

Effects of Conventional Pesticides on the Preimaginal Developmental Stages and on Adults of *Trichogramma cordubensis* (Hymenoptera: Trichogrammatidae)

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The effects of seven pesticides sprayed on hosts with parasitoids at different phases of egg to adult development (24, 24–48, 48–72, 72–96, 120–144, 192–216 h) of *Trichogramma cordubensis* (Vargas & Cabello) were studied. The effect of these pesticides on the mortality of adult parasitoids upon contact with the hosts immediately or 24 h after the treatments was also tested. One organophosphate insecticide (trichlorfon), one organochlorine insecticide (endosulfan), two pyrethroids (deltamethrin and lambda-cyhalothrin), a commercial formulation of *Bacillus thuringiensis* subsp. *Kurstaki*, and two fungicides (acetamide + dithiocarbamate and basic copper sulphate) were selected for testing. All the tests were carried out with fresh solutions of commercial insecticides applied on host eggs at the recommended concentration. The pesticides applied at different development phases did not affect the duration of parasitoid development, except endosulfan, which delayed the parasitoid preimaginal development for one day. With few exceptions, the number of parasitized host eggs that turned black (i.e. with parasitoid prepupae) did not differ significantly between the pesticide treatments and the control. The chemical insecticides affected the adult emergence rates significantly, while the other products resulted in emergence rates similar to control values. The longevity of adult progeny was very short when endosulfan or trichlorfon (< 1 and < 2 days, respectively) were applied. Overall, endosulfan was the pesticide most harmful to the preimaginal development stages of *T. cordubensis*. Therefore, the use of this product should be avoided when this species is part of an integrated pest control programme.

Keywords: *Trichogramma cordubensis*, insecticides, fungicides, toxicity

INTRODUCTION

Natural enemies of lepidopteran agricultural pests such as *Autographa gamma* (L.), *Chryso-deixis chalcites* (Esper), *Helocoverpa armigera* (Hübner), *Noctua pronuba* (L.), *Peridroma sausia* (Hübner), *Phlogophora meticulosa* (L.), *Pseudaletia unipuncta* (Haworth), *Spodoptera*

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littoralis (Boisduval) and *Pieris brassicae* (L.) can be a key component for their management. *Trichogramma cordubensis* Vargas & Cabello is one of the most important parasitoids of these lepidopteran pests on the island of São Miguel-Azores (Portugal) (Garcia *et al.*, 1994; Garcia, 1995). Low rates of parasitism have been reported in several agricultural regions and this may be due partly to the extensive use of insecticides (Gullan & Cranston, 1992; Driesche & Bellows, 1996). To promote integrated pest control methods in Azorean crops, where the use of pesticides cannot be completely excluded, efforts have been undertaken to evaluate the safety of the most frequently used pesticides for potential native natural enemies of these lepidopteran agricultural pests, such as *T. cordubensis*.

Although a wide range of literature is available on the effects of pesticides on *Trichogramma* (Jalali & Singh, 1993; Kumar *et al.*, 1994; Branco & França, 1995; Kring & Smith, 1995; Sterk *et al.*, 1999) little is known about the lethal effects of pesticides on *T. cordubensis*.

In this study, the effects of seven different pesticides on the following biological parameters of *T. cordubensis* are examined and compared: adult mortality, duration of preimaginal development, number of parasitized host eggs that turned black, adult emergence rates and the longevity of adult progeny.

MATERIALS AND METHODS

Insects

Adults of *T. cordubensis* were collected originally from São Miguel Island, Azores (Portugal) (Garcia, 1995), and maintained on *Ephesthia kuehniella* Zeller (Lepidoptera: Pyralidae) eggs for the previous 8 years in laboratory conditions, according to the methods of Tavares and Vieira (1992).

