2003 BELTWIDE COTTON CONFERENCES, NASHVILLE, TN – JANUARY 6-10

INSECTICIDE SUSCEPTIBILITY OF LOUISIANA BOLLWORM AND TOBACCO BUDWORM POPULATIONS

D.R. Cook, J. Temple, R.H. Gable, S. Micinski, W.F. Waltman, A.M. Stewart, B.R. Leonard, and R.D. Bagwell
Louisiana State University AgCenter
Baton Rouge, LA

Abstract

Sixteen pairs of pheromone-baited wire cone traps representing 11 parishes in Louisiana were used to survey insecticide susceptibility of tobacco budworm and bollworm from Jun to Sep during 2002. Percent survival (10µg/vial cypermethrin in AVT) of tobacco budworm moths ranged from 47% to 69%, with a mean survival of 61%. Percent survival (5µg/vial cypermethrin in AVT) for bollworm moths ranged from 26% to 42%, with a mean survival of 34%. No bollworm control failures with pyrethroids were reported in Louisiana during 2002. Susceptibility of tobacco budworm and bollworm to spinosad also was monitored using the AVT (5µg/vial and 15µg/vial concentrations). Tobacco budworm survival ranged from 31% to 70% and 0% to 20% for the 5µg/vial and 15µg/vial concentrations, respectively. Higher than expected survival (31% to 56% at 15µg/vial) of male tobacco budworm moths was observed at several locations in Northeast Louisiana. Bollworm survival ranged from 47% to 63% and 11% to 18% for the 5µg/vial and 15µg/vial concentrations, respectively. Problems in controlling infestations of tobacco budworm following applications of Tracer 4SC (spinosad) were reported in isolated fields in Northeast Louisiana during 2002.

Introduction

Insecticide resistance in key insect pests is an important issue in cotton production. Two important cotton pests in the Mid-South and Southeastern United States are the tobacco budworm, *Heliothis virescens* (F.), and the bollworm, *Helicoverpa zea* (Boddie). Resistance to organochlorines, DDT, organophosphates (Sparks 1981), and carbamates (Elzen et al. 1992) has been reported with both species. Resistance in tobacco budworm populations to pyrethroid insecticides was documented in Arkansas (Plapp et al. 1987), Louisiana (Leonard et al. 1987), Mississippi (Roush and Luttrell 1987), and Texas (Allen et al. 1987, Plapp et al. 1987) during 1986. In response, pyrethroid resistance management plans were implemented in those states (Anonymous 1986).

Systematic insecticide resistance monitoring of tobacco budworm moths using the adult vial test (AVT) described by Plapp et al. (1987) has been used in annual surveys for over 15 years. In Louisiana, pyrethroid (10µg/vial cypermethrin) resistance in tobacco budworm populations increased from 1986 to 1993 (Graves et al. 1994), peaking at a mean survival of 48% for the period of May through Aug in 1993. Resistance levels stabilized from 1994 to 1996 with a mean survival of 39% (Bagwell et al. 1997). Pyrethroid resistance again increased during 1997 to 2001 (Bagwell et al. 2001, Cook et al. 2002) with survival ranging from 50% to 61%. In response to the high levels of resistance in tobacco budworm populations, pyrethroids were not recommended for tobacco budworm control in Louisiana after 1998.

Pyrethroid resistance monitoring of bollworm populations began in Louisiana during 1988. Mean bollworm survival to a 5µg/vial concentration of cypermethrin has increased from 2% in 1988 to 21% in 2001 (Graves et al. 1994, Bagwell et al. 2001, Cook et al. 2002). Resistance to insecticides including DDT and organochlorine insecticides has been reported in bollworm (Sparks 1981). Field control failures (Walker et al. 1998) resulting from pyrethroid-resistant populations of bollworm (Brown et al. 1998) have been reported in South Carolina. In most cotton production areas, organophosphates, carbamates, and pyrethroids have generally remained effective against bollworm (Kharboutli et al. 1999, Brickle et al. 2000, Bagwell et al. 2001).

