MONITORING BOLLWORMS FOR PYRETHROID RESISTANCE, 2007-2016

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Abstract

Bollworms develop on many hosts, with each generation likely to use a different host. Pyrethroid insecticides are applied to control many pests in cotton as well as in other crops. Control of bollworms with pyrethroids has become erratic and is no longer recommended in some states. Bollworm pheromone traps were monitored from May to September in nine or ten states stretching from Virginia to Texas each year from 2007-2016. Trapped healthy male moths were tested for resistance to cypermethrin, a pyrethroid insecticide. Average survival at a rate of 5 µg/vial of cypermethrin during 2016 was 36.1%, higher than ever observed before and more than two times higher than during 2008-2013. All 10 states had survival rates greater than 20% and four states (Arkansas, Georgia, South Carolina, and Virginia) had survival rates exceeding 40%. This spread of resistance to all regions is an indication of insect movement and continued selection for pyrethroid resistance. It also suggests that resistance alleles are becoming fixed in populations and that pyrethroids should no longer be expected to provide adequate control of bollworms consistently in any regions of the southern United States.

Introduction

Bollworm, *Helicoverpa zea*, is a pest in numerous crops where it may be exposed to pyrethroid insecticides. Since it can have 5 or more generations per year in the southern U.S., it has the potential to develop large populations. One to two of these generations occur in cotton, sometimes causing substantial economic loss. Because pyrethroid insecticides are relatively inexpensive, they were traditionally the first choice of growers for foliar control of bollworms. However, control with pyrethroids has become erratic in some regions, so knowledge of the susceptibility of bollworms to pyrethroid insecticides is critical for effective management of this pest.

Monitoring pyrethroid resistance in bollworms has been conducted for numerous years, beginning in 1988 in a few states and then coordinated throughout the cotton belt in 1989-1990 (Rogers et al. 1990). Since then monitoring has continued at various levels every year. Throughout this time the methodology has remained consistent using a method developed by Plapp et al. (1987). Male moths are captured in a pheromone trap and placed in a glass vial that was previously treated with insecticide. Mortality is recorded after 24 h. A concentration of 5 µg cypermethrin / vial has been used with baseline survival generally less than 10% (Martin et al. 1999).

Materials and Methods

Hartstack pheromone traps were placed in various locations in ten states across the cotton belt from VA to TX. Pheromones (Luretape with Zealure, Hercon Environmental) were changed every 2 weeks. Some traps were monitored at least weekly from May until September, but most were monitored over a shorter period when cotton was susceptible to bollworm feeding. Healthy moths caught in these traps were subsequently tested for pyrethroid resistance. Moths were individually placed in 20 ml scintillation vials that had been previously coated with 0 or 5 µg cypermethrin per vial. Vial preparation for all locations except Louisiana was done at Starkville MS and shipped to cooperators as needed throughout the year. Louisiana data are from vials prepared in Louisiana. At all locations, moths were kept in the vials for 24 h and then checked for mortality. Moths were considered dead if they could no longer fly. Reported survival was corrected for control mortality (Abbott 1925).

Results and Discussion

A total of 8047 moths were assayed during 2016. The number of assayed moths per state range from 120 in Missouri to 1815 in Virginia. Average survival to the 5 µg cypermethrin / vial concentration was 36.1% in 2016 (Table 1), which was the highest rate of survival since monitoring began in 2007 and more than twice as high as most years (Fig. 1). The states that had been having the highest survival didn't change much in 2016, but the states that previously had susceptible populations had large increases in survival (Fig. 2), with South Carolina going from 6.4% to 43.3% survival in one year. Arkansas and Texas also saw >15% increases in survival from 2015 to 2016. For the first time since monitoring began, all states had >20% survival. The earliest tests with available data conducted during 1998-2001 did not have more than 20% survival in any state, and even as recently as 2012, this level of survival only occurred in Louisiana and Virginia. The rapid spread of resistance during the last two years suggests that the genetics of resistance have become well established, and any fitness costs associated with resistance are minor enough that these genes have spread throughout the southern United States. As a result, pyrethroid insecticides should not be expected to provide consistent, satisfactory control of bollworm populations in any region. While they may still provide control at times, efficacy will be erratic and often poor. Pyrethroids have already been removed from the list of recommended insecticides for bollworm control in Louisiana and Mississippi (Beuzelin et al. 2016, Catchot et al. 2017) and warnings about control failures due to pyrethroid resistance are included in Arkansas (Studebaker et al. 2017).

Table 1. Bollworm survival (% corrected for control mortality) to 5 µg cypermethrin per vial in 24-h vial tests during 2016.

