Integrated Pest Management against *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae) and *Paysandisia archon* (Burmeister, 1880) (Lepidoptera: Castniidae) on palms

In Cyprus, the majority of palms grown on the island are more of historic and decorative interest and less of date production. In the case of palm pests, the problem of their control is not an entomological one, but mainly, one of management. For the successful management of economically important pests like red palm weevil (*Rhynchophorus ferrugineus*) and palm borer *Paysandisia archon* (PA), it is mandatory to adopt a combination of methods and approaches, including public awareness campaigns (lectures, seminars, training, information posted on the Agricultural Research Institute and the Department of Agriculture websites, informative leaflets/posters, radio and TV presentations, popular articles in local magazines and newspapers), quarantine, cultural, mechanical, biological, pheromone trapping, chemical treatments, etc. Before launching any pest control programme, the quantitative relationship between yield and/or palm tree losses and pest population levels are estimated in order to compute the economic injury level for each pest. Therefore, combined use of all the available management measures in a rational way is the basis for the development of integrated pest control strategies. For the success of IPM, all methods listed above should be combined in a judicious manner and implemented accordingly. Just following a few methods and neglecting other proven methods will not give the desired results. Before deciding on the palm species to plant in various landscapes, it is important to know their sensitivity to both RPW and palm borer.

This project was co-funded by the European Fund for Rural Development, the Cohesion Fund and the European Social Fund.
Sensitive palm species to RPW
- *Areca catechu* (betelnut palm)
- *Syagrus (=Arecastrum) romanzoffiana* (queen palm)
- *Arenga pinnata* (sugar palm)
- *Borassus flabellifer* (toddy palm)
- *Calamus merrillii* (palasan)
- *Caryota cumingii* (fishtail palm), *C. maxima* (mountain fish tail palm)
- *Cocos nucifera* (coconut)
- *Corypha utan* (= *C. gebanga* and *C. elata*) (gebang palm)
- *Elaeis guineensis* (African oil palm)
- *Livistona decipiens* (ribbon fan palm), *L. chinensis* (Chinese fan palm), *L. chinensis var. subgloboosa*
- *Metroxylon sagu* (sago palm)
- *Onocosperma horrida* (thorny palm), *O. tigillarium* (nibung palm)
- *Rostovnec regia* (Cuban royal palm)
- *Phoenix canariensis* (Canary Island date palm), *P. dactylifera* (date palm), *P. sylvestris* (east Indian wine palm)
- *Ravena rivularis* (Majesty palm)
- *Rostovnec regia* (regal palm)
- *Sabal blackburniana* (= *umbraculifera*) (Hispaniola palm)
- *Trachycarpus fortunei* (Chinese windmill palm)
- *Washingtonia filifera* (California fan palm)

Secondary hosts of RPW
- *Agave americana* (American agave)
- *Saccharum officinarum* (sugarcane)

Referred Resistant hosts
- *Washingtonia robusta* (Mexican fan palm), *Chamaerops humilis* (Mediterranean fan palm)

Sensitive palm species to palm borer
- *Brahea armata* (Mexican blue palm), *B. edulis* (Guadalupe palm)
- *Butia capitata* (Jelly Palm), *B. yatay* (Yatay palm)
- *Chamaerops humilis* (Mediterranean fan palm)
- *Livistona chinensis* (Chinese fan palm), *L. decipiens* (Weeping cabbage palm), *L. saribus* (taraw palm)
- *Phoenix canariensis* (Canary Island date palm), *P. dactylifera* (date palm), *P. reclinata* (Senegal date palm), *P. roebelenii* (pygmy date palm), *P. sylvestris* (silver date Palm)
- *Sabal mexicana* (Mexican palmetto), *S. minor* (Dwarf Palmetto), *S. palmetto* (cabbage palm)
- *Syagrus romanzoffiana* (queen palm)
- *Trachycarpus fortunei* (Chinese windmill palm)
- *Trithrinax campestris* (Thatch palm)
- *Washingtonia filifera* (California fan palm), *W. robusta* (Mexican fan palm)
Management measures
The biological characteristics of RPW and PA make their control extremely difficult (their larvae are endophagous except for a very short time from eclosion to entering the host plant). As *P. archon* is not a pest in its native range, no control methods for this species have been developed so far.

