Susceptibility of *Cotesia marginiventris* (Cresson) (Hymenoptera: Braconidae) to Field Rates of Selected Cotton Insecticides[1, 2]

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ABSTRACT The parasitoid *Cotesia marginiventris* (Cresson) was treated topically with minimum recommended field rates of formulated insecticides commonly used in cotton insect control. The 14 insecticides were acephate, azinphosmethyl, bifenthrin, cyhalothrin, cypermethrin, endosulfan, esfenvalerate, fipronil, methomyl, methyl parathion, oxamyl, profenofos, thiodicarb, and AC 303,630. Eleven of the 14 insecticides were extremely toxic to *C. marginiventris*, causing 80 to 100% mortality of adult wasps, whereas treatment with thiodicarb, oxamyl, and acephate resulted in lower mortality of *C. marginiventris* males and females. For both male and female *C. marginiventris*, thiodicarb and oxamyl were less toxic than acephate. Esfenvalerate was the least toxic pyrethroid for *C. marginiventris* females. Of the three insecticides used in boll weevil control (oxamyl, azinphosmethyl, and methyl parathion), oxamyl was the least toxic to *C. marginiventris*. Selective use of the insecticides which result in higher survival could facilitate conservation of *C. marginiventris*.

KEY WORDS Budworm, parasitoid, insecticide susceptibility

The beet armyworm, *Spodoptera exigua* (Hübner), is typically a secondary pest in cotton. Falcon et al. (1971) and Eveleens et al. (1973) demonstrated that outbreaks of this pest can be generated by insecticide treatments used to suppress the plant bug, *Lygus hesperus* Knight in cotton in California. More recently, Ruberson et al. (1994) reported that disruptions by insecticides of the large and diverse complex of natural enemies of the beet armyworm in cotton in Georgia can contribute to outbreaks of this pest. *Cotesia marginiventris* (Cresson) is an important natural enemy of 21 lepidopteran species (Marsh 1979). McCutcheon et al. (1990) reported that *C. marginiventris* is often the most prevalent parasitoid of soybean looper, *Pseudoplusia includens* (Walker), a lepidopterous pest of soybean and cotton in South Carolina. Parasitism rates in populations of beet armyworm larvae collected in Georgia were 46.8% and 40.2% in 1992 and 1993, respectively, with *C. marginiventris* as the predominant parasitoid for both years (Ruberson et al. 1994). Because

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insecticide treatments can disrupt populations of this parasitoid, determining the susceptibility of this natural enemy to insecticides is important in understanding the impact of these insecticides on the natural enemy population in the field. Ruberson et al. (1993) reported that *C. marginiventris* was highly susceptible to residues of organophosphate and pyrethroid insecticides. We conducted this study to determine mortality of this natural enemy exposed by direct contact with lowest recommended field rates of formulated insecticides presently used in control of insect pests in cotton.

Materials and Methods

Rearing. Adult *C. marginiventris* were obtained from a colony established at the USDA/ARS research facility at Tifton, GA in 1994. This wasp was reared from larvae of *Heliothis virescens* (F.) using procedures similar to those of Powell and Hartley (1987), except that the cages used in this study were smaller. The bottom of our rearing cage was a host diet tray as described by Powell and Hartley (1987). The top was an empty bottom tray with large (10.2 × 25.4 cm) screened openings for air flow. When the top was secured to the bottom tray with tape, the total cage size was 34.6 × 65.4 × 6.7 cm, allowing free movement for the wasps. Our laboratory colony of *C. marginiventris* was maintained with a constant supply of dilute honeywater (50%) at 60% to 70% RH, 26 to 28°C, and 14:10 (L:D) h conditions. Host larvae were reared on an agar soybean flour-wheat germ diet (King and Hartley 1985) at 26.7 ± 2°C, 50 ± 5% RH and a photoperiod of 15:9 (L:D) h. Adult parasitoids used in the studies were 1 d old.

Insecticide susceptibility test. Insecticides were chosen based on class and current use against insect pests in cotton. All insecticides were obtained as formulated concentrates from local chemical companies and diluted with water before use. Low field rates were used for all 14 insecticides. The 14 insecticides and the field rates (kg [AI]/ha) included: acephate (Orthene®, [1.05], Valent USA Corporation, Walnut Creek, CA), azinphosmethyl (Guthion®, [0.175], Miles Inc., Kansas City, MO), bifenthrin (Capture®, [0.084], FMC Corporation, Philadelphia, PA), cyhalothrin (Karate® [0.035], ICI Americas Inc., Wilmington, DE), cypermethrin (Ammo® [0.056], FMC Corporation), endosulfan (Thiodan®, [1.05], FMC Corporation), esfenvalerate (Asana®, [0.05], Dupont, Wilmington, DE), fipronil (Exp. No. 60720A, [0.035], Rhone-Poulenc Ag Company, Research Triangle, NC), methomyl (Lannate®, [0.175], Dupont), methyl parathion [0.35], oxamyl (Vydate®, [0.175], Dupont), profenofos (Curacron® [1.05], CIBA-GEIGY Corporation, Greensboro, NC) thiodicarb (Larvin®, [0.84], Rhone-Poulenc Ag Company), and code name AC 303,630 (Pirate® [0.28], American Cyamid, Wayne, NJ). Water alone was sprayed for controls.