Monitoring of tobacco budworm and bollworm susceptibility to spinosad began during 1991 and 2000, respectively in Louisiana. Bollworm and tobacco budworm moths were monitored from May to Sep using 5µg and 15µg concentrations of spinosad in the AVT. In 2001, the mean tobacco budworm survival was 11% and 13% for the 5µg/vial and 15µg/vial concentrations of spinosad, respectively (Cook et al. 2002). Mean survival of bollworm moths was 11% at the 5µg/vial concentration and 10% at the 15µg/vial concentration (Cook et al. 2002).

This report summarizes the results of monitoring tobacco budworm and bollworm populations exposed to cypermethrin and spinosad with the AVT. Control problems associated with Tracer applications were reported in localized areas of Northeast Louisiana during the 2002 growing season. In response to these observations, collections from these fields also were tested for susceptibility to spinosad in laboratory bioassays. The results were compared to that of 1991 and 2001 field collections and a laboratory reference colony.

Materials and Methods

Adult vial bioassays (AVT) similar to those described by Plapp et al. (1987, 1990) were utilized to monitor the susceptibility of field collected tobacco budworm and bollworm moths to cypermethrin (Chem Service, Inc., P.O. Box 599, West Chester, PA 19381) and spinosad (Tracer 4SC, Dow Agrosciences, 9330 Zionsville Rd., Indianapolis, IN 46268). Stock solutions of cypermethrin and spinosad were made by dissolving technical grade insecticide in acetone. Serial dilutions were made from each stock solution to yield the desired insecticide concentrations. The interior surface of 20 ml glass scintillation vials was coated with insecticide by pipetting 0.5 ml of the appropriate insecticide solution into the vials. These vials were rotated on a modified hot dog roller (heating element disconnected) until all of the acetone had evaporated. Vials were stored in a dark environment until used.

Male tobacco budworm and bollworm moths were collected using wire cone traps (Hartstack et al. 1979) baited with artificial sex pheromone lures (Hendricks et al. 1987) from May through Sep. Moths were collected from 11 parishes within the cotton production regions of Louisiana. In addition, more intensive sampling was conducted at or near the Northeast Research Station (Macon Ridge location, Franklin Parish), the Red River Research Station (Bossier Parish), and the Dean Lee Research Station (Rapides Parish). The insecticide concentrations used in these monitoring efforts included 10µg/vial cypermethrin for tobacco budworm, 5µg/vial cypermethrin for bollworm and 5µg/vial and 15µg/vial spinosad for both tobacco budworm and bollworm. Moths were placed into insecticide-treated and control (non-treated) vials (1 moth/vial) and mortality was determined after 24-h of exposure (HAE). Only moths that appeared healthy were used for testing. Moths were considered dead if they were incapable of sustained flight for 3 ft. Data were corrected for control mortality using Abbott's (1925) formula.

Tobacco budworm larvae were collected from fields in which control problems were experience following Tracer 4SC (spinosad) applications and placed into 30 ml plastic cups (Solo Cup Company, Urbana, IL 61801) containing meridic diet described by Shour and Sparks (1981). Field collected insects were allowed to complete one generation in the laboratory to achieve adequate numbers of larvae for laboratory bioassays. Technical grade spinosad was dissolved in acetone, and serial dilutions were used to yield the desired concentrations. One µl of solution was applied to the thoracic dorsum of each larva using a Hamilton microsyringe. Larvae in the control treatment were treated with 1µl of acetone. A minimum of 40 larvae (larval weight, 15-25 mg) per dose was utilized in all bioassays. Mortality was determined at 72 hours after treatment. Larvae were considered dead if they could not right themselves after being rolled onto their dorsal surface. Data were corrected for control mortality (Abbott 1925) and analyzed by probit analysis using Polo PC (LeOra Software 1987

Results and Discussion

Approximately 400 tobacco budworm moths were assayed for pyrethroid susceptibility from Jun to Sep 2002. Percent survival in Jun, Jul, Aug, and Sep was 67%, 69%, 47%, and 68%, respectively, with an average survival of 61% (Table 1). Tobacco budworm survival during Jun and Sep was the highest observed for those respective months since resistance monitoring was initiated in Louisiana. Average survival for the entire season was similar to that observed during 1999 to 2001. These data further indicate that pyrethroids are no longer a viable option for tobacco budworm control in Louisiana and justify their removal from Louisiana Cooperative Extension Service recommendations.

