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Insecticide Trials for Control of Tarnished Plant Bug on Cotton

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Abstract

This bulletin reviews results from small-plot and laboratory insecticide evaluations of tarnished plant bug, *Lygus lineolaris* (Palisot De Beauvois), on cotton in Mississippi from 1982 to 1997, as well as results from trials completed in other states and published in "Arthropod Management Tests." Efficacy of the pyrethroid class of insecticides has declined over time in Mississippi and other cotton-growing states since 1982. Organophosphates as a class demonstrated a sharp decline in efficacy following 1985 in Mississippi and other states. Efficacy of the carbamate class of insecticides fluctuated greatly over time, but results did not indicate a continued decline in efficacy. Two newer classes of insecticides -- chloronicotinyl and fiprole -- show promise for use in tarnished plant bug management on cotton in Mississippi. Summaries of a limited number of trials including adjuvants indicate that efficacy of some organophosphates may be increased by use of a buffering adjuvant. Tables of Mississippi evaluations and summaries of individual compounds, combinations, and rates

are presented.

Introduction

The tarnished plant bug is an important cotton pest in the mid-South region of the United States. In the annual cotton insect loss reports published in the Proceedings of the Beltwide Cotton conferences, tarnished plant bugs were listed as the second most important cotton pests in Mississippi during 1984 and 1989, and the third most important in 1980, 1983, 1988, 1990, and 1991-1993. According to Williams (1997), there were more foliar applications of insecticide applied for tarnished plant bugs in Mississippi during the 1996 growing year than there were for the number-one pest group, the heliothentines. Mississippi producers lost 22,512 bales of cotton during 1997 because of damage from tarnished plant bugs (Williams 1998), making it the third most important cotton insect pest in 1997. Through the last 12 years, the number of insecticide applications applied per acre has remained relatively stable, while the cost of those insecticides has risen sharply (Figure 1). Increased crop loss has also been associated with the tarnished plant bug during this period (Figure 2). Losses attributed to the tarnished plant bug may well continue to increase in the future as boll weevil and budworm are reduced as threats to Mississippi cotton and coincidental control of tarnished plant bug by treatments targeting those two insect species declines.

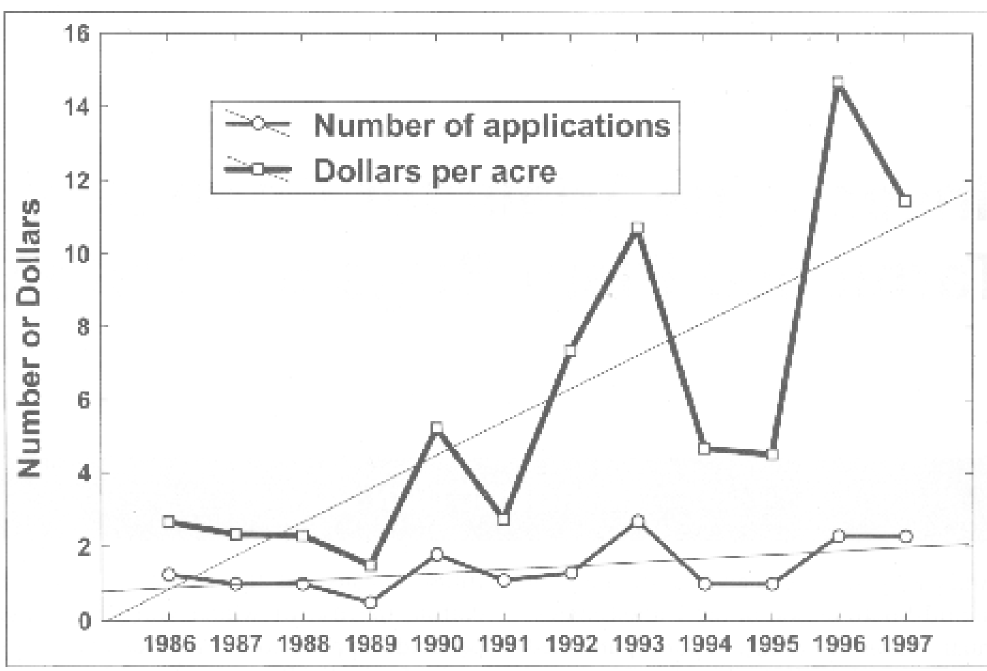

Figure 1. Estimated number of insecticide applications and cost per acre associated with tarnished plant bug management in Mississippi from 1986-1997. Slanted lines are linear regression lines indicating slight increased numbers of insecticide applications and large increase in cost with time (From Crop Loss Reports, Beltwide Cotton Conferences, 1987-1998).

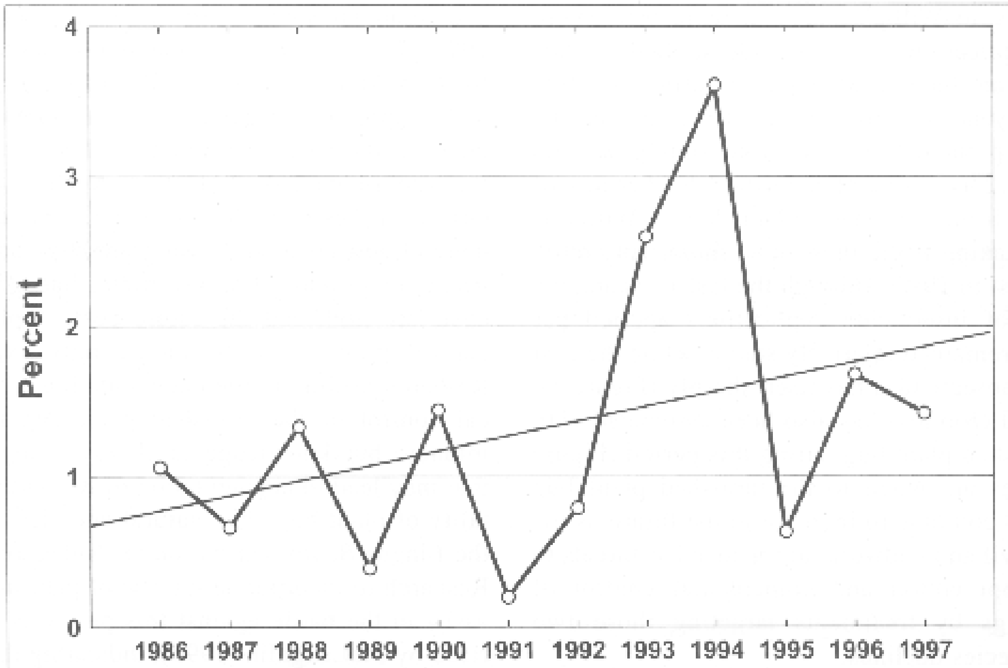

Figure 2. Percent of crop loss attributed to the tarnished plant bug in Mississippi from 1986-1997. The slanted line is the linear regression line demonstrating increased crop loss to the tarnished plant bug over time. (From Crop Loss Reports, Beltwide Cotton Conferences, 1987-1998).

The need for tarnished plant bug control in Mississippi cotton is likely to increase in the future because of the advent of transgenic (Bt) cotton, the use of which will reduce pyrethroid pesticide applications. Another contributing factor is the probability of reduced insecticide applications for control of boll weevils as a result of the eradication program. Our arsenal of materials for control of the tarnished plant bug is shrinking because of insecticide resistance to pyrethroids and organophosphates (Snodgrass and Scott 1988, 1996). Legislative action has removed chlorpyrifos from Mississippi's arsenal because of threat to catfish production ponds, and all organophosphates and carbamates are under close scrutiny by the Environmental Protection Agency and the Office of Pesticide Management. The development of new chemistries for plant bug control has begun to provide new materials, but associated costs are high and the future cost of plant bug control promises to be increasingly expensive. Research leading to the understanding of biological control of tarnished plant bug is in its infancy, but knowledge is slowly being gained that may lead to augmentation of the natural mortality of tarnished plant bug by "natural enemies" such as the fungus *Beauveria bassiana* (Ruberson 1998). Research to incorporate the use of pheromones to assist in the battle against this pest was summarized by McLaughlin (1998), indicating that nothing of real promise in this respect is on the immediate horizon. Host plant resistance studies indicate that the nectariless and earliness traits tend to increase yield in the presence of tarnished plant bug (Scott et al. 1988; Merideth 1998). These need to be used in conjunction with the transgenic varieties to help reduce the probability of increased tarnished plant bug damage resulting from reduced insecticide applications that secondarily control *Lygus*. These characteristics have not been widely incorporated for tarnished plant bug management.

