INSECTICIDE RESISTANCE MONITORING IN LEPIDOPTERAN COTTON PESTS

Russell J. Ottens, John R. Ruberson, and Phillip M. Roberts
Department of Entomology, University of Georgia, Tifton

Abstract

In 2005, larvae and adults of the bollworm, *Helicoverpa zea*, and the tobacco budworm, *Heliothis virescens*, were bioassayed for resistance to selected pyrethroid and carbamate insecticides.

Bollworm cultures were established from larvae collected in Tift County corn in June 2005. Tobacco budworm cultures were established from larvae collected in tobacco or cotton in June 2005 in Appling, Bacon, Coffee, Jeff Davis, Tift, Treutlen, and Ware Counties. Third instar F_1 or F_2 progeny were treated with 89.9% technical grade cyhalothrin, 92.4% technical grade cypermethrin, or 98% technical grade methomyl. Stock solutions in acetone were prepared and serially diluted to obtain the desired concentrations. Larvae were observed 72 hr post-treatment for mortality.

For adult bollworm and tobacco budworm bioassays, moths were collected in the summer of 2005 from pheromone traps placed near cotton fields in Tift, Sumter, and Decatur Counties. Tests were performed using 20 ml scintillation vials coated with an acetone solution of 92.4% technical grade cypermethrin with dosages ranging from 1 to 10 µg/vial and an acetone check. One moth was placed in each vial and survival was checked after 24 hours.

In the adult bioassays of corn earworms from three different counties, we observed elevated cypermethrin tolerance compared to previous years. For Tift County tobacco budworms, a diagnostic dosage displayed nearly 3x greater survival than in 2004 and 6x greater survival than in 2003. Similar elevated tolerance was observed in larval bioassays of corn earworms from Baker, Crisp, Seminole, and Terrell counties.

In the larval bioassays, susceptibility of all the various populations of tobacco budworms for both cyhalothrin and cypermethrin was increased in comparison with historical levels. Tift Co. F_1 and F_2 larvae were found to be ca 49x and 6x more tolerant to cyhalothrin, respectively, than the Tift Co. long-term average. For cypermethrin, they were ca 9x and 3x more tolerant to cyhalothrin, respectively, than the long-term average. Corn earworm larvae appeared more tolerant to both cypermethrin and methomyl in comparison with 2004 values and more tolerant to cypermethrin than historical levels. These results indicate that tolerance to pyrethroids in the bollworm and tobacco budworm may be increasingly widespread in Georgia, and that there is a great need for growers to utilize insecticide resistance management practices to steward these products.

Introduction

Insecticides remain the method of choice for control of lepidopteran pests in Georgia cotton, though great strides have been made during the past two decades in reducing chemical use. The successful eradication of the boll weevil combined with the planting of transgenic cotton, effective scouting, and careful crop management have all served to significantly lessen reliance on insecticides. Nevertheless, the older insecticides, particularly pyrethroids, continue to play a key role in management of pests in cotton due to their general effectiveness and low costs. Newer insecticides have become available, but their specificity tends to impose limits on their general utility, and they are more expensive to use. It is, therefore, important that we understand the susceptibility of target pests to insecticides so that we can continue to use them effectively and make appropriate management decisions to prolong the life of effective insecticides.

Since 1979, we have performed bioassays on major lepidopteran cotton pests to monitor development of insecticide resistance. In recent years, there have been increasingly frequent reports of pyrethroid failures targeting tobacco budworm in cotton and tobacco. Throughout most of the past 26 years, Georgia did not experience any widespread resistance problems, while other states did. In 2004, we documented significantly greater pyrethroid tolerance in populations of the tobacco budworm from Colquitt, Terrell, and Tift Counties than was observed in our historical dataset. We expanded the sampling area in 2005 to examine unsprayed populations of tobacco budworm from tobacco fields of south-central Georgia. Sampling insects prior to insecticide application would provide us with a baseline of susceptibility for the early generations of tobacco budworm prior to insecticidal selection. We also monitored corn earworm pheromone traps in 4 counties, and collected corn earworm larvae in several locations where pyrethroid failures were reported.

