AFPP – PALM PEST MEDITERRANEAN CONFERENCE
NICE – 16, 17 AND 18 JANUARY 2013

CHEMICAL CONTROL OF THE RED PALM WEEVIL *RHYNCHOPHORUS FERRUGINEUS* AND THE CASTNIID PALM BORER *PAYSANDISIA ARCHON*

J.A. JACAS [(1)] AND Ó. DEMBILIO [(1)]

[(1)] Universitat Jaume I (UJI),
Unitat Associada d'Entomologia Agrícola UJI-Institut Valencià d'Investigacions Agràries (IVIA),
Departament de Ciències Agràries i del Medi Natural,
Campus del Riu Sec,
Av. de Vicent Sos Baynat, s/n.
E-12071 Castelló de la Plana, Spain
jacas@uji.es

SUMMARY

The chemical control of *R. ferrugineus* and *P. archon* is constraint due to the biology of the target pests, that spend most of their life cycles tunneling the palms, and to the limited amount of active substances available. Although several application methods have been designed to target immature stages of both pests when protected in the palm tissues (as drench and injection), further research is needed to identify new selective molecules and delivery methods. Nowadays, chemical control has to be carefully combined with other more sustainable methods to prevent the appearance of resistance and other undesirable side-effects of pesticide use. In this short revision, we will discuss different application methods that, contrary to other control methods, can be used as curative tools. Such a precious use of these biocides makes critical to raise awareness among stakeholders about the importance of proper insecticide use to ensure their sustainability.

Key words: foliar spray, stipe injection, drench application, insecticidal paint.

RÉSUMÉ

CONTRÔLE CHIMIQUE DU CHARANÇON ROUGE DES PALMIERS *Rhynchophorus ferrugineus* ET DU PAPILLON PALMIVORE *Paysandisia archon*.

La lutte chimique contre *R. ferrugineus* et *P. archon* est contrainte par la biologie de ces ravageurs, qui passent l'essentiel de leur vie à creuser dans les palmiers, et par le nombre limité de matières actives disponibles. Bien que plusieurs méthodes d'application aient été mises au point pour atteindre les stades pré-imaginaux des deux ravageurs présents dans les tissues des palmiers (trempage des bases foliaires et injection dans le stipe) des recherches complémentaires sont nécessaires pour identifier de nouvelles molécules sélectives et de nouvelles méthodes d'application. Actuellement, la lutte chimique doit être conduite de manière prudente en l'associant à d'autres moyens plus durables pour prévenir l'apparition de résistance et d'autres effets indésirables des pesticides conventionnels. Dans cette brève synthèse, nous discutons diverses méthodes d'application qui contrairement à d'autres peuvent être utilisées en curatif. L'emploi de ces méthodes et produits particuliers sont cruciaux pour faire prendre conscience aux praticiens de l'importance d'une utilisation appropriée des insecticides pour en assurer la durabilité.

Mots-clés : pulvérisation foliaire, injection, trempage, badigeonnage

INTRODUCTION

The recent emergence of the castniid palm borer, *Paysandisia archon* (Burmeister) (Lepidoptera, Castniidae), as a pest in the Mediterranean region makes necessary the development of sustainable control strategies against it. However, the non-pest status of this species in its area of origin (Uruguay and neighboring areas) has resulted in a lack of information on its biology, natural enemies and control methods. Contrarily, the longtime recognized economic importance of the red palm weevil, *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae), as a pest of different palm species around the world has prompted many funding agencies to sponsor activities aimed at a better knowledge of its biology and control. As a consequence, chemical treatments, both preventative and curative, have been devised to limit and contain infestations of *R. ferrugineus* in palms. However, data relative to *P. archon* are very limited.

