# STATUS OF INSECTICIDE RESISTANCE IN TOBACCO BUDWORM AND BOLLWORM IN LOUISIANA DURING 1995

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## Abstract

Resistance was documented to representative chemicals from the three major classes of insecticides (carbamates, organophosphates and pyrethroids) used to control tobacco budworms, *Heliothis virescens* (F.), on cotton in the United States. Over 2100 male tobacco budworm moths were bioassayed for pyrethroid resistance from May through September 1995 against a 10 $\mu$g dose of cypermethrin utilizing the adult vial test. Pyrethroid resistance levels during 1995 were similar to 1994 levels. Also, 200 male tobacco budworm moths were bioassayed for resistance to profenofos using the adult vial test. Resistance to profenofos was lower than in 1994. Low densities of tobacco budworm populations generally persisted in Louisiana during 1995. However, field control failures did occur in fields with moderate to heavy tobacco budworm populations. Topical application bioassays of larval progeny from several 1995 field collections of tobacco budworms indicated significant resistance to carbamate, pyrethroid and organophosphate insecticides. Resistance to all three classes also was detected from the progeny of an Alabama field collection of tobacco budworm. Over 2100 male bollworm, *Helicoverpa zea* (Boddie), moths were bioassayed against 1,2 and 5 $\mu$g/vial doses of cypermethrin. Data from these bioassays were similar to those obtained from 1988-1994, but indicate that bollworm susceptibility to pyrethroids may be changing.

## Introduction

During 1986, pyrethroid resistance in tobacco budworm, *Heliothis virescens* (F.) was documented in Arkansas (Plapp et al. 1987), Mississippi (Roush and Luttrell 1987), Louisiana (Leonard et al. 1987) and Texas (Allen et al. 1987, Plapp et al. 1987) using several bioassay techniques. In response to this development, pyrethroid resistance management plans were initiated for the Mid-South states of Arkansas, Louisiana, Mississippi (Anonymous 1986) and Texas. Wide-spread monitoring of male tobacco budworm moths for pyrethroid resistance has been conducted in these states since 1987 using a glass vial technique (Plapp et al. 1987) commonly referred to as the adult vial test (AVT).

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Tobacco budworm resistance to pyrethroid insecticides continued to increase from 1986 to 1992 (Graves et al. 1988, Graves et al. 1989, Graves et al. 1990, Graves et al. 1991, Graves et al. 1992, Graves et al. 1993, Graves et al. 1994, and Bagwell et al. 1995). Pyrethroid resistance levels peaked in 1993 when the seasonal mean survival reached 48 percent. Tobacco budworm resistance to profenofos, methomyl and endosulfan also was detected in 1993. Thus, by 1993 tobacco budworm populations had developed resistance to the three major insecticide classes (carbamates, organophosphates and pyrethroids) used for tobacco budworm control. Over 22,000 male tobacco budworm moths were bioassayed for pyrethroid resistance from 1987 to 1993 against the 10 µg dose of cypermethrin utilizing the AVT.

Over 15,100 male bollworm moths were bioassayed for pyrethroid resistance from 1987 to 1993. Bollworm males were exposed to 1, 2 and 5 $\mu$g dose of cypermethrin utilizing the adult vial technique. No significant changes in bollworm susceptibility to pyrethroids were detected during this period.

Resistance was again documented to representative chemicals from the three major classes of insecticides (carbamates, organophosphates and pyrethroids) used to control tobacco budworms, *Heliothis virescens* (F.), on cotton in the United States in 1994. Over 2500 male tobacco budworm moths were bioassayed for pyrethroid resistance from May through September 1994 against 10 and/or 30 $\mu$g doses of cypermethrin utilizing the AVT. Average pyrethroid resistance levels during this period in 1994 were slightly lower than 1993 levels. Also, 1058 and 620 male tobacco budworm moths were bioassayed for resistance to profenofos and methomyl, respectively, using the AVT. Resistance was detected to both insecticides but in comparison to 1993 levels of resistance were lower. Few tobacco budworm field control failures occurred in 1994 because tobacco budworm populations were generally light to moderate. Topical application bioassays of larval progeny from several 1994 field collections of tobacco budworms indicated significant resistance to carbamates, pyrethroids and organophosphates. Resistance to all three insecticide classes also was detected from the progeny of an Alabama field collection of tobacco budworm. Over 1800 male bollworm, *Helicoverpa zea* (Boddie), moths were bioassayed against 1,2 and 5 $\mu$g/vial doses of cypermethrin in 1994. Data from these bioassays were similar to those obtained from 1988-1993 and indicate that bollworms remain susceptible to pyrethroids.

The success of insecticide resistance management relies heavily upon the intelligent use of all available classes of insecticides and non-chemical management practices. It is important to monitor susceptibility to the various insecticides to detect any changes or problems which may occur. This study was conducted to evaluate the susceptibility of tobacco budworm and bollworm from

Louisiana to selected insecticides in 1995. This information is essential to update and refine current insecticide resistance management guidelines.

## Materials and Methods

### Adult Vial Test

Wire cone traps (Harstack et al. 1979) baited with artificial sex pheromone lures (Hendricks et al. 1987) were used to collect tobacco budworm and bollworm male moths from May through September. Although males were collected from most cotton production areas of Louisiana, more intensive sampling was conducted on or near the Northeast Research Station (St. Joseph Location, Tensas Parish), Northeast Research Station (Macon Ridge Location, Franklin Parish) and Red River Research Station (Bossier Parish).