Materials and Methods

Larval Bioassays. Bollworm cultures were established from larvae collected in Tift County corn in June 2005. Tobacco budworm cultures were established from larvae collected in tobacco or cotton in June 2005 in Appling, Bacon, Coffee, Jeff Davis, Tift, Treutlen, and Ware Counties. Field-collected larvae were reared to adulthood and eggs were collected from the moths confined in 1 gal plastic containers with cheesecloth lids serving as oviposition sites. Upon hatching, neonate larvae were placed on pinto bean meal synthetic diet in 30 ml plastic cups. Both F_1 and F_2 larvae were used for the bioassays. All life stages of the insects were held in an incubator at 27 $\pm$ 2^{o}C, ca 60% RH and a 14:10 hr light: dark cycle.

Evaluation of larval susceptibility of *H. zea* basically followed protocol outlined in the ESA Standard Test Method for detection of resistance in *Heliothis* spp. (Anon. 1970). Larvae were treated with 99.2% technical grade acephate, 89.9% technical grade cyhalothrin, 92.4% technical grade cypermethrin, 98% technical grade methomyl, or 95% technical grade permethrin. Stock solutions in acetone were prepared and serially diluted to obtain the desired concentrations. Microgram equivalents were calculated, adjusting for the percent active ingredient in the technical materials. One microliter of solution was applied to the dorsal thoracic region of each larva using a Microliter no. 705 (Hamilton Company, Reno, NV) hand-held applicator. Three to five replications were used in each bioassay with ten third instar, 30-40 mg larvae per dosage and an acetone check.

Observations were made 72 hr post-treatment and a larva was considered dead if it made no movement when prodded with a pencil point. Larvae were considered moribund if they moved when prodded, yet appeared black and as small or smaller than their size at treatment. These were considered alive when determining LD (lethal dosage) values, but considered dead when calculating ED (effective dosage) values. In many instances, larvae treated with pyrethroids linger on several days beyond observation time as moribund larvae that eventually die. For this reason we present ED values as well as LD values to present a more complete picture of dosage-response. Data were analyzed using Daum's (1970) probit analysis computer program.

Adult Bioassays. For adult tobacco budworm bioassays, moths were collected in the summer of 2005 from pheromone traps placed near a Tift Co cotton field. For adult bollworm bioassays traps were placed in the same Tift Co. location as well as adjacent to cotton fields at Branch Stations of the University of Georgia in Attapulgus (Decatur Co.) and Plains (Sumter Co.). Pheromone lures attached to each trap were replaced every two weeks. The morning of each test, the trap tops were brought to the laboratory and the moths were removed for the bioassays. The empty trap tops were then returned to the field. In all instances, bioassayed moths were trapped the previous night and never confined during the heat of the day.

Tests were performed using 20 ml scintillation vials coated with an acetone solution of 92.4% technical grade cypermethrin with dosages ranging from 1 to 10 µg/vial and an acetone check. A total volume of 0.5 ml of acetone/insecticide mixture was placed in each vial and rolled horizontally on a modified hot dog roller until the acetone had evaporated. The vials were then stored in a freezer until used. As in the larval bioassays, the amount of technical compound weighed out for the stock solution was corrected for purity. One moth was placed in each vial with the cap screwed on loosely. Percent survival was checked after 24 hours. Counts were taken for live, knocked-down (moribund), and dead moths. Only moths able to fly in a normal manner were counted as alive. Numbers assayed varied with the number of moths available and the percentage data were transformed (arcsin(√%)) prior to analysis with the General Linear Models procedure of SAS (SAS Institute 1988).

To evaluate corn earworms, we set up pheromone traps in 6 Georgia counties (Burke, Decatur, Jeff Davis, Screven, Sumter, and Tift) and monitored them throughout the season. In practice, moth responses to the traps were low, despite season-long trapping, and did not provide enough moths to permit us to obtain definitive results. In addition, Dr. Phillip Roberts collected corn earworm larvae in several cotton fields where pyrethroid applications had failed to provide acceptable results. These fields were in Baker, Crisp, Seminole, and Terrell counties. Collected larvae were held placed on diet and held in the laboratory to obtain adults. Emerged adults were set up in oviposition cages (supplied with a 5% honey water solution; 25EC, L:D 14:10) in groups of 40-60 moths. Eggs were collected from the cages as they became available. Most of the eggs were shipped to Dr. B. Rogers Leonard (Louisiana State University) for testing. We retained some eggs here, but oviposition declined quickly and we were unable to obtain enough eggs to conduct tests here. The results from Dr. Leonard are provided below.

