RELATIONSHIP OF ADULT VIAL TEST DATA ON PYRETHROID RESISTANCE TO FIELD CONTROL OF TOBACCO BUDWORM IN COTTON[1,2]

S. Micinski, R. G. Luttrell[3], B. R. Leonard[4], and J. B. Graves[5]

Louisiana Agricultural Experiment Station
Louisiana State University Agricultural Center
Red River Research Station, P.O. Box 8550,
Bossier City, LA 71113

ABSTRACT

During 1989, studies were conducted on the Red River Research Station, Bossier City, LA and on a farm near Greenwood, MS to relate the level of pyrethroid resistance in the tobacco budworm, *Heliothis virescens* (F.), as measured by the adult vial test (AVT) to field control on cotton, *Gossypium hirsutum* L. Data were also collected from both sites using a neonate larval leaf dip bioassay. LC_{50} values from the AVT in Louisiana ranged from a low of 1.78 µg/vial on June 29 to a high of 20.75 on August 29. LC_{50} values from the AVT in Mississippi ranged from a low of 2.2 µg/vial on June 26 to a high of 27.0 on August 3. Male and female tobacco budworms did not differ significantly in their response (LC_{50} and LC_{90} levels) to cypermethrin in the AVT. Also, the responses of tobacco budworm moths (29% males) hand-collected in Louisiana on August 30 did not differ significantly from the LC_{50}'s and LC_{90}'s of moths captured in pheromone-baited traps on the same night. LC_{50} values for cypermethrin in the neonate larval bioassays in Louisiana ranged from 10.6 PPM in June to 34.8 in August. In Mississippi, LC_{50}'s increased from 15.2 PPM in July to 21.7 in September. Despite the increased tolerance to cypermethrin late in the season, adequate field control of the bollworm, *Helicoverpa zea* (Boddie), - tobacco budworm complex (primarily tobacco budworm) was maintained in Louisiana throughout the test period. Infestation levels in the test plots were low, especially during late July and August.

INTRODUCTION

The pyrethroids have been widely used since their introduction in the late 1970's for control of the tobacco

[1] Lepidoptera: Noctuidae

[2] Approved for publication by the Director of the Louisiana Agricultural Experiment Station as manuscript number 90-84-4291.

[3] Department of Entomology, Mississippi State University, Drawer EM, Mississippi, MS 39762.

[4] Northeast Research Station, Box 438, St. Joseph, LA 71366.

[5] Department of Entomology, Louisiana State University, Baton Rouge, LA 70803.

budworm, *Heliothis virescens* (F.), and the bollworm, *Helicoverpa zea* (Boddie). Even before the pyrethroids were introduced, it was apparent that field populations varied in their susceptibility to this class of insecticide (Davis et al. 1977, Harding et al. 1977). Additional data obtained after the introduction of the pyrethroids followed similar patterns (Crowder et al. 1979, Twine and Reynolds 1980, Plapp 1981, Martinez-Carrillo and Reynolds 1983, Staetz 1985). The first control failures attributed to pyrethroid resistance in the tobacco budworm occurred in West Texas in 1985. These failures were confirmed in the laboratory as a 16-fold decrease in susceptibility to permethrin (Plapp and Campanhola 1986). In 1986, control failures resulting from decreased pyrethroid susceptibility were observed in cotton fields in Arkansas, Louisiana and Mississippi (Leonard et al. 1987, Luttrell et al. 1987, Plapp et al. 1987, Roush and Luttrell 1987, Leonard et al. 1988a). Furthermore, cross-resistance among the pyrethroid insecticides has been documented (Jensen et al. 1984, Plapp and Campanhola 1986, Leonard et al. 1988b).

Plapp et al. (1987) developed a glass vial bioassay technique (adult vial test - AVT) which allowed for the rapid determination of resistance levels within a field population using male moths collected from pheromone-baited wire cone traps. This technique has now been used for several years to monitor the levels of pyrethroid resistance in the tobacco budworm across the cotton belt (Graves et al. 1988a, 1988b, Luttrell et al. 1988, Riley 1988, Simonet et al. 1988, Campanhola and Plapp 1989, Riley 1989).