The interior of glass scintillation vials (20 ml) were coated with cypermethrin (10 $\mu$g/vial for tobacco budworm and 1, 2, and 5 $\mu$g/vial for bollworm). The 10 $\mu$g/vial dose of cypermethrin is lethal to homozygous pyrethroid susceptible tobacco budworm moths as well as moths heterozygous for pyrethroid resistance (Plapp et al. 1987). Only homozygous pyrethroid resistant tobacco budworm moths survive 10 $\mu$g/vial dose, and it can be used as a discriminating dose for this species. A discriminating dose has not been determined for the bollworm. Vials were stored in a dark area to prevent photodegradation of the pyrethroid insecticide. Acetone-treated vials were used to check for natural moth mortality, which was generally less than 10%.

During 1995, the AVT also was used to monitor for resistance to profenofos. This chemical was selected to represent the organophosphate class of insecticides. Preparation and storage of vials treated with these chemicals was accomplished as recommended by Kanga et al. (1993). Discriminating doses used for profenofos (10 and 20 $\mu$g/vial) were similar to those suggested by Kanga et al. (1993).

Male moths were removed from the traps early in the morning to prevent desiccation. Only moths that appeared to be young and healthy were used in these tests. One moth was placed in each vial and held at room temperature for 24 hours. Mortality was determined by removing the moths from the vials and tossing them into the air. If the moth was unable to fly or could fly only a short distance (< 3 meters), it was recorded as dead. All data were corrected for control mortality using Abbott's (1925) formula.

### Larval Topical Application Test

Initially, a dose-mortality line for each insecticide was established for the LSU laboratory colony (LSU-LAB). Then the diagnostic dose for each insecticide was determined by selecting the approximate $LD_{80-90}$ for the LSU-LAB colony because this dose should differentiate between susceptible and resistant insects (McCutchen et al. 1989, Halliday and Burnham 1990). At this dose, most of the resistant insects should survive the treatment. The diagnostic doses selected initially for each insecticide then were reevaluated against the LSU-LAB colony and adjustments were made to correct for mortality extremes (Martin et al. 1994). At least fifty individuals were tested for each bioassay with the exception of the evaluation of the Alabama colony to cypermethrin. A minimum of 50 insects were used because a sample of 50 individuals is suitable to document resistance at a frequency of $\geq$10% with 95% accuracy (Roush and Miller 1986).

Colonies of tobacco budworm were established by collecting eggs and/or larvae from several locations in Louisiana and one location in Alabama. The collection dates and locations of tobacco budworm colonies included in the present study are shown in Table 1. All of the field colonies were collected from cotton with the exception of the MRS colony, which was collected from velvetleaf, *Abutilon theophrasti* Medicus. The LSU-LAB colony of tobacco budworm was originally established in 1977 by collections from cotton fields in Louisiana (Leonard et al. 1988). This colony has been maintained without exposure to insecticides since its introduction into the laboratory.

All of the laboratory and field colonies were reared in a similar manner. Adults were confined in 3.8-liter cardboard cartons covered with cotton gauze as an oviposition substrate and were fed a 10% sugar water solution. The temperature was maintained at approximately 27±3°C under a 14:10 LD photoperiod. Eggs were removed at least every other day and allowed to hatch at room temperature. Larvae were reared on a pinto bean and wheat germ diet according to procedures described by Leonard et al. (1988).

Technical-grade samples of cypermethrin (FMC, Middleport, NY), profenofos (CIBA, Greensboro, NC) and methomyl (DuPont Agricultural Products, Wilmington, DE), were obtained from the manufacturers for the bioassays. Technical materials were diluted to a 1% stock solution in acetone and refrigerated until needed.

Topical bioassay procedures were similar to those outlined in the E.S.A. standard test method for determining relative susceptibility levels in *Heliothis* spp. (Anonymous 1970), except that third instars weighing 20±5 mg were used, as is now generally accepted (Mullins and Pieters 1982). Before treatment, larvae were removed from stock colonies and placed on fresh diet. Insects were treated on the dorsal surface of the thorax with 1 $\mu$l aliquots of acetone alone (control), serial dilutions from technical grade insecticides dissolved in acetone or a previously determined discriminating dose of a technical grade insecticide dissolved in acetone. Fifty larvae from the first laboratory generation of each field collected colony were treated. After treatment, the larvae were held at 27±3°C and 55-65% RH under a 14:10 LD photoperiod. Mortality was

determined after 72 hours. The criterion for mortality was inability of a larva to move within 15 seconds after being prodded with a blunt probe. Control mortality was never greater than 5%; data were corrected using Abbott's (1925) formula. The responses of the laboratory reference colonies and field colonies were analyzed using a specific linear contrasts (SAS 1988).

## Results and Discussion

### Adult Vial Tests

From May through September 1995, 2131 male tobacco budworm moths from 12 parishes were bioassayed for pyrethroid resistance using the AVT at the discriminating dose of 10 $\mu$g of cypermethrin per vial (Tables 2, 3, and 4 and Figure 1). When these data are summarized by location (parish) and month (Table 3) several observations can be made. Pyrethroid resistance (i.e. percent survival) was lowest during May and June (10-23%), the period when pyrethroids are not recommended for use in the Insecticide Resistance Management Plan for Louisiana (Leonard et al. 1995). Resistance to pyrethroids increased dramatically in July (29-65%) as soon as the pyrethroid use period began and peaked in August and September (41-72%). These data indicate that the non-pyrethroid use period is still useful in managing pyrethroid resistance.

