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Recognition, management and inspection protocol for *Rhynchophorus ferrugineus* Olivier on Palm Trees

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Technical Manual No. 2
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Recognition, management and inspection protocol for *Rhynchophorus ferrugineus* Olivier on Palm Trees

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1. Introduction

The red palm weevil, *Rhynchophorus ferrugineus*, Olivier (Coleoptera: *Curculionidae*) is a species native to tropical regions of Asia and Polynesia. However, the continued export of palm trees infested with *R. ferrugineus* has facilitated its spread to the Middle East, the Mediterranean, the Canary Islands, the Maghreb region of North Africa, Japan, China and the Caribbean.

These insects attack many palm species of the Arecaceae family, most of which are economically important and are cultivated for their food or ornamental interest. Their main hosts are the coconut palm (*Cocos nucifera* L.) and the oil palm (*Elaeis guineensis* Jacq.), among other large palms. In Spain, the red palm weevil has been observed on the Canary Island palm (*Phoenix canariensis* H. Wildpret) and its hybrids, and less frequently on the date palm (*Phoenix dactylifera* L.). The complete list can be consulted at https://gd.eppo.int/taxon/RHYCFE/hosts.

2. *Rhynchophorus ferrugineus* Olivier as a pest

2.1 Description and biology

Rhynchophorus ferrugineus has four developmental stages: egg, larva, pupa and adult. The incubation period of the eggs lasts 3 to 5 days. Larval development lasts 45 to 60 days and pupation is between 20 and 25 days. In Spain, the complete cycle takes between three and four months.

Adults have an oval body and are 2 to 5 cm long. Insects of this family are characterised by a beak-shaped extension of the head (rostrum),where the characteristic reddish-ferruginous, club-shaped antennae are located. The prothorax has highly visible black spots of variable sizes and shapes. The elytra are black and striated. Males have short setae on the distal part of the rostrum and in the dorsal position, which differentiate them from females which lack them. Adults move by flight or climbing from the ground to the tops of palm trees.

The **egg** is oval-shaped, 1 to 2.5 mm long, creamy or yellowish in colour and shiny. Females lay an average of 300-400 eggs in the soft tissue of the crown.

The **larvae** develop inside the living tissues of the palm tree, until they reach a size of between 3 and 5 cm in length. Once the tissues are dead, the larvae cannot live. Initially they are creamy white in colour, turning yellow as they mature. The larvae are rough, segmented, eruciform and apodous, moving by rhythmic contractions of the thoracic segments. They have powerful mandibles that allow them to pierce the plant tissues of its host.

Pupa are mainly located at the base of the palm trees, loose or inserted inside, surrounded by an oval puparium 4 to 6 cm long, made by larvae from the fibres of the palm tree itself.

The adults do not usually leave the palm tree where they have developed until it is practically destroyed, so several generations can exist in the same tree and all stages of the pest can coexist. They fly to colonise other palm trees with a preference for trees with wounds. The adult males already on a tree will emit pheromones that attract more males and females, which explains their gregarious nature. External temperature has an influence on movements, as the winter cold seems to limit the spread of the pes.

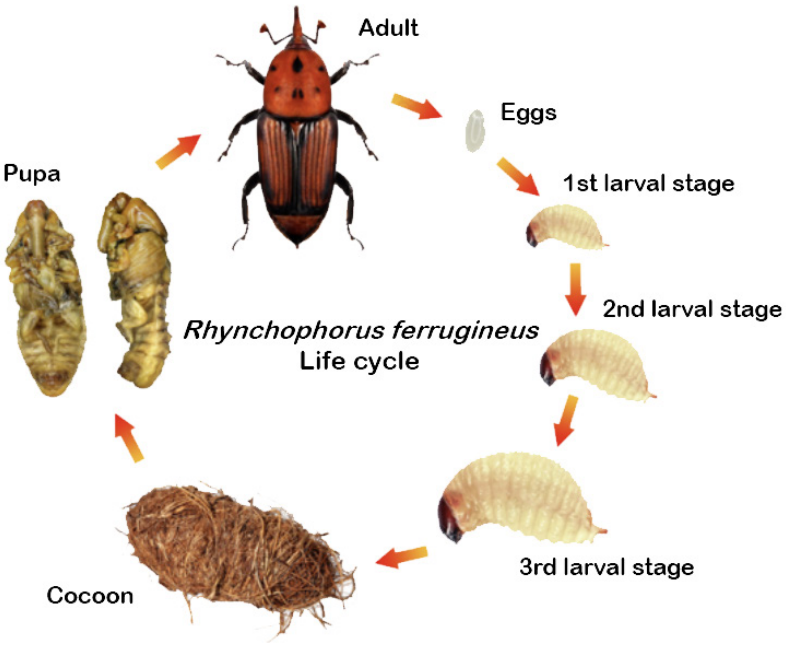

Figure 1. Life cycle of *R. ferrugineus*.

2.2 Identification

Features such as the surface of the dorsum, the shape of the rostrum, the shape of the mandibles and the scutellum are used to differentiate genera of the family *Dryophthoridae*. However, the following features may serve to distinguish *Rhynchophorus* from similar looking genera. These include the rostrum which is usually cylindrical (except in *R. quadrangulus*), the dorsum is densely setose (except in *R. cruentatus*), and punctate in males. The scutellum is long and broad at the base and the pronotum has a complete basal submarginal groove and usually lacks a basal lobe, also the spermatheca is truncated distally.

