EFFICACY AND DURATION OF EARLY SEASON INSECTICIDES ON TRANSGENIC Bt COTTON

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Abstract

Field studies were established in a cotton production system of the Mississippi Delta in 1995 and 1996 to examine the effects of various insecticide treatments on the cumulative insect feeding patterns and fruit initiation in pre-squaring cotton *Gossypium hirsutum*. In 1995, studies were established with a conventional variety, 'Suregrow 125', and this study identified the effects of insecticide treatments on cumulative feeding patterns of cotton bollworm *Helicoverpa zea* (Boddie), tobacco budworm *Heliothis virescens* (Fabricus), and tarnished plant bug *Lygus lineolaris* (Palisot de Beauvois). In 1996, studies were established on 'Nucotn 33b' to dilute the effect of Lepidoterae feeding and isolate the effects of tarnished plant bug on presquaring cotton. No treatment decreased the incidence of damage terminals at any sampling date. Initial control of tarnished plant bug with Provado treatments was slow, which was similar to observations in 1995. Vydate C-LV + Lannate LV consistently provided less control of tarnished plant bug and resulted in lower lint yield from fruiting branches produced during early season. The lack of control from Vydate C-LV + Lannate LV also resulted in delay of maturity when compared to Orthene treated cotton.

Introduction

Insect pest are a major limiting factor in cotton production systems of the Mississippi Delta. Pest populations in transgenic *Bt* cotton will continue to change and consist of non-lepidopteran pest as tarnished plant bug, boll weevil *Anthonomous grandis* (Boheman), and stink bugs *Nezara viridula* (Linnaeus), *Acrosternum hilare* (Say), *Euschistus servus* (Say).

Tarnished plant bugs and cotton fleahoppers *Pseudatomoscelis seriatus* (Reuter) occur primarily during early season. Tarnished plant bugs can destroy meristematic tissue in developing plant terminals (Leigh et al. 1988). An accumulation of feeding periods from tarnished plant bug can lead to damaged plant terminals and subsequently lead to aborted square positions or low square retention during early cotton development. The effects of cumulative feeding patterns has been described as an adequate indicator of pest infestation levels in crop production systems (Ruppel, 1983, Morrill and Wrona, 1987, Harris et al., 1992). This cumulative index explains the presence of insect pest in cotton as insect-days or the accumulation of an insect population over time.

An early season pest population has been defined as those populations occurring on pre-squaring cotton or seedlings up to the sixth node (Rosenheim, 1985). Beneficial arthropod populations often initially increase during mid-late June. Early fruit loss can occur before this period if adequate control is not achieved. If insecticide treatments are timed to precede this increase in beneficial population, the negative effect of early season insecticides on beneficial insect populations can be offset, although some researchers (Green et al., 1995) indicate a significant decrease in beneficial species when pyrethroid insecticides were applied to early developing cotton during mid-late June.

Protecting early developing fruit from insect damage has been considered a necessary step in the development of crop earliness (Parvin et al., 1987). Turnipseed et al. noted a one week delay in harvest maturity when mechanical induced square removal was implemented for four weeks, although this resulted in no yield loss. Phelps et al., 1997 noted a delay in harvest maturity when mechanical induced square removal was implemented for 2, 3, and 4 weeks. These removal periods delayed harvest maturity from 2 - 14 days, respectively. Effective and timely insecticide applications are essential to prevent insect damage in cotton systems. Early fruit retention is essential to high production yields. Jenkins et al., 1995 have determined the relative value of fruit on both early and full season cultivars. Averaging 'DES 119' with 'Deltapine 90', approximately $347.00/acre can be accounted for on nodes 5 through 10. This study reports the effects of early season insecticide treatments on control, duration of control, delay and yield characteristics of cotton.

Materials and Methods

Five commercially applied insecticides were evaluated for effectiveness in control and length of control against early season insects of cotton. A cotton production system with a history of high tarnished plant bug populations was selected in Sunflower county, MS, adjacent to the Sunflower river. Cotton variety 'Nucotn 33b' was planted 26 April 1996 on a Dundee silt loam soil. Plots contained 16 rows and included four replications per treatment for three treatments and 8 replications for the pyrethroid treatments. The original design of the study was a 7 treatment experiment replicated 4 times. Rapid growth and rainfall prevented the second application of insecticide, which resulted in a 5 treatment design with 2 treatments being replicated 8 times.