Over 1,100 bollworm moths were assayed for pyrethroid susceptibility from Jun to Sep 2002. Percent survival for Jun, Jul, Aug, and Sep was 28%, 42%, 26%, and 28%, respectively, with a mean survival of 34% (Table 2). Survival observed during Jun, Jul, Aug, and Sep was higher than previously observed for the respective months in Louisiana. Bollworm survival (42%) during Jul was the highest observed for the 5µg/vial concentration of cypermethrin since the initiation of bollworm resistance monitoring in Louisiana. However, no field control failures of bollworm with pyrethroids were reported in Louisiana during 2002. Pyrethroids remain the most cost-effective insecticides for bollworm control in cotton.

Tobacco budworm survival (123 insects) for the 5µg/vial concentration of spinosad during Jun, Jul, and Aug was 31%, 43%, and 70%, respectively with an average survival of 51% (Table 3). Tobacco budworm survival at the 5µg concentration during Jun, Jul, Aug, and the season average was higher than that previously observed for the respective periods in Louisiana. Survival (414 insects) at the 15µg/vial concentration during Jun, Jul, Aug, and Sep was 20%, 9%, 13%, and 0%, respectively (Table 3). The average survival at 15µg was 10% and was lower than that observed during 2000 and 2001. Higher than expected survival (33%-50% at 15µg/vial) of male tobacco budworm moths was observed at several locations in Northeast Louisiana.

Bollworm survival (367 insects tested) for the 5µg/vial concentration of spinosad during Jun, Jul, and Aug was 47%, 55%, and 63%, respectively, with an average survival of 56% (Table 4). Survival was higher than that previously observed in Louisiana. Bollworm survival (934 insects tested) at the 15µg/vial concentration during Jun, Jul, and Aug was 18%, 15%, and 11%, respectively, with an average survival of 14% (Table 4).

Problems controlling infestations of bollworm / tobacco budworm larvae with applications of Tracer 4SC (spinosad) occurred in isolated fields in Northeast Louisiana during 2002. The Peck, Giltner, and Giltner II colonies had significantly higher LD_{50} values compared to the LSU Lab 2001 (laboratory reference) colonies based on non overlap of the 95% confidence limits (Table 5). The LD_{50} values of these colonies were not significant different from those of the 1991 and 2001 colonies collected from cotton fields and the 2001 velvetleaf colony, with one exception (2002 Giltner colony significantly lower LD_{50} value compared to the 2001 Giltner Swamp colony). These control problems likely resulted from mixed populations of bollworm and tobacco budworm larvae, field configuration that limited the effectiveness of aerial insecticide applications, and frequent rainfall events that reduced the residual efficacy of the insecticide applications.

Acknowledgments

The assistance of Carroll Pinnell-Allison and Barrett McKnight and the financial support of the LSU AgCenter, Cotton Incorporated, and Louisiana's cotton producers are greatly appreciated.

References

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

Allen, C. T., W. L. Multer, R. R. Ninzenmayer, and J. S. Armstrong. 1987. Development of pyrethroid resistance in *Heliothis* populations in cotton in Texas, pp. 332-335. *In* Proceedings 1987 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Anonymous. 1986. Cotton entomologists seek to delay pyrethroid resistance in insects. MAFES Res. Highlights 49:8.

