Toxicity and Residual Activity of Insecticides Against *Tamarixia triozae* (Hymenoptera: Eulophidae), a Parasitoid of *Bactericera cockerelli* (Hemiptera: Triozidae)

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ABSTRACT *Bactericera cockerelli* (Sulc) (Hemiptera: Triozidae) is one of the most economically important pests of potato, tomato, and peppers in Central America, Mexico, the United States, and New Zealand. Its control is based on the use of insecticides; however, recently, the potential of the eulophid parasitoid *Tamarixia triozae* (Burks) (Hymenoptera: Eulophidae) for population regulation has been studied. Because *T. triozae* is likely to be exposed to insecticides on crops, the objective of this study was to explore the compatibility of eight insecticides with this parasitoid. The toxicity and residual activity (persistence) of spirotetramat, spiromesifen, beta-cyfluthrin, pymetrozine, azadirachtin, imidacloprid, abamectin, and spinosad against *T. triozae* adults were assessed using a method based on the residual contact activity of each insecticide on tomato leaf discs collected from treated plants growing under greenhouse conditions. All eight insecticides were toxic to *T. triozae*. Following the classification of the International Organization of Biological Control, the most toxic were abamectin and spinosad, which could be placed in toxicity categories 3 and 4, respectively. The least toxic were azadirachtin, pymetrozine, spirotetramat, spiromesifen, imidacloprid, and beta-cyfluthrin, which could be placed in toxicity category 2. In terms of persistence, by day 5, 6, 9, 11, 13, 24, and 41 after application, spirotetramat, azadirachtin, spiromesifen, pymetrozine, imidacloprid, beta-cyfluthrin, abamectin, and spinosad could be considered harmless, that is, placed in toxicity category 1 (<25% mortality of adults). The toxicity and residual activity of some of these insecticides allow them to be considered within integrated pest management programs that include *T. triozae*.

KEY WORDS potato psyllid, biological control, parasitoid, pesticide, residual activity

The potato psyllid, *Bactericera cockerelli* (Sulc) (Hemiptera: Triozidae), is one of the most important pests of solanaceous crops such as potato, tomato, and peppers in Central America, Mexico, the United States, and New Zealand (Pletsch 1947; Wallis 1955; Cranshaw 1993, 1994; Munyaneza et al. 2007; Hansen et al. 2008; Liefting et al. 2008). This psyllid causes direct feeding damage to plants but also injects toxic saliva during feeding and excretes honeydew that encourages the growth of sooty molds. However, the greatest problem with this psyllid is its capacity to transmit the plant-pathogenic bacterium *Candidatus* Liberibacter *psyllaurous* (*C.* L. *solanacearum*) (Munyaneza et al. 2007, Gao et al. 2009, Camacho-Tapia et al. 2011, Butler and Trumble 2012), which causes zebra chip (ZC) disease in potatoes (Hansen et al. 2008, Liefting et al. 2008, Lin et al. 2009, Crosslin and Munyaneza 2009, Munyaneza 2012); this is one of the most devastating potato diseases in the U.S. state of Texas and northern Mexico (Munyaneza et al. 2008). In Texas, ZC was responsible for yield losses in potato of more than 20% between 2006 and 2008; this was equivalent to a loss of 33.4 million dollars per annum (CNAS 2006, Wen et al. 2009, Munyaneza 2012). In Mexico, presence of *B. cockerelli* and the associated transmission of phytoplasma diseases was responsible for yield losses of more than 50% in fresh tomatoes grown in Guanajuato and Michoacán in the 1990s (Garzón-Tiznado et al. 2009).