The objective of this study was to relate the results from the AVT to field control of the tobacco budworm at specific sites throughout the season and to compare the results of the AVT with data from neonate larval leaf dip bioassays. Data were also collected on the AVT responses comparing male and female tobacco budworm adults. Male and female tobacco budworms reared from eggs collected in the field and reared from eggs of moths collected in the field, were tested using the AVT to determine if a differential response existed between males and females. Additionally, the response to cypermethrin of hand-collected moths was compared to that of moths captured in pheromone-baited traps. This study was a joint effort between personnel of the Louisiana and Mississippi Agricultural Experiment Stations, and PEG-US (Pyrethroids Efficacy Group, United States Branch).

MATERIALS AND METHODS

Louisiana Field Procedures. This study was conducted in a 1.94 ha cotton field on the Red River Research Station (RRRS), Bossier City, LA. during 1989. The field was fertilized with 27.2 kg N per ha on April 5 and planted to Stoneville 453 cotton on April 27. A hopper-box fungicide treatment (Apron/Terraclor at 0.5 kg/100 kg seed) was applied at planting. The field was divided into three plots. The control plot was 44 rows x 139 m and the treated plots consisted of 48 rows x 139 m (all on 1.02 m centers). The two insecticide treatments were different rates of cypermethrin (0.034 and 0.067 kg [AI]/ha). The cypermethrin treatments (Cymbush^{R} 3EC, ICI Americas, Inc., Wilmington, DE) were applied on 22 June, 12 and 21 July, and 2, 10, 17, and 24 August.

Field control observations were made on the following dates: 6, 12, 18, 25 July, and 1, 8, and 14 August. Observations from each plot included: 1) the number of eggs and larvae of bollworm-tobacco budworms/100 terminals; 2) the number of bollworm-tobacco budworm and boll weevil damaged squares/100 squares (all dates except July 6); and 3) the number of bollworm-tobacco budworm larvae/100 squares (all dates except July 6).

Additional insecticide treatments were used to manage other cotton pests. Acephate (90 [SP]; Valent USA Corp., Walnut Creek, CA) at 0.28 kg [AI]/ha was applied on 13 June. Methyl parathion (4 [EC]; Cheminova, Lemvig, Denmark) was applied on 12 July and 23 and 30 August. Azinphosmethyl (2 [EC]; Mobay Corporation, Kansas City, MO) was applied on 20 July and 1 August. Encapsulated methyl parathion (2 [F]; Pennwalt Corp., Philadelphia, PA) was applied on 10 August. The test was terminated on 5 September by applying cypermethrin at 0.068 kg [AI]/ha to all plots. Cyfluthrin (2 [EC]; Mobay Corp.) at 0.037 kg [AI]/ha and flucythrinate (2.5 [EC]; American Cyanamid Corp., Princeton, NJ) at 0.045 kg [AI]/ha were oversprayed on 11 and 21 September, respectively.

Mississippi Field Procedures. In Mississippi, the study sites were two production fields in Leflore County near Greenwood. Both fields were ca. 60 ha in size and each was divided into two equal size plots for bollworm-tobacco budworm control with the two rates of cypermethrin as described in the Louisiana study. Untreated checks were not included in the design. One of the sites was located in the northern region of the county near Schlater (N. Leflore site), and the other site was in the southern region near Morgan City (S. Leflore site). Standard agronomic practices for the region were used at both sites and both were irrigated with center-pivot systems. Insecticide applications were not made immediately before (2 days) or after irrigation. The North Leflore site was planted to Deltapine 20 cotton on 22 May. Row spacing was the same as described for the Louisiana study. The South Leflore planting date was 2 to 3 weeks later than normal (May 5).

Insect control, other than that necessary for bollworm-tobacco budworm, was based on routine sampling and recommendations of private consultants employed by each grower. Both fields were treated with aldicarb (0.56 kg [AI]/ha) (Temik^{R} 15G, Rhone-Poulenc Ag. Co., Research Triangle Park, NC) at planting and both received multiple applications of azinphosmethyl (0.28 kg [AI]/ha) for boll weevil control on an "as needed" basis. The North Leflore site received an application of dicrotophos (0.34 kg [AI]/ha) (Bidrin^{R} 8E, E. I. du Pont de Nemours & Co., Inc., Wilmington, DE) for aphid control on 12 June. Insect pressure was relatively low during June and July, and bollworm-tobacco budworm control was not necessary until late July. Treatments for bollworm-tobacco budworm control were initiated at the North Leflore site on 30 July. A second application was made on 9 August. Cypermethrin treatments were applied to the plots at the South Leflore site on 3 and 7 August. Because the grower was not satisfied with the level of control obtained, an application of sulprofos (1.4 kg [AI]/ha) (Bolstar^{R} 6E, Mobay Corp., Kansas City, MO) was made across both plots at the South Leflore site on 11 August.