Current trends in pesticide registration requirements by the EPA tend to reduce the profitability in maintaining insecticides in general, and the legislative undercurrent is that of eliminating some of the less environmentally friendly compounds altogether. In order to identify resistance trends and to provide both efficacy and economic considerations for decision making, it is important to historically review the efficacy of all insecticides used for tarnished plant bug control in Mississippi. Although new classes of insecticides have been developed that demonstrate efficacy against tarnished plant bug, they may not completely replace the current standards. One insecticide, imidacloprid, received registration for tarnished plant bug control on cotton in 1996. Fipronil, representing yet another class of chemistry that is effective against tarnished plant bug, is on the registration track. Ondoxicarb, a new compound under development, is also nearing registration on cotton for use against budworm and bollworm. It is reported to have efficacy against the tarnished plant bug. Other compounds yet to be named are under development by the chemical industry.

For many years, organophosphate and pyrethroid insecticides have been the insecticide classes of choice for control of the tarnished plant bug. Efficacy of organophosphates for plant bug control has fluctuated considerably over the years and within geographical locations of Mississippi (Snodgrass and Scott 1988). There is evidence that resistance of the pest to some compounds is less pronounced early in the season and is more pronounced late in the season after several insecticide applications have been made to the cotton crop (Snodgrass and Scott 1996; Holloway et. al. 1998). These trends are important in the overall program for management decisions in the future, and they emphasize the critical importance of maintaining an arsenal of functional control agents for this pest.

This bulletin is a review of the insecticide evaluations made for tarnished plant bug control on cotton in Mississippi. It also includes comments about pesticide evaluations in other states that have been published in "Arthropod Management Tests" (previously "Insecticide and Acaricide Tests") in order to help establish a picture of the control of tarnished plant bugs in cotton.

Methods and Materials

Most of the tests summarized herein were applied on cotton planted and managed as a commercial crop. Plots were typically four to eight rows wide and 50-60 feet (15.2-18.3 m) long arranged with four rows of unsprayed cotton between plots. Insecticides were typically applied with a high-clearance plot spray tractor with nozzles spaced for 38-inch (96.5 cm) row spacing at 19-inch (48.3 cm) centers (two nozzles per row) with one nozzle directly over the row and one directly between rows. Evaluations were made 2 or more days after application by sweep net, drop-cloth, or visual sampling techniques. The carrier was always water, and the volumetric application rate ranged from 5 to 10 gallons (18.9-37.8 L) per acre.

A few laboratory studies were completed in an electronically controlled spray chamber. Plant bugs were collected from wild flowers and confined on sprayed leaf disks in Petri dishes for these studies.

In other studies, cloth sleeves were used to enclose the upper portions of treated plants and thus cage tarnished plant bugs on the plants. These sleeves were placed over the plants, secured with elastic fasteners, gathered at the point of fastening, and completely covered with aluminum foil before spraying. After the spray application was dry, the aluminum foil was removed. Then, each sleeve was extended, 10 tarnished plant bugs were placed inside, and the upper end was closed with an elastic fastener or string. These plants were cut after 24 hours and searched for survivors. Plant bugs used in sleeve-cage and spray-chamber trials were usually collected from wild host plants by use of sweep nets. Collections were usually made the day before the trial, and plant bugs were held on wild blooms or green beans overnight.

To make observations of trends and general comparisons of results between insecticide classes, years, or individual insecticides, the mean insect count for each treatment in each test was normalized against the mean insect count occurring in the untreated or water-treated check plots. The mean insect count from the treated plot was divided by that of the untreated (Efficacy Ratio = Treated/Untreated). This produced an efficacy ratio of 0 for 100% control and 1 for no control. Percent control was then computed by subtracting the efficacy ratio from 1, and multiplying the result by 100 [Percent control = (1 - efficacy ratio) * 100].

Many comparisons made with the normalized data assume that materials tested for tarnished plant bug control were tested at optimum or nearly optimum rates. This assumption allows comparison of insecticide classes or study of trends within an insecticide class over time; however, a few trials used ovicidal or low rates that would lower the means in these summaries. Many test parameters that could significantly affect original test results are ignored in such comparisons, and this should be kept in mind while considering these results. These include temperature during the trial, wind turbulence during application, type of spray equipment used, rainfall or lack of rainfall during the trial, number of samples taken after application, number of applications of insecticide, and other factors. One factor that could significantly affect normalized results -- the time between spray application and evaluation, or days after treatment (DAT) -- will be discussed more fully in the results section. Typically, 2-3 days lapsed between spray application and evaluation, but occasionally 2 or more applications were made during a trial. For our purposes, season-long trials with many applications were restricted to fewer than 12 days after spray application so that comparisons with other tests would be more acceptable. This essentially limited the number of spray applications to two or fewer.

Results

The number of plant bugs per sample for Mississippi during 1993-1997 on untreated plots averaged 14.4 (SD=26.1). Out-of-state trials published in "Arthropod Management Tests" averaged 15.4 (SD=23.1) insects per untreated sample. The 1995 season proved to be a high-plant-bug season, and the untreated plots averaged 24.2 insects per sample, nearly twice as many as other years (Figure 3). Sampling differences between trials were not identified in the results since the initial comparison of treated vs. untreated plots was always within trials. Thus, we assume that the sampling was adequate to effectively identify efficacy, regardless of the evaluation method used (i.e. visual, sweep-net, or drop-cloth). Table 1 lists the compounds used in the trials. Summaries of insecticide class results are reported in Appendix A. Results of individual Mississippi trials are summarized in Appendix B.

Table 1. List of compounds and trade names for materials used in Mississippi efficacy trials for plant bug control.

Compound	Trade Name
Acephate	Orthene
Amitraz	Baam Mitac Ovasyn
Azinphosmethyl	Guthion
Bifenthren	Capture
Buffer	Buffer
Carbofuran	Furadan
CGA 215944	CGA 215944
Chlordimeform	Fundal Galecron
Chlorpyrifos	Lorsban XRM-4656
Cyfluthrin	Baythroid BAY FCR 1272
Cyhalothrin	Karate
Cypermethrin	Ammo Cymbush FMC 45806
Deltamethrin	Decis
Dicrotophos	Bidrin
Dimethoate	Cygon
Endosulfan	Thiodan Phaser
Esfenvalerate	Asana
Ethyl Parathion	Ethyl Parathion
EXP 60342A	EXP 60342A
EXP 60720A	EXP 60720A
Fenpropathrin	Danitol
Fipronil	Fipronil Regent
Flucythrinate	AC 222705 Payoff
Fluvalinate	Maveric(k)
Imidacloprid	Admire Provado NTN 33893
Invert Sugar	V10009
Kinetic	Kinetic
Malathion	Cythion Fyfanon
Methamidophos	Monitor
Methyl Parathion	Methyl Parathion
MO 070616	MO 070616
Monocrotophos	Azodrin
Oxamyl	Vydate
Permethrin	Ambush FMC 33297 Pounce
Phosmet	Imidan
Phosphamidon	Dimecron Swat
Profenofos	Curacron CGA 15324
Pymethrozine	CGA 215944
Pyrrole	AC303 630 Pirate
Sulprofos	Bolstar Bay NTN 9306
Thidocarb	Larvin
Tralomethrin	HAG 107 RU 25474 Scout
Zetamethrin	Fury