Because of the pest status of *B. cockerelli*, large quantities of insecticides have been used for its control. This increases the probability of resistance, resurgence of secondary pests, environmental contamination, and elimination of natural enemies (Goolsby et al. 2007, Vega-Gutiérrez et al. 2008, Gharalari et al. 2009, Yang et al. 2010). To reduce the dependence on insecticides and to maintain or improve levels of control, it is necessary to include natural enemies within integrated pest management (IPM) strategies for this pest (Luna-Cruz et al. 2011, Liu et al. 2012, Cerón-González et al. 2014, Rojas et al. 2015). One of the most promising natural enemies of *B. cockerelli* is *Tamarixia triozae* (Burks) (Hymenoptera: Eulophidae), a solitary synovigenic

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ectoparasitoid that both parasitizes and feeds directly on fourth- and fifth-instar nymphs of *B. cockerelli* (Johnson 1971, Cerón-González et al. 2014, Rojas et al. 2015). *T. triozae* has been recorded in the United States and Mexico, where it contributes to regulation of *B. cockerelli* populations in some potato- and tomato-growing regions (Jensen 1957, Johnson 1971, Lomeli-Flores and Bueno 2002). Bravo and López (2007) reported that, on an insecticide-free chilli crop in Oaxaca, Mexico, the level of parasitism reached 80%. However, in potato crops in southern Texas, only 5–20% parasitism was recorded; these low levels are attributed to the absence of alternative hosts and the widespread use of insecticides (Liu et al. 2012, Rojas et al. 2015).

Although some efforts have been made to use selective insecticides (Schmutterer 1990), the evidence suggests that insecticides negatively affect survival of *T. triozae*. For example, Luna-Cruz et al. (2011) reported that abamectin and spinosad were highly toxic to *T. triozae* adults, making them a toxicity category 3 insecticide according to the classification of the International Organization of Biological Control (IOBC; Hassan 1992); furthermore, imidacloprid inhibited emergence of the parasitoid. To date, only Luna-Cruz et al. (2011) and Liu et al. (2012) have conducted evaluations of insecticides on *T. triozae*; in the former, both the host and the parasitoid were evaluated together, and in the latter, the evaluations were developed in the absence of the host. Variation in methodologies can lead to different results because, in the absence of the host, the parasitoids may spend less time in contact with the contaminated surface (Luna-Cruz et al. 2011).

Control of *B. cockerelli* may be improved by integrating its natural enemies, such as *T. triozae*, in to management strategies (Butler and Trumble 2012, Cerón-González et al. 2014, Rojas et al. 2015). Nevertheless, because of the risk of *C.* L. *psyllaurous* transmission on potato, tomato, and pepper, the use of insecticides to eliminate the vector quickly cannot be excluded. For this reason, this study was conducted to evaluate the acute toxicity and residual activity of eight insecticides against *T. triozae*.

Materials and Methods

Rearing of *B. cockerelli* and *T. triozae*. Tomato plants (*Solanum lycopersicum* L.) variety Sun 7705 were used for both insect rearing and assays. The plants were grown in plastic pots (15 liters) in a substrate of peat moss (Premier®, Quebec, Canada) + tezontle (porous volcanic gravel) (2:1). From sowing to 60 d of age, the plants were fertilized with a nutrient solution (Steiner 1961) using an automated irrigation system providing 12 mmol/liter N and micronutrients.

The *B. cockerelli* colony was established from approximately 200 insecticide-susceptible adults that had been reared at Queretaro, Koppert Mexico, and maintained thereafter in a greenhouse at the Colegio de Postgraduados, Texcoco, Estado de Mexico (19° 29′49″ N, 98° 53′49″ W). Adults were placed on 45- to 60-d-old potted tomato plants in entomological cages (90 by 90 by 95 cm) entirely covered by a mesh screen and allowed to oviposit for 72 h to provide nymphs for experiments. This process was repeated periodically to provide sufficient numbers of nymphs for experiments. Plants were watered daily with the nutrient solution as described above.

The parasitoid colony was established from a mixture of ~150 parasitized *B. cockerelli* nymphs collected from a tomatillo crop (*Physalis ixocarpa* Brot. and Hormem.) in Salvatierra, Guanajuato (20° 12′49″ N, 100° 52′49″ W), and 200 adult parasitoids from a population that had been reared in a greenhouse since 2008 at the Colegio de Postgraduados. For experiments, tomato plants infested by fourth-instar *B. cockerelli* nymphs were placed in entomological cages similar to those described previously. Adult *T. triozae* parasitoids from the stock colony were introduced into these cages to feed and oviposit. After 6–8 d, tomato leaves with psyllid nymphs exhibiting evidence of parasitism (nymphs that were a dark brown, coppery color and adhering to the leaf) were removed, placed in acrylic cages (50 by 50 by 35 cm) and incubated at 25 ± 2°C, 70–80% RH, and a photoperiod of 12:12 (L:D) h until adult parasitoid emergence. Emerging adults were provided with honey ad libitum and used in experiments within 24 to 48 h.