One common feature of the chemical control methods developed against *R. ferrugineus* is that because of the concealed nature of most of its life cycle, pesticide applications have to be repeated frequently and cannot be discontinued for effective control (Murphy & Briscoe, 1999; Faleiro, 2006; Jacas et al., 2011). Another critical feature of the management of *R. ferrugineus* and *P. archon* in Europe is related to the use of palms as amenity plants in green areas (gardens, parks, avenues, etc.). Because most of these areas are public, there are deep concerns about the environmental pollution caused by these treatments, including side-effects on particularly vulnerable groups as children or elderly people (Faleiro, 2006; Llácer *et al.*, 2010). Furthermore, as a consequence of the implementation of Directive 91/414 (OJEU, 2009) on the sustainable use of pesticides in Europe, the application of many insecticides has been restricted and these restrictions are especially severe when dealing with palms outside the nurseries where palms are produced. Therefore, some pesticides that can be used in third countries and that had been used in Europe in the past are no longer permitted in the European Union (EU). As a result, from the 25 main groups of insecticides established by IRAC (2012) based on their mode of action, only four groups belonging to the broad group of neurotoxic insecticides can be identified among the few active substances authorized in different EU countries against *R. ferrugineus* and/or *P. archon*. These groups are (a) the acetylcholinesterase inhibitors (group 1B organophosphates as Chlorpyrifos and Fosmet), (b) the sodium channel modulators (group 3A pyrethroids as Cyfluthrin), (c) the nicotinic acetylcholine receptor agonists (group 4A neonicotinoids as Clothianidin, Imidacloprid and Thiametoxam), and (c) the chloride channel activators (group 6 as the avermectin Abamectin). However, not all groups are authorized in all EU countries and, for example, pyrethroids are not allowed in Spain (Table 1). The compound effect of such a limited number of insecticides available and the repeated treatments is a high risk for resistance against these products in *R. ferrugineus* and *P. archon*. Hence, there is an urgent need for the identification of new physiologically selective pesticides that could purposely target *R. ferrugineus* and/or *P. archon*. Naturally occurring toxins such as arthropod-derived hormones and venoms, and entomopathogenic fungi-derived metabolites (Mazet *et al*. 1994; Fitches *et al.,* 2004; 2010; Quesada-Moraga & Vey, 2004) could become an important source of this type of insecticides with enhanced selectivity and therefore reduced environmental impact by comparison with conventional neurotoxic insecticides. Additionally, selective application techniques, such as injection, could help reducing the environmental hazard associated to any pesticide application. In any case, pesticides should not become the cornerstone of the management of these pest species and chemical control should be a complement of other more sustainable methods within an Integrated Pest management (IPM) perspective.

Below, different pesticide application techniques developed against *R. ferrugineus* and/or *P. archon* will be discussed.

FOLIAR SPRAY

From the four groups of insecticides authorized in the EU against palm borers, groups 1A, 3A and 4A can be used as foliar sprays (El-Sebay, 2004; Kaakeh, 2006; Soroker et al., 2006; MAGRAMA, 2012). However, as mentioned earlier, no pyrethroids (group 3A) are authorized in Spain (MAGRAMA, 2012) and the future of neonicotinoids (group 4A) is uncertain because of the recent proof of negative impact on pollinators' behavior of Imidacloprid and Thiametoxam (Krupke et al., 2012). Therefore, the urgent need for new molecules against *R. ferrugineus* and *P. archon* is even higher for this type of treatment.

Insecticides used as foliar sprays are usually applied every 30-60 days depending on the season (frequency should increase along with temperature during the summer months and decrease during winter) (Dembilio and Jacas, 2010; Dembilio et al., 2012). The crown should be thoroughly treated to reach the base of the palms where cracks and crevices are used by adult females to oviposit and by last instar larvae to produce their cocoon and pupate. Frequency is not a critical issue for nurseries. However, it can become a serious problem for municipalities and other institutions having to protect large numbers of palms in a short time. To solve the problem of having to reach the top of the palm when treating the palms with any kind of pesticides, including biopesticides with entomopathogenic nematodes or fungi (Llácer et al., 2009; Dembilio et al., 2010 a,b), the use of a fixed 4 mm line holding 2–4 microsprinklers on the top of the crown has been implemented. In cities like Valencia, Spain, most palms in public areas have such a line fixed on the top of the stipe down to a height of 2.5 m. When needed, this line is directly connected to a pump on a carrying platform, and the pesticide is applied from it with no need actually to get to the top of the palm stipe (Dembilio et al., 2010).