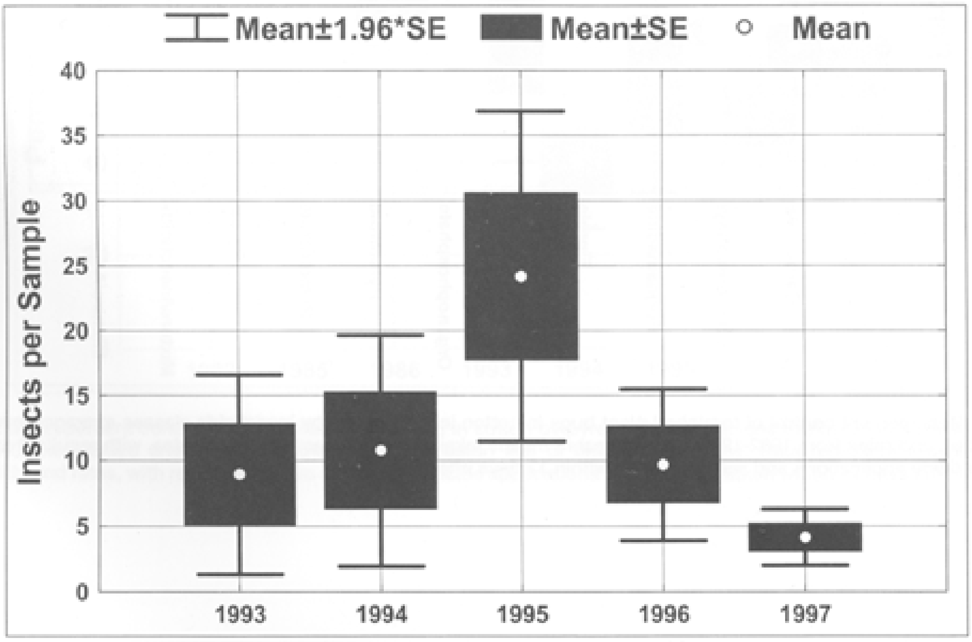

Figure 3. Mean tarnished plant bugs per sample from the untreated or water-treated check plots in trials in Mississippi from 1993-1997.

General Results

Figure 4 illustrates the overall efficacy of all classes of compounds tested in Mississippi since 1982. Based on these evaluations of the compounds tested, only the newer compounds averaged above 60% control. These included a fiprole (fipronil), as well as a chloronicotinyl compound (imidacloprid) and a pymethrozine. Over time and insecticides, the fiprole and pymethrozine compounds appear to have provided the best results. These newer compounds have not been in use long enough for the selection of resistant plant bug populations and hence demonstrate high efficacy. The values for organophosphates in Figure 4 include compounds that demonstrated little efficacy toward the tarnished plant bug in these studies (ethyl parathion, azinphosmethyl, and methyl parathion), when in reality several organophosphates were very effective (Figure 11). Organophosphates, pyrethroids, and the chloronicotinyl insecticides were approximately equivalent in efficacy when all compounds and rates were considered. The addition of an adjuvant appears to increase efficacy somewhat overall (based on a few insecticide/adjuvant entries), but the insecticidal mixtures tested provided only about 60% control, similar to organophosphates and pyrethroids. The organochlorine compound endosulfan averaged over 40% control; however, the standard error (SE) was broad, indicating that the compound was not consistently efficacious. The formamidine insecticide tested (chlordimiform) was not effective against plant bugs and is no longer registered for use on cotton.

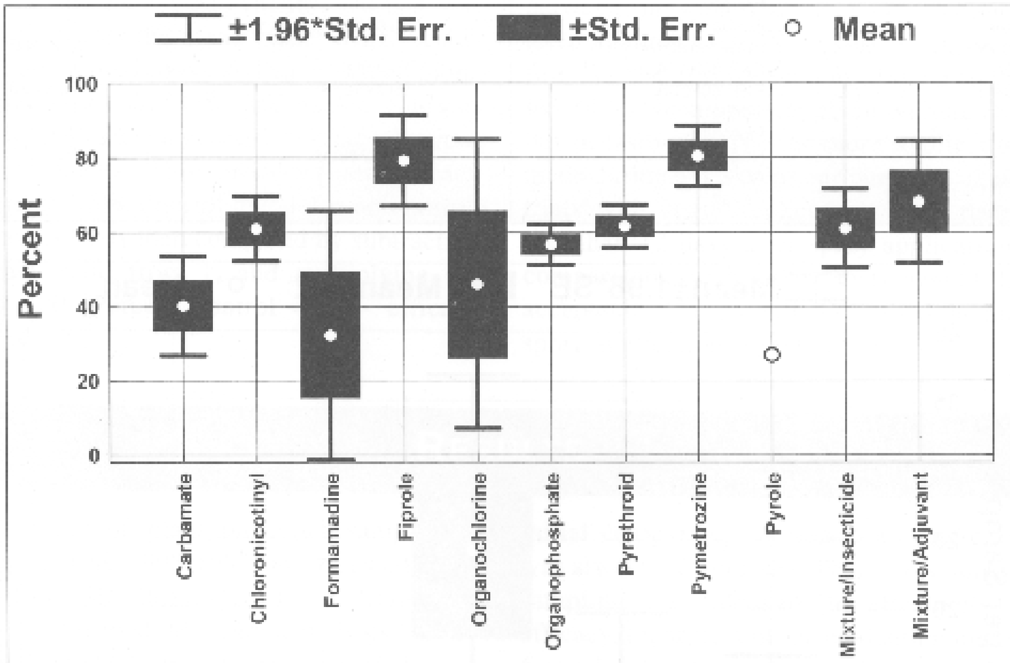

Figure 4. Mean percent control of tarnished plant bugs in cotton in Mississippi by insecticide classes averaged over years, insecticides, and rates from 1982-1997. Data represent means taken from all insecticides and rates, with results from two or less insecticide applications and samples taken within 12 days after treatment.

Pyrethroids Results

There are clear indications of reduced efficacy over time within the pyrethroid and organophosphate classes. Pyrethroids evaluated in 1982 provided 94% control, compared with 73% in 1986 and an average of about 56% over the last 5 years (Figure 5). Pyrethroids, introduced to the cotton market in the late 1970s and early 1980s, were extremely effective broad-spectrum insecticides used extensively for bollworm and budworm control. Tarnished plant bug resistance to pyrethroids would therefore be expected and has been documented (Holloway et al. 1998; Snodgrass and Scott 1996). A decline of pyrethroid efficacy is not evident from the combined data from all other cotton-growing states (excluding Mississippi), as published in "Arthropod Management Tests" (Figure 6). Note that tests for efficacy against the tarnished plant bug are lacking in other states after 1994. Data for all states (including Mississippi) for 1981-1997 indicate a general trend over time for decreased pyrethroid efficacy (Figure 7). Because of this trend, the summary of individual pyrethroid efficacy data (Figure 8) may be misleading. High values for permethrin and fluvalinate in Figure 8 are probably results of testing during the early years of pyrethroid use before plant bugs developed resistance. Danitol (fenpropathrin) has never been registered for use on Mississippi cotton, but it has seen use in other states for silver leaf white fly control.

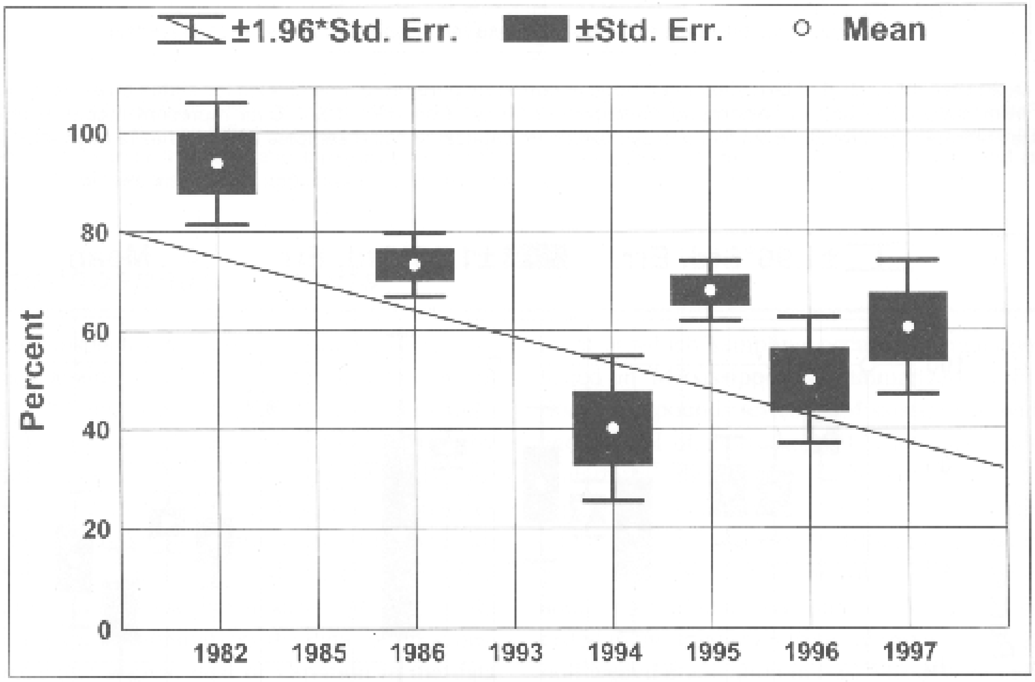

Figure 5. Mean percent control of the tarnished plant bug in cotton by pyrethroid insecticides evaluated in Mississippi from 1982-1997. The slanted line represents the linear regression line of efficacy over time. Data represent means from all pyrethroids and rates, with results from two or less insecticide applications and samples taken within 12 days after treatment.