A laboratory spray chamber (Bouse et al. 1970) was used to topically treat adult wasps. The chamber was calibrated to deliver 56 liter/ha, using single TX 6 cone nozzle, moving at 3.2 km/hr and maintaining 2,109 g/cm^2 pressure at the spray nozzle. Height of the nozzle above the spray surface was 30.5 cm.

Insects were aspirated into new plastic Petri dishes (100 × 15 mm) containing Whatman no. 1 filter paper on the bottom, lightly anesthetized with CO_2 and immediately placed uncovered on the spray surface in the chamber for treatment. A treatment replicate consisted of 5 male (single Petri dish) and 5 female (single

Petri dish) adult parasitoids. Each treatment was replicated 5 times so there were 5 Petri dishes per treatment per sex. For each treatment, all 10 Petri dishes were sprayed during a single pass of the spray nozzle. Each control replicate included 3 male (single Petri dish) and 3 female (single Petri dish) adult parasitoids. Each control was replicated 5 times so there were 5 Petri dishes per treatment per sex. These 10 Petri dishes were also sprayed together. A treatment was sprayed and then a control was sprayed a few minutes later. Before the test, a hole (55 mm diam.) was cut in the top of the Petri dish and covered with organdy mesh to increase air movement. After spraying, the top of the Petri dish (with honey on the underside) was placed on the dish. Sprayed insects were then placed in an environmental chamber maintained at 25 ± 2°C, 50 ± 5% RH and a photoperiod of 14:10 (L:D) h. After 24 h these insects were checked for dead and live individuals. Moribund wasps were recorded as dead. There were 5 replicates for each insecticide resulting in 25 individual parasitoids of each sex treated per insecticide. A split block design was used. The main unit consisted of 14 chemicals, and the subunit consisted of 2 sexes.

Data analysis. One hundred percent mortality was obtained for many of the treatments in this study. Thus, analysis of variance was not an appropriate test because the assumptions of homogeneity of variance and normal distribution were not met. Therefore, confidence intervals for percentage mortality were based on the binomial distribution. Mortality data were compared among insecticides. Mortality data for *C. marginiventris,* for three chemicals, did meet the assumptions for an analysis of variance test. In this case, percentage mortality data were converted to arcsine values and analyzed by analysis of variance (ANOVA) (SAS 1988). Means were separated by a least significant differences test.

Results and Discussion

Not more than 6 of the 420 control parasitoids died at the end of the 24 h test period. Therefore, it was concluded that spraying with water had no effect on parasitoids, and mortality data were not corrected for control mortality.

Eleven of the 14 insecticides tested were extremely toxic to male and female *C. marginiventris,* causing 80 to 100% mortality of adult wasps (Table 1). Treatment with 3 insecticides (thiodicarb, oxamyl, and acephate) resulted in significantly higher survival of *C. marginiventris* adults than was found with the other 11 insecticides tested. For both male and female *C. marginiventris,* thiodicarb and oxamyl were significantly less toxic than acephate (Table 2). Of the three insecticides used in boll weevil control, (oxamyl, azinphosmethyl, and methyl parathion), oxamyl was the least toxic to *C. marginiventris.*

Residual and topical application studies previously conducted for *C. marginiventris* complement the results of our direct contact studies (Table 3). The carbamate thiodicarb was relatively non-toxic to the parasitoids whether the adults were directly sprayed with the insecticide or exposed to residues of the insecticide. This insecticide also resulted in low mortality for *Microplitis croceipes* (Cresson) and *Cardiochiles nigriceps* Vierick, parasitoids of *H. virescens* (Tillman 1995) and *Geocoris punctipes* (Say), a predator of this and other lepidopterous pests (McCutcheon and DuRant 1993). Another carbamate, oxamyl was relatively non-toxic to *C. marginiventris* in our studies. Similarly, oxamyl induced no significant

Table 1. Mortality of male and female *Cotesia marginiventris* to directly applied insecticides at lowest recommended field rate.

