

J.R. Faleiro and Abdulrahman S. Al Dawood

12.1 Good agronomic practices

Several agronomic practices influence the incidence and build-up of RPW in the field (Sallam, El-Shafie and Al-Abdan, 2012; Ben Salah, 2018) and the efficiency of visual inspection and other treatments. In this context, the following practices should be adopted/studied to reduce the risk of infestation and facilitate better management of the pest.

12.1.1 Palm density (spacing) in the field

Closely spaced palms, especially in traditional groves with limited penetration of sunlight, offer a suitable microclimate for RPW, probably due to enhanced in-grove humidity (Aldryhim and Al-Bukiri, 2003). Adopting a wider spacing of at least 8 x 8 metres could help keep RPW away.

12.1.2 Field sanitation

To efficiently manage RPW in the field, it is essential to maintain a clean plantation devoid of weeds and dead palms that facilitate breeding of the pest and obstruct the implementation of the IPM practices, particularly those related to palm inspection, preventive and curative treatments and removal of severely infested palms.

12.1.3 Offshoot management

Young date palms in the susceptible age group of less than 15–20 years often have a large number of offshoots, which makes visual inspection of such palms to detect infestation extremely difficult. Regular leaf/offshoot pruning and also offshoot removal is therefore indispensable. Preventive soaking of the offshoots and the trunk with insecticide immediately after these operations is essential to kill and to repel the RPW attracted by the volatiles produced by the wounds (**Figure 92**). Furthermore, removal of offshoots without treating the wound on the mother palm with insecticide often results in gravid female weevils getting attracted to these sites for egg laying, resulting in a new infestation. This is also true for wounds caused on the palm due to frond pruning. Olfactory-system disruption, leading to failure of odour-stimulus detection, has potential for RPW pest-control strategies.

12.1.4 Frond pruning

Wounds caused on the palm after frond pruning that are not treated with a repelling insecticide (chlorpyriphos) to neutralize the palm volatiles emitted, can also result in infestation by attracting female weevils to such odours, resulting in oviposition. In some countries, it is therefore recommended to carry out frond pruning during the winter when weevil activity is at its lowest level.

©FAO/J.R. Faleiro

Figure 92. **Protect fresh wounds on the trunk with insecticide immediately after removing offshoots**

12.1.5 Irrigation method adopted

Open flood irrigation, particularly in plantations where the water touches the collar region of the trunk, is known to attract RPW. The use of controlled drip irrigation instead of open flood irrigation is therefore recommended. In homestead or landscape gardens, palm trunks should be insulated with polythene sheets at the base to prevent the splashing of water from sprinklers and other irrigation systems that also leads to infestation.

Agro-techniques adopted that are favourable to RPW (open flood irrigation, growing of fodder and weeds close to the palms, failure to clean the fronds and aerial offshoots) can significantly contribute to an increase in RPW infestation by providing a favourable microclimate for the pest (**Figure 93** and **Figure 94**).

Figure 93. **Open flood irrigation with fodder and weeds growing close to date palm facilitates RPW attack**

Figure 94. **Irrigation water in contact with the palm: predisposes the palm to RPW attack**

12.1.6 Role of fertilizers in the management of RPW

Very little is known about the relationship between RPW infestation and the application of macro- (NPK) and micro-nutrients (Zn, Si, Fe, Mn, Mg, soluble silica, etc.). Some very preliminary results indicate that palms fertilized with diatomaceous earth could offer better resistance to infestation by RPW.

12.1.7 Varietal selection

Palm species exhibit varying degrees of resistance to attack by RPW (Al-Ayedh, 2008; Faleiro *et al.*, 2014). However, host plant resistance has not been exploited for the management of RPW. Although RPW is known to have a differential preference for palm varieties in the field, farmers cultivate certain traditionally established date palm varieties. National research institutions should carry out studies to identify the factors of resistance and incorporate these into the traditionally cultivated varieties. Exploiting host plant resistance through gene silencing (RNA interference) for better management of RPW is an option that needs to be investigated.

