EVALUATION OF SELECTED COMMERCIAL AND EXPERIMENTAL INSECTICIDES AGAINST LEPIDOPTERAN COTTON PESTS IN LOUISIANA

B.R. Leonard, J. B. Graves, E. Burris, S. Micinski, and V. Mascarenhas; Assoc. Professor, Professor, Assist. Professor, Assoc. Professor, and Res. Assistant, respectively; LSU Agricultural Center Baton Rouge, LA; and S. H. Martin, Product Development Rep., Zeneca Ag Products Ruston, LA

Abstract

Laboratory bioassays were conducted to establish baseline toxicity data for Pirate (AC303,630) and Spinosad (DE-105) on tobacco budworm and bollworm in 1991-92. In a leaf dip bioassay, Pirate LC_{50}'s were slightly higher (1.5-2.5x) than a cypermethrin LC_{50} observed for a laboratory (LSU-LAB) tobacco budworm colony. In a topical diet study, LC_{50} values of several field collected tobacco budworm colonies exposed to Pirate ranged from 18.8-38.2 ppm, a 2.0x level of variation. The Pirate LC_{50} for a laboratory (Stoneville) colony of bollworm was generally lower than LC_{50}'s for laboratory and field tobacco budworm colonies. In larval topical tests, the range of Spinosad LD_{50}'s among several tobacco budworm colonies ranged from 0.4-8.5 µg/g (21.4x level of variation). A series of small plot field tests conducted in Louisiana during 1989-95 evaluated the efficacy of Pirate and Spinosad against tobacco budworm, bollworm, soybean looper and beet armyworm. In these tests, Pirate and Spinosad generally provided control of Lepidopteran pests equal to or greater than that afforded by pyrethroid, organophosphate and carbamate standards.

Introduction

Several Lepidopteran insect pests have the potential of reaching economic injury levels in Louisiana cotton fields during July and August (Baldwin et al. 1995). The most common members of this pest complex include the tobacco budworm, Heliothis virescens (F.), bollworm Helicoverpa zea (Boddie), beet armyworm, Spodoptera exigua (Hubner), and soybean looper, Pseudoplusia includens (Walker). Although, the tobacco budworm and bollworm are the most common and widespread pests, beet armyworm and soybean looper infestations have caused devastating losses in many fields during recent years.

This insect pest complex is reducing the profitability of cotton by reducing crop yields and by increasing the cost of control with insecticides. Yield losses are one indication of poor control with insecticides. In Louisiana, yield losses from the this pest complex have ranged from 2.3-7.5% during 1986-95 (Head 1986-93, Williams 1994-96). Although these insect pests are effectively controlled with labelled insecticides in many areas of the southern U.S., the frequency of treatments applied and actual use rates have increased dramatically. The cost of controlling these pests in Louisiana has signifi-cantly changed and ranged from a low of $25 in 1989 to a high of $55 in 1995. In 1994-95, many producers in Mississippi and Alabama experienced severe yield losses (25-75%) from this insect complex, which further illustrates the importance of these pests and the lack of effective control strategies.

The ability of this insect pest complex to develop resistance to foliar insecticides has been a persistent problem for over 30 years. Although many individual insecticides have been labelled for control of these pests, these chemicals can be grouped into only five classes to which many populations of these insects have developed resistance (Sparks 1981, Leonard et al. 1990, Brewer and Trumble 1994, Martin 1994). Louisiana cotton producers have been fortunate that new classes of foliar insecticides for control of these insects have become registered just as resistance occurred to the product recom-mended at that time. However, the most recent introduction of a class of insecticides (pyrethroids) occurred in the late 1970's and the cotton industry is overdue for registration of new technology to use in IPM strategies.

New insecticide technology is desperately needed in the cotton production system to maintain profitability. Although genetic engineering has produced tobacco budworm and soybean looper resistant cotton varieties that will be available in 1996, limited seed quantities, other insect pest problems and agronomic issues may restrict their adoption into production systems. Novel foliar insecticides for control of the Lepidopterous cotton pests are needed to efficiently manage crop production costs. It is the objective of this report to establish baseline data and describe the field performance of Pirate (AC303,630) and Spinosad (DE-105). These are two experimental foliar insecticides that are proceeding toward registration with the Environmental Protection Agency (EPA) for use on cotton.