Within the genus *Rhynchophorus*, *R. ferrugineus* may be confused with other species, in some cases requiring expert help for its correct identification.

- ***R. bilineatus:*** length 25-35 mm, black except for the pronotum which may be blackish-brown, black or very dark red and dull, with a dark ochre or dark red inverted U-shaped pattern. Matt striated elytra and blackish rostrum are similar to *R. ferrugineus*.

- ***R. cruentatus:*** length 25-35 mm, variable in colour (dark reddish-brown to black), with smooth, reddish-brown or black elytra, truncated distally. The male's rostrum lacks setae.

- ***R. palmarum***: length 30-45 mm, dorsally flattened, deep black with very fine, smooth and shiny velvety pubescence. Elytra longitudinally striated and velvety. Males have a mushroom brush on the rostrum.

- ***R. phoenicis:*** length 25-40 mm, variable in colouring (reddish brown to dark brown to almost black), with the dorsal area brighter and darker than the ventral area. Males have a mushroom brush on the rostrum.

- ***R. vulneratus:*** length 2.5-4 cm, colouring varies from dark reddish-brown to black, with a medium red band on the thorax. Elytra reddish-brown with striations. Males have a mushroom brush on the dorsal line of the rostrum which females lack.

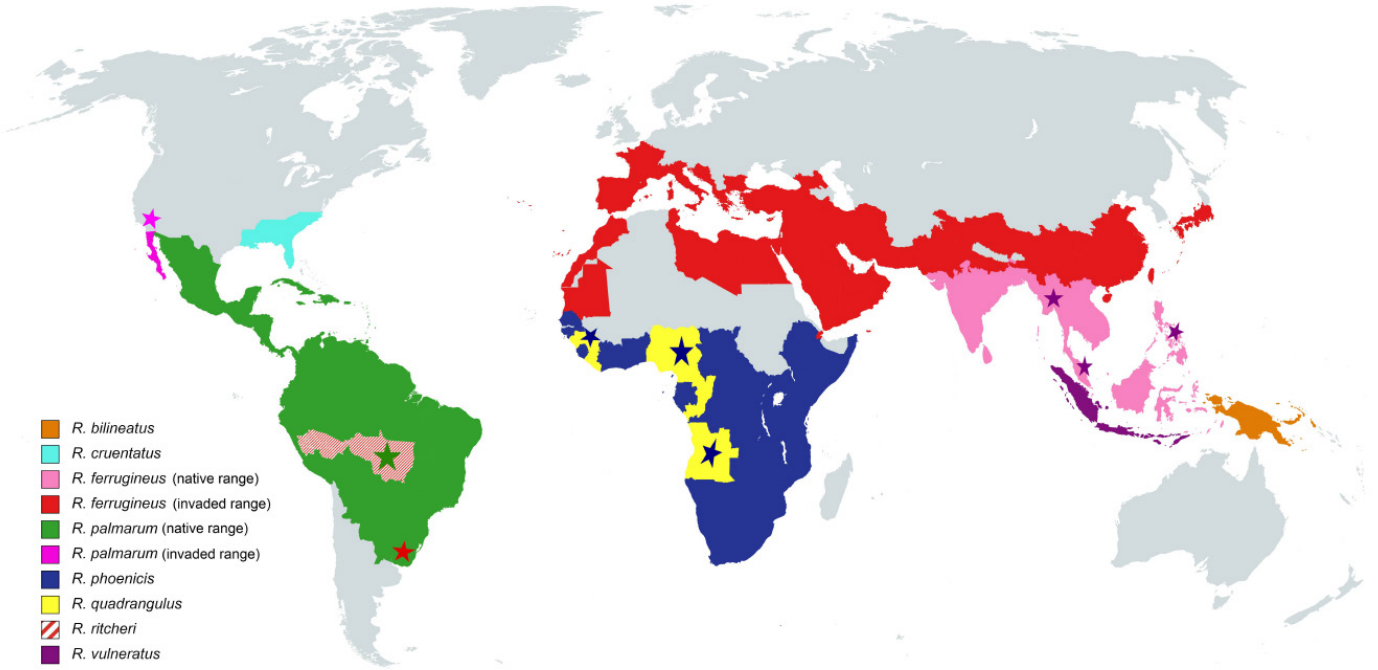

Figure 2. Global distribution of species of the genus *Rhynchophorus*, with indication of native and introduced ranges. The green star indicates the presumed native range overlap between *R. palmarum* and *R. ritcheri* in South America. The dark blue star represents the range overlap between *R. phoenicis* and *R. quadrangulus* in Africa, and the maroon star indicates the overlap between *R. ferrugineus* and *R. vulneratus* in Southeast Asia. The red star in Uruguay, South America, indicates a 2022 invasion of *R. ferrugineus* in Canelones. The magenta star in southern California, USA, indicates an invasion of *R. palmarum* in San Diego County, probably from Tijuana, Baja California, Mexico (taken from Hoddle et al., 2023).

2.3 Location of *R. ferrugineus* on the palm tree

In Canary Island palms, the adults of *R. ferrugineus* settle in the crown of the tree, as they prefer to feed on young tissue, migrating to the upper part of the palm so females can lay their eggs. The females lay their eggs in holes made with their faces in wounds created during harvesting and pruning. In date palms, infestations usually begin in the areas where the young shoots are found, with the infestation progressing slowly, as the date palm is more resistant than the Canary Island palm.