Insecticides

All the tests were done with fresh solutions of commercial pesticides prepared in water. Five insecticides (one organophosphate, one organochlorine, two pyrethroids and a commercial formulation of *Bacillus thuringiensis*) and two fungicides (acetamide + dithiocarbamate and basic copper sulphate) were tested at the concentrations indicated in Table 1. Pesticides for testing were selected on the basis of their use for the control of different pests in agricultural fields in the Azores archipelago, and concentrations were those recommended by the manufacturer for the control of lepidopteran and fungal pests.

Bioassay 1

In order to test the effects of various pesticides on the immature stages of *T. cordubensis*, 280 yellow cards (1.5 × 0.8 cm) were prepared, each with 500 *E. kuehniella* eggs glued to it. Each egg card was exposed to 15 females of *T. cordubensis* and placed inside a glass tube (7 × 1 cm) for 24 h. Forty cards with *E. kuehniella* eggs, < 24 h after parasitization, were

TABLE 1. Details of pesticides tested against *T. cordubensis*

Active ingredient	Pesticide	Formulation	Concentration tested (%)	Company
Trichlorfon	Diptrex 80	80% PS	0.20	Bayer
Endosulfan	Thiodan	35% EC	0.65	Sapac
Deltamethrin	Decis	2.8% EC	0.05	Hoechst
Lambda-cyhalothrin	Karate	5.5% EC	0.05	Zeneca Agro
<i>Bacillus thuringiensis</i>				
Berliner subsp. <i>Kurstaki</i>	Dipel	16 000 UI WP	0.10	Bayer
Acetamide + dithiocarbamate	Milraz	4.8 + 58% SP	0.25	Bayer
Basic copper sulphate	Calda bordalesa	25% SP	2.50	Quimigal
Distilled water	Control			

each sprayed with 6 ml of an aqueous suspension of one of the insecticides using Potter tower equipment (Burkard, Rickmansworth, UK) at 2 bar. Controls were sprayed with distilled water. This resulted in homogeneous spray coverage of $9.52 \pm 2.17 \mu\text{l}$ (mean \pm SD) of fluid per cm^2 , corresponding to the concentrations recommended by the manufacturer (1000 l/ha. Egg cards 24–48, 48–72, 72–96, 120–144, 192–216 h after parasitization were treated similarly. The effects of the treatments on the development times of the parasitoid, on the number of parasitized host eggs that turned black (i.e. with parasitoid prepupae), on the adult emergence rates and on adult longevity were recorded. Each treatment was repeated four times, and there were five replicate cards in each treatment (i.e. $n = 20$ egg cards per each treatment).

Bioassay 2

In order to test the effect of the various pesticides on the mortality of adults of *T. cordubensis*, 80 egg cards, prepared as described in Bioassay 1, were each sprayed with one of the same seven pesticides or with water (control). After egg cards had dried, 24 h after spraying, 15 *T. cordubensis* females were introduced into the glass tube containing the treated hosts. Each treatment was repeated four times, and there were five replicate cards in each treatment (i.e. $n = 20$ egg cards per each treatment). Mortality of the parasitoid adults was observed 6, 24 and 48 h after the first contact with the hosts. During the first 24 h, parasitoids were in contact with the treated eggs. After being in contact with the hosts, parasitoids were kept in the same tubes but without the hosts, supplied only with honey solution, for another period of 24 h.

All tests were done under controlled conditions, at $22 \pm 1^\circ\text{C}$, $70 \pm 5\%$ relative humidity (RH) and with a photoperiod of 16L:8D h.

Statistical Analysis

Differences in parasitoid development times, number of parasitized host eggs that turned black and adult longevity were determined by ANOVA using $\sqrt{(x + 0.5)}$ -transformed data. Adult emergence rates and parasitoid mortality (Bioassay 2) were analysed by ANOVA using arcsine \sqrt{x} -transformed data (Zar, 1996). When ANOVA showed significant differences ($P < 0.05$) among the means, paired comparisons of each mean were made using Student–Newman–Keuls tests (Zar, 1996). Parasitoid mortality, after contact with the pesticides, was analysed by ANOVA using arcsine \sqrt{x} -transformed data. All analyses were performed using SPSS 6.1 (Norusis, 1994) for the Macintosh system.