1. Detection

   a. Survey (Scouting), visual inspection. An important component of plant protection programmes is the survey of all available and accessible palms in private/public gardens, at regular intervals. More attention should be paid on palm species sensitive to damage by RPW and PA, i.e. the Canary island date palm, *Phoenix canariensis*, the date palm, *P. dactylifera*, the Mediterranean fan palm, *Chamaerops humilis*, and others. Visual observations for damage symptoms should be made both on palm parts (stipe, leaves and leaves’ bases) as well as on offshoots (i.e. date palm *P. dactylifera*, Mediterranean fan palm *C. humilis*) (see below for offshoots). Once a month, especially during the critical seasons; April-June, September-November, it is also necessary to inspect other palm species from the base and up to the crown with the use elevating equipment.

   b. Bioacoustics method. Bioacoustics is a very useful tool for early detection of RPW, PA, and other palm insects that have a cryptic life cycle. It is essential mainly at the entry points (ports) for detecting such invasive insect pests at an early stage of infection/development.

2. Cultivation/Sanitation

   Farming practices play an important role in the health of the palms and also the infestation levels. Good agricultural practices have a bearing on the overall impact of RPW. Specifically, it is necessary to:

   - Carry out sanitation (pruning, stype cleaning, removal of leaves, etc) in nurseries, gardens, landscapes, and other establishments during winter when no migration/flight activity takes place. Use the following techniques:
     - Cut into small pieces and burn
     - Prune foliage 120 cm from base
     - Always treat injuries with an insecticide and fungicide. Wounds should be quickly covered to stop the release of kairomones, which attract the adults. Female weevils will lay eggs in any opening
     - Fertilising, irrigation, control of soil and foliar diseases have no specific time frame limitations for their application

3. Mechanical measures. They are applied in cases of severely damaged or dead palms. Usually such palms are neglected or abandoned by the owners/growers for a long period of time. The best procedures
for removing such palms are the following: a) cut damaged palms into small pieces, spray them with an approved insecticide in order to kill any alive adults and/or larvae, cover them with entomological nets, and then safely transfer them to a dumping area, b) burn them until they are completely destroyed, c) transfer and bury them (in a depth of 1-2 metres), d) shred them (noting that eggs are not destroyed by the shredding machine).

4. Management of Offshoots. In date palm cultivation offshoots are highly valued as planting material and fetch high returns for professional farmers. It is very important that the removal and transportation of offshoots from one region to another meets the plant quarantine and sanitary legislations and all the measures the Ministry of Agriculture, Natural Resources and Environment announces from time to time. When an offshoot is removed from the mother palm, the fresh and exposed tissue on the stem (both of the mother palm and the cut offshoot) should be treated with an insecticide, targeting: a) the females that are attracted by the kairomones and the eggs laid by them, b) the newly hatched larvae of RPW and, c) any adults/larvae hidden in the fibres of the offshoot.

5. Identification of damage signs/symptoms

1) R. ferrugineus. In early stages of infestation, a brown viscous fluid oozes out from the tunnels in the trunk and base of the frond petiole. This liquid solidifies upon exposure to air and some brown flakes can be seen. Another symptom is the presence of bore holes with chewed up fibres. These fibers give out a very foul smell, characteristic of RPW damage. This is a real confirmation of the presence of fresh damage inside the palm. Other symptoms include yellowing and/or dried central “heart” leaves, damage of leaves’ bases, and damaged leaves that are under partial or total slope resembling an open “umbrella”. Other evidence for RPW presence are the cocoons found in damaged leaves/stype/ground close to the host, and the pest itself.

2) P. archon. Early symptoms can be seen on offshoots of date palm P. dactylifera and the Mediterranean fan palm C. humilis, where their leaves are chewed and/or dried (depending on the period of observation). A brown viscous liquid oozes out from the site of damage. In infested palms, abundant sawdust extruding from larval galleries on the crown and/or stype (trunk) is visible at the outermost extremity of the galleries. Pupal exuvia on the outside of the stype are also found (May-August). Other symptoms/evidence for PA presence on palm hosts are the following:

- perforated or nibbled leaves (non specific) (i.e. T. fortunei, C. humilis, W. filifera)
- gallery holes (axial and transversal) within the stype (i.e. T. fortunei, C. humilis, W. filifera) and leaf petioles (i.e. Phoenix spp. observed when cut)
- presence of adults (during their flight period (May-August))
- presence of eggs in the palm fibres
- abnormal development of auxiliary leaf buds
- deformation and abnormal twisting of stypes
- abnormal drying up of the palm, especially the core leaves
- Heavy larval attack may kill the palm tree. Infested hosts can be asymptomatic

6. Decision Making about Treatment. After identifying an infested palm a treatment decision should be made. Based on the phase or the period (early stage, etc) the symptoms observed as well as the severity of damage, treatment may be classified into 3 categories:

Category I - Early stage damage, slight damage symptoms. The chances that such palms (or offshoots) damaged by both pests shall recover are fairly high (various measures for such palms are given below).