State	May	June	July	Aug	Sep	Overall	Bollworms tested
AR	13.3	38.1	52.1	41.0		40.6	499
GA		53.1	38.2	55.6	37.3	47.8	1126
LA	30.1	29.2	51.2	28.1	25.4	32.0	1512
MS	9.8	38.6	51.4	34.1	20.6	36.6	1081
MO			20.8			20.8	120
NC				40.1	25.0	31.4	176
SC		37.5	32.3	50.5	45.2	43.3	920
TN				34.4		34.4	438
TX			38.9	25.0	28.0	30.6	360
VA		36.5	39.3	46.2	43.3	43.2	1815
Average	17.7	38.8	40.5	39.4	32.1	36.1	8047

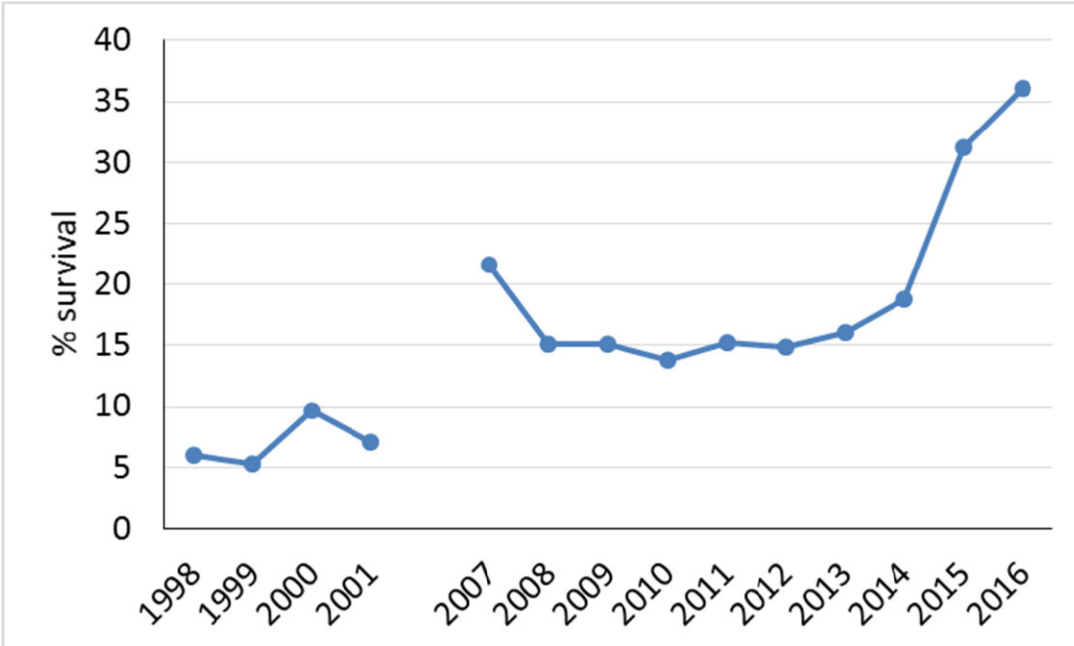

Fig. 1. Beltwide bollworm average survival per year at 5 µg cypermethrin per vial from 1998 – 2016.

