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ARTHROPOD MANAGEMENT

Survival of Selected Generalist Predaceous Insects Exposed to Insecticide Residues on Cotton

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INTERPRETIVE SUMMARY

With insecticide resistance and environmental concerns on the increase, it is imperative to investigate various components of insect management in cotton. Efficacy against pests such as the tobacco budworm and cotton bollworm is of utmost importance. We must develop strategies to maintain the effectiveness of insecticides and decrease the rate of insect resistance. Conservation of important natural enemies is needed to develop a functional cotton integrated pest management program.

These studies show some differences in survival rates of two predators when exposed to residues of commonly used insecticides. However, caution should be taken in interpretation of these results because of the possibility that predators could have been repelled and might not have made contact with the toxic chemical within the field cages.

The predators, bigeyed bugs and hooded beetles, occur in dense populations during July in South Carolina. Residues of most of the insecticides tested are not significantly toxic to the bigeyed bugs. Specifically, the treatments consisting of carbamates (methomyl (0.45 lb [AI] a^{-1}) and thiodicarb (0.75 and 0.60 lb [AI] a^{-1}) with and without amitraz (0.125 lb [AI] a^{-1}) allowed greatest survival. Use of the carbamates should be helpful in developing cotton integrated pest management systems.

The treatments that resulted in significantly higher mortality than untreated control were acephate (0.75 and 0.50 lb [AI] a^{-1}), with and without amitraz; profenofos (0.75 lb [AI] a^{-1}), with and without amitraz; and cyhalothrin (0.25 lb [AI] a^{-1}). Because the bigeyed bug is an effective predator of heliothine species, acephate, profenofos, and cyhalothrin should be used only after careful consideration when absolutely necessary.

Residues of most of the insecticides tested were significantly toxic to hooded beetle. The only treatments that allowed significant survival of hooded beetles were cyhalothrin (0.025 lb [AI] a^{-1}) and methomyl (0.45 lb [AI] a^{-1}), with and without amitraz. Growers should not base integrated pest management decisions on residual effects of insecticides on the hooded beetle because its effectiveness has not been documented in the field. Furthermore, when insect resistance to the commonly used pyrethroid cyhalothrin is taken under consideration, along with its toxic effect on the bigeyed bugs, it is best for growers to use this very effective insecticide as judiciously as possible.

ABSTRACT

Cotton insect management should include conservation of natural enemies of major pests. This study was conducted to determine residual effects of commonly used insecticides on two predators of two major cotton pests, the tobacco budworm [*Heliothis virescens* (F.)] and the cotton bollworm [*Helicoverpa zea* (Boddie)]. Survival of the bigeyed bug, *Geocoris punctipes* (Say) (Hemiptera: Lygaeidae), and the hooded beetle, *Notoxus monodon* (F.)(Coleoptera: Anthicidae), was observed after exposure to residues of insecticides applied to cotton in 1992 and 1993 in Florence, SC. The predators were introduced into cages and exposed to residues for 48 h in cotton 4 h after field application. The insecticides included organophosphates (sulprofos, profenofos, and acephate) and carbamates (methomyl and thiodicarb), alone and in combination with the formamidine amitraz, an ovicide. A commercial formulation of a biological insecticide, *Bacillus thuringiensis* subsp. *kurstaki*, was applied only in combination with amitraz, and the pyrethroid cyhalothrin was applied alone. Survival of *G. punctipes* was significantly less in acephate, acephate + amitraz, profenofos + amitraz,

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and cyhalothrin than in the untreated check in one or more years. Treatments containing organophosphates and thiodicarb were toxic to *N. monodon* as was *B. thuringiensis* + amitraz. The use of selective insecticides may result in the preservation of important natural enemies.

Predaceous arthropods commonly found in cotton in the Southeast include the bigeyed bug and the hooded beetle. McCutcheon et al. (1995) reported that populations of bigeyed bugs in cotton in South Carolina began to increase in early July and reached a density of 20 per 24 m of row by early September of 1994. Hooded beetle populations increased during mid July, but they were not as abundant, reaching only 10 per 24 m of row. Both are predators of agricultural pests, including the tobacco budworm and the cotton bollworm.

