STATUS OF INSECTICIDE RESISTANCE IN TOBACCO BUDWORM AND BOLLWORM IN LOUISIANA DURING 1999

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Abstract

In 1999, resistance was again documented in tobacco budworm populations to pyrethroid insecticides. Over 509 tobacco budworm moths were bioassayed for pyrethroid resistance from May through August 1999 using a discriminating dose of 10 µg in the adult vial test. Pyrethroid resistance levels in 1999 were the highest monitored. Percent survival in May, June, July and August was 46, 64, 53, and 58%, respectively. The high survival level in May and June indicates that a large percentage of the tobacco budworm population was resistant to pyrethroids before growers began to use pyrethroids for tobacco budworm control. The data indicates that pyrethroids no longer provide effective control of tobacco budworm populations. Over 809 male bollworm moths were assayed against a 5µg/vial dose of cypermethrin. Bollworm moth survival levels were similar to 1998 levels. Percent survival in May, June, July and August was 18, 13, 15 and 16%, respectively. This data indicates that bollworm susceptibility to pyrethroid insecticides is 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).

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, Bagwell et al. 1995 and Bagwell et al. 1996). Pyrethroid resistance levels peaked in 1993 when the seasonal mean survival reached 48 percent. Pyrethroid resistance levels declined slightly in 1994 to 39%, but still remained high enough to result in field control failures. 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 24,500 male tobacco budworm moths were bioassayed for pyrethroid resistance from 1987 to 1993 against the 10 mg dose of cypermethrin utilizing the AVT.

Over 16,900 male bollworm moths were bioassayed for pyrethroid resistance from 1987 to 1994. Bollworm males were exposed to 1, 2 or 5 µg dose of cypermethrin utilizing the AVT. No significant changes in bollworm susceptibility to pyrethroids were detected during this period. Over 2100 male bollworm, *Helicoverpa zea* (Boddie), moths were bioassayed against 1,2 or 5 µg/vial doses of cypermethrin during 1995. Data from these bioassays were similar to those obtained from 1988-1994, but indicated that bollworm susceptibility to pyrethroids may be changing.

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 during 1995 (Bagwell et al. 1996). Over 2100 male tobacco budworm moths were bioassayed for pyrethroid resistance from May through September 1995 against a 10 µg dose of cypermethrin utilizing the AVT. Pyrethroid resistance levels during 1995 were similar to 1994 levels. Also, 200 male tobacco budworm moths were bioassayed for resistance to profenofos using the AVT. 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.

In 1996, 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 (Bagwell et al. 1997). Over 1900 male tobacco budworm moths were bioassayed for pyrethroid resistance from May through August 1996 against a 10 µg dose of cypermethrin utilizing the adult vial test. Pyrethroid resistance levels during 1996 were similar to 1995 levels. Two-hundred male tobacco budworm moths were bioassayed for resistance to profenofos using the adult vial test. Resistance to profenofos was similar to 1995 levels. Also,

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199 male tobacco budworm moths were bioassayed for resistance to methomyl using the adult vial test. Resistance to methomyl was similar to 1995 levels. Generally, resistance to carbamates, organophosphates and pyrethroids appears to have stabilized based on monitoring data from 1987 through 1996. Low densities of tobacco budworm populations generally persisted in Louisiana during 1996. However, field control failures did occur in fields with moderate to heavy tobacco budworm populations. Topical application bioassays of larval progeny from several 1996 field collections of tobacco budworms indicated significant resistance to carbamate, pyrethroid and organophosphate insecticides. Over 3600 male bollworm, *Helicoverpa zea* (Boddie), moths were bioassayed against a 5 µg/vial dose of cypermethrin. In 1997, resistance was again documented in tobacco budworm populations to pyrethroid insecticides.

