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THE RED PALM WEEVIL IN SICILY: THE INTRODUCTION AND SPREAD OF AN INVASIVE ALIEN SPECIES

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ABSTRACT

The red palm weevil (RPW), *Rhynchophorus ferrugineus* Olivier (Coleoptera: Curculionidae), is a pest from Southeast Asia accidentally introduced into North Africa and Europe two decades ago. In Sicily, RPW was recorded for the first time in 2005, then, in few years, it established becoming the most severe pest of ornamental palm species in urban, monumental and country areas. In this paper, we first report the history of its introduction and spread. Then, we reviewed the preventative and curative strategies that have been implemented with variable degrees of success in containing the invasive alien pest. Finally, we focus on the development of new strategies to detect early infestations and to prevent or contain RPW attacks.

Key words: *Rhynchophorus ferrugineus,* pheromone, mass trapping, repellent compound, push and pull.

RESUME

LE CHARANÇON ROUGE DES PALMIERS EN SICILE : INTRODUCTION ET DIFFUSION D'UNE ESPECE EXOTIQUE INVASIVE.

Le charançon rouge des palmiers (CRP), *Rhynchophorus ferrugineus* Olivier (Coleoptera: Curculionidae), est un ravageur provenant du Sud-Est de l'Asie, accidentellement introduit en Afrique du Nord et en Europe il y a 20 ans. En Sicile, le CRP a été détecté pour la première fois en 2005, puis, en quelques années, il s'y est installé en devenant le plus nuisible des ravageurs des palmiers ornementaux dans les aires urbaines, historiques et agricoles. Dans ce travail, il est d'abord exposé l'histoire de son introduction et de sa diffusion. Les stratégies préventives et curatives pour limiter ce phytophage sont ensuite décrites, avec leurs différents degrés de réussite. Enfin, l'article présente le développement de nouvelles stratégies pour détecter les infestations précoces et pour prévenir ou limiter les attaques du CRP.

Mots-clés : *Rhynchophorus ferrugineus*, phéromone, piégeage de masse, composé répulsif, push and pull.

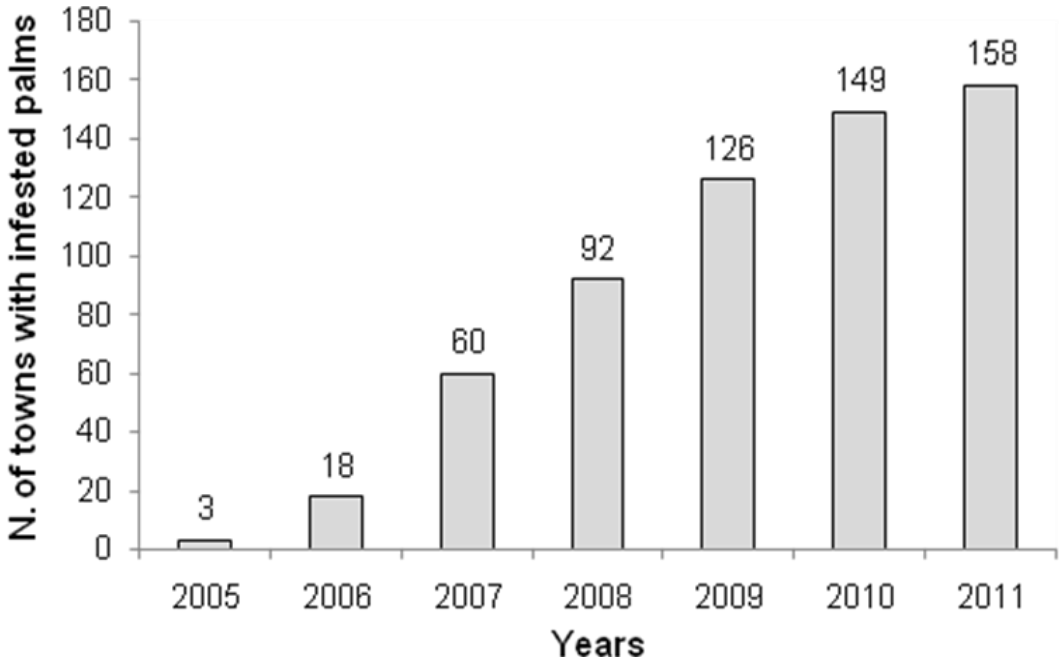
INTRODUCTION

Rhynchophorus ferrugineus Olivier (Coleoptera: Curculionidae), commonly called the red palm weevil (RPW), is one of the most severe pests accidentally introduced in several European countries of the Mediterranean basin during the last ten years (Jacas *et al.*, submitted). Its introduction was probably a consequence of commercial exchanges of date palm trees from contaminated areas of North Africa.
In this paper we report the history of colonization of the RPW in Sicily, focusing on the spread of the pest and outlining the control methods that are currently tested in experimental setups under laboratory, semi-field and field conditions.

