STATUS OF INSECTICIDE RESISTANCE IN TOBACCO BUDWORM AND BOLLWORM IN LOUISIANA DURING 2000

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Abstract

In 2000, resistance was again documented in tobacco budworm populations to pyrethroid insecticides. Over 686 tobacco budworm moths were bioassayed for pyrethroid resistance from May through August 2000 using a discriminating dose of 10 µg in the adult vial test. Pyrethroid resistance levels in 2000 were similar to those measured since 1997. Percent survival in May, June, July and August was 62, 22, 43, and 63, 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 1445 male bollworm moths were assayed against a 5µg/vial dose of cypermethrin. Bollworm moth survival levels were similar to 1998 and 1999 levels. Percent survival in May, June, July and August was 13, 20, 19 and 14%, 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.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:785-790 (2001)
National Cotton Council, Memphis TN

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, 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 (Bagwell et al. 1999). 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.

In 1999, resistance was again documented in tobacco budworm populations to pyrethroid insecticides (Bagwell et al. 2000). 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.

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 (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 2000, 686 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 high during May (50-75%) declined in June and July (0-57%) and was again high in August (0-86%). Percent survival in August was excessively high in Franklin (86%) parish. This data indicates that insecticide resistance to tobacco budworm was present long before growers began using pyrethroids for this control and that pyrethroids will not provide effective control of tobacco budworm populations.

Comparing the mean yearly responses of tobacco budworm moths bioassayed at 10 µg cypermethrin per vial during 2000 to that determined for the period of 1987-1999 revealed that pyrethroid resistance levels were similar to 1997-1999 (54%--Table 3 and Figure 1). Overall survival in 2000 was 61%, 60 in 1999, 50% in 1999, 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 2000, 1035 male bollworm moths from 15 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 6-25%, 0-44%, 9-50% and 0-44% 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 2000 was similar to that of 1999 and 1998. Although no documented cases of field control failures occurred in 2000, the data does indicate that bollworm susceptibility to pyrethroids is changing.

Implications

Resistance levels to pyrethroids in tobacco budworm in 2000 was similar to those levels observed since 1997. 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 2000. Overall populations of tobacco budworm were high in 2000. However, only about 20% of the states cotton crop was planted to a non-Bt cotton variety. Bollworm survival was similar in 2000 to 1999 and 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.

Acknowledgements

The financial support given by Cotton Incorporated and IRAC/US to support insecticide resistance monitoring in Louisiana is gratefully acknowledged. Appreciation is expressed to Carol Pinnell-Alison and Marion Farris of the Louisiana Cooperative Extension Service for their assistance in collecting tobacco budworm and bollworm male moths and conducting pyrethroid resistance bioassays.

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Table 1. Response of tobacco budworm male moths to cypermethrin during 2000.

			10ug/vial	
Parish	**Location**	**Date**	**#Tested**	**%Survival**
Bossier	RRRS	5/18/2000	10	50
Caddo	Gilliam	5/18/2000	10	50
Rapides	Dean Lee	5/18/2000	10	70
Bossier	RRRS	5/25/2000	10	70
Ouachita	Fondale	5/25/2000	10	60
Rapides	Alexandria	5/25/2000	10	63
Morehouse	Mer Rouge	6/20/2000	7	57
Bossier	RRRS	6/21/2000	10	30
Natchitoches	Powhatan	6/21/2000	10	0
Bossier	RRRS	7/6/2000	20	61
Avoyelles	Bunkie	7/6/2000	5	0
East Carroll	Gassoway	7/11/2000	18	67
East Carroll	Gassoway	7/18/2000	30	57
Bossier	RRRS	7/20/2000	20	30
Grant	Colfax	7/20/2000	7	57
Rapides	Dean Lee	7/20/2000	10	38
Franklin	MRRS	7/20/2000	10	30
Bossier	RRRS	8/3/2000	20	70
Red River	Coushatta	8/3/2000	5	60
Grant	Colfax	8/3/2000	5	0
Caddo	Dixie	8/3/2000	10	75
Franklin	MRRS	8/3/2000	10	78
Catahoula	Peck	8/3/2000	14	79
Morehouse	Oak Ridge	8/17/2000	10	80
East Carroll	Monticello	8/17/2000	14	50
East Carroll	Gassoway	8/17/2000	20	70
Morehouse	Jones	8/17/2000	12	75
Bossier	RRRS	8/17/2000	10	67
Catahoula	Peck	8/17/2000	20	65
Franklin	MRRS	8/17/2000	25	88
Morehouse	Jones	8/25/2000	10	80
East Carroll	Gassoway	8/25/2000	10	60
East Carroll	Waverly	8/25/2000	9	33
Bossier	RRRS	8/31/2000	10	67

[1] Percent survival at 10 ug/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 2000[1].

Parish	**May**	**June**	**July**	**August**
Avoyelles	-	-	0	-
Bossier	60	30	45	77
Caddo	50	-	-	75
Catahoula	-	-	-	71
East Carroll	-	-	59	57
Franklin	-	-	30	86
Grant	-	-	57	0
Morehouse	-	57	-	78
Natchitoches	-	0	-	-
Ouachita	60	-	-	-
Rapides	75	-	38	-
Red River	-	-	-	60

[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, 1987-2000.