2.4 Incidents and damage to palm trees

The damage caused by this insect is produced by the larvae during feeding. In general, the palm trees attacked do not show any change at the beginning of the attack, the symptoms appear in a mild form for a few months and progressively evolve until the tree dies.

The symptoms that can be seen externally are mainly based on the presence of circular or oval holes in the leaflets of the leaves, cuts in the middle or apical area of the leaves and galleries in the rachis of the leaves. In an advanced stage of the attack, asymmetry is produced in the crown of the palm tree due to the collapse of the upper ring leaves over the lower ones, which may or may not be accompanied by dry leaves. Very frequently, the youngest newly emerged leaves collapse, giving rise to a general decay in this area. These symptoms indicate the seriousness of the damage caused to the palm tree due to colonisation of the terminal bud by the larvae. In date palms, it is usual to find populations of this insect in the young shoots or on the trunk, as the tender lateral and basal buds are very attractive to adults.

The symptoms of affected palm trees will depend on the stage of infestation. It is important to recognise these symptoms well to be able to detect them early and eliminate affected plant material.

Figure 3. Visual symptoms of palm trees infested by *R. ferrugineus*: a) initial damage in Canary Island palm trees, b) crown collapse, c) presence of eaten leaflets, d) presence of pelleted leaflets, e) damage to the apical bud and f) collapse of the central tuft of young leaves (Sources: EPPO Global Database and GMR Canarias S.A.U.).

Figure 3 (cont.). Visual symptoms of palms infested by *R. ferrugineus*: g) damage to the stipe, h) presence of galleries inside and outside the stipe, i) presence of fibres and j) leaf galleries and presence of puparia (Sources: EPPO Global Database, GMR Canarias S.A.U. and Küchenkraut).

2.5 Dispersion modes

The attraction of *Rhynchophorus* adults, both males and females, is due to the existence of the aggregation pheromone, the kairomones of the host plant and the synergistic effect between the two semiochemicals.

Adults of *R. ferrugineus* tend to remain on the affected stipe, probably due to synergies between semiochemicals. When the level of infestation is high, the stipe is not able to ensure offspring of further generations, adults make short flights to locate new host plants; if not located, they usually return to the same stipe. Adults of *R. ferrugineus* fly upwind, following the trail of food attractants that are carried by the wind.

3. Control measures

3.1 Cultural control

These procedures can be varied and aim to prevent or reduce the incidence of *R. ferrugineus* in palm trees:

- Decrease the planting density to reduce moisture accumulation within palm plantations due to irrigation. Increase sunlight penetration by increasing the distance between trees, this will prevent a microclimate suitable for *R. ferrugineus*. Planting frames of 8x8 m are recommended.

- Use of drip irrigation systems to reduce excess humidity in the plantation, thus curbing the ideal conditions for the reproduction of

R. ferrugineus. In private or landscaped gardens, the stipe of the palm tree should be insulated with polyethylene sheeting at the base to prevent water splashing from sprinklers.

- Use of sanitised planting material.

- Pruning and conditioning the palm tree in winter, when the weevil's activity is low, so that the volatiles released from the cuts in the tissue will not attract gravid females.

- In young date palms (less than 15-20 years old), the leaves and shoots must be pruned regularly, and then a preventive insecticide treatment applied to prevent gravid females from being attracted by the volatiles released by plant tissue and laying new eggs, leading to a new infestation.

- Correct management of palm residues affected by *R. ferrugineus* through shredding, burial or incineration to kill the larvae, pupae and adults of this weevil. Shredding the plant material is a costly technique, so an alternative is to cut the infested trunks and treat them with insecticides to kill emerging weevils and adults attracted to the cut material. Plant debris should be buried so that the shallowest part is at least two metres from the surface. The remains must be treated with an approved insecticide and quicklime before covering with soil. The burial area must be stamped down.

3.2 Mechanical sanitation

The plant sanitation technique consists of eliminating the plant tissue affected by the pest and all living forms of the insect, as required by current legislation. In this way, if the palm bud has not been damaged by the insect, it is able to sprout again and therefore regenerate. Furthermore, this technique has the advantage that in the event that the palm bud has been seriously affected and does not resprout, at least with this action we have managed to eliminate the source of the *R. ferrugineus* infestation for other nearby trees.

Sanitation involves using a sharp tool until healthy tissue is reached. Infested tissue, if cut into small pieces, needs no further treatment (eggs and larvae will die quickly in the dried tissue). This simple mechanical sanitation has two major advantages. It can be easily carried out by the farmer, and no infested tissue is moved out of the infested area, thus avoiding any risk of spread. The damaged palm tissue is then sprayed with an insecticide repellent or with clay or plaster paste to prevent attracting females.

3.3 Preventive treatments

At present, preventive insecticide applications can use either chemical or natural products. They have two purposes: (i) to kill the adults hidden at the base of leaves, and (ii) to protect the palm trees by killing the adult females and early stages of the pest.

Preventive insecticide applications must be carried out either by spraying/soaking of specific areas of the palm tree or by injection (only for ornamental palms). To guarantee the effectiveness of preventive insecticide treatments and minimise risks to human health and the environment, the following points must be respected:

- Preventive insecticide treatments must only be applied to palm trees in the infested area and for a limited period established according to the evolution of trap catches.

- The following measures should be considered when applying preventive insecticides.

    - In case of showers/soaking, the pesticide solution (10 to 20 l of solution per palm) should be directed at the base of the crown leaves (ornamental palms over 2 m) and the inner whorls of the leaves, the trunk up to 2 mm and the stipes (date palms and small ornamental palms).

