PROSPECTS FOR FIELD MANAGEMENT OF PYRETHROID-RESISTANT CORN EARWORM (COTTON BOLLWORM) POPULATIONS IN SOUTH CAROLINA

J. T. Walker, M. J. Sullivan, S. Turnipseed, M. E. Roof and T. M. Brown
Department of Entomology, Clemson University
Clemson, SC

Abstract

Resistance to pyrethroid insecticides in the corn earworm, also known as cotton bollworm, *Helicoverpa zea* Boddie, was a factor in reduced control of this pest in South Carolina in 1996 and 1997. Details are discussed of one pyrethroid failure in conventional cotton in Estill in 1996. Corn earworms collected from that field in September 1996 were resistant to cyhalothrin, cypermethrin and permethrin when tested in the laboratory. Resistance was confirmed by monitoring in 1997. Males captured in pheromone traps in Estill and nearby Ulmer in 1997 were resistant to cyhalothrin. Adults reared from larvae collected from cotton plants in Cameron and Holly Hill, 90 miles to the north, displayed high resistance. All moths trapped in the Pee Dee Region 180 miles to the north of Estill were susceptible. Strategies for controlling the pyrethroid-resistant corn earworm in conventional and transgenic cotton are discussed.

Introduction

We present a review of the events in South Carolina during 1996 and 1997 when control of corn earworm became difficult. Pyrethroid resistance was documented and a monitoring program was established. Furthermore, we discuss the available alternatives and the strategies necessary for controlling the tobacco budworm in South Carolina. Complete details of the original detection of pyrethroid resistance in Estill in 1996 and surveillance with cyhalothrin in 1997 have been published (Brown et al. 1998).

Since their registration in 1978, the most effective and economical insecticides for control of the corn earworm in South Carolina have been the synthetic pyrethroids. This pest is relatively tolerant of transgenic cotton expressing the *Bacillus thuringiensis* toxin (Bt-cotton) when compared to the tobacco budworm, *Heliothis virescens* (Sims et al., 1996). For this reason, pyrethroids must be sprayed once or twice for the control of corn earworm when moderate to heavy pressure is encountered. Resistance to pyrethroids could present a difficult challenge for control of the corn earworm, even in the presence of Bt-cotton.

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Cotton Production and Insect Control in South Carolina

The cotton acreage in South Carolina is located in the Pee Dee and Savannah Valley Regions, which we commonly call "North of the Lakes" and "South of the Lakes," respectively, referring to the Santee-Cooper Lakes which divide the agricultural coastal plain. Sixty to 65% of our total acreage is typically north of the lakes and 30 to 35% is south of the lakes. The mixture of crops is typically 44% corn, 30% soybeans, 26% cotton south of the lakes. There are significant differences in insect pressure and spray habits between these two areas. Growers south of the lakes spray conventional cotton an average of 6 times (with a range of 5 - 8), growers north of the lakes spray an average of 4 times (with a range of 2 - 5). This difference, plus tendencies towards higher rates of pyrethroids and Temik® (aldicarb), result in higher insect control costs south of the lakes.

A typical insect year for us is somewhat simpler than in other parts of the cotton belt. We plant in April or May, and sometimes into the first week of June. With adequate moisture for Temik® uptake and subsequently good thrips control, we can reach the first bloom stage of cotton on about July 4 with no insecticide sprays. We have no need to control the boll weevil because we are in the eradicated zone. We do have a tobacco budworm flight every year in June, but we are able to ignore it most years; less than 5% of our acreage is sprayed in June for tobacco budworm. We also have occasional plant bug problems, but again, most years we can tolerate them in most fields. After July 4, typically between July 6 and July 15, corn earworm emerges from corn fields and move into cotton. Whereas our June flight is all tobacco budworm, our July 4 flight is 95% corn earworm, and we usually do not see a tobacco budworm moth again until middle or late August.

In conventional cotton, we spray at a threshold of 15 to 20 three-day-old eggs, spray again 5 to 7 days later, depending on pressure, and never look back. In Bt-cotton, we spray on a higher egg threshold, 75 per 100 plants, spray again 7 days later and then manage for late season pests such as stink bug, fall armyworm and continued corn earworm pressure. A typical series of scouting reports would show eggs increasing shortly after July 4, peaking sharply in mid-July then tapering off around August 1. Our second or August corn earworm flight is usually less troublesome than the July flight. Total live worms and % boll damage both follow egg lay in predictable fashion.

Materials and Methods

Insect infestations were estimated by scouting fields and inspecting whole plants. Infestation data and insecticide application records were provided by Lonnie Bull, Bull Pest Management, Cameron, SC. Observations related to control failure are given in "Results." Larvae were collected from problem fields of conventional cotton in Estill on September 13 and 17, 1996 and colonized for subsequent susceptibility tests in the laboratory at Clemson University. A collection on August 7 was insufficient for testing.