RPW SPREAD

In Italy the first palms killed by RPW were recorded in 2005 in Acireale, a town located in the eastern part of Sicily (Longo and Tamburino, 2005). Here and in the neighboring town of Acicastello50 heavily infested palms were recorded at the end of 2005. In the same year, RPW was recorded in the town of Marsala in the western part of the region, and, at the end of the year, in Palermo (Longo *et al.*, 2008). In public gardens of Palermo during the first half of 2006 only 3 infested palms were observed, cut and destroyed; however, a few months later, 113 infested palms were recorded (Lo Verde *et al.*, 2009). Even though all infested palms in public areas were destroyed, 70 new cases were observed at the beginning of 2007 (Lo Verde *et al*., 2009). Most probably the delay before cutting and destroying the infested palms in private gardens allowed the RPW spreading into new areas of the town. At the end of September 2007 there were more than 800 infested palms in Palermo, and in November 2008 1,400 newly infested palms were observed (data from Agriculture Extension and Development Service of Sicily Region). The latest official data show that were about 6,600 infested palms in Palermo, about 5,400 of them were cut and destroyed (Table I).
RPW showed a similar rapid progression across the Sicily region. In fact, from the first three locations of infestation the RPW has moved progressively to the rest of the region, probably making advantage of passive transport of infested plants. In 2006 RPW infestations occurred in 15 other towns including Catania. In 2007 there were 28 towns with infested palms, and 763 palms were killed by the weevil (Conti *et al*. 2008). Then, RPW spread rapidly towards south, west and east, and all along the coastal fringe, with a rapid increase of the number of towns with infested and killed palms (Figure 1) (Table I).

Figure 1 - Progression of RPW infestations in Sicilian towns in the period 2005-2011.
Progression des infestations de CRP dans les villes siciliennes de 2005 à 2011.



Globally, at the end of 2008 the total number of palms killed by the RPW in Sicily was about 10,000 (Longo *et al*., 2011). During 2009 the RPW continued progressively its diffusion and infestation, and, at the end of 2009, the palms infested in Sicily were more than 20,000 (Longo *et al*., 2011).

Table I - Number of Canary island palms (*Phoenix canariensis* Hort. ex Chabaud) infested by RPW in Sicily from July 2007 to December 2009
Nombre de palmiers des Canaries (Phoenix canariensis Hort. ex Chabaud) infestés par le CRP en Sicile de juillet 2007 à décembre 2009.

Provinces	Infested palms	Cut and destroyed palms
Agrigento	553	543
Catania	5,029	4,523
Enna	21	15
Messina	91	88
Palermo	6,631	5,474
Ragusa	1,224	920
Siracusa	113	76
Trapani	5,312	4,653
TOTAL	**18,974**	**16,292**

HOST PALM

In Sicily, RPW attacked mainly *Phoenix canariensis* Hort. ex Chabaud, the Canary island palm. This species is used for ornamental purposes, therefore RPW became a serious pest of the urban, monumental and country landscape (Noto and Romano, 1987). Moreover, other palm species were infested by the weevil, such as *Phoenix dactylifera L.*, *Washingtonia* spp. and *Chamaerops humilis* L., the dwarf palm, a native species of the Mediterranean basin (Table II). In this particular case, during visual surveys conducted on September 2011 in the protected area of the Zingaro Natural Reserve (Trapani province), the presence of *R. ferrugineus* was detected on five 50-years old *C. humilis,* that were killed by the RPW (Suma and Longo, unpublished data).

Table II - Number of infested palms recorded from 2007 to 2010 in Sicily, subdivided for plant species.

Nombre de palmiers infestés détectés en Sicile de 2007 à 2009, répartis par espèces botaniques.