Pyrethroid resistance levels were similar in all the major cotton producing areas of Louisiana (Table 3). The highest levels of pyrethroid resistance were found in the upper Red River Valley (Natchitoches, Caddo and Bossier parishes). Pyrethroid resistance levels in Northeast Louisiana parishes were slightly lower than those in the upper Red River Valley.

Comparing the responses of tobacco budworm moths bioassayed at 10 $\mu$g cypermethrin per vial during 1995 to that determined for the period of 1987-1994 revealed that pyrethroid resistance levels were similar to 1994 (Table 4 and Figure 1). Overall survival in 1995 was 39% compared to 39% in 1994, 48% in 1993, 40% in 1992, 36% in 1991, 37% in 1990, 25% in 1989, 16% in 1988 and 15% in 1987.

From May through August 1995, 2120 male bollworm moths from 10 parishes were bioassayed for pyrethroid resistance using the AVT at doses of 1, 2, and 5 $\mu$g of cypermethrin per vial (Tables 5 and 7). Survival at 1, 2, and 5 $\mu$g per vial ranged from 40-67%, 20-45%, and 0-8%, respectively. Percent survival of bollworm moths at 2 $\mu$g of cypermethrin per vial by location and month is shown in Table 6. Survival was similar in all parishes regardless of pyrethroid usage. Survival was highest during July. July is the time that bollworms occur in cotton in the greatest numbers. Overall survival at 1, 2, and 5 µg of cypermethrin per vial during 1995 appeared to be similar to survival at these doses during 1988-1994 (Table 7 and Figure 2). There appears to be a trend for increased bollworm survival at the 1 and 2 µg/vial dose. There is, however, no clear indication that bollworms are developing resistance to pyrethroids.

Responses of male tobacco budworm moths to 10 and 20 $\mu$g/vial of profenofos are given in Tables 8 and 9. Mean survival at 10 and 20 $\mu$g/vial was 6 and 3%, respectively. Resistance levels to profenofos were lower in 1995 than in 1993 and 1994 (Table 10).

### Larval Topical Application Tests

Tobacco budworms from five locations in Louisiana and one location in Alabama (Prattville) exhibited resistance to cypermethrin, profenofos and methomyl based on topically applied discriminating doses of these insecticides (Table 11). Mortality levels of three colonies at the discriminating dose of cypermethrin (0.0125 $\mu$g/20 mg larva) was 0% compared to 60% for the LSU-LAB colony. Mortality levels for the colonies to the discriminating dose of profenofos (0.09 $\mu$g/larva) ranged from 4 to 36% compared to 98% for the LSU-LAB colony. Mortality levels for the six colonies to the discriminating dose of methomyl (2.5 $\mu$g/larva) ranged from 8 to 52% compared to 51% for the reference LSU-LAB colony.

The 0% mortality value for the Alabama strain to cypermethrin confirms that tobacco budworm resistance to pyrethroid insecticides was again present in Alabama in 1995. Resistance to the carbamate and organophosphate insecticides also was detected in this colony.

## Implications

Resistance in tobacco budworm to carbamate, organophosphate and pyrethroid insecticides was documented again during 1995. Resistance levels to pyrethroids and organophosphates in tobacco budworm were similar in 1995 to 1994. Overall populations of tobacco budworm were low in 1995 (Figures 3, 4, 5, 6, 7, and 8) . As a result, few tobacco budworm field control failures occurred although control in most fields was not satisfactory despite high control costs. Although there appears to be a trend for increased bollworm survival, there have been no reported cases of inadequate field control of bollworm populations. These data indicated that the Insecticide Resistance Management Plan has helped forestall the loss of pyrethroid insecticides for bollworm/tobacco budworm control in cotton.

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collecting tobacco budworm and bollworm male moths and conducting pyrethroid resistance bioassays.

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Table 1. Location, date and host of tobacco budworm field collections during 1994.

| Colony | Host | Date | Collection Location |
|---|---|---|---|
| MRS | Velvetlear | July 17 | Macon Ridge Research Station, Winnsboro, LA |
| Derry | Cotton | July 20 | Derry, LA |
| Evelyn | Cotton | July 20 | Evelyn, LA |
| Prattville | Cotton | July 20 | Prattville, AL |
| RRRS | Cotton | August 28 | Red River Research Station Bossier City, LA |
| Cheneyville | Cotton | August 29 | Cheneyville, LA |

Table 2. Responses of tobacco budworm male moths to cypermethrin during 1995.