Insecticide	Rate (kg[AI]/ha)	n	Mean percentage of mortality (± 95% CI)* males	females
thiodicarb (C)**	0.84	25	16 (4-24)	4 (0-8)
oxamyl (C)	0.175	25	32 (16-44	8 (0-16)
methomyl (C)	0.175	25	100 (86-100)	100 (86-100)
endosulfan (OC)	1.05	25	100 (86-100)	100 (86-100)
acephate (OP)	1.05	25	84 (72-92)	52 (32-60)
azinphosmethyl (OP)	0.175	25	100 (86-100)	100 (86-100)
methyl parathion (OP)	0.35	25	100 (86-100)	100 (86-100)
profenofos (OP)	1.05	25	100 (86-100)	100 (86-100)
esfenvalerate (P)	0.05	25	96 (88-100)	80 (68-92)
bifenthrin (P)	0.084	25	92 (84-100)	96 (88-100)
cyhalothrin (P)	0.035	25	100 (86-100)	100 (86-100)
cypermethrin (P)	0.056	25	96 (88-100)	92 (84-100)
fipronil (PP)	0.035	25	100 (86-100)	100 (86-100)
AC 303, 630 (PY)	0.28	25	100 (86-100)	100 (86-100)

*confidence interval (95%) based on binomial distribution.
**C = carbamate, OC = organochlorine, OP = organophosphate, P = pyrethroid, PP = phenopyrazole, PY = pyrrole.

mortality in adult *C. marginiventris* caged on treated cotton leaves (J. Ruberson personal communication). Mortality was much higher for *M. croceipes* females than for *C. nigriceps* females when treated with oxamyl (Tillman 1995). Methomyl, the third carbamate we studied, was very toxic to *C. marginiventris,* and also was very toxic to *Campoletis sonorensis* (Carlson), a parasitoid of *H. virescens*, when the insecticide was topically applied (Elsey and Cheatman 1976). However, mortality for *G. punctipes* was only 37% when the insect was exposed to residues of this insecticide (McCutcheon and DuRant 1993). Topical application of an older carbamate, carbaryl, revealed that this insecticide was very toxic to *Bracon mellitor* (Say), an ectoparasitoid of the boll weevil (Adams and Cross 1967) and to *C. sonorensis* (Lingren et al. 1972). So thiodicarb and oxamyl may be less toxic to natural enemies, but other carbamates may be highly toxic to natural enemies especially when these insects are directly sprayed with the insecticides.

Table 2. Mortality of male and female *C. marginiventris* to three directly applied insecticides at lowest recommended field rate.*

			Mean percentage of mortality	
Insecticide	Rate (kg[AI]/ha)	n	males	females
thiodicarb	0.84	25	16 a	4 a
oxamyl	0.175	25	32 a	8 a
acephate	1.05	25	84 b	52 b

*Values within a column followed by the same letter are not significantly different ($P > 0.05$); comparisons were based on LSD. All data were transformed by arcsine before analysis.

All of the organophosphates, except acephate for the females, resulted in very high mortality for *C. marginiventris.* Both direct contact and topical application studies with azinphosmethyl and methyl parathion demonstrated that these insecticides were highly toxic to this parasitoid (Table 3). Methyl parathion is highly toxic to many other natural enemies in cotton including *G. punctipes, Hippodamia convergens* (Guërin-Mëneville), and *Chrysopa carnea* Stephens (Wilkinson et al. 1975), *B. mellitor* (Adams and Cross 1967), and *M. croceipes* and *C. nigriceps* (Tillman 1995). Azinphosmethyl resulted in high mortality for other braconids, *M. croceipes* and *C. nigriceps* (Tillman 1995) and *B. mellitor* (O'Brien et al. 1985). Profenofos resulted in 100% mortality for *C. marginiventris* in our direct contact study and in the residual studies conducted by Ruberson et al. (1993) and Wilkinson et al. (1979) (Table 3). This insecticide and sulprofos were highly toxic to *C. marginiventris* and *H. convergens* (Wilkinson et al. 1979), *M. croceipes* and *C. nigriceps* (Tillman 1995), and *C. carnea* larvae (Plapp and Bull 1978), but less toxic to *G. punctipes* (Wilkinson et al. 1979, McCutheon and DuRant 1993) in residual toxicity tests. Endosulfan is highly toxic to *C. marginiventris* and to *M. croceipes* and *C. nigriceps* (Tillman 1995). Acephate was toxic to *C. marginiventris* and to *M. croceipes* and *C. nigriceps* (Tillman 1995). Acephate was toxic to *M. croceipes* in direct contact studies (Tillman 1995) and in residue studies (Powell and Scott 1991). High mortality occurred when *G. punctipes* was exposed to residues of this insecticide (McCutcheon and DuRant 1993). This insecticide, however, was less toxic to *C. marginiventris, C. nigriceps* (Tillman 1995), *C. sonorensis* (Plapp and Vinson 1977), and *C. carnea* larvae (Plapp and Bull 1978).