After the second week of August, responsibility for bollworm-tobacco budworm control was returned to the

agricultural consultants and both fields were oversprayed with mixtures of chlordimeform (0.14 kg [AI]/ha) plus full label rates of pyrethroids or with sulprofos (1.12 kg [AI]/ha) as needed. Both fields received two insecticide applications for bollworm-tobacco budworm control after 25 August. Although experimental treatments were terminated after two applications at both sites, resistance monitoring was continued at both sites through September.

During the mid-June to late-August period, each plot was monitored twice a week. Observations were the same as those described for the Louisiana study.

Louisiana and Mississippi AVT Procedures. A set of eight wire cone traps (Hartstack 1979) were placed around the perimeter of the Louisiana PEG-US/University Trial for collection of adult male tobacco budworms. Five additional traps at nearby sites on the RRRS were also monitored during the Louisiana test.

At the North Leflore site in Mississippi, 10 wire cone traps were placed around the perimeter of the field. The South Leflore site had 14 wire cone traps surrounding the field.

For both the Louisiana and Mississippi sites, male moths to be used in the AVT were removed in the early morning and only those males that appeared to be healthy were used in these tests. Adults from both PEG-US sites (Louisiana and Mississippi) and from the RRRS pheromone-baited traps were placed individually in 20 ml glass scintillation vials which were coated with a residual film of cypermethrin as described by Plapp et al. (1987). Technical-grade cypermethrin (ICI Americas, Wilmington, DE) was used in the treatment of the vials. Dosage levels ranged from 5 to 100 μg/vial. Acetone treated vials were included as controls. Three to five doses (10-30 moths/dose) were used to estimate each dose/mortality line. One male was placed in each vial and the vials were held on their sides at room temperature. At 24 h after exposure, adults unable to fly more than a short distance (<3 m) were recorded as dead.

Leaf Dip Bioassay. Larvae used in the leaf dip bioassays were obtained from the LSU or MSU-lab colony or from ovipositing females collected in or near the Louisiana or Mississippi PEG-US/University Trial fields. Tobacco budworm females were hand collected at night and placed in 3.8 L cardboard cartons with a 10% sugar water solution for food. Cotton gauze was used to cover the cartons and served as an ovipositional substrate. Eggs were collected daily and allowed to hatch at room temperature. Only neonate larvae (<1 day old) were used in the test. Formulated cypermethrin was used in these bioassays. Untreated cotton leaves were dipped into a cypermethrin-distilled water solution for 20-30 seconds, removed and allowed to dry. A minimum of 6 doses (in PPM) and 3 replications were used to estimate each dose/mortality line. Neonate larvae were transferred to 1-oz plastic cups (5/cup) using a camel hair brush. The treated leaf was placed over the cup and covered with a piece of moistened cotton wadding. This was sandwiched between the cup and a wax coated paper lid to produce a uniform disc for larval exposure. Cups were inverted and held at 26.7°C, 65 -70% RH and a 14:10 (L:D) photoperiod. Mortality was determined 48 h posttreatment. Larvae were recorded as dead if they were unable to move after being prodded with a blunt probe.

Data Analyses. Laboratory data from both Louisiana and

Mississippi were analyzed and probit regressions were estimated using a microcomputer based probit analysis (MicroProbit 3.0, T.C. Sparks and A.P. Sparks, Louisiana State University, Baton Rouge, unpublished data). All data were corrected for control mortality using Abbott's (1925) formula.