DRENCH APPLICATION

Neonicotinoids (group 4A) have systemic properties and therefore can be applied as a drench. The SL (soluble liquid concentrate) formulation of Imidacloprid was successfully tested in laboratory against *R. ferrugineus* (Cabello et al. 1997). However, this formulation can easily precipitate when applied as a drench if not adequately protected. To avoid this problem, an OD (oil dispersion) formulation of Imidacloprid was developed. This formulation was tested under semi-field conditions by Llácer et al. (2012) and in the field by Dembilio et al. (2010a). Preventive and curative semi-field trials (potted plants) with this formulation applied to *Phoenix canariensis* showed 100 % and 94 % efficacies, respectively, (Llácer et al., 2011). Furthermore, preventive treatments had high efficacies, over 95 %, for at least 45 days after application (Llácer et al., 2012). In a field assay, two applications of Imidacloprid OD in early and late spring successfully reduced mortality of *P. canariensis* palms to less than 27 % compared to more than 84 % for untreated control palms (Dembilio et al. 2010a). Drench applications of Imidacloprid were also successfully used in date palm plantations in Israel (Soroker *et al.,* 2005). Because of environmental concerns about the impact of this type of applications on the aquifers, drench applications are usually restricted to nurseries and cannot be repeated more than twice per year (Table 1).

STIPE INJECTION

This type of treatment, which exploits ecological selectivity, illustrates one of the current trends in the chemical control of palm borers. Stem injections of the organophosphate Chlorpyrifos combined with foliar sprays of the same pesticide have been used against *R. ferrugineus* (Hernández-Marante *et al*., 2003). This pesticide is not currently used in injections. Instead, the neonicotinoids Imidacloprid and Thiametoxam and Abamectin can be applied using this technique (Table 1).

Pesticides used for stipe injection have to be adequately mixed with adjuvants prior to use to prevent precipitation and facilitate movement within the palm. A mixture of Abamectine and Neem Oil was tested in ornamental *P. canariensis* by injection at 1.5 atmospheres (Polizzi et al 2009). In Egypt, El-Sebay (2004) used this method to test 15 insecticides against *R. ferrugineus* in date palms. This author pointed out that low pressure was more effective and safer than high pressure injection. The most effective active substances idenfified by El-Sebay (2004) were the organophosphates Chlorpyrifos, Diazinon, Phenthoate and Methomyl. However, the effectiveness of these treatments is still uncertain. Furthermore, there is a strong debate among palm experts about the pros and cons of the application of this technique to palms (Speranza, 2008). Because of the discussions about how palms actually recover from the holes produced during the injection, new assays aimed at disentangling how palms heal wounded tissues could shed light on this alternative method for delivering pesticides. These assays should also provide evidence on how systemic products are translocated within palms to target palm tissues where *R. ferrugineus* and *P. archon* immature stages live and feed.

INSECTICIDAL PAINTS

The efficacy of an insecticidal paint based on the organophosphate Chlorpyrifos and the juvenile hormone mimic Pyriproxyfen (IRAC group 7C; IRAC, 2012) in a microencapsulated formulation (1.5 % and 0.063 %, respectively) was studied by Llácer et al. (2010). This insecticidal paint was applied on the stipe and the base of the fronds of palms. Laboratory results showed that Pyriproxyfen had no effect against *R. ferrugineus* when applied in this microencapsulated formulation and Chlorpyrifos was the responsible of the efficacy of this product against the weevil. In semi-field assays, the paint was highly effective as preventive treatment. However, it was dismissed as curative insecticide. One single application of this paint could prevent infestation for up to 6 months with a mean efficacy over 83 %. Current field trials with this encapsulated paint have confirmed these results.

CONCLUSION

Chemical control of palm borers (*R. ferrugineus* and *P. archon*) is a difficult task because of several reasons: (1) the cryptic habits of these pest species, (2) the limited amount of active substances available and (3) environmental and safety concerns about the use of pesticides in green areas. In this context, the management of *R. ferrugineus* and *P. archon* should not rely on pesticides only. Chemical control should be carefully combined with other more sustainable methods (biological control, semiochemical-based methods, cultural control, etc.) to prevent the appearance of resistance and other undesirable side-effects of insecticide use. However, insecticides are a precious tool that can be used in critical situations where other methods would simply fail. Therefore, it is vital to raise awareness among growers about the importance of proper pesticide use to ensure their sustainability.

ACKNOWLEDGMENTS

Authors' current research on palm borers is funded by the EU Commission (project FP7-KBBE-2011-5 - 289566) and the Valencian Conselleria d'Agricultura, Pesca i Alimentació (project IVIA 5611).

REFERENCES

Cabello T., De La Pena J., Barranco P., Belda J., 1997 - Laboratory evaluation of imidacloprid and oxamyl against *Rhynchophorus ferrugineus*. In: Tests of Agrochemicals and Cultivars, no. 18, pp. 6-7. Association of Applied Biologists, Wellesbourne (GB).