12.2 General management recommendations

Here are some further suggestions for successful management of RPW:

- Promote awareness among farmers and related stakeholders about the significance of the RPW issue.
- Develop a protocol for visual inspection of RPW infestation in a language easily understood by farmers and other supporting staff.
- Develop a quick, reliable, cost-effective, and easily applicable early detection device or technique for RPW infestation.
- Conduct a risk assessment of the area, adopting both visual observation and pheromone traps.
- Develop and popularize good agronomic practices that limit RPW attack.
- Develop a follow-up plan for preventive measures, including clean plantations and sanitation, wounds treatment, removal of neglected orchards, pheromone trapping, and insecticide applications via spray and injection.
- Assess the potential of new semiochemical IPM tools against RPW, including repellent and attract-and-kill products and the use of dry traps.
- Explore the potential of indigenous biocontrol agents (nematodes, fungi, viruses, etc.) and identify an efficient delivery system for their application against RPW.
- Encourage the establishment of tissue culture laboratories for the production and supply of RPW free planting material.
- Train plant quarantine staff and other law enforcement authorities on the phytosanitary aspects related to RPW.
- Develop a protocol for the rational use of preventive insecticide applications.
- Use preventive insecticide treatments based on infestation foci and trap capture data.
- Test a range of insecticides and register them against RPW.
- Carry out residue analysis trials before authorizing injection for preventive treatments in date palms.
- Develop procedures for removal and disposal of infested palms that are cost-effective and can be carried out at the farm itself.
- Explore the possibility of onsite incineration/small shredders of the removed palms through mobile incinerating trucks/mobile shredding machines.
- Strengthen extension programmes, activities, knowledge sharing mechanisms, communications, and farmers' organizations.
- Establish defined coordination mechanisms with non-governmental organizations, the private sector and cooperatives to make the programme more effective.
- Introduce a participatory approach, including training for farmers and farm workers (Farmers Field School), to empower them with knowledge and field practices.
- Strengthen cooperation between institutions at the national level and initiate programmes of cooperation at the regional and international level.
- Use social media to expedite transmission of information on the management of RPW.

Bibliography

Abbas, M.S.T., Hanounik, S.B., Shahdad, A.S. & Al-Bagham, S.A. 2006. Aggregation pheromone traps, a major component of IPM strategy for the red palm weevil, Rhynchophorus ferrugineus in date palms (Coleoptera: Curculionidae). *Journal of Pest Science*, 79: 69–73.

Abraham, V.A., Faleiro, J.R., Al Shuaibi, M.A. & Al.Abdan, S. 2001. Status of pheromone trap captured female red palm weevils from date gardens in Saudi Arabia. *Journal of Tropical Agriculture*, 39: 197–199.

Abraham, V.A. & Kurian, C. 1975. An integrated approach to the control of *Rhynchophorus ferrugineus* F. the red weevil of coconut palm. Proceedings of the 4th Session of the FAO Technical Working Party on Coconut Production, Protection and Processing, 14–25 September, Kingston, Jamaica.

Abraham, V.A., Shuaibi, M.A. Al, Faleiro, J.R., Abozuhairah, R.A. & Vidyasagar, P.S.P.V. 1998. An integrated management approach for red palm weevil, *Rhynchophorus ferrugineus* Oliv., a key pest of date palm in the Middle East. *Journal for Scientific Research: Agricultural Sciences*, 3: 77–83.

Abuagla, A.M. & Al-Deeb, M. 2012. Effect of bait quantity and trap color on the trapping efficacy of the pheromone trap for the red palm weevil, *Rhynchophorus ferrugineus*. *Journal of Insect Science*, 12: 120 [online]. [Cited 20 June 2019]. http://doi.org//10.1673/031.012.12002

Al-Ayedh, H. 2008. Evaluation of date palm cultivars for rearing the red date palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae). *Florida Entomologist*, 91: 353–358.

Al-Ayedh, H.Y. & Al Dhafer, H.M. 2015. Does *Oryctes elegans* (Coleoptera: Scarabaeidae) abundance determine future abundance of *Rhynchophorus ferrugineus* (Coleoptera: Rhynchophoridae) in the date palms of Saudi Arabia? *African Entomology*, 23(1): 43–47.

Aldawood, A.N., Alsagan, F., Altuwariqi, H., Almuteri, A. & Rasool, K. 2013. Red palm weevil chemical treatments on date palms in Saudi Arabia: results of extensive experimentations. Colloque méditerranéen sur les ravageurs des palmiers, 16–18 Janvier 2013, Nice, France. Association Française de Protection des Plantes, Alfortville, France. [Cited 11 March 2019]. https://www.cabi.org/ISC/FullTextPDF/2013/20133300783.pdf

Aldhryhim, Y.N. & Al.Ayedh, H.Y. 2015. Diel flight activity patterns of the red palm weevil (Coleoptera: Curculionidae) as monitored by smart traps. *Florida Entomologist*, 98(4): 1019–1024.