In studies conducted by Lopez et al. (1976), bigeyed bugs, when confined in petri dishes, consumed from 30 to 51 tobacco budworm eggs during a 48-h period. They also reported that bigeyed bugs reduced tobacco budworm eggs by 26% when confined on cotton terminals at a density of 25 eggs per terminal for 48 h. When confined with 20 tobacco budworm eggs in petri dishes, one hooded beetle consumed an average of 12.3 eggs (61.5%) during a 48-h period (McCutcheon and Webster, 1996).

While both predators frequently occur in the field and can consume a high percentage of tobacco budworm eggs in the laboratory, their activity against heliothine species is still being investigated. Egg predation by *G. punctipes* has been reported by Bell and Whitcomb (1964). Recently, Ruberson and Greenstone (1998) reported on the use of ELISA assays to determine the presence of heliothine egg protein in predators collected from a 20-ha cotton field. They reported that *G. punctipes* is one of the three major predators of heliothine eggs as indicated by ELISA; however, *N. monodon* was one of the least important predators of heliothine eggs.

Conservation of natural enemies of key agricultural pests is important because it has the potential to reduce insecticide use, and thereby delay insect resistance (Greene et al. 1995). In South Carolina, densities of natural enemies increased in cotton when pyrethroid insecticides were not applied during early season in June. *Notoxus* spp. and *Geocoris* spp. were the most abundant predators followed by spiders, ants, lady beetles, lacewings, and damsel bugs. The beneficial arthropods increased natural control of the tobacco budworm, but the increases had little impact on the cotton bollworm which occurs later in the growing season.

Major predaceous arthropods in that study were the bigeyed bugs and hooded beetles. In addition, tobacco budworms show increasing levels of pyrethroid resistance in areas with heavy and moderate use of pyrethroids in cotton (Elzen et al., 1994; Luttrell et al., 1988; Plapp et al., 1988; Sparks, 1981).

Field tests and bioassays also have shown differences among pesticides in toxicity to *G. punctipes* (Lingren and Ridgway, 1967; Wilkinson et al., 1979). Therefore, preservation of beneficial insects is increasingly important in cotton pest management because it has the potential to help reduce the need for pyrethroid applications.

The study we report on in this paper was conducted with the two most prevalent predaceous arthropods in cotton in South Carolina to determine residual effects of insecticides commonly used in cotton insect management systems. During July, the period when insecticides are most often applied against heliothine species, it is important to document potential effects of the use of selective insecticides on two of the most abundant predaceous arthropods, *G. punctipes* and *N. monodon*. The insecticides tested in this study are commonly used in cotton insect management, or they are potential candidates for use in integrated pest management systems.

MATERIALS AND METHODS

Cotton variety Deltapine Acala 90 was planted on 11 May 1992 and 10 May 1993 at the Clemson University Pee Dee Research and Education Center in Florence, SC. Cultural practices included the application of the herbicides Treflan 4EC (2.2 L ha^{-1}) and Meturon DF (2.0 kg ha^{-1}) and the insecticide/nematicide aldicarb 15G (5.6 kg ha^{-1}) in furrow. There were 9 to 10 plants per meter of row. Treatments were replicated four times and arranged in a randomized complete block design with blocking based on soil texture.

Table 1. Insecticide treatments and field rates (proprietary name and formulation, [kg active ingredient/ha], and manufacturer) applied to cotton in Florence, SC during 1992 and 1993.