    - In the case of ornamental palms, the option of attaching tubes to deliver pesticide showers to the bases of the canopy leaves requires periodic displacements.

    - For ornamental palms, injection treatments should be applied a limited number of times and only as part of a pest eradication programme. For date palms, injection should not be applied, as no official data on the content of insecticide residues in dates after injection are currently available.

3.4 Curative treatments

In date palms, the infestation usually starts at the base. However, in Canary Island palms or Washingtonia palms, infestation enters via the trunk, so the following methods could be used:

a) Surface infestation: mechanical removal of larvae, cleaning of affected tissues, application of mastic, chemical treatment.

b) Deeper but not severe infestation: use of systemic products by injection or in irrigation water (when irrigation is localised), complementary chemical treatments by spraying.

3.5 Biological control

Although there are many references to natural enemies of *R. ferrugineus*, very few meet the requirements for effective pest control.

However, the control exerted by entomopathogenic fungi, with emphasis on *Beauveria bassiana*, is of particular importance. It is recommended to use strains of this fungus that are adapted to a particular niche, as they compete in their natural environment, and their specific requirements for temperature, humidity and UV radiation may influence their success as a biocontrol agent. Treatments with *B. bassiana* can be applied by targeted sprays at the base of leaves and in attractant and infective devices.

Entomopathogenic nematodes of the genus Steinernema (Rhabditida: *Steinernematidae*) are also an effective tool in the control of larvae, pupae and adults of *R. ferrugineus*. They can be applied preventively or curatively. In a treatment with entomopathogenic nematodes the following aspects should be considered:

- Maintain the cold chain until application (2-8 ºC).
- Remove filters from treatment machines to prevent nematodes from becoming stuck in them.
- Stir the broth from preparation to application, thus avoiding sedimentation and mortality of the nematodes.
- Do not apply in the middle of the day or in hot weather, as nematodes are sensitive to UV radiation.

3.6 Biotechnological control

Trapping system

The *R. ferrugineus* trapping system using semiochemicals can provide an estimation of population dynamics, population fluctuation, dispersal and facilitates the implementation of control measures.

a) Trapping for mass trapping: Traps should be placed within a radius of 1000 m from the point where infested palms are detected. The recommended trap density is 1 trap every 50 m in the case of palm tree alignments in streets or avenues, 1 trap for each roundabout with palm trees, 1 trap every 2500 m2 in parks and orchards (at least 1 trap per plot).

   As we know that some adults attracted by the traps do not fall into the traps but are attracted by nearby palms, palms within a 50 m radius of the traps should be treated regularly. Mass trapping should be carried out mainly from spring to autumn. If after 12 months, no weevils have been caught, the device could be converted into a monitoring device.

b) Monitoring traps: A monitoring trap should be placed in areas where it is suspected that the weevil may have arrived. The trap density should be 1 trap per 3 ha. Monitoring traps must be maintained throughout the year. As in the case of mass trapping, palm trees in the vicinity of the traps should be protected with preventive insecticide treatments.

Characteristics of the traps

There are currently several models and colours of traps available, all of which are suitable for implementing a trapping net. Of these, the black, cone-shaped traps catch more than 90% of the weevils they attract.

The trap should include an aggregation pheromone (ferrugineol, 4-methyl-5-nonanol, 3- 7mg/day), plant material (sugar cane, apple, palm pieces, dates, etc.), components present in the volatile profile of the host (ethyl acetate esters, ethyl propionate or ethanol mixtures) and water to maintain humidity and retain captured weevils.

The traps should preferably be placed in the shade and never at the foot of a palm tree, but halfway between the point chosen to place the trap and neighbouring palm trees.

Traps should be placed, in the case of bucket traps, buried in the ground to just below the level of the openings, and in the ground unburied in the case of cone traps.

They must be checked periodically (at least every 15 days) to remove and record the number of weevils trapped, check that they are properly set and replenish the water level. In traps exposed to the sun, a weekly check is necessary during the summer. Fermenting material should be renewed every 3 weeks. Contents should be renewed periodically, according to the manufacturer's instructions and the environmental conditions in the area.

Smart sensor traps allow automated monitoring and wireless data transmission, enabling near real-time data visualisation by smart devices.

Sterile insect technique

This involves the mass production of males, which are then sterilised in their pupal stage by gamma radiation and released into the field to compete with wild insects. The sterile insects copulate with wild females and transfer sterile sperm to them. This causes the eggs to become infertile, leading to a reduction in the population. It is a very advantageous method due to its high specificity, but it is very expensive and requires substantial infrastructure, so it is used only when weevil populations are low. Sterile male *R. ferrugineus* can be used to act as a vehicle for *B. bassiana* spores in weevil-infested palm trees.

Table 1. List of traps and attractants authorised for the control of *R. ferrugineus* in Spain.

