ANNUAL REPORT

COTTON INSECT PEST MANAGEMENT
Agreement 10-648TN
Scott Stewart, The University of Tennessee

Funding for this project was used to partially support general extension activities such as scout training, moth trapping, insect damage surveys, resistance monitoring, and insecticide testing and on-farm evaluations of various insect control technologies and treatment thresholds. In addition, funds were also used to help support several regional projects as described herein.

1) Moth Trapping. Despite the use of Bt-transgenic cotton on over 95% of the acreage in Tennessee, bollworm and tobacco budworm still compose an important pest complex. Bollworms may cause significant economic damage to Bt cotton fields, and the bollworm/budworm can be even more damaging to non-Bt cotton. More importantly, the threat of tobacco budworm infestations results in high adoption of Bt cotton. Resistance to pyrethroid insecticides in tobacco budworm populations makes distinguishing between budworm and bollworm infestations very critical in non-Bt cotton. Using a pyrethroid insecticide on a "worm" infestation which contains a significant percentage of tobacco budworms often results in serious economic losses.

Area-wide monitoring remains a valuable tool in predicting the occurrence and size of pest populations. Pheromone trapping programs for bollworm, tobacco budworm, and beet armyworm provide insight into the timing and intensity of moth flights. For example, unusually high trap catches for a particular species can alert consultants and producers to the potential for impending outbreaks. When performed on a regional level and over a number of years, moth trapping can indicate historical and geographical patterns in the distribution of pest populations. Moth monitoring improves the decision making process, helping crop managers in the selection of insecticides and to indicate the need for intensified sampling efforts. This ultimately helps to minimize control costs and/or yield losses incurred by producers. Traps can also be used to collect moths used in assays for resistance to pyrethroid insecticides.

Pheromone moth traps for corn earworm (CEW or bollworm), tobacco budworm (TBW), and beet armyworm (BAW) were run on a weekly basis from early May through mid August. Traps were located in cotton growing areas of each county and were usually placed on the borders of cotton fields. All pheromone lures were obtained from Great Lakes IPM (Vestaburg, MI) and were changed at two week intervals. At least one, and usually two, sets of bollworm and tobacco budworm traps were run in each of the following 12 counties in West Tennessee: Carroll, Crockett, Dyer, Fayette, Gibson, Hardeman, Haywood, Shelby, Tipton, Lake, Lauderdale, and Madison. One beet armyworm trap was located in each of the above counties.

Outcomes: Moth catches for each trap were reported weekly on the UTcrops News Blog (http://news.utcrops.com/) which was distributed to agents, cotton producers, consultants and other agricultural professionals. The UTcrops News Blog was launched in February of 2011 and has successfully replaced the IPM newsletter format that was used previously.

Tobacco budworm moth catches were low compared to previous years. Most tobacco budworm moths were caught in Madison, Dyer, Gibson and Lake counties (Figs. 1 and 2). Few if any fields of cotton were treated for tobacco budworm considering the low acreage of non-Bt cotton. It is believed that these moths originated from non-cotton hosts, and moth catches were relatively low for the remainder of the season. The highest single-trap capture was recorded in Dyer County (Newbern area) where 35 moths were caught the week preceding May 10. These moths likely originated from wild host plants.

Catches of corn earworm (i.e., bollworm) moths in pheromone traps were higher than tobacco budworm, particularly during early August and were higher than average population observed since 2004 (Fig. 4). The bollworm is Tennessee's most significant caterpillar pest in cotton because this species is able to cause economic injury to Bt cotton which composes the vast majority of the acreage. A peak of moth activity was observed in June with a much larger moth flight occurring in August. Some areas experience sustained bollworm pressure beginning in August. The highest moth catches were observed in Madison, Dyer Lake and Gibson counties (Fig. 3). The highest single trap catch (185 moths/week) occurred at the West Tennessee research and Education center in mid-August where substantial bollworm pressure was observed.

Many more beet armyworm moths were caught in 2012, mainly during July and August (Fig. 1), compared with previous years. However, this did not translate into significant reports of field infestations. The lack of infestations observed in cotton was influenced by the near universal adoption of Bt cotton.

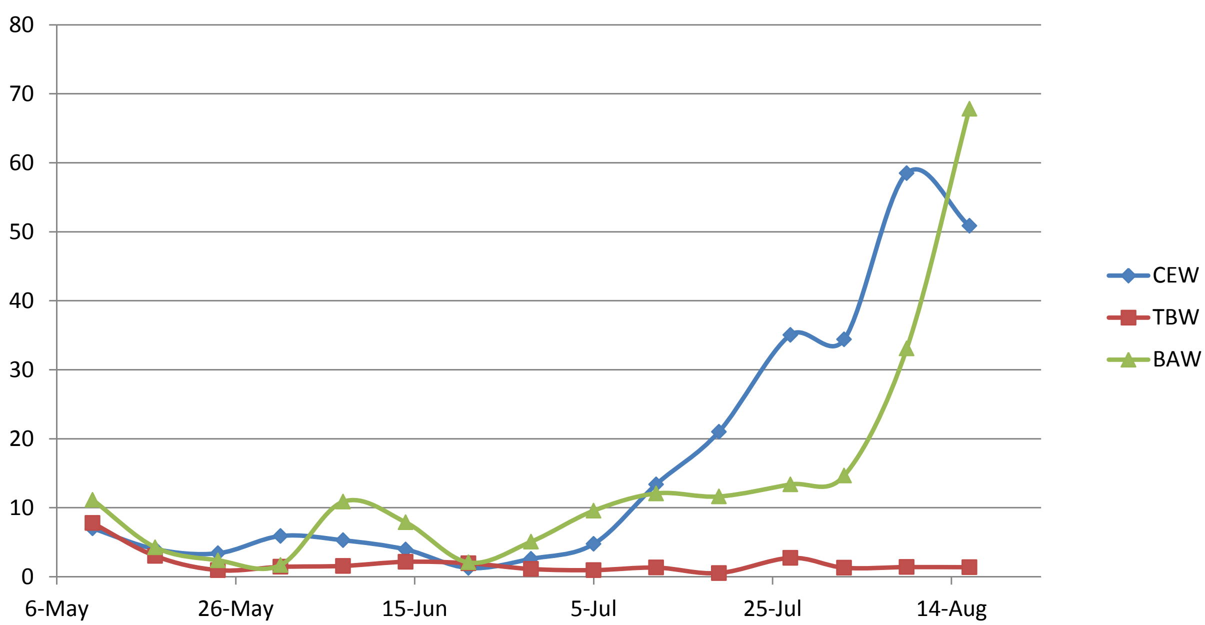

Figure 1. Average number of tobacco budworm (TBW), corn earworm (CEW), and beet armyworm (BAW) moths caught per trap in pheromone traps across West Tennessee (2012).

Trapping did not necessarily reflect all local variations in pest densities observed in cotton fields, in part because trap density was not high and because other factors influence oviposition and survival of these pests in cotton. However, the pheromone trapping program did an excellent job of predicting the variable populations of corn earworm (i.e., bollworm) observed in different parts of the state.

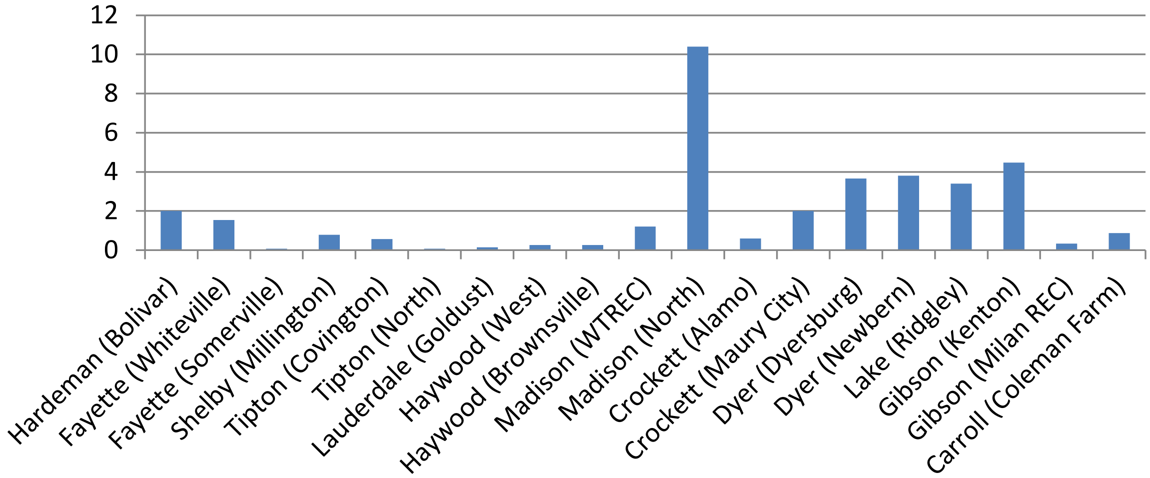

Figure 2. Seasonal average number of tobacco budworm moths caught per trap per week at each trap location during 2012.