Sweep net and visual sampling procedures were initiated on 24 May 1996 and continued at 2 day intervals through 4 June 1996. Insect sampling consisted of 50 sweeps with a

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:x-x (1997)
National Cotton Council, Memphis TN

15 inch sweep net and visual examination of 25 cotton plants per plot. Ten plants within these counts were examined for damaged terminals and other physical characteristics of damage. Terminals were examined for Heliothine eggs, larvae and insect damage. Insects collected in the sweep net were anesthetized with ether and placed in a kill bucket containing a cotton wick soaked with ethyl acetate. These samples were transported to the laboratory where insects collected were identified and counted.

Insecticide treatments were applied with a Melroe Spray Coupe delivering 5 gpa. Insecticide treatments were initiated on 25 May 1996, when the fifth leaf of the cotton plant had expanded to the size of a quarter. These insecticide treatments included Provado at 0.047 lb ai/A, Baythroid at 0.036 lb ai/A, Karate at 0.033 lb ai/A, Orthene at 0.33 lb ai/A, and Vydate C-LV at 0.25 lb ai/A plus Lannate LV at 0.22 lb ai/A.

Insect days (ID), Lygus days were calculated as: $ID = (X_{i+1} - X_i)[(Y_i + Y_{i+1}) / 2]$ where X is sample days and Y are sample numbers. Cumulative insect days were computed by summing the individual insect days.
Delay was measured by calculating the Julian day each treatment reached NAWF5 (five nodes above white flower) and the day cotton reached 80% open boll. Four harvest dates were initiated and included: 20, 28 August, 04, 11 September. These harvest dates represent 138, 146, 153, 160 DAP (days after planting). Cotton was air dried and ginned on a microgin. Yield measurements were calculated as pounds of lint per acre and also used as measures of delay.

Data was analyzed using Proc. Mixed (SAS 1989 - 1993) to include treatments with eight replications in comparisons.

Results and Discussion

Insect Control and Duration of Insect Control

Sweep net sampling resulted in various plant feeding species and beneficial arthropods being observed. Phytophagous insects observed were: cotton fleahopper *pseudatomoscelis seriatus* (Reuter), false chinchbug *Nysius raphanus* (Howard), fleabeetle *Chaetocnema pulicaria* (Melsheimer), grasshopper *Melanoplus* spp., leafhopper (Cicadellidae), spotted cucumber beetle *Diabrotica undecimpunctata howardi* (Barber), striped cucumber beetle *Acalymma vittatum* (Fabricius), tarnished plant bug, three corned alfalfa hopper *Spissistilus festinus* (Say), and yellow striped armyworm *Spodoptera ornithogalli* (Guenee). Beneficial arthropods observed were: ants (Formicidae), spiders (Araneae), bigeyed bug *Geocoris punctipes* (Say), whitemarked fleahopper *Spanagonicus albofasciatus* (Reuter), Coccinelids, damsel bug (Nabidae), predaceous mirids *Deraeocoris nebulosus* (Ehler), hymonopterous parasatoids, lacewings (Chrysopidae and Hemerobiidae), and minute piratebug *Orius* spp.

Pretreatment counts were initiated on 24 May. For discussion, sampling dates will be referred to as their respective DAT (days after treatment). Mean nodes per plant were similar at all sampling dates, except where Baythroid treated cotton had less mean nodes than cotton treated with Karate 10DAT (Table 1). No treatment decreased the incidence of damaged terminals at any sampling date (Table 2). At 1DAT, cotton treated with Karate had more flagged leaves than Provado or Vydate C-LV + Lannate LV, although these numbers are not numerically high. No other differences were noted at any other sampling dates (Table 3).

Infestation levels were measured as number of tarnished plant bugs per 100 sweeps. No differences were noted in tarnished plant bugs at 24 May or 1DAT. Provado provided less control of tarnished plant bug than other insecticide treatments 4DAT, although control increased at 6DAT. At 6DAT, Provado and Karate provided more control of tarnished plant bug than did Vydate C-LV + Lannate LV, and Provado controlled tarnished plant bug better when compared to Orthene. Vydate C-LV + Lannate LV gave less control of tarnished plant bug than other treatments at 8DAT, but was similar to all treatments 10DAT. In addition, cotton treated with Baythroid had accumulated less tarnished plant bugs than Karate 10DAT (Table 4).

Cumulative infestations of tarnished plant bug (Lygus days) were similar up to 5DAT with all insecticide treatments. At 6 or 7DAT, Karate had less of an accumulation of lygus days than did Vydate C-LV + Lannate LV, but at 6DAT both treatments were similar to other treatments in the study. In addition, Provado and Baythroid had lower lygus days than Vydate C-LV + Lannate LV. Cotton treated with Vydate C-LV + Lannate LV had accumulated 13.22 and 17.87 lygus days 8 and 9DAT, respectively, which was greater than all other treatments. At 10DAT, cotton treated with Baythroid had accumulated less total lygus days than Orthene or Vydate C-LV + Lannate LV, although Orthene treatments were similar to cotton treated with Provado and Karate (Table 5).