Over 745 tobacco budworm moths were bioassayed for pyrethroid resistance from May through August 1997 using a discriminating dose of 10 µg in the adult vial test (Bagwell et al. 1998). Pyrethroid resistance levels were the highest documented since inception of monitoring in 1987. Percent survival in June was 51%. Previously, the highest level of survival observed in June between 1987 and 1996 had been 29%. This data indicates there was an increased use of pyrethroids in June 1997. Over 1821 male bollworm moths were assayed against a 5µg/vial dose of cypermethrin. Bollworm moth survival levels continue to increase slowly. July survival levels were 14% , the highest observed since inception of monitoring in 1988. This data indicates that bollworm susceptibility to pyrethroid insecticides is changing.

In 1998, resistance was again documented in tobacco budworm populations to pyrethroid insecticides. Over 769 tobacco budworm moths were bioassayed for pyrethroid resistance from May through August 1997 using a discriminating dose of 10 µg in the adult vial test. Pyrethroid resistance levels in 1998 were slightly lower than in 1997. Percent survival in May, June, July and August was 41, 48, 51, and 60%, respectively. The high survival level in May and June indicates that a large percentage of the tobacco budworm population was resistant to pyrethroids before growers began to use pyrethroids for tobacco budworm control. The data suggests that pyrethroids may no longer provide effective control of tobacco budworm populations. Over 1950 male bollworm moths were assayed against a 5µg/vial dose of cypermethrin. Bollworm moth survival levels increased dramatically in 1998. July survival levels were 27% , the highest observed since inception of monitoring in 1988. This data indicates that bollworm susceptibility to pyrethroid insecticides is changing.

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 1998. This information is essential to update and refine current insecticide resistance management guidelines.

Materials and Methods

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 August. 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 µg/vial for tobacco budworm and 5 µg/vial for bollworm). The 10 µg/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 µg/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%.

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.

Results and Discussion

From May through August 1999, 509 male tobacco budworm moths from 12 parishes were bioassayed for pyrethroid resistance using the AVT at the discriminating dose of 10 µg of cypermethrin per vial (Tables 1, 2, and 3 and Figure 1). When these data are summarized by location (parish) and month (Table 2), several observations can be made. Pyrethroid resistance (i.e. percent survival) was lowest during May(38-67%), then increased slightly in June to (11-91%) and remained high through August. This data indicates that

insecticide resistance to tobacco budworm was present long before growers began using pyrethroids for this control.

Comparing the mean yearly responses of tobacco budworm moths bioassayed at 10 µg cypermethrin per vial during 1999 to that determined for the period of 1987-1997 revealed that pyrethroid resistance levels were the highest ever documented(60%--Table 3 and Figure 1). Overall survival in 1998 was 50%, 55% in 1997, 39% in 1996, 39% in 1995, 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 1999, 809 male bollworm moths from 20 parishes were bioassayed for pyrethroid resistance using the AVT at a dose of 5 µg of cypermethrin per vial (Tables 4,5 and 6). Survival at 5 µg per vial by parish ranged from 0-40%, 0-20%, 0-31%, and 0-50% in May, June, July and August, respectively (Table 5). Survival was similar in all months sampled and in parishes regardless of pyrethroid usage. Survival at 5 mg of cypermethrin per vial during 1999 was the similar to that of 1998, the highest level observed since the inception of monitoring. Although no documented cases of field control failures occurred in 1999, the data does indicate that bollworm susceptibility to pyrethroids is changing.

Implications

Resistance levels to pyrethroids in tobacco budworm in 1999 was the highest ever observed. High levels of pyrethroid resistance were documented in tobacco budworm populations in May. This may indicate that either a reversion to susceptibility during overwinter did not occur or that at-planting pyrethroid applications selected for resistant individuals. Regardless, pyrethroids did not offer an effective control tool for tobacco budworm in 1999. Overall populations of tobacco budworm were low in 1999. However, in those fields where tobacco budworm populations were high, insecticide control was not satisfactory and control costs were high. Bollworm survival was similar in 1999 to 1998, however, there have been no documented cases of inadequate field control of bollworm populations. These data indicate that the pyrethroids no longer offer effective control of tobacco budworm populations and that pyrethroid control failure on bollworm may occur in the near future.

