LABORATORY TOXICITY OF INSECTICIDE RESIDUES TO *ORIUS INSIDIOSUS*, *GEOCORIS PUNCTIPES*, *HIPPODAMIA CONVERGENS*, AND *CHRYSOPERLA CARNEA*

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Abstract

Adults obtained from laboratory cultures of the insidious flower bug, *Orius insidiosus* (Say), big-eyed bug, *Geocoris punctipes* (Say), convergent lady beetle, *Hippodamia convergens* Guerin-Meneville, and green lacewing, *Chrysoperla carnea* Stephens, were evaluated in spray chamber bioassays to ten insecticides, including four newer insecticides with novel modes of action. There was considerable variation in response among the species tested to the insecticides. In general, malathion was more toxic than other insecticides to all species. *Chrysoperla carnea* was highly sensitive to most of the insecticides. One-half of the insecticides caused no mortality in *G. punctipes*; *O. insidiosus* and *H. convergens* were more sensitive. Spinosad was more favorably selective than other insecticides tested on all species.

Introduction

Integrated pest management (IPM) in cotton production recommends the preservation of beneficial insects for control of various insect pests. Emphasis on IPM is especially important in early season cotton, when beneficials are capable of maintaining some pests below economic thresholds. Chemical insecticidal sprays are increased, however, as the growing season progresses and numbers of pest insects become more numerous and plant fruiting structures become more susceptible to attack. Information on the toxicitites of various cotton insecticides to several key beneficial species is therefore important in selection of compounds that will minimize mortality of these species.

The insidious flower bug, *Orius insidiosus* (Say), the big-eyed bug, *Geocoris punctipes* (Say), the convergent lady beetle, *Hippodamia convergens* Guerin-Meneville, and the green lacewing, *Chrysoperla carnea* Stephens are four important predators of several economic pests of cotton (Sterling et al. 1989). Pitts and Pieters (1982) found that the number of adult *H. convergens* and larval *C. carnea* caged on greenhouse cotton was significantly reduced by treatment with methomyl compared with treatment with chlordimeform. Field application of pyrethroid and organophosphorus insecticides significantly reduced the *Heliothis* spp. predator complex in cotton, compared with an untreated check (Roach and Hopkins 1981). Field testing of dimethoate, fenvalerate, and flucythrinate significantly reduced populations of most beneficial arthropods when applied to early season cotton in Mississippi (Scott et al. 1986). Leggett (1992) found that predaceous arthropods in Arizona cotton were reduced after application of ULV malathion, but populations completely recovered two weeks after treatment.

Several other studies document the toxic effect of cotton insecticides on beneficials (Pape and Crowder 1981, Yokoyama and Pritchard 1984, Yokoyama et al. 1984, Butler and Las 1983, Scott et al. 1983, Rajakulendran and Plapp 1982). The effects of four new compounds at field rates on populations of beneficials: spinosad (Tracer), fipronil (Regent), chlorfenapyr (Pirate), and imidacloprid (Provado) have been tested on cotton beneficials (Pietrantonio and Benedict 1997, Sparks et al. 1997, England et al. 1997, Peterson et al. 1996, Murray and Lloyd 1997). Our study documents more comprehensibly the toxicities of these new compounds, plus additional standard compounds, on four beneficial insect species using a spray chamber bioassay.

Materials and Methods

The *O. insidiosus* culture was originally collected from cotton near Weslaco, TX, in September 1996. Adult *G. punctipes*, *H. convergens*, and *C. carnea* cultures were obtained from Biofac Crop Care, Mathis, TX. Adults of *O. indidiosus* were maintained on green beans as an ovipositional substrate. All colonies were provided *Helicoverpa zea* (Boddie) eggs as food and moistened cotton wicks as a water source. Adults were maintained in 14.5cm X 2.5cm ventilated plastic petri dishes, with 40-60 insects per dish. All species were held at 80° F, 55-60% RH, and a 14L:10D photoperiod. Adults were less than one week old when tested.