Bagwell, R. D., D. R. Cook, B. R. Leonard, S. Micinski, and E. Burris. 2001. Status of insecticide resistance in tobacco budworm and bollworm in Louisiana during 2000, pp. 785-790. *In* Proceedings 2001 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Brickle, D. S., S. G. Turnipseed, and M. J. Sullivan. 2000. Comparison of different chemistries and rates against bollworm in Bt and conventional cotton, pp. 971-975. *In* Proceedings 2000 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Brown, T. M., P. K. Bryson, D. S. Brickle, S. Pimprale, F. Arnette, M. E. Roof, J. T. Walker, and M. J. Sullivan. 1998. Pyrethroid-resistant *Helicoverpa zea* and transgenic cotton in South Carolina. Crop Protection 17: 441-445.

Cook, D. R., B. R. Leonard, and J. Gore. 2001. Evaluation of spinosad, indoxacarb, and S-1812 against selected lepidopteran pests, pp. 808-812. *In* Proceedings 2001 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Cook, D. R., B. R. Leonard, R. D. Bagwell, S. Micinski, J. Gore, R. H. Gable, and A. M. Stewart. 2002. Insecticide susceptibility of Louisiana bollworm and tobacco budworm populations, CD-ROM H042.pdf. *In* Proceedings 2002 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Elzen, G. W., B. R. Leonard, J. B. Graves, E. Burris, and S. Micinski. 1992. Resistance to pyrethroid, carbamate, and organophosphate insecticides in field populations of tobacco budworm (Lepidoptera: Noctuidae) in 1990. J. Econ. Entomol. 85:2064-2072.

Graves, J. B., B. R. Leonard, E. Burris, S. Micinski, S. H. Martin, C. A. White, and J. L. Baldwin. 1994. Status of insecticide resistance in tobacco budworm and bollworm in Louisiana, pp. 769-774. *In* Proceedings 1994 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Hartstack, A. W., J. A. Witz, and D. R. Buck. 1979. Moth traps for the tobacco budworm. J. Econ. Entomol. 75:519-522.

Hendricks, D. E., T. N. Shaver, and J. L. Goodenough. 1987. Development of bioassay of molded polyvinyl chloride substrates for dispensing tobacco budworm (Lepidoptera: Noctuidae) sex pheromone bait formulations. Environ. Entomol. 16:605-613.

Kharboutli, M. S., C. T. Allen, C. Capps, and L. Earnest. 1999. 1998 bollworm and tobacco budworm control studies, pp. 1186-1189. *In* Proceedings 1999 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

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* Proceedings 2000 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

LeOra Software. 1987. POLO-PC a user's guide to Probit or Logit analysis. LeOra Software, Berkeley, CA.

Plapp, F. W., G. M. McWhorter, and W. H. Vance. 1987. Monitoring for pyrethroid resistance in the tobacco budworm in Texas-1986, pp. 324-326. *In* Proceedings 1987 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Plapp, F. W., Jr., J. A Jackman, C. Campanhola, R. E. Frisbie, J. B. Graves, R. G. Luttrell, W. F. Kitten, and M. Wall. 1990. Monitoring and management of pyrethroid resistance in tobacco budworm (Lepidoptera: Noctuidae) in Texas, Mississippi, Louisiana, Arkansas, and Oklahoma. J. Econ. Entomol. 83:335-341.

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* Proceedings 1987 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Shour, M. H. and T. C. Sparks. 1981. Biology of the soybean looper, *Pseudoplusia includens*: characterizations of last stage larvae. Ann. Entomol. Soc. Am. 74: 531-535.

Sparks, T. C. 1981. Development of resistance in *Heliothis zea* and *Heliothis virescens* in North America. Bull. Entomol. Soc. Am. 27: 186-192.

Walker, J. T., M. J. Sullivan, S. Turnipseed, M. E. Roof, and T. M. Brown. 1998. Prospects for field management of pyrethroid-resistant corn earworm (cotton bollworm) populations in South Carolina, pp. 1145-1147. *In* Proceedings 1998 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Table 1. Summary of cypermethrin (10µg/vial) resistance monitoring data for tobacco budworm male moths, 1987-2002.