Formulation	Proprietary name	Application rate	Manufacturer	Location
		kg a.i. ha^{-1}		
organophosphates				
sulprofos	Bolstar 6E	1.12	Bayer Corporation	Kansas City, MO
profenofos	Curacron 8E	0.84	Novartis Corporation	Greensboro, NC
acephate	Orthene 75S	0.84	Valent USA Corporation	Walnut Creek, CA
carbamates				
methomyl	Lannate 1.8WS	0.504	E.I. DuPont de Nemours & Co.	Wilmington, DE
thiodicarb	Larvin 3.2AF	0.84	Rhone-Poulenc Ag Company	Research Triangle Park, NC
The above treatments were applied alone and in combination with the following ovicide in 1992.				
amitraz	Ovasyn 1.5E	0.14	AgrEvo USA Co.	Wilmington, DE

Insecticide treatments were applied 25 July 1992 and 27 July 1993 with a John Deere 6000 Hi-Cycle equipped with a CO_2 delivery system and 6X hollow cone tips operating at 60 psi to deliver a total spray of 7.5 gpa as a foliar application. Plots were eight rows wide and 15.2 m long.

There were 13 treatments in 1992 and seven in 1993. The bulk of the treatments are summarized in Table 1. In addition, a commercial formulation of the biological insecticide, *B. thuringiensis* subspecies *kurstaki* (Dipel ES [8×10^9 International Units], Abbott, North Chicago, IL), was evaluated in combination with amitraz in 1992. A synthetic pyrethroid, lambda-cyhalothrin (Karate [0.028 kg a.i. ha^{-1}], Zeneca Ag Products, Wilmington, DE), was evaluated alone. In 1993, only the treatments without amitraz were applied at the same rates [kg (AI)/ha] as in 1992 with the exception of acephate [0.56] and thiodicarb [0.672].

Adult *G. punctipes* and *N. monodon* were collected using a sweep net from untreated soybean about 1.6 km away from the test plots on the day of each test. Predaceous arthropods were placed (five per carton) by species in cardboard cartons (480 mL) and transported to the laboratory. These insects were then held in ventilated cages constructed from 480-mL cartons with the top and bottom removed, and a piece of nylon hosiery (30-cm) slipped over the entire cage. One end of the hosiery was left open until introduction of insects, and then it was secured with a wire twist.

Using an aspirator, one *G. punctipes* was introduced into each of 12 cages per plot for a total of 48 bugs per treatment, and two *N. monodon* were introduced into each of 10 cages per plot for a total of 80 beetles per treatment. A piece of paper towel (1.5 cm^2) with 20 tobacco budworm eggs from a laboratory colony on it was placed into each cage.

In the field, terminal buds and foliage of the cotton plants were carefully examined and gently shaken to dislodge naturally occurring arthropods. The cages were positioned over terminal buds and foliage, filling most of the area of the cage, and secured with a wire twist. The predaceous arthropods were caged over treated cotton foliage beginning at 4 h post-treatment. After 48 h of exposure, the predator and caged section of the cotton plant were removed and transported to the laboratory to record predator survival. In 1993, an additional rate of survival was recorded after 24 h by direct observation in the field. Predators were considered alive if they moved within 5 s after being nudged with forceps.

Data were analyzed using the ANOVA-2 procedure of MSTAT (Power, 1985). An arcsine transformation was applied to all percentage values before being subjected to analysis of variance (ANOVA) to maintain homogeneity of variance. Means were separated using Least Squares Difference (LSD). Treatment mortality data were corrected to the control mortality using Abbott's formula (Abbott, 1925).

RESULTS AND DISCUSSION

Geocoris punctipes

Survival of bigeyed bugs was significantly affected by some of the insecticide treatments (Table 2). Percentage survival was significantly less in the acephate, profenofos + amitraz, and acephate + amitraz treatments than in the untreated check. Acephate alone and profenofos + amitraz reduced survival by 86.4%. Acephate + amitraz reduced survival by 72.8%. Mortality rate in cyhalothrin, sulprofos + amitraz, and profenofos treatments was

Table 2. Mean percent survival of predaceous arthropods introduced 4 h post-treatment and exposed for 48 h in cotton in 1992. Florence, SC†.