Complete details of susceptibility test methods have been reported (Brown et al. 1998). Briefly, acetone solutions of insecticides were applied topically to 35-mg larvae and mortality was scored after 48 h. Adults were exposed for 24 h to insecticide-coated glass scintillation vials.

From the results of Estill96 adult susceptibility tests, doses were calculated for surveillance in 1997 (Brown et al. 1998). Susceptibility test kits included vials treated with acetone only, 2.5 μg cyhalothrin, and 10.0 μg cyhalothrin. Pheromone traps were set to collect males near cotton fields south of the lakes in Barton, Edisto, Estill, and Ulmer and north of the lakes in Darlington County, Lee County, Sumter County and Marlboro County. Captured moths, collected in the morning, were transported to Edisto Research and Experiment Station in Blackville or the Pee Dee Research and Experiment Station in Florence, where vial tests were done.

On August 5 and 19, 1997, Mitchell Roof was called to inspect fields near Cameron and Holly Hill with suspected resistance to pyrethroids. Larvae were collected and delivered to Clemson for rearing and bioassay. Field generation adults were exposed to cyhalothrin at 2.5 μg per vial.

Results

Observations in the Field

A summary from consultant Lonnie Bull's scouting reports on the Emmett Rouse Farm in 1996 illustrates the problem encountered. When the grower and consultant involved looked at the live worm and boll damage counts (Table 1) relative to the spray dates (Table 2) they suspected something was wrong. We approached this problem field the same way we approached all problem fields at that time; I. e., we looked for an application error. The timing seemed to be good, the product and rate was good. We switched from air to ground equipment, increased spray volume, eliminated Solubor® (sodium borate), and buffered the pH of our spray water. When we still failed to eliminate insects, we really did not think too much about it, because we never achieve complete elimination once a corn earworm infestation is established. After an application of Karate® (cyhalothrin) at 0.04 lb/ac plus Larvin® (thiodicarb) at 0.16 lb/ac on August 5, the grower was insistent again that something was wrong. Resistance was suspected, so larvae were collected as described under "Methods."

Resistance in Estill in 1996

Adults of Estill96 were 24-fold resistant to cyhalothrin at the median lethal dose and this was significant by 95% confidence limits (Brown et al. 1998). Field generation adults from larvae collected in Estill in 1996 were tested first with cypermethrin. At 2.5 μg per vial of cypermethrin, there was 17.6% mortality of Estill96 F_1 adults (n=34) compared to 92% mortality of H. zea-S (n=25). There was no control mortality of H. zea-S (n=22). The surviving adults from the Estill collection were bred to produce a colony, Estill96, from which there was only 6.6% mortality at 2.5 μg per vial of cyhalothrin (n=106) compared to 100% mortality of H. zea-S (n=20).

Larvae of Estill96 exhibited 35-fold resistance to cyhalothrin at the median lethal dose when compared to H. zea-S and this was significant by 95% confidence limits (Brown et al. 1998). There was only 5-fold resistance to permethrin, a pyrethroid with less use in recent years. Permethrin resistance was calculated from baseline data obtained in 1982 from a collection made in Elliott, South Carolina.

Confirmation and Monitoring in 1997

Analysis of hybrid progeny from matings of Estill96 to H. zea-S indicated that cyhalothrin resistance was incompletely dominant in expression in adults (Brown et al. 1998). A dose of 2.5 μg per vial killed all susceptible adults. A dose of 10 μg per vial was sufficient to kill all hybrids while also killing approximately 80% of Estill96 adults. The doses of 2.5 μg per vial and 10 μg per vial were chosen to prepare susceptibility test kits for surveillance for resistance for the next season.

Resistance was observed in Estill and other locations south of the lakes again in 1997; complete surveillance results have been reported (Brown et al. 1998). Samples in June were fully susceptible; however in July and August, there were significant numbers of survivors in Estill and in Ulmer, 20 miles north. There was 25.6% survival 2.5 μg per vial in Estill during July 1997 (n=254).

Samples from several counties in the Pee Dee Region were fully susceptible to cyhalothrin in July and August; 75 adults were exposed to 2.5 μg per vial with no survivors. This is in contrast to 97 (17.9%) survivors among 541 moths from Estill and Ulmer exposed to cyhalothrin at 2.5 μg per vial.

Field generation adults from larvae collected in Cameron and Holly Hill in 1997 were also highly resistant to cyhalothrin. There was 80% survival in moths from Cameron and 87.5% survival in moths from Holly Hill at the 2.5 μg dose. There was no control mortality in this experiment. These data demonstrated additional sites of resistance approximately 90 miles north of Estill.