Dembilio, Ó. and Jacas, J.A. 2011a. Basic bio-ecological parameters of the invasive Red Palm Weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae), in *Phoenix canariensis* under Mediterranean climate. Bulletin of Entomological Research, 101, 153-163.

Dembilio Ó., Llácer E., Martínez de Altube MM., Jacas JA., 2010a - Field efficacy of imidacloprid and *Steinernema carpocapsae* in a chitosan formulation against the red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) in *Phoenix canariensis*. Pest Management Science, 66, 365-370.

Dembilio Ó., Quesada-Moraga E., Santiago-Álvarez C., Jacas JA., 2010b - Biocontrol potential of an indigenous strain of the entomopathogenic fungus *Beauveria bassiana* (Ascomycota; Hypocreales) against the red palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae). Journal of Invertebrate Pathology, 104, 214-221

Dembilio O., Tapia G., Téllez MM., Jacas JA., 2012 - Lower temperature thresholds for reproduction of the Red Palm Weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) in a Mediterranean climate. Bulletin of Entomological Research, 102, 97-102.

El-Sebay Y., 2004 - Control of red palm weevil, *Rhynchophorus ferrugineus* Oliv. (Coleoptera: Curculionidae) in Egypt. Egyptian Journal of Agricultural Research, 82, 1581-1589.

Faleiro JR., 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.

Fitches EC., Edwards MG., Mee C., Grishin E., Gatehouse AMR., Edwards JP., Gatehouse JA., 2004 - Fusion proteins containing insect-specific toxins as pest control agents: snowdrop lectin delivers fused insecticidal spider venom toxin to insect haemolymph following oral ingestion. Journal of Insect Physiology, 50, 61-71.

Fitches EC., Bell HA., Powell ME., Back E., Sargiotti C., Weaver RJ., Gatehouse JA.,, 2010 - Insecticidal activity of scorpion toxin (ButaIT) and snowdrop lectin (GNA) containing fusion proteins towards pest species of different orders. Pest Management Science, 66, 74-83.

Hernández-Marante D., Folk F., Sanchez A., Fernandez-Escobar R., 2003 - Control of red palm weevil (*Rhynchophorus ferrugineus* Olivier) using trunk injections and foliar sprays. Boletín de Sanidad Vegetal, Plagas, 29, 563–574 (in Spanish).

IRAC (Insecticide Resistance Action Committee)., 2012 - IRAC MoA Classification Scheme. http://www.irac-online.org/content/uploads/MoA-classification.pdf (accessed september 2012)

Jacas JA., Dembilio O., Llácer E., 2011 - Research activities focused on management of red palm weevil at the UJI-IVIA Associated Unit (Region of Valencia, Spain). OEPP/EPPO, Bulletin OEPP/EPPO Bulletin, 41, 122-127.

Kaakeh W., 2006 - Toxicity of imidacloprid to developmental stages of *Rhynchophorus ferrugineus* (Curculionidae: Coleoptera): laboratory and field tests. Crop Protection, 25, 432–439.

Krupke CH., Hunt GJ., Eitzer BD., Andino G., Given K., 2012 - Multiple Routes of Pesticide Exposure for Honey Bees Living Near Agricultural Fields. PLoS ONE 7(1), e29268.

Llácer E., Dembilio O., Jacas JA., 2010 - Evaluation of the Efficacy of an Insecticidal Paint Based on Chlorpyrifos and Pyriproxyfen in a Micro-encapsulated Formulation against the Red Palm Weevil, *Rhynchophorus ferrugineus*. Journal of Economic Entomology, 103, 402-408.

Llácer E., Martínez de Altube MM., Jacas JA., 2009 - Evaluation of the efficacy of *Steinernema carpocapsae* in a chitosan formulation against the red palm weevil, *Rhynchophorus ferrugineus* in *Phoenix canariensis*. Biocontrol, 54, 559-565.

Llácer E., Negre M., Jacas JA., 2012 - Evaluation of oil dispersion imidacloprid to control *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) on young palm trees. Pest mangement Science, 68, 878-882.

OJEU (Official Journal of The European Union) 2009 - Directive 2009/128/ED of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides. Official Journal of the European Union L, 309, 71-86.