Results and Discussion

Larval Bioassays. The ED_{50}, ED_{90}, LD_{50}, and LD_{90} values for the 2005 Tift Co. bollworm larval bioassays are presented in tables 1, 2, 3, and 4, respectively. All values for cypermethrin and methomyl were higher than the Tift Co. value for 2004. All values for cypermethrin were higher than the average of bioassays performed on Tift Co. larvae since 1983. The ED_{50} of 1.02 μg/g larval wt. was ca 4x greater than the 2004 value and ca 3x greater than the Tift Co. long term average (including 2005) of 0.87 μg/g larval wt. since testing began in 1983 (Table 1). The ED_{50} of 5.54 μg/g larval wt. for methomyl was ca 3x greater than the 2004 value and only slightly higher than the Tift Co. long term average (including 2005) of 5.52 μg/g larval wt. since testing began in 1979 (Table 1).

The ED_{50}, ED_{90}, LD_{50}, and LD_{90} values for the 2005 tobacco budworm larval bioassays are presented in tables 5, 6, 7, and 8, respectively. All values for cyhalothrin were higher (or the same in the case of the ED_{50} for Ware Co.) than the Tift Co. value for 2004, and higher still than the average of bioassays performed on Tift Co. larvae since 1985. An ED_{50} of 4.87 μg/g larval wt. was found in Tift Co. F_1 larvae and 0.56 μg/g larval wt. in Tift Co. F_2 larvae, ca 49x and 6x higher, respectively, than the Tift Co. long term average (including 2005) of 0.10 μg/g larval wt. since 1985 (Table 5). If the 2005 bioassay is not included in the long-term Tift Co. average, Tift Co. F1 larvae are ca 77x higher and Tift Co. F2 larvae are ca 9x higher. Prior to 2004, our highest Tift Co. ED_{50} was 0.13 μg/g larval wt. in 1988. Even larvae from Ware Co., which appeared the culture most susceptible to cyhalothrin, had an ED_{50} ca 3x greater than the long-term Tift Co. average. For cypermethrin, some ED_{50} values were lower than those of Tift Co. in 2004, but all were increased in comparison with the Tift Co. long-term average (including 2005) of 0.87 μg/g larval wt. since testing began in 1983 (Table 5). An ED_{50} of 7.70 μg/g larval wt. was found in Tift Co. F1 larvae and 2.44 μg/g larval wt. in Tift Co. F2 larvae, ca 9x higher and almost 3x higher, respectively, than the Tift Co. long-term average. These findings should be of special concern as it appears there is pyrethroid resistance in tobacco budworms from all counties bioassayed.

Ware Co. tobacco budworm larvae bioassayed with our carbamate insecticide, methomyl, gave an ED_{50} of 1.24 μg/g larval wt. (Table 5). This was considerably lower than Tift Co. larvae for 2004 as well as the long-term Tift Co. average (including 2005) of 7.90 μg/g larval wt. since testing began in 1979. Time and labor constraints precluded us from additional methomyl bioassays. A value of 2.84 μg/g larval wt. was observed in F2 tobacco budworm larvae from Terrell Co. bioassayed in 2004. This apparent lack of concomitant elevation of tolerance for carbamate insecticides contrasts with the findings of Zhao et al. (1996). They observed cross-resistance among both the carbamate and organophosphate insecticides in a budworm population from Louisiana. Similar cross-resistance between pyrethroids and other insecticides have also been observed elsewhere (McCaffrey 1998), but multiple pyrethroid resistance mechanisms have been reported in various heliothine species. Nevertheless, the difference between our results and those of Zhao et al. (1996) suggests that other resistance mechanisms may be present in our populations than those for at least some populations in the Midsouth.