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Table 1. Response of tobacco budworm male moths to cypermethrin during 1999.

			Percent Survival[1]	
Parish	**Location**	**Date**	**10 µg/vial**	**# Tested**
Bossier	RRRS	20-May	29	10
Avoyelles	Bunkie	26-May	67	10
Bossier	RRRS	26-May	40	10
Morehouse	Bonita	1-Jun	81	16
Morehouse	Collinston	1-Jun	92	12
Morehouse	Mer Rouge	1-Jun	95	7
Quachita	Millhaven	1-Jun	29	7
Richland	Start	1-Jun	91	11
Tensas	Sommerset	1-Jun	85	20
Avoyelles	Bunkie	2-Jun	25	15
Caldwell	Riverton	2-Jun	18	10
E. Carroll	Gassoway	7-Jun	75	14
Morehouse	Bonita	7-Jun	50	16
Morehouse	Collinston	7-Jun	50	16
Tensas	Sommerset	7-Jun	75	8
Bossier	RRRS	9-Jun	50	5
Caddo	Dixie	9-Jun	33	15
Caddo	Gilliam	9-Jun	0	5
Rapides	Cheneyville	9-Jun	0	5
Rapides	Rapides	9-Jun	11	15
Red River	Coushatta	9-Jun	86	10
Bossier	RRRS	16-Jun	80	10
Caddo	Dixie	16-Jun	57	10
Red River	Coushatta	16-Jun	70	20
Avoyelles	Bunkie	23-Jun	40	10
Bossier	RRRS	23-Jun	83	10
Red River	Coushatta	23-Jun	67	10
Red River	Coushatta	7-Jul	50	10
Bossier	RRRS	21-Jul	44	10
Tensas	Sommerset	22-Jul	56	40
Bossier	RRRS	4-Aug	94	20
Caddo	Dixie	4-Aug	47	15
Caldwell	Riverton	4-Aug	53	10
Natchitoches	Powhatan	4-Aug	53	15
Rapides	Alexandria	4-Aug	50	10
Red River	Coushatta	4-Aug	67	20
Bossier	RRRS	18-Aug	50	10
Caddo	Dixie	18-Aug	35	10
Morehouse	Collinston	18-Aug	75	4
Natchitoches	Powhatan	18-Aug	11	10
Red River	Coushatta	18-Aug	33	6
Tensas	Sommerset	18-Aug	67	12

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

Table 2. Percent survival of tobacco budworm male moths at 10 µg/vial by parish and month during 1999[1].

Parish	May	June	July	August
Avoyelles	67	32	-	-
Bossier	38	71	44	86
Caddo	-	38	-	43
Caldwell	-	18	-	53
East Carroll	-	75	-	-
Morehouse	-	70	-	75
Natchitoches	-	-	-	38
Ouachita	-	29	-	-
Rapides	-	11	-	50
Red River	-	78	50	67
Richland	-	91	-	-
Tensas	-	82	56	67

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

Table 3. Monthly summary of cypermethrin resistance monitoring data for tobacco budworm male moths obtained using a discriminating dose of 10 µg per vial, 1987-1999.

	Percent Survival[1] (Number Tested)				
Year	May	June	July	August	Total
1987	20	13	18	12	15 (2607)
1988	12	5	14	26	16 (2214)
1989	11	9	19	40	25 (3057)
1990	12	14	36	43	37 (3605)
1991	16	21	31	42	36 (3539)
1992	14	22	39	58	40 (4281)
1993	22	29	46	58	48 (2823)
1994	20	26	44	50	39 (1716)
1995	18	20	37	49	39 (2131)
1996	23	24	50	43	39 (1966)
1997	26	51	51	63	55 (745)
1998	41	48	51	60	50 (769)
1999	46	64	53	58	60 (509)

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

Table 4. Response of bollworm male moths to cypermethrin during 1999.