RESULTS AND DISCUSSION

Infestations of eggs and larvae were the highest during early July in the Louisiana test. Based on number of moths observed in the field from dusk to 11 PM, the bollworm was the dominant species in June and early July while the tobacco budworm was the dominant species from mid-July through August. Eggs per 100 terminals ranged from 79-105 on the first sampling date, 6 July. Terminal egg counts declined rapidly after 6 July and never exceeded 10/100 terminals after 18 July. Larvae/100 terminals peaked on 12 July. Numbers of larvae/25 plants were highest on the first sampling date of whole plant examinations, 12 July (prior to the cypermethrin application of 12 July). The cypermethrin plots (0.034 and 0.067 kg [AI]/ha) had 2 and 2.5 times the number of larvae/25 plants compared with the untreated control plots. The higher numbers of larvae in the treated plots were probably the result of beneficial arthropod mortality from the 22 June application. Larvae/25 plants declined rapidly after 12 July. The cypermethrin plots (0.034 and 0.067 kg [AI]/ha) had two and four sampling dates, respectively, with 0 larvae/25 plants. Percent larval damaged squares declined for all treatments after 12 July. After 18 July, the cypermethrin treated plots never exceeded 5% damaged squares. The cypermethrin treated plots generally had fewer damaged squares compared to the number in the control plot. Damaged squares in the control plot exceeded 5% on all sample dates except 1 August. Boll weevil, *Anthonomus grandis* Boh., pressure was high throughout the test period in all plots. In the cypermethrin (0.067 kg [AI]/ha) treated plot, boll weevil damaged squares exceeded 15% on all sample dates except 25 July and 14 August.

At the North Leflore site in Mississippi, peak egg infestations were detected on 29 July (14% of plants infested) and 8 August (23% of plants infested). Square damage was greater than 5% on only three dates (7% on 2 and 11 August, and 10% on 14 August). On 14 August, 5% of the squares examined contained larvae. At the South Leflore site, peak egg infestations were observed on 25 July (17% of plants infested) and 1 August (9% of plants infested). However, infestation levels were higher than 5% from 24 July to 7 August. Based on pheromone trap captures, the field was initially infested with the bollworm. About a week later, tobacco budworm trap captures increased sharply. Square damage was greater than 5% at the South Leflore site on 1 (7%), 10 (9%), and 15 (11%) August.

The LC_{50} and LC_{90} values for the AVT from Mississippi and Louisiana (from both the PEG-US/University and RRRS pheromone traps) are shown in Table 1. LC_{50} values in Louisiana ranged from a low of 1.78 µg/vial (PEG traps) on 29 June to a high of 20.75 (RRRS traps) on 29 August. In North Leflore Co., MS, LC_{50} values ranged from 2.2 µg/vial on 26 June to 27.0 on 3 August. The range of LC_{50} values from Louisiana and Mississippi were similar during the season. Riley (1988) reported AVT LC_{50} values ranging from 0.4 to 9.7 µg/vial from tests in Arkansas, Louisiana, and Mississippi. The highest level of resistance

TABLE 1. Response of Tobacco Budworm Adult Males to Cypermethrin in a Treated Vial Bioassay (24-h reading), PEG-US/University Trials, RRRS, Bossier City, LA. and N. Leflore Co., MS., 1989.[a]

Strain/ Collection	Date	n	Slope (SE)	µg/vial LC_{50} (95% CL)	µg/vial LC_{90} (95% CL)
Louisiana					
PEG-US	6/16	60	1.99 (0.52)	4.73 (2.79-8.45)	20.82 (10.77-122.04)
PEG-US	6/20	80	1.86 (0.51)	5.00 (2.33-7.86)	24.41 (13.87-113.23)
PEG-US	6/20	80	1.28 (0.37)	5.56 (2.69-9.81)	55.42 (22.97-1016.79)
RRRS	6/20	80	1.73 (0.74)	4.30 (0.63-7.93)	23.67 (10.92->4500)
PEG-US	6/23	70		<5.0	<30
RRRS	6/23	80	1.56 (0.43)	2.77 (0.98-4.45)	18.27 (10.26-88.30)
PEG-US	6/29	32	2.39 (0.75)	1.78 (0.33-3.65)	6.13 (2.93-21.67)
RRRS	6/29	50	3.90 (1.00)	6.71 (4.19-9.31)	14.30 (10.19-29.90)
RRRS	7/06	40	2.72 (0.67)	2.34 (0.96-4.18)	7.09 (4.04-17.31)
PEG-US	7/25	123	1.79 (0.27)	9.89 (7.06-14.22)	51.33 (31.15-117.95)
RRRS	7/25	118	1.59 (0.27)	10.61 (7.20-15.75)	67.92 (38.28-193.37)
PEG-US	8/03	50	3.01 (0.81)	10.71 (4.54-17.14)	27.77 (17.36-59.11)
RRRS	8/03	50	1.51 (0.61)	18.89 (1.92-40.47)	131.95 (55.47->3000)
PEG-US	8/08	100	1.01 (0.32)	6.56 (1.07-13.06)	121.09 (47.20->3000)
RRRS	8/08	100	1.26 (0.31)	7.76 (2.72-13.60)	80.77 (40.35-426.68)
PEG-US	8/29	100	3.42 (0.45)	7.85 (5.73-10.18)	18.62 (14.26-26.06)
RRRS	8/29	100	2.24 (0.36)	20.75 (14.73-30.26)	77.37 (48.66-170.31)
PEG-US	8/30	100	1.39 (0.32)	20.38 (11.86-35.64)	168.34 (76.82-1095.41)
RRRS	8/30	100	1.37 (0.31)	15.42 (8.36-25.77)	131.11 (63.19-705.98)
PEG-US	8/31	100	3.20 (0.39)	11.46 (8.30-15.00)	28.80 (21.95-40.04)
Hand-Collected	8/30	100	1.61 (0.34)	11.65 (6.48-18.18)	72.85 (40.56-248.51)