Category II - Sloped outermost leaves, galleries on leaves’ bases bored by RPW larvae. This is the most critical decision to make because it is unknown if the meristem is damaged by the larvae of RPW and/or
P. archon and in what extent (dendrosurgery may show this). Extension specialists have to be very careful and use their experience to categorise such palms as recoverable or not.

**Category III - Palms with severe infestation.** “Umbrella-like shape”, sloped and/or dried central leaves. There is no cure and such palms should be removed carefully and treated in order to kill any living stages of the pest remaining inside the palm parts. More details about this are given under mechanical methods.

6.1. **Chemical control.** So far, chemical control is the most effective method for controlling RPW using approved insecticides at the recommended dose. There are two approaches of chemical control: a) preventive chemical control and, b) curative chemical control.

6.1a. **Preventive applications.** Palm trees are sprayed regularly with a recommended insecticide. With this method, the palms are treated with an insecticide to prevent the entry of RPW or other insects into the plant tissues. Though the method of spraying with high performance sprayers may give good coverage on the surface, the insecticide doesn’t penetrate uniformly the fibers of the crown and crevices of the stem, leaving the hidden weevils unaffected. When soaking the palm crowns (foliar/crown showers) the insecticide should be applied slowly through the central leaves in order to soak all the fibers in the crown and percolate down to the stem. This method was found to be quite effective in killing the hidden insects and also reduces the chances of pollution, spillage of pesticide(s), and air contamination. The preventive soaking or spraying must be done with the recommended insecticide once in every 3-4 months and mainly during the critical periods (April-June, September-November). All approved insecticides should be rotated in order to prevent the development of resistance. For the foliar/crown, showers should be applied every 90 days by rotating: (1) chlorpyrifos 48%EC (25cc/10 litres of water), (2) imidacloprid* 20%SL (7.5cc/10 litres of water), and (3) endomopathogenic nematodes (5-10 million nematodes + corresponding application liquid/palm tree (small palms) and 20-30 million nematodes + corresponding application liquid/palm tree (big palms). The dosage per palm tree is fixed, and only the amount of water required to apply the dose varies according to the palm tree size.

6.1b. **Curative applications.** Curative applications refer to both foliar/crown showers and/or stem injection (endotherapy). Stem injections are mainly applied in cases of low RPW population densities. It is recommended to give a stem injection in a very systematic manner to completely eliminate all stages of the pest hidden inside the stem. The damaged site is cleaned slightly to trace the spread and intensity of infestation. All trees with stem injection are examined at weekly intervals to monitor the effectiveness of the method.

**a) Foliar/crown showers** to be done every 40-45 days by rotating: (1) chlorpyrifos 48% EC (25cc/10 litres of water), (2) imidacloprid* 20% SL (7.5cc/10 litres of water), (3) thiamethoxam* 25% WG (4gr/10 litres of water).

**b) Stem injection-endotherapy.** Alternatively, every 45 days by rotating systemic insecticides: (1) imidacloprid 20% SL, (2) thiamethoxam 25% WG, (3) abamectin 1.8% EC, (4) lambda-cyhalothrin 2.5% EC (already registered for use in palms in Spain, Italy and France). Use these active ingredients mainly during RPW dispersion/flight activity periods (i.e. April-June, September-November).

*these active ingredients not to be used during flowering

7. **Pheromone Trapping.** Trapping of RPW in food baited traps with pheromone lures contribute to the decrease of the population levels. It is necessary to take certain precautions like regular servicing, on-time replacement of exhausted lures and placement of traps. Palms around the pheromone traps should be checked regularly for any potential infestations and whenever an infestation is noticed, immediate additional measures should be taken.
8. Biological Control. Several potential biological agents and natural enemies have been identified internationally, however neither none of them is quite effective under field conditions to control RPW and PA. Among them, the best results against RPW larvae and adults are given by the entomopathogenic nematodes (i.e. *Steinernema* spp, *Heterorhabditis* spp), various entomopathogenic fungi, i.e., *Beauveria bassiana* and *Metarhizium anisopliae*. For better results, their use should be frequent and needs to be done under specific conditions that may significantly increase the cost of treatment.

The project under the title “Bio-ecological and molecular study of red palm weevil *Rhynchophorus ferrugienus* and palm borer *Paysandisia archon* and their integrated management” was funded by the Research Promotion Foundation of Cyprus and the Structural Funds.

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