Changes in lygus days were measured between sampling dates to identify any increase in feeding accumulation. There were no differences in the change of lygus days 1DAT, although a significant change was observed with Provado treatments 4DAT. This slow initial control was noted in 1995 with Provado treatments. At 6DAT, Provado and Karate treatments had less change in lygus day accumulation than did Vydate C-LV + Lannate LV. All treatments, except Vydate C-LV + Lannate LV, demonstrated less change in accumulation of lygus days 8DAT, although Vydate C-LV + Lannate LV was similar to all other treatments, except Baythroid 10DAT. In addition, less of an increase in lygus days were noted with Baythroid treaments when compared to Karate (Table 6).

All phytophagous insects were grouped to identify treatment control of all plant feeding species involved in this particular system. Provado was less effective than Baythroid, Karate or Vydate C-LV + Lannate LV in controlling all phytophagous insects observed in the study 1DAT. Again, this is similar to results in 1995. No differences in control of phytophagous insects were noted 4DAT. Lower levels of phytophagous insects were noted in cotton treated with Karate when compared to cotton treated with Orthene or Vydate C-LV + Lannate LV 6DAT. In addition, Provado and Baythroid treatments were more effective than Vydate C-LV + Lannate LV. Higher levels of phytophagous insects were collected in cotton treated with Vydate C-LV + Lannate LV, than other treatments 8DAT. At 10DAT, lower levels of phytophagous insects were found in cotton treated with Karate than cotton treated with Provado and Baythroid (Table 7).

No differences were observed with any insecticide treatment in reducing beneficial populations up to 6DAT. Cotton treated with Orthene and Provado had a greater impact on beneficial populations than did Karate 8DAT. No other differences were noted in treatments with beneficial populations 10DAT (Table 8).

Plant Development and Yield

The node of first fruit was similar for all treatments involved in the study. In addition, Karate provided a greater fruit set than Provado or Vydate C-LV + Lannate LV. Cotton treated with Orthene reached NAWF5 on Julian day 194.75, which was less time required than cotton treated with Vydate C-LV + Lannate LV. Orthene treated cotton reached 80% open boll on Julian day 245.50, which was earlier than all other treatments (Table 9).

Lint cotton harvested from treatments of Vydate C-LV + Lannate LV was less during early season development than with Baythroid, Karate or Orthene 138 DAP, although lint harvested from cotton treated with Vydate C-LV + Lannate LV was similar to Provado treated cotton at this harvest date. There were no differences in cotton harvested from any treatment 146 DAP. Lint harvested from cotton treated with Baythroid was greater than that of cotton treated with Orthene 153 and 160 DAP, although lint harvested was greater at 160 DAP with cotton treated with Vydate C-LV + Lannate LV than all other treatments, which could be considered an estimate of delay in harvest maturity (Table 11). When lint yields from the first two harvest dates were combined, cotton treated with Baythroid or Orthene produced more lint yield than Vydate C-LV + Lannate LV treatments. When the first three harvest dates were combined, only cotton treated with Baythroid produced more lint cotton than Vydate C-LV + Lannate LV treatments. In additon, compensation in late season lint production was observed at the final harvest date with Vydate C-LV + Lannate LV treatments or when comparisons of total lint yield were made. Lint cotton harvested from Baythroid or Vydate C-LV + Lannate LV treatments was greater than lint cotton harvested from Orthene treatments (Table 12). In addition, delay in maturity observed in Vydate C-LV + Lannate LV treatments should be considered a major factor in harvest feasibility.

Acknowledgments

We thank Sammy Soignier, Field Consultant, Inverness, MS, and Scott Hutcheson, area agent assistant, Greenville, MS for their assistance in the field study and again Robertson Planting Company for their cooperation.

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Table 1. Mean nodes per plant determined at specified sampling dates.

	Node[1]					
Treatment	Pre	1DAT[3]	4DAT	6DAT	8DAT	10DAT
Provado	4.90a[2]	5.66a	6.90a	7.58a	8.50a	9.16ab
Baythroid	4.94a	5.99a	6.83a	7.89a	8.60a	8.96a
Karate	4.96a	5.73a	6.64a	7.95a	8.36a	9.26b
Orthene	4.95a	5.96a	6.68a	7.73a	8.18a	9.21ab
Vydate + Lannate	4.87a	6.08a	7.13a	7.73a	8.50a	9.23ab

[1]A node is defined as each mainstem branch excluding, cotyledonary branches, having leaves one inch in diameter or greater.
[2]Means followed by the same letter are not significantly different at the 0.1 probability level according to the LSD method.
[3]DAT, days after treatment.