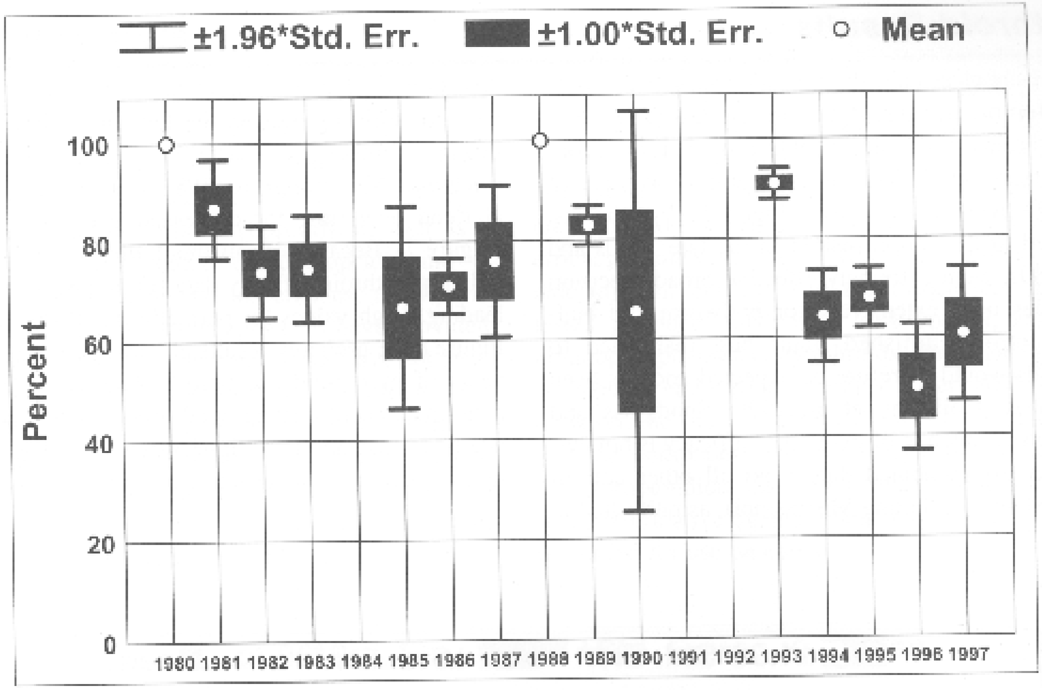

Figure 6. Mean percent control of tarnished plant bugs in cotton by pyrethroid insecticides for states other than Mississippi. Data are from tests published in "Arthropod Management Tests" from 1982-1997. Data represent means taken from all pyrethroids and rates, with results from two or less insecticide applications and samples taken within 12 days after treatment.

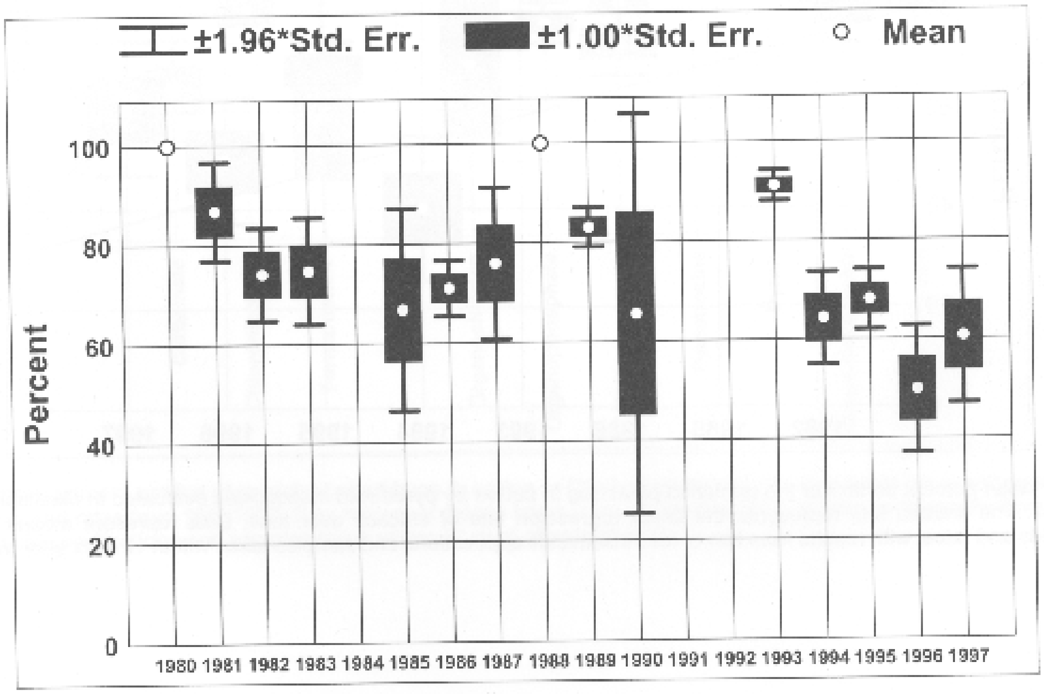

Figure 7. Mean percent control of tarnished plant bugs in cotton by pyrethroid insecticides for all states, including Mississippi. Data represent means taken from all pyrethroids and rates, with results from two or less insecticide applications and samples taken within 12 days after treatment.

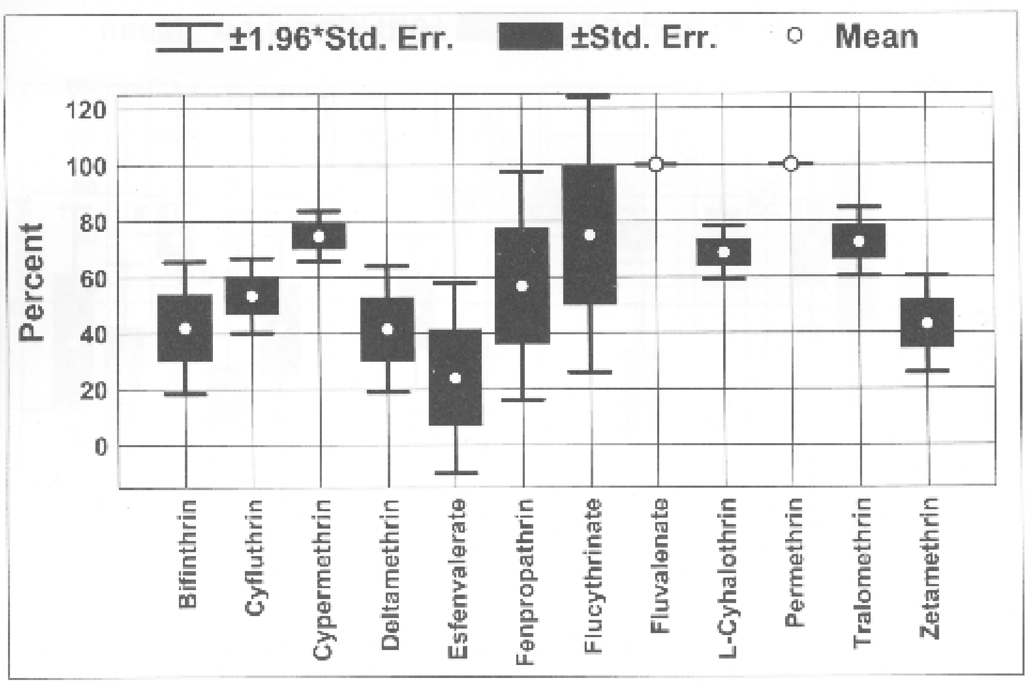

Figure 8. Efficacy of individual pyrethroids averaged across rates and years for Mississippi. High efficacy values for cypermethrin and flucythrinate may reflect the efficacy of a new class of insecticide on a non-resistant population, since they would have been tested earlier than the later generation pyrethroids. Data represent means from all pyrethroids and rates, with results from two or less insecticide applications and samples taken within 12 days after treatment.