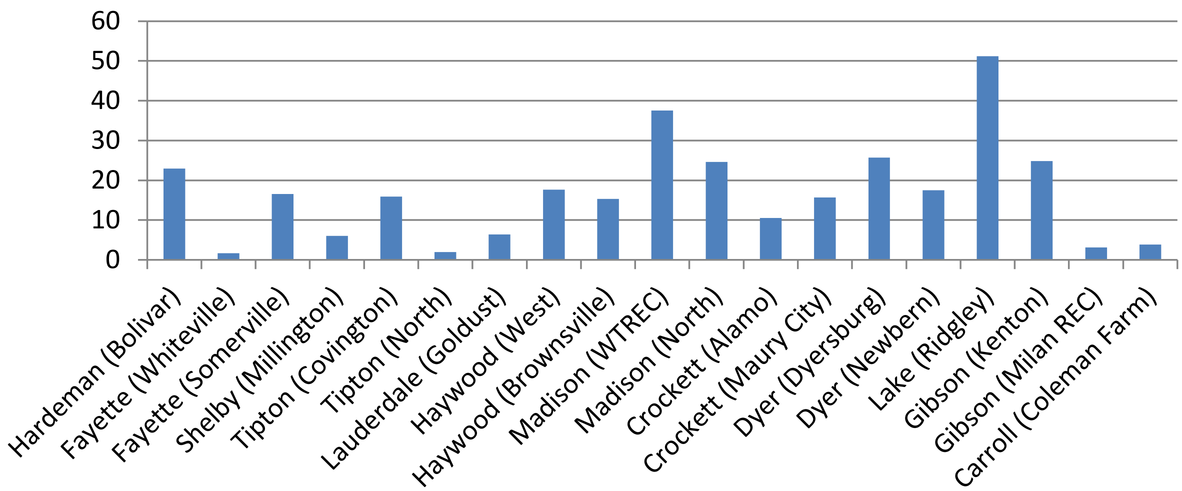

Figure 3. Seasonal average number of corn earworm (bollworm) moths caught per trap per week at each trap location during 2012.

We also participated in a national fall armyworm trapping effort, PestWatch (http://www.pestwatch.psu.edu/). Results are available online and will not be reported here.

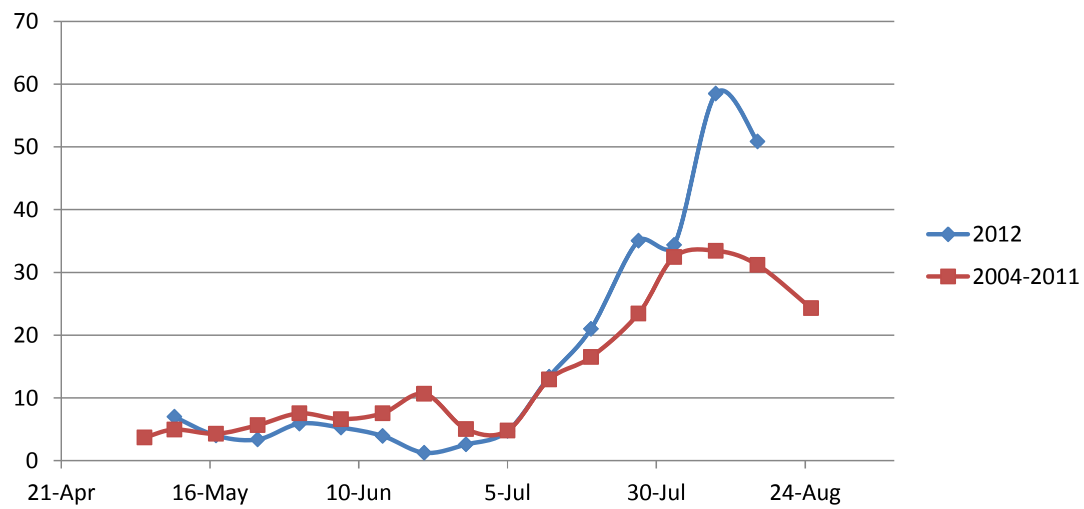

Figure 4. Average statewide catches of corn earworm (bollworm) moths, comparing 2012 to the average catches for 2004 - 2011.

2) Relative Efficacy of Bt Cottons. An annual survey of boll damage in production fields has not been done for the past two years, partly because of the lack of non-Bt cotton fields for comparative purposes. These data indicated the relative performance of Bt cottons in reducing boll damage caused by caterpillar pests (Table 1, Bollgard II > WideStrike > Bollgard>Non-Bt). Instead, in 2011 and 2012, we compared the efficacy of Bt technologies in controlling bollworm infestations at the West TN Research and Education Center in Jackson and at two off-station locations. These include comparisons of non-Bt, Bollgard II, WideStrike, TwinLink and experimental Bt cotton traits. Experiments were done as small-plot, replicated trials,. Company agreements currently prevent reporting direct comparisons between some Bt technologies.

Table 1. Summary of boll damage surveys from 2002 - 2010 showing percent damage caused by caterpillar pests (primarily bollworm) in West Tennessee.

Trait	2002	2003	2004	2005	2006	2007	2008	2009	2010	Avg. (Years)
Non Bt	9.39	8.29	2.04	1.50	5.13	0.72	1.48	2.85	---	3.93 (2002-2009)
Bollgard	2.41	3.21	0.31	0.08	1.25	0.18	0.33	---	---	1.11 (2002-2008)
Bollgard II	---	1.05	0.13	0.08	0.15	0.08	0.05	0.33	0.19	0.15 (2005-2010)
WideStrike	---	---	---	0.12	0.35	0.13	0.10	0.41	0.78	0.32 (2005-2010)

Total bolls sampled ≈ 141,000

<u>Outcomes:</u> As previously documented, tests indicated that WideStrike technologies do not reduce bollworm populations and injury as much as Bollgard II technologies, but both technologies still provided substantial protection compared with non-Bt cotton (Fig. 5). In 2012, insecticide applications targeting bollworm populations significantly improved the yields observed in non-Bt cotton, but did not improve yields in a WideStrike or Bollgard II variety (e.g., Fig. 6). Other experiments were also performed but not included in this report. Data from

the last two years indicated that TwinLink cotton provides control of bollworm infestations similar to that of Bollgard II (e.g., Fig. 7). Based on on-going and previous research, data suggest that all Bt technologies that are commercially available, including TwinLink, will require foliar insecticide applications for the control of moderate and high bollworm infestations. The insecticide Prevathon (DuPont) has provided consistently better control of bollworm infestations than alternative treatments (Fig. 6).

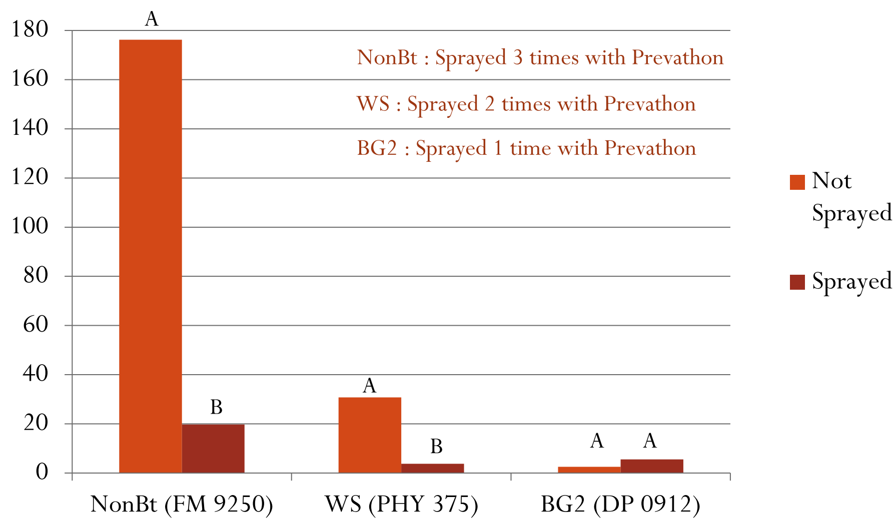

Figure 5. Cumulative fruit damage square damage of non-Bt, Bollgard II and WideStrike cotton treated with Prevathon (20 oz/acre). Bars not labeled with a common letter are significantly different (Fisher's Protected LSD, $P < 0.05$).

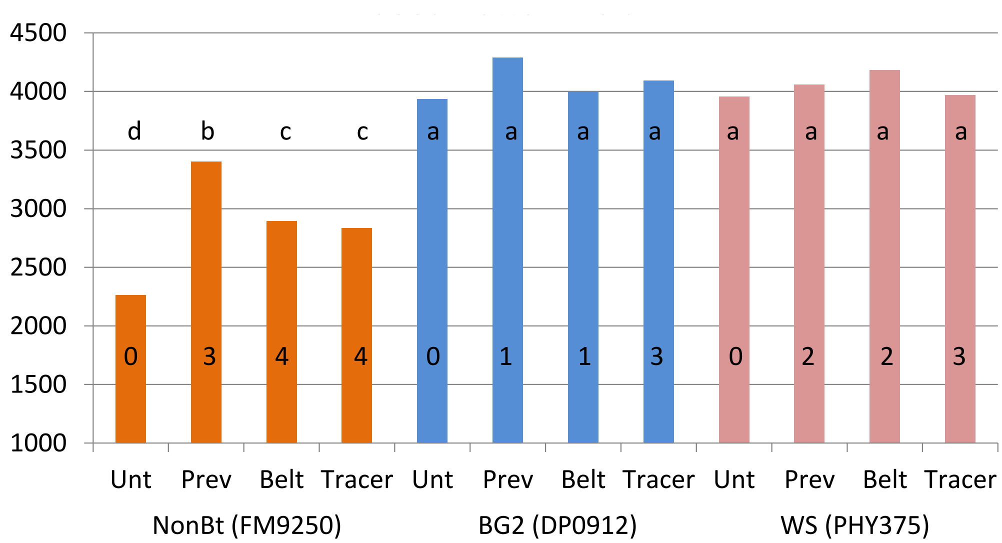

Figure 6. Seedcotton yield (lb/acre) of non-Bt, Bollgard II and WideStrike cotton treated with different insecticides. Numbers on the bars indicate the total number of applications. Bars not labeled with a common letter are significantly different (Fisher's Protected LSD, $P < 0.05$). Unt = untreated, Prev = Prevathon (20 oz/acre), Belt SC (3 oz/acre), Tracer (2.9 oz/acre).

