Susceptibility of *Microplitis croceipes* and *Cardiochiles nigriceps* (Hymenoptera: Braconidae) to Field Rates of Selected Cotton Insecticides[1]

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ABSTRACT *Microplitis croceipes* (Cresson) and *Cardiochiles nigriceps* Vierick, parasitoids of *Heliothis virescens* (F.), were treated topically with field rates of 14 formulated insecticides commonly used in cotton insect control. The 14 insecticides were oxamyl, thiodicarb, endosulfan, acephate, azinphosmethyl, chlorpyrifos, dicrotophos, dimethoate, methyl parathion, profenofos, bifenthrin, cyhalothrin, cyfluthrin, and cypermethrin. With the exception of thiodicarb, all insecticides were extremely toxic to *M. croceipes*, causing 100% mortality of adult wasps. Treatment with thiodicarb resulted in high survival of adults for each parasitoid species. Acephate was extremely toxic to *M. croceipes*, but relatively non-toxic to *C. nigriceps*. Mortality also was lower for *C. nigriceps* females than for *C. nigriceps* males and *M. croceipes* for both sexes when wasps were treated with oxamyl. Nine of the 14 insecticides tested were extremely toxic to *C. nigriceps*, causing 100% mortality of adult wasps. Treatment with 5 insecticides - thiodicarb, acephate, oxamyl, azinphosmethyl, and cypermethrin - resulted in higher survival for *C. nigriceps* adults than was obtained for the other nine insecticide treatments. For both male and female *C. nigriceps*, thiodicarb and acephate were less toxic than the other three insecticides. Generally, these five insecticides were less toxic to females than males. An exception was the lower mortality of male *C. nigriceps* versus females of this species for treatment with acephate. Of the three insecticides commonly used for boll weevil control (oxamyl, azinphosmethyl, and methyl parathion), oxamyl was the least toxic to *C. nigriceps* females. Cypermethrin was less toxic to *C. nigriceps* females than the other three pyrethroids tested. Selective use of insecticides which permit higher parasitoid survival could facilitate conservation of these native biological control agents.

KEY WORDS Tobacco budworm, parasitoids, insecticide susceptibility.

Microplitis croceipes (Cresson) and *Cardiochiles nigriceps* Vierick are parasitoids of *Heliothis virescens* (F.) and *Heliothis subflexa* (Guneeé). *M. croceipes* also parasitizes *Helicoverpa zea* (Boddie). Both of these wasp species have been reported as prominent parasitoids attacking their respective hosts on spring wild host plants of larvae of these noctuids (Snow et al. 1966, Lewis and Brazzel 1968, Smith et al. 1976, Mueller and Phillips 1983, Stadelbacher et al.

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1984). These parasitoids are also important in cotton. *M. croceipes* (Bottrell et al. 1968, Burleigh and Farmer 1978, King et al. 1985) and *C. nigriceps* (Lewis et al. 1972) can parasitize a large proportion (>50%) of larvae in *Heliothis* field populations.

H. virescens has developed resistance to pyrethroids (Luttrell et al. 1987, Leonard et al. 1988). One method of managing pyrethroid resistance is to rotate different classes of insecticides used for insect control (e.g., C.A.S.T. 1983). This would involve using organophosphate, carbamate, organochlorine, and formanidine insecticides along with pyrethroids for control of *H. virescens.* This management strategy is currently utilized in the Mississippi Delta; thus, natural enemies in cotton fields are being exposed to these five classes of insecticides.

Both *M. croceipes* and *C. nigriceps* have been considered for use in areawide management programs for control of *H. virescens*. *M. croceipes* has been reported to be less susceptible to many pyrethroids than to organophosphate and carbamate insecticides in the laboratory (Powell et al. 1986, Elzen et al. 1987). Because insecticide susceptibility tests have not been performed for *C. nigriceps,* it is unknown whether there are any differences in insecticide susceptibility between these two parasitoids. This information is vital in choosing which parasitoid species to release in an augmentation program.

Generally, one of three methods has been used to determine toxicity of insecticides to parasitoids: (1) topical application of technical grade insecticides in the laboratory, (2) topical application of recommended field rates of formulated insecticides using a spray table, and (3) exposure to residues of insecticides applied to foliage at recommended field rates. The first method is best for ascertaining relative insect responses to insecticides and understanding the method of detoxification of insecticides. The second method is a good measure of the effect an insecticide will have when it is directly sprayed on a parasitoid in the field. The third method is the best of the three methods for assessing the effect of insecticide residues on parasitoids. We used the second method to compare the mortality of *M. croceipes* and *C. nigriceps* adults exposed to direct contact with field rates of formulated insecticides presently used in control of insect pests in cotton.