Assays to Determine Toxicity and Residual Activity/Persistence of Insecticides to *T. triozae*. Eight commercial formulations of insecticides were evaluated (Table 1), including representatives from the different toxicological groups most commonly recommended for management of *B. cockerelli* and other pests of solanaceous crops in Mexico and the United States.

The experiment was run between January and February 2012 in a plastic greenhouse at 23 ± 7°C and 70–80% RH and an average of 506.2 watt/m^2 light intensity; the plastic of the greenhouse was 75% transparent, offering protection against ultraviolet (UV) degradation, and it was located at the Tlapeaxco experimental station of the Universidad Autónoma Chapingo, in Texcoco, Mexico (19° 47′29″ N, 99° 20′59″ W). Ninety 4-week-old tomato plants were transplanted individually into black polyethylene bags (15 liters) containing tezontle as a growth substrate; each plant was separated by 30 cm from the next plant and all were fertilized and irrigated as described previously. After 2 wk, each plant was staked and grown thereafter as a single vertical cordon, with axillary shoots being removed manually every week.

For each insecticide treatment, the maximum concentration recommended for the control of *B. cockerelli* was used (Table 1); additionally, we used the surfactant Inex A®1.5 ml/liter of water in each treatment. Individual 3.5-month-old plants were sprayed to runoff with the corresponding insecticide concentration using a motorized backpack sprayer (Arimitsu™, Osaka, Japan) at 1,723.7 Kpa (=250 PSI). Excess moisture on the foliage was left to dry completely for a further 2 h. To prevent contamination between treatments during spray application, plants were covered with a polyethylene cover (mesh size 200 μm) before adjacent

Table 1. Insecticides and the concentrations assessed using a residual exposure method, against *Tamarixia triozae* adults

Active ingredient (a.i.)	Commercial name	Concentration (g a.i /liter)[a]	Concentration used[b] (mg a.i. /liter)	Toxicological group	Mode of action
Spirotetramat	Movento 150 OD	150	300	Tetronic acid	Inhibits lipid biosynthesis; regulates growth
Spiromesifen	Oberon SC	240	480	Tetronic acid	Inhibits lipid biosynthesis; regulates growth
Beta-Cyfluthrin	Bulldock 125 SC	125	87.5	Pyrethroid	Modulates sodium channels; acts on nervous system
Pymetrozine	Plenum 50 GS	500	1300	Pymetrozine	Selectively blocks homopteran feeding
Azadirachtin	PHC Neeem SA	31.2	1056	Azadiractin	Inhibits feeding and interferes with the molting process
Spinosad	Spintor 12 SC	120	204	Spinosins	Antagonist of nicotinic acetylcholine receptors; acts on nervous system.
Imidacloprid	Confidor 350 SC	350	1155	Neonicotinoid	Antagonist of acetylcholine receptors; acts on nervous system.
Abamectin	Agrimec 1.8 CE	18	72	Avermectin	Activator of sodium channels; acts on nervous and muscular systems.

[a] Concentrations in commercial products; insecticides recommended by the manufacturer for control of *B. cockerelli*, and other pests.
[b] The amount of water used was equivalent to 300 liters/ha.

treatments were applied (Table 1). All insecticide treatments were applied on the same day and the treated plants were randomly distributed within the greenhouse. There were 10 replicate plants for each treatment, and control plants were treated with tap water plus the surfactant only. Treated plants were labeled for easy identification and to ensure that the leaves sampled for evaluation of toxicity and residual activity were always from the correct treatment.