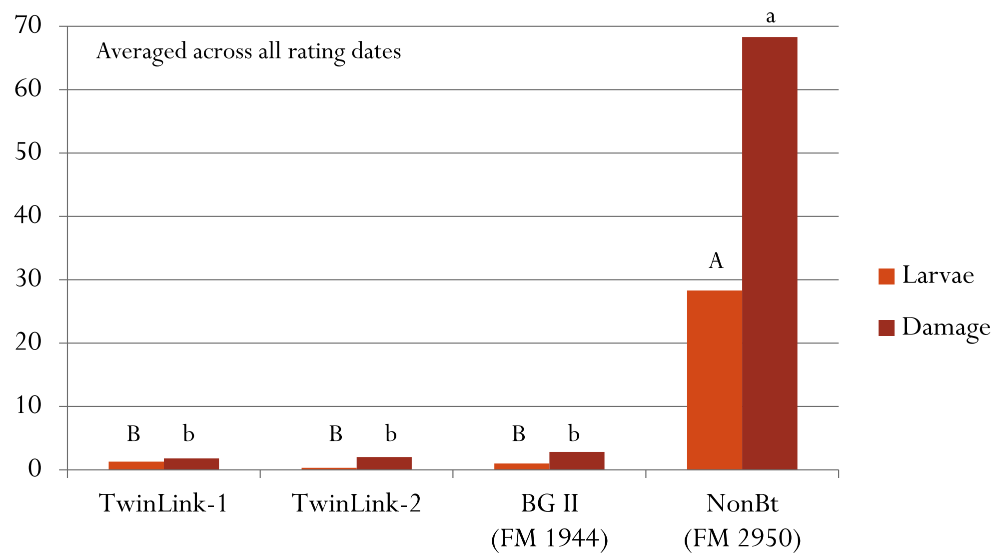

Figure 7. Average, cumulative larval counts and fruit damage for TwinLink, Bollgard II and non-Bt cotton varieties in plots not treated with insecticides for lepidopteran pests. Bars not labeled with a common letter are significantly different (Fisher's Protected LSD, $P < 0.05$).

3) Herbicide/Insecticide Interactions. A study was conducted in 2010 and 2011 at the West Tennessee Research and Education Center in Jackson. The objective of this research was to evaluate the tolerance of Phytogen 375 WRF (WideStrike) cotton to the herbicides Ignite or Sequence when applied alone or tank mixed with various insecticides for thrips control.

Outcome: The results of this study are being published and indicated that Ignite (Liberty) applications on WideStrike cotton could potentially reduce yield, at least when cotton was already stressed by thrips injury. Tank mixing insecticides with either Ignite or Sequence only marginally increased plant injury and had little effect on yield.

Publication: Stewart, S. D., L. E. Steckel and S. J. Steckel. *In press*. Evaluation of WideStrike® cotton (*Gossypium hirsutum* L.) injury from early season herbicide and insecticide tank mixes. J. Cotton Sci.

4) Resistance Monitoring. Insects are well known to develop resistance to insecticides. There is increasing documentation of insecticide resistance in populations of bollworm, tarnished plant bug and cotton aphids in the Midsouth. Therefore, an insecticide resistance monitoring program was instigated in 2006 for both bollworm and tarnished plant bug populations collected in West Tennessee. Monitoring resistance of key insect pests helps to document resistance and implement insect resistance management plans. Vial assays of adults are used in both cases.

In 2012, no monitoring was done for tarnished plant bug, although insecticide testing indicates high resistance to the pyrethroid insecticides (data not shown). Vial assays using 5 ug/vial cypermethrin, a synthetic pyrethroid, were again performed on bollworm moths. This represents a discriminating dose where 90% or higher of susceptible moths are expected to die after 24 h exposure. Fresh bollworm (i.e., corn earworm) moths were collected from traps that were baited with pheromone lure on the previous night. All moths were collected in Madison County at the West Tennessee Research and Education Center (WTREC). For several years and as part of a cooperative effort, moths from the above tests have been submitted to scientists in Mississippi (F. Musser, R. Jackson) who are assaying moths using a technique that determines if the larval host was a C_3 or C_4 plant. These data are being collected to better understand the population dynamics of bollworm and determine the impact of host origin on resistance levels. C_3 plants are broadleaves such as cotton and soybean. C_4 plants are usually grasses, and presumably any bollworms testing positive for C_4 plants developed on corn or sorghum because these are primary hosts during the time frame of moth trapping.

Outcomes: A total of 584 moths were used in the vial tests between 19 July and 21 August, 2012. Percent survival after 24 h was recorded for moths in treated and untreated vials. Average survival for moths collected in Tennessee that were exposed to 5 ug of cypermethrin was 13.2%, which is similar to previous years (Fig. 8). Survival in vials indicated that pyrethroid resistance levels of bollworms collected in Tennessee was similar to surrounding states but considerably lower than that found in Louisiana and Virginia. Across all states, survival rates have been highest during July (Fig. 9). Carbon isotope testing has indicated that most moths during July came from C_4 plants such as corn, which corresponds to the time when bollworm moths would be emerging from corn fields. So some increase in survival may be due to increased fitness of moths originating from corn. Tennessee data indicate a level of resistance that should not result in field control insecticide failures when spraying pyrethroid insecticides for the control of bollworm infestations. However, across a broad geography, there has been an overall reduction in moth susceptibility to cypermethrin in vial assay test in the last decade (data not shown).

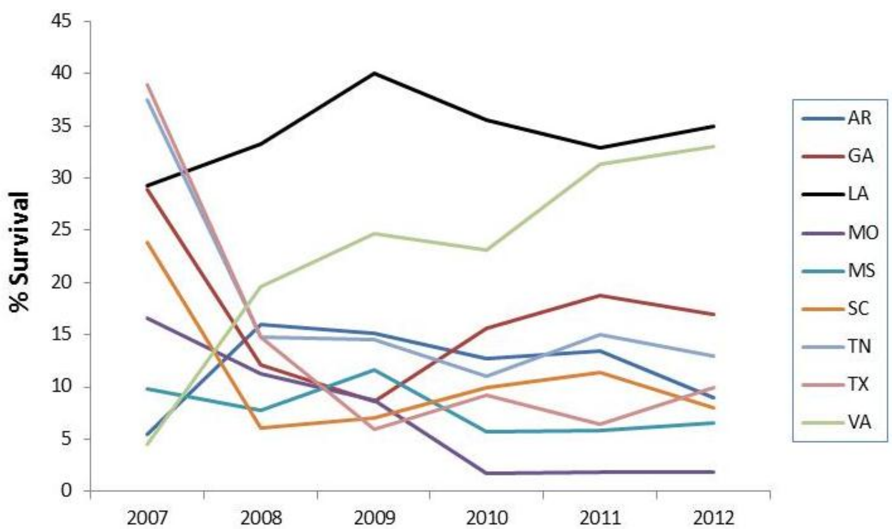

Figure 8. Survial of corn earworm moths to cypermethrin @ 5 µg/vial for multiple states from 2007-2012. Figure courtesty of Fred Musser, Mississippi State University.

An experiment in Lake County documented a field control failure of most neonicitnoid insecticides in controlling infestations of cotton aphid (Fig. 9). Insecticdes that did not provide adequate control included imidacloprid (Admire Pro), thiamethoxam (Centric), and clothianidin (Belay). Aphids from this field were sent to Dr. Jeff Gore (Mississippi State University) who assayed this population and confirmed neonicotinoid resistance, with an LC50 value indicating 10-15 fold level resistance to thiamethoxam (Table 2). The observation of field control failure with most neonicitinoid insecticides is consistent with observations from other states in the Midsouth and suggests that this class of chemistry is rapidly losing efficacy on aphid infestations in cotton. Alternative insecticides with different modes of action, such and flonicamid (Carbine) and sulfoxaflor (Transform) will likley be necessary to control cotton aphid infestation in the future.

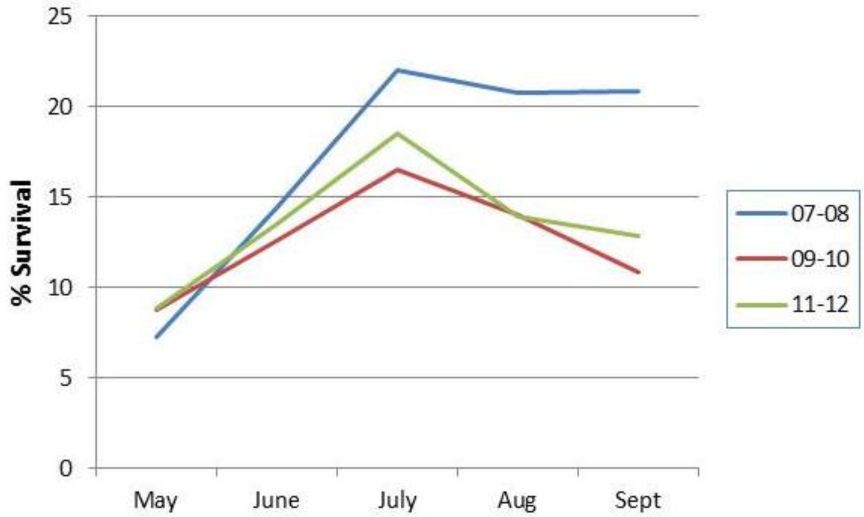

Figure 9. Survial of corn earworm moths to cypermethrin at 5 µg/vial across multiple states from 2007-2012. Figure courtesy of Fred Musser, Mississippi State University.