Adult Bioassays. A diagnostic dose of cypermethrin is considered to be 10 µg/vial for *H. virescens* and 5 µg/vial for *H. zea*. At 10 µg/vial, there was 19.4% survival for Tift Co. *H. virescens*, nearly 3x greater than the 2004 value of 6.7% and 6x greater than the 2003 value of 3.2% (Table 9). At 5 µg/vial, there was 14.0% survival for *Helicoverpa zea* from Tift County compared to 3.8% from the same location last year (Table 9). Similar survival results were found for 5 µg/vial with moths from both Decatur and Sumter Counties, though far fewer trials were run to obtain them.

The corn earworms assayed by Dr. Leonard (from Baker, Crisp, Seminole, and Terrell counties) also exhibited elevated tolerance to pyrethroids, although not to the extent observed in the tobacco budworms we studied. Based on comparisons with a susceptible laboratory colony, Dr. Leonard reported the LD_{50}'s and resistance ratios (RR) for the counties as follows: Baker County LD_{50} = 0.077, RR = 1-6; Crisp County LD_{50} = 0.056, RR = 0-4; Seminole County LD_{50} = 0.091, RR = 1-7; Terrell County LD_{50} = 0.067, RR = 1-5. The LD_{50} of the susceptible populations ranged from 0.013 to 0.065.

Although the resistance ratios were not excessive for the corn earworms tested, it is apparent that the tolerance is indeed elevated, and is elevated at multiple locations. This contrasts with the experience in South Carolina in 1999, when elevated pyrethroid tolerance in the corn earworm also was observed, but only in a single county. The magnitude of pyrethroid resistance in Georgia corn earworms is still somewhat low, but the occurrence of this phenomenon in multiple spatially disparate counties indicates that growers must be more cautious in their use of pyrethroids than has been the case in the past. Growers must be certain to use the higher labeled rates when treating corn earworm populations to eliminate heterozygous individuals. In addition, the increased use of alternative modes of action is critical for prolonging the usable life of pyrethroids against heliothine pests. The elevated pyrethroid tolerance observed in Georgia corn earworms may behave as the South Carolina tolerance, which disappeared the season following detection. Or it may not. It is critical that growers prepare for increased problems with pyrethroids so that we can prolong the useful life of these important compounds, and continue to manage corn earworms.

Apparent pyrethroid resistance in larval and adult tobacco budworms should be viewed with great concern. Our 2005 results were the most widespread incidence of pyrethroid tolerance in the bollworm and tobacco budworm of any year to date. Future monitoring in Georgia is essential.

References Cited

Anonymous. 1970. Second conference on test methods for resistance in insects of agricultural importance. Bull. Entomol. Soc. Am. 16:147-153.

Daum, R. J. 1970. A revision of two computer programs for probit analysis. Bull. Entomol. Soc. Am. 16:10-15.

McCaffrey, A.R. 1998. Resistance to insecticides in heliothine Lepidoptera: a global view. Phil. Trans. R. Soc. Lond. B 353: 1735-1750.

SAS Institute. 1988. SAS/STAT User's Guide. SAS Institute, Cary, NC

Zhao, G. R.L. Rose, E. Hodgson & R.M. Roe. 1996. Biochemical mechanisms and diagnostic microassays for pyrethroid, carbamate, and organophosphate insecticide resistance/cross-resistance in the tobacco budworm, Heliothis virescens. Pesticide Biochem. Physiol. 56: 183-195.

Table 1. ED_{50}'s for various insecticides against Tift Co. larval *Helicoverpa zea* (CEW) at 72 hr post-treatment. 2005.

Chemical	Gen.	No. Reps	ED_{50} (µg/g larval wt.)	95% C.I.	Change (+/-) from Tift Co. 2004	Change (+/-) from Tift Co. avg	Slope $\pm$ SE
Cypermethrin	F_1	5	1.02	0.78 - 1.31	+0.78	+0.69	2.26 $\pm$ 0.33
Methomyl	F_2	4	5.54	3.78 - 7.44	+3.86	+0.02	2.17 $\pm$ 0.43

Table 2. ED_{90}'s for various insecticides against Tift Co. larval *Helicoverpa zea* (CEW) at 72 hr post-treatment. 2005.