Five leaflets were removed from randomly selected plants within each treatment 24 h after spraying, and then every 72 h up to day 43 (22 sampling dates), and transported to the laboratory. In the laboratory, a leaf disc was cut from each sampled leaflet (4.5 cm in diameter) per treatment. Each leaf disc was placed with its adaxial side down in a plastic petri dish (4.5 cm in diameter and 1.5 cm in depth). To each petri dish, 10 fourth-instar *B. cockerelli* nymphs were introduced and the lid replaced. Immediately after this, 10 unsexed *T. triozae* adults, 24-48-h-old, were introduced, through a small hole made previously in the side of the dish, and the hole sealed. All petri dishes were placed randomly in a rearing chamber and incubated at 25 ± 2°C, 70–80% RH, and a photoperiod of 12:12 (L:D) h. We included *B. cockerelli* nymphs in the experiment to ensure that the parasitoids would spend time on the insecticide-treated leaf disc while they were foraging for their hosts (Luna-Cruz et al. 2011). Parasitoid mortality was recorded 24 h after exposure to the treated tomato leaf discs. An insect was considered dead if it did not respond when stimulated with the hairs of a fine camel-hair brush. As there were five replicate leaf discs per treatment (10 × 5 parasitoids) and 22 evaluations were made during the course of the experiment (50 × 22 parasitoids), 1,100 parasitoids in total were evaluated per treatment.

Data Analysis. The mortality data, expressed as a proportion of the total number of insects tested, were analyzed using logistic regression with the statistical package GenStat v 8.0 (Payne et al. 2005). First, a comparison among treatments was made, followed by a comparison amongst sampling dates, and the interaction between these factors. After that, a negative binomial linear regression was also performed, including all 22 sampling points, to determine the tendency for residual insecticide activity on the tomato leaves over time, using the statistical software package SAS for Windows 9.0 (SAS Institute 2002).

We used the equation of the regression line of each insecticide to estimate the toxicity and persistence of each insecticide according to the classification categories used by the IOBC to describe pesticide activity against natural enemies under greenhouse conditions (Hassan 1992). The four toxicity categories are: 1) harmless (Category 1, <25% of mortality); 2) slightly harmful (Category 2, 25–50% mortality); 3) moderately harmful (Category 3, 50–75% mortality); and 4) harmful (Category 4, >75% mortality). The persistence is classified as: 1) short lived (Category 1, becomes harmless in <5 d); 2) slightly persistent (Category 2, becomes harmless after 5-15 d); 3) moderately persistent (Category 3, becomes harmless after 16-30 d); and 4) persistent (Category 4, only becomes harmless after >30 d).

Results

T. triozae was susceptible to all the insecticides tested, but there were significant differences in susceptibility among treatments ($\chi^2_8 = 1396.66$, $P < 0.001$), sampling dates ($\chi^2_{21} = 1399.82$, $P < 0.001$), and an interaction between the two ($\chi^2_{168} = 420.68$, $P < 0.001$). The greatest mortality was recorded 24 h after application in all treatments but varied between 37.9% (azadirachtin) and 98.9% (spinosad) (Table 2). Toxicity of all insecticides declined over time, but the rate of decline varied among the treatments; spinosad and abamectin were the most toxic and also persisted longer than the other insecticides, which all caused <25 % mortality within 13 days (Table 2; Fig. 1).

Using the linear regression equation for each insecticide, it was possible to allocate each insecticide to IOBC categories for toxicity and persistence (Table 2). Spirotetramat, spiromesifen, and azadirachtin were the least toxic, even after just 24 h (Category 2, slightly harmful) and also had the least residual activity against *T. triozae*; they reached toxicity Category 1 (harmless) within 5–6 d of treatment (= persistence Category 2,

Table 2. Toxicity and persistence of insecticides against *Tamarixia triozae* using the classification of the IOBC