Discussion

Pyrethroid resistance in corn earworm was documented in Estill in 1996 and confirmed in 1997 comparing surveillance results among samples throughout South Carolina. The extent of resistance was not fully defined, but it was found as far north as Cameron. No resistant moths were detected north of the lakes in 1997.

Resistance to permethrin in larvae was previously reported for corn earworm larvae collected in 1991 from sweet corn in Illinois and from cotton in Missouri (Abd-Elghafar et al., 1993). More intense resistance to cyhalothrin in South Carolina may indicate evolution of a resistance mechanism selective toward cyhalothrin which is applied much more than permethrin.

Surveillance results in 1997 south of the lakes in South Carolina were similar to previous records from pheromone traps in Louisiana. The average mortality of *H. zea* collected from cotton in September in Louisiana from 1988 to 1993 from cypermethrin at 2 μg per vial was 74% and the lowest value was 52% mortality in 1993 (Bagwell, et al., 1997). We observed only 17.6% mortality at 2.5 μg per vial of cypermethrin and only 6.6% mortality at 2.5 μg per vial of cyhalothrin, a dose killing all of our susceptible laboratory strain.

Genetic partial dominance of cyhalothrin resistance has important implications for control and for surveillance programs. This means that progeny from fully susceptible moths which mate with resistant moths can possess partial resistance. This type of resistance may be spread rapidly in areas where pyrethroid use continues.

There had been few problems controlling corn earworm with pyrethroids in South Carolina in the past. "Hot spots" of suspect resistance had been observed with cypermethrin vial tests in Louisiana (J. B. Graves, personal communication); however, our results suggest an established focus of resistance in the area south of the lakes in South Carolina.

We must now look for alternative controls including Bt-cotton, spinosad, or other new chemistries, and to consider reduced rates of insecticides to preserve beneficial insects. Also, we cannot ignore that pyrethroids are a valuable tool in an overall resistance management plan which includes the preservation of Bt-cotton and new insecticides. An estimated 33% of cotton acreage in South Carolina was planted to Bt-cotton in 1997. Bt-cotton was considerably more popular south of the lakes, with 53% Bt-cotton planted compared to 21% north of the lakes. The proportion of Bt-cotton was higher in the counties surrounding Estill with 75% in Hampton, 58% in Allendale, 69% in Barnwell, and 60% in Bamberg (Dan Pitts, Monsanto, unpublished data).

Conclusions

1. Pyrethroid resistant corn earworm was found south of the lakes, but not north of the lakes.

2. The levels of the resistance have not caused widespread field failures, but have eliminated the forgiveness level (margin of error) we are accustomed to with synthetic pyrethroids against corn earworm in cotton.
3. The elimination of our forgiveness level places a higher premium on timing, rate, coverage and interval during our corn earworm moth flight; therefore, we must attack eggs and day-old larvae.
4. We cannot delay to exploit advantageous factors and options which include:

   a. no boll weevils
   b. no June spray needed for tobacco budworms
   c. minimal *Lygus* problems
   d. we can conserve beneficial insects until our post-
   July 4 corn earworm flight
   e. Bt-cotton
   f. pyrethroids in their window
   g. pyrethroids plus ovicides
   h. new chemistries such as spinosad.

Disclaimer

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Table 1. Scouting report from field 321 of the Emmett Rouse farm in 1996. Cotton KC311 was planted 5/17(m/d) and insects were scouted by Lonnie Bull. First square was on 6/19, first bloom on 7/11 and maturity on 8/27.

Counts of tobacco budworm and corn earworm				
Date	Eggs	S. Larvae	L. Larvae	%Damage
6/4	0	0	0	-
6/10	4	2	0	-
6/13	14	2	0	-
6/19	12	12	0	-
6/25	13	10	0	-
6/28	10	4	2	-
7/1	6	2	0	-
7/8	8	2	2	-
7/11	18	2	0	0
7/17	100	6	0	0
7/22	200	15	4	8
7/26			(insecticide applied)	
7/31	26	4	16	12
8/6	14	0	7	10
8/13	28	0	5	6
8/20	24	4	2	6
8/27	20	8	0	6
9/4	22	10	5	14

Table 2. Pyrethroid insecticides Karate® (cyhalothrin), Decis® (deltamethrin) and Fury® (cypermethrin) and mixtures applied to field 321 of the Emmett Rouse farm in 1996. Cotton KC311 was planted 5/17(m/d).

Date	Insecticide	lb/ac	Method
7/14	Karate	0.029	air
7/21	Karate	0.029	air
7/26	Karate	0.029	air
8/1	Karate	0.029	
	+methyl parathion		air
8/5	Karate	0.04	
	+thiodicarb	0.17	ground
8/15	Decis	0.016	ground
8/23	Decis	0.016	ground
9/6	Fury	0.03	ground