Chemical	Gen.	No. Reps	ED_{90} (µg/g larval wt.)	95% C.I.	Change (+/-) from Tift Co. 2004	Change (+/-) from Tift Co. avg	Slope $\pm$ SE
Cypermethrin	F_1	4	3.76	2.65 - 6.62	+2.85	+2.56	2.26 $\pm$ 0.33
Methomyl	F_2	4	21.54	14.44 - 47.10	+11.84	-16.24	2.17 $\pm$ 0.43

Table 3. LD_{50}'s for various insecticides against Tift Co. larval *Helicoverpa zea* (CEW) at 72 hr post-treatment. 2005.

Chemical	Gen.	No. Reps	LD_{50} (µg/g larval wt.)	95% C.I.	Change (+/-) from Tift Co. 2004	Change (+/-) from Tift Co. avg	Slope $\pm$ SE
Cypermethrin	F_1	5	1.42	1.08 - 1.92	+1.11	+0.49	1.96 $\pm$ 0.30
Methomyl	F_2	4	10.49	7.33 - 15.77	+8.37	-21.59	1.91 $\pm$ 0.44

Table 4. LD_{90}'s for various insecticides against Tift Co. larval *Helicoverpa zea* (CEW) at 72 hr post-treatment. 2005.

Chemical	Gen.	No. Reps	LD_{90} (µg/g larval wt.)	95% C.I.	Change (+/-) from Tift Co. 2004	Change (+/-) from Tift Co. avg	Slope $\pm$ SE
Cypermethrin	F_1	5	6.44	4.12 - 13.97	+4.74	+0.99	1.96 $\pm$ 0.30
Methomyl	F_2	4	49.20	27.41 - 204.08	+26.53	-1605.23	1.91 $\pm$ 0.44

Table 5. ED_{50}'s for various insecticides against larval *Heliothis virescens* (TBW) at 72 hr post-treatment. 2005.

Chemical	Gen.	No. Reps	ED_{50} (µg/g larval wt.)	95% C.I.	Change (+/-) from Tift Co. 2004	Change (+/-) from Tift Co. avg	Slope $\pm$ SE
Cyhalothrin							
Appling Co.	F_2	4	0.96	0.68 - 1.51	+0.68	+0.86	1.22 $\pm$ 0.22
Bacon Co.	F_2	4	1.12	0.73 - 1.78	+0.84	+1.02	1.09 $\pm$ 0.23
Jeff Davis Co.	F_2	3	0.66	0.45 - 0.99	+0.38	+0.56	1.54 $\pm$ 0.35
Tift Co.	F_1	4	4.87	2.32 – 5.47	+4.59	+4.77	1.78 $\pm$ 0.32
Tift Co.	F_2	4	0.56	0.42 - 0.72	+0.28	+0.46	1.85 $\pm$ 0.27
Ware Co.	F_2	4	0.28	0.18 - 0.41	+0.0	+0.18	1.13 $\pm$ 0.18
Cypermethrin							
Appling Co.	F_1	4	3.42	2.65 - 4.45	-2.39	+2.54	1.82 $\pm$ 0.22
Bacon Co.	F_1	5	2.84	1.93 - 4.49	-2.97	+1.96	1.02 $\pm$ 0.17
Coffee Co.	F_1	4	3.16	2.34 - 4.17	-2.65	+2.28	1.72 $\pm$ 0.23
Jeff Davis Co.	F_2	4	1.01	0.75 - 1.33	-4.80	+0.14	1.63 $\pm$ 0.19
Tift Co.	F_1	4	7.70	5.72 - 11.04	+1.89	+6.82	1.46 $\pm$ 0.22
Tift Co.	F_2	4	2.44	1.85 - 3.32	-3.37	+1.56	1.65 $\pm$ 0.25
Treutlen Co.	F_2	4	3.46	2.72 - 4.43	-2.35	+2.58	1.89 $\pm$ 0.24
Ware Co.	F_1	4	2.27	1.63 - 3.15	-3.54	+1.40	1.41 $\pm$ 0.20
Methomyl							
Ware Co.	F_2	5	1.24	0.98 - 1.56	-11.68	-6.66	2.03 $\pm$ 0.26

Table 6. ED_{90}'s for various insecticides against larval *Heliothis virescens* (TBW) at 72 hr post-treatment. 2005.