Materials and Methods

Insecticides

Technical-grade cypermethrin (FMC, Middleport, NY), Pirate (AC303,630; American Cyanamid, Princeton, NJ) and Spinosad (DE-105; DowElanco, Indianapolis, IN), were obtained from the manufacturers. Technical materials were diluted to a 1% stock solution in acetone and refrigerated until needed. Formulated samples of cyfluthrin (Baythroid 2EC; Bayer, Kansas City, MO), cypermethrin (Ammo 3EC; FMC, Middleport, NY), lambda-cyhalothrin (Karate 1EC; Zeneca Ag Chemicals,

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:825-830 (1996)
National Cotton Council, Memphis TN

Memphis, TN), Pirate (American Cyanamid, Princeton, NJ), profenofos (Curacron 8EC, CIBA Crop Protection, Research Triangle Park, NC), Spinosad (DowElanco, Indianapolis, IN), sulprofos (Bolstar 6EC, Bayer, Kansas City, MO), and thiodicarb (Larvin 3.2F, Rhone Poulenc Ag, Research Triangle Park, NC) were obtained for the field tests.

Laboratory Bioassays

Several laboratory and field colonies were tested to establish baseline data for the toxicity of Pirate and Spinosad and to compare those values to that of a pyrethroid, cypermethrin. The LSU-LAB colony of tobacco budworm was originally established in 1977 by collections from cotton fields in Louisiana (Leonard et al. 1988). The Stoneville strain (STV-LAB) of bollworm has been maintained at the Southern Insect Management laboratory USDA-ARS, Stoneville, MS for several years. Both colonies have been maintained without exposure to insecticides since their introduction into the laboratory.

Field-collected colonies of tobacco budworm were established by collecting eggs and/or larvae from several locations in Louisiana, Mississippi, and Texas. The collection dates and locations of tobacco budworm colonies tested against Pirate and Spinosad are shown in Tables 1 and 2, respectively. All of the field colonies were collected from cotton with the exception of the Clarksdale strain (CLK), which was collected from velvetleaf, <u>Abutilon theophrasti</u> Medicus.

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 maintained in the Department of Entomology at the Louisiana Agricultural Experiment Station and reared on a pinto bean and wheat germ diet according to procedures described by Leonard et al. (1988).

The larval topical procedures methods used to test Spinosad are similar to those outlined in the E.S.A. standard test method for determining relative susceptibility levels in <u>Heliothis</u> and <u>Helicoverpa</u> spp. (Anonymous 1970) with some modifications by Martin (1994). Third instar larvae (20±5 mg) were used in all tests. Before treatment, larvae were removed from stock colonies and placed on fresh diet. Insects were treated on the dorsal surface of the thorax with 1μl aliquots of acetone alone (control) or serial dilutions from technical grade insecticides dissolved in acetone.

The leaf dip bioassay was used initially to compare the toxicological responses of the LSU-LAB strain to cypermethrin and Pirate. Freshly excised cotton leaves were dipped in water alone (control) or serial dilutions from formulated insecticides dissolved in water. The leaves were allowed to dry and one third instar (20±5 mg) was placed on each leaf.

A diet topical method was used later to determine the toxicological responses to tobacco budworm and bollworm to Pirate. The surface of rearing media in 1-oz. cups was topically treated with 100 μl aliquots of acetone alone (control) or serial dilutions from technical grade insecticides dissolved in acetone. The diet was allowed to dry and one third instar (20±5 mg) was placed in each cup.

The dose-mortality line for each insecticide was determined from 4 or 5 doses with 10 insects treated per dose and was based on 2 or 3 replicates. After treatment, the larvae were held at 27±3°C and 55-65% RH under a 14:10 LD photoperiod. Mortality was determined after 48-72 hours. The criterion for mortality was inability of a larva to move within 15 seconds after being prodded with a blunt probe. Results were analyzed using a microcomputer based probit analysis (POLO-PC, LeOra Software, 1119 Shattuck Ave., Berkeley, CA 94707). Control mortality was never greater than 5%; data were corrected using Abbott's (1925) formula. LD_{50}'s were considered significantly different if 95% confidence limits failed to overlap.

Field Trials

These tests were conducted during 1990-95 at the Red River Research Station near Bossier City, LA; Macon Ridge Location of the Northeast Research Station near Winnsboro, LA; and St. Joseph Location of the Northeast Research Station near St. Joseph, LA. Recommended cultural practices and integrated pest management strategies were used to maintain all plots in a similar manner within each test. In some instances, variety and planting date were manipulated to increase the probability of obtaining economic infestations of native populations of tobacco budworm, bollworm, beet armyworm, and soybean looper. During some years, cotton seed of a single recommended cultivar was sequentially planted on multiple dates in large blocks. Selective insecticides were applied for control of non-target pests during the tests.