TABLE 1. (continued)

Mississippi					
N. Leflore	6/08	200	1.81 (0.64)	3.3 (0.06-4.7)	16.7 (11.1-133.3)
N. Leflore	6/15	200	3.80 (0.63)	6.4 (5.6-7.2)	13.9 (11.4-19.8)
N. Leflore	6/26	200	1.65 (0.68)	2.2 (0.02-3.8)	13.3 (9.1-250.3)
N. Leflore	7/27	300	2.36 (0.30)	8.1 (6.8-9.4)	28.1 (21.7-42.2)
N. Leflore	8/03	300	2.80 (0.26)	27.0 (23.3-31.3)	77.8 (62.8-103.8)
N. Leflore	8/14	400	1.95 (0.19)	16.1 (5.9-41.3)	72.8 (32.1-5802.1)
N. Leflore	8/17	300	2.37 (0.29)	8.4 (7.2-9.8)	29.3 (22.5-44.0)
N. Leflore	9/03	300	1.58 (0.26)	6.6 (4.8-8.2)	42.1 (28.0-89.2)
N. Leflore	9/14	300	1.64 (0.21)	19.1 (14.7-23.8)	114.9 (80.8-119.1)
N. Leflore	9/21	200	1.47 (0.40)	7.6 (2.9-10.9)	56.5 (34.3-256.0)
N. Leflore	9/28	200	1.94 (0.25)	10.7 (8.8-12.8)	75.5 (49.1-152.5)

[a] **Louisiana:** PEG-US/University treatments on 6/22, 7/12, 7/21, 8/2, 8/10, 8/17, and 8/24. General spraying of pyrethroids on the RRRS began on July 7, 1989. **Mississippi:** PEG-US/University treatments on 7/30 and 8/9.

determined by the AVT in 1987 occurred in the Brazos River Valley of Texas (Riley 1988, 1989).

On 29 June and 29 August, the response (LC_{50}) of the male tobacco budworms in the AVT in Louisiana indicated that the moths from the RRRS traps were more tolerant to cypermethrin than the moths from the PEG traps. This differential response was noted only on 29 August at LC_{90}. Other comparisons indicated no significant differences in response between the two sets of traps at LC_{50} or LC_{90} and it is unlikely these differences are real. Also, tobacco budworm moths (29% males) hand-collected on 30 August did not differ significantly from moths captured in RRRS or PEG pheromone traps in their response to cypermethrin. Although LC_{50} values generally increased as the season progressed, confidence intervals were generally too large to detect significant differences between most LC_{50} values. However, LC_{50} values of adults from the RRRS traps on 29 August and from the PEG traps on 30 August in Louisiana were significantly higher than LC_{50}'s for tobacco budworms collected prior to 25 July. In Mississippi, LC_{50} values from 3 August and 14 September were significantly higher than LC_{50}'s for collections made prior to 3 August.