Materials and Methods

Rearing. Adult *M. croceipes* and *C. nigriceps* were obtained from a colony established from parasitoids that emerged from *H. virescens* larvae collected in wild geranium and cotton, respectively, in Washington, Co., MS, in 1993. Laboratory colonies of *M. croceipes* and *C. nigriceps* were maintained in 85 × 44.5 × 30 cm cages with a constant supply of dilute honeywater (50%) at 60-70% RH, 26 to 28°C, and a photoperiod of 14:10 (L:D) h. These parasitoids were reared from larvae of *H. virescens* using the procedures of Powell and Hartley (1987). 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. Adults were held no longer than 3 d before testing.

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. The 14 insecticides and the field rates (kg [AI]/ha) included: oxamyl (Vydate, [0.175], Dupont, Wilmington, DE), thiodicarb (Larvin, [0.84], Rhone-Poulenc Ag Company, Research Triangle, NC), endosulfan (Thiodan, [1.05], FMC Corporation, Philadelphia, PA), acephate (Orthene, [1.05], Valent USA Corporation, Walnut Creek, CA), azinphosmethyl (Guthion, [0.175], Miles Inc., Kansas City, MO), chlorpyrifos (Lorsban, [0.7], DowElanco, Indianapolis, IN), dicrotophos (Bidrin, [0.28], DuPont), dimethoate (Cygon [0.28], American Cyanamid Company, Wayne, NJ), methyl parathion [0.35], profenofos (Curacron [1.05], CIBA-GEIGY Corporation, Greensboro, NC), bifenthrin (Capture, [0.084], FMC Corporation), cyhalothrin (Karate [0.035], ICI Americas Inc., Wilmington, DE), cyfluthrin (Baythroid [0.042], Mobay Corp., Kansas City, MO), and cypermethrin (Ammo [0.056], FMC Corporation). Lowest field rates recommended for *H. virescens* in the 1993 Mississippi State University Insect Control Guide (Mississippi State University) were used. 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 a 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 of each species. These 4 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 of each species. These 4 Petri dishes also were sprayed together. A treatment was sprayed and the control was sprayed a few minutes later. Before the test, a hole (55 mm in 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 yielding 25 individual parasitoids treated per insecticide. A split block design was used. The main unit consisted of 14 chemicals and the subunit consisted of 2 species by 2 sexes.

Data Analysis. A mean of 100% 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 between males and females within a species, between parasitoid species, and among insecticides. Mortality data for *C. nigriceps,* for five 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 (LSD).

Results and Discussion

None of the 840 control parasitoids were found dead at the end of any 24-h test period. Because spraying with water had no effect on the wasps, these results are not shown.

Mortality of male and female *M. croceipes* and *C. nigriceps* adults to the insecticides studied are shown in Table 1. With the exception of thiodicarb, all of the 14 insecticides were extremely toxic to *M. croceipes,* causing 100% mortality of adult wasps. Treatment by thiodicarb resulted in significantly lower mortality for *M. croceipes* males and females than treatment by the other chemicals tested. Also, thiodicarb was less toxic to *M. croceipes* females than to *M. croceipes* males. Other authors have reported similar results for *M. croceipes.* Elzen et al. (1987) reported no mortality for thiodicarb (1.35 kg [AI]/ha) and 100.0% mortality for acephate (0.375 kg [AI]/ha) in *M. croceipes* adults using the spray table technique. Powell et al. (1986) found high mortality for methyl parathion (LD50-13.2), azinphosmethyl (LD50-25.5), and chlorpyrifos (LD50=21.7) for *M. croceipes.*

In contrast to *M. croceipes,* nine of the insecticides caused high mortality for *C. nigriceps* adults. Treatment with acephate resulted in significantly lower mortality for *C. nigriceps* than for *M. croceipes.* Mortality also was significantly lower for *C. nigriceps* females than for *C. nigriceps* males and *M. croceipes* for both sexes when wasps were treated with oxamyl. The insecticides oxamyl and acephate have been and are presently widely used in cotton fields against the boll weevil and plant bugs, respectively. Differential susceptibility to these two insecticides, which occurs between *C. nigriceps* and *M. croceipes,* may be a partial explanation for the greater numbers of *C. nigriceps* over *M. croceipes* observed in cotton fields in the Mississippi Delta for the last few years.

In general, when differences in susceptibility occurred between the sexes, mortality was higher for the males than the females. Elzen et al. (1987) also reported higher mortality for male over female adult *M. croceipes* for some insecticides. Differential susceptibility between the sexes could be due to the smaller size of the males over females. Conservation of female parasitoids searching the field for host would be an important aspect of an integrated pest management program.

Five insecticides – oxamyl, thiodicarb, acephate, azinphosmethyl, and cypermethrin – caused lower than 96-100% mortality for *C. nigriceps* adults (Table 2). For both males and females, thiodicarb and acephate were significantly less toxic than the other three insecticides. Generally, these five insecticides were less toxic to females than males. An exception was the significantly lower mortality of male *C. nigriceps* versus females of this species for treatment with acephate. Of the three insecticides used in boll weevil control (oxamyl, azinphosmethyl and methyl parathion), oxamyl was the least toxic to *C. nigriceps* females. Cypermethrin was significantly less toxic to *C. nigriceps* females than the other three pyrethoids tested.