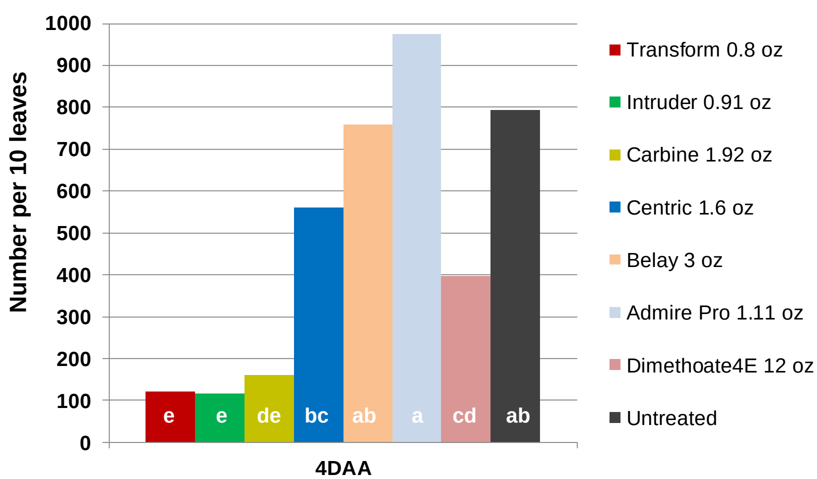

Figure 10. Numbers of cotton aphids four days after application with various insecticides, Lake County, TN, 2012 (Mean separation: Fisher's Protected LSD, P < 0.05).

Table 2. Leaf-dip bioassays with thiamethoxam (Centric 40WG) against cotton aphids in 2008-2012. LC50's are reported as parts per million 72 hours after treatment.

			Thiamethoxam	
Colony	Year	Trts.	LC50 (CI)	X^2 (*P*)
Grenada, MS	2012	1	42.72 (31.29-67.56)	0.30 (0.88)
Starkville, MS	2012	?	30.52 (24.85-39.58)	0.63 (0.64)
Stoneville, MS	2012	2	55.70 (38.56-	0.79 (0.53)

			100.38)	
Winn., LA	2012	?	16.15 (13.62-19.38)	1.36 (0.25)
Jonesville, LA	2012	2	22.14 (18.56-26.99)	0.42 (0.79)
N. Carolina	2012	?	19.05 (15.37-24.46)	0.24 (0.94)
TN, UTC	2012	0	14.88 (10.06-24.31)	1.72 (0.13)
TN, Centric	2012	1	15.10 (12.32-18.91)	1.14 (0.34)

Courtesy of Jeff Gore, Mississippi State University.

5) Regional Projects. In 2012, $9,000 in core Cotton Incorporated funding was received to support several regional research efforts (Project No. 12-362). Full reports on these efforts have been submitted separately by project leaders. However, shortened summaries are included here because state-support funding is substantially used to complete these efforts, and Tennessee also participated in additional and unfunded regional projects.

a) Impact on spray adjuvants and spray volume on insecticide performance (PIs: Don Cook, et al.). As in 2011, trials were conducted across the Midsouth during 2012 to evaluate the impact of spray adjuvants on insecticide performance against thrips, tarnished plant bug and spider mites. Trials were conducted on research stations and grower farms where sufficient infestation levels were encountered. The adjuvants included in these trials represent several classes according to the Compendium of Herbicide Adjuvants (Table 3).

Table 3. List of adjuvants used as treatments, adjuvant category, and application rates.

Adjuvant	Adjuvant Category	Rate (%v/v)
Agri-Dex	Crop Oil Concentrate	1%
Penetrator Plus	Crop Oil Concentrate + Deposition Agent + Buffering Agent	1%
Induce	Nonionic Surfactant	0.25%
Dyne-Amic	Methylated Seed Oil + Organo-Silicone Surfactant + Nonionic Surfactant	0.5%
Kinetic	Organo-Silicone Surfactant	0.25%
Dyna-Pak	Nonionic Surfactant + Nitrogen Source	1%
Hyper-Active	Deposition, Retention, and Wetting Agent	0.25%
Cohere	Nonionic Spreader-Sticker	0.125%
Cide-Winder	High Surfactant Oil Concentrate	0.5%
Liberate	Nonionic Surfactant + Deposition Agent + Methylated Seed Oil	0.5%
LI-700	Nonionic Surfactant + Buffering Agent	0.25%
Interlock	Deposition Agent	6 oz/acre
Preference	Nonionic Surfactant	0.5%
Supermax AMS	Buffering Agent + Deposition Agent	0.5%
SuperFact	Nonionic Surfactant	0.25%

In each trial, one insecticide was applied at a standard rate with all or selected adjuvants listed in Table 3. The insecticide was also applied alone and a non-treated control was included. Treatments were applied with high clearance ground applicators calibrated to deliver 10 GPA. Thrips densities were determined by sampling five plants from the center two rows of each plot using a whole plant washing procedure. Densities of tarnished plant bugs were determined by sampling 10 row feet from the center two rows with a black drop cloth. Numbers of spider mites were counted on 10 leaves from the center two rows of each plot. Data were subjected to ANOVA procedures, with means separated according to Fisher's Protected LSD.

Outcomes: In Tennessee, adjuvants did not significantly improve the performance of the selected insecticides on the control of thrips, tarnished plant bug or spider mites (Figs. 11-13). This is consistent with observations in other states except when significant rainfall events occurred after application. The impact of rainfall or simulated rainfall on the performance of insecticides will be further investigated in 2013.

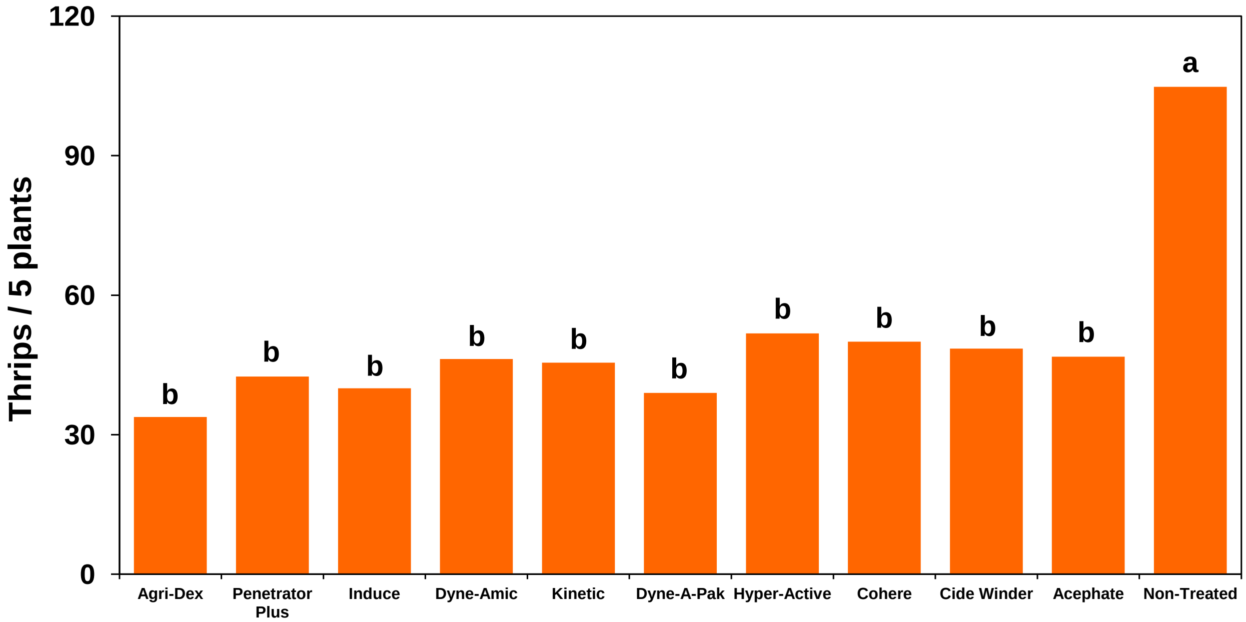

Figure 11. Impact of selected adjuvants on the performance of Acephate 90S (0.15 lb/acre) against thrips at 3 DAT, 2012 TN (Mean separation: Fisher's Protected LSD, $P < 0.05$).