Neonate tobacco budworm larvae reared from moths collected in and around the Louisiana PEG-US/University test area in June, July, and August showed a significant increase in cypermethrin tolerance as the season progressed (Table 2). Tolerance also increased in the Mississippi study from July to September although the increase was not statistically significant for neonate larvae reared from the eggs of field collected moths. In Louisiana, LC_{50} values ranged from 10.6 parts per million (PPM) in June to 34.8 in August. Cypermethrin in the Louisiana test was 35, 94, and 116 times more toxic to the LSU-lab strain of tobacco budworms than to the June, July, and August field collections of tobacco budworm, respectively. In Mississippi, cypermethrin was 51 and 72 times more toxic to the MSU-lab strain of budworms than to the July and September field collections of tobacco budworms.

Male and female tobacco budworms tested in Louisiana did not differ significantly in their response (LC_{50} or LC_{90} levels) to cypermethrin (Table 3). Also, these responses did not differ significantly based on the method of field collection (eggs vs. adults). Despite the tobacco budworm's increased tolerance to cypermethrin late in the season (Table 1), acceptable control was achieved with cypermethrin in the treated plots in Louisiana. No square damage was found in any of the treatments in an additional sample (50 squares) taken from each treatment on 22 August.

Acceptable levels of bollworm-tobacco budworm control were obtained with both rates of cypermethrin at the North Leflore site in Mississippi. Although the South Leflore grower was concerned about the lack of control observed following the second application of cypermethrin treatments to the South study area , differences between treatments in number of insects surviving treatment and resulting square damage were not observed. The South Leflore field was planted late and the grower was justifiably concerned with maturity of the crop. Both study sites produced yields near 1000 kg lint/ha.

Resistance data obtained using the leaf dip bioassay and neonate larvae corresponded well to the data obtained using the AVT. Similar results were obtained by PEG-US in evaluating

TABLE 2. Response in PPM of Neonate Tobacco Budworm Larvae to Cypermethrin in a Leaf Dip Bioassay, 1989.

Strain/ Collection[a]	n	Slope (SE)	LC_{50} (CL)	RR[b]	LC_{90} (CL)
Louisiana					
LSU-lab	525	2.09 (0.20)	0.3 (0.26-0.37)	--	1.28 (0.97-1.89)
PEG-US June	420	1.47 (0.17)	10.6 (8.19-13.18)	35	77.60 (53.12-138.50)
PEG-US July	274	2.95 (0.34)	28.1 (24.07-32.38)	94	76.20 (61.87-103.28)
PEG-US August	490	2.64 (0.26)	34.8 (29.16-40.34)	116	106.30 (89.04-134.13)
Mississippi					
MSU-lab	900	0.94 (0.06)	0.3 (0.11-0.83)	--	7.87 (2.62-87.10)
DuPont 84-R[c]	500	1.49 (0.12)	43.7 (16.6-95.8)	146	316.30 (132.5-3385.7)
S. Leflore July	500	1.43 (0.13)	15.2 (2.9-40.1)	51	119.10 (43.8-1.1 x 10^4)
S. Leflore Sept	500	2.26 (0.17)	21.7 (18.5-25.5)	72	79.90 (63.4-107.0)
S. Leflore July[d]	600	1.60 (0.15)	34.4 (10.1-90.9)	115	216.30 (84.4-1.5 x 10^4)

[a] **Louisiana:** PEG-US June neonate larvae obtained from the eggs of 50 moths collected in the PEG-US/University Trial test site on June 19-21. PEG-US July neonate larvae obtained from eggs of 11 moths collected in the test site on July 24-26. PEG-US August neonate larvae obtained from the eggs of ca. 115 moths collected near the test site on August 28 and 29.
[b] **Louisiana:** LC_{50} of PEG-US larvae/LC_{50} of LSU-lab larvae. **Mississippi:** LC_{50} of DuPont or S. Leflore Co. larvae/LC_{50} of MSU-lab larvae.
[c] The DuPont 84-R strain was obtained from E. I. du Pont de Nemours & Co. and was considered to be resistant to pyrethroid insecticides. These insects were initially collected in 1984 from the Imperial Valley of California. Budworms were routinely selected with exposure to the pyrethroids in the laboratory.
[d] Neonate larvae obtained from field collected eggs.

TABLE 3. Response of Male and Female Tobacco Budworm Moths to Cypermethrin in the AVT (24-h reading), Louisiana, 1989.