| Parish[1] (Location) | Date | % Survival[2] (10 µg/vial) |
|---|---|---|
| Caddo | May 10 | 0 |
| Tensas | May 11 | 17 |
| Caddo | May 17 | 25 |
| Caddo (Belcher) | May 23 | 23 |
| Tensas | May 30 | 20 |
| Tensas | June 6 | 20 |
| Richland | June 6 | 22 |
| Catahoula | June 6 | 20 |
| Caddo | June 6 | 25 |
| Grant | June 13 | 10 |
| Caddo | June 13 | 30 |
| Richland (Mangham) | June 12, 13 | 29 |
| Franklin (Baskin) | June 13 | 21 |
| Richland (Mangham) | June 16 | 10 |
| Franklin (Baskin) | June 16, 17 | 23 |
| Rapides (Meeker) | June 20 | 11 |
| Grant (Colfax) | June 20 | 9 |
| Natchitoches | June 20 | 12 |
| Bossier (Red River Sta.) | June 20 | 17 |
| Caddo | June 20 | 14 |
| Richland (Archibald) | June 21 | 10 |
| Morehouse (Collinston) | June 21 | 17 |
| Catahoula (Peck) | June 21 | 22 |
| Tensas (Waterproof) | June 21 | 21 |
| Tensas (Waterproof) | July 11 | 25 |
| Natchitoches (Derry) | July 18 | 33 |
| Caddo (Gilliam) | July 18 | 37 |
| Tensas (Waterproof) | July 19 | 35 |
| Richland (Archibald) | July 19 | 44 |
| Franklin (Crowville) | July 19 | 40 |
| Franklin (Crowville) | July 20 | 29 |
| Franklin (Baskin) | July 20 | 20 |
| Richland (Mangham) | July 20 | 30 |
| Grant (Colfax) | July 21 | 40 |
| Natchitoches (Derry) | July 21 | 43 |
| Natchitoches (Allen) | July 21 | 50 |
| Madison | July 19, 21 | 38 |
| Madison | July 24 | 36 |
| Tensas (Newellton) | July 24 | 11 |
| Franklin (Crowville) | July 24 | 32 |
| Rapides (Meeker) | July 25 | 33 |
| Grant (Colfax) | July 25 | 30 |
| Natchitoches (Derry) | July 25 | 47 |
| Caddo | July 25 | 37 |
| Tensas (Waterproof) | July 26 | 29 |
| Catahoula (Peck) | July 26 | 44 |
| Franklin (Baskin) | July 26 | 30 |
| Richland (Archibald) | July 26 | 20 |
| Bossier (Red River Sta.) | July 28 | 65 |
| Madison | Aug. 6 | 45 |
| Franklin (Crowville) | Aug. 6 | 20 |
| Rapides (Meeker) | Aug. 8 | 33 |
| Grant (Colfax) | Aug. 8 | 46 |
| Natchitoches (Derry) | Aug. 8 | 57 |
| Caddo (Dixie) | Aug. 8 | 45 |
| Caddo (Belcher) | Aug. 8 | 58 |
| Tensas | Aug. 9 | 45 |
| Richland (Archibald) | Aug. 9 | 37 |
| Bossier (Red River Sta.) | Aug. 9, 10 | 61 |
| West Carroll (Epps) | Aug. 14 | 66 |
| Madison | Aug. 14 | 68 |
| Tensas (Somerset) | Aug. 14 | 68 |

Table 2 Continued.

| | | |
|---|---|---|
| Rapides (Meeker) | Aug. 15 | 75 |
| Natchitoches (Derry) | Aug. 15 | 65 |
| Bossier (Red River Sta.) | Aug. 15 | 60 |
| Caddo | Aug. 15 | 58 |
| Tensas (Waterproof) | Aug. 16 | 45 |
| Tensas (Somerset) | Aug. 21 | 50 |
| Franklin (Crowville) | Aug. 22 | 45 |
| Tensas (Waterproof) | Aug. 22 | 43 |
| Natchitoches (Derry) | Aug. 23 | 60 |
| Grant (Colfax) | Aug. 23 | 48 |
| Franklin (Baskin) | Aug. 23 | 40 |
| Richland (Archibald) | Aug. 23 | 50 |
| Madison (Afton) | Aug. 23 | 44 |
| Madison (Swampers) | Aug. 23 | 33 |
| Madison (Delta) | Aug. 23 | 29 |
| Franklin (Crowville) | Aug. 23 | 33 |
| Madison (Waverly) | Aug. 23 | 40 |
| West Carroll (Epps) | Aug. 23 | 32 |
| Rapides (Meeker) | Aug. 28 | 40 |
| Rapides (Dean Lee Sta.) | Aug. 28 | 39 |
| Bossier (Red River Sta.) | Aug. 28 | 68 |
| Tensas (Somerset) | Aug. 28 | 47 |
| Morehouse (Collinston) | Aug. 29 | 52 |
| Franklin (Crowville) | Aug. 29 | 83 |
| West Carroll (Epps) | Aug. 29 | 50 |
| Tensas (Somerset) | Aug. 29 | 43 |
| Madison (Afton) | Aug. 29 | 38 |
| Madison (Waverly) | Aug. 29 | 35 |
| Madison (Swampers) | Aug. 29 | 41 |
| Madison (Waverly) | Sept. 5 | 36 |
| Madison (Swampers) | Sept. 5 | 52 |
| West Carroll (Epps) | Sept. 5 | 52 |
| Madison (Afton) | Sept. 6 | 26 |
| Tensas (Somerset) | Sept. 6 | 27 |
| Bossier (Red River Sta.) | Sept. 19 | 72 |

[1] If a specific location is not given for a parish, the data represent collections from two or more locations in the parish.

[2] Percent survival at 10 µg/vial is an estimate of the percent homozygous pyrethroid-resistant males present.

Table 3. Percent survival of tobacco budworm male moths at 10 µg cypermethrin per vial by parish and month during 1995.[1]

| Parish | May | June | July | August | September |
|---|---|---|---|---|---|
| Rapides | - | 11 | 33 | 44 | - |
| Grant | - | 10 | 35 | 47 | - |
| Natchitoches | - | 13 | 43 | 60 | - |
| Bossier | - | 18 | 65 | 66 | 72 |
| Caddo | 17 | 19 | 37 | 54 | - |
| Tensas | 19 | 21 | 29 | 49 | 27 |
| Catahoula | - | 21 | 44 | - | - |
| Franklin | - | 23 | 34 | 43 | - |
| Richland | - | 22 | 31 | 45 | - |
| Morehouse | | 17 | - | 52 | - |
| Madison | - | - | 38 | 42 | 37 |
| West Carroll | - | - | - | 41 | 52 |

[1] Percent survival is an estimate of the percent homozygous pyrethroid-resistant males present.