Treatments were arranged in a randomized complete block design and replicated 4-6 times. Treated plots within each trial consisted of 4-8 rows (40 inch centers) x 50 ft. The insecticide treatments in these tests included Pirate 3F (0.2, 0.25, 0.3, and 0.35 lb AI/acre), Spinosad 3.33F/4SC (0.02-0.023, 0.045, 0.06-0.067, and 0.09 lb AI/acre), selected pyrethroids (Ammo 3EC, 0.03-0.08 lb AI/acre; Baythroid 2EC, 0.028-0.033 lb AI/acre; and Karate 1EC, 0.028-0.04 lb AI/acre) and selected non-pyrethroids (Bolstar 6EC, 1.0-1.5 lb AI/acre; Curacron, 0.5-1.0 lb AI/acre; and Larvin 3.2F, 0.25-0.9 lb AI/acre). Treatments were timely applied targeting hatching eggs and <3 day old larvae or applied as rescue treatments against established infestations of tobacco budworm and bollworm. Usually, 2-7 applications of each treatment were applied within each test. In tests designed to specifically measure efficacy against beet armyworm and soybean looper, treatments were applied as single rescue treatments against established infestations in various stages of larval development. Applications in all tests were made with a hand-held boom and CO_2 charged delivery system or a tractor mounted boom and compressed air delivery system calibrated to deliver 5-10 gallons total spray/acre through Teejet TX-8 hollow cone nozzles (2/row) at 31-38 psi.

Treatment efficacy against tobacco budworm and bollworm was determined by examining 25-100 fruit (squares)/plot. Plots were sampled at 2-4 days after treatment (DAT) on several posttreatment sample dates for evidence of damage. The center two rows of each plot in selected tests were mechanic-ally harvested to estimate seed cotton yields. In tests designed to primarily evaluate insecticidal activity against tobacco budworm and bollworm, visual defoliation ratings were used to determine treatment effects on beet army-worm and soybean looper injury to cotton plants. The defoliation rating values were based on the following scale: 0 (no feeding injury), 1 (feeding injury within the lower 1/3 of the plant), 2 (feeding injury within the lower 1/3 and middle 1/3 of the plant), 3 (feeding injury throughout the plant). In the tests designed to evaluate insecticide efficacy against beet armyworm and soybean looper, plots were sampled using a sweep net (15 inch diameter) or shake cloth (6 row feet). Usually 10-25 sweep net samples or 1-2 shake sheet samples/plot were taken at 2-3 DAT and 5-7 DAT.

For all tobacco budworm and bollworm trials, the data for individual sample dates were pooled to determine mean treatment effects following multiple applications. Results for all tests were subjected to analysis of variance (ANOVA) to determine significant treatment effects. Duncan's Multiple Range test (P=0.05) was used to compare treatment means within each respective test (SAS Institute 1988).

Results and Discussion

Laboratory Bioassays

In the leaf dip bioassay, Pirate LC_{50}'s were slightly higher (1.5-2.5x) than the LC_{50} value for cypermethrin against the LSU-LAB colony of tobacco budworm (Table 3). However, these values are similar to those presented by Treacy et al. (1991) for Pirate and cypermethrin in a leaf dip bioassay.

In the topical diet study, LC_{50} values for Pirate ranged from 18.8-38.2 ppm, which was only a 2.0x level of variation among tobacco budworm colonies (Table 4). Only the LC_{50} value for the Snook, TX colony was significantly different from that of the LSU-LAB strain. This value, however, was not significantly different from those of the other field colonies. The LC_{50} value for the Stoneville lab colony of bollworm was significantly lower than LC_{50}'s for all but one of the tobacco budworm colonies. However, additional field colonies of bollworm should be tested to determine the natural range of variation.

LD_{50}'s for Spinosad against the LSU-LAB and field colonies of tobacco budworm in 1991-92 ranged from 0.4-8.5 µg/g (Table 5). Six of the field colonies had LD_{50}'s significantly lower than that for the LSU-LAB strain while five field colonies had LD_{50}'s similar to that of the laboratory strain. These data indicate a considerable level (21.4x) of variation in responses among tobacco budworm populations in the field. Leonard et al. (1988) found LD_{50}'s for third instar tobacco budworm exposed to selected pyrethroids to vary from 0.1-2.7 µg/g, a 25x level of variation. Many of the values reported for Spinosad in this study fall within this range and suggest that, at least in a larval topical bioassay, the toxicities of Spinosad and selected pyrethroids to tobacco budworm are similar. A review of LD_{50} values for insecticides tested against third instar tobacco budworm by Sparks et al. (1995) showed spinosyn A (Spinosad is a mixture of spinosyn A & D) to provide similar levels of toxicity to the pyrethroids. In addition, activity of spinosyn A and Spinosad in laboratory bioassays appears to be higher than that of other non-pyrethroid insecticides recommended for control of tobacco budworm in cotton.

Field Tests With Tobacco Budworm and Bollworm

Fifteen field tests were conducted 1991-95 to compare the efficacy of Pirate to recommended insecticide standards on tobacco budworm and bollworm damaged fruiting forms (Table 6). In eleven of the fifteen tests, one or more rates of Pirate significantly reduced fruiting form injury compared to that in that in the untreated plots (UTC). In eleven of twelve tests comparing the efficacy of Pirate to a pyrethroid (SP), one or more rates of Pirate were equal to or better that the SP treatment. In all nine tests comparing the efficacy of Pirate to an organophosphate/carbamate (OP/CB) standard, one or more rates of Pirate produced results similar to or better than those in the OP/CB treatments.