			Percent Survival	
Parish	Location	Date	5 µg/vial	# Tested
Bossier	RRRS	20-May	38	10
Concordia	Vidalia	21-May	20	5
E. Baton Rouge	Ben Hur	21-May	0	5
Red River	Coushatta	26-May	0	10
Rapides	Alexandria	26-May	17	10
Grant	Colfax	26-May	0	5
Rapides	Dean Lee	26-May	0	5
St. Landry	St. Landry	26-May	33	5
Bossier	RRRS	26-May	43	10
Caddo	Dixie	26-May	25	10
Caddo	Gilliam	26-May	0	10
Morehouse	Mer Rouge	1-Jun	20	17
DeSoto	Evelyn	2-Jun	0	5
Bossier	RRRS	2-Jun	0	10
Bossier	RRRS	9-Jun	17	10
Caddo	Dixie	9-Jun	0	10
Bossier	RRRS	16-Jun	29	10
Red River	Coushatta	16-Jun	25	10
Bossier	RRRS	23-Jun	0	10
Red River	Coushatta	23-Jun	0	8
Franklin	MRRS	7-Jul	0	5
Franklin	Fort Necessity	7-Jul	25	5
Caddo	Dixie	7-Jul	20	5
Caldwell	Riverton	7-Jul	0	5
Bossier	RRRS	7-Jul	43	10
Rapides	Alexandria	7-Jul	20	10
Avoyelles	Bunkie	7-Jul	0	10
Red River	Coushatta	7-Jul	25	10
Rapides	DLRS	7-Jul	30	10
Franklin	Gilbert	12-Jul	36	25
Ouchita	Millhaven	13-Jul	30	11
E.Carroll	Hollybrook	20-Jul	18	11
E.Carroll	Gassoway	20-Jul	0	10
Ouchita	Monroe	20-Jul	21	11
Madison	Swampers	20-Jul	0	10
Morehouse	Collinston	20-Jul	0	10
Richland	Start	20-Jul	22	9
Morehouse	Bonita	20-Jul	44	10
Rapides	Cheneyville	21-Jul	0	10
Avoyelles	Bunkie	21-Jul	0	10
Bossier	RRRS	21-Jul	10	10
Rapides	Alexandria	21-Jul	50	5
Red River	Coushatta	21-Jul	0	10
Red River	Coushatta	21-Jul	0	10
Caddo	Gilliam	21-Jul	0	5
Caddo	Dixie	21-Jul	0	5
Ouchita	Millhaven	27-Jul	9	11
Richland	Start	27-Jul	38	10
Tensas	Somerset	27-Jul	13	8
Madison	Swampers	29-Jul	0	10
W.Carroll	Epps	29-Jul	9	11
Richland	Archibald	3-Aug	36	14
Morehouse	Jones	3-Aug	20	10
Madison	Swampers	3-Aug	10	10
Madison	Tallulah	3-Aug	0	10
Tensas	Somerset	3-Aug	17	14
E.Carroll	Gassoway	3-Aug	11	20
E.Carroll	Hollybrook	3-Aug	15	20
Richland	Start	3-Aug	20	10
Caldwell	Riverton	4-Aug	40	5
Caddo	Dixie	4-Aug	33	5
Bossier	RRRS	4-Aug	33	15
Natchitoches	Powhatan	4-Aug	50	10
DeSoto	Evelyn	4-Aug	40	5
Red River	Coushatta	4-Aug	11	10
Rapides	Alexandria	4-Aug	11	10
Avoyelles	Bunkie	4-Aug	0	10
Ouchita	Monroe	9-Aug	0	5
Morehouse	Collinston	9-Aug	0	8
E.Carroll	Gassoway	9-Aug	0	7
Morehouse	Mer Rouge	9-Aug	0	11

Richland	Start	9-Aug	0	10
Morehouse	Jones	9-Aug	20	10
Morehouse	Bonita	9-Aug	10	10
Madison	Tallulah	9-Aug	11	10
Morehouse	Mer Rouge	9-Aug	0	8
Bossier	RRRS	18-Aug	11	10
Red River	Coushatta	18-Aug	0	10
Grant	Colfax	18-Aug	0	7
St. Landry	St. Landry	18-Aug	0	7
Caddo	Dixie	18-Aug	22	10
Morehouse	Bonita	18-Aug	0	8
Morehouse	Mer Rouge	18-Aug	38	16
E.Carroll	Gassoway	18-Aug	10	10
Madison	Tallulah	18-Aug	43	7

Table 5. Percent survival of bollworm male moths at 5 µg cypermethrin per vial by parish and month during 1999.