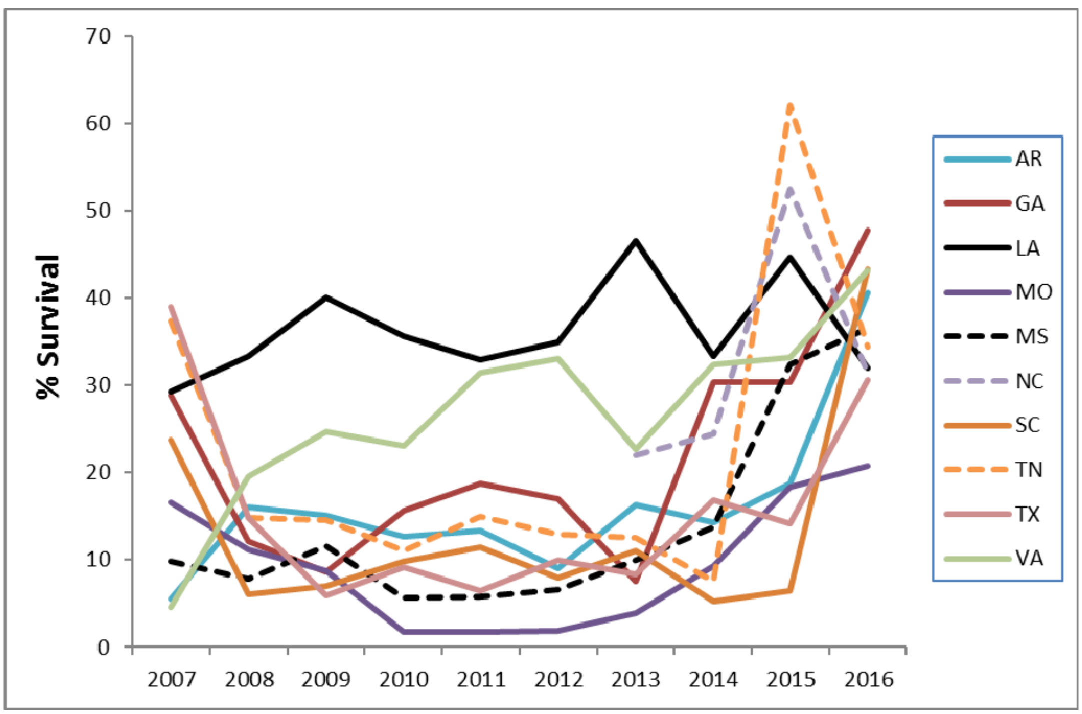

Fig. 2. Average bollworm survival by state per year at 5µg cypermethrin per vial from 2007 – 2015.

Tobacco budworm is considered resistant to pyrethroids when there is substantial survival of the moths at the 10 µg/vial concentration of cypermethrin because only moths that are homozygous for pyrethroid resistance can survive this concentration (Plapp 1987). Recent bollworm testing in Louisiana has had about 25% survival at 10 µg/vial when survival at 5 µg/vial was between 30 and 45%. This relationship of survival rates at these concentrations is similar in tobacco budworm (Plapp et al. 1987), so many of our bollworm populations throughout the southern U.S. are resistant to pyrethroid insecticides, and control from this class of chemistry will be inconsistent at best.

Bollworm adults are highly mobile (Lingren et al. 1994, Beerwinkle et al. 1995), which would suggest that pyrethroid resistance would quickly spread from one region to another. Pyrethroid resistance persisted in pockets for several years, but now appears to have become widespread throughout the cotton belt. Erratic field control of larvae observed for a number of years is consistent with this pattern of resistance development.

Moth survival has traditionally been highest during July and August. Since most larvae develop on corn during June to early July, the moths captured during late July and August mostly developed on corn, an excellent host plant for bollworm (Musser et al. 2010). As a result, bollworms can tolerate a higher concentration of insecticide. This trend continued to be observed in 2015 and 2016 when overall survival was much higher than in previous years (Fig 3).

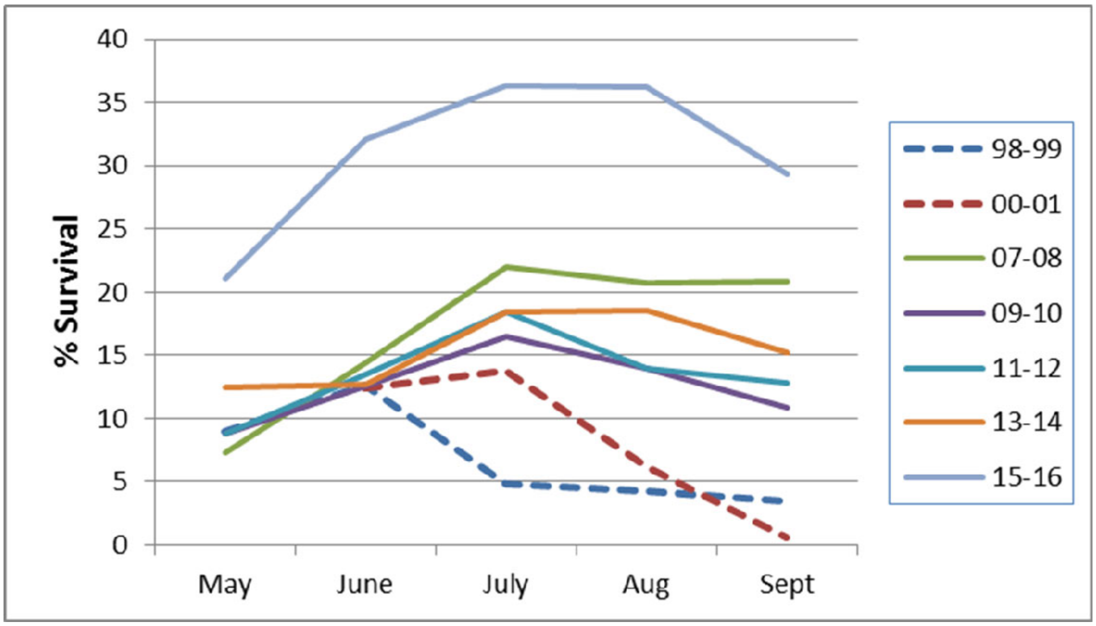

Figure 3. Average bollworm survival by month in 2-year increments at 5µg cypermethrin per vial during 1998-2001 and 2007– 2016.

