INSECTICIDE RESISTANCE MONITORING IN LEPIDOPTERAN COTTON PESTS

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Introduction

Insecticides remain the tool of choice for control of lepidopteran pests that exceed economic thresholds in many Georgia row crops, though great strides have been made during the past two decades in reducing chemical use. Insecticides, particularly pyrethroids, continue to play a key role in management of lepidopteran pests due to their general effectiveness to Lepidopteran and other pests, and their low costs. Newer insecticides have become available, but the specificity of many of them tends to impose limits on their general utility, and they are significantly more expensive to use. Further, pyrethroids provide some level of activity against stink bugs, and have historically been effective against corn earworms in Bollgard cotton. It is, therefore, important that we understand the susceptibility of target pests to the older insecticides, especially pyrethroids, so that we can continue to use them effectively and make appropriate management decisions to prolong the life of effective insecticides.

In recent years, there have been increasingly frequent reports of pyrethroid failures targeting tobacco budworm (TBW) in cotton and tobacco. In 2004, we documented significantly greater pyrethroid tolerance in populations of the TBW from Colquitt, Terrell, and Tift Counties than was observed in our historical dataset. We observed the same problem with TBW on a larger scale in 2005. And in 2005, we found elevated levels of pyrethroid tolerance in corn earworm (CEW) populations, and several pyrethroid failures were reported. In 2006, we continued our monitoring efforts for both TBW and CEW in Georgia.

Materials and Methods

In 2006, larvae of the tobacco budworm, *Heliothis virescens*, were bioassayed for resistance to the pyrethroid insecticides cypermethrin and cyhalothrin. Cultures were established from eggs and/or larvae collected in tobacco in various Georgia counties. Collections were made in Appling (TBW and CEW), Jeff Davis County (TBW and CEW), Miller County (CEW), Mitchell County (CEW), Terrell County (CEW), Tift County (CEW), Union County (CEW), and Ware County (TBW and CEW). Field-collected larvae were reared to adulthood. These parent moths were confined in 1 gal plastic containers with cheesecloth lids serving as oviposition sites. When the eggs hatched, neonate larvae were placed on pinto bean meal synthetic diet in 30 ml plastic cups. F_1 larvae were used for bioassays, with the exception of the Tift County cultures, where F_2 larvae were also used. Both TBW and CEW populations were reduced in 2006 relative to previous years, with TBW being particularly difficult to find. Only Appling and Jeff Davis counties yielded enough TBW to get suitable test results. 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. virescens* basically followed the protocol outlined in the ESA Standard Test Method for detection of resistance in *Heliothis* spp. (Anon. 1970). Larvae were treated with 89.9% technical grade cyhalothrin, or 92.4% technical grade cypermethrin. 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 for a more complete picture of dosage-response. Data were analyzed using Daum's (1970) probit analysis computer program, and 95% confidence intervals were calculated.

To evaluate corn earworm adults, we set up pheromone traps in 6 Georgia counties (Burke, Decatur, Jeff Davis, Montgomery, 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.

Results and Discussion

The ED_{50} values for the 2006 TBW larval bioassays are presented in Table 1. All values for cyhalothrin were higher in the Tift County test population than the average of bioassays performed on Tift Co. TBW larvae since 1985. The historical change in the ED_{50} values for the TBW in Georgia are shown in Figure 1.

For cypermethrin, all ED_{50} values for the CEW and TBW, except the Tift Co. F_2 CEW larvae and Ware County CEW larvae and Jeff Davis County TBW larvae, were higher than those of Tift Co. in 2005; however, all were elevated in comparison with the Tift Co. long term average (including 2005) of 0.36 µg/g larval wt. for CEW and 2.44 µg/g larval wt. for TBW since testing began in 1983 (Table 1).