			Geocoris punctipes (Say)		*Notoxus monodon* (F.)	
Insecticide†	**Rate kg a.i. ha^{-1}**	**Insecticide class‡**	**% Survival ± SEM§**	**Corrected mortality(%)¶**	**% Survival + SEM§**	**Corrected mortality(%)¶**
Untreated	**- - -**	**- - -**	**81.3 ± 4.5a**		**80.0 ± 8.2a**	
Methomyl + Amitraz	**0.504 + 0.140**	**C + F**	**78.2 ± 4.5a**	**3.7**	**42.3 ± 8.3abc**	**47.5**
Thiodicarb + Amitraz	**0.840 + 0.140**	**C + F**	**78.2 ± 4.5a**	**3.7**	**23.2 ± 9.6 bc**	**68.8**
Thiodicarb	**0.840**	**C**	**45.3 ± 6.5ab**	**44.3**	**8.3 ± 8.2c**	**90.0**
Methomyl	**0.504**	**C**	**45.3 ± 6.5ab**	**44.3**	**51.2 ± 9.1ab**	**36.3**
Sulprofos	**1.120**	**OP**	**45.3 ± 6.5ab**	**44.3**	**4.3 ± 8.8c**	**95.0**
***B. thuringiensis* + Amitraz**	**8 IU# + 0.140**	**B + F**	**45.3 ± 6.5ab**	**44.3**	**17.2 ± 9.8c**	**78.8**
Profenofos	**0.840**	**OP**	**33.3 ± 5.3ab**	**59.3**	**4.3 +8.4c**	**59.3**
Sulprofos + Amitraz	**1.120 + 0.140**	**OP + F**	**33.3 ± 5.3ab**	**59.3**	**25.2 + 9.8bc**	**59.3**
Cyhalothrin	**0.028**	**P**	**33.3 ± 5.3ab**	**59.3**	**55.3 ± 9.1ab**	**31.3**
Acephate + Amitraz	**0.840 + 0.140**	**OP + F**	**22.6 ± 4.8b**	**72.8**	**0c**	**100.0**
Profenofos + Amitraz	**0.840 + 0.140**	**OP + F**	**11.3 ± 4.8b**	**86.4**	**21.4 ± 8.2c**	**73.8**
Acephate	**0.840**	**OP**	**11.3 ± 4.3b**	**86.4**	**0c**	**100.0**

† Four replicates of 12 *G. punctipes* per replicate (one per cage) and 10 *N. monodon* per replicate (two per cage).

‡ Insecticide Class: B = biological C= carbamate; 0P = organophophate; P = pyrethroid; F= formamidine

§ Means followed by the same letter within a column are not significantly different (F = 4.57; df = 12,36; P > 0.05; least significant difference test).

¶ Mean mortality corrected by Abbott's formula (Abbott 1925).

 # International Units

59.3 %, which was not significantly different from the untreated control. Likewise, there were no significant differences among the untreated control and thiodicarb, methomyl, sulprofos, and *B. thuringiensis* + amitraz.

Mortality rate in each of these chemical treatments was 44.3%. Mortality rate in each of the two carbamates + amitraz was only 3.7%. Other studies with predators agree with results of the present study. For example, Yokoyama et al. (1984) reported that acephate residues were more toxic than methomyl to *G. pallens*. In studies with *G. pallens* Stål, carbamate methomyl did not significantly affect adult mortality 25 to 192 h after a 24 h exposure to residues on cotton leaves (Yokoyama and Pritchard, 1984). Also, Boyd and Boethel (1998) reported that thiodicarb was less toxic to *G. punctipes* adults than permethrin, spinosad, and methyl parathion.

No differences were detected in survival rate between chemical insecticides applied alone or in combination with amitraz. Therefore, treatments consisting of amitraz were not included in the study the following year.