RESULTS

Bioassay 1

The treatments applied at different development phases did not affect the duration of parasitoid development significantly (of approximately 13 days) (Table 2). However, with endosulfan, the preimaginal development was delayed for one day, but the sample size was too small to conclude if there was a significant difference (Table 2).

With few exceptions, pesticides did not significantly affect the number of parasitized host eggs that turned black (Table 3). Differences were observed when treatments were performed at < 24 and 72–96 h after parasitization. In the first case, the number of parasitized host eggs treated with endosulfan was significantly smaller than those treated with lambda-cyhalothrin. In the second case (72–96 h after parasitism), the number of parasitized host eggs was significantly higher when deltamethrin was applied in comparison with basic copper sulphate (Table 3).

Adult emergence rates of the parasitoids from the first four treatments (chemical insecticides) were significantly inferior to the control values (Table 4). The adult emergence rates of *T. cordubensis* were reduced to near zero by endosulfan. Lambda-cyhalothrin reduced the emergence rate by approximately 40%, and deltamethrin reduced it by approximately 26%.

TABLE 2. Mean (\pm SD) of the duration of development (days) when seven pesticides were applied on different phases of the development of *T. cordubensis*

Pesticide	< 24	24–48	48–72	72–96	120–144	192–216
Trichlorfon	13.1 \pm 0.7a	13.1 \pm 0.6a	13.2 \pm 0.6a	13.0 \pm 0.8a	13.1 \pm 0.9a	13.0 \pm 1.0a
Endosulfan	14.4 \pm 1.2*	14.0 \pm 1.0*	14.5 \pm 0.7*	14.3 \pm 1.0*	15.0 \pm 0.0*	—
Deltamethrin	13.1 \pm 0.6a	13.3 \pm 0.6a	13.3 \pm 0.6a	13.2 \pm 0.8a	13.1 \pm 0.8a	13.4 \pm 0.8a
Lambda-cyhalothrin	13.1 \pm 0.8a	13.0 \pm 0.7a	13.5 \pm 0.5a	13.2 \pm 0.6a	13.3 \pm 0.4a	13.5 \pm 0.5a
<i>Bacillus thuringiensis</i>	13.0 \pm 0.7a	13.1 \pm 0.7a	13.5 \pm 0.5a	13.3 \pm 0.9a	13.3 \pm 0.9a	13.4 \pm 0.7a
Acetamide + dithiocarbamate	13.0 \pm 0.7a	13.1 \pm 0.8a	13.0 \pm 0.9a	13.0 \pm 0.9a	13.0 \pm 0.9a	13.0 \pm 0.9a
Basic copper sulphate	13.0 \pm 0.7a	13.1 \pm 0.8a	13.3 \pm 0.9a	13.3 \pm 0.9a	13.3 \pm 0.8a	13.3 \pm 0.9a
Control	13.0 \pm 0.7a	12.9 \pm 0.8a	13.1 \pm 0.7a	13.1 \pm 0.7a	13.0 \pm 0.7a	13.4 \pm 0.7a
ANOVA						
<i>F</i>	0.06	0.06	0.70	0.34	0.41	0.90
df	6	6	6	6	6	6
<i>P</i>	> 0.05	> 0.05	> 0.05	> 0.05	> 0.05	> 0.05

ANOVA *F*, df and *P*-values.Means in each column followed by a different letter are significantly different ($P < 0.05$, Student–Newman–Keuls test).

* Sample size was too small to include in analysis.