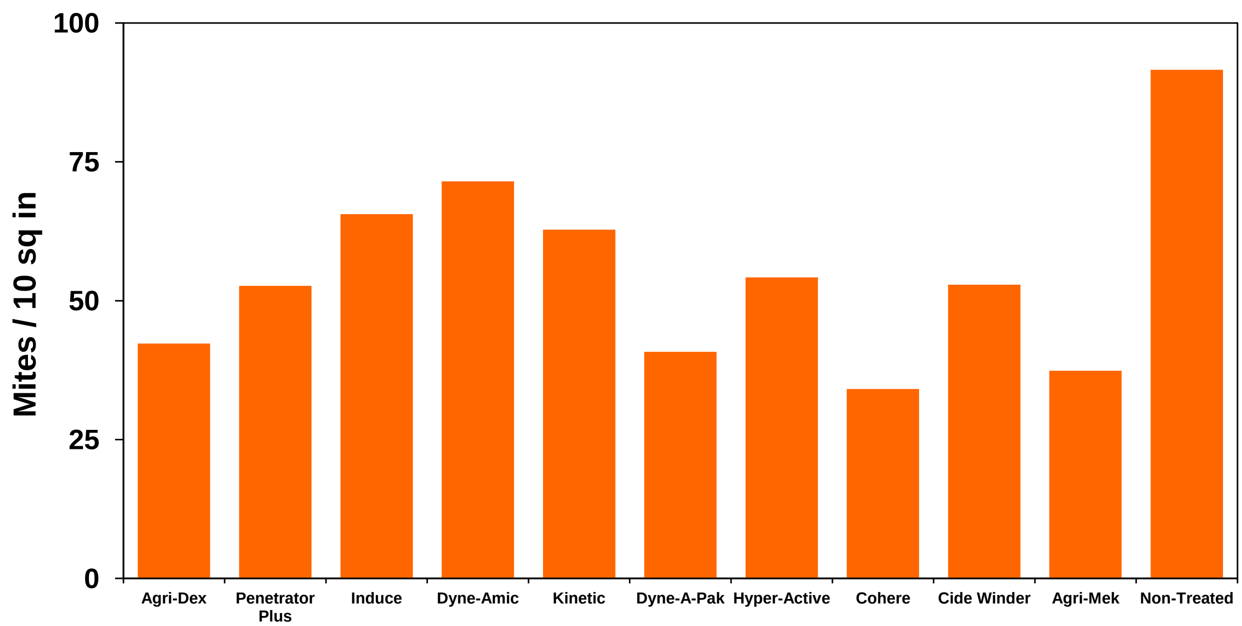

Figure 12. Impact of selected adjuvants on the performance of Agri-Mek 0.15 EC (4.3 oz/acre) against spider mites at 5 DAT, 2012 TN (Mean separation: Fisher's Protected LSD, $P < 0.05$).

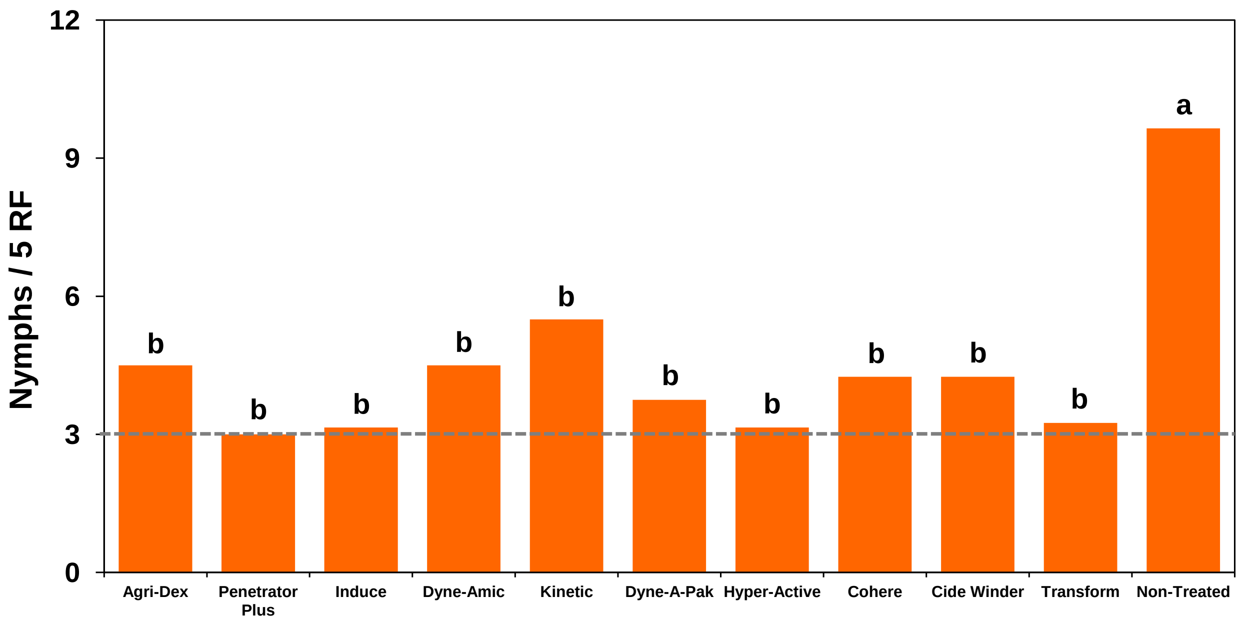

Figure 13. Impact of selected adjuvants on the performance of Centric 40WG (1.25 oz/acre) against plant bug at 3 days after treatment, 2012 TN (Mean separation: Fisher's Protected LSD, $P < 0.05$).

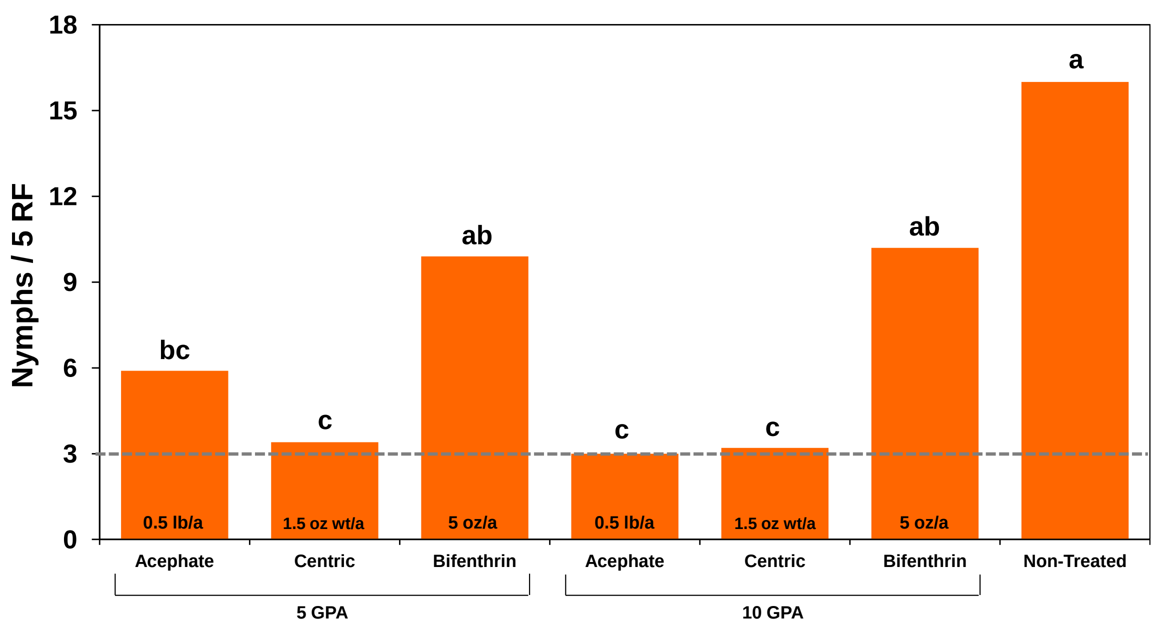

Figure 14. Effect of spray volume on control of tarnished plant bug with selected insecticides at 6 DAT, TN, 2012 (Mean separation: Fisher's Protected LSD, $P < 0.05$).

In 2012, one experiment was done in Tennessee to evaluate the impact of spray volume on insecticide performance against tarnished plant bug (Fig. 14). Application volume did not significantly impact the performance of acephate, bifenthrin (Brigade) or thiamethoxam

(Centric) in 2012. Bifenthrin did not significantly reduce population of plant bugs compared with untreated plots, indicating a high level of pyrethroid resistance. In 2011, all insecticide treatments with the exception of bifenthrin at 10 GPA reduced plant bug densities compared to the non-treated control (Fig. 15). In this trial, a reduced application volume (5 GPA) tended to improve control compared with applications at 10 GPA.

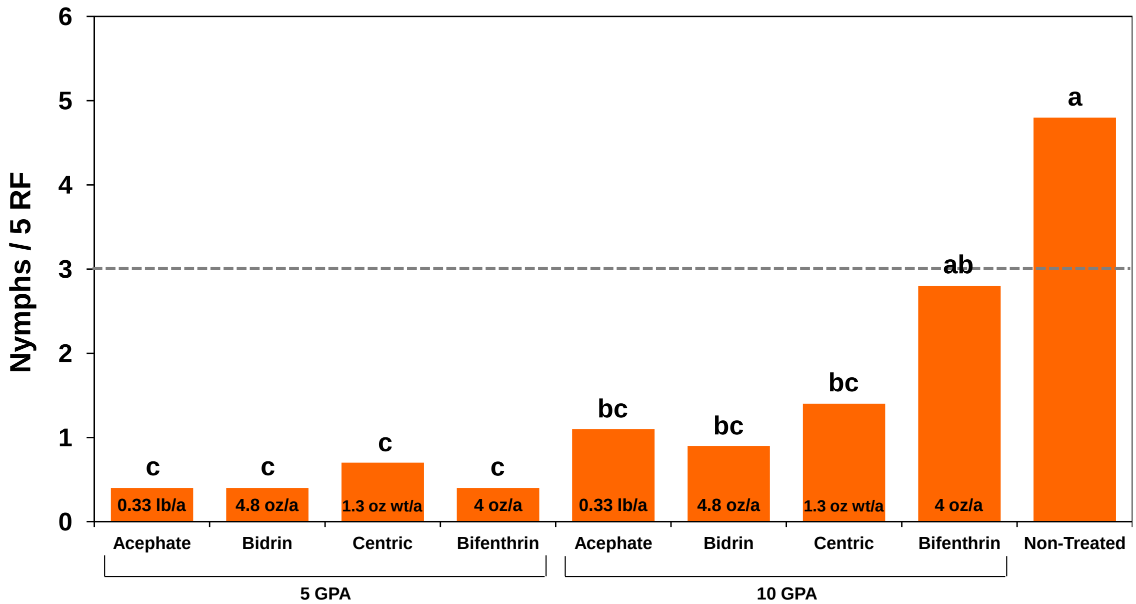

Figure 15. Effect of spray volume on control of tarnished plant bug with selected insecticides at 5 DAT, TN, 2011 (Mean separation: Fisher's Protected LSD, $P < 0.05$).

b) Evaluation of cotton yield loss and varietal response to spider mite infestations (PIs: Jeff Gore, et al.).