Insecticide	Regression line	Category 4		Category 3		Category 2		Category 1		Persistence Category
		Days after treatment	Mortality (%)	Days after treatment	Mortality (%)	Days after treatment	Mortality (%)	Days after treatment	Mortality (%)	
Spirotetramat	$y = 42.9e^{-0.115x}$	–	–	–	–	1	38.2	5	25.0	2
Azadirachtin	$y = 41.803e^{-0.098x}$	–	–	–	–	1	37.9	6	25.0	2
Spiromesifen	$y = 48.903e^{-0.114x}$	–	–	–	–	1	42.0	6	25.0	2
Pymetrozine	$y = 49.575e^{-0.082x}$	–	–	–	–	1	46.3	9	25.0	2
Imidacloprid	$y = 40.252e^{-0.048x}$	–	–	–	–	1	37.9	11	25.0	2
Beta-cyfluthrin	$y = 65.88e^{-0.079x}$	–	–	1	61.4	4	50.0	13	25.0	2
Abamectin	$y = 84.694e^{-0.053x}$	1	80.9	2	75.0	10	50.0	24	25.0	3
Spinosad	$y = 102.13e^{-0.035x}$	1	98.9	9	75.0	20	50.0	41	25.0	4

Mortality: harmless <25%, category 1; slightly harmful 25–50%, category 2; moderately harmful 50–75%, category 3; and harmful >75%, category 4. Persistence categories: short-lived < 5 d, category 1; slightly persistent 5–15 d, category 2, moderately persistent 16–30 d, category 3; and persistent >30 d, category 4).

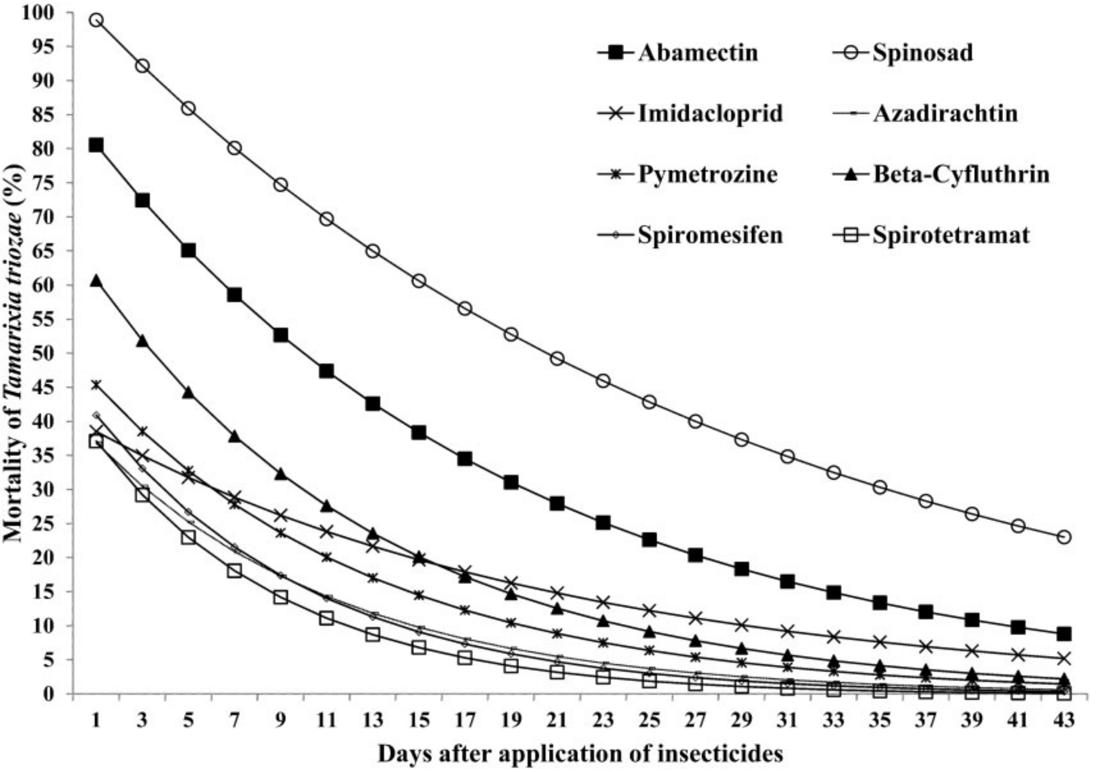

Fig. 1. Toxicity and persistence of eight insecticides against adult *Tamarixia triozae* on tomato plants grown in a greenhouse; lines adjusted after Abbott (1925) transformation.

slightly persistent); pymetrozine and imidacloprid were also slightly harmful (Category 2) and slightly persistent (Category 2), although it took 9 and 11 d, respectively, before they became harmless (Category 1). Beta-cyfluthrin was moderately harmful (toxicity Category 3) but only slightly persistent (persistence Category 2), becoming harmless by day 13. Abamectin and spinosad were both harmful (toxicity Category 4) and either moderately persistent (persistence Category 3; abamectic) or persistent (persistence Category 4; spinosad), only becoming harmless (toxicity Category 1) after 24 and 41 d, respectively (Table 2).