Aldryhim, Y. & Al-Bukiri, S.. 2003. Effect of irrigation on within-grove distribution of red palm weevil *Rhynchophorus ferrugineus*. *Journal for Scientific Research: Agricultural and Marine Sciences*, 8: 47–49.

Al-Saoud, A.H.. 2013. Effect of ethyl acetate and trap colour on weevil captures in red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) pheromone traps. *International Journal of Tropical Insect Science*, 33(3): 202–206.

Avand Faghih, A. 1996.The biology of red palm weevil, *Rhynchophorus ferrugineus* Oliv. (Coleoptera: Curculionidae) in Saravan region (Sistan and Balouchistan Province, Iran). *Applied Entomology and Phytopathology*, 63: 16–18.

Ávalos, J.A., Martí-Campoy, A. & Soto, A. 2014. Study of the flying ability of *Rhynchophorus ferrugineus* (Coleoptera: Dryophthoridae) adults using a computer-monitored flight mill. *Bulletin of Entomological Research*, 104: 462–470.

Ben Salah, M. 2018. Field operations in date palm and their importance for reducing pest infestation. *In* M. El Bouhssini & J.R. Faleiro, eds. *Date Palm Pests and Diseases: Integrated Management Guide*, pp. 210–222. Beirut, Lebanon, International Center for Agricultural Research in the Dry Areas.

Dembilio, Ó. & Jacas, J.A. 2012. Bio-ecology and integrated management of the red palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae), in the region of Valencia (Spain). *Hellenic Plant Protection Journal*, 5: 1–12.

Dembilio, Ó, Jacas, J.A. & Llácer, E. 2009. Are the palms *Washingtonia filifera* and *Chamaerops humilis* suitable hosts for the red palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae)? *Journal of Applied Entomology*, 133: 565–567.

El Bouhssini, M. & Faleiro, J.R. 2018. *Date palm pests and diseases: integrated management guide*. Beirut, Lebanon, International Center for Agricultural Research in the Dry Areas. 232 pp.

El-Shafie, H.A.F. & Faleiro, J.R. 2017. Optimizing components of pheromone-baited trap for the management of red palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) in date palm agro-ecosystem. *Journal of Plant Diseases and Protection*, 24(3): 279–287.

El-Shafie, H.A.F., Faleiro, J.R., Al-Abbad, A.H., Stoltman, L. & Mafra-Neto, A. 2011. Bait-free attract and kill technology (Hook™ RPW) to suppress red palm weevil, *Rhynchophorus Ferrugineus* (Coleoptera: Curculionidae) in date palm. *Florida Entomologist,* 94(4): 774–778.

Esteban-Durán, J., Yela, J.L., Beitia-Crespo, F. & Jiménez-Álvarez, A. 1998. Biología del curculiónido ferruginoso de las palmeras *Rhynchophorus ferrugineus* (Olivier) en laboratorio y campo: ciclo en cautividad, peculiaridades biológicas en su zona de introducción en España y métodos biológicos de detección y posible control (Coleoptera: Curculionidae: Rhynchophorinae) [Biology of the red palm weevil *Rhynchophorus ferrugineus* (Olivier) in the laboratory and field: life cycle, biological characteristics in its zone of introduction in Spain, biological methods of detection and possible control (Coleoptera: Curculionidae: Rhynchophorinae)]. *Boletín de Sanidad Vegetal*, 24(4): 737–748.

European and Mediterranean Plant Protection Organization (EPPO). 2007. *Rhynchophorus ferrugineus* and *Rhynchophorus palmarum*. PM 7/83 (1). *Bulletin OEPP/ EPPO Bulletin* 37, 571–579.

European and Mediterranean Plant Protection Organization (EPPO). 2009. *Rhynchophorus ferrugineus* found on *Howea forsteriana* in Sicilia, Italy. *EPPO Reporting Service* No. 3: 2009/051.

European Commission. 2007. Commission Decision of 25 May 2007 on emergency measures to prevent the introduction into and the spread within the Community of *Rhynchophorus ferrugineus* (Olivier). 2007/365/EC. *Official Journal of the European Union*, L 139: 24–27.

European Commission. 2008. Commission Decision of 6 October 2008 amending Decision of 2007/365/EC on emergency measures to prevent the introduction into and the spread within the Community of *Rhynchophorus ferrugineus* (Olivier). 2008/776/EC. *Official Journal of the European Union*, L 266: 14.