	Month – Percent Survival (Number Tested)					
Year[1]	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Mean**
1987	20	13	18	12	15	15 (2607)
1988	12	5	14	26	30	16 (2214)
1989	11	9	19	40	36	25 (3057)
1990	12	14	36	43	48	37 (3605)
1991	16	21	31	42	49	36 (3539)
1992	14	22	39	58	56	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)
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)
2001	69	47	73	76	57	59 (728)
2002	-	67	69	47	68	61 (392)

[1]Data prior to 2001 summarized in Bagwell et al. (2001).

Table 2. Summary of cypermethrin (5µg per vial) resistance monitoring data for bollworm male moths, 1988-2002.

	Month – Percent Survival (Number Tested)					
Year[1]	May	Jun	Jul	Aug	Sep	Mean
1988	0	0	3	2	3	2 (439)
1989	-	-	5	6	3	4 (170)
1990	0	0	6	1	2	2 (561)
1991	2	5	7	4	8	5 (1666)
1992	3	2	11	7	12	8 (932)
1993	-	0	7	7	9	7 (483)
1994	3	9	10	8	-	8 (500)
1995	3	0	8	7	-	6 (580)
1996	4	3	9	5	-	7 (3697)
1997	4	4	14	7	-	9 (1821)
1998	12	14	27	19	-	18 (1950)
1999	18	13	15	16	-	16 (809)
2000	13	20	19	14	-	16 (1445)
2001	10	6	32	13	16	21 (829)
2002	-	28	42	26	28	34 (1119)

[1]Data prior to 2001 summarized in Bagwell et al. (2001).

Table 3. Responses of field-collected male tobacco budworm moths to spinosad in AVT, 1991-1993 and 2000-2002.

		Month - Percent Survival (Number Tested)					
Year	Conc.	May	Jun	Jul	Aug	Sep	Mean
1991[1]	5µg	-	-	-	5	4	5 (390)
	15µg	-	-	-	3	3	3 (295)
1992	5µg	-	-	6	-	-	6 (200)
	15µg	-	-	0.5	-	-	0.5 (200)
1993	5µg	-	-	-	7	18	13 (262)
	15µg	-	-	-	2	1	1 (262)
2000	5µg	-	-	21	51	66	48 (436)
	15µg	-	-	8	18	38	21 (429)
2001	5µg	4	9	15	19	12	11 (423)
	15µg	0	1	19	17	0	13 (781)
2002	5µg	-	31	43	70	-	51 (123)
	15µg	-	20	9	13	0	10 (414)

[1]Data prior to 2001 summarized in Cook et al. (2001).

Table 4. Responses of field-collected male bollworm moths to spinosad in AVT, 2000-2002.

		Month - Percent Survival (Number Tested)					
Year	Conc.	May	Jun	Jul	Aug	Sep	Mean
2000[1]	5µg	-	-	52	58	-	54 (149)
	15µg	-	-	26	5	-	19 (145)
2001	5µg	0	4	40	7	3	11 (310)
	15µg	0	0	28	3	0	10 (311)
2002	5µg	-	47	55	63	-	56 (367)
	15µg	-	18	15	11	-	14 (934)

[1]Data prior to 2001 summarized in Cook et al. (2001).

Table 5. Responses of tobacco budworm larvae from field and laboratory colonies to topical applications of spinosad.

Colony	LD_{50}[1]	95% C.L.	Slope±S.E.
1991 Field collections[2]	0.036-0.043 0.043	0.016-0.082	N/R[3]
2001			
LSU Lab 2001 (lab reference)[2]	0.009	0.004-0.018	0.68 ± 0.07
Velvetleaf (pre-season field reference)[2]	0.029	0.011-0.048	1.14 ± 0.18
2001 Field Collections[2]	0.05-0.103	0.029-0.178	N/R[3]
2002			
Peck	0.049	0.028-0.075	1.04 ± 0.12
Giltner	0.042	0.027-0.061	1.27 ± 0.13
Giltner II	0.092	0.034-0.165	1.22 ± 0.15

[1]µg/larva.
[2]Summarized in Cook et al. 2002.
[3]Not reported.