Chemical	Gen.	No. Reps	ED_{90} (µg/g larval wt.)	95% C.I.	Change (+/-) from Tift Co. 2004	Change (+/-) from Tift Co. avg	Slope ± SE
Cyhalothrin							
Appling Co.	F_2	4	10.65	4.83-53.04	+8.86	+10.21	1.22 ± 0.22
Bacon Co.	F_2	4	16.76	6.86-136.07	+14.97	+16.32	1.09 ± 0.23
Jeff Davis Co.	F_2	3	4.51	2.30-23.46	+2.72	+4.07	1.54 ± 0.35
Tift Co.	F_1	4	18.29	10.14-55.19	+16.50	+17.85	1.78 ± 0.32
Tift Co.	F_2	4	2.76	1.86-5.29	+0.97	+2.32	1.85 ± 0.27
Ware Co.	F_2	4	3.79	2.00-12.02	+2.00	+3.35	1.13 ± 0.18
Cypermethrin							
Appling Co.	F_1	4	17.36	11.62-32.02	-25.18	+12.32	1.82 ± 0.22
Bacon Co.	F_1	5	51.01	21.71-255.86	+8.47	+45.97	1.02 ± 0.17
Coffee Co.	F_1	4	17.47	11.55-33.52	-25.07	+12.43	1.72 ± 0.23
Jeff Davis Co.	F_2	4	6.15	4.21-10.55	-36.39	+1.11	1.63 ± 0.19
Tift Co.	F_1	4	57.71	31.98-159.71	+15.17	+52.67	1.46 ± 0.22
Tift Co.	F_2	4	14.66	8.83-35.52	-27.88	+9.62	1.65 ± 0.25
Treutlen Co.	F_2	4	16.52	11.25-29.96	-26.02	+11.48	1.89 ± 0.24
Ware Co.	F_1	4	18.46	10.77-45.39	-24.08	+13.42	1.41 ± 0.20
Methomyl							
Ware Co.	F_2	5	5.31	3.83-8.72	-84.20	-89.52	2.03 ± 0.26

Table 7. LD_{50}'s for various insecticides against larval *Heliothis virescens* (TBW) at 72 hr post-treatment. 2005.

Chemical	Gen.	No. Reps	LD_{50} (µg/g larval wt.)	95% C.I.	Change (+/-) from Tift Co. 2004	Change (+/-) from Tift Co. avg	Slope ± SE
Cyhalothrin							
Appling Co.	F_2	4	1.73	1.04 - 4.89	+1.38	+1.45	0.91 ± 0.22
Bacon Co.	F_2	4	2.28	1.36 - 6.21	+1.93	+2.00	0.86 ± 0.22
Jeff Davis Co.	F_2	3	1.09	0.72 - 2.34	+0.74	+0.81	1.30 ± 0.34
Tift Co.	F_1	4	5.74	3.56 – 10.71	+5.39	+5.46	1.43 ± 0.28
Tift Co.	F_2	4	1.19	0.86 - 1.81	+0.84	+0.91	1.34 ± 0.23
Ware Co.	F_2	4	0.51	0.32 - 0.84	+0.16	+0.23	0.91 ± 0.17
Cypermethrin							
Appling Co.	F_1	4	5.85	4.50 - 8.00	-2.78	+1.20	1.70 ± 0.20
Bacon Co.	F_1	5	3.90	2.63 - 6.68	-4.73	-0.75	0.99 ± 0.16
Coffee Co.	F_1	4	4.59	3.45 - 6.16	-4.04	-0.06	1.67 ± 0.23
Jeff Davis Co.	F_2	4	1.44	1.09 - 1.89	-7.19	-3.21	1.67 ± 0.19
Tift Co.	F_1	4	11.78	8.36 - 19.29	+3.15	+7.13	1.36 ± 0.22
Tift Co.	F_2	4	4.32	3.27 - 6.31	-4.31	-0.33	1.77 ± 0.27
Treutlen Co.	F_2	4	6.02	4.55 - 8.53	-2.61	+1.37	1.58 ± 0.22
Ware Co.	F_1	4	3.13	2.26 - 4.53	-5.50	-1.52	1.31 ± 0.18
Methomyl							
Ware Co.	F_2	5	2.70	1.48 - 7.36	-10.72	-29.69	1.95 ± 0.45