Sex	n	Slope + SE	µg/vial LC_{50} (95%CL)	µg/vial LC_{90} (95% CL)
Adults reared from eggs collected in the field[a]				
Males	104	1.35 + 0.28	7.83 (4.14-12.33)	69.66 (36.99-257.85)
Females	87	1.38 + 0.30	11.47 (6.79-19.58)	96.03 (44.89-530.89
Total	191	1.34 + 0.20	9.33 (6.37-13.06)	83.94 (48.87-212.04)
Adults reared from the eggs of adults collected in the field[b]				
Males	95	2.26 + 0.31	7.26 (4.76-10.07)	26.78 (19.17-41.89)
Females	73	2.50 + 0.37	9.79 (0.47-25.79)	31.83 (12.31-784.50)
Total	168	2.48 + 0.24	8.28 (1.92-17.20)	27.28 (13.15-119.60)

[a] Eggs collected August 30.
[b] Adults collected August 28 and 29.

various techniques for estimating pyrethroid resistance (Riley 1988).

In summary, the tobacco budworm AVTs and neonate larval leaf dip bioassays from these studies indicated that tolerance to cypermethrin increased during the season. Despite the relatively high LC_{50} values reported during the August portion of the study, field control of the tobacco budworm and bollworm in Louisiana in the treated plots was adequate even at the lower rate of cypermethrin. Nevertheless, tolerance to cypermethrin at this location was higher than had been previously reported and the need to follow management strategies that will slow further resistance development is greater than ever.

Male and female tobacco budworms responded in a similar manner to cypermethrin as indicated by the results of the AVT. Although LC_{50} values were numerically higher for females, this can probably be explained by the fact that females weigh more than males. Additionally, tobacco budworm moths (29% males) captured by hand responded to cypermethrin in the AVT in the same manner as moths captured in pheromone traps. Furthermore, the response of moths reared from eggs deposited in the same field where the moths were hand-collected was not significantly different from moths captured in nearby pheromone-baited traps. Therefore, resistance data from moths captured in pheromone-baited traps are representative of the fields in close proximity to the traps.

These data indicate that AVT for resistance monitoring using males from pheromone traps placed on the perimeter of a field are indicative of the resistance level of females ovipositing in that field. Additional studies to further document this relationship are needed.

ACKNOWLEDGEMENT

The authors wish to express their appreciation to PEG-US for partial funding for this study. The study was a cooperative effort between the authors and PEG-US. PEG-US members involved in the design and protocols used in this study include Harlan Feese and Ben Rogers (ICI Americas, Inc), Walt Mullins (Mobay Corporation), Steve Riley (E.I. Du Pont & Co.), Chuck Staetz (FMC Corporation), James Whitehead (Hoechst-Roussel Agri-Vet Co.), Dan Clower (Private Consultant), and Geni Certain (Meister Publishing Co.).

LITERATURE CITED

Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18: 256-257.

Campanhola, C., and F. W. Plapp. 1989. Pyrethroid resistance in the tobacco budworm (Lepidoptera: Noctuidae): insecticide bioassays and field monitoring. J. Econ. Entomol. 82: 22-28.

Crowder, L. A., M. S. Tollefson, and T. F. Watson. 1979. Dosage-mortality studies of synthetic pyrethroids and methyl parathion on the tobacco budworm in Central Arizona. J. Econ. Entomol. 72: 1-3.

Davis, J. W., D. A. Wolfenbarger, and J. A. Harding. 1977. Activity of several synthetic pyrethroids against the boll weevil and *Heliothis* spp. Southwest. Entomol. 2: 164-169.

Graves, J. B., B. R. Leonard, A. M. Pavloff, G. Burris, K.