TABLE 3. Mean (\pm SD) number of parasitized host eggs that turned black when seven pesticides were applied on different phases of the development of *T. cordubensis*

Pesticide	< 24	24–48	48–72	72–96	120–144	192–216
Trichlorfon	218.5 \pm 40.6ab	215.8 \pm 38.1a	214.2 \pm 61.3a	239.8 \pm 36.4ab	231.3 \pm 46.7a	224.2 \pm 57.2a
Endosulfan	200.4 \pm 44.3a	228.0 \pm 42.8a	233.0 \pm 48.1a	230.9 \pm 29.2ab	228.3 \pm 35.9a	225.9 \pm 52.0a
Deltamethrin	212.2 \pm 46.5ab	243.2 \pm 42.9a	241.0 \pm 37.2a	262.7 \pm 29.4a	237.9 \pm 38.1a	225.8 \pm 50.3a
Lambda- cyhalothrin	244.6 \pm 27.0b	236.9 \pm 35.5a	229.0 \pm 57.0a	254.3 \pm 48.2ab	215.0 \pm 40.9a	230.8 \pm 33.2
<i>Bacillus thuringiensis</i>	229.3 \pm 40.8ab	216.5 \pm 45.0a	241.0 \pm 31.3a	221.0 \pm 51.7ab	240.7 \pm 39.7a	234.7 \pm 52.7a
Acetamide + dithio- carbamate	232.7 \pm 40.8ab	240.2 \pm 38.3a	235.9 \pm 35.2a	244.3 \pm 36.4ab	241.9 \pm 39.2a	233.5 \pm 42.0a
Basic copper sulphate	211.8 \pm 35.1ab	212.5 \pm 42.3a	226.0 \pm 45.0a	219.6 \pm 63.0b	243.0 \pm 37.7a	239.8 \pm 45.1a
Control	232.2 \pm 27.7ab	233.0 \pm 49.3a	210.9 \pm 32.1a	238.0 \pm 43.6ab	233.2 \pm 40.1a	224.2 \pm 52.0a
ANOVA						
<i>F</i>	2.87	1.66	1.02	2.34	0.66	0.31
df	7	7	7	7	7	7
<i>P</i>	< 0.01	> 0.05	> 0.05	< 0.05	> 0.05	> 0.05

ANOVA *F*, df and *P*-values.Means in each column followed by a different letter are significantly different ($P < 0.05$, Student–Newman–Keuls test).

Basic copper sulphate, when applied 24–48, 72–96, 120–144 and 192–216 h after parasitism differed significantly from the control values, with a similar effect to trichlorfon (Table 4).

The longevity of adult progeny was very short when endosulfan or trichlorfon (< 1 and < 2 days, respectively) were applied. With the other products, longevity varied from 10 to 16 days without significant differences among pesticides. Aside from organophosphate and organochlorine insecticides, only lambda-cyhalothrin, applied 72–96 h after parasitization, significantly reduced longevity when compared with the control (Table 5).

TABLE 4. Adult emergence rates (\pm SD) when seven pesticides were applied on different phases of the development of *T. cordubensis*

Pesticide	< 24	24–48	48–72	72–96	120–144	192–216
Trichlorfon	91.0 \pm 05.3a	92.6 \pm 03.0a	89.4 \pm 05.7a	87.7 \pm 08.8a	88.7 \pm 05.1a	91.4 \pm 04.3a
Endosulfan	00.4 \pm 00.8b	00.1 \pm 00.3b	00.0 \pm 00.1b	00.2 \pm 00.3b	00.1 \pm 00.4b	00.0 \pm 00.0b
Deltamethrin	74.5 \pm 04.8c	69.0 \pm 09.3c	70.2 \pm 08.7c	65.3 \pm 11.3c	65.8 \pm 13.7c	67.0 \pm 11.5c
Lambda-cyhalothrin	62.4 \pm 13.6d	56.8 \pm 15.0d	57.3 \pm 15.5d	51.2 \pm 22.9c	45.7 \pm 20.3d	51.8 \pm 14.9d
<i>Bacillus thuringiensis</i>	96.1 \pm 01.4e	95.5 \pm 01.6e	96.5 \pm 01.7e	95.6 \pm 02.6d	96.4 \pm 01.2e	95.5 \pm 02.8e
Acetamide + dithiocarbamate	95.4 \pm 01.8e	96.2 \pm 02.2e	96.7 \pm 01.5e	96.0 \pm 01.3d	95.7 \pm 01.7e	95.3 \pm 01.8e
Basic copper sulphate	94.3 \pm 02.1e	93.2 \pm 02.4a	94.4 \pm 02.2e	91.1 \pm 07.9a	90.0 \pm 06.3a	90.4 \pm 04.7a
Control	96.0 \pm 01.3e	95.9 \pm 02.1e	91.4 \pm 02.4e	95.4 \pm 02.0d	96.1 \pm 01.5e	95.2 \pm 02.0e
ANOVA						
F	808.7	752.3	677.9	307.9	385.3	610.2
df	7	7	7	7	7	7
P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