Table 8. LD_{90}'s for various insecticides against larval *Heliothis virescens* (TBW) at 72 hr post-treatment. 2005.

Chemical	Gen.	No. Reps	LD_{90} (µg/g larval wt.)	95% C.I.	Change (+/-) from Tift Co. 2004	Change (+/-) from Tift Co. avg	Slope ± SE
Cyhalothrin							
Appling Co.	F_2	4	44.48	11.06-1,920.95	+41.61	+41.21	0.91 ± 0.22
Bacon Co.	F_2	4	68.96	16.26-4,976.83	+66.09	+65.69	0.86 ± 0.22
Jeff Davis Co.	F_2	3	10.54	3.90-213.44	+7.67	+7.27	1.30 ± 0.34
Tift Co.	F_1	4	45.38	20.27-243.45	+42.51	+42.11	1.43 ± 0.28
Tift Co.	F_2	4	10.78	5.37-40.95	+7.91	+7.51	1.34 ± 0.23
Ware Co.	F_2	4	13.22	5.01-95.66	+10.35	+9.95	0.91 ± 0.17
Cypermethrin							
Appling Co.	F_1	4	33.13	20.58-68.78	-58.89	-66.95	1.70 ± 0.20
Bacon Co.	F_1	5	76.56	29.82-458.80	-15.46	-23.52	0.99 ± 0.16
Coffee Co.	F_1	4	26.81	16.89-56.67	-65.21	-73.27	1.67 ± 0.23
Jeff Davis Co.	F_2	4	8.49	5.76-14.87	-83.53	-91.59	1.67 ± 0.19
Tift Co.	F_1	4	103.38	49.19-410.97	+11.36	+3.30	1.36 ± 0.22
Tift Co.	F_2	4	22.99	13.18-61.65	-69.03	-77.09	1.77 ± 0.27
Treutlen Co.	F_2	4	39.12	22.45-100.49	-52.9	-60.96	1.58 ± 0.22
Ware Co.	F_1	4	29.68	15.97-83.97	-62.34	-70.40	1.31 ± 0.18
Methomyl							
Ware Co.	F_2	5	12.26	5.31-372.59	-80.86	-747.21	1.95 ± 0.45

Table 9. Percent survival at 24 hr post-treatment of Tift Co. adult *Heliothis virescens* and *Helicoverpa zea* in glass vial cypermethrin bioassays. Tifton, GA, 2005.

Dosage (µg/vial)	*H. zea*			*H. virescens*		
	No. of trials	Total No. of moths	% Survival ± SD	No. of trials	Total No. of moths	% Survival ± SD
10	19	222	1.6 ± 2.5	13	83	19.4 ± 4.9
5	19	222	14.0 ± 4.1	13	83	50.9 ± 3.7
1	19	222	41.8 ± 4.0	13	82	58.1 ± 4.7
0	19	232	89.2 ± 0.3	13	83	82.6 ± 1.1

Table 10. Percent survival at 24 hr post-treatment of Attapulgus and Plains, GA adult *Heliothis zea* in glass vial cypermethrin bioassays. Tifton, GA, 2005.

Dosage (µg/vial)	*H. zea* - Attapulgus			*H. zea* - Plains		
	No. of trials	Total No. of moths	% Survival	No. of trials	Total No. of moths	% Survival ± SD
10	1	20	0.0	3	69	1.1 ± 3.3
5	1	20	15.0	3	69	15.2 ± 11.4
1	1	20	25.0	3	69	34.8 ± 5.6
0	1	20	95.0	3	69	81.2 ± 0.8