In seven of eleven field tests comparing the effects of Pirate to the SP and OP/CB standards on seedcotton yields, one or more rates of Pirate significantly increased yields compared to that in the untreated plots (Table 7). In eight of nine tests comparing yields of Pirate to those of SP's, one or more rates of Pirate produced yields equal to or better than the SP treatment. In six of eight tests comparing the yields of Pirate to the OP/CB's, one or more rates of Pirate produced results similar to or better than those in the OP/CB treatments.

Thirteen field tests were conducted during 1989-95 to compare the efficacy of Spinosad to SP and OP/CB standards on tobacco budworm and bollworm damaged fruiting forms (Table 8). In twelve of the thirteen tests, one or more rates of Spinosad significantly reduced fruiting form injury compared to that in the untreated plots. All eleven tests comparing the efficacy of Spinosad to a SP showed one or more rates of Spinosad to be equal to or better that in the SP treatment. In ten tests comparing the efficacy of Spinosad to the OP/CB standards, one or more rates of Spinosad produced results similar to or better than those in the OP/CB treatments. Thompson et al. (1995) showed more consistent control of tobacco budworm and bollworm in field tests with Spinosad than with a SP, cypermethrin. Variation in control with SP treatments was probably related to the occurrence of SP resistant populations in some tests.

In six of ten field tests comparing the effects of Spinosad to the SP and OP/CB standards on seedcotton yields, one or more rates of Spinosad significantly increased yields compared to that in the untreated plots (Table 9). In all eight tests comparing yields of Spinosad to those of SP's, one or more rates of Spinosad produced yields equal to or better than the SP treatment. In eight tests comparing the yields of Spinosad to the OP/CB standards, one or more rates of Spinosad produced results similar to or better than those in the OP/CB treatments.

Insecticide Efficacy Against Beet Armyworm and Soybean Looper

Pirate and Spinosad treated plots in the tobacco budworm and bollworm field tests were evaluated for defoliation by beet armyworm and soybean looper. Pirate and Spinosad at all rates significantly reduced defoliation levels compared to that in untreated plots (Tables 10 and 11). In two of four tests, defol-iation ratings in Pirate treated plots were significantly lower than those in the SP and OP/CB treated plots. Spinosad treated plots in two tests had signifi-cantly lower defoliation ratings compared to those in OP/CB treated plots.

Six and three tests evaluated the efficacy of a single application of Pirate or Spinosad, respectively, against beet armyworm and soybean looper (Table 12). Pirate treated plots had significantly fewer beet armyworm larvae compared to that in the untreated plots at 2-4 DAT in three tests and at 5-7 DAT in four tests. Spinosad in all tests except one and all tests significantly reduced beet armyworm numbers compared to that in the untreated plots at 2-4 DAT and 5-7 DAT, respectively. Pirate and Spinosad significantly reduced numbers of soybean loopers on both sample dates below that in the untreated plots in all tests. Both of these insecticides consistently provided control of beet armyworm and soybean looper equal to or greater than that observed in the other insecticide treated plots. Pirate and Spinosad have provided consistent and satisfactory control of the cotton pests in Mississippi tests (Furr and Harris 1995, Thompson et al. 1995).

The data from the field tests presented in this report briefly summarize the efficacy of Pirate and Spinosad against tobacco budworm, bollworm, soybean looper and beet armyworm. These results coupled with previously published information confirm the potential of these products to manage Lepidopteran pests in cotton.

Acknowledgments

The authors express their sincere appreciation to the student employees in the Cotton Laboratory, LSU Department of Entomology, who assisted in insect rearing and preparation of the laboratory bioassays. In addition, we wish to thank the summer field personnel at both locations of the Northeast Research Station and at the Red River Research Station for plot maintenance, pesticide application and data collection.

References

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

2. Anonymous. 1970. Standard method for detection of insecticide resistance in Heliothis zea (Boddie) and H. virescens (F.). Bull. Entomol. Soc. Amer. 16:147-149.

3. Baldwin, J. L., D. C. Rester, J. B. Graves, E. Burris, S. Micinski and B. R. Leonard. 1995. Control cotton insects. LA. Cooperative Extension Serv. Pub. 1829. 20 pp.

4. Brewer, M. J. and J. T. Trumble. 1994. Beet armyworm resistance to fenvalerate and methomyl: Resistance variation and insecticide synergism. J. Agric. Entomol. 11: 291-300.