Discussion

Rational use of insecticides requires prior assessment of their effectiveness and specificity, particularly in relation to natural enemies. We have demonstrated that the parasitoid *T. triozae* was negatively affected by eight insecticides that are currently recommended for use in the management of *B. cockerelli*; however, the degree of toxicity varied depending on the insecticide and the time after application.

We confirmed that the most toxic chemicals were the contact and translaminar insecticides spinosad and abamectin, which are known to both attack the nervous system (Tanaka 1987, Salgado 1998, IRAC 2012), and be persistent in the environment (Luna-Cruz et al. 2011, Liu et al. 2012, Biondi et al. 2013). In our study, they had the longest residual activity against *T. triozae* compared with the other insecticides. It is likely that this is because the parasitoids were in close contact with the sprayed leaf; we observed *T. triozae* foraging constantly on its host and the leaf disc, and some lipo-soluble insecticide molecules may be absorbed through the integument (Wigglesworth 1966). The active ingredients of spinosad and abamectin are lipo-soluble and, apparently, were not destroyed by UV radiation or the temperature within the greenhouse, as they persisted for 41 and 24 d, respectively. Regular use of these insecticides could affect the establishment of *T. triozae* and other parasitoids (Williams et al. 2003).

In contrast, insecticides such as azadirachtin, with modes of action that repel pests/inhibit feeding and growth, mostly affect immature stages (Brück et al. 2009, IRAC 2012) and do not persist more than 7 d and might be considered more compatible with *T. triozae*. In our study, azadirachtin caused the lowest mortality (37.9%) 24 h after application and this fell to 21.9% within 7 d. This result could be attributed to the mode of action of the product; as a feeding inhibitor or growth regulator (Ascher 1993, IRAC 2012), its effects require more time to become evident. For example, azadirachtin is known to have long-term sublethal effects on other parasitoid species such as *Aphitis melinus* DeBach (Hymenoptera: Aphelinidae) (Vanaclocha et al. 2013) and *Bracon nigricans* Szepligeti (Hymenoptera: Braconidae); azadirachtin had no acute toxicity against *B. nigricans* larvae, but sublethal effects were observed at the pupal stage (Biondi et al. 2013). Therefore, their acute toxicity, which was what we evaluated here, would not be sufficient for us to believe that they are completely innocuous; it is unlikely that an assessment after 24 h, or evaluating only acute toxicity, would reveal the long-term effects of this insecticide, and more assays are necessary to establish its complete effect on adults of *T. triozae*.

Systemic insecticides, such as pymetrozine and spirotetramat, which penetrate the leaf surface become less able to cause mortality by contact over time. For example, Hall and Nguyen (2010) found that spirotetramat was inoffensive to *Tamarixia radiata* (Waterston) (Hymenoptera: Eulophidae), a sibling species of *T. triozae*; they used 179 mg a.i. per liter on C*itrus paradisi* MacFaiden (Sapindales: Rutaceae) leaves and it caused only 26.1% mortality of *T. radiata* after 24 h, falling to 2.9% after 22 d. Despite using a higher concentration of spirotetramat on *T. triozae* (300 mg a.i. per liter), we also found only 2.1% mortality in *T. triozae* 25 d after application. Liu et al. (2012) found that application of spiromesifen at 192 mg a.i. per liter on *T. triozae* adults did not cause any mortality after 24 h. However, in our study, using the higher recommended concentration of the same product (480 mg a.i. per liter), the mortality of *T. triozae* reached 42% 24 h after application, but did fall to 22% within 7 d. The difference in mortality after 24 h may not only have been because of the concentration, but also because Liu et al. (2012) kept the parasitoid in glass vials on tomato leaves without any hosts (psyllid nymphs). As indicated in our methodology, we provided fourth-instar *B. cockerelli* nymphs in the experimental unit and it is likely that, as the parasitoid explored or fed on the host, it spent more time in contact with the insecticide residue on the leaves. This level of parasitoid exposure may lead to results that are closer to reality in a greenhouse or in the field (Luna-Cruz et al. 2011).