Many of the pyrethroids have been found to be very toxic to *C. marginiventris* and other natural enemies. Cyhalothrin resulted in 100% mortality in our direct toxicity tests and in the residual toxicity tests conducted by Ruberson et al. (1993). Spraying this insecticide directly onto *M. croceipes* and *C. nigriceps* adults resulted in 100% mortality (Tillman 1995), whereas exposure of *M. croceipes* to residues of the insecticide resulted in lower mortality (26.8%) (Powell and Scott 1991). *Geocoris punctipes,* however, was highly susceptible to residues of this pyrethroid (McCutcheon and DuRant 1993).

Table 3. Review of susceptibility of *Cotesia marginiventris* to insecticides.

Insecticide	Rate	Method*	Mortality	Reference
thiodicarb 3.2L (C)	0.4 lbs AI/A	R	2.0%	Ruberson et al. 1993
	0.9 lbs AI/A	R	8.0%	Ruberson et al. 1993
diflubenzuron 2L (GR)	0.06 lbs AI/A	R	0.0%	Ruberson et al. 1993
	0.125 lbs AI/A	R	0.0%	Ruberson et al. 1993
azinphosmethyl (OP)		T	LD_{50} = 0.0027	Lingren et al. 1972
methyl parathion (OP)		T	LD_{50} = 0.0004	Lingren et al. 1972
profenofos 8EC (OP)	0.75 lbs AI/A	R	100.0%	Ruberson et al. 1993
	1.0 lbs AI/A	R	100.0%	Ruberson et al. 1993
profenofos 4EC	1121 g AI/ha	R	100.0%	Wilkinson et al. 1979
	561 g AI/ha	R	100.0%	Wilkinson et al. 1979
sulprofos 6EC (OP)	1682 g AI/ha	R	100.0%	Wilkinson et al. 1979
	561 g AI/ha	R	100.0%	Wilkinson et al. 1979
cyhalothrin 1EC (P)	0.025 lbs AI/ha	R	100.0%	Ruberson et al. 1993
	0.04 lbs AI/ha	R	100.0%	Ruberson et al. 1993
fenvalerate 2.4EC (P)	224 g AI/ha	R	13.3%	Wilkinson et al. 1979
	56 g AI/ha	R	0.0%	Wilkinson et al. 1979
permethrin 2EC (P)	140 g AI/ha	R	95.8%	Wilkinson et al. 1979
	64 g AI/ha	R	40.8%	Wilkinson et al. 1979

*R=exposure to residues, T=topical application

Some pyrethroids, especially the first generation pyrethroids, exhibited moderate to low toxicity to natural enemies. In this study, esfenvalerate was the least toxic pyrethroid for *C. marginiventris* females. Exposure to residues of this insecticide resulted in low mortality for *M. croceipes* (Powell and Scott 1991). Fenvaleate also was not very toxic to *M. croceipes* (Powell et al. 1986), *C. carnea* (Plapp and Bull 1978), *C. sonorensis* (Plapp and Vinson 1977), *G. punticeps* (Wilkinson et al. 1979), and *C. marginiventris* (Wilkinson et al. 1979). There is a wide range in response among species to cypermethrin. This insecticide was toxic to *C. marginiventris* as well as *M. croceipes*, but slightly less toxic to *C. nigriceps* (Tillman 1995) when sprayed directly onto adult females. Exposure to residues, however, resulted in low mortality for *M. croceipes* (Katayama et al. 1987). In topical application tests, mortality was high for *C. sonorensis* (Rajakulendran and Plapp 1982), low for *H. convergens* (Coats et al. 1979), and low for *C. carnea* larvae (Rajakulendran and Plapp 1982).

In summary, for *C. marginiventris* the range from least to moderate toxicity appears to be dimilin, thiodicarb, fenvaleate, oxamyl, acephate, permethrin, and esfenvalerate. Methomyl, endosulfan, all the organophosphates (except acephate), second generation pyrethroids, and the insecticides which represented two new chemical families, phenolpyrazole and pyrole, were very toxic to this parasitoid. Because disruptions of the natural enemy complex which attack the beet armyworm can contribute to outbreaks of this pest species, selective use of insecticides should facilitate conservation of *C. marginiventris*. This is a wide open area of research. However, we must identify management strategies such as using selective insecticides or growing protected nurseries of natural enemies to conserve natural enemies which help prevent outbreaks of pest species.

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