European Commission. 2010. Commission Decision of 17 August 2010 amending Decision 2007/365/EC as regards the susceptible plants and the measures to be taken in cases where *Rhynchophorus ferrugineus* (Olivier) is detected. 2010/467/EU. *Official Journal of the European Union*, L 226: 42–45.

Faleiro, J.R. 2006. A review of the issues and management of the red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Rhynchophoridae) in coconut and date palm during the last one hundred years. *International Journal of Tropical Insect Science,* 26: 135–154.

Faleiro, J.R., Abdallah Ben, A., Ashok Kumar, J., Shagagh, A. & Al-Abdan, S. 2010. Sequential sampling plan for area-wide management of red palm weevil, *Rhynchophorus ferrugineus* (Olivier) in date plantations of Saudi Arabia. *International Journal of Tropical Insect Science,* 30(3): 145–153.

Faleiro, J.R., El-Saad, M.A. & Al-Abbad, A.H.. 2011. Pheromone trap density to mass trap *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae/ Rhynchophoridae/ Dryophthoridae) in date plantations of Saudi Arabia. *International Journal of Tropical Insect Science,* 31(1–2): 75–77.

Faleiro, J.R. & Satarkar, V.R. 2005. Attraction of food baits for use in red palm weevil, *Rhynchophorus ferrugineus* Olivier pheromone traps. *Indian Journal of Plant Protection,* 33(1): 23–25.

Faleiro, J.R., El-Shafie, H.A.F., Ajlan, A.M. & Sallam, A.A. 2014. Screening date palm cultivars for resistance to red palm weevil, *Rhynchophorus ferrugineus* (Coleptera: Curculiondae). *Florida Entomologist,* 97(4): 1529–1536.

Faleiro, J.R., Al-Shuaibi, M., Abraham V.A. & 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. *Journal for Scientific Research: Agricultural Sciences,* 4(1): 5–9.

FAO. 2015. *Import verification. A guide to import verification for national plant protection organizations*. Rome, IPPC Secretariat, FAO. 34 pp. (also available at https://www.ippc.int/en/publications/86041/).

FAO. 2016. *Plant pest surveillance. A guide to understand the principal requirements of surveillance programmes for national plant protection organizations*. Rome, IPPC Secretariat, FAO. 60 pp. (also available at https://www.ippc.int/en/publications/86051/).

FAO. 2017a. *Current situation of red palm weevil in the NENA region. Current situation of management practices, challenges/weaknesses and available research and technologies for its improvemen*t. Rome. 25 pp. (also available at www.fao.org/3/a-ms664e.pdf).

FAO. 2017b. *Framework strategy for eradication of red palm weevil.* Scientific consultation and high-level meeting on red palm weevil management, 29–31 March 2017, Rome. 32 pp. (also available at www.fao.org/3/a-mt054e.pdf).

FAO. 2019. Proceedings of the Scientific Consultation and High-Level meeting on Red Palm Weevil management (Shoki Al-Dobai, Maged Elkakhy and Romeno Faleiro: Editors): 29–31 March 2017, Rome, Italy. 200 pp(also available at http://www.fao.org/3/ca1541en/CA1541EN.pdf).

Ferry, M. & Gómez, S. 2011. Rectification of current erroneous biological and technical conceptions to succeed the control of the red palm weevil in urban environment. Presentation to the 59th annual meeting of the Entomological Society of America, 13–16 November 2011, Reno, NV, USA. [Cited 4 August 2019]. http://propalmes83.com/images/pdf/111115-ESA-control-of-the-RPW-in-urban-environment.pdf

Ferry, M. & Gómez, S. 2012a. Charançon rouge des palmiers, mises au point sur la lutte [Red palm weevil, focus on the management]. *Phytoma*, 658: 38–41.

Ferry, M. & Gómez, S. 2012b. *Control integrado del picudo rojo: métodos curativos y preventivos, estrategia, SIG y legislación [Integrated control of the red palm weevil: curative and preventive methods, strategy, GIS and legislation].* Manuel de formación. Spain, Diputación de Alicante. 186 pp.

Ferry, M. & Gómez, S. 2015. La stratégie de la dernière chance pour sauver les palmiers [The last chance strategy to save palms]. *Princeps*, 1: 125–134.

