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ARTHROPOD MANAGEMENT

Field Evaluations of Sulfoxaflor, a Novel Insecticide, Against Tarnished Plant Bug (Hemiptera: Miridae) in Cotton

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ABSTRACT

Tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), is a damaging pest of cotton, *Gossypium hirsutum* L., grown in mid-southern U.S. states that include Arkansas, Louisiana, Mississippi, Missouri, and Tennessee. Chemical control tactics have been the primary method for managing infestations, but this strategy has become less effective due to development of insecticide-resistant populations. The objective of this study was to evaluate the efficacy of sulfoxaflor against a range of tarnished plant bug infestation levels compared to acephate, the most widely utilized insecticide. Across infestation levels (12 locations, 49 trials), sulfoxaflor applied at ≥ 50 g ai/ha provided control and yield levels similar to that observed with acephate. Against moderate infestations, single applications of sulfoxaflor (≥ 50 g ai/ha) or acephate reduced infestations below the action threshold 64 to 83% of the time through 8 d after application. Two applications of these same treatments and application timings against high infestations resulted in frequencies below the action threshold of 71 to 93%. Number of nymphs did not significantly differ between application of 50 and 75 g ai/ha of sulfoxaflor and acephate within single or sequential timings. As with any insecticide, effective tarnished plant bug control will depend on the quality of the application, pest population dynamics, and re-infestation intervals. Routine scouting practices will be necessary in determining the timing of insecticide treatments following a sulfoxaflor application. The new mode of action and efficacy provided by sulfoxaflor can be incorporated in cotton integrated pest management programs for tarnished plant bug that utilizes multiple insecticides.

Tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), is a damaging pest of cotton, *Gossyium hirsutum* L., in the mid-southern U.S. Adults and nymphs can cause injury to cotton at any phenological growth stage. During early plant development, tarnished plant bug can feed on cotton seedlings causing the plant terminal to abort and result in loss of apical dominance (Burris et al. 1997; Tugwell et al. 1976). More often, tarnished plant bug causes injury to floral buds (squares), flowers, and fruit (bolls). Tarnished plant bug feeding to small squares and bolls results in abscission (Russell, 1999). Flowers and larger squares fed upon are not abscised, but feeding results in necrosis of anthers and staminal columns, crinkling and cupping of petals, and abscission of the ensuing boll (Pack and Tugwell, 1976). Tarnished plant bug is also capable of penetrating bolls ≤ 12 d old (Greene et al., 1999; Horn et al., 1999; Russell, 1999). The cumulative impact of tarnished plant bug injury to cotton is typically delayed crop maturity and yield reductions (Layton, 2000).

In 2008, *Lygus* spp. [*Lygus hesperus* (Knight) and *L. lineolaris*] was the most damaging arthro-

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pod pest in cotton (Williams, 2009b). Of particular concern are tarnished plant bug infestations in the mid-southern states of Tennessee, Missouri, Arkansas, Louisiana, and Mississippi that required 1.4, 1.9, 2.2, 2.7, and 4.9 insecticide applications per acre, respectively, during 2008 to manage those infestations (Williams, 2009a). Tarnished plant bug infestations in this region typically are prolonged (prior to and through an approximate 5-wk period of flowering) and have overlapping generations requiring management. Several cultural control tactics are recommended to manage tarnished plant bug, including alternate (non-cotton) host plant management, cotton field placement and proximity to emigrating populations, planting early maturing cotton varieties, and utilization of varieties with host-plant resistance characters (Gore et al., 2009; Leonard, 2008; Snodgrass et al., 2006; Stewart and Layton, 2000). However, chemical control tactics remain the primary method for managing tarnished plant bug infestations in cotton (Scott and Snodgrass, 2000).