Components	Trade name	Owner
Traps	Crosstrap®	Sanidad Agricola Econex, S.L.
	Rhynchonex® 17 roja	Sanidad Agricola Econex, S.L.
	Rhynchonex® 7,5 roja	Sanidad Agricola Econex, S.L.
	Kenotrap® Picudo	Kenogard, S.A.
	Opennatur® Rhynchophorus ferrugineus	OpenNatur, S.L.
	Picusan®	SanSan Prodesing S.L.
	Pitfall Trap®	OpenNatur, S.L.
	Sistema picudotrap®	SemioTrap, S.L.
Pheromones	Crosstrap®	Sanidad Agricola Econex, S.L.
	Rhynchonex® 17 roja	Sanidad Agricola Econex, S.L.
	Rhynchonex® 7,5 roja	Sanidad Agricola Econex, S.L.
	Kenotrap® Picudo	Kenogard, S.A.
	Opennatur® Rhynchophorus ferrugineus	OpenNatur, S.L.
	Picusan®	SanSan Prodesing S.L.
	Pitfall Trap®	OpenNatur, S.L.
	Sistema picudotrap®	SemioTrap, S.L.
Kairomonas	Crosstrap®	Sanidad Agricola Econex, S.L.
	Rhynchonex® 17 roja	Sanidad Agricola Econex, S.L.
	Rhynchonex® 7,5 roja	Sanidad Agricola Econex, S.L.

Push-Pull and Attraction and Death

Semiochemicals have been identified that act as repellents and, in combination with attractants such as aggregation pheromones, could be used to develop push-pull strategies in which repellents (methyl salicylate, α-pinene, 1-octen-3-ol and geraniol) push weevils away from areas of interest, while baited pheromone traps generate the attraction to draw weevils away from the area of interest. Another way to exploit the chemical ecology of palm weevils is through "attract-and-kill" techniques, in which an inert matrix infused with an aggregation pheromone attracts the weevils and, upon interaction with the matrix, they receive a lethal dose of a contact insecticide.

3.7 Chemical control

Insecticides are widely used to control the red palm weevil and are applied as sprays or paints on leaf bases and stipes, as soil and trunk injections, or as soil or crown drenching. Insecticides can be applied preventively to protect uninfested palm trees from weevils, or curatively to eliminate weevils in the early stages of infestation. Excessive use of insecticides can lead to the development of resistance and unacceptable residue levels in palm food crops. The following active substances are currently authorised for treatments against *R. ferrugineus* on palms:

Table 2. List of commercial products authorised for the control of *R. ferrugineus* on palm trees in Spain.

Trade name (Headline)	Active substance	Method of application
Epik® (Sipcam Inagra)	Acetamiprid 20% [SP] P/P	Aerial spraying and endotherapy
Revive II® (Syngenta España)	Benzoato de emamectina 9,5% [AL] P/V	Endotherapy
Kaiso Sorbie® (Nufarm España)	Lambda Cihalotrin 5% [ES] P/P	Aerial spraying
Sivanto Prime® (Bayer)	Flupiradifurona 20% [SL] P/V	Endotherapy