Hallett, R.H., Gries, G., Gries, R., Borden, J.H., Czyzewska, E., Oehlschlager, A.C., Pierce, Jr., H.D., Angerilli, N.P.D. & 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. & Borden, J.H. 1999. Pheromone trapping protocols for the Asian palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae). *International Journal of Pest Management,* 45: 231–237.

Hoddle, M.S., Hoddle C.D., Faleiro, J.R., El-Shafie, H.A.F., Jeske, D.R. & Sallam, A.A. (2015). How far can the red palm weevil (Coleoptera: Curculionidae) fly? Computerized flight mill studies with field-captured weevils. *Journal of Economic Entomology*, 108(6): 2599–2609.

Hussain, A., Rizwan-ul-Haq, M., Al-Jabr, A.M. & Al-Ayedh, H.Y. (2013). Managing invasive populations of red palm weevil: A worldwide perspective. *Journal of Food, Agriculture & Environment*, 11(2): 456–463.

ISPM 4. 2017. *Requirements for the establishment of pest free areas*. Rome, IPPC Secretariat, FAO. (also available at https://www.ippc.int/en/publications/614/).

ISPM 6. 2018. Surveillance. Rome, IPPC Secretariat, FAO. (also available at https://www.ippc.int/en/publications/615/).

ISPM 7. 2016. *Phytosanitary certification system*. Rome, IPPC Secretariat, FAO. (also available at https://www.ippc.int/en/publications/613/).

ISPM 10. 2016. *Requirements for the establishment of pest free places of production and pest free production sites*. Rome, IPPC Secretariat, FAO. (also available at https://www.ippc.int/en/publications/610/).

ISPM 12. 2017. *Phytosanitary certificates*. Rome, IPPC Secretariat, FAO. (also available at https://www.ippc.int/en/publications/609/).

ISPM 20. 2017. *Guidelines for a phytosanitary import regulatory system*. Rome, IPPC Secretariat, FAO. (also available at https://www.ippc.int/en/publications/602/).

ISPM 23. 2016. *Guidelines for inspection*. Rome, IPPC Secretariat, FAO. (also available at https://www.ippc.int/en/publications/598/).

ISPM 31. 2016. *Methodologies for sampling of consignments*. Rome, IPPC Secretariat, FAO. (also available at https://www.ippc.int/en/publications/588/).

Lever, R.J.W. 1969. Pests of the coconut palm. FAO Agricultural Studies Report No. 77. Rome. viii + 190 pp.

Malumphy, C., Eyre, D. & Anderson, H. 2016. Red palm weevil. *Rhyncophorus ferrugineus. Plant Pest Factsheet*. York, UK, Department for Environment Food and Rural Affairs.

Massoud M.A., Sallam, A.A., Faleiro, J.R. & Al-Abdan, S.. 2012. Geographic information system-based study to ascertain the spatial and temporal spread of red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) in date plantations. *International Journal of Tropical Insect Science,* 32(2): 108–115.

McMaugh, T. 2005. *Guidelines for surveillance for plant pests in Asia and the Pacific*. Australian Centre for International Agricultural Research (ACIAR) Monograph No. 119. Canberra, ACIAR. 192 pp.

Milosavljević, I., ElShafie, H.A.F., Faleiro, J.R., Hoddle, C.D., Lewis, M. & Hoddle, M.S. 2019. Palmageddon: the wasting of ornamental palms by invasive palm weevils, *Rhynchophorus* spp. *Journal of Pest Science*, 92(1): 143–156.

Murphy, S.T. & 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.

Niblett, C.L. & Bailey, A.M. 2012. Potential applications of gene silencing or RNA interference (RNAi) to control disease and insect pests of date palm. *Emirates Journal of Food and Agriculture*, 24(5): 462–469.

Nirula, K.K. 1956. Investigations on the pests of coconut palm. Part-IV. *Rhynchophorus ferrugineus*. *Indian Coconut Journal*, 9: 229–247.

Oehlschlager, A.C. 2016. Palm weevils' pheromones: discovery and use. *Journal of Chemical Ecology*, 42(7): 617–630.

Potamitis, I. & Rigakis, I. 2015. Smart traps for automatic remote monitoring of *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae). *PeerJ Preprints*, 3: e1337v1 [online]. [Cited 11 March 2019]. https://dx.doi.org/10.7287/peerj.preprints.1337v1.