Control of tarnished plant bug in some areas has become less effective due to the development of insecticide-resistant populations. Synthetic pyrethroid resistance became widespread in tarnished plant bug populations in the Mississippi River delta of Arkansas, Louisiana, and Mississippi by the mid-1990s, with these insects also demonstrating resistance to several organophosphates and cyclodienes (Snodgrass, 1996). More recently, an increasing number of tarnished plant bug populations in Mississippi and Louisiana has demonstrated resistance to one of the recommended standards, acephate (Copes et al., 2010; Snodgrass and Scott, 2002; Snodgrass et al., 2009). In spite of resistance, acephate continues to be the most common insecticide used to manage tarnished plant bug infestations in cotton. One of the initial practices to overcome declining susceptibility to acephate has been an increase in the frequency of applications. In addition, use rates have increased over the last two decades from 0.37 to 0.56 kg ai/ha to 0.84 to 1.12 kg ai/ha, resulting in maximum active ingredient allowed by the label in a season (Copes et al., 2008, 2010; Kharbouti and Allen, 1998; Snodgrass and Scott, 2002; Snodgrass et al., 2009). Snodgrass et al. (2009) suggested that new insecticide classes effective against tarnished plant bug are needed because rotation among the current insecticide classes is not sustainable. Many tarnished plant bug populations already express resistance to one or more of these classes of insecticides. Sulfoxaflor is a new active ingredient within the sulfoximine insecticide class that acts via a unique interaction with the nicotinic receptor (Watson et al., 2011; Zhu et al., 2010). Sulfoxaflor has demonstrated broad activity against sucking insect pests including species within the families Aleyrodidiae, Aphididae, Delphacidae, Margarodidiae, and Miridae. No cross-resistance to other insecticide classes has been detected (Babcock et al., 2011; Zhu et al., 2010). The objective of the following study was to determine the effectiveness of sulfoxaflor against tarnished plant bug in mid-southern U.S. cotton.

MATERIALS AND METHODS

Efficacy of sulfoxaflor against tarnished plant bug on flowering cotton was evaluated in 49 trials located across 12 mid-southern U.S. locations from 2008 through 2010 (Table 1). At each test site, cultural practices including fertility, irrigation, and weed management, as recommended by state extension guidelines, were used to maintain experimental plots for optimum crop productivity. The entire test area was managed for lepidopteran pests using transgenic *Bacillus thuringiensis* cotton and chemical controls with no activity against tarnished plant bug (i.e., no pyrethroids were used). Lepidopteran-specific insecticides included rynaxapyr (Dupont Coragen 200 g/L SC, E.I. du Pont de Nemours and Co., Wilmington, DE), spinosad (Tracer 480 g/L SC, Dow AgroSciences, Indianapolis, IN) and methoxyfenozide (Intrepid 240 g/L F, Dow AgroSciences LLC, Indianapolis, IN). Early season thrips [primarily *Frankliniella fusca* (Hinds)] infestations were managed with thiamethoxam (Cruiser 600 g/L FS, Syngenta Crop Protection, Greensboro, NC), aldicarb (Temik 150 g/kg G, Bayer Crop Science, Research Triangle Park, NC), or acephate applied as a seed, in-furrow, or foliar treatment. Tarnished plant bug and cotton aphid, *Aphis gossypii* Glover, were managed as needed and based on action thresholds with foliar applications of thiamethoxam (Centric 400 g/kg WG, Syngenta Crop Protection, Greensboro, NC) before cotton plants developed to flowering stage and prior to application of experimental treatments. Insecticides used to manage thrips and aphids were applied at a sufficient length of time prior to initiation of experiments to not have an effect on plant bug infestation levels.

Table 1. Field trials evaluating the efficacy of sulfoxaflor against tarnished plant.bug in mid-southern U.S. cotton.