Organophosphate Results

Organophosphates have demonstrated a rather stable efficacy against plant bugs in the last 5 years in Mississippi. Although an average of 92 samples indicated 80% control of tarnished plant bugs by organophosphates in 1982, the average for trials conducted from 1982-1997 was 57%. Figure 9 summarizes all the organophosphate data over time for all trials for Mississippi without regard to DAT, number of applications, or insect stage of growth. Similarly, Figure 10 summarizes the data for all states. It is obvious that a great deal of variation in the data occurs from year to year and that there is a general reduction in efficacy in data beginning in 1986. Some of the variation in these general data summaries is undoubtedly related to the number of days after treatment at which sampling occurred. Organophosphates tested in Mississippi are summarized in Figure 11. Some compounds tested in Mississippi provided average control of more than 50%: acephate, dimethoate, malathion, dicrotophos, phosphamidon, monocrotophos (monocrotophos is no longer available for use on cotton), and profenofos. Efficacy of malathion was boosted to about 95% control in one instance by the addition of a buffer. Although ULV malathion was not tested in the small-plot trials, observations made during boll weevil eradication in East Mississippi indicate that it is very effective in tarnished plant bug control. Results for out-of-state studies are shown in Figure 12. Dimethoate and malathion indicate good activity on tarnished plant bugs in the out-of-state data.

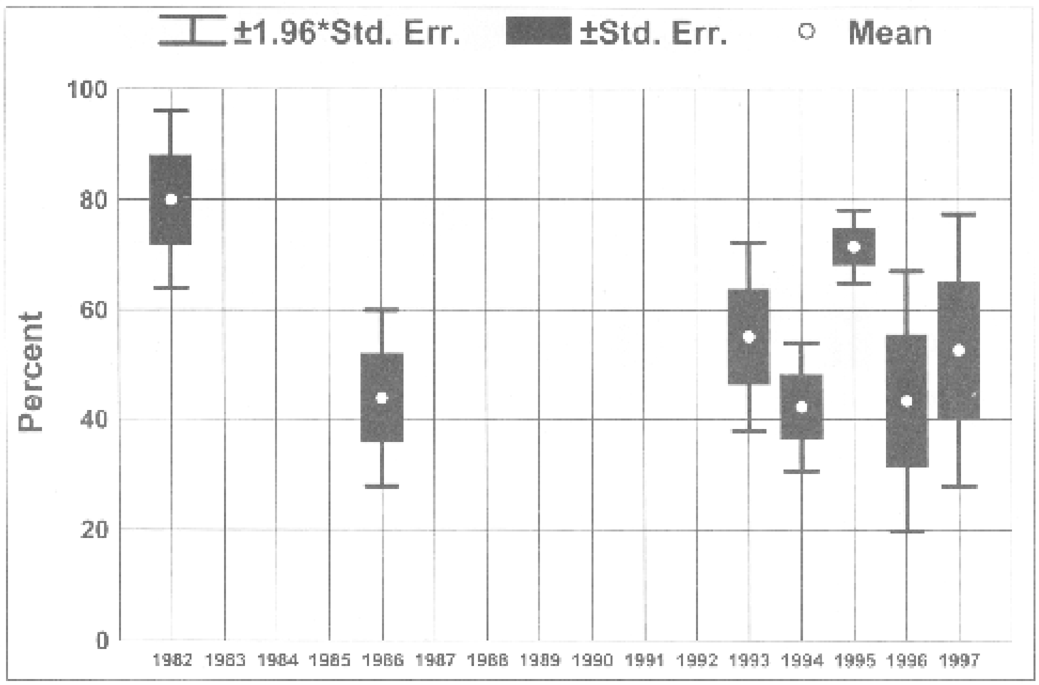

Figure 9. Mean percent control of tarnished plant bugs in cotton by organophosphate insecticides evaluated in Mississippi from 1982-1997. Data represent all organophosphate compounds and rates, with results from two or less insecticide applications and samples taken within 12 days after treatment.

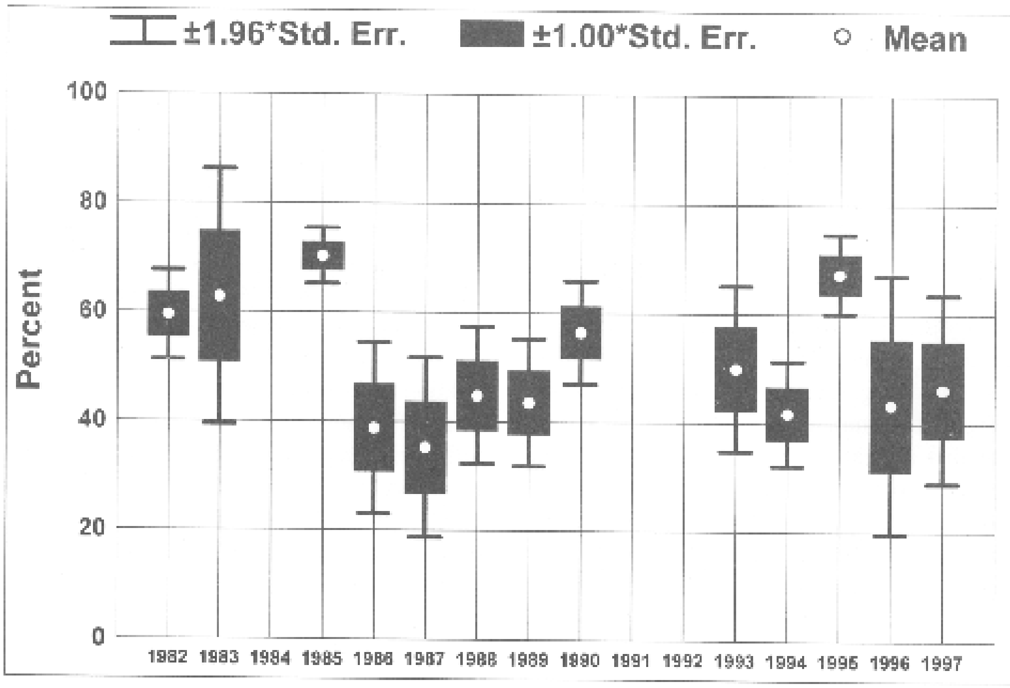

Figure 10. Mean percent control of tarnished plant bugs in cotton by organophosphate insecticides evaluated in all cotton-producing states, including Mississippi from 1982-1997. Data represent means from all organophosphate compounds and rates, with results from two or less insecticide applications and samples taken within 12 days after treatment.