Of the four insecticide classes studied here, the organophosphate and the pyrethroid classes included some insecticides which were highly toxic to *M. croceipes* and *C. nigriceps.* However, the organophosphate acephate was less toxic to *C. nigriceps* females than to *M. croceipes.* Relative toxicity of some

Table 1. Mortality of male and female *M. croceipes* and *C. nigriceps* to fourteen topically applied insecticides at lowest recommended field rate.

			Mean percentage of mortality (± 95% CI)*			
			M. croceipes		*C. nigriceps*	
Insecticide	Rate**	n	males	females	males	females
thiodicarb (C)†	0.84	25	44 (28-60)	0 (0-14)	0 (0-14)	0 (0-14)
oxamyl (C)	0.175	25	100 (86-100)	92 (84-100)	92 (84-100)	60 (44-76)
acephate (OP)	1.05	25	100 (86-100)	100 (86-100)	0 (0-14)	36 (20-52)
azinphosmethyl (OP)	0.175	25	100 (86-100)	100 (86-100)	100 (86-100)	88 (76-96)
chlorpyrifos (OP)	0.7	25	100 (86-100)	100 (86-100)	100 (86-100)	100 (86-100)
dicrotophos (OP)	0.28	25	100 (86-100)	100 (86-100)	100 (86-100)	100 (86-100)
dimethoate (OP)	0.28	25	100 (86-100)	100 (86-100)	100 (86-100)	100 (86-100)
methyl parathion (OP)	0.35	25	100 (86-100)	100 (86-100)	100 (86-100)	100 (86-100)
profenofos (OP)	1.05	25	100 (86-100)	100 (86-100)	96 (88-100)	100 (86-100)
endosulfan (OC)	1.05	25	100 (86-100)	100 (86-100)	100 (86-100)	100 (86-100)
bifenthrin (P)	0.084	25	100 (86-100)	100 (86-100)	100 (86-100)	100 (86-100)
cyhalothrin (P)	0.035	25	100 (86-100)	100 (86-100)	100 (86-100)	100 (86-100)
cyfluthrin (P)	0.042	25	100 (86-100)	96 (88-100)	96 (88-100)	96 (88-100)
cypermethrin (P)	0.056	25	100 (86-100)	96 (88-100)	100 (86-100)	88 (76-96)

* confidence interval (95%) based on binomial distribution.
** kg [AI]/ha.
† C = carbamate, OC = organochlorine, OP = organophosphate, P = pyrethroid.

Table 2. Mortality of male and female *C. nigriceps* to five topically applied insecticides at lowest recommended field rate.*

			Mean percentage of mortality	
Insecticide	Rate**	n	males	females
thiodicarb (C)†	0.84	25	0 a,A	0 a, A
acephate (OP)	1.05	25	0 a, A	36 b, B
oxamyl (C)	0.175	25	92 b, A	60 c, B
azinphosmethyl (OP)	0.175	25	100 b, A	88 d, B
Cpermethrin (P)	0.056	25	100 b, A	88 d, B

*Values within a column or a row followed by the same letter, lower- or upper-case, respectively, are not significantly different ($P > 0.05$); comparisons within a column were based on LSD, comparisons within a row were based on ANOVA. All data were transformed by arc-sine before analysis.
** kg [AI]/ha.
† C = carbamate, OP = organophosphate, P = pyrethroid.

pyrethroids has been reported to be low for *M. croceipes* adults. For example, in laboratory topical tests, permethrin and flucythrinate have a relative toxicity of 6.5% and 3.3%, respectively (Powell et al. 1986). Survival was high for *M. croceipes* adults caged on cotton treated with field rates of flucythrinate and fenvalerate (Powell and Scott 1985). Also, both Powell et al. (1986) and Elzen et al. (1987) determined that fenvalerate caused low mortality for *M. corceipes* adults for laboratory topical rates and low field rates (using a spray table), respectively. Powell and Scott (1991) reported high survival for *M. croceipes* adults exposed to residues of cypermethrin and cyhalothrin applied at field rates to cotton. However, low survival was found for each of the pyrethroids studied in this paper. The differences detected in our study probably resulted from differences in methodology. Because survival of *M. croceipes* adults exposed to residues of cypermethrin on cotton was higher than survival when the adults were exposed to direct contact with this insecticide, toxicity is likely to be higher when parasitoids are exposed to direct contact with insecticides than when exposed to residues. Both types of exposure occur in a cotton field. Therefore, both types of methodology are applicable to field situations. The important point to be made here is that no insecticide class can be assumed as a whole to be more or less toxic for a parasitoid species, and susceptibility of parasitoids to insecticides should be determined for individual chemicals.

In conclusion, results of these tests and other reported tests indicate that *C. nigriceps,* and to a lesser extent *M. croceipes,* are relatively tolerant of only a few insecticides. Selective use of insecticides which permit higher parasitoid survival could facilitate conservation of the native biological control agents.

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