ANOVA F, df and P-values.

Means in each column followed by a different letter are significantly different ($P < 0.05$, Student–Newman–Keuls test).TABLE 5. Mean (\pm SD) adult progeny longevity (days) when seven pesticides were applied on different phases of the development of *T. cordubensis*

Pesticide	< 24	24–48	48–72	72–96	120–144	192–216
Trichlorfon	01.7 \pm 0.8a	01.8 \pm 0.7a	01.7 \pm 0.6a	01.5 \pm 1.1a	01.9 \pm 0.7a	02.0 \pm 0.4a
Endosulfan	< 1*	< 1*	< 1*	< 1*	< 1*	—
Deltamethrin	12.5 \pm 5.3b	13.2 \pm 5.2b	13.3 \pm 6.1b	13.4 \pm 5.8bc	12.9 \pm 5.1b	12.3 \pm 4.4b
Lambda-cyhalothrin	11.1 \pm 4.8b	11.3 \pm 4.9b	11.8 \pm 4.4b	11.0 \pm 4.9b	10.6 \pm 3.9b	11.7 \pm 4.6b
<i>Bacillus thuringiensis</i>	15.7 \pm 6.7b	14.4 \pm 6.9b	15.7 \pm 6.8b	16.0 \pm 6.5bc	16.2 \pm 7.1b	15.5 \pm 6.2b
Acetamide + dithiocarbamate	14.8 \pm 0.7b	15.3 \pm 7.6b	15.6 \pm 6.6b	15.5 \pm 6.5bc	15.8 \pm 7.3b	16.3 \pm 7.1b
Basic copper sulphate	15.5 \pm 6.7b	14.6 \pm 6.1b	14.3 \pm 5.7b	16.3 \pm 7.5bc	15.1 \pm 6.8b	16.3 \pm 6.6b
Control	16.5 \pm 7.0b	15.4 \pm 7.2b	15.8 \pm 7.2b	16.9 \pm 7.5c	16.2 \pm 8.9b	15.3 \pm 6.6b
ANOVA						
F	23.57	19.77	22.41	25.36	20.81	23.96
df	6	6	6	6	6	6
P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

ANOVA F, df and P-values.

Means in each column followed by a different letter are significantly different ($P < 0.05$, Student–Newman–Keuls test).

* Sample size was too small to include in analysis.

Bioassay 2

In all tests, including the control, the mortality of the females increased with time.

Endosulfan was the most quickly and highly toxic pesticide for adults of *T. cordubensis*, causing 100% mortality. Trichlorfon gave slower, but similar results (Table 6).

Both pyrethroids (deltamethrin and lambda-cyhalothrin) reduced the parasitoid population by approximately 25%, 48 h after the first contact with pesticide. Comparing these results with those obtained for the other products, we observed some significant differences between pyrethroids and the other treatments (Table 6).

Bacillus thuringiensis and the two fungicides, acetamide + dithiocarbamate and basic copper sulphate, did not cause significant mortality in *T. cordubensis* as compared with the control. Only acetamide + dithiocarbamate caused a greater mortality 48 h after the first contact with the pesticide, when treated eggs were given to parasitoids immediately (Table 6).