Formulated insecticides tested were fipronil [Regent 2.5 emulsifiable concentrate (EC); Rhone-Poulenc Agric. Co., Research Triangle Park, NC], spinosad [Tracer 4 suspension concentrate (SC); DowElanco, Indianopolis, IN], chlorfenapyr [Pirate 3 (SC); American Cyanamid Co., Parsippany, NJ], imidacloprid [Provado 1.6 flowable (F); Bayer, Inc., Kansas City, MO], cyfluthrin [Baythroid 2 (EC); Bayer, Inc., Kansas City, MO], oxamyl [Vydate 2.76 concentrated low volume (CLV); E. I. Dupont de Nemours & Co., Wilmington, DE], endosulfan (Phaser 3 (EC); AgrEvo USA Co., Wilmington, DE], profenofos [Curacron 8 (EC); Novartis, Greensboro, NC], azinphos-methyl [Guthion 3 (F); Bayer, Inc., Kansas City, MO], and malathion [Fyfanon 9.79 ultra low volume (ULV); Cheminova, Inc., Wayne, NJ].

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Spray Chamber Bioassay

Cotton, *Gossypium hirsutum* L. (>Sure-Grow 125'), grown in 11cm diameter plastic pots in a greenhouse were treated with insecticides using a laboratory spray chamber (DeVries Mfg., Hollandale, MN). The sprayer was calibrated to deliver 6 gallons per acre using one TX-4 nozzle at 25 psi and 3 mph. For ULV application of malathion, the compressed-air system was replaced with a modified ULVA+ spinning disk atomizer head (Dramm Corp., Manitwoc, WI; Elzen unpublished). Rates of formulated insecticides applied were selected by referring to an appropriate control guide (Norman and Sparks 1997) or from manufacturer=s recommendations (in the case of non-registered materials). Greenhouse-grown cotton plants were sprayed with either insecticide or water. One leaf from each sprayed plant was excised after drying and placed in a 14cm X 2.5cm ventilated petri dish, with water-moistened filter paper placed on the bottom of each dish. Five adults were aspirated into each dish and 6 dishes were replicated for each treatment. Adults were exposed to 30 min, 24 h, or 72 h old residues of each insecticide. Sprayed plants for one and three day residual tests were held in a greenhouse at approximately 85° F until time to excise leaves and expose insects. Adults exposed to each compound at each residue period were held for 72 hours at 80° F, 55-60% RH, and a 14L:10D photoperiod. In the case of *C. carnea*, exposure was for 24 h only, because preliminary data indicated high sensitivity to insecticides in this species. Data were taken at 24, 48, and 72 h after exposure (24 h with *C. carnea*); mortality was assessed by failure of movement when prodded by a probe. Control mortality was never greater than 10.0%; data were corrected for control mortality using Abbott's (1925) formula. Percent mortalities were arcsine transformed and analyzed by analysis of variance; means were separated by least significant differences [$P \leq 0.05$ (SAS Institute 1988)].

Results and Discussion

At the rates tested, azinphos-methyl, imidacloprid, and spinosad were significantly less toxic to *O. insidiosus* than other treatments. Of the newer insecticides tested, fipronil and chlorfenapyr were intermediate in toxicity. Profenofos and malathion appeared to be most toxic to *O. insidiosus*. Most of the insecticides were persistent in the residual tests; however, there was a marked decrease in toxicity of endosulfan and cyfluthrin at three days after application (Table 1). Pietrantonio and Benedict (1997) rated chlorfenapyr as slightly harmful (causing 25-50% mortality) to *O. insidiosus*. They also reported that spinosad was harmless (causing <25% mortality to *O. insidiosus*, in agreement with our findings. Schoonover and Larson (1995) reported that spinosad was 450-fold less toxic to *O. insidiosus* than cypermethrin. England et al. (1997) found 76% mortality in *O. insidiosus* exposed to endosulfan treated cotton leaves [0.51 lb(AI)/a] 24 h after exposure; we observed 46.7% mortality to endosulfan [1.5 lb(AI)/a] 72 h after exposure. They also reported that oxamyl and malathion ULV caused 100% mortality; however, at the same rates we observed high mortality with malathion, but much lower mortality with oxamyl (Table 1).

Geocoris punctipes was very tolerant of many of the insecticides tested, with responses at 10% mortality or less to cyfluthrin, profenofos, endosulfan, spinosad, oxamyl, imidacloprid, and azinphos-methyl (Table 2). Therefore, residual tests were not done on these materials. Malathion and chlorfenapyr were intermediate in toxicity and fipronil produced the highest percentage mortality. Tillman and Mulrooney (1997) reported higher mortality in *G. punctipes* treated with the same rate of ULV malathion as in our study, but they reported similar mortality with the same rate of fipronil (although applied ULV). There was a slight decrease in the toxicity of chlorfenapyr and fipronil in the 72 h residuals (Table 2). Fipronil was more toxic to *G. punctipes* than to *O. insidiosus* (Table 1), which was overall more sensitive to insecticides, perhaps due to its much smaller size. Mizell and Sconyers (1992) observed 77.6% mortality to *G. punctipes* exposed to 127.4 ppm of imidacloprid, in contrast to our results where very low mortality was found (Table 2). Their method was based upon dipping plastic petri dishes or diet cups with lids into pesticide solutions; thus, the entire arena would have been coated with insecticide, whereas in our tests, only leaves were exposed to insecticide.