In 1993, mean percentage survival of bigeyed bugs introduced 4 h post-treatment was significantly lower in acephate, cyhalothrin, and profenofos treatments than in the untreated control after 24 and 48 h of exposure (Table 3). As in 1992, acephate treatments were highly toxic to the bigeyed bug, reducing survival by 89.7% after 48 h. Cyhalothrin also reduced survival by 89.7% after 48 h. Profenofos was also toxic to bigeyed bugs, reducing survival by 39.5%. In contrast, bigeyed bug survival in the other chemicals (thiodicarb, methomyl, and sulprofos) was similar to the untreated control. Percentage mortality did not exceed 10% after 24 h and 20% after 48 h. The carbamates were generally less harmful than the other classes of insecticides to the bigeyed bug.

Notoxus monodon

Survival of hooded beetles introduced 4 h post-treatment in the control cages where no insecticide was applied was similar to survival in treatments of cyhalothrin and those containing methomyl (Table 2). Rate of mortality of hooded beetles exposed to residues of these insecticides ranged from 31 to 48% during 1992. While cyhalothrin was highly toxic to bigeyed bugs, the residue did not significantly increase mortality of hooded beetles. Methomyl residues were not significantly toxic to bigeyed bugs or hooded beetles. As with bigeyed bugs, treatments of acephate alone and in combination with amitraz were significantly toxic

Table 3. Mean percent survival of *Geocoris punctipes* (Say) introduced 4 h post-treatment in cotton in 1993. Florence, SC.

Insecticidea†	Rate kg (AI)/ha	Insecticide class‡	24 h		48 h	
			% Survival ± SEM§	Corrected mortality,%¶	% Survival ± SEM§	Corrected mortality,%¶
Untreated	- - -	-	90.3 ± 4.8a		90.3 ± 5.2a	
Thiodicarb	0.672	C	90.3 ± 4.8a	0	90.3 ± 5.2a	0
Methomyl	0.504	C	81.2 ± 4.5ab	10.1	81.2 ± 5.1ab	10.1
Sulprofos	1.120	OP	81.2 ± 4.5ab	10.1	72.5 ± 4.5ab	19.7
Profenofos	0.840	OP	54.6 ± 5.8bc	39.5	54.6 ± 5.5b	39.5
Acephate	0.560	OP	36.4 ± 5.9c	59.7	9.3 ± 4.3c	89.7
Cyhalothrin	0.028	P	27.5 ± 6.8c	69.5	9.3 ± 4.3c	89.7

† Four replicates of 12 *G. punctipes* per replicate with one per cage.
‡ Insecticide Class: C = carbamate; OP = organophosphate; P = pyrethroid.
§ Means followed by the same letter within a column are not significantly different (F = 14.69; df = 6, 18; P > 0.05; least significant difference test).
¶ Mean mortality corrected by Abbott's formula (Abbott 1925).

Table 4. Mean percent survival of *Notoxus monodon* (F.) introduced 4 h post-treatment in cotton in 1993. Florence, SC.

Insecticide†	Rate kg (AI)/ha	Insecticide class‡	24 h		48 h	
			% Survival ± SEM§	Corrected mortality,%¶	% Survival ± SEM§	Corrected mortality, %¶
Untreated	- - -	- - -	90.3 ± 5.0a		90.3 ± 5.4a	
Cyhalothrin	0.028	P	81.2 ± 5.0ab	10.1	54.6 ± 5.4ab	39.5
Methomyl	0.504	C	72.5 ± 5.0ab	19.7	63.7 ± 5.4ab	29.7
Sulprofos	1.120	OP	63.5 ± 5.0ab	29.7	45.5 ± 5.4b	49.8
Thiodicarb	0.672	C	63.5 ± 5.0ab	29.7	45.5 ± 5.4b	49.8
Profenofos	0.840	OP	54.6 ± 5.0b	39.5	36.4 ± 5.4b	59.7
Acephate	0.560	OP	0 c	100.0	0 c	100.0

† Four replicates of 10 *cages of N. monodon* per replicate, with two predators per cage.
‡ Insecticide class: C = carbamate; OP = organophosphate; P = pyrethroid.
§ Means followed by the same letter within a column are not significantly different (*F* = 7.32; df = 6,18; *P* > 0.05; least significant difference test).
¶ Mean mortality corrected by Abbott's formula (Abbott 1925).