The CEW population most tolerant to pyrethroids was the Terrell County population (Table 1), which is notably where field failures occurred in 2006. Unexpectedly, however, the second highest level of tolerance occurred in the Union County population of extreme northern Georgia. This is unexpected because that region has had very little historical use of pyrethroids, so the pressure to develop resistance is very low. Nevertheless, the tolerance level was quite high, suggesting that the insects were migrants from other areas where pyrethroid pressure is higher. The lowest tolerance was observed in the Ware County CEW, which was comparable to that of the Tift County F_2 larvae. The historical change in the ED_{50} values for the CEW in Georgia are shown in Figure 2.

Elevated pyrethroid tolerance appears to be widespread in Georgia, with increased tolerance now documented in southwestern, south central, and east central counties (Table 1). The presence of very elevated tolerance in extreme northern Georgia, where pyrethroid use is very limited, indicates that tolerant moths are probably migrating into the area from other regions where pyrethroid use is much higher.

Widespread pyrethroid resistance in larval tobacco budworms in Georgia should be viewed with great concern. The 2005 results were the most widespread incidence of pyrethroid tolerance in tobacco budworm of any year to date, and the data from only two albeit widespread counties in 2006 suggest that pyrethroid resistance remains widespread and very high in TBW. These results mean that in the first generation of tobacco budworms attacking tobacco, resistance to pyrethroids is already elevated, and the likelihood of failure with these insecticides is great. Further, the potential for selecting even greater resistance levels in subsequent generations of TBW is quite high if pyrethroids are applied to the early-season generations of this pest. As such, it is critical to avoid pyrethroids use for control of TBW in tobacco. If pyrethroids are used, they will need to be used at the highest labeled rate to have any notable effect. However, the probability of failure with the high rate is quite high, and this pyrethroid usage will only create an even more resistant tobacco budworm for the remainder of the growing season. Future monitoring of pyrethroid resistance in tobacco budworms in Georgia is essential.

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 including at least one location with very little history of pyrethroid use (Union County). 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 and a single year. The magnitude of pyrethroid resistance in Georgia corn earworms is still somewhat low, but the occurrence of this phenomenon in multiple spatially disparate counties over two years indicates that growers must be increasingly cautious in their use of pyrethroids. Growers must be certain to use the higher labeled rates when treating corn earworm populations to eliminate heterozygous individuals, and reduce the frequency of resistant alleles in the population. 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 in observed in Georgia corn earworms has thus far not behaved as the South Carolina tolerance, which disappeared the season following detection, and this should be cause for concern. In addition, the Union County population suggests that pyrethroid resistance in the CEW is a highly mobile attribute, so the risk of spread is very great. 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.

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References

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Table 1. ED_{50}'s for various insecticides against larval *Helicoverpa zea* (CEW) and *Heliothis virescens* (TBW) at 72 hr post-treatment. 2006.

Chemical	Gen.	No. Reps	ED50(µg/g larval wt.)	95% C.I.	Change (+/-) from Tift Co. 2005	Change (+/-) from Tift Co. avg	Slope ± SE
Cyhalothrin - CEW							
Tift Co.	*F1*	4	0.45	0.36 – 0.56	-	+0.38	2.30 ± 0.27
Tift Co.	*F2*	4	0.26	0.20 – 0.35	-	+0.19	1.63 ± 0.24
Cypermethrin - CEW							
Jeff Davis Co.	*F1*	4	1.10	0.75 - 1.46	+0.08	+0.74	1.77 ± 0.34
Miller Co.	*F1*	3	1.39	0.93 - 1.96	+0.37	+1.03	1.61 ± 0.30
Mitchell Co.	*F1*	5	1.04	0.81 – 1.28	+0.02	+0.68	2.52 ± 0.33
Terrell Co.	*F1*	3	2.51	1.20 - 7.35	+1.49	+2.15	0.94 ± 0.25
Tift Co.	*F1*	5	1.25	0.96 - 1.59	+0.23	+0.89	1.80 ± 0.24
Tift Co.	*F2*	4	0.79	0.22 – 1.58	-0.23	+0.43	1.71 ± 0.43
Union Co.	*F1*	4	1.68	1.21 - 2.32	+0.66	+1.32	1.52 ± 0.19
Ware Co.	*F1*	2	0.72	0.55 - 0.89	-0.30	+0.36	4.18 ± 0.86
Cypermethrin - TBW							
Appling Co.	*F1*	4	3.46	2.08 – 11.16	+1.02	+2.59	1.11 ± 0.32
Jeff Davis Co.	*F1*	5	2.15	1.67 – 2.84	-0.29	+1.28	1.98 ± 0.27