Impact of twospotted spider mites on cotton yield. This experiment involved infesting spider mites at different growth stages during the cotton season and assessing the impact of infestations on cotton growth and yield. It was performed at multiple locations. Results in Tennessee were similar to average results.

Outcome: This experiment was completed in 2011. Results across multiple locations indicated that spider mites significantly reduced yield, with greater impact on yield if infestations began earlier in the season. These data also indicated that infestations of spider mites beginning 800 DD60s after first flower did not impact yield.

Publication: Gore, J., D. R. Cook, A. Catchot, F. R. Musser, S. D. Stewart, B. R. Leonard, G. Lorenz, G. Studebaker, D. S. Akin, K. V. Tindall and R. E. Jackson. *In press*. Impact of twospotted spider mite (Acari: Tetranychidae) infestation timing on cotton yields. J. Cotton Sci.

Injury response of cotton varieties to spider mite infestations. A second year of research was completed in Tennessee and across the Midsouth in 2012 to measure the response of multiple cotton varieties to injury from spider mites. The treatments were arranged in a split-block design with four replications. The main-plot factor had two levels and included infested with spider mites or non-infested. The sub-plot factor was cotton variety. A total of eight commercially available cotton varieties were planted at each location. The varieties were chosen based on phenotypic differences in leaf characteristics ranging from smooth to hairy. The varieties included Phytogen 375 WRF (semi-smooth), Phytogen 499 WRF (semi-smooth), Stoneville 5288 B2F (very hairy), Stoneville 5458 B2F (Hairy), Deltapine 1133 B2F (smooth), Deltapine 0912 B2F (semi-smooth), Deltapine 0949 B2F (light-hairy), and Deltapine 1034 B2F (smooth). Plot size was 2 rows by 20 ft. In the infested blocks, mites were infested on all varieties between the third true leaf and six true leaf stages. The infestation procedures followed those described in the previous experiment. The non-infested blocks were sprayed with miticides as needed to minimize migration of mite into those plots. Ratings of spider mite densities and injury were measured weekly beginning one week after infestation and continued for 6 weeks after infestation. The ratings included the number of mites from 10 leaves (10 sq in.). Additionally, leaf reddening ratings were taken on a scale of 0-5 as described above. At the last rating (6 weeks after infestation) plant heights were recorded from 10 plants in each plot. Percent defoliation was estimated on the last sampling date. At the end of the season, plots were harvested and seedcotton weights were determined. A sample of seedcotton from each plot will be ginned to determine percent lint of each variety.

<u>Outcomes:</u> Treatment responses in Tennessee were similar to overall trends. The amount of spider mite injury observed across locations varies considerably in 2011 and 2012 (Fig. 16). Spider mite infestations significantly reduced yields, regardless of whether injury ratings indicated high, moderate or low infestation levels (Figs. 17-19). Although injury ratings resulting from spider mite infestations varied somewhat across varieties (data not shown), the yield response of all varieties to infestation was similar (e.g., Fig. 20). These data are being prepared for publication.

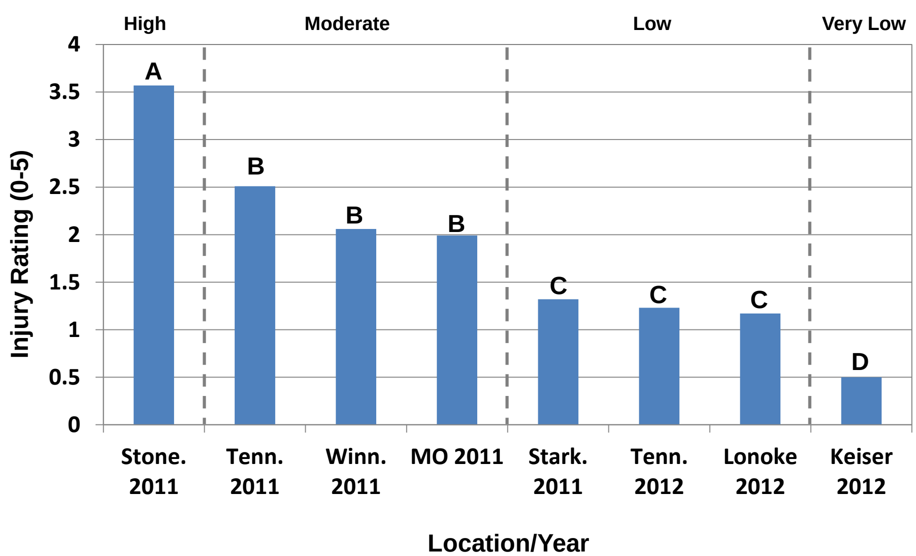

Figure 16. Mean injury ratings of spider mite infestations across all varieties. Figure courtesy of Jeff Gore, Mississippi State University (Mean separation: Fisher's Protected LSD, P < 0.05).

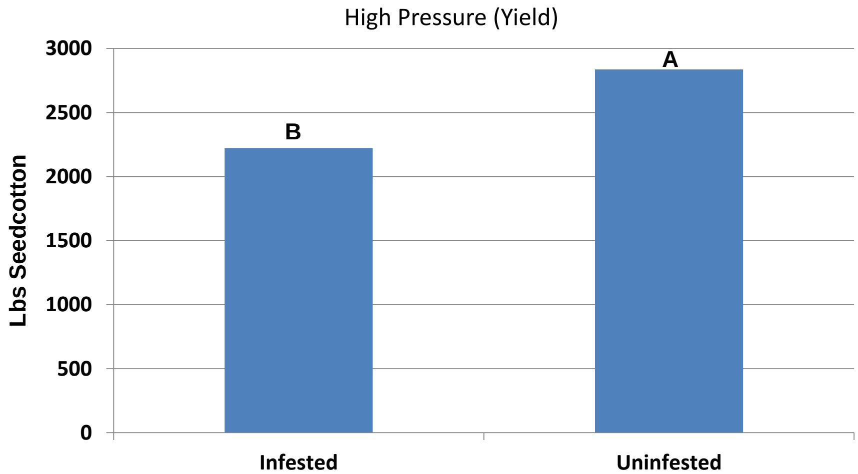

Figure 17. Mean response of cotton yield to infestations of spider mites across all varieties at high pressure locations. Figure courtesy of Jeff Gore, Mississippi State University.

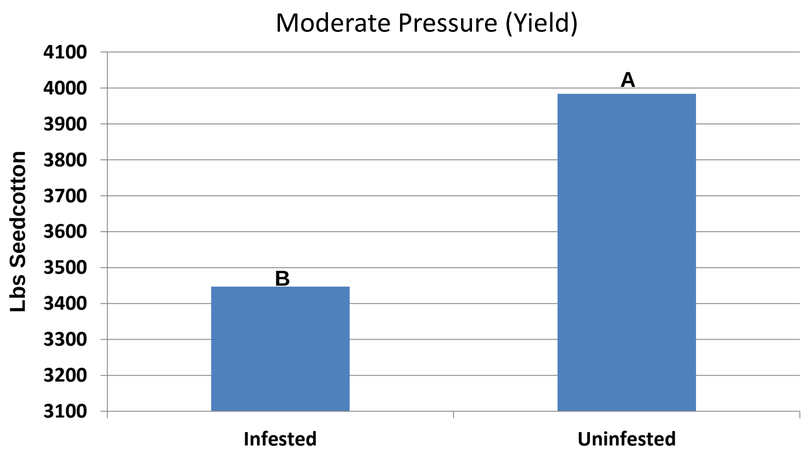

Figure 18. Mean response of cotton yield to infestations of spider mites across all varieties at moderate pressure locations. Figure courtesy of Jeff Gore, Mississippi State University.

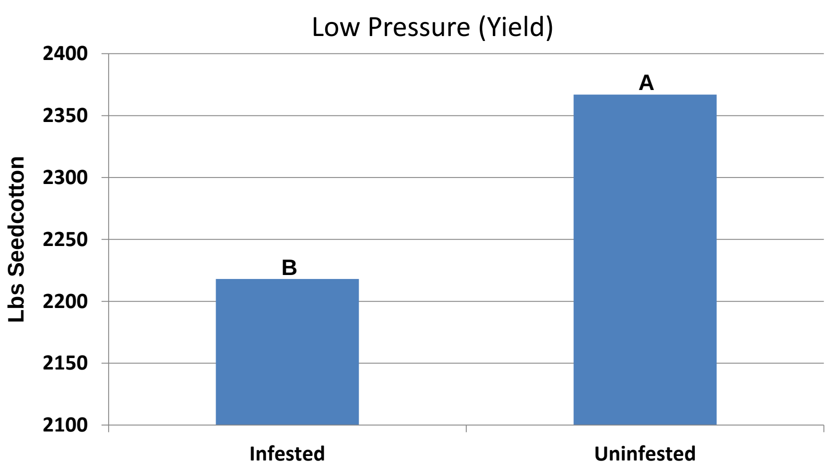

Figure 19. Mean response of cotton yield to infestations of spider mites across all varieties at low pressure locations. Figure courtesy of Jeff Gore, Mississippi State University.