Even though pyrethroids are not applied to control bollworms as frequently as in the past, there are still many pyrethroid applications made in the agricultural landscape for various pests. This sustained selection for resistance genes continues to decrease pyrethroid susceptibility, making the choice of this class of chemistry for managing bollworms a risky decision that will often result in unsatisfactory control.

Conclusions

Pyrethroid susceptibility in bollworms over the cotton belt has decreased during the last 10 years in all states. Resistance appeared first in a few states, but over the last 2 years has spread to all participating states. The level of resistance observed in bollworm during 2016 was comparable to survival rates of tobacco budworm when it was first considered resistant to pyrethroid insecticides during the 1980s. Because pyrethroid insecticides are still frequently used to control other pests in the agricultural landscape, selection for more pyrethroid resistance continues. Control of bollworm larvae with pyrethroids at this time is erratic and often unacceptable. Therefore, some states have removed pyrethroids from their list of insecticides recommended for bollworm control.

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References

Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18: 265-267.

Beerwinkle, K. R., J. D. Lopez, D. Cheng, P. D. Lingren, and R. W. Meola. 1995. Flight potential of feral *Helicoverpa zea* (Lepidoptera: Noctuidae) males measured with a 32-channel, computer-monitored, flight-mill system. Environ. Entomol. 24: 1122-1130.

Beuzelin, J., S. Brown, J. Davis, L. D. Foil, K. Healy, F. Huang, D. Kerns, A. Morgan, D. Pollet, G. Reagan, D. Reed, D. Ring, T. Schowalter, M. Stout, and T. Smith. 2016. 2016 Louisiana Insect Pest Management Guide, LSU AgCenter, Pub. 1838.

Catchot, A., C. Allen, J. Bibb, D. Cook, W. Crow, J. Dean, D. Fleming, D. Dodds, J. Gore, T. Irby, E. Larson, B. Layton, N. Little, J. MacGown, S. Meyers, F. Musser, and S. Winter. 2017. Insect Control Guide for Agronomic Crops, Mississippi State University Extension Service, Publ. 2471.

Lingren, P. D., J. K. Westbrook, V. M. Bryant, J. R. Raulston, J. F. Esquivel, and G. D. Jones. 1994. Origin of corn earworm (Lepidoptera: Noctuidae) migrants as determined by citrus pollen markers and synoptic weather systems. Environ. Entomol. 23: 562-570.

Martin, S. H., R. D. Bagwell, M. L. Boyd, B. L. Freeman, G. A. Herzog, D. R. Johnson, M. B. Layton, B. R. Leonard, N. Liu, G. T. Payne, P. V. Pietrantonio, M. E. Roof, M. J. Sullivan, J. W. Van Duyn, and J. R. Weeks. 1999. Status of bollworm, *Helicoverpa zea*, susceptibility to pyrethroids: IRAC-US 1998 update, pp. 867-871. *In:* Proceedings, Beltwide Cotton Conferences. 3-7 January, 1999. Orlando, FL. National Cotton Council, Memphis, TN.

Musser, F. R., R. E. Jackson, J. K. Greene, B. R. Leonard, S. D. Stewart, M. N. Parajulee, J. J. Adamczyk, G. M. Lorenz, D. S. Akin, K. V. Tindall, D. A. Herbert, and P. M. Roberts. 2010. Pyrethroid resistance monitoring of bollworms, pp. 1259-1264. *In:* Proceedings, Beltwide Cotton Conferences. Jan. 4-7, 2010. New Orleans, LA. National Cotton Council, Memphis, TN.

Plapp, F. W., Jr. 1987. Managing resistance to synthetic pyrethroids in the tobacco budworm, pp. 224-226. *In:* Proceedings, Beltwide Cotton Conferences. Jan. 4-8, 1987. Dallas, TX. National Cotton Council, Memphis, TN.

Plapp, F. W., Jr., G. M. McWhorter, and W. H. Vance. 1987. Monitoring for pyrethroid resistance in the tobacco budworm in Texas - 1986, pp. 324-326. *In:* Proceedings, Beltwide Cotton Conferences. Jan. 4-8, 1987. Dallas, TX. National Cotton Council, Memphis, TN.

Rogers, B., H. D. Feese, S. L. Riley, C. A. Staetz, J. Whitehead, and W. Mullins. 1990. *Heliothis* resistance monitoring in the cotton belt: PEG-US update, pp. 163-164. *In:* Proceedings, Beltwide Cotton Conferences. Jan. 9-14, 1990. Las Vegas, NV. National Cotton Council, Memphis, TN.

Studebaker, G., J. Davis, J. D. Hopkins, D. R. Johnson, K. Loftin, G. Lorenz, N. Seiter, P. Spradley, J. Zawislak, D. T. Johnson, and T. Teague. 2017. Insecticide recommendations for Arkansas, University of Arkansas Cooperative Extension Service, MP 144.