Jansen et al. (2011) assessed pymetrozine against adults of the braconid *Aphidius rhopalosiphi* De Stefani Pérez (Hymenoptera: Braconidae) using a residual contact method and found 68% mortality 48 h after treatment at a concentration of 750 mg a.i. per liter. In the study of Liu et al. (2012), the concentration of pymetrozine applied was 190 mg a.i. per liter and caused a mortality of only 4.2% 24 h after exposure. In our study, the pymetrozine concentration was 1,300 mg a.i. per liter and caused 46.3 % mortality after 24 h. This demonstrates a clear effect of concentration; it is important to note that the concentrations used were all relevant, as they reflected the recommended concentrations for the countries where the experiments were done.

Eight days after application, imidacloprid was reported as harmless at 139 mg a.i. per liter for the related parasitoid species *T. radiata* (Hall and Nguyen 2010). In contrast, in our study, the same insecticide at a higher concentration (1,155 mg a.i. per liter) caused 39% mortality of *T. triozae* after 24 h and 29% 7 d after application. This product could, therefore, be considered slightly toxic to adults when sprayed on tomato foliage under greenhouse conditions.

Despite several studies indicating that toxicity of spinosad was low against some natural enemy species (Saunders and Bret 1997, Williams et al. 2003, Biondi et al. 2012), other studies report that it is toxic to *T. triozae* adults (Luna-Cruz et al. 2011, Liu et al. 2012); our study confirms this and also establishes that spinosad persists for close to 41 d (25% mortality) in greenhouse conditions. In general, greenhouse tests have reported longer persistence periods for spinosad than field studies (Jones et al. 2005, Liu et al.2012). This increased persistence could be related to the rate of photodegradation and precipitation. When spinosad is applied to field crops, it is exposed to sunlight and rain; photolysis is the primary form of degradation of this product (Crouse et al. 2001, Williams et al. 2003). Liu and Li (2004) found that spinosins A and D degrade in less than 6 h under UV light (350 nm); they also suggest that the pH of water affects degradation. Moreover, Saunders and Bret (1997) reported that the half-life of spinosin A was 1.6 to 16 d depending on the amount of light it received. Sántis et al. (2012) reported that the plastic covering of greenhouses reduced UV radiation by up to 75%. It is likely that the prolonged persistence of spinosad in our study was owing to the greenhouse covering, the temperature, and the plant canopy shade. Nevertheless, these conditions can be considered typical for greenhouse tomato production on the high plateau of Mexico.

The difference in residual activity of insecticides against *T. triozae* can be attributed to a number of factors including the method of exposure, the susceptibility of the species, the capacity of absorption of the compound through residual contact, and the environmental conditions where the assays were conducted. We found that, overall, six insecticides (spirotetramat, azadirachtin, spiromesifen, pymetrozine, imidacloprid, and beta-cyfluthrin) could be classified as only slightly persistent (Category 2), while spinosad and abamectic would be classified as persistent (Category 4) and moderately persistent (Category 3), respectively. We can conclude that the less toxic and less persistent insecticides have the potential to be used in IPM programs that includes *T. triozae*. Nevertheless, we would like to emphasize that our work was intended to address only acute toxicity of the insecticides tested, and the potential sublethal effects on *T. triozae* must be further evaluated to fully understand the effect of insecticides on this natural enemy (Desneux et al. 2007, Biondi et al. 2013). We also suggest that the variability in parasitoid mortality observed in other studies, including those conducted in greenhouses, could be reduced if hosts were included in the experimental set up. This is a more natural system and ensures that the parasitoids contact the treated surfaces. We also suggest that a description of the plastic greenhouse covering be included in future studies to estimate the amount of radiation and UV light that the insecticides receive.

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