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Short communication. Toxicity of abamectin, acetamiprid, imidacloprid, mineral oil and an industrial detergent with respect to *Encarsia formosa* (Gahan) parasitizing *Trialeurodes vaporariorum* Westwood nymphs

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Abstract

The control of *Trialeurodes vaporariorum* on tomato with *Encarsia formosa* is influenced by the use of insecticides. Nine days after allowing *E. formosa* adults to lay their eggs in *T. vaporariorum* nymphs on tomato plants, insecticide solutions (abamectin, mineral oil, acetamiprid, an industrial detergent and imadacloprid) were applied at the highest recommended dosages to tomato leaflets in Petri dishes using a Potter tower (four replicates, each involving 20 parasitized nymphs). Adult parasitoids began to emerge on day 7 post-application; this lasted 3-4 days, peaking on day 9 post-application. All the tested products killed the *E. formosa* pupae (an effect significantly different [$P \leq 0.05$] to that achieved with the water control). The products with the greatest toxicity were the detergent (62.99% mortality) and mineral oil (49.55% mortality; no significant difference). The effect of abamectin, the third most toxic agent (33.05% mortality), was not statistically different to that of the mineral oil. Imidacloprid (20.17% mortality) and acetamiprid (20.71% mortality) were the least toxic treatments and could be used (along with abamectin to a lesser extent) in integrated whitefly management programmes involving *E. formosa* pupae. At the concentrations used, the mineral oil and industrial detergent are not recommended for use in such programmes given their high toxicity to *E. formosa* pupae.

Additional key words: control, greenhouse whitefly, IPM, parasitoids, tomato.

Resumen

Nota corta. Toxicidad de abamectina, acetamiprid, imidacloprid, aceite mineral y un detergente en *Encarsia formosa* (Gahan) parasitando ninfas de *Trialeurodes vaporariorum* Westwood

Los insecticidas influyen sobre el control de *Trialeurodes vaporariorum* en tomate mediante *Encarsia formosa.* Se estudió el efecto en laboratorio de las mayores dosis recomendadas comercialmente de abamectina, aceite mineral, acetamiprid, detergente e imidacloprid, más un control con agua, sobre cuatro repeticiones de 20 ninfas parasitadas de la mosca blanca. Se aplicaron soluciones de dosis calculadas para una placa Petri estándar sobre folíolos de tomate en una torre Potter, 9 días después de introducir parasitoides adultos en las placas Petri (cuando las ninfas parasitadas se veían oscuras). Los parasitoides adultos comenzaron a emerger el día 7 desde las aplicaciones; la emergencia duró 3-4 días, tuvo un máximo el día 2 y decreció luego gradualmente. Todos los productos mataron las pupas de *E. formosa* y fueron diferentes ($P \leq 0,05$) del control. Los productos con mayor mortalidad fueron el detergente (62,99%) y el aceite mineral (49,55%), que no difirió estadísticamente del primero, y tampoco con abamectina (33,05%), el siguiente tratamiento en mortalidad. Imidacloprid (20,17%) y acetamiprid (20,71%) fueron los tratamientos menos tóxicos, y podrían ser utilizados (y en menor grado por abamectina) en programas de control integrado de plagas para la mosca blanca que incluyan *E. formosa,* principalmente como pupas. A las concentraciones aplicadas, el aceite mineral y el detergente industrial no son recomendables es estos programas, debido a su alta toxicidad sobre pupas de *E. formosa.*

Palabras clave adicionales: control integrado de plagas, mosca blanca de los invernaderos, parasitoides, tomate.

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The whitefly *Trialeurodes vaporariorum* Westwood is a primary pest of greenhouse tomato plants in the Quillota Commune (5th Region of Chile). The major problem it causes is indirect damage due to the accumulation of honeydew, the removal of which increases production costs (Araya *et al.,* 2005a).

This species is normally controlled preventively using anti-aphid nets, weed handling, and the elimination of post-harvest crop remains, etc. However, these controls are commonly insufficient and alternative methods are required (Estay and Bruna, 2002). Of the six parasitoids that directly affect *T. vaporariorum* on tomato crops in Chile, *Encarsia formosa* (Gahan) is the most effective in the Quillota area (Estay and Bruna, 2002) (information on the biology of *E. formosa* can be found in Araya *et al.* [2005b]). In severe infestations, however, even *E. formosa* is unable to control the pest effectively, and insecticides have to be used. Unfortunately, this also reduces the effectiveness of the parasitoid.