Sallam, A.A., El-Shafie, H.A.F. & Al-Abdan, S. 2012. Influence of farming practices on infestation by red palm weevil *Rhynchophorus ferrugineus* (Olivier) in date palm: a case study. *International Research Journal of Agricultural Science and Soil Science,* 2: 370–376.

Save Algarve Palms. 2019. Host palms. In: *Save algarve palms* [online]. [Cited 29 March 2019]. www.savealgarvepalms.com/en/weevil-facts/host-palm-trees

Shagagh, A., Abbad, A.H. Al, Dan Dan, A.M., Ben Abdallah, A. & Faleiro, J.R. 2008. Enhancing trapping efficiency of red palm weevil pheromone traps with ethyl acetate. *Indian Journal of Plant Protection,* 36: 310–311**.**

Soffan, A., Antony, B., Abdelazim, M., Shukla, P., Witjaksono, W., Aldosari, S.A. & Aldawood, A.S. 2016. silencing the olfactory co-receptor RferOrco reduces the response to pheromones in the red palm weevil, *Rhynchophorus ferrugineus*. *PLoS ONE,* 11(9): e0162203 [online]. [Cited 11 March 2019]. https://doi.org/10.1371/journal.pone.0162203.

Soroker, V., Harari, A. & Faleiro, J.R. 2015. The role of semiochemicals in date pest management. *In* W. Wakil, J.R. Faleiro & T.A. Miller, eds. *Sustainable pest management in date palm: current status and emerging challenges,* pp. 315–346. Switzerland, Springer International Publishing. xx + 429 pp.

Soroker, V., Nakache, Y., Landau, U., Mizrach, A., Hetzroni, A. & Gerling, D. 2004. Utilization of sounding methodology to detect infestation by *Rhynchophorus ferrugineus* on palm offshoots. *Phytoparasitica,* 32: 6–8.

Vacas, S., Melita, O., Michaelakis, A., Milonas, P., Minuz, R., Riolo, P., Abbass, M.K. 2016. Lures for red palm weevil trapping systems: aggregation pheromone and synthetic kairomone. *Pest Management Science,* 73(1): 223–231.

Vacas, S., Primo, J. & Navarro-Llopis, V. 2013. Advances in the use of trapping systems for *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae): traps and attractants. *Journal of Economic Entomology,* 106: 1739–1746.

Vidyasagar, P.S.P.V. & Aldosari, S.A, eds. 2011. *IPM of red palm weevil* (الإدارة المتكاملة لسوسة النخيل الحمراء). Riyadh, Saudi Arabia, Chair of Date Palm Research. Technical publication No.1. 20 pp.

Vidyasagar, P.S.P.V., Hagi, M., Abozuhairah, R.A., Al-Mohanna, O.E. & Al-Saihati, A.A. 2000. Impact of mass pheromone trapping on red palm weevil adult population and infestation level in date palm gardens of Saudi Arabia. *Planter,* 76 (891): 347–355.

Wattanapongsiri, A. 1966. A revision of the genera *Rhynchophorus* and *Dynamis* (Coleoptera: Cuculionidae). *Department of Agriculture Science Bulletin,* 1. Bangkok, Thailand. 328 pp.

World Trade Organization (WTO). 1994. *Agreement on the Application of Sanitary and Phytosanitary Measures*. Geneva, WTO.

Red Palm Weevil

Guidelines on management practices

Since gaining a foothold on date palm in the Near East during the mid-1980s, the red palm weevil (RPW) *Rhynchophorus ferrugineus* Olivier has spread rapidly over the last three decades and is now a major pest of palms in a diverse range of agro-ecosystems worldwide. In most of the countries affected, failure to manage RPW can be attributed to lack of awareness about this pest and to lack of systematic and coordinated control actions or management strategies that involve all stakeholders. These guidelines have been developed by FAO to support all those involved in the day-to-day management of RPW in the field (including farmers and pest-management professionals), researchers, and the decision makers and administrative stakeholders who support implementation of integrated pest management (IPM) strategies for RPW. Written by internationally recognized RPW experts, the guidelines describe the biology and host range of RPW and address all aspects of RPW-IPM, including surveillance, phytosanitary measures, early detection, pheromone trapping protocols, preventive and curative chemical treatments, removal and safe disposal of severely infested palms, and best agricultural practices to mitigate attacks by this lethal pest of palms.

INTERNATIONAL YEAR OF
PLANT HEALTH
2020

ISBN 978-92-5-132189-8
9 789251 321898
CA7703EN/1/02.20