Location (county/parish)	Year	Infestation Level[z]	Treatment Program (Trials)[y]
Bevis Corner, AR (Lonoke)	2008	Moderate	A (1)
Marianna, AR (Lee)	2008	Moderate	B (1)
Lonoke, AR (Lonoke)	2009	Moderate	C (1)
Winnsboro, LA (Franklin)	2008, 2009	Moderate	A (1), B (1)
St. Joseph, LA (Tensas)	2009, 2010	Moderate	B (2), C (1)
Stoneville, MS (Washington)	2008, 2008, 2010	Moderate	B (5), C (1)
Greenville, MS (Washington)	2010	Moderate	B (1)
Wayside, MS (Washington)	2009, 2010	Moderate	B (2)
Glendora, MS (Tallahatchie)	2008, 2009	Moderate	B (1), C (1)
Jackson, TN (Madison)	2009, 2010	Moderate	B (3)
Marianna, AR (Lee)	2009, 2010	High	A (1), B (2), C (1)
Winchester, AR (Drew)	2009	High	C (1)
Rohwer, AR (Desha)	2008	High	B (1)
St. Joseph, LA (Tensas)	2010	High	B (1)
Winnsboro, LA (Franklin)	2009	High	A (1)
Stoneville, MS (Washington)	2009, 2010	High	A (1), B (2)
Greenville, MS (Washington)	2008, 2009	High	B (3), C (1)
Wayside, MS (Washington)	2008, 2009, 2010	High	A (3), B (6), C (1)
Glendora, MS (Tallahaticchie)	2010	High	B (1)
Jackson, TN (Madison)	2010	High	B (1)

[z] Trials with area under insect pressure curve average < 3x action threshold and ≥ 3x action threshold within the nontreated treatment was categorized as moderate and high infestation, respectively.

[y] Treatments applied once (A), treatments applied twice at a 3- to 7-d interval (B), or treatments duplicated and applied both once and twice (C).

Insecticide treatments were applied to plots 12.2 to 15.2 m in length by four to eight rows wide (91.4–101.6-cm centers) arranged in a randomized complete block design and replicated four times. Treatments were delivered using a volume of 74.8 to 93.5 L/ha at 206.8 to 448.2 kPa through hollow cone nozzles. Treatments evaluated included a nontreated control, sulfoxaflor at 25, 50, and 75 g ai/ha (500 g/kg WDG or 240 g/L SC, Dow AgroSciences LLC, Indianapolis, IN) and acephate at 1121 g ai/ha (Orthene 900 g/kg S, Valent USA Corp., Walnut Creek, CA). Within a trial, all treatments were applied using one of the following regimes: one application; two applications at a 3- to 7-d interval between sprays; or treatments were applied to duplicate plots, half of which received a second application of the same treatment at 3 to 7 d following the first application. This treatment regime was designed to compare the efficacy of single and sequential applications of varying insecticide treatments. Nontreated plots were included within each trial as a reference of tarnished plant bug population densities.

Treatments were initiated to cotton during the flowering growth stage (approximately first week of flowering) when tarnished plant bugs reached the recommended action threshold of three adults or nymphs per 1.5 row-m using a black drop cloth (76 by 91 cm) (Catchot, 2012; Leonard, 2012; Stewart et al., 2012; Studebaker, 2012). For treatments applied twice, the second application was initiated after the first sampling date following the first application in which the average of four nontreated plots within a trial were ≥ 2-fold above the action threshold. Following each treatment application, tarnished plant bug nymphs were sampled in each plot every 3 to 5 d until all insecticide treatments exceeded threshold. Single application treatments were also sampled for the same duration as treatments applied twice when both regimes occurred within the same trial. A black drop cloth was used for sampling and was placed between two adjacent, center rows within a plot. All cotton plants within the length of the drop cloth were shaken to dislodge tarnished plant bug nymphs. Nymphs were assessed because they are less mobile as compared to adults and therefore more reliably collected in small-plot studies (Layton 2000). Two drop cloth samples were obtained per plot with data reported as number per 1.5 row-m (1 drop cloth). Drop cloths were used in these studies because they are the most reliable means for sampling nymphs that represent the population in a cotton field (Snodgrass, 1993). Furthermore, after plants begin to bloom, scouting recommendations emphasize use of drop cloths for estimating infestations relative to action thresholds (Catchot, 2012). Once sampling was completed at approximately 7 to 15 d after the second application, treated and nontreated plots were oversprayed on a weekly basis until all plants reached “cutout” (physiological maturity) to reduce the impact of tarnished plant bugs and other pests capable of causing plant injury and yield loss. Harvest aids (boll openers and defoliants) were applied at a single timing when the average of treated plots reached recommended crop maturities.