Araya *et al.* (2005a) reported that 24 h after application, the insecticides imidacloprid, acetamiprid and abamectin were toxic to *E. formosa* adults. In other studies, the toxicity of a number of pesticides was reported to be lower when the parasitoids were protected inside the body of the host; this has been indicated for *E. formosa* by Viggiani *et al.* (1998), for *Aphidius ervi* Haliday by Zuazúa *et al.* (2003), and for *Apanteles glomeratus* (L.) by Araya *et al.* (2005c).

With the aim of selecting the best pesticides for use in integrated pest management (IPM) systems involving *E. formosa,* the objective of this work was to evaluate the toxicity of a number of treatments (imidacloprid, acetamiprid, abamectin, mineral oil and an industrial detergent) on the pupae of this parasitoid while inside the bodies of *T. vaporariorum* nymphs. All the agents tested are commonly used to control this whitefly on greenhouse tomato crops in the Quillota area.

To provide a secure and permanent supply of specimens for the experiment, *Trialeurodes vaporariorum* and *E. formosa* were reared on tomato plants as described by Estay (1993) and Araya *et al.* (2005b). Nine days after the nymphs had been parasitized, medium size tomato leaflets with at least 20 parasitized nymphs were collected and placed on Petri dishes with wet filter paper to immobilize the leaflets during insecticide application.

The insecticides described in Table 1 (0.63 ml) were applied (at the highest dosage recommended for application in the field) to the lower side of the leaflet over an 8 s period using a Potter tower. The treated leaflets were left to dry for 15-20 min at room temperature and then placed in other Petri dishes containing moistened paper. The lids had a window covered with a cloth screen to prevent a lethal chamber effect. These Petri dishes were kept at 25°C and a relative humidity of 55 ± 5% under a 16:8 h light-dark cycle. Petri dishes containing water were used as controls. Each treatment was replicated four times.

The toxicity of the insecticides with respect to *E. formosa* pupae was assessed based on the methodology described by Oomen (1988). The adults that emerged 10 days after the applications were counted. Emergence was examined under binocular magnification. Pupae with exit holes were deemed to have produced live wasps; those with no holes and which appeared dry and dorsally flattened were considered not to have

Table 1. Products applied on pupae of *Trialeurodes vaporariorum* parasitized by *Encarsia formosa*

Treatments	Commercial products	Commercial product (hl^{-1})	Active ingredient ($mg\ L^{-1}$)
Abamectin	Fast 1,8 EC	100 ml	18
Mineral oil	Citroliv	1500 ml	14250
Acetamiprid	Mospilan SP	35 g	70
Detergent	Quix	500 ml	—
Imidacloprid	Confidor Supra	40 ml	204
Control	Water	—	—

The concentration of the active ingredient of the detergent Quix is not provided because of its high variability.

produced live adults. Percentage mortality was corrected for the emergence seen in the controls according to Abbott's (1925) formula; the insecticides were then classified using Hassan's toxicity scale (Hassan, 1992). Pesticides causing >30% mortality were considered toxic to *E. formosa;* no further evaluations were deemed necessary. Those causing <30% mortality were considered potentially toxic and subjected to toxicity tests under semi-field conditions (see Oomen, 1988). Their toxicity with respect to the adult parasitoids was also investigated (see Araya *et al.,* 2005a).

The results were normalized by transformation with the function arcsine $\sqrt{(\% \text{ mortality}/100)}$, and then analysed by ANOVA. Significant differences ($P \leq 0.05$) were detected using Duncan's multiple range test (Duncan, 1955).

The emergence of adult parasitoids from the pupae began on day 7 after the application of insecticides, and lasted 3-4 days, peaking on day 9 post-application. Table 2 shows the *E. formosa* pupal mortality rate at 10 days post-application. All the treatments caused some mortality, and all caused significantly ($P \leq 0.05$) more than the control. The most toxic treatments were the detergent and the mineral oil (no significant difference [NSD]). The third most lethal insecticide was abamectin (NSD compared to the mineral oil). Imidacloprid and acetamiprid were the least toxic.