5. Furr, R. E. and F. A. Harris. 1995. Evaluation of insecticide efficacy for beet armyworm in Mississippi, pp. 902-903. In Proceedings, Beltwide Cotton Production Confer. National Cotton Council, Memphis, TN.

6. Head, R. B. 1986-93. Beltwide cotton insect losses. In Proceedings, 1986-93 Beltwide Cotton Production Confer. National Cotton Council, Memphis, TN.

7. Leonard, B. R., T. C. Sparks and J. B. Graves. 1988. Variation in resistance of tobacco budworm and bollworm (Lepidoptera: Noctuidae) to insecticides. J. Econ. Entomol. 81:1521-1528.

8. Leonard, B. R., D. J. Boethel, A. N. Sparks Jr., M. B. Layton, J. S.. Mink, A. M. Pavloff, E. Burris and J. B. Graves. 1990. Variations in soybean looper (Lepidoptera: Noctuidae) response to selected insecticides. J. Econ. Entomol. 83:27-34.

9. Martin, S. H. 1994. Investigations on insecticide resistance in tobacco budworm, Heliothis virescens (F.), and boll weevil, Anthonomus grandis grandis (Boheman), in the Mid-South. Ph.D dissertation, Louisiana State University, Baton Rouge, LA. 158 pp.

10. SAS Institute. 1988. SAS/STAT users guide, version 6.03 [ed.], SAS Institute, Cary, NC.

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

12. Sparks, T.C., G.D. Thompson, L.L. Larson, H.A. Kirst, O.K. Jantz, T.V. Worden, M. B. Hertlein and J.D. Busacca. 1995. Biological characteristics of the Spinosyns: a new naturally derived insect control agents, pp. 903-907. In Proceedings, Beltwide Cotton Production Confer. National Cotton Council, Memphis, TN.

13. Thompson, G.D., J.D. Busacca, O.K. Jantz, P.W. Borth, S.P. Nolting, J.R. Winkle, R.L. Gantz, R.M. Huckaba, B.A. Nead, L.G. Peterson, D.J. Porteous and J.M. Richardson. 1995. Field performance in cotton of Spinosad: a new naturally derived insect control system, pp. 907-910. In Proceedings, Beltwide Cotton Production Confer. National Cotton Council, Memphis, TN.

14. Treacy, M. F., T. P. Miller, I. E. Gard, J. B. Lovell and D. B. Wright, Jr. 1991. Characterization of insecticidal properties of AC303,630 against tobacco budworm, Heliothis virescens (F.) larvae, pp. 738-740. In Proceedings, Beltwide Cotton Production Confer. National Cotton Council, Memphis, TN.

15. Williams, M. R. 1994-96. Beltwide cotton insect losses. In Proceedings, 1994-96 Beltwide Cotton Production Confer. National Cotton Council, Memphis, TN.

Table 1. Collection dates, generation tested and sample number of tobacco budworm and bollworm exposed to Pirate in a topical diet laboratory bioassay, 1991.

Colony	Date Collected	Generation Tested	Number Tested
Tobacco Budworm			
LSU-LAB	----------	N/A	180
Clarksdale, MS	28 May	6th	180
Friars Point, MS	5 Sep	7th	50
Bossier City, LA-1	21 Aug	5th	150
Bossier City, LA-2	28 Aug	8th	210
Cheneyville, LA	24 Sep	6th	150
Snook, TX	16 Aug	4th	180
Uvalde, TX	15 Aug	6th	182
Bollworm			
Stoneville Lab	----------	N/A	188

Table 2. Collection dates, generation tested and sample number of tobacco budworm and bollworm exposed to Spinosad in a larval topical laboratory bioassay, 1991-92.

Colony	Date Collected	Generation Tested	Number Tested
1991			
LSU-LAB	----------	N/A	205
Bossier City, LA	21 Aug	2nd	215
Cheneyville, LA	24 Sep	3rd	75
Clarksdale, MS	28 May	2nd	132
Tensas, LA	19 Aug	4th	50
Friars Point, MS	5 Sep	3rd	120
Snook, TX	16 Aug	2nd	25
Uvalde, TX	15 Aug	2nd	150
1992			
LSU-LAB	----------	N/A	150
Harlingen, TX	12 Jul	2nd	110
Bossier City, LA (Jun)	19 Jun	3rd	149
Bossier City, LA (Jul)	23 Jul	6th	130
Bossier City, LA (Aug)	21 Aug	5th	130

Table 3. Responses of the LSU-LAB tobacco budworm colony to Pirate and cypermethrin in a leaf dip bioassay, 1991.

Insecticide[1]	48 Hour LC_{50}[2] (95% CL)	Slope±SE
Pirate	4.92 (3.45-6.48)	4.89±1.06
Pirate	8.44 (5.79-15.68)	1.76±0.38
Cypermethrin	3.31 (2.37-4.19)	3.42±0.78

[1]Pirate tested twice.
[2]LC_{50} reported in PPM of solution.