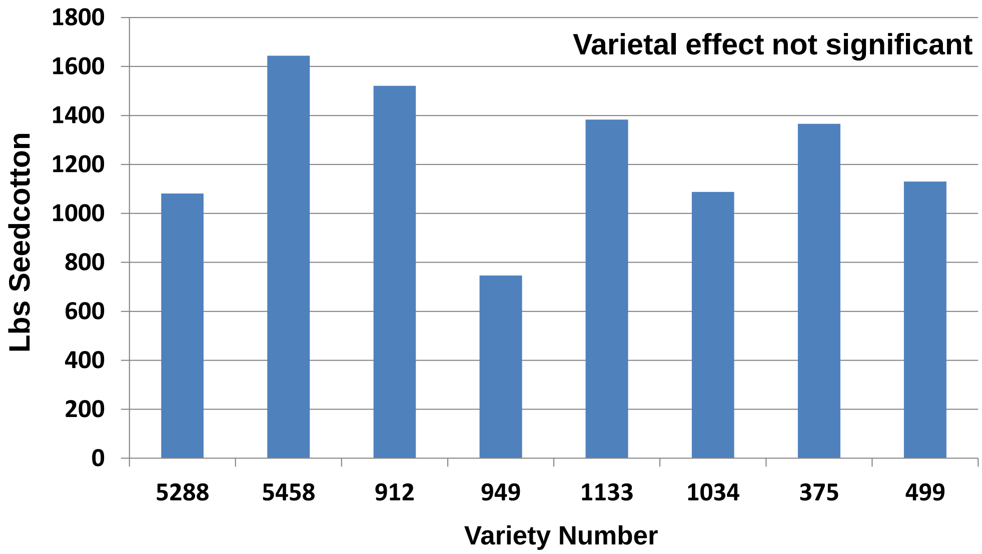

Figure 20. Mean reduction in seedcotton yield for different cotton varieties (see text) caused by high infestations of spider mites compared with uninfested plots. Data are averages across multiple locations. Figure courtesy of Jeff Gore, Mississippi State University.

c) Management of thrips with foliar insecticide and at-planting treatments (PIs: Scott Akin, S. D. Stewart, et al.). Ending in 2011, a standardized experiment was implemented at many locations across the Cotton Belt including Madison Co., Tennessee. The main intent of this study is to determine in which conditions do scheduled, foliar applications of insecticide for the control of thrips on seedling cotton result in improved yield. Base treatments included untreated seed, aldicarb (Temik, 4 lb/acre), imidacloprid (Gaucho 0.375 mg ai/seed), and at some locations, thiamethoxam (Cruiser, 0.34 mg ai/seed). A regional effort to evaluate commercially available seed treatment packages was initiated in 2012. Treatments also included totally untreated seed (black seed) and fungicide only treated seed (Dynasty CST).

Outcomes: Data from research in 2009-2011 has been and continues to be prepared for publication (see below).

Publications:

Stewart, S. D., et al. *Submitted*. Survey of thrips species infesting cotton across the southern U.S. Cotton Belt. J. Cotton Sci.

Akin, D. S., J. Eric Howard, G. Lorenz, G. Studebaker, S. D. Stewart, D. Cook, J. Gore, A. L. Catchot, B. R. Leonard, S. Micinski, K. Tindall, A. Herbert, D. L. Kerns, R. E. Jackson, M. Toews, P. Roberts, J. Bacheler, D. Reisig and J. Greene. 2012. Evaluation of automatic insecticide applications following preventative insecticides for thrips. Pp. 1102-1106 in Proceedings Beltwide Cotton Conf.

For data collected in Tennessee during 2012, yield was not significantly affected by insecticide/fungicide seed treatments (data not shown). However, treatments containing thiamethoxam (Cruiser, Avicta Duo) did not reduce thrips injury or thrips numbers compared with treatments not having an insecticide applied to the seed (Figs. 20, 21). Anecdotal observations indicate that use of pre-emergent herbicides is negative affecting the performance of insecticide seed treatments, and additional research is planned in 2013 to investigate this possibility.

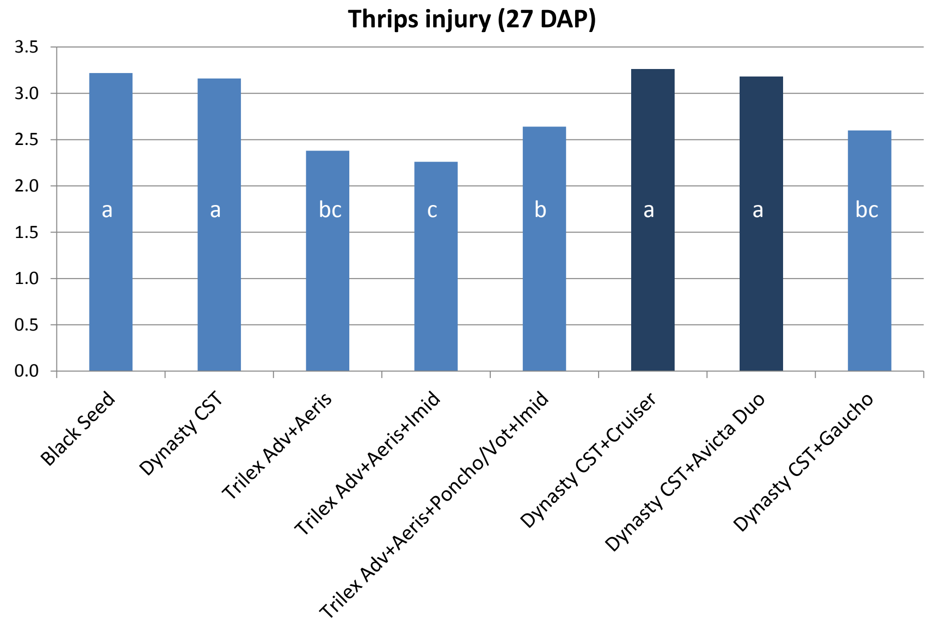

Figure 21. Thrips injury on a 0 - 5 scale at 27 days after planting for PHY375 WRF treated with various commercial seed treatments, TN, 2012. Bars not labeled with a common letter are significantly different (Fisher's Protected LSD, $P < 0.05$).

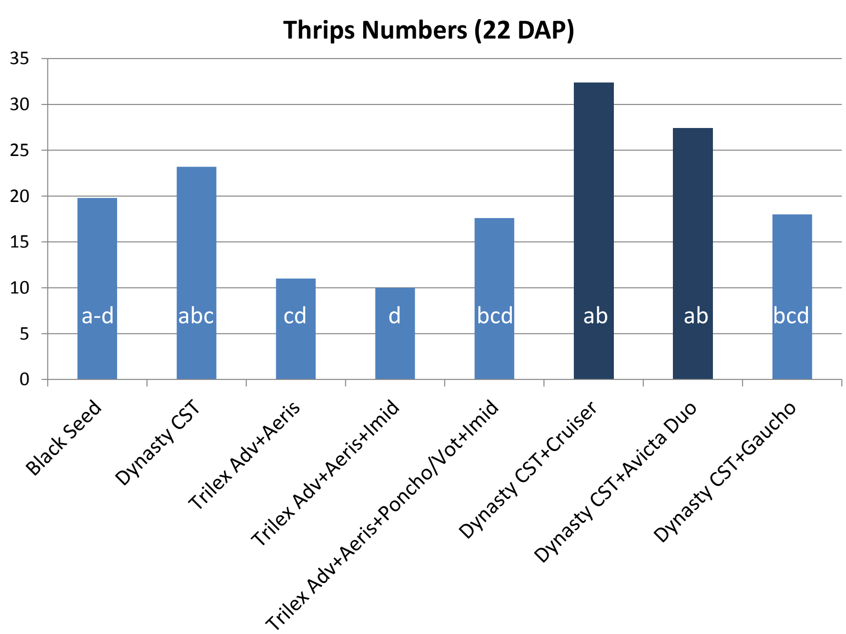

Figure 22. Thrips numbers per 5 plants at 22 days after planting for PHY375 WRF treated with various commercial seed treatments, TN, 2012. Bars not labeled with a common letter are significantly different (Fisher's Protected LSD, $P < 0.05$).

d) Impact of novaluron on tarnished plant bug adults (F. Musser et al.). The objective of this study was to verify non-lethal impacts of Diamond insecticide found from lab colony research (reduced oviposition rate and egg hatch rate) with wild tarnished plant bug (TPB) populations. Treatments were 1) cotton sprayed with novaluron (Diamond, 6 oz/acre) and 2) cotton not sprayed with insecticide until after insects are collected for the trial.

The trial was successfully conducted at four locations in the Mid-south. It was attempted at 2 additional locations, but sufficient adults could not be collected at these locations following the application, so no data from these locations were collected. Plot size varied from a 40 acre field to 16 rows wide. The Diamond-treated plot were sprayed using typical ground spraying equipment at 10 GPA when adult TPB populations exceeded the treatment threshold. Adults were collected from the sprayed and unsprayed plots 6 hr to 2 days after application. Insects were shipped to Starkville, MS where they were placed in rearing containers. Upon arrival the insects were fed artificial diet (AR, TN) or fresh green beans or broccoli plus artificial diet (MS). After 2-3 days, the vegetables were removed and they were fed only the artificial diet from this point forward in all replicates. A gel-filled oviposition pack was placed on the cage to collect the eggs. Diet and oviposition packs were changed 3 times per week. Eggs and dead males and females were counted at each change. The trial continued for 3 weeks or until the adults died or failed to oviposit. Oviposition rate and nymph hatch rate were compared from the sprayed and unsprayed fields to estimate the impact of Diamond on these parameters.