	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)
2000	62	22	43	63	61 (686)

[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 2000.

			5ug/vial	
Parish	**Location**	**Date**	**#Tested**	**%Survival**
Bossier	RRRS	5/18/00	10	30
Rapides	Alexandria	5/18/00	10	25
Rapides	Dean Lee	5/18/00	10	25
Caddo	Gilliam	5/18/00	10	33
Caddo	Dixie	5/18/00	10	14
Bossier	RRRS	5/25/00	10	20
Rapides	Alexandria	5/25/00	10	0
Rapides	Dean Lee	5/25/00	10	20
Caddo	Gilliam	5/25/00	20	6
Caddo	Dixie	5/25/00	20	5
Ouachita	Fondale	5/25/00	20	6
East Carroll	Gassoway	6/20/00	10	13
Bossier	RRRS	6/21/00	10	0
Rapides	Alexandria	6/21/00	9	44
Caddo	Gilliam	6/21/00	10	22
Caddo	Dixie	6/21/00	10	20
East Carroll	Gassoway	6/27/00	10	23
Morehouse	Mer Rouge	7/6/00	10	0
Morehouse	Jones	7/6/00	15	0
Rapides	Cheneyville	7/6/00	20	30
Rapides	Alexandria	7/6/00	10	10
Avoyelles	Bunkie	7/6/00	10	11
Red River	Coushatta	7/6/00	10	40
Bossier	RRRS	7/6/00	20	33
Caddo	Dixie	7/6/00	10	11
Caldwell	Riverton	7/6/00	10	20
Caddo	Gilliam	7/6/00	5	50
Ouachita	Fondale	7/6/00	15	20
Catahoula	Peck	7/6/00	20	25
Morehouse	Mer Rouge	7/11/00	14	14
East Carroll	Monticello	7/11/00	14	27
East Carroll	Gassoway	7/11/00	16	17
East Carroll	Gassoway	7/18/00	24	27
Richland	Start	7/18/00	20	17
Morehouse	Jones	7/18/00	14	50
Rapides	Cheneyville	7/20/00	10	11
Natchitoches	Powhatan	7/20/00	10	25
Avoyelles	Bunkie	7/20/00	10	11
Red River	Coushatta	7/20/00	10	20

Table 4, Continued

Parish	Location	Date	5ug/vial #Tested	%Survival
Bossier	RRRS	7/20/00	20	10
Caldwell	Riverton	7/20/00	10	0
Ouachita	Fondale	7/20/00	10	0
Franklin	MRRS	7/20/00	20	22
Catahoula	Peck	7/20/00	9	33
East Carroll	Gassoway	8/1/00	28	7
Morehouse	Jones	8/1/00	10	0
Morehouse	Mer Rouge	8/1/00	20	15
Bossier	RRRS	8/3/00	20	17
Natchitoches	Powhatan	8/3/00	10	0
Grant	Colfax	8/3/00	10	13
Avoyelles	Bunkie	8/3/00	10	33
Rapides	Alexandria	8/3/00	10	27
Red River	Coushatta	8/3/00	20	28
Caddo	Dixie	8/3/00	10	25
Franklin	Fort Necessity	8/3/00	5	0
Caddo	Gilliam	8/3/00	5	80
Ouachita	Fondale	8/3/00	5	0
Catahoula	Peck	8/3/00	10	22
Franklin	MRRS	8/3/00	20	15
Morehouse	Mer Rouge	8/17/00	7	19
Morehouse	Jones	8/17/00	7	14
Rapides	Cheneyville	8/17/00	10	0
Rapides	Cheneyville	8/17/00	10	0
Bossier	RRRS	8/17/00	10	0
Rapides	Alexandria	8/17/00	10	13
Red River	Coushatta	8/17/00	10	20
Grant	Colfax	8/17/00	10	0
East Carroll	Gassoway	8/25/00	10	25
Rapides	Cheneyville	8/31/00	10	0
Rapides	Alexandria	8/31/00	6	0
Red River	Coushatta	8/31/00	10	0
Bossier	RRRS	8/31/00	10	0

Table 5. Percent survival of bollworm male moths at 5 µg cypermethrin per vial by parish and month during 2000.

Parish	May	June	July	August
Avoyelles	-	-	11	33
Bossier	25	0	11	13
Caddo	9	21	50	44
Caldwell	-	-	10	-
Catahoula	-	-	28	22
East Carroll	-	18	25	11
Franklin	-	-	22	14
Grant	-	-	-	13
Morehouse	-	-	9	13
Natchitoches	-	-	25	0
Ouachita	6	-	13	0
Rapides	16	44	16	6
Red River	-	-	31	15
Richland	-	-	17	-
St. Landry	-	-	18	-

Table 6. Monthly summary of cypermethrin resistance monitoring data for bollworm moths. 1999-2000.

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)
							18(1950)
5	1998	12	14	27	19	-	
5	1999	18	13	15	16		16(809)
5	2000	13	20	19	14	-	16(1445)

[1] Percent survival at indicated dose.

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