Ratchford, and S. Micinski. 1988a. Monitoring pyrethroid resistance in tobacco budworm in Louisiana during 1987: resistance management implications. J. Agric. Entomol. 5: 109-115.
Graves, J. B., B. R. Leonard, A. M. Pavloff, S. Micinski, G. Burris, and K. Ratchford. 1988b. Status of pyrethroid resistance in tobacco budworm in Louisiana, pp. 353-356. *In* Proc. Beltwide Cotton Prod. Res. Conf., Nat. Cotton Council, Memphis, Tenn.
Harding, J. A., F. F. Huffman, D. A. Wolfenbarger, and J. W. Davis. 1977. Insecticidal activity of alpha-cyano-3-phenoxybenzyl pyrethroids against the boll weevil and tobacco budworm. Southwest. Entomol. 2: 42-45.
Hartstack, A. W. 1979. Moth traps for the tobacco budworm. J. Econ. Entomol. 72: 519-522.
Jensen, M. P., L. A. Crowder, and T. F. Watson. 1984. Selection for permethrin resistance in the tobacco budworm (Lepidoptera: Noctuidae). J. Econ. Entomol. 77: 1409-1411.
Leonard, B. R., J. B. Graves, T. C. Sparks, and A. M. Pavloff. 1987. Susceptibility of bollworm and tobacco budworm larvae to pyrethroid and organophosphate insecticides, pp. 320-324. *In*: Proc. Beltwide Cotton Prod. Res. Conf., Nat. Cotton Council, Memphis, Tenn.
Leonard, B. R., J. B. Graves, T. C. Sparks, and A. M. Pavloff. 1988a. Variation in resistance of field populations of tobacco budworm and bollworm (Lepidoptera: Noctuidae) to selected insecticides. J. Econ. Entomol. 81: 1521-1528.
Leonard, B. R., T. C. Sparks, and J. B. Graves. 1988b. Insecticide cross-resistance in pyrethroid-resistant strains of tobacco budworm (Lepidoptera: Noctuidae). J. Econ. Entomol. 81: 1529-1535.
Luttrell, R. G., R. T. Roush, A. Ali, J. S. Mink, M. R. Reid, and G. L. Snodgrass. 1987. Pyrethroid resistance in field populations of *Heliothis virescens* (Lepidoptera: Noctuidae) in Mississippi in 1986. J. Econ. Entomol. 80: 985-989.
Luttrell, R. G., J. B. Graves, and J. R. Phillips. 1988. Performance of pyrethroid insecticides against *Heliothis virescens* in the mid-south during 1987, pp. 232-236. *In*: Proc. Beltwide Cotton Prod. Res. Conf., Nat. Cotton Council, Memphis, Tenn.
Martinez-Carrillo, J. L., and H. T. Reynolds. 1983. Dosage-mortality studies with pyrethroids and other insecticides on the tobacco budworm (Lepidoptera: Noctuidae) from the Imperial Valley, California. J. Econ. Entomol. 76: 983-986.
Plapp, F. W. 1981. Toxicity of synthetic pyrethroids to laboratory and field populations of the tobacco budworm in central Texas. J. Econ. Entomol. 74: 207-209.
Plapp, F. W., and C. Campanhola. 1986. Synergism of pyrethroids by chlordimeform against susceptible and resistant *Heliothis*, pp. 167-169. *In*: Proc. Beltwide Cotton Prod. Res. Conf., Nat. Cotton Council, Memphis, Tenn.
Plapp, F. W., G. M. WcWhorter, and W. H. Vance. 1987. Monitoring for pyrethroid resistance in the tobacco budworm in Texas -1986, pp. 324-326. *In*: Proc. Beltwide Cotton Prod. Res. Conf., Nat. Cotton Council, Memphis, Tenn.
Riley, S. L. 1988. An overview of the status of pyrethroid resistance in the U.S. during 1987, pp. 223-230. *In*: Proc. Beltwide Cotton Prod. Res. Conf., Nat. Cotton Council,

Memphis, Tenn.
Riley, S. L. 1989. Pyrethroid resistance in *Heliothis virescens*: current US management programs. Pestic. Sci. 26: 411-21.
Roush, R. T., and R. G. Luttrell. 1987. The phenotypic expression of pyrethroid resistance in *Heliothis* and implications for resistance management, pp. 220-224. *In*: Proc. Beltwide Cotton Prod. Res. Conf., Nat. Cotton Council, Memphis, Tenn.
Simonet, D. E., S. L. Riley, A. Watkinson, and J. R. Whitehead. 1988. PEG-U.S. monitoring program: adult vial tests, pp. 334-336. *In*: Proc. Beltwide Cotton Prod. Res. Conf., Nat. Cotton Council, Memphis, Tenn.
Staetz, C. A. 1985. Susceptibility of *Heliothis virescens* (F.) (Lepidoptera: Noctuidae) to permethrin from across the cotton belt: a five-year study. J. Econ. Entomol. 78: 505-510.
Twine, P. H., and H. T. Reynolds. 1980. Relative susceptibility and resistance of the tobacco budworm to methyl parathion and synthetic pyrethroids in Southern California. J. Econ. Entomol. 58: 525-526.