Palm species	Number of infested plants
Phoenix canariensis	19,722
Phoenix dactylifera	8
Washingtonia spp.	16
Erithea spp.	3
Sabal sp.	20
Chamaerops humilis	5
Howea forsteriana	4
Jubaea chilensis	3
Trachycarpus fortunei	1

CONTROL METHODS

The RPW is a concealed tissue borer: the larvae tunnel into leaves and stems, killing the single meristematic apex and causing palm death (Ferry and Gomez, 2002). This type of damage makes it difficult to detect symptoms of RPW attack at an early stage of infestation and, consequently, the short period that might allow effective control measures can be missed (Faleiro *et al.*, 2002; Faleiro, 2006; Longo *et al.*, 2008). As a consequence, it is vital to get a reliable diagnosis of the condition of palms and that the RPW infestation is rapidly detected. Many methods of control with variable degrees of success have been implemented in European countries to eradicate and contain *R. ferrugineus*.

In Sicily, in the framework of a three-year national research program (DIPROPALM project, funded by the Italian Ministry of Agricultural, Food and Forestry Policies) several attempts had been made to limit the destructive activity of the weevil from the beginning of its detection. In 2009, preliminary tests with the stem injection technique and different insecticides have been carried out under semi-field conditions with artificially infested *P. canariensis*, but were of minor effectiveness. At the same time, some trials were also conducted using different commercially available formulations of entomopathogenic nematodes (EPNs) under both semi-field and field conditions in urban areas. In these conditions EPNs demonstrated a poor efficacy, as RPW mortality rates were lower than 60%. However, if correctly handled the use of the EPNs could represent a very promising strategy to adopt in urban conditions, especially considering their safety for non-target vertebrates and for the environment. In 2010, a set of experiments was conducted to estimate the minimum time interval between insecticide applications as preventative method against RPW infestations. To achieve this aim the insecticide persistence of chlorpyrifos-methyl, clothianidin, abamectin and deltamethrin, applied as a foliar spray, was determined under semi-field conditions. The results showed that untreated palms collapsed 30 days after the beginning of the infestation, while all treated plants were asymptomatic, and no significant differences were recorded among them. In fact, after an eight months period (from July to March), the dissection of all the sprayed palms did not show any significant presence of the weevil independently from the number of treatments carried out. Under these experimental conditions one single treatment with chlorpyrifos-methyl or clothianidin is able to prevent the RPW infestation for about 8 months.

At the same time, the attention of researchers focused mainly on developing a pheromone trapping system for a monitoring or mass trapping program. In the first case, a monitoring program was established in eastern Sicily since 2007. A total of 30 traps baited with the synthetic male-produced aggregation pheromone, Ferrugineol ([*4S*,*5S*]-4-methyl-5-nonanol), ethyl acetate emulsion, and a water solution of sugar beet molasses as co-attractants were

installed in the town of Catania and its surrounding areas. Traps were checked twice per week and all the specimens therein present were collected and checked in the laboratory. Data on the total number of the caught weevils, their sex and the sex-ratio are reported in Table III.

Table III - Numbers of RPW males and females captured by pheromone and kairomone baited traps, placed in the town of Catania, in the years 2007-2011.
Nombre de CRP mâles et femelles capturés avec des pièges à phéromone et kairomone dans la ville de Catane de 2007 à 2011.

Year	N. traps	Males	Females	Total adults	Sex ratio (M:F)
2007	30	369	880	1,249	1 : 2.38
2008	30	888	2,269	3,157	1 : 2.56
2009	30	1,953	4,016	5,969	1 : 2.06
2010	30	3,924	7,406	11,330	1 : 1.89
2011	30	5,280	9,328	14,608	1 : 1.77