Table 2. Percent damaged terminals determined at specified sampling dates.

	Damaged Terminals[1]					
Treatment	Pre	1DAT[3]	4DAT	6DAT	8DAT	10DAT
Provado	12.10a[2]	10.00a	0.00a	0.75a	1.00a	2.25a
Baythroid	10.00a	9.25a	0.50a	1.00a	0.50a	1.00a
Karate	11.50a	7.00a	1.00a	1.00a	2.50a	3.50a
Orthene	8.10a	8.00a	0.00a	0.75a	1.00a	2.25a
Vydate + Lannate	9.10a	6.00a	0.00a	0.75a	1.00a	1.25a

[1]A damaged terminal was determined if terminal feeding followed by tissue decay was observed.
[2]Means followed by the same letter are not significantly different at the 0.1 probability level according to the LSD method.
[3]DAT, days after treatment.

Table 3. Black flags observed at specified sampling dates.

	Black Flags[1]					
Treatment	Pre	1DAT[2]	4DAT	6DAT	8DAT	10DAT
Provado	0.00a[3]	0.00a	0.00a	0.00a	0.00a	0.00a
Baythroid	0.00a	1.50ab	0.50a	0.00a	0.00a	0.00a
Karate	0.50a	1.63b	0.50a	0.00a	0.00a	0.00a
Orthene	0.00a	1.42ab	0.00a	0.00a	0.00a	0.00a
Vydate + Lannate	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a

[1]A black flag is defined as any discoloration of unfurled terminal leaves caused by feeding on leaf petiole.
[2]DAT, days after treatment.
[3]Means followed by the same letter are not significantly different at the 0.1 probability level according to the LSD method.

Table 4. Tarnished plant bugs per 100 sweeps observed at specified sampling dates.

	Tarnished plant bugs					
Treatment	Pre	1DAT[2]	4DAT	6DAT	8DAT	10DAT
Provado	0.00a[1]	0.50a	0.50a	0.00a	2.00a	3.25ab
Baythroid	0.25a	0.25a	0.00b	1.00abc	0.75a	2.00a
Karate	0.50a	0.00a	0.00b	0.50ac	1.00a	4.00b
Orthene	0.00a	0.00a	0.00b	2.00bc	2.00a	3.75ab
Vydate + Lannate	1.00a	0.00a	0.00b	2.50b	4.50b	3.25ab

[1]Means followed by the same letter are not significantly different at the 0.1 probability level according to the LSD method.
[2]DAT, days after treatment.

Table 5. Lygus days observed throughout sampling period.

	Lygus days					
Treatment	5/24	5/25	5/26	5/27	5/28	5/29
Provado	0.00a[1]	0.25a	0.75a	1.20a	1.73a	2.25a
Baythroid	0.25a	0.50a	0.75a	0.91a	1.00a	1.00a
Karate	0.25a	0.38a	0.38a	0.38a	0.38a	0.38a
Orthene	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a
Vydate + Lannate	1.00a	1.50a	1.50a	1.50a	1.50a	1.50a

Table 5. continued.

Lygus days						
Treatment	5/30	5/31	6/1	6/2	6/3	6/4
Provado	2.50a[1]	2.50ab	3.50a	5.48a	8.12a	11.2ab
Baythroid	1.50a	2.50ab	3.38a	4.13a	5.50a	7.50a
Karate	0.63a	1.13a	1.88a	2.88a	5.38a	9.38ab
Orthene	1.00a	3.00ab	5.0ab	7.00a	9.88a	13.5b
Vydate + Lannate	2.75a	5.25b	8.75b	13.2b	17.87b	22.5c

[1]Means followed by the same letter are not significantly different at the 0.1 probability level according to the LSD method.

Table 6. Change in lygus day accumulations observed throughout sampling period.

	Change in accumulation[1]				
Treatment	1DAT[2]	4DAT	6DAT	8DAT	10DAT
Provado	0.74a[3]	1.50a	0.25a	3.05a	5.85ab
Baythroid	0.50a	0.25b	1.50ab	1.63a	3.38a
Karate	0.13a	0.00b	0.75a	1.75a	6.50b
Orthene	0.00a	0.00b	3.00ab	4.05a	6.60ab
Vydate + Lannate	0.50a	0.00b	3.75b	8.05b	9.35b

[1]Changes in accumulation are recorded as increases from: 5/24-5-/26, 5/26-5/29, 5/29-5/31, 5/31-6/2, 6/2-6/4.
[2]DAT, days after treatment.
[3]Means followed by the same letter are not significantly different at the 0.1 probability level according to the LSD method.