Hippodamia convergens was generally less tolerant of the insecticides tested than *G. punctipes*. Significantly less toxicity (<10%) was found with spinosad, oxamyl, chlorfenapyr, and fipronil compared with other treatments. Cyfluthrin, azinphos-methyl, and malathion were significantly more toxic than other treatments (Table 3). There was a decrease in toxicity of endosulfan, profenofos, and malathion in 24 and 72 h residual tests. Schoonover and Larson (1995) found that spinosad was 1000-fold less toxic to *H. convergens* than cypermethrin. Similar to our findings on the toxicity of fipronil, Kaakeh et al. (1996) found that fipronil was least toxic to *H. convergens* of seven insecticides, including carbamate, pyrethroid, and organophosphorus compounds applied topically. In addition, imidacloprid, which produced 48.3% mortality in our tests, was found to cause 78.3% mortality to *H. convergens* at 127.4 ppm by Mizell and Sconyers (1992) and was the most toxic insecticide tested on *H. convergens* by Kaakeh et al. (1996). England et al. (1997), as in our results, found high mortality with malathion; however our results disagree on oxamyl (Table 3), where they reported 100% mortality. They reported no mortality with endosulfan [0.51 lb(AI)/a]; we found 46.7% mortality [1.5 lb(AI)/a]. Wiley et al. (1995) stated that chlorfenapyr has low to moderate impact on beneficials. We found that chlorfenapyr was low in toxicity only to *H. convergens*.

Chrysoperla carnea was generally more susceptible to insecticide treatment than the other species tested. Preliminary data indicated that tests could not be carried out past 24 h of exposure; residual tests were also not done. Spinosad and cyfluthrin were significantly less toxic than other treatments to *C. carnea*. The remaining materials all produced mortalities greater than 60%. Fipronil and chlorfenapyr, which were low in toxicity only to *H. convergens*, were highly toxic to *C. carnea* (Table 4).

In summary, azinphos-methyl was very high in toxicity to *H. convergens* and *C. carnea*, but very low in toxicity to *O. insidiosus* and *G. punctipes*. Cyfluthrin was highly toxic to *H. convergens*, intermediate in toxicity to *C. carnea* and *O. insidiosus*, and non-toxic to *G. punctipes*. Chlorfenapyr was highly toxic to *C. carnea*, non-toxic to *H. convergens*, and intermediate in toxicity to *O. insidiosus* and *G. punctipes*. Endosulfan was highly toxic to *C. carnea*, non-toxic to *G. punctipes*, and intermediate in toxicity to *O. insidiosus* and *H. convergens*. Fipronil was highly toxic to *G. punctipes* and *C. carnea*, intermediate in toxicity to *O. insidiosus*, and low in toxicity to *H. convergens*. Imidacloprid was highly toxic to *C. carnea*, intermediate in toxicity to *H. convergens*, and low in toxicity to *O. insidiosus* and *G. punctipes*. Malathion was intermediate in toxicity to *G. punctipes* and highly toxic to the other species tested. Oxamyl was non-toxic to *G. punctipes* and *H. convergens* and somewhat low to intermediate to *O. insidiosus* and *C. carnea*, respectively. Profenofos was non-toxic to *G. punctipes* and intermediate to high in toxicity to the remaining species. Spinosad was low in toxicity to *O. insidiosus* and *C. carnea* and non-toxic to *G. punctipes* and *H. convergens*.

There was considerable variability in response of the four species tested to the insecticides selected. However, spinosad was consistently least toxic to the species tested. This is consistent with the study of Murray and Lloyd (1997) who reported that spinosad was not disruptive to predator populations in Australian cotton and suggested that the product has an important role in integrated management programs. Further, Hendrix et al. (1997) reported that spinosad was softer on beneficials than chlorfenapyr, deltamethrin (Decis), *lambda*-cyhalothrin (Karate), or acephate (Orthene), and Pietrantonio and Benedict (1997) rated spinosad as harmless (causing <25% mortality) to *Cotesia plutellae* (Kurdjumov) in laboratory studies.