Initial analyses of data indicated that results were influenced by tarnished plant bug population levels and persistence of infestations. Therefore, each of the 49 trials were categorized based on overall level of tarnished plant bug nymph numbers using the area under the infestation pressure curve (AUIPC) transformation as described by Siebert et al. (2008). The AUIPC was calculated for nontreated plots within each trial then divided by the number of days within the sampling period resulting in an AUIPC average or number of tarnished plant bug nymphs collected in nontreated plots on a per-day basis. A trial with an AUIPC average of < 9.0 nymphs (< 3x action threshold) within the nontreated treatment was categorized as moderate infestation. Trials with an AUIPC average ≥ 9.0 nymphs (≥ 3x action threshold) within the nontreated treatment were categorized as high infestation.

Nymph counts within each trial were evaluated by level of infestation at specified evaluation intervals. In the moderate infestation across trial summarization, evaluation intervals included 2 to 5 d and 6 to 8 d after the first application and 2 to 5 d, 6 to 8 d, and 9 to 12 d after the second application. In the high infestation across trial summarization, evaluation intervals included 2 to 5 d and 6 to 8 d after the first application and 2 to 5 d, 6 to 8 d, 9 to 12 d, and 13 to 15 d after the second application. In both moderate and high infestation summaries, data following the first application also included data from plots that later received a second application.

Evaluation of the count data on any single evaluation interval revealed a mixture of Poisson and negative binomial distributions. In addition, some of the individual test data had larger than expected numbers of zeros for populations. Therefore, a gamma-Poisson Bayesian model with noninformative priors that included parameters to model over dispersion and zero inflation was utilized (Ntzoufras, 2009). BRugs software was used to build 95% credible intervals to compare treatment means (R Development Core Team, 2005; Thomas et al., 2006). Credible intervals provide a probability level that a mean value is contained within the calculated interval (Box-Steffensmeier et al., 2008). Treatment means were considered significantly different if 95% credible intervals did not overlap (Carlin and Lewis, 2000).

In addition to comparing treatments based on reductions of mean numbers of nymphs, a second evaluation based on population levels relative to an action threshold was tabulated and consisted of the number of times a trial treatment mean remained below the action threshold (< 3.0 bugs per 1.5 row-m) within each evaluation interval. These frequencies were tabulated for both the moderate and high infestation levels and analyzed as nominal, binomial data at the 5% level using generalized linear model techniques (JMP, 2009). Contrasts within the generalized linear model framework were used to compare specific frequencies and reported as χ^2 values with associated probabilities. Cotton yield (seed cotton) was harvested in 23 trials (seven for moderate infestations and 16 for high infestations) from the entire length of the center two rows of each plot using a mechanical picker. Seed cotton per plot (kg/ha) was transformed to kg lint/ha using a standardized lint:seed ratio of 38%. Yields were analyzed using a normal distribution Bayesian model and noninformative priors from which 95% credible intervals were constructed.

RESULTS

Comparison of Moderate and High Tarnished Plant Bug Infestation Levels. Infestations of tarnished plant bugs ranged from moderate to high during 2008 to 2010, with 56% of all trials classified as high (Table 1). Mean number of tarnished plant bug nymphs ranged from 6.0 to 8.6 per 1.5 row-m in nontreated plots across all sampling intervals in moderate infestations, as compared with 12.5 to 19.7 nymphs per 1.5 row-m in high infestations (Tables 2, 3). The frequency at which tarnished plant bugs nymphs were below the action threshold (3 adults and/or nymphs per 1.5 row-m) in nontreated plots under moderate infestations at 2 to 5 d and 6 to 8 d after the first application and 2 to 5 d, 6 to 8 d, and 9 to 12 d after the second application was 14, 13, 23, 30, and 14%, respectively. The frequency at which tarnished plant bugs nymphs were below the action threshold in nontreated plots under high infestations at 2 to 5 d and 6 to 8 d after the first application and 2 to 5 d, 6 to 8 d, 9 to 12 d, and 13 to 15 d after the second application was 1, 0, 1, 5, 10, and 8%, respectively.