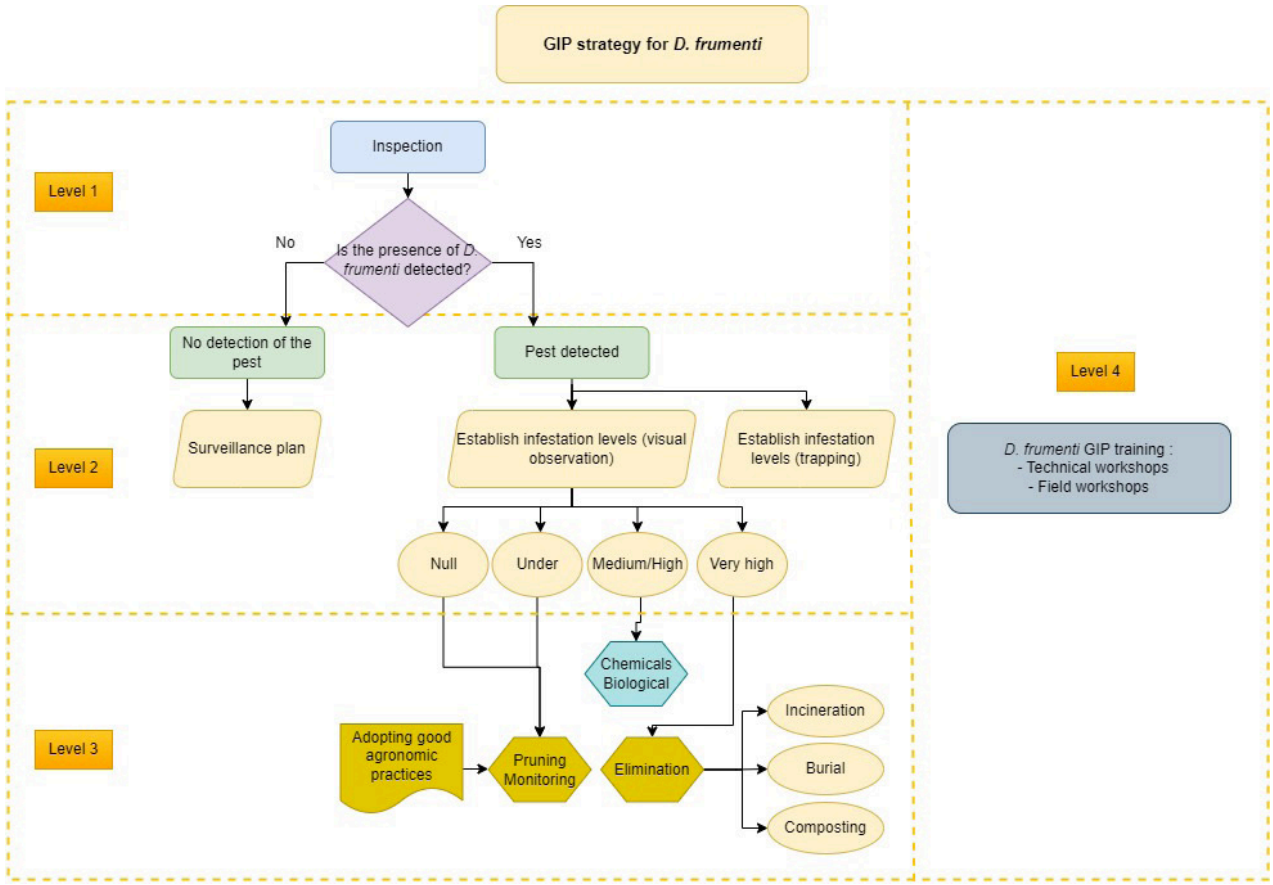

Figure 4. IPM strategy for R. ferrugineus (Source: Prepared by authors).

4. Plan for the control and eradication of *R. ferrugineus* in the Canary Islands. Action strategies.

The strategy carried out in the Canary Islands that led to the eradication of *R. ferrugineus* consisted of creating visibility and public awareness, legislative support, elaboration of a risk assessment and contingency plan, implementation of IPM (trapping, chemical control, intensive inspections and removal of infested palms), data transmission and decision making through a GIS system. In 2005, *R. ferrugineus* was detected in the Canary Islands and a year later the IPM strategy was implemented. Since 2013, no new infestations or captures have been detected, declaring the Canary Islands free of *R. ferrugineus* in May 2016.

4.1 Early detection

Early detection of infested palms, combined with monitoring of adults using traps baited with semiochemicals, is key to the successful management of the palm weevil. Early detection techniques include:

4.1.1 Visual recognition

Despite its difficulty, visual inspection of palms for red palm weevil infestation is recommended. **Visual inspection** of palm trees should be carried out on a quarterly basis in non-infested areas and bimonthly in infested areas.

In the case of Canary Island palms, the damage is mainly located in the crown of the palm, so it should be checked if there is/are any:

- drooping outer leaves, with tears at the level of the insertion with the trunk.
- general collapse of the leaf crown.
- faded appearance of the youngest leaves of the central plume, with yellowish or reddish-brown colouration.
- holes in the cut of the flap.
- remnants of pupae among the tábalas (lower part of the petiole) and leaves.
- arrow-shaped leaves at an angle to the vertical.
- twisting of the leaves in the axils.
- leaflets eaten or pelleted.
- eaten and/or truncate rachis.
- presence of 1-2 cm diameter galleries in leaf cross-sections.
- fibre remains.

In the case of date palms, the damage will be observed mainly at the base of the stipe and on the young shoots, so check if there are any:

- reddish or black exudation and fibrous debris.
- leafy plantlets with eaten leaves.
- holes in the leaf axils.
- remnants of pupae among the tábalas and leaves.

Visual inspection of palm canopies can also be carried out using drones with high- resolution cameras.

4.1.2 Mechanical traction survey

Operators should pull the leaves of the palms to check if they are easily detached due to the presence of *R. ferrugineus*. Similarly, an operator can pull leaves that have been cut off to check if they separate easily and if galleries can be observed inside them as a result of an infestation.

4.1.3 Olfactory recognition

Metal rods should be inserted between interstices of the leaves and directed towards the trunk. These should be smelt once they have been removed, as the smell of fermentation is characteristic of the presence of weevils. This detection can also be carried out using sniffer dogs.

4.1.4 Auditory recognition

Using audio-detectors, the sounds produced by the larvae as they gnaw on plant material and move around inside the infested palm can be identified.

4.1.5 Reconnaissance using infrared cameras and thermal imaging

The use of infrared cameras and thermal imaging is based on the comparison of the thermal spectrum of

the radiation emitted by the crowns of infested palms versus healthy ones.

4.2 Training

Operators who carry out pruning and other practices on palm trees must be accredited and obtain an authorisation card to guarantee correct handling of palm trees, and knowledge of all the necessary measures and protocols, as stipulated in the law in force.

4.3 Removal of palms with a high infestation of *R. ferrugineus*

Palm trees affected by *R. ferrugineus* and those which, in the opinion of the technicians, constitute a serious danger of spreading the pest, must be destroyed. To do this, the following steps must be taken:

- Protection and isolation of the area: Spread plastic sheeting at ground level and around the palm tree to collect any debris that may fall during the eradication process.

- Cutting of leaves: All leaves must be cut off using cutting tools or chainsaws. The leaves must be sprayed with an approved insecticide and then wrapped in plastic (more than 200 gauge thickness) to prevent the adults from leaving.

- Crown and stipe cutting: The crown is sprayed with an authorised insecticide and then wrapped in plastic. Use a chainsaw to separate the crown from the stipe. The stipe should be cut from the part closest to the ground and cut into pieces according to its height and location. The stump should be sealed with paste, and the Phoenix dactylifera and Washingtonia spp stumps must be extracted.

- Cleaning of the area and transport: Palm waste should be transported in a covered lorry to the place where the shredder is located or to the landfill site for its controlled destruction. All the remains of the soil must be collected by brushing or raking, depending on the surface on which the palm tree is located. At the end of the operation, all tools and the truck must be disinfected with a disinfectant solution.

- Burying the remains of the palm tree: The remains of the palm tree must be buried at least 2 m deep so that the top of the plant material is 2 m from the surface. The remains must be treated with an authorised insecticide and quicklime before being covered with soil. The burial should be stamped down.