to hooded beetles. The other organophosphates applied alone and in combination with amitraz also were significantly toxic to hooded beetles. Thiodicarb alone and in combination with amitraz and *B. thuringiensis* in combination with amitraz also were significantly toxic to hooded beetle, reducing survival by 90.0, 68.8, and 78.8%, respectively. In laboratory tests with other predaceous arthropods, effects of pesticides varied (Mizell and Schiffhauer, 1990). Methomyl was the only chemical that was common to the present study; however, mortality from all chemicals was greater than 70% in the coccinellid, *Cycloneda sanguinea* (L.).

When hooded beetles were introduced 4 h post-treatment in 1993, acephate had significant residual activity against this predator with no survival after 24 h (Table 4). Profenofos also was significantly different from the untreated control, decreasing survival by 40%. Survival of hooded beetles in cyhalothrin, sulprofos, and the carbamate treatments was similar to that in the untreated control after 24 h. After 48 h, percent survival was significantly less than the control in the acephate, profenofos, thiodicarb, and sulprofos treatments. Survival was reduced by 49.8% (sulprofos and thiodicarb), 59.7% (profenofos), and 100% (acephate). As in 1992, survival of hooded beetles in cyhalothrin and methomyl treatments was similar to survival in untreated control after 48h.

Results indicate that specific predaceous arthropods have varying levels of susceptibility to chemical insecticides. Caution should be taken in interpretation of these results because of the possibility of repellency rather than differences in susceptibility to certain chemicals. Also, statistical analysis of data in some cases did not reveal differences between apparent low survival rates in treated plots and the untreated control. If it had been possible to include more blocks within the time allowed, statistical differences may have been more probable. Therefore, it is important to recognize certain trends in survival rate. Cages were designed to provide an environment that would allow predators to come in contact with treated plant material; however, it is not known whether all predators made contact with chemical residues. Only residual effects were examined, and direct topical application of insecticides would result in different responses. Overall, more of the insecticides had an effect on hooded beetle than on bigeyed bug.

This study indicates that the carbamates methomyl and thiodicarb applied alone or in combination with amitraz at the rates commonly used in cotton pest management allow survival of the bigeyed bug similar to the untreated control. Survival rates of bigeyed bugs in treatments containing sulprofos and the *B. thuringiensis* + amitraz treatment were not significantly different from untreated control. Profenofos applied alone resulted in percentage mortality of 59.3 and 39.5% of bigeyed bug in 1992 and 1993, respectively. Cyhalothrin treatments resulted in 59.3 and 89.7% mortality in bigeyed bugs in 1992 and 1993, respectively. Cyhalothrin and treatments containing methomyl were not significantly toxic to hooded beetles after 48 h. Generally, the treatments containing organophosphates were toxic to the hooded beetle, along with the treatments of thiodicarb and *B. thuringiensis* + amitraz.

This study focused on the two most abundant predaceous arthropods in the cotton ecosystem during much of the growing season in South Carolina. Commonly used insecticides were examined to determine their potential in conservation of predators by observing residual toxicity. While it is documented that the bigeyed bug is an effective predator in cotton ecosystems, the role of hooded beetles as effective predators is still being investigated. Carbamates should be considered highly for inclusion in the pest management system when bigeyed bugs are abundant. Acephate should be avoided if one wants to conserve either of the predators. The pyrethroid cyhalothrin treatment resulted in high mortality of bigeyed bugs and allowed high survival of hooded beetles. Therefore, it is important to consider minimal applications of cyhalothrin when a grower has other options for heliothine control.

More information is needed on the effectiveness of these predators, and growers cannot rely on their populations for controlling heliothine populations during July in South Carolina. Future studies should focus on qualitative studies of both the bigeyed bug and hooded beetle and the potential effect of each predator on insect pests in various cropping systems.

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