Impact of Insecticide Treatments on Tarnished Plant Bug Mean Numbers in Moderate Infestations. All rates of sulfoxaflor and acephate applied once significantly ($P < 0.05$) reduced mean tarnished plant bug nymphs relative to nontreated plots at 2 to 5 d and 6 to 8 d after the first application (Table 2). Numbers of nymphs were significantly ($P < 0.05$) greater in plots treated with 25 g ai/ha than 75 g ai/ha of sulfoxaflor at 2 to 5 d after application. Mean numbers were not significantly different ($P > 0.05$) between treatments of 50 and 75 g ai/ha of sulfoxaflor and acephate at 2 to 5 d after the initial application. At 6 to 8 d and at 9 to 12 d after application, tarnished plant bug numbers were not significantly different among insecticide treatments applied once ($P > 0.05$).

At 2 to 5 d after the second application, number of tarnished plant bugs were significantly less ($P < 0.05$) for 50 g ai/ha and 75 g ai/ha of sulfoxaflor applied twice compared with all other insecticide treatments applied once. In contrast, mean number of tarnished plant bugs were not significantly different ($P > 0.05$) between 25 g ai/ha of sulfoxaflor applied twice and insecticide treatments applied once, and numbers of tarnished plant bug were not significantly different ($P > 0.05$) between acephate applied twice and 50 g ai/ha or 75 g ai/ha sulfoxaflor, or acephate applied once. Tarnished plant bug numbers were not significantly different ($P > 0.05$) among sulfoxaflor and acephate treatments applied twice at 2 to 5 d after the second application. At 6 to 8 d and 9 to 12 d after the second application there were no significant differences in number of nymphs among sequential treatments ($P > 0.05$) and all insecticide treatments significantly reduced populations compared with nontreated plots, except for acephate at 9 to 12 d.

Table 2. Efficacy of sulfoxaflor and acephate applied once or twice at a 3- to 7-d interval for the management of moderate[z] infestation levels of tarnished plant bug nymphs, 2008-2010.

	Mean number of tarnished plant bug nymphs per 1.5 row-m (95% Credible Interval)				
	2 to 5DAA1[y]	6 to 8DAA1	9 to 12DAA1[x] (2 to 5DAA2)	6 to 8DAA2	9 to 12DAA2
Sulfoxaflor (25 g ai/ha)	3.3 (2.7 – 3.9)	3.8 (2.9 – 4.7)	5.4 (3.4 – 8.2)	-----	-----
Sulfoxaflor (50 g ai/ha)	2.4 (2.0 – 2.9)	3.0 (2.4 – 3.8)	3.9 (2.7 – 5.4)	-----	-----
Sulfoxaflor (75 g ai/ha)	1.9 (1.6 – 2.3)	2.4 (1.8 – 3.2)	4.4 (2.7 – 6.5)	-----	-----
Acephate (1121 g ai/ha)	2.3 (1.9 – 2.8)	3.2 (2.4 – 4.2)	3.9 (2.7 – 5.4)	-----	-----
Sulfoxaflor (25 g ai/ha) – 2x[w]	-----	-----	2.5 (1.7 – 3.5)	3.1 (2.2 – 4.1)	4.1 (2.9 – 5.6)
Sulfoxaflor (50 g ai/ha) – 2x	-----	-----	1.7 (1.2 – 2.2)	2.5 (1.7 – 3.4)	3.2 (2.2 – 4.4)
Sulfoxaflor (75 g ai/ha) – 2x	-----	-----	1.2 (0.7 – 2.0)	2.5 (1.6 – 3.4)	3.4 (2.5 – 4.3)
Acephate (1121 g ai/ha) – 2x	-----	-----	2.1 (1.4 – 3.0)	2.7 (1.7 – 4.1)	4.6 (2.8 – 7.3)
Nontreated	7.1 (6.2 – 8.0)	6.8 (5.9 – 7.7)	6.1 (5.1 – 7.1)	6.0 (4.7 – 7.5)	8.6 (7.0 – 10.6)

Mean within columns are significantly different if 95% credible intervals do not overlap ($\alpha = 0.05$).