4.4 Establishment of surveillance areas and zones

When *R. ferrugineus* is detected on an isolated palm tree or there is an outbreak, the following actions must be taken:

- Establish intensive surveillance area of 1 km radius around the outbreak, with the objective of inspecting and censusing 100% of the palm trees in the area.

- Target surveillance of an area of 3 km radius around the outbreak, in which possible affected palm trees will be identified. Locate the most likely high-risk areas such as public and private gardens, nurseries, etc.

- Create a protection zone with a radius of 5 km around the outbreak and a buffer zone with a radius of 10 km around the outbreak in which the phytosanitary measures stipulated in the legislation must be applied.

- Where several outbreaks are in proximity, an area around the outbreaks, the perimeter of which is at least 10 km from any of the outbreaks, should be declared an affected zone. Within the interior, a protection zone should be established with a perimeter of at least 5 km from any of the outbreaks.

4.5 Conditions for pruning

- Only the pruning of dry and senescent leaves is permitted, without cutting them at stipe level, preserving those leaves that are strongly attached and removing those that are easily detached.

- On small palm trees, the tendency is to tie up the green leaves.

- The cleaning of stipes must always be accompanied by the application of a phytosanitary product (fungicide and authorised insecticide) and brushing the stipes is prohibited.

- If it is necessary, for reasons of public safety, to cut green leaves, the scar shall be treated with an authorised phytosanitary product and then be coated with russet-coloured oil paint or pruning mastic. The cuts must always be clean and must not cause tears. If any other operation is necessary that causes cuts to the plant, insecticides and mastic must be used to cover the wounds.

- Pruning waste must be transported covered with plastic or similar material to an authorised waste disposal site. Tools must be disinfected prior to use for each specimen treated. Those carrying out pruning and other cultural practices on palm trees must be accredited by the competent authority.

4.6 Transplanting palm trees

Palm trees should be prepared for transplanting at least one month before it takes place by carrying out the following steps:

1. Two phytosanitary treatments (insecticide and fungicide) must be applied with a 15-day interval between them.

2. 15 days after the last treatment, the transplantation process can begin.

3. The tips of the leaves must be cut off, except for the bud, to reduce wind resistance and transpiration. All inflorescences and fruit on the palm should also be removed. The tree should be wrapped in cane or similar material to reduce transpiration and damage during transport. This should be kept in place until the palm tree takes root in its new location. Before wrapping, any cuts should be treated with mineral oil and sealed with a dark-coloured oil paint or mastic. The cut leaves should be taken to the dump in the shortest possible time.

4. The root ball must be of sufficient diameter. The roots must also be treated with a fungicide, an insecticide and a rooting product.

5. The hole in which the palm tree is to be placed must be opened before the palm tree is moved and transplanting should be carried out immediately.

6. The following physical and chemical products must be added. These must be mixed with the soil of the land or soil provided until a homogeneous product is obtained: 100 g of slow-release NPK type complex fertiliser, 100 g of 18% calcium superphosphate and 80 l of peat.

7. If there is excess soil, it must be removed.

8. The transplanting hole should be about twice the size of the hole needed to accommodate the root ball, so that part of it can be filled with the above mixture.

9. The stipe shall be adequately protected from mechanical damage during the lifting by the crane.

10. Once the palm tree has been transplanted, it must be correctly supported.

11. Back-up irrigation must be carried out at the time of transplanting so that the dripline contains water.

12. Work should be carried out by an accredited specialist gardening company using appropriate techniques and safety measures.

13. The work must be supervised by a technician from the competent body. The date of commencement of the work must be communicated at least 48 hours in advance, in writing to the competent authority. The designated technician must supervise operations and may order its suspension there are insufficient guarantees of success.

14. All costs and expenses of any kind incurred in connection with transplantation and/or removal shall be the responsibility of the applicant.

4.7 GIS data management

In addition, a GIS (geographic information system) has been developed which includes a database to centrally store all the information collected during the work related to the red palm weevil infestations.

Data include location, census, eliminations, status, traps, phytosanitary treatments, warnings, nurseries, etc. A mobile application for collecting data in the field with a PDA and a web viewer can be used, in which all types of data stored in the database and susceptible to being represented in space are included. The GIS has been an essential tool for the efficient coordination of the control and eradication plan for the red palm weevil.

6. Survey protocol for *R. ferrugineus* in palm trees

6.1 Sites to be inspected

Surveys should be based on the observation of symptoms of *R. ferrugineus* infestations, focusing on sites with a high risk of pest introduction, such as new palm plantations, recent transplantations, nurseries or landfills.

6.2 Timing of inspections

The most dangerous period for flights of red palm weevils is from March to October. During this period, the adults of the species are most active and can cause significant damage to palm trees. It is important to be alert and take control measures during these months to protect palm trees from this pest.

6.3 Inspection procedure

6.3.1 Recognition of adults

Diagnostic characters for identifying *R. ferrugineus* are that adults have an oval body, 2 to 5 cm long. They have a beak-shaped prolongation on the head (rostrum), where the characteristic reddish-ferruginous, club-shaped antennae are located. The prothorax has highly visible black spots of variable size and shape. The elytra are black and striated. Males have short mushrooms on the distal part of the rostrum and in the dorsal position, which differentiate them from females which lack them.

6.3.2 Recognition of damage

It is important to visually recognise the damage caused by *R. ferrugineus* on palm trees to be able to detect them early and eliminate affected plant material, as detailed in section 2.4 of this document.