Table 4. Monthly summary of cypermethrin resistance monitoring data for Louisiana obtained using a discriminating dose of 10 µg/vial, 1987-1995.

| | Percent Survival[1] (Number Tested) | | | | | | |
|---|---|---|---|---|---|---|---|
| Year | May | June | July | Aug. | Sept. | Oct. | Total |
| 1987 | 20 | 13 | 18 | 12 | 15 | -- | 15(2607) |
| 1988 | 12 | 5 | 14 | 26 | 30 | -- | 16(2214) |
| 1989 | 11 | 9 | 19 | 40 | 36 | 28 | 25(3057) |
| 1990 | 12 | 14 | 36 | 43 | 48 | 44 | 37(3605) |
| 1991 | 16 | 21 | 31 | 42 | 49 | 36 | 36(3539) |
| 1992 | 14 | 22 | 39 | 58 | 56 | 37 | 40(4281) |
| 1993 | 22 | 29 | 46 | 58 | 68 | -- | 48(2823) |
| 1994 | 20 | 26 | 44 | 50 | 59 | -- | 39(1716) |
| 1995 | 18 | 20 | 37 | 49 | 49 | -- | 39(2131) |

[1]Percent survival is an estimate of the percent homozygous pyrethroid-resistant males present.

Table 5. Responses of bollworm male moths to cypermethrin during 1995.

| Parish | | % Survival | | |
|---|---|---|---|---|
| (Location) | Date | 1 µg/vial | 2 µg/vial | 5 µg/vial |
| Tensas | May 17 | 50 | 25 | 0 |
| Bossier (Red River Sta.) | May 18 | 75 | 15 | 0 |
| Bossier (Red River Sta.) | May 23 | 50 | 20 | 5 |
| Caddo (Gilliam) | May 23 | 35 | 20 | 5 |
| Grant (Colfax) | June 6 | -- | 33 | -- |
| Rapides (Dean Lee Sta.) | June 6 | 60 | -- | 0 |
| Rapides (Dean Lee Sta.) | June 13 | -- | 30 | -- |
| Richland (Archibald) | June 13 | 44 | 11 | 0 |
| Natchitoches | June 13 | 50 | 13 | 0 |
| Caddo | June 13 | 55 | 30 | 0 |
| Bossier (Red River Sta.) | June 13 | 47 | 27 | -- |
| Caddo | June 20 | 33 | 17 | 0 |
| Bossier (Red River Sta.) | June 20 | 35 | 23 | 0 |
| Natchitoches | June 20 | 22 | 22 | 0 |
| Grant (Colfax) | June 20 | 50 | 37 | 0 |
| Rapides (Dean Lee Sta.) | June 20 | 20 | 13 | 0 |
| Richland | June 28 | 22 | 11 | 0 |
| Morehouse | July 11 | 60 | 53 | 8 |
| Franklin (Baskin) | July 11 | 60 | 62 | -- |
| Catahoula (Peck) | July 11 | 62 | 57 | -- |
| Richland (Archibald) | July 11 | 67 | 44 | -- |
| Tensas | July 11 | 60 | 62 | -- |
| Caddo | July 11 | 67 | 53 | 3 |
| Bossier (Red River Sta.) | July 11 | 70 | 35 | 10 |
| Natchitoches | July 11 | 77 | 57 | 7 |
| Grant (Colfax) | July 11 | 64 | 50 | 9 |
| Rapides (Dean Lee Sta.) | July 11 | 75 | 50 | 5 |
| Rapides (Meeker) | July 11 | 67 | 42 | 10 |
| Rapides | July 18 | 85 | 45 | -- |
| Grant (Colfax) | July 18 | 75 | 50 | 10 |
| Natchitoches (Derry) | July 18 | 70 | 60 | 15 |
| Caddo (Gilliam) | July 18 | 60 | 55 | 5 |
| Tensas | July 19 | 45 | 35 | 5 |
| Franklin (Baskin) | July 19 | 60 | 35 | 5 |
| Richland (Archibald) | July 19 | 60 | 47 | -- |
| Madison | July 21 | 50 | -- | -- |
| Rapides (Meeker) | July 25 | 90 | 35 | -- |
| Morehouse (Collinston) | July 26 | 70 | 43 | 13 |
| Rapides (Dean Lee Sta.) | Aug. 8 | 65 | 25 | 10 |
| Grant (Colfax) | Aug. 8 | 55 | 40 | 5 |
| Natchitoches (Derry) | Aug. 8 | 65 | 50 | 10 |
| Caddo | Aug. 8 | 60 | 47 | 7 |
| Tensas | Aug. 9 | 40 | 30 | -- |
| Franklin (Baskin) | Aug. 9 | 50 | 35 | 5 |
| Catahoula (Peck) | Aug. 9 | 60 | 20 | -- |
| Richland (Archibald) | Aug. 9 | 40 | 25 | -- |
| Bossier (Red River Sta.) | Aug. 15 | 75 | 50 | -- |
| Morehouse (Collinston) | Aug. 17 | 53 | 33 | 7 |

Table 6. Percent survival of bollworm male moths at 2 µg of cypermethrin per vial by parish and month during 1995.

| Parish | June | July | August |
|---|---|---|---|
| Rapides | 20 | 43 | 25 |
| Grant | 35 | 50 | 40 |
| Natchitoches | 18 | 38 | 50 |
| Bossier | 24 | 35 | 50 |
| Caddo | 25 | 54 | 47 |
| Tensas | -- | 43 | 30 |
| Franklin | -- | 40 | 35 |
| Morehouse | -- | 47 | 33 |
| Catahoula | -- | 57 | 20 |
| Richland | 11 | 46 | 25 |