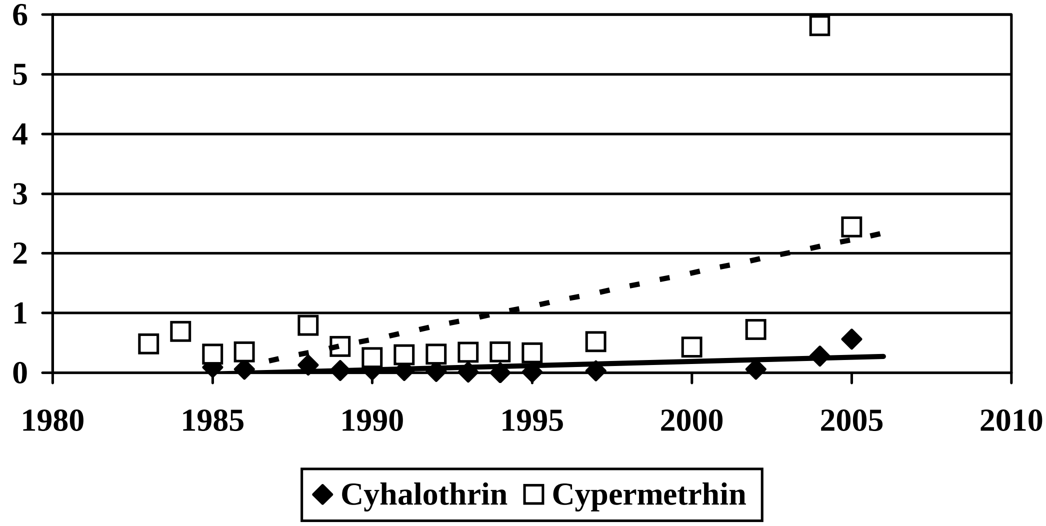

Fig. 1. ED_{50} values in µg/g larval wt for λ-cyhalothrin and cypermethrin against larval tobacco budworms, *Heliothis virescens*.

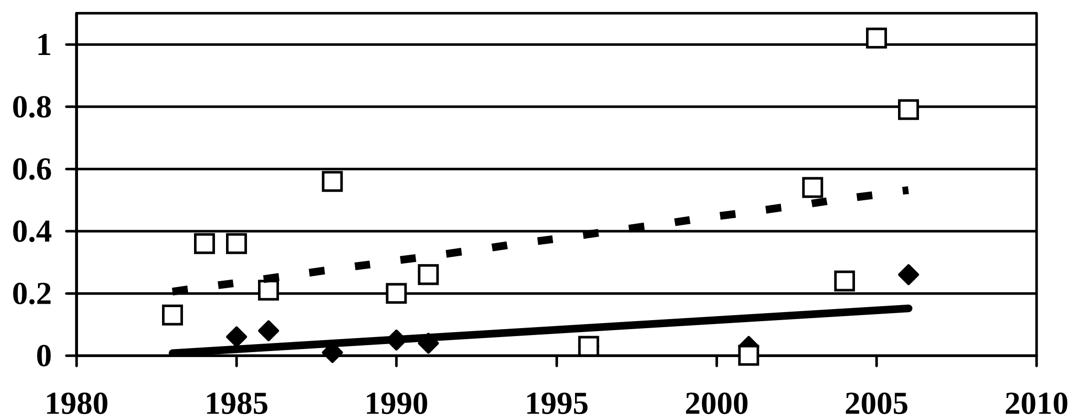

Fig. 2 ED_{50} values in µg/g larval wt for λ-cyhalothrin and cypermethrin against larval bollworms, *Helicoverpa zea*.