TABLE 6. Mortality rates (\pm SD) when seven pesticides were applied on adults of *T. cordubensis*

Pesticide	0 h after treatment			24 h after treatment		
	6 h	24 h	48 h	6 h	24 h	48 h
Trichlorfon	29.1 \pm 39.3a	94.8 \pm 14.1a	100.0 \pm 00.0a	40.7 \pm 47.9a	89.2 \pm 20.6a	99.7 \pm 01.5a
Endosulfan	100.0 \pm 00.0b	100.0 \pm 00.0a	100.0 \pm 00.0a	98.0 \pm 05.3b	100.0 \pm 00.0a	100.0 \pm 00.0a
Deltamethrin	06.4 \pm 07.4c	15.5 \pm 11.9b	17.5 \pm 11.9b	05.1 \pm 04.9c	18.7 \pm 14.1b	20.6 \pm 14.9b
Lambda-cyhalothrin	06.3 \pm 08.9c	17.9 \pm 18.8b	21.4 \pm 19.9b	06.7 \pm 06.9c	19.2 \pm 13.9b	26.3 \pm 20.0b
<i>Bacillus thuringiensis</i>	00.3 \pm 01.5c	03.7 \pm 06.2c	04.2 \pm 07.3c	00.7 \pm 03.0c	04.4 \pm 07.0c	05.9 \pm 07.6c
Acetamide + dithiocarbamate	00.3 \pm 01.5c	03.1 \pm 01.5c	23.6 \pm 39.4b	00.3 \pm 01.5c	04.1 \pm 05.6c	06.3 \pm 08.7c
Basic copper sulphate	00.0 \pm 00.0c	02.7 \pm 07.2c	04.7 \pm 09.8c	00.3 \pm 01.5c	05.3 \pm 05.8c	08.6 \pm 09.4c
Control	00.0 \pm 00.0c	00.3 \pm 01.3c	03.5 \pm 04.7c	00.3 \pm 01.5c	02.8 \pm 05.3c	04.6 \pm 05.3c
ANOVA						
F	112.5	318.8	133.6	72.1	249.2	302.2
df	7	7	7	7	7	7
P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

ANOVA F, df and P-values.

Means in each column followed by a different letter are significantly different ($P < 0.05$, Student–Newman–Keuls test).

Results show that the tested pesticides have a high residual effect, since the mortality values were similar when the parasitoids contacted with the pesticide immediately or 24 h after the treatments.

DISCUSSION

Of the pesticides evaluated in this study, the organochlorine and organophosphate insecticides were the most toxic to *T. cordubensis*. However, trichlorfon was less toxic than endosulfan. The pyrethroids were less harmful, with deltamethrin being less toxic than lambda-cyhalothrin. *Bacillus thuringiensis* and the two fungicides were not harmful to *T. cordubensis*. These pesticides did not affect parameters such as the duration of development and the number of parasitized host eggs that turned black before treatment.

A negative effect was observed on both the adult emergence rates and the longevity of adult progeny (Bioassay 1) when endosulfan and trichlorfon were applied. The first parameter was also influenced by the pyrethroids. These results indicate that the egg chorion of *E. kuehniella* did not protect the parasitoid.

As observed for *T. cordubensis*, a very low adult emergence rate of *T. australicum* Girault and *Trichogrammatoidea armigera* Nagaraja has been reported by Dutt and Somchoudhury (1986) and Jalali and Singh (1993), respectively, when endosulfan was applied to immature forms of the parasitoids. Contrary to our findings, endosulfan sprays have been found to be of low toxicity to *T. pretiosum* (Riley) (Hohmann, 1991, 1993), to *T. chilonis* Ishi (Santharam & Kumaraswami, 1985; Kumar *et al.*, 1994) and to *T. perkinsi* Girault (Dutt & Somchoudhury, 1986).