Table 7. Monthly summary of cypermethrin resistance monitoring data for bollworms moths, 1988-1995.

| | | % Survival (Number Tested) | | | | | |
|---|---|---|---|---|---|---|---|
| Dose | Year | May | June | July | August | Sept. | Total |
| 1 | 1988 | 10[1] | 0 | 64 | 34 | 30 | 43(515)[2] |
| 2 | | 0 | - | 7 | 15 | 20 | 13(253) |
| 5 | | 0 | 0 | 3 | 2 | 3 | 2(439) |
| 1 | 1989 | - | - | 57 | 60 | 38 | 53(220) |
| 2 | | - | - | 49 | 48 | 30 | 43(220) |
| 5 | | - | - | 5 | 6 | 3 | 4(170) |
| 1 | 1990 | 19 | 33 | 44 | 34 | 24 | 33(1064) |
| 2 | | 5 | 25 | 28 | 16 | 15 | 21(1040) |
| 5 | | 0 | 0 | 6 | 1 | 2 | 2(561) |
| 1 | 1991 | 25 | 54 | 50 | 43 | 37 | 44(1909) |
| 2 | | 11 | 23 | 31 | 23 | 26 | 24(1830) |
| 5 | | 2 | 5 | 7 | 4 | 8 | 5(1666) |
| 1 | 1992 | 31 | 32 | 55 | 45 | 46 | 42(1241) |
| 2 | | 24 | 19 | 41 | 34 | 19 | 31(1295) |
| 5 | | 3 | 2 | 11 | 7 | 12 | 8(932) |
| 1 | 1993 | - | 22 | 53 | 50 | 55 | 49(530) |
| 2 | | - | 21 | 36 | 30 | 48 | 33(733) |
| 5 | | - | 0 | 7 | 7 | 9 | 7(483) |
| 1 | 1994 | 37 | 50 | 60 | 56 | - | 55(643) |
| 2 | | 27 | 33 | 45 | 42 | - | 40)683) |
| 5 | | 3 | 9 | 10 | 8 | - | 8(500) |
| 1 | 1995 | 53 | 40 | 67 | 58 | - | 59(773) |
| 2 | | 20 | 23 | 45 | 38 | - | 36(767) |
| 5 | | 3 | 0 | 8 | 7 | - | 6(580) |

[1] Percent survival at indicated dose.
[2] Number in parenthesis indicates number of moths tested.

Table 8. Responses of tobacco budworm male moths to profenofos during 1995.

| | | % Survival | |
|---|---|---|---|
| Parish | Date | 10 µg/vial | 20 µg/vial |
| Grant | Aug. 28 | 7 | 2 |
| Natchitoches | Aug. 28 | 5 | 0 |
| Richland | Aug. 29 | 4 | 0 |
| Bossier | Aug. 28 | 7 | 4 |

Table 9. Responses of tobacco budworm male moths at various dosages of profenofos by month during 1995.

| Dose | % Survival | | | | |
|---|---|---|---|---|---|
| (µg/vial) | June | July | August | September | Total |
| 10 | - | - | 6 | - | 6 |
| 20 | - | - | 3 | - | 3 |

Table 10. Monthly summary of profenofos resistance monitoring data for tobacco budworm, 1993-1995.

| Dose | | % Survival (Number Tested) | | | | |
|---|---|---|---|---|---|---|
| ($\mu$g/vial) | Year | June | July | August | September | Total |
| 10 | 1993 | - | - | 23 | 43 | 34(135) |
| 20 | | 7 | 5 | - | 14 | 10(155) |
| 10 | 1994 | - | - | 13 | 12 | 12(249) |
| 20 | | - | - | 7 | 0 | 5(280) |
| 10 | 1995 | - | - | 6 | - | 6(200) |
| 20 | | - | - | 3 | - | 3(200) |

Table 11. Responses of third instar tobacco budworm to discriminating doses of selected insecticides

| | Cypermethrin | Profenofos | Methomyl |
|---|---|---|---|
| Colony | 0.0125 $\mu$g/larvae | 0.09 $\mu$g/larvae | 2.5 $\mu$g/larvae |
| LSU-LAB | 60 | 98 | 51 |
| Prattville | 0 | 4 | 12 |
| Cheneyville | -- | 36 | 52 |
| Derry | -- | -- | 8 |
| Evelyn | 0 | 6 | 22 |
| MRS | 0 | 20 | 28 |
| RRRS | -- | -- | 14 |

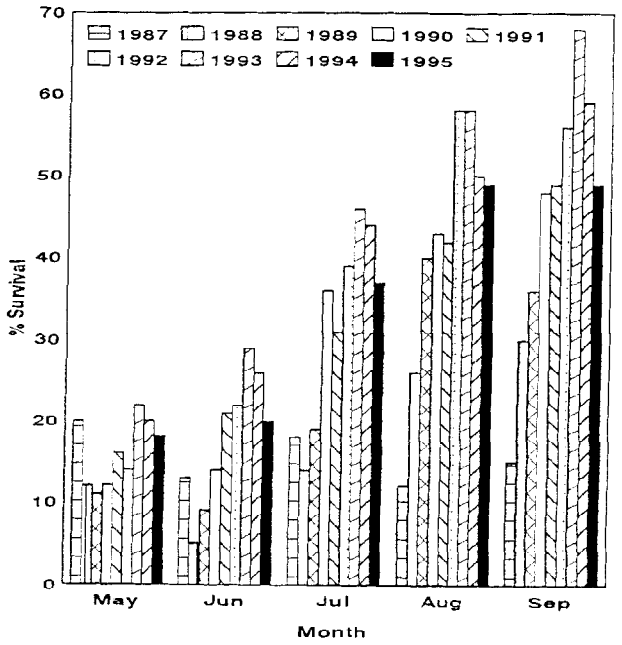


**Figure 1.** Percent survival of tobacco budworm male moths exposed to a discriminating dose (10 $\mu$g/vial) of a pyrethroid (cypermethrin) by month and year, 1987-1995.