Because of its capacity to form a film on the insects (Chapman *et al.,* 1963; Metcalf and Flint, 1980; Matta and López, 1986; Sazo, 1989; Sazo and Piña, 1989), the mineral oil may have caused the asphyxia and death of the *E. formosa* pupae inside the *T. vaporariorum* nymphs. The oil also enters the spiracles and corrodes the tracheae, affects the muscles and nerves (Davidson *et al.,* 1991), and impedes the establishment of the juvenile stages in any scales that might emerge shortly after treatment (Chapman *et al.,* 1963).

The *E. formosa* pupae affected by the detergent looked dehydrated and shrunken; dissection confirmed that they were dead. According to Álvarez (1988), detergents kill pests by dissolving the waxes and other lipids of the epicuticle, leading to dehydration.

The 33.05% mortality caused by abamectin applied at 18 mg L^{-1} was less than the 47% obtained by Zchori-Frein *et al.* (1994) with 11.24 mg L^{-1} under the same conditions of temperature and humidity. This discrepancy is probably due to the different application and evaluation methodologies used. In the above-mentioned study, *E. formosa* pupae were submerged for 5 s in the insecticide; this generally leads to greater mortality than spraying.

The lower *E. formosa* pupal mortality caused by imidacloprid and acetamiprid agrees with that indicated by Viggiani *et al.* (1998), who reported high emergence rates (NSD) for the parasitoid after treating pupae with these insecticides. A low imidacloprid-induced mortality rate has been reported for *Aphidius ervi* Haliday when the parasitoid is protected by the body of its host. Zuazúa *et al.* (2003) observed that imidacloprid caused low mortality and allowed high adult emergence in mummies of parasitized *Acyrthosiphon pisum* (Harris) aphids. The affording of protection by the host body has also been reported in mummified aphids, in which *Aphidius rhopalosiphi* De Stefani Perez appeared to be safe from the action of a number of insecticides (Borgemeister *et al.,* 1993).

Table 2. Effect of the insecticides on the mortality of *Encarsia formosa* pupae on tomato leaflets and their toxicity category

Treatments	Mortality (%)[1]	Corrected mortality (%)[2]	Categories of toxicity[3]
Detergent	63.32 a	62.99	2
Mineral oil	50.00 ab	49.55	2
Abamectin	33.65 bc	33.05	2
Acetamiprid	21.42 c	20.71	1
Imidacloprid	20.89 c	20.17	1
Control	0.89 d	0.00	—

[1] Means in the same column with different letters are significantly different ($P \leq 0.05$) according to Duncan's (1955) multiple range test. [2] Mortality corrected by Abbott (1925). [3] According to the Hassan scale (Hassan, 1992).

Although in this experiment the imidacloprid and acetamiprid treatments were innocuous to *E. formosa* pupae, their relatively rapid action on the adults of this parasitoid (Araya *et al.,* 2005a) casts doubts about their usefulness in IPM. After evaluating the effects of 18 insecticides on *E. formosa* pupae and adults in the laboratory, Hayashi (1996) concluded that imidacloprid and acetamiprid should not be used in programs that involve this parasitoid. Tzeng and Kao (1999) also evaluated the effect of imidacloprid and acetamiprid on *Eretmocerus orientalis* Silvestri, a parasitoid of *Bemisia argentifolii* Bellows & Perring, and obtained results that warned against the use of either against this whitefly. However, their toxicity classification scale was different since they considered 80-99% mortality to be indicative of «moderate toxicity». The less intense effect of these insecticides on *E. formosa* pupae in the present study indicates, however, that they could be used in such programs. Abamectin showed a similar trend. The comparison of different studies therefore needs to be performed carefully, taking into account the methodologies and toxicity classification scales used.

These results complement those obtained with *E. formosa* adults by Araya *et al.* (2005a), and corroborate that parasitoids inside the body of their hosts are less affected by a number of insecticides.

In conclusion, imidacloprid and acetamiprid (and to a lesser extent abamectin) could be used in IPM programmes involving *E. formosa* pupae designed to control whiteflies on tomato. At the concentrations used in this experiment, the mineral oil and the industrial detergent are not recommended for any such programme given their toxicity with respect to the parasitoid pupae. It would not be correct, however, to assume that the same results might be obtained for other mineral oils or detergent-based products.

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