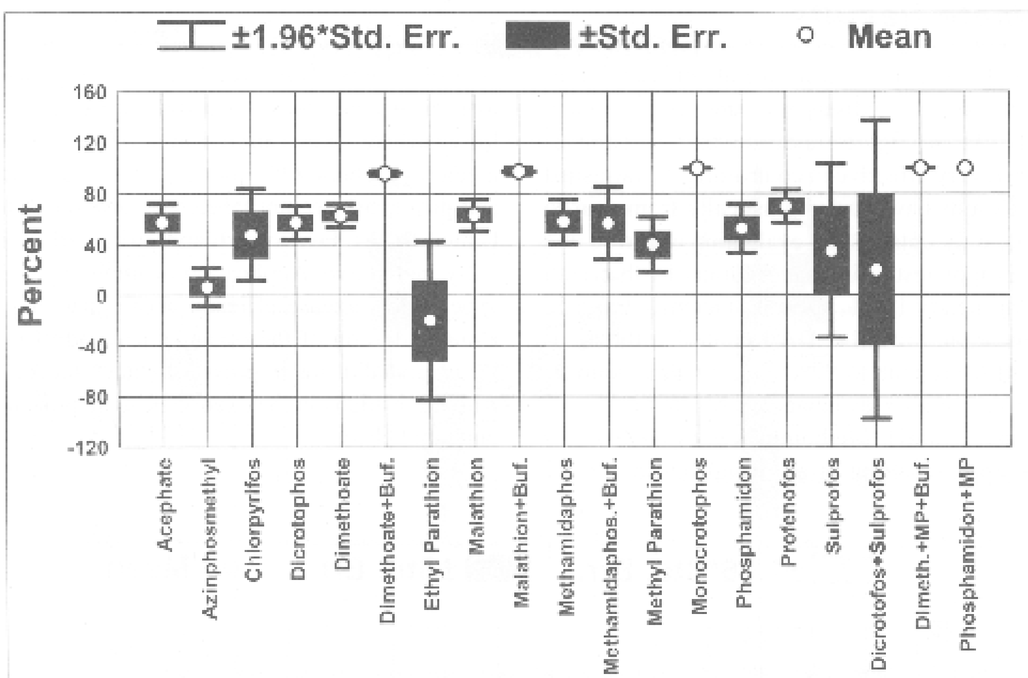

Figure 11. Mean percent control of tarnished plant bugs by individual organophosphate insecticides in Mississippi from 1982-1997. Data represent means from all organophosphates and rates, with results from two or less insecticide applications and samples taken within 12 days after treatment. (Abbreviations: buf. = buffer, dicrot. = dicrotophos, MP = methyl parathion, and sulpr. = sulprofos.)

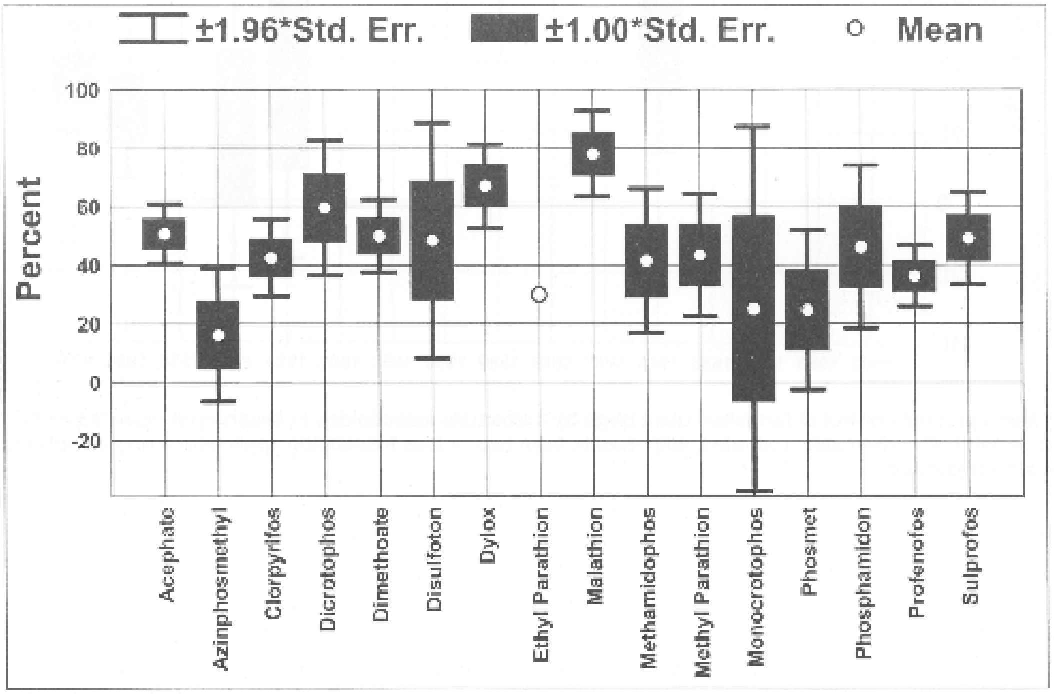

Figure 12. Mean percent control of tarnished plant bugs by organophosphate insecticides in states other than Mississippi from 1982-1997. Data represent means from all organophosphates and rates, with results from two or less insecticide applications and samples taken within 12 days after treatment. (Abbreviations: chlordim. = chlordimiform and monocr. = monocrotophos.)

Carbamate Results

Figures 13 and 14 reflect overall efficacy summaries over time for Mississippi and out of state, respectively. These figures indicate that carbamates have not been very effective in controlling the tarnished plant bug. Results have varied drastically from year to year, and the only outstanding evaluation occurred in a 1995 Mississippi test using carbofuran. In that test, mortality was nearly 100%, a result of a single trial and single application. From 1-7 DAT, control with carbofuran ranged from none to 97% after a single application. Other carbamates evaluated in Mississippi were thiodicarb and oxamyl. Methomyl was evaluated outside Mississippi, resulting in an overall mean percent control of 59%. Fenoxycarb (an insect growth regulator), pirimicarb, and mexicarbate were also evaluated. Mexicarbate was approximately as effective as methomyl (about 70% control). However, mexicarbate and pirimicarb are not labeled for use on cotton in the United States. Fenoxycarb and pirimicarb were essentially ineffective. Application of methomyl with an oil appears to increase efficacy above that of methomyl alone. Addition of the organosilicate adjuvant Kinetic to oxamyl did not improve efficacy, and plots ended with more adults in the oxamyl-Kinetic plots than in the untreated check.

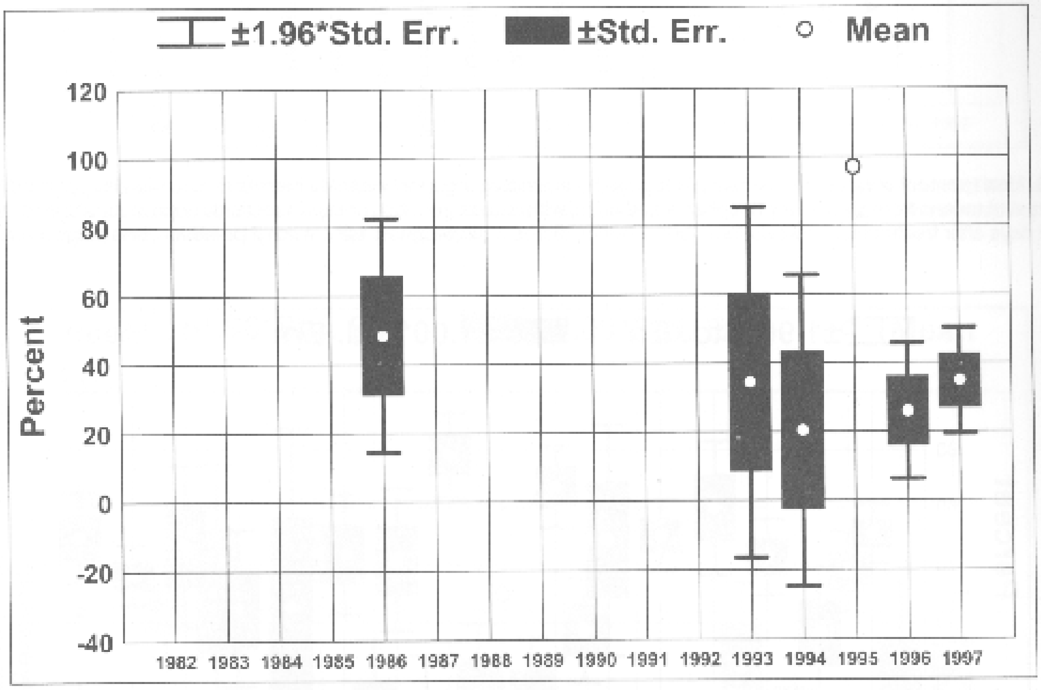

Figure 13. Mean percent control of tarnished plant bugs by carbamate insecticides in Mississippi from 1982-1997. Data represent means from all carbamates and rates, with results from two or less insecticide applications and samples taken within 12 days after treatment.