MAGRAMA (Ministerio de Agricultura, Alimentación y Medio Ambiente) 2012 - Registro de Productos Fitosanitarios. http://www.magrama.gob.es/es/agricultura/temas/medios-de-produccion/productos-fitosanitarios/fitos.asp/pags/fitos/fitos.asp (accessed september 2012).

Mazet I., Huang S., Boucias DG., 1994 - Detection of toxic metabolites in the hemolymph of *Beauveria amorpha* infected *Spodoptera exigua* larvae. Experientia. 50, 142-147 (1994).

Murphy ST., Briscoe BR., 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, 35-46.

Polizzi G., Fruscione C., Parlavecchio G., Morabito M., Longo S., 2009 - Efficacia dell'endoterapia a pressione per il contenimento del Punteruolo rosso delle palme nel centro urbano di Catania. La ricerca scientifica sul punteruolo rosso e gli altri fitofagi delle palme in Sicilia, 1, 179-184.

Quesada-Moraga E., Vey A., 2004 - Bassiacridin, a Protein Toxic for Locusts Secreted by the Entomopathogenic Fungus *Beauveria bassiana*. Mycological Research, 108, 441-452.

Soroker V., Blumberg D., Haberman A., Hamburger-Rishard M., Reneh S., Talebaev S., Anshelevich L., Harari AR., 2005 - Current status of red palm weevil infestation in date palm plantations in Israel. Phytoparasitica, 33, 97-106.

Soroker V., Gindin G., Glazer I., Pinhas J., Levsky S., Eliahu M., Biton S., Haberman A., Nakache Y., Gerling D., Mizrach A., Hetzroni A., 2006 - The red palm weevil infestation in Israel: occurrence and management. In: I Jornada International sobre el Picudo Rojo de la Palmeras. Agroalimed, Generalitat Valenciana, pp. 59-79 (English and Spanish).

Speranza S., 2008 - Uso dell'endoterapia nel controllo del *Rhynchophorus ferrugineus* (Olivier). Dies Palmarum, Sanremo (Italy), Centro Studi e Ricerche sulle Palme http://www.sanremopalme.org/images/files/dies_2008/speranza_2008_uso_dellendoterapia_nel_controllo_del_rhynchophorus_ferrugineus_olivier.pdf (accessed July 2012)

Table 1. Active substances, doses, and application techniques authorized against *Rhynchophorus ferrugineus* and *Paysandisia archon* in Spain.
Matières actives, doses d'emploi et techniques d'application autorisées contre *Rhynchophorus ferrugineus* et *Paysandisia archon* en Espagne.

Active substance	**Dose**	**Application technique**	**Additional information**
Abamectin 1.8 EC (P/V)	20-80 ml per palm	Stipe injection. One single application or two (half dose) at 15-45 day interval. Application by authorized companies only	Authorized in green areas
Chlorpyrifos 48 % EC (P/V)	150-200 ml hl^{-1}	Foliar spray	
Phosmet 50 % WP (P/V)	150-250 g hl^{-1}	Foliar spray	
Imidacloprid 20 % OD (P/V)	50-75 ml hl^{-1}	Foliar spray	
	8-10 l ha^{-1}	Drench application. Maximum of two applications 30-40 days apart per year	Authorized in nurseries only
	4-10 ml per palm	Stipe injection every 45-55 days from March to November. Injection 1.5-2.0 m below the crown by authorized companies only	Authorized in green areas
Imidacloprid 20 % SL (P/V)	50-75 ml hl^{-1}	Foliar spray	
	8-10 l ha^{-1}	Drench application allowed in nurseries. Maximum of two applications 30-40 days apart	Authorized in nurseries only
	4-10 ml per palm	Stipe injection every 45-55 days from March to November. Injection 1.5-2.0 m below the crown by authorized companies only.	Authorized in green areas
Thiametoxam 25% WP (P/P)	40 g hl^{-1}	Foliar spray. Maximum of two applications 7-14 days apart (total amount ≤ 400 g ha^{-1})	
	400 g ha^{-1}	Drench application	
	5-20 g per palm	Stipe injection	Authorized in green areas

Source: MAGRAMA (2012). Registro de Productos Fitosanitarios. http://www.magrama.gob.es/es/agricultura/temas/medios-de-produccion/productos-fitosanitarios/registro/menu.asp (September 2012)