<u>Outcomes:</u> Initial mortality after collection was high in the first two collections made (AR, TN) until we learned that a transition period fed green beans or broccoli was critical for survival. In all replicates, oviposition ceased for several days following collection in both treatments. Oviposition started after 4-5 days, and females alive at that point are reported in Table 1. There was little evidence of reduced oviposition at any locations (Table 1). Reduced oviposition rate was not consistent in work with the laboratory colony, so this result is not unexpected. The stronger and more consistent response in the laboratory was reduced egg hatch rate. This was observed at Tennessee, but not from any of the other collections. Overall, no measures of reproduction approached being significant ($P>0.30$). There has been some discussion about why the results were not consistent over all locations. Both MS collections were from plots that were only 16 rows wide. One of these collections was made just 6 hrs after application to minimize the risk of adult movement into and out of the plots. However, this may have minimized insecticide exposure. The Arkansas collection was made during active migration from corn, so the 2 days between application and collection may have diluted the insecticide impact. A final explanation may be that the stress of being moved into a laboratory setting which caused them to stop ovipositing for several days may change their physiology such that the impact of Diamond was not as apparent. The collaborators are interested in conducting this trial again in 2013 with large plots and a refined rearing protocol as used for the last collections.

Table 4. Tarnished plant bug reproduction following an application of Diamond or nothing at four Midsouth cotton fields during 2012.

Site	Trt	Fem	Fem Days	Eggs	Eggs/F Day	Nymphs	Nym/F day	% hatch
AR	Check	14	81	255	3.15	88	1.09	34.5
	Diamond	16	103	302	2.93	106	1.03	35.1
TN	Check	7	83	340	4.10	**175**	**2.11**	**51.5**
	Diamond	5	68	289	4.25	**75**	**1.10**	**26.0**
MS 1	Check	32	375	2361	6.30	983	2.62	41.6
	Diamond	13	175	1145	6.54	520	2.97	45.4
MS 2	Check	14	121	851	7.03	351	2.90	41.2
	Diamond	22	199	1247	6.27	422	2.12	33.8
Overall	Check	67	660	3807	5.77	1597	2.42	41.9
	Diamond	56	545	2983	5.47	1123	2.06	37.6

Fem- number of females present in the container at the beginning of the recorded oviposition period. Fem Days- total days for all females (ex. 3 females alive for 5 days = 15 fem days).

Table courtesy of F. Musser (Mississippi State University)

e) Bee project - assessing the impact of neonicotinoid seed treatments on pollinators (PIs: Scott Stewart, Gus Lorenz, Angus Catchot, et al.). A firestorm of scientific and environmentalist debate surrounds the impact that insecticides, and seed treatments in particular, are having on pollinator health. The use of neonicotinoid seed treatments are routinely mentioned as a contributing factor of "Colony Collapse Disorder" in honey bees. Some scientific literature (e.g., Krupke et al. 2012, Tapparo et al. 2012) has implicated insecticide seed treatments. These articles suggest that pollinators are being exposed to debilitating and sometimes lethal levels of neonicotinoid insecticides while foraging for nectar and pollen on crops and on wild flowers in agricultural areas, where contaminated talc or graphite being used as a seed lubricant in planters is purportedly being exhausted outside the field during planting. Insecticide seed treatments are used widely on many major field crops because they have low acute toxicity, good efficacy on insect pests and are easily implemented and a relatively low cost. The insecticides involved in the proposed study include Gaucho (imidacloprid), Cruiser (thiamethoxam) and Poncho or NipsIt (clothianidin). This issue is affecting many agricultural crops including cotton, corn and soybean. Additional legislation regulating the use of insecticide seed treatments is currently being deliberated. There is no question that cancellation or substantial regulation on the use of these insecticides could have a significant negative impact on crop production. In fact, the use of imidacloprid has been banned in many European countries. Conversely, it is important to determine how neonicotinoid insecticides, at the rates being used in typical southern agricultural systems, are impacting pollinator health. If this is the case, appropriate mitigating action will be needed but tempered by the needs of agricultural production.

The specific objective of the activities described below is to determine the concentration of neonicotinoid insecticides found in soil, pollen and nectar, wild flowers around field perimeters, and in honey bees and pollen being collected by foraging bees to determine the potential exposure of insect pollinators to these insecticides. In 2012, samples were collected from small plot research trials and from representative agricultural production areas in the Midsouth including Arkansas, Mississippi and Tennessee. In total, approximately 1,200 individual samples were collected including those listed below.

1) Pre-plant soil samples from fields with a previous, know history of insecticide seed treatment during the previous cropping season (to test residual/carry-over concentrations of neonicotinoid insecticides).
    a) Soils samples from 10 fields per state (4 samples per field) were collected from cotton, corn, soybean or wheat.
2) Field perimeter sampling of wild flowers to test for contamination caused by the drift of talc, graphite or soil resulting from the planting of insecticide treated seed.
    a) Approximately 30 fields of cotton, corn or soybean were sampled across all states.
        i. 2-4 samples per field were collected within 20 m of the field edge.
        ii. 2-4 samples per field were collected from 50 - 250 m of the field edge.
3) During early flowering, pollen, nectar and soil samples were collected from replicated insecticide seed treatment tests in cotton, corn and soybean.
    a) Cotton - nectar (3 locations), pollen (5 locations), soil (5locations)
        i. 4 reps of four insecticide seed treatments per location.
    b) Corn - pollen (5 locations) and soil (5 locations).
        i. 4 reps of 5 insecticide treatments per location.
    c) Soybean - whole flowers (5 locations), soil (5 locations).
        i. 4 reps of 4 insecticide treatments per location.
4) Bee and bee pollen samples from local apiaries in agricultural productions areas.
    a) Bees from 4-5 apiaries per state (4 hives per apiary) were collected during the planting window and also during the flowering period of local crops.
        i. Pollen being carried by returning foragers was also collected from these bees and will be analyzed separately.

<u>Outcomes:</u> Mass spectrometric analyses of samples are currently being done by the USDA national Science Laboratory in Gastonia, North Carolina. In some, cases, samples were composited into larger samples to achieve the desired level of detection sensitivity. As results become available, it will be important to remember that the proposed analyses only tests for the potential exposure of bees to neonicotinoid insecticides. It does not directly test the toxicological activity of the concentrations that might be found. However, results should be very reflective of typical agricultural production systems in the South and provide a real-world baseline for future studies. Therefore, they will add insight into the potential risks that neonicotinoid insecticides pose to pollinators in southern agricultural systems. If these insecticides are found to be a problem, we must develop a plan to reduce exposure but maintain their use where possible. If we find that neonicotinoid levels do not pose a substantial risk and/or a lower risk to pollinators compared with alternative treatments, we can defend our use of the insecticides. Additional testing will be done in 2013 guided partly on the pending results of the above research.

References:
Krupke, C. H., G. J. Hunt, B. D. Eitzer, G. Andino and K. Given 2012. Multiple routes of pesticide exposure for honey bees living near agricultural fields. PLos ONE: 7(1): 1-8.

Tapparo, A., D. Maton, C. Giori, A. Zanella, L. Solda, M. Mazaro, L. Vivan and V. Girolami. 2012. Assessment of environmental exposure of honeybees to particulate matter containing neonicotinoid insecticides from corn coated seed. Environ. Sci. Tech. 46(5): 2592-9.

6) Other Activities. Funding for this project is used to support general IPM Extension activities in Tennessee and an insecticide screening program. This includes the delivery of the annual Cotton Scout School held at the West Tennessee Research and Education Center. Scouts are delivered classroom-style and in-field training related to cotton plant development, insect management (identification, sampling, etc.) and disease and weed identification. A scouting notebook was prepared for each attendee. This project also supports the preparation and publication of *Insect Control Recommendations for Field Crops* (UT Publication, PB1768) which contains IPM information for cotton and other crops. This publication is also available on the web at UTcrops.com (www.utcrops.com). In addition, numerous insecticide trials and other experiments were established in 2012 to investigate various insect control practices and strategies for cotton pests. In all cases, replicated trials were established in an RCB design, usually with four replicates, and analyzed using appropriate statistical methods.

Outcomes: Approximately 75 scouts participated in the Cotton Scout School during 2012. A scouting notebook was prepared for each attendee. 1,500 copies of the *Insect Control Recommendations for Field Crops* (PB1768) were distributed to clientele groups. Demand for this publication has nearly doubled since insect control recommendations for cotton, corn, soybean, wheat, sorghum and pasture were included in one publication.

Approximately 30 other experiments not reported above were successfully established in cotton to investigate various insect control practices and strategies. The data generated from these activities are used to validate and modify extension insect control recommendations for Tennessee. These evaluations included insecticide efficacy trials for thrips, spider mites, plant bugs, stink bugs and bollworm. For example, tests included several new insecticides and insecticide formulations such as sulfoxaflor (Transform) and chlorantraniliprole (Prevathon or Besiege for control of plant bug and caterpillar control, respectively. The results of these experiments have been individually summarized and are available on UTcrops.com at the following link: http://www.utcrops.com/MultiState/MultiState.htm. This website also serves as a data warehouse for some efficacy trial done by other universities in the Midsouth.