The emergence rate of adults was reduced significantly by the pyrethroids deltamethrin and lambda-cyhalothrin. Kring and Smith (1995), when studying the effects of cyhalothrin in *T. pretiosum*, also observed a reduction in the emergence rate. Sterk *et al.* (1999) found similar results when applying lambda-cyhalothrin to pupae of different species of *Trichogramma*. On the other hand Hohmann (1991, 1993) obtained different results with *T. pretiosum*, as did Jalali and Singh (1993) with *Trichogrammatoidea armigera* and Kuman *et al.* (1994) with *T. chilonis* when deltamethrin was applied.

Trichlorfon did not affect the adult emergence rate of *T. cordubensis*, but reduced adult longevity greatly when treatment was performed on preimaginal stages. This reduction in

longevity will therefore in turn cause a reduction in the number of hosts parasitized by these wasps.

Bacillus thuringiensis did not affect the biological parameters of *T. cordubensis* measured in this study. Sterk *et al.* (1999) found similar results for a long list of beneficial organisms.

Fungicides were found to be safe to all stages of *T. cordubensis*, as suggested by Jalali and Singh (1993) and Sterk *et al.* (1999) for other fungicides applied to beneficial organisms. Results show that these fungicides can be used simultaneously with *T. cordubensis*, allowing the development of integrated pest management programmes in the Azores.

The mortality of adults was not affected by the pyrethroids after 6 h of contact. However, when this period is longer (i.e. 24 or 48 h) the mortality of the parasitoids is significantly higher than the control values (Bioassay 2). Previous studies had also demonstrated that these pyrethroids can be very dangerous for *Trichogrammatoidea armigera*, *T. chilonis* and *T. pretiosum* (Jalali & Singh, 1993; Kumar *et al.*, 1994; Branco & França, 1995). Endosulfan was very harmful to adult *T. cordubensis*, with very high mortality values after a short period of contact (Bioassay 2). This also has been reported for *T. evanescens* Westwood by Chan (1978), for *T. cacaecia* Marchal by Hassan *et al.* (1983) and for *Trichogrammatoidea armigera* by Jalali and Singh (1993). However, this effect was more moderate in studies of *T. pretiosum* (Jacobs *et al.*, 1984) and *T. australicum* (Dutt & Somchoudhury, 1986).

The mortality of the adults was similar when parasitoids contacted immediately or 24 h after the treatments, indicating that all pesticides had a high residual effect.

Of the seven pesticides tested here, endosulfan was the most harmful to the preimaginal developmental stages of *T. cordubensis*. Therefore, its use should be avoided when this species is part of an integrated pest control programme. Nevertheless, additional studies are required to determine whether a low concentration of these pesticides can be used safely in agricultural pest control without affecting natural enemies of the pests.