Parish	May	June	July	August
Avoyelles	-	-	0	0
Bossier	40	13	24	25
Caddo	13	0	7	25
Caldwell	-	-	0	40
Concordia	20	-	-	-
DeSoto	-	0	-	40
E. Baton Rouge	0	-	-	-
East Carroll	-	-	10	11
Franklin	-	-	29	-
Grant	0	-	-	0
Madison	-	-	0	12
Morehouse	-	20	21	14
Natchitoches	-	-	-	50
Ouachita	-	-	18	0
Rapides	9	-	19	11
Red River	0	8	8	6
Richland	-	-	31	21
St. Landry	33	-	-	0
Tensas	-	-	13	17
West Carroll	-	-	9	-

Table 6. Monthly summary of cypermethrin resistance monitoring data for bollworm moths, 1988-1999.

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	591666)
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)
5	1996	4	3	9	5	-	7(3697)
5	1997	4	4	14	7	-	9(1821)
5	1998	12	14	27	19	-	18(1950)
5	1999	18	13	15	16		16(809)

[1] Percent survival at indicated dose.

[2] Number in parenthesis indicates number of moths tested.

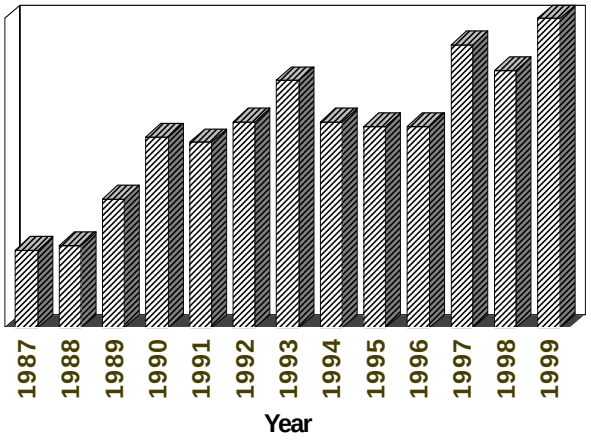

Figure 1. Percent survival of tobacco budworm male moths exposed to a discriminating dose (10 µg/vial) of a pyrethroid (cypermethrin) by month and year, 1987-1999.

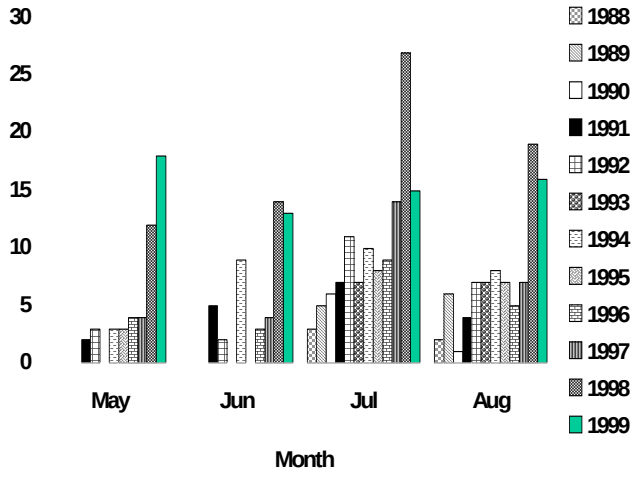

Figure 2. Percent survival of bollworm male moths exposed to 5 μg/vial dose of a pyrethroid (cypermethrin) by year, 1988-1999.