In a different experiment, traps were tested as early detection tool of pest infestations, linking data of captured adults to visual observations on palms. It is already known that early infestations escape detection because they do not cause obvious visual symptoms on the slightly infested palms. Only the advanced stages of the infestation become obvious because of the collapse of the fronds induced by the feeding and tunneling of the larvae. Since May 2006, a surveillance/monitoring system has been developed and tested in Sicily in order to verify the efficacy of the traps in attracting RPW adults in infested areas, and also in RPW-free areas with impending insect colonization. During this study a total of 58 pheromone baited traps were installed at 45 sites located in Sicily each comprising Canary island palms with different symptoms of infestation and at 10 sites where the Canary island palms were apparently free from any infestation. During the inspection of the traps, the number of captured RPW adults was recorded and these data were classified as: *1) congruent* if the traps caught (positive) in infested areas and did not catch (negative) in uninfested areas, *2) incongruent* if no catches were recorded in RPW infested areas, and *3) premonitory* when RPW were captured in areas with apparently healthy palm trees that only later became infested. The observations obtained from the trap monitoring system indicated that 55.6% of the traps provided congruent responses that reflected the presence or absence of RPW in the 45 sites. However, incongruent responses were recorded in 40% of these 45 sites. In 60% of the 10 sites with apparently healthy palms, the traps were effective in forecasting the impending infestations by the RPW. The premonitory responses obtained have to be considered particularly useful for early detection of the insect arrival in an area and for the adoption of preventive control measures. The time elapsed between the observations of the first adults in the traps and the appearance of the first symptoms could represent the key factor for implementing timely management actions to prevent the spread of the weevil.
In other field experiments pheromone traps were tested as a tool for a RPW direct control strategy. A first mass trapping experiment was carried out from April 2008 to April 2009 in the town of Marsala using 47 pheromone and kairomone baited bucket traps. This trapping showed positive results, determined as total number of 4,010 captured adults (Lo Bue *et al*. 2010). Then, a mass trapping experiment was performed on a large-scale in Palermo from May 2009 to September 2010, within a two-year project founded by the Sicilia Region (2009-2010). After involving public administrations and citizens by an advertising campaign, 500 pheromone- and kairomone-baited traps, were distributed in public and private gardens from May to September 2009. In total, these traps caught about 140,000 *R. ferrugineus* adults with a female biased sex ratio of about 80% females (Colazza, Peri, Lo Bue, Guarino unpublished data).

In order to assess the role of the synthetic esters as co-attractants, an experiment was carried out under laboratory and under field conditions. The combined use of ethyl propionate and ethyl acetate with molasses caused more captures than that of one ester alone suggesting that the blend of esters is mimicking more strongly the palm odor than one ester alone (Guarino *et al*., 2011).
Finally, the inhibitory effect of several synthetic compounds was evaluated. In field trapping experiments conducted in the city of Palermo during the summers of 2010 and 2011 several synthetic compounds, selected by laboratory screenings, were evaluated for their ability to disrupt the attractiveness of pheromone- and kairomone-baited traps towards RPW adults. In these experiments α-pinene, tested singly or in combination with methyl salicylate (2010) or menthone (2011), reduced trap catches by about 30 to 40% (Guarino *et al.*, 2012).
These results on repellent candidate compounds represent a first step in the development of a more complex strategy to modify the RPW search behavior; the repellent compounds screened in this study need to be implemented in the context of a “push and pull” strategy in natural situations in urban environments. The basic idea of this strategy is to protect the plants using a combination of repellents that push pest insects away from the palms and attractive pheromone-lures, which pull them into the traps (Cook *et al.*, 2007). This strategy has provided useful results for the management of several species of bark beetles (Zhang and Schlyter, 2005), and might be transferred to the RPW. In this way, a simultaneous employment of repellent compound releasers, that push RPW adults away from the palms, and pheromone and kairomone baited traps, could increase the efficiency of mass trapping, thus preserving palms from new infestations and minimizing the risks of RPW "spillover" onto susceptible hosts (Guarino *et al.*, 2012).

CONCLUSIONS

The rapid spread of RPW in Sicily despite a constant monitoring activity, and prompt curative measures and containment operations, as cutting and destroying of infested palms, demonstrates that the control of this invasive pest is a complicated operation, since an effective cooperation of citizens, municipalities, nurseries, and other involved subjects is often lacking. Moreover, due to the concealed nature of the larvae, the management of this pest is difficult, as the efficacy of pesticides and other control measures is often limited and there is a lack of effective early detection methods. Under these circumstances, great efforts are made currently by the scientific community to develop protocols for the detection of RPW early infestations in quarantine palm trees using dogs, acoustic devices and infrared technology. In this context, in addition to develop the “push and pull strategy”, our attention is focused on early detection by trained dogs. We are developing and validating a dog training protocol by comparing the dogs’ responses to different insect developmental stages, artificially infested palm trees of main host species, or their volatiles.

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