Cotton IPM is highly complex and relies on many factors. However, any understanding we can gain regarding the selectivity of pesticides will be beneficial. It is especially important to obtain data on the selectivity of newer insecticides with novel modes of action, because these may replace conventional insecticides for use on resistant pest species.

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Table 1. Toxicity of Selected Insecticides to *O. insidiosus* Adults in a Spray Chamber Bioassay.

Treatment	Lb(AI)/a	% Mortality , 72 h		
		Residual Time		
		30 min	24 h	72 h
Azinphos-methyl	0.25	0.0a	---	---
Imidacloprid	0.047	5.9a	---	---
Spinosad	0.089	10.0a	---	---
Oxamyl	0.25	38.3b	45.0a	41.6ab
Fipronil	0.05	43.3bc	43.3a	56.7bc
Endosulfan	1.5	46.7bc	43.3a	17.5a
Chlorfenapyr	0.35	52.2bc	50.0a	55.6bc
Cyfluthrin	0.05	53.0bc	62. 5a	30.0ab
Profenofos	0.25	73.3c	50.0a	51.7abc
Malathion ULV	0.92	76.6c	80.0a	78.9c
		F = 10.04	F = 0.55	F = 2.83
		df = 9, 50	df = 6,35	df = 6, 35

Means within a column by residual time followed by the same letter are not significantly different ($P \geq 0.05$; least significant difference [SAS Institute 1988]).

Table 2. Toxicity of Selected Insecticides to *G. punctipes* Adults in a Spray Chamber Bioassay.

Treatment	Lb(AI)/a	% Mortality , 72 h		
		Residual Time		
		30 min	24 h	72 h
Cyfluthrin	0.05	0.0a	----	----
Profenofos	0.25	0.0a	----	----
Endosulfan	1.5	0.0a	----	----
Spinosad	0.089	0.0a	----	----
Oxamyl	0.25	0.0a	----	----
Imidacloprid	0.047	6.7a	----	----
Azinphos-methyl	0.25	10.0a	----	----
Maltahion ULV	0.92	56.7b	----	----
Chlorfenapyr	0.35	66.7bc	73.3a	66.7a
Fipronil	0.05	86.7c	83.3a	40.0a
		F = 18.63	F = 0.56	F = 1.57
		df = 9, 50	df = 2, 15	df = 2, 15

Means within a column by residual time followed by the same letter are not significantly different ($P \geq 0.05$; least significant difference [SAS Institute 1988]).

Table 3. Toxicity of Selected Insecticides to *H. convergens* Adults in a Spray Chamber Bioassay.

Treatment	Lb(AI)/a	% Mortality , 72 h		
		Residual Time		
		30 min	24 h	72 h
Spinosad	0.089	0.0a	----	----
Oxamyl	0.25	0.0a	----	----
Chlorfenapyr	0.35	3.3a	----	----
Fipronil	0.05	6.7a	----	----
Endosulfan	1.5	46.7b	20.0a	20.8a
Imidacloprid	0.047	48.3b	43.4ab	56.7bc
Profenofos	0.25	60.0b	33.3ab	23.3a
Cyfluthrin	0.05	93.3c	86.7c	76.7bc
Azinphos-methyl	0.25	93.3c	86.7c	96.7c
Malthion ULV	0.92	93.3c	66.7bc	50.0b
		F = 20.89	F = 6.30	F =7.97
		df = 9,50	df = 5,30	df = 5,30

Means within a column by residual time followed by the same letter are not significantly different ($P \geq 0.05$; least significant difference [SAS Institute 1988]).

Table 4. Toxicity of Selected Insecticides to *C. carnea* Adults in a Spray Chamber Bioassay.

Treatment	Lb(AI)/a	% Mortality, 24 h
		Residual Time, 30 min
Spinosad	0.089	23.3 a
Cyfulthrin	0.05	36.7 a
Oxamyl	0.25	66.7 b
Profenofos	0.25	76.7 b
Imidacloprid	0.047	83.3 bc
Malathion ULV	0.92	86.7 bc
Endosulfan	1.5	90.0 bc
Chlorofenapyr	0.35	93.3 c
Azinphos-methyl	0.25	96.7 c
Finopril	0.05	100.0 c
		F = 8.42
		df = 9,50

Means followed by the same letter are not significantly different ($P \geq 0.05$; least significant difference [SAS Institute 1988]).