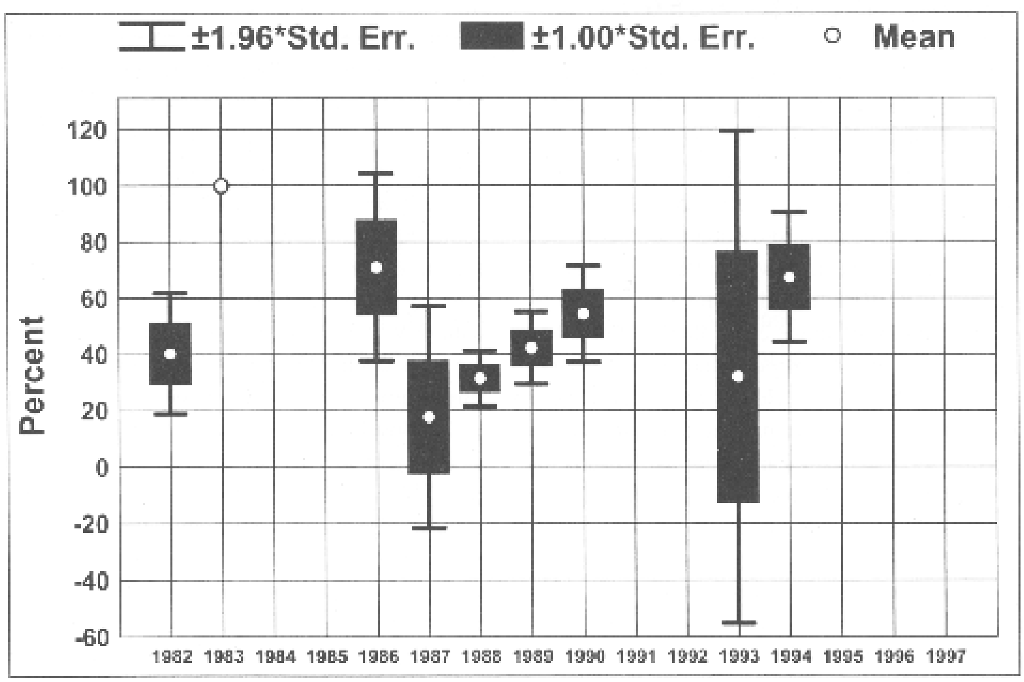

Figure 14 . Mean percent control of tarnished plant bugs by carbamate insecticides in states other than Mississippi from 1982-1997. Data represent means from all carbamates and rates, with results from two or less insecticide applications and samples taken within 12 days after treatment.

Miscellaneous Class Results

Four additional classes of insecticides were evaluated in Mississippi. These classes each contain a single compound that is registered or awaiting registration for use on cotton. Of these, imidacloprid (a nicotinyl compound) and fipronil (a fiprole) are effective in tarnished plant bug control. Both classes provided good control in these tests, with relatively narrow standard error bands, indicating consistent efficacy within and across evaluations. Few evaluations of these compounds from other states were published in "Arthropod Management Tests" during the years of this review. Hence, the data for these four classes for all states are summarized in Figure 15 and represent primarily Mississippi evaluations. Results of the fiprole (fipronil) and chloronicotinyl (imidacloprid) compounds in 1997 (Figure 15) are unexpectedly low. By restricting DAT to less than 5 days, the mean percent control by fipronil is increased drastically to more than 80% (Figure 16); however, 1996 results for imidacloprid were somewhat reduced, and the standard error increased by that restriction. This finding fits the concept that imidacloprid may take a longer time for mortality to occur than was the case with organophosphates or pyrethroids. Figure 17 indicates reduced efficacy relative to increased DAT for fipronil and imidacloprid. Although this information is compounded with various test or sampling parameters, it seems apparent that optimum DAT should be less than 3 days. Addition of Kinetic, a silicon-based additive, to imidacloprid gave increased control in 1993 evaluations in Mississippi, but it did not positively affect efficacy in 1994 or 1995. Overall efficacy of imidacloprid with or without Kinetic was about 60%. The majority of the trials containing imidacloprid were conducted with a single application of insecticide.

Endosulfan, the only organochlorine evaluated, was inconsistent in its results, resulting in a large standard error (Figure 15). Because it is strictly a contact insecticide, its efficacy would be highly dependent on good coverage of the plant during application. Thus, endosulfan tests are perhaps more sensitive to application parameters such as wind, droplet size, and volumetric application rate. The data for the 1993 and 1994 evaluations were published as trial means, indicating that an average of more than one post spray sample is included in the mean.

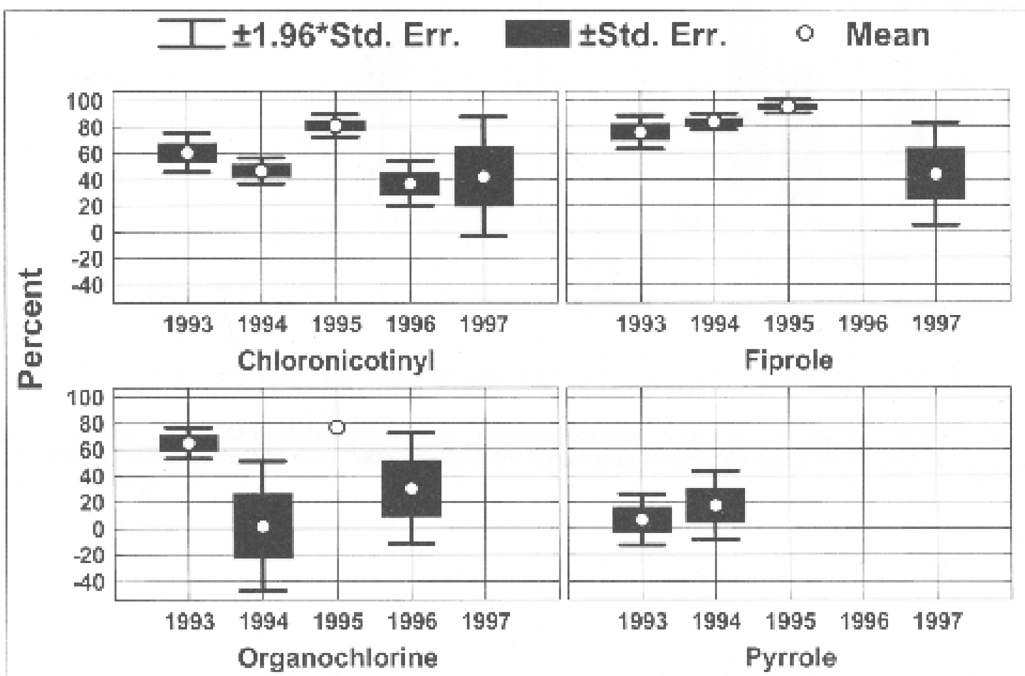

Figure 15. Mean percent control of tarnished plant bugs by four classes of insecticide in all states from 1993-1997. Data represent means from all rates, with results from two or less insecticide applications and samples taken within 12 days after treatment.

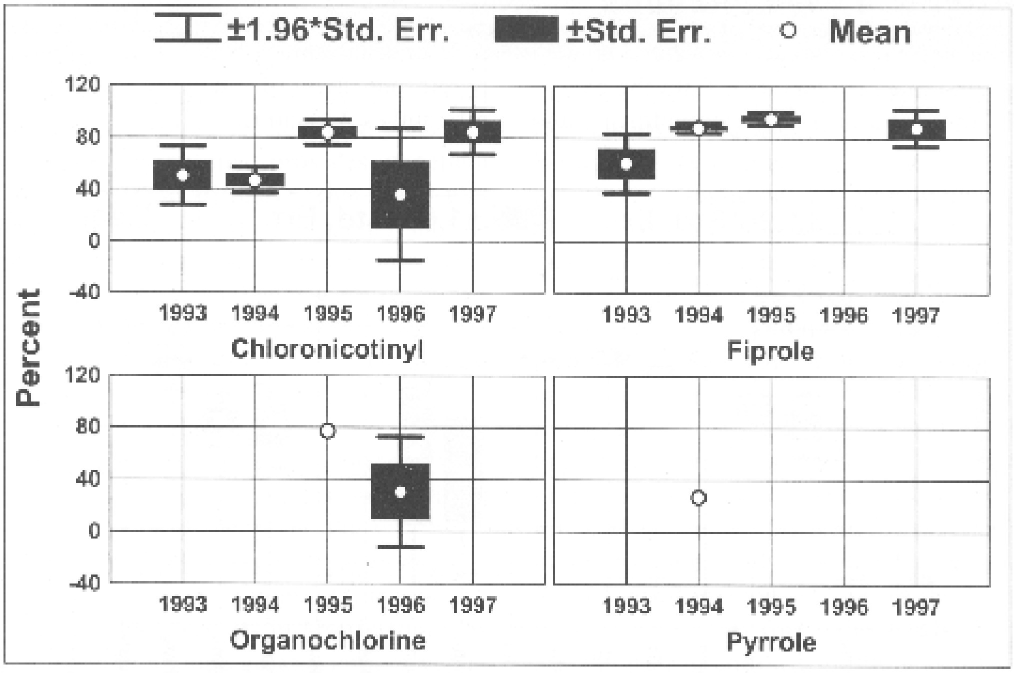

Figure 16. Mean percent control of tarnished plant bugs by four classes of insecticide in all states from 1993-1997. Data are restricted to 4 days after treatment and represent means from all rates.