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REFERENCES

- BRANCO, M.C. & FRANÇA, F.H. (1995) Impacto de inseticidas e bioinseticidas sobre adultos de *Trichogramma pretiosum*. *Horticultura Brasileira* **13**, 199–201.
- CHAN, K.C. (1978) The effect of some insecticides on the common *Trichogramma* (*T. evanescens* Westwood). *Grad I Lozaraska Nauka* **15**, 73–79.
- DRIESCHE, R.G. VAN & BELLOWS, T.S., JR. (1996) *Biological Control*. Chapman & Hall, New York, NY, USA.
- DUTT, N. & SOMCHODHURY, A.K. (1986) Mortality response of immature and adult forms of *Trichogramma perkinsi* Girault and *Trichogramma australicum* Girault to few insecticides. *Indian Journal of Entomology* **48**, 23–31.
- GARCIA, P. (1995) *Trichogramma cordubensis* Vargas & Cabello (Hym., Trichogrammatidae) na ilha de S. Miguel (Açores): Aspectos de Sistemática e Ecologia. Dissertation, Universidade dos Açores, Açores.
- GARCIA, P., OLIVEIRA, L. & TAVARES, J. (1994) *Trichogramma cordubensis* (Hym., Trichogrammatidae): a dynamics study of an Azorean population, in *Trichogramma and Other Egg Parasitoids* (WAJNBURG, E., Eds) 4th International Symposium. *Les Colloques de l'INRA* **73**, 189–192.
- GULLAN, P.J. & CRANSTON, P.S. (1992) *The Insects: An Outline of Entomology*. Chapman & Hall, New York, NY, USA.
- HASSAN, S.A., BIGLER, F., BOGENSCHÜTZ, H., BROWN, J.U., FIRTH, S.J., HUANG, P., LEDIEU, M.S., NATON, E., OOMEN, P.A., OVERMEER, W.P.J., RIECKMANN, W., SAMSOE-PETERSEN, L., VIGGIANNI, G. & VAN ZON, A.Q. (1983) Results of the second joint pesticide testing programme by the IOBC/WPRS Working Group 'Pesticides and Beneficial Arthropods'. *Zeitschrift für Angewandte Entomologie* **95**, 151–158.
- HOHMANN, C.L. (1991) Efeito de diferentes insecticidas sobre a emergência de *Trichogramma pretiosum* (Hymenoptera: Trichogrammatidae). *Anais da Sociedade Entomológica do Brasil* **20**, 59–65.
- HOHMANN, C.L. (1993) Efeito de alguns insecticidas sobre adultos de *Trichogramma pretiosum* RILEY. *Anais da Sociedade Entomológica do Brasil* **22**, 563–568.
- JACOBS, R.J., KOUSKOLEKAS, C.A. & GROSS, H.R., JR. (1984) Responses of *Trichogramma pretiosum*

- (Hymenoptera: Trichogrammatidae) to residues of permethrin and endosulfan. *Environmental Entomology* **13**, 355–358.
- JALALI, S.K. & SINGH, S.P. (1993) Susceptibility of various stages of *Trichogrammatoidea armigera* Nagaraja to some pesticides and effect of residues on survival and parasitizing ability. *Biocontrol Science and Technology* **3**, 21–27.
- KRING, T.J. & SMITH, T.B. (1995) *Trichogramma pretiosum* efficacy in cotton under Bt-insecticides combinations. *Cotton Insect Research and Control Conference*, pp. 856–857.
- KUMAR, M.G., SUNDARABADU, P.C. & EDWARD, Y.S.J.T. (1994) Contact toxicity of insecticides to ecotypes of egg parasitoid *Trichogramma chilonis* Ishii. *Madras Agriculture Journal* **81**, 437–439.
- NORUSIS, M.J. (1994) *SPSS Advanced Statistics 6.1*. SPSS Inc., USA.
- SANTHARAM, G. & KUMARASWAMI, T. (1985) Effect of some insecticides on the emergence of the parasitoid, *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae). *Entomon* **10**, 47–48.
- STERK, G., HASSAN, S.A., BAILLOD, M., BAKKER, F., BIGLER, F., BLÜMEL, S., BOGENSCHÜTZ, H., BOLLER, E., BROMAND, B., BRUN, J., CALIS, J.N.M., COREMANS-PELSENEER, J., DUSO, C., GARRIDO, A., GROVE, A., HEIMBACH, U., HOKKANEN, H., JACAS, J., LEWIS, G., MORETH, L., POLGAR, L., ROVERSTI, L., SAMSOE-PETERSEN, L., SAUPHANOR, B., SCHAUB, L., STÄUBLI, A., TUSET, J.J., VAINIO, A., VAN DE VEIRE, M., VIGGIANI, G., VIÑUELA, E. & VOGT, H. (1999) Results of the seventh joint pesticide testing programme carried out by the IOBC/WPRS-Working Group 'Pesticides and beneficial organisms'. *Biocontrol* **44**, 99–117.
- TAVARES, J. & VEIRA, V. (1992) Produção em massa de *Ephestia kuehniella* Zeller (Lep., Pyralidae) IV—Técnicas de recolha dos adultos e ovos. *Açoreana* **7**, 461–470.
- ZAR, J.H. (1996) *Biostatistical Analysis*. Prentice-Hall International Editions, London, UK.