6.3.3 Sample collection

When damage is observed or the presence of adults or larvae of *R. ferrugineus* is detected, several samples should be collected and sent to a diagnostic laboratory for correct identification.

Samples should be sent to the laboratory as soon as possible, in an airtight container. If this is not possible, and shipment is delayed or the arthropod is not alive, adults should be shipped dry, protected in cotton wool to avoid breakage of legs and antennae. If larvae of *R. ferrugineus* are collected, they should be placed in an airtight container with 70% alcohol for preservation.

6.4 Inspection

Visual inspection of palm trees should be carried out on a quarterly basis in non-infested areas and bimonthly in infested areas.

In the case of Canary Island palms, the damage is mainly located in the crown of the palm, so it should be checked if there is/are any:

- outer leaves drooping, with tears at the level of the insertion with the trunk.
- general collapse of the leaf crown.
- faded appearance of the youngest leaves of the central plume, with yellowish or reddish-brown colouration.
- holes in the cut of the flap.
- remnants of pupae among the tábalas (lower part of the petiole) and leaves.
- arrow-shaped leaves at an angle to the vertical.
- twisting of the leaves in the axials.
- leaflets eaten or pelleted.
- eaten and/or truncated rachis.
- presence of 1-2 cm diameter galleries in leaf cross-sections.
- fibre remains.

In the case of date palm trees, the damage will be observed mainly at the base of the stipe and on the young shoots, so check if there are any:

- reddish or black exudation and fibrous debris.
- leafy plantlets with eaten leaves.
- holes in the leaf axils.
- remnants of pupae among the tábalas and leaves.

In the **mechanical inspection**, an operator can pull the leaves of the palms to check if they are easily detached due to the presence of *R. ferrugineus*. Similarly, an operator can pull leaves that have been cut off to check if they separate easily and if galleries can be observed inside them as a result of the infestation.

The **olfactory inspection** can be carried out by inserting metal rods between the interstices of the leaves and directed towards the trunk. These should be smelt once they have been removed, as the smell of fermentation is characteristic of the presence of the weevil. This detection can also be carried out using sniffer dogs.

The **auditory inspection** can be performed using audio-detectors to identify the sounds produced by the larvae when gnawing on the plant material and when moving inside the infested palm tree.

In addition, an inspection can be carried out using infrared cameras and thermal imaging, as the thermal spectrum of the radiation emitted by the palm crowns is different between palm trees affected by *R. ferrugineus* and healthy palms.

6.4.2 Trapping system

Mass trapping

Traps should be placed within a radius of 1000 m from the point where infested palms are detected. The recommended trap density is 1 trap every 50 m in the case of palm tree alignments in streets or avenues, 1 trap per roundabout with palm trees, 1 trap every 2500 m2 in parks and orchards (at least 1 trap per plot).

Mass trapping will take place mainly from spring to autumn. If after 12 months, no weevils have been caught, the device could be converted into a monitoring device.

Monitoring

A monitoring trap should be placed in areas where it is suspected that the weevil may have arrived. Trap density should be 1 trap per 3 ha. Monitoring traps should be maintained throughout the year. As in the case of mass trapping, palm trees in the vicinity of traps should be protected with preventive insecticide treatments.

Characteristics of the traps

There are currently several models and colours of traps available, all of which are suitable for implementing a trapping net. Of these, the black, cone-shaped traps catch more than 90% of the weevils they attract.

The trap should include a combination of pheromone (ferrugineol, 4-methyl-5-nonanol, 3- 7mg/day), plant material (sugar cane, apple, palm pieces, dates, etc.), components present in the volatile profile of the host (ethyl acetate esters, ethyl propionate or ethanol mixtures) and water to maintain humidity and retain captured weevils.

The traps should preferably be placed in the shade and never at the foot of a palm tree, but halfway between the point chosen to place the trap and neighbouring palm trees.

Traps must be placed, in the case of bucket traps, buried in the ground to just below the level of the openings, and in the ground unburied in the case of cone traps.

They must be checked periodically (at least every 15 days) to remove and record the number of weevils trapped, check that they are properly set and replenish the water level. In traps exposed to the sun, a weekly check is necessary during the summer.

Fermenting material should be renewed every three weeks. The contents should be renewed periodically according to the manufacturer's instructions and the environmental conditions in the area.

Smart sensor traps allow automated monitoring and wireless data transmission, enabling near real-time data visualisation by smart devices.

6.5 Procedure after the occurrence of the first outbreak

When an isolated palm tree or an outbreak affected by *R. ferrugineus* is detected, carry out the following actions:

- Establish an intensive surveillance area of 1 km radius around the outbreak, with the aim of inspecting and censusing 100% of the palm trees in the area.
- Target surveillance on an area of 3 km radius around the outbreak, in which possible affected palm trees will be identified. Locate the most likely high-risk areas such as public and private gardens, nurseries, etc.
- Create a protection zone with a radius of 5 km around the outbreak and a buffer zone with a radius of 10 km around the outbreak in which the phytosanitary measures stipulated in the legislation must be applied.
- Where several outbreaks are in close proximity, an area around the outbreaks, the perimeter of which is at least 10 km from any of the outbreaks, should be declared an affected zone. Within the interior, a protection zone may be established with a perimeter of at least 5 km from any of the outbreaks.

6.6 Notification of pest occurrence

Notification of the presence or suspicion of the pest should be immediately communicated to the competent authority for plant health.

6.7 Bibliography

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