Table 4. Responses of the LSU-LAB, field-collected tobacco budworm, and Stoneville laboratory bollworm colonies to Pirate in a topical diet bioassay, 1991.

Colony	72 Hour LC_{50}[1] (95% CL)	Slope±SE
Tobacco Budworm		
LSU-LAB	21.45 (18.09-25.15)	4.69±0.74
Clarksdale, MS	25.14 (20.24-32.19)	2.50±0.33
Friars Point, MS	18.78 (11.94-28.19)	2.97±0.88
Bossier City, LA-1	27.05 (21.73-33.74)	3.14±0.47
Bossier City, LA-2	17.38 (14.66-20.73)	3.34±0.43
Cheneyville, LA	19.30 (15.93-23.56)	3.31±0.44
Snook, TX	38.22 (30.39-49.39)	2.44±0.37
Uvalde, TX	26.48 (21.49-32.23)	3.04±0.45
Bollworm		
Stoneville Lab	10.64 (9.14-13.50)	4.90±1.35

[1]LC_{50} reported in PPM of solution.

Table 5. Responses of the LSU-LAB and field-collected tobacco budworm colonies to Spinosad in a larval topical bioassay, 1991-92.

Colony	72 Hour LD_{50}[1] (95% CL)	Slope±SE
1991		
LSU-LAB	4.65 (3.00-6.85)	1.39±0.20
Bossier City, LA	1.80 (0.95-2.95)	1.06±0.19
Cheneyville, LA	0.40 (0.004-1.30)	0.77±0.26
Tensas, LA	1.75 (0.85-3.35)	2.14±0.65
Clarksdale, MS	1.80 (1.00-2.85)	1.53±0.31
Friars Point, MS	0.85 (0.45-1.30)	2.18±0.49
Snook, TX	8.55 (4.20-29.75)	2.26±0.50
Uvalde, TX	2.15 (0.80-4.10)	2.26±0.50
1992		
Harlingen, TX	2.10 (1.30-4.40)	1.27±0.31
Bossier City, LA (Jun)	1.00 (0.70-1.35)	2.37±0.53
Bossier City, LA (Jul)	2.45 (1.85-3.50)	2.26±0.44
Bossier City, LA (Aug)	1.20 (0.90-1.70)	2.64±0.43

[1]Expressed as µg of insecticide/g of larval weight.

Table 6. Efficacy of Pirate and recommended standards against tobacco budworm and bollworm in field tests in Louisiana, 1991-95.

	Percent Damaged Fruiting Forms						
Year/	Pirate[1]						
Test	A	B	C	D	SP[2]	OP/CB[2]	UTC[2]
1991							
MRS-1	3.2a	-----	3.6a	-----	-----	-----	8.4a
MRS-2	-----	-----	20.0b	-----	-----	20.4b	32.0a
NRS	-----	5.0a	4.4a	4.8a	4.6a	2.4a	8.3a
1992							
MRS-1	-----	-----	15.8b	13.6b	14.4b	12.1b	24.8a
MRS-2	21.0b	-----	-----	13.4c	17.2bc	-----	29.6a
NRS	-----	-----	4.0c	3.6c	6.2b	-----	9.4a
1993							
MRS-1	7.6ab	-----	4.6c	3.8c	4.8c	4.6c	9.4a
MRS-2	20.8b	-----	-----	13.2cd	17.2bc	-----	29.6a
RRS-1	-----	-----	9.2b	7.6b	7.6b	-----	20.8a
RRS-2	-----	6.4a	8.0a	----	4.8a	5.2a	11.6a
1994							
MRS	6.0b	6.6b	-----	-----	----	7.4b	11.2a
RRS	-----	-----	17.0b	-----	4.0c	7.6bc	28.0a
1995							
MRS	5.6bc	-----	-----	3.8cd	3.6cd	2.0d	9.4a
NRS	-----	-----	-----	2.0ab	3.6a	-----	2.2ab
RRS	-----	-----	1.4c	-----	11.4b	7.4bc	24.6a

Means in rows followed by a common letter are not significantly different (P=0.05;DMRT).

[1]Rates of Pirate; A=0.2 lb AI/acre, B=0.25 lb AI/acre, C=0.3 lb AI/acre and D=0.35 lb AI/acre.

[2]SP refers to a pyrethroid standard, OP refers to an organophosphate standard, CB refers to a carbamate standard, and UTC refers to an untreated control.

Table 7. Seedcotton yields of plots treated with Pirate and recommended standards in Louisiana field tests ,1991-95.