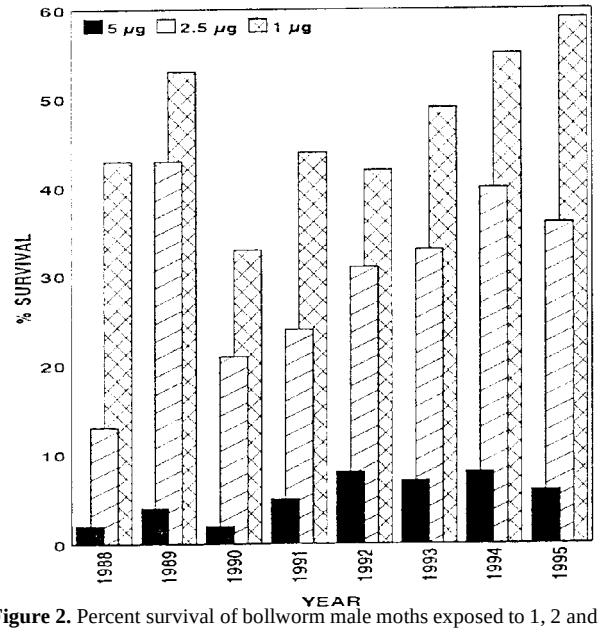


**Figure 2.** Percent survival of bollworm male moths exposed to 1, 2 and 5 µg/vial dose of a pyrethroid (cypermethrin) by year, 1987-1995.