Table 7. Total phytophagous insect population per 100 sweeps observed at specified sampling dates.

	Phytophagous insects[1]					
Treatment	Pre	1DAT[2]	4DAT	6DAT	8DAT	10DAT
Provado	6.50a	3.00a[3]	1.25a	2.00a	7.90a	11.75a
Baythroid	6.25a	0.75b	1.00a	1.75a	5.25a	9.50a
Karate	4.50a	0.75b	0.50a	1.00a	3.75a	5.00b
Orthene	7.00a	1.00ab	0.25a	4.00c	3.90a	9.75ab
Vydate + Lannate	6.00a	0.00b	0.25a	6.00bc	16.90b	6.75ab

[1]Phytophagous insects are defined as any plant feeding insects that could potentially feed and damage terminal bud.
[2]DAT, days after treatment.
[3]Means followed by the same letter are not significantly different at the 0.1 probability level according to the LSD method.

Table 8. Total beneficial insect population per 100 sweeps observed at specified sampling dates.

	Beneficial insects					
Treatment	Pre	1DAT[1]	4DAT	6DAT	8DAT	10DAT
Provado	5.60a	2.50a[2]	6.00a	2.10a	2.10a	8.00a
Baythroid	2.25a	2.00a	5.50a	4.00a	4.75ab	5.25a
Karate	4.00a	3.75a	10.5a	4.25a	8.25b	5.00a
Orthene	5.60a	0.50a	3.00a	4.10a	2.10a	10.00a
Vydate + Lannate	2.10a	0.50a	5.50a	5.10a	5.10ab	2.50a

[1]DAT, days after treatment.
[2]Means followed by the same letter are not significantly different at the 0.1 probability level according to the LSD method.

Table 9. Fruiting characteristics and measurements of earliness observed through mapping data and final calculations.

Treatment	Node of First Fruit	Percent Fruit Set	Julian Day at NAWF5[1]	Julian Day at 80%
Provado	5.64a[2]	88.93a	198.00ab	248.75a
Baythroid	6.17a	91.90ab	198.13ab	248.75a
Karate	5.91a	94.88b	195.88ab	248.75a
Orthene	6.13a	90.34ab	194.75a	245.50b
Vydate + Lannate	5.88a	90.26a	199.25b	251.00a

[1]NAWF, node above white flower. Earliness measurements were determined by calculating a Julian calendar day at which each treatment reached NAWF5 and 80% open.
[2]Means followed by the same letter are not significantly different at the 0.1 probability level according to the LSD method.

Table 10. Node Above White Flower NAWF at specified sampling dates.

NAWF			
Treatment	7/10	7/17	7/24
Provado	6.52a[1]	4.53ab	2.30a
Baythroid	6.00a	4.30ab	2.35a
Karate	6.09a	3.94a	2.05a
Orthene	5.90a	5.93c	2.15a
Vydate + Lannate	6.67a	5.08bc	3.38b

[1]Means followed by the same letter are not significantly different at the 0.1 probability level according to the LSD method.

Table 11. Yield increments determined by harvest intervals.

	lbs lint/acre			
Treatment	138DAP[1]	146DAP	153DAP	160DAP
Provado	211.98ab[2]	281.49a	325.16ab	205.48ab
Baythroid	251.02a	318.89a	342.98a	256.81a
Karate	221.49a	281.36a	312.04ab	219.14ab
Orthene	260.35a	285.10a	243.05b	94.12b
Vydate + Lannate	128.67b	266.68a	305.95ab	434.38c

[1]DAP, days after planting.
[2]Means followed by the same letter are not significantly different at the 0.1 probability level according to the LSD method.

Table 12. Combined[1] yield increments determined by harvest intervals.

	lbs lint/acre		
Treatment	Yield 1	Yield 2	Total Yield
Provado	495.06ab[2]	822.91ab	1024.11abc
Baythroid	569.91a	912.89a	1169.70ac
Karate	502.86ab	814.90ab	1034.03abc
Orthene	547.04a	792.79ab	882.62b
Vydate + Lannate	396.93b	705.57b	1135.79c

[1]Yield combinations were determined by adding yield at 8/20 plus 8/28 (Yield 1), 8/20 plus 8/28 plus 9/4 (Yield 2), and combining all yield harvest dates for total yield.
[2]Means followed by the same letter are not significantly different at the 0.1 probability level according to the LSD method.