	Seedcotton Yield (lb/acre)						
Year/	Pirate[1]						
Test	A	B	C	D	SP[2]	OP/CB[2]	UTC[2]
1991							
MRS-1	3286a	-----	3420a	-----	-----	-----	3243a
NRS	-----	1865ab	1586bc	2008a	2189a	1920bc	1503c
1992							
MRS-1	-----	-----	1810a	1921a	1904a	1689a	1218b
NRS	-----	-----	2297ab	2342ab	2076b	2639a	2289a
1993							
MRS-1	1529a	-----	1581a	1757a	1519a	1476a	1378a
RRS-1	-----	-----	1848a	1735a	1699a	-----	1196b
RRS-2	-----	1928a	1818a	-----	1665ab		1903a
	1414b						
1994							
MRS	1699a	1633a	-----	-----	-----	1241b	1284b
RRS	-----	-----	1656b	-----	2546a	2305a	1199b
1995							
MRS	839b	-----	-----	859b	843b	1121a	552c
NRS	-----	-----	-----	2275a	1673b	-----	1588b

Means in rows followed by a common letter are not significantly different (P=0.05;DMRT).

[1]Rates of Pirate; A=0.2 lb AI/acre, B=0.25 lb AI/acre, C=0.3 lb AI/acre and D=0.35 lb AI/acre.

[2]SP refers to a pyrethroid standard, OP refers to an organophosphate standard, CB refers to a carbamate standard, and UTC refers to an untreated control.

Table 8. Efficacy of Spinosad and recommended standards against tobacco budworm and bollworm in field tests in Louisiana, 1989-95.

	Percent Damaged Fruiting Forms						
Year/	Spinosad[1]						
Test	A	B	C	D	SP[2]	OP/CB[2]	UTC[2]
1989							
MRS	1.6b	5.2b	-----	1.2b	4.0b	-----	8.8a
NRS	8.0ab	12.0ab	-----	4.0b	12.0ab	4.0b	16.0a
1991							
MRS-1	-----	1.6b	-----	0.8b	0.8b	0.9b	3.2a
MRS-2	-----	21.2b	-----	19.6b	23.2b	23.2b	34.4a
RRS	-----	0.4c	-----	0.4c	3.6ab	2.0b	4.4a
1992							
MRS-1	10.0bc	7.6c	5.6c	6.8c	15.0b	13.4b	24.2a
MRS-2	13.2b	-----	12.8b	-----	17.2b	-----	29.6a
1993							
MRS	-----	1.2b	0.6b	0.6b	2.0b	2.0ab	2.8a
RRS	-----	7.6a	5.6a	4.6a	8.0a	7.0a	12.6a
1994							
MRS	8.6bc	9.8b	-----	4.8c	-----	9.8b	16.0a
RRS	-----	19.2b	-----	25.2b	-----	30.8b	56.0a
1995							
NRS	-----	1.0b	-----	-----	3.6a	-----	2.2a
RRS	-----	-----	1.4c	-----	11.4b	7.4c	24.6a

Means in rows followed by a common letter are not significantly different (P=0.05; DMRT).

[1]Rates of Spinosad; A=0.023-0.03 lb AI/acre, B=0.045 lb AI/acre, C=0.06-0.067 lb AI/acre and D=0.09 lb AI/acre.

[2]SP refers to a pyrethroid standard, OP refers to an organophosphate standard, CB refers to a carbamate standard, and UTC refers to an untreated control.

Table 9. Seedcotton yields of plots treated with Spinosad and recommended standards in Louisiana field tests, 1989-95.

	Seedcotton Yield (lb/acre)						
Year/	Spinosad[1]						
Test	A	B	C	D	SP[2]	OP/CB[2]	UTC[2]
1989							
MRS	1790a	1993a	-----	1957a	2173a	-----	1728a
NRS	2895ab	3043a	-----	3133a	3060a	2689b	2890ab
1991							
MRS-1	-----	3263a	-----	3368a	3279a	3299a	3214a
1992							
MRS-1	1813ab	2035a	1803a	2090a	1600b	1689b	1133c
1993							
MRS	-----	1549bc	1676ab	1856a	1607b	1607b	1343c
RRS	-----	1785a	1912a	1880a	1904a	1824a	1457b
1994							
MRS	1395bc	1598ab	-----	1804a	-----	1454bc	1258c
RRS	-----	1427a	-----	1424a	-----	1623a	944b
1995							
NRS	-----	2020a	-----	-----	1673a	-----	1588a
RRS	-----	-----	1800a	-----	1519ab	1551ab	1370b

Means in rows followed by a common letter are not significantly different (P=0.05; DMRT).

[1]Rates of Spinosad; A=0.023-0.03 lb AI/acre, B=0.045 lb AI/acre, C=0.06-0.067 lb AI/acre and D=0.09 lb AI/acre.

[2]SP refers to a pyrethroid standard, OP refers to an organophosphate standard, CB refers to a carbamate standard, and UTC refers to an untreated control.