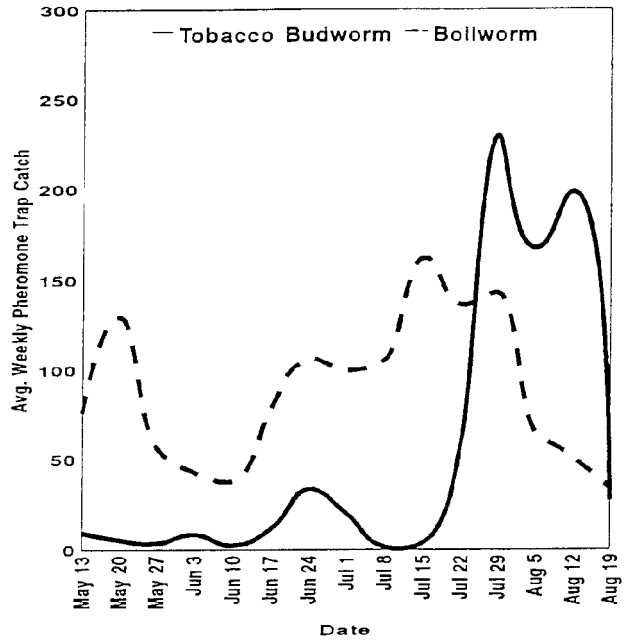


**Figure 3.** Weekly mean tobacco budworm/bollworm pheromone trap catch for Bossier and Caddo parishes during 1995.

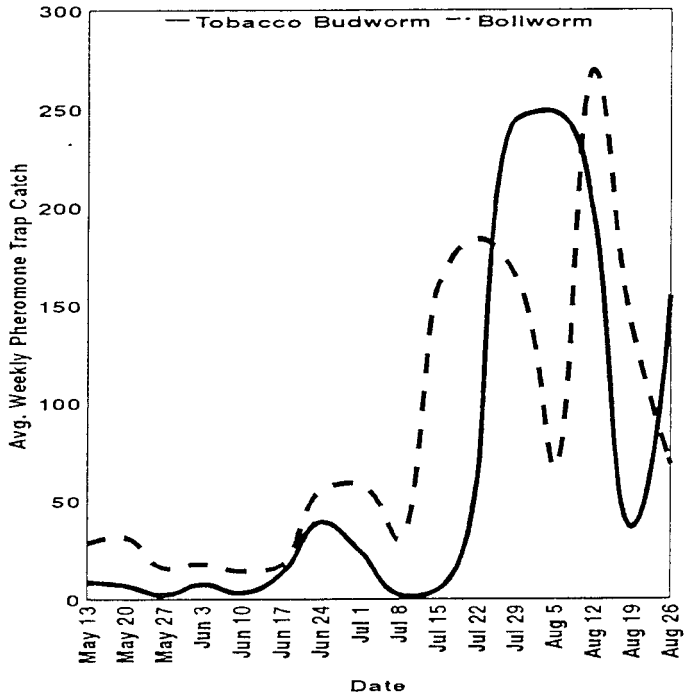


**Figure 4.** Weekly mean tobacco budworm/bollworm pheromone trap catch for Grant and Natchitoches parishes during 1995.

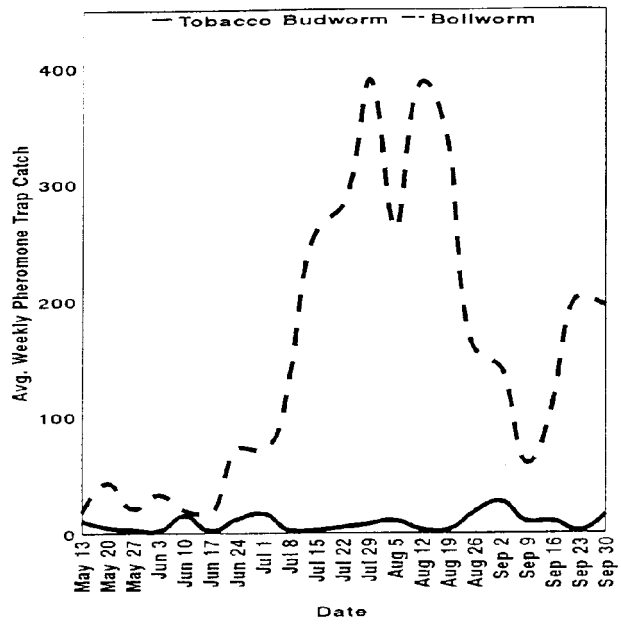


**Figure 5.** Weekly mean tobacco budworm/bollworm pheromone trap catch for Rapides and Avoyelles parishes during 1995.

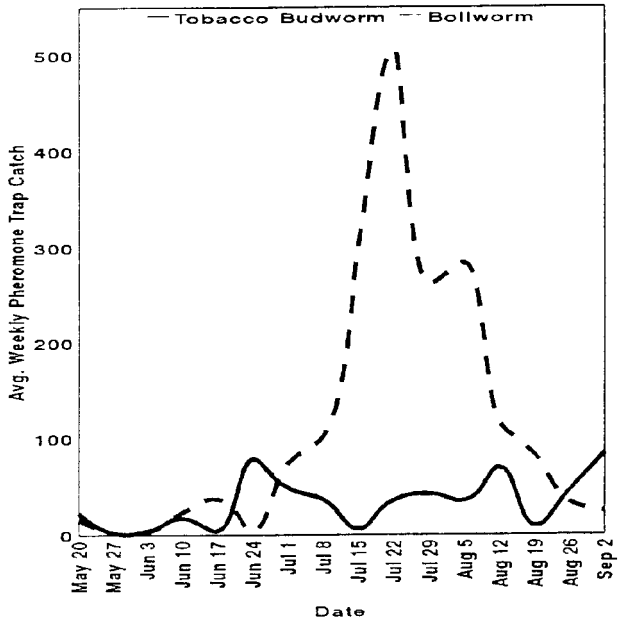


**Figure 6.** Weekly mean tobacco budworm/bollworm pheromone trap catch for East Carroll, north Madison, Morehouse, Ouachita, north Richland, and West Carroll parishes during 1995.

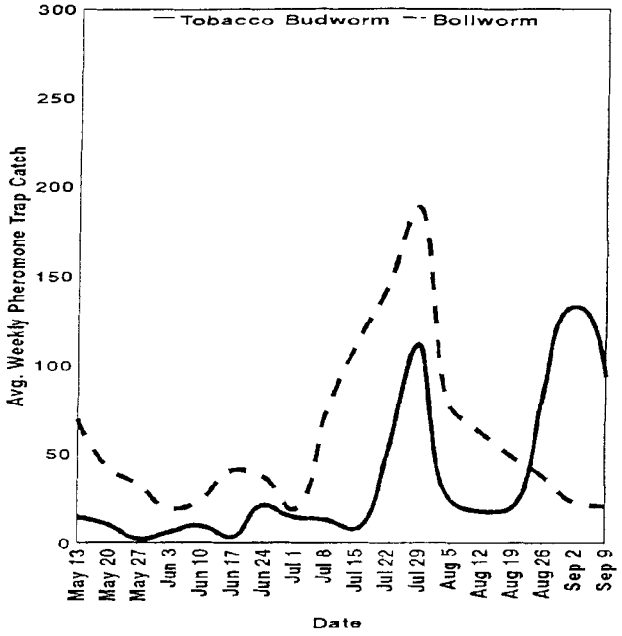


**Figure 7.** Weekly mean tobacco budworm/bollworm pheromone trap catch for Caldwell, Franklin, south Madison, south Richland, and Tensas parishes during 1995.

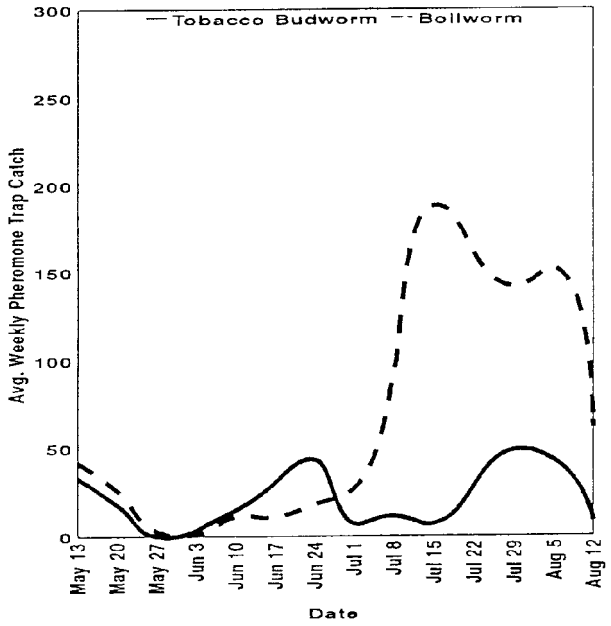


**Figure 8.** Weekly mean tobacco budworm/bollworm pheromone trap catch for Catahoula and Concordia parishes during 1995.