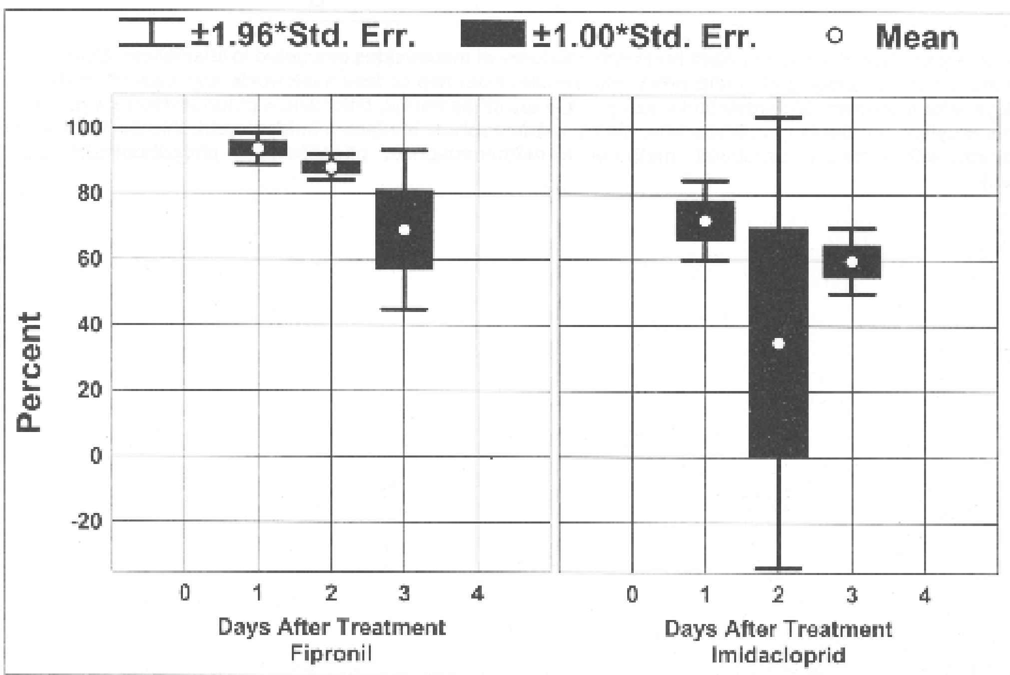

Figure 17. Mean percent control of tarnished plant bugs by fipronil and imidacloprid in all states. Data based on number of days between treatment and sampling indicate that the optimum sampling time is 1 day after treatment.

Mixed Compound Results

Efficacies of various mixtures were evaluated over years and rates (Figure 18). With the exception of the chlorpyrifos-tralomethrin and tralomethrin-amitraz mixtures, which include a pyrethroid, none of the spray mixtures were significantly efficacious.

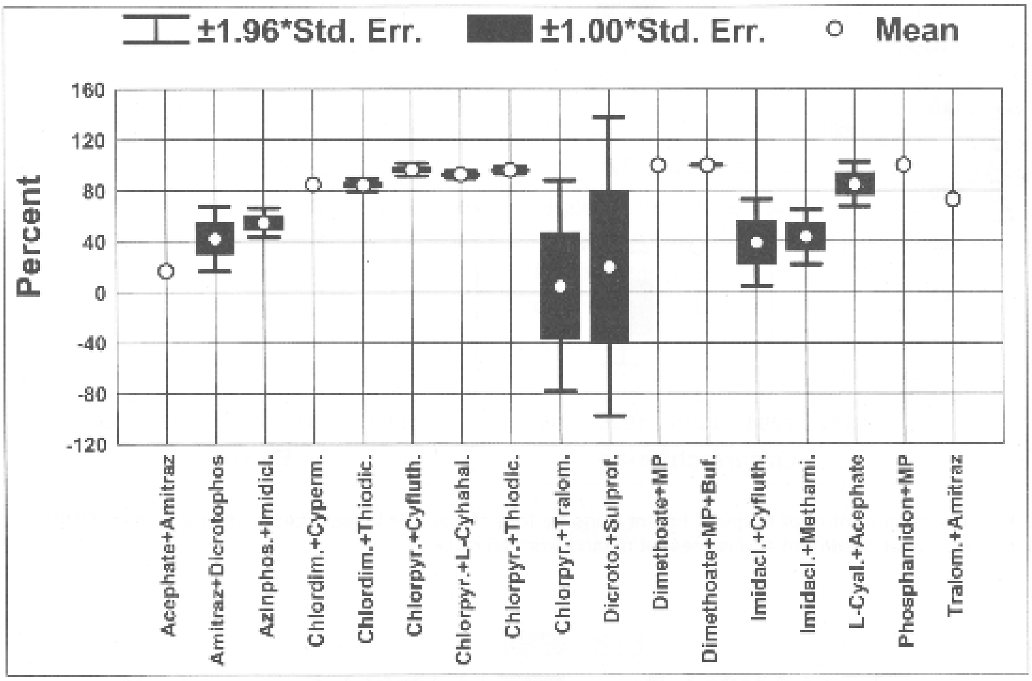

Figure 16. Percent control of tarnished plant bugs with mixtures of insecticides evaluated in Mississippi from 1982-1997. Data represent means from all insecticides and rates, with results from two or less insecticide applications and samples taken within 12 days after treatment. (Abbreviations: azinphos. = azinphosmethyl, chlordim. = chlordimeform, cyperm. = cypermethrin, cyfluth. = cyfluthrin, dimeth. = dimethoate, dicrot. = dicrotophos, imidacl. = imidacloprid, thiodic. = thiodicarb, l-cyhal. = L-cyhalothrin, MP = methyl parathion, methami. = methamidaphos, phospham. = phosphamidon, and tralom. = tralomethrin.)

Summary

Based on these evaluations, there is no compound currently registered for tarnished plant bug management on cotton that provides excellent control. It is important to realize that small-plot insecticide evaluations against a highly mobile pest such as the plant bug may be negatively biased because of immigrating insects from surrounding cotton during the period of pesticide evaluation. Insecticides used in field-sized applications might actually provide much better control than indicated in this report. In addition, the number of applications and the DAT prior to sampling are often critical parameters in pesticide evaluations for the tarnished plant bug.

Since sprays for boll weevil management secondarily reduced plant bug numbers, the anticipated absence of boll weevils in Mississippi may cause plant bugs to assume greater importance as a cotton pest. In the past, applications of pyrethroids targeting lepidopteran larvae on cotton also reduced tarnished plant bug numbers. Because of broad acceptance of cotton with the Bollgard ™ gene and the lower probability for pyrethroid treatment on transgenic cotton, a method to selectively control the tarnished plant bug is becoming a necessity.

A search for a bacterial toxin that will affect plant bugs is underway, and work with pheromones and other behavior-related avenues are being explored. Such work might lead to transgenic cotton plants with a gene that produces bug-toxic proteins similar to the budworm-toxic proteins produced by the Bollgard ™ gene. It might also lead to attractants or insect growth regulators to selectively manage the pest in cotton. Such control methods are far in the future, however, and we must find ways to effectively manage the pest in cotton with the least disruption to beneficial insects in Mississippi cotton.

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