Table 10. Effect of Pirate on late-season defoliation in Louisiana cotton fields by soybean looper and beet armyworm, 1991-94.

Year/ Test	Defoliation Ratings (0-3 scale)[1] Pirate[2] A	B	C	D	SP[3]	OP/CB[3]	UTC[3]
1991							
MRS	-----	-----	0.8b	-----	-----	0.8b	2.3a
1993							
MRS	0.1c	-----	0.3c	-----	2.3b	2.6ab	3.0a
NRS	0.5b	-----	0.5b	-----	1.0b	0.5b	2.0a
1994							
MRS	0.0c	-----	0.0c	-----	-----	1.4b	2.1a

Means in rows followed by a common letter are not significantly different (P=0.05; DMRT).

[1]Defoliation rating scale: 0 (no feeding injury), 1 (feeding injury within the lower 1/3 of the plant), 2 (feeding injury within the lower 1/3 and middle 1/3 of the plant), 3 (feeding injury throughout the plant).

[2]Rates of Pirate; A=0.2 lb AI/acre, B=0.25 lb AI/acre, C=0.3 lb AI/acre and D=0.35 lb AI/acre.

[3]SP refers to a pyrethroid standard, OP refers to an organophosphate standard, CB refers to a carbamate standard, and UTC refers to an untreated control.

Table 11. Effect of Spinosad on late-season defoliation in Louisiana cotton fields by soybean looper and beet armyworm, 1991-93.

Year/ Test	Defoliation Ratings (0-3 scale)[1] Spinosad[2] A	B	C	D	SP[3]	OP/CB[3]	UTC[3]
1991							
MRS	-----	1.3b	-----	0.5c	1.5c	2.5a	2.5a
1993							
MRS	0.0c	1.1c	0.7c	0.0c	2.0b	2.6a	2.7a

Means in rows followed by a common letter are not significantly different (P=0.05; DMRT).

[1]Defoliation rating scale: 0 (no feeding injury), 1 (feeding injury within the lower 1/3 of the plant), 2 (feeding injury within the lower 1/3 and middle 1/3 of the plant), 3 (feeding injury throughout the plant).

[2]Rates of Spinosad; A=0.023-0.03 lb AI/acre, B=0.045 lb AI/acre, C=0.06-0.067 lb AI/acre and D=0.09 lb AI/acre.

[3]SP refers to a pyrethroid standard, OP refers to an organophosphate standard, CB refers to a carbamate standard, and UTC refers to an untreated control.

Table 12. Efficacy of selected insecticides against beet armyworm and soybean looper in Louisiana field tests, 1994-95.

Test/ Treatment	Rate/ Acre (lb AI)	Beet Armyworm 2-4DAT	Beet Armyworm 5-7DAT	Soybean Looper 2-4DAT	Soybean Looper 5-7DAT
		Number/10 Sweep Sample[1]			
MRS94-1					
Pirate 3SC	0.25	----	----	0.8c	1.0d
Larvin 3.2F	0.45	----	----	9.3b	7.5cd
Lorsban 4EC	1.0	----	----	16.5ab	16.0bc
Untreated	----	----	----	19.8a	18.3ab
MRS94-2					
Pirate 3SC	0.25	0.5b	0.5a	----	----
Larvin 3.2F	0.45	2.5b	1.5a	----	----
Untreated	----	12.0a	6.5a	----	----
MRS94-3					
Pirate 3SC	0.2	----	0.5c	----	----
Pirate 3SC	0.35	----	1.0c	----	----
Spinosad 3.33SC	0.067	----	0.5c	----	----
Karate 1EC	0.04	----	9.5a	----	----
Untreated	----	----	6.7b	----	----
		Number/row foot[2]			
NRS95					
Pirate 3SC	0.2	0.5b	0.6c	----	----
Spinosad 4SC	0.067	0.7b	0.4c	----	----
Larvin 3.2F	0.6	1.7b	1.9bc	----	----
Lorsban 4EC	1.0	0.9b	0.6c	----	----
Untreated	----	5.1a	3.9ab	----	----
MRS95-1					
Pirate 3SC	0.175	0.9b	0.1b	0.2b	0.1b
Larvin 3.2F	0.6	1.2ab	0.5b	0.3b	0.2b
Untreated	----	5.6a	1.1a	2.2a	0.7a
MRS95-2					
Pirate 3SC	0.35	0.0a	0.2b	0.2b	0.0b
Spinosad 4SC	0.067	0.1a	0.0b	0.2b	0.0b
Untreated	----	0.6a	1.2a	3.3a	0.5a

Means in columns within each test followed by a common letter are not significantly different (P=0.05; DMRT).

[1]Treatments evaluated with a sweep net.

[2]Treatments evaluated with a shake sheet.