[z] Moderate infestation summarization was comprised of trials with an area under insect pressure curve average of < 9.0 nymphs (<3x action threshold) within the nontreated treatment.

[y] Evaluation interval: days after application one or two.

[x] Evaluation interval of 9 to 12 d after application for those treatments that received only one application.

[w] Insecticides applied twice at a 3 to 7 d interval between applications.

Table 3. Efficacy of sulfoxaflor and acephate applied once or twice at a 3- to 7d interval for the management of high[z] infestation levels of tarnished plant bug nymphs, 2008-2010.

	Mean number of tarnished plant bug nymphs per 1.5 row-m (95% Credible Interval)					
	2 to 5DAA1[y]	6 to 8DAA1	9 to 12 DAA1 (2 to 5DAA2)[x]	6 to 8DAA2	9 to 12DAA2	13 to 15DAA2
Sulfoxaflor (25 g ai/ha)	5.5 (4.7 – 6.4)	5.1 (4.2 – 6.0)	7.0 (5.4 – 8.8)	----	----	----
Sulfoxaflor (50 g ai/ha)	5.1 (4.5 – 5.8)	4.0 (3.4 – 4.7)	6.9 (5.0 – 9.3)	----	----	----
Sulfoxaflor (75 g ai/ha)	4.3 (3.8 – 4.9)	3.6 (2.8 – 4.5)	6.0 (3.9 – 9.0)	----	----	----
Acephate (1121 g ai/ha)	3.4 (2.8 – 3.9)	4.7 (3.5 – 6.3)	6.1 (3.5 – 10.1)	----	----	----
Sulfoxaflor (25 g ai/ha) – 2x[w]	----	----	3.5 (2.9 – 4.2)	3.6 (3.0 – 4.3)	4.2 (3.4 – 5.1)	7.1 (4.5 – 10.9)
Sulfoxaflor (50 g ai/ha) – 2x	----	----	2.8 (2.2 – 3.4)	2.2 (1.6 – 2.8)	3.1 (2.4 – 3.9)	5.1 (3.4 – 7.4)
Sulfoxaflor (75 g ai/ha) – 2x	----	----	2.1 (1.6 – 2.7)	1.9 (1.1 – 2.8)	2.9 (2.2 – 3.8)	3.9 (2.8 – 5.0)
Acephate (1121 g ai/ha) – 2x	----	----	2.0 (1.5 – 2.5)	2.3 (1.6 – 3.2)	3.3 (2.4 – 4.2)	9.7 (6.0 – 15.6)
Nontreated	15.9 (13.9 – 18.2)	13.1 (11.1 – 15.4)	16.9 (15.0 – 19.0)	12.5 (10.7 – 14.6)	12.5 (10.3 – 15.0)	19.7 (13.9 – 27.6)

Mean within columns are significantly different if 95% credible intervals do not overlap (α = 0.05).

[z] High infestation summarization was comprised of trials with an area under insect pressure curve average of ≥ 9.0 nymphs (≥ 3x action threshold) within the nontreated treatment.

[y] Evaluation interval: days after application one or two.

[x] Evaluation interval of 9 to 12 d after application for those treatments that received only one application.

[w] Insecticides applied twice at a 3- to 7-d interval between applications.

Impact of Insecticide Treatments on Tarnished Plant Bug Frequency Below Threshold in Moderate Infestations. A single application of 50 g ai/ha or 75 g ai/ha of sulfoxaflor and acephate reduced numbers > 69% of the time below the action threshold (Fig. 1). Sulfoxaflor applied at 25 g ai/ha reduced infestations of tarnished plant bugs below the action threshold less frequently than other insecticide treatments at 2 to 5 d after application (paired comparison, χ2, *P*-value: 25 g ai/ha and 50 g ai/ha, 3.885, 0.0487; 25 g ai/ha and 75 g ai/ha, 17.352, < 0.0001; 25 g ai/ha and acephate, 8.772, 0.0031). Sulfoxaflor applied at 75 g ai/ha more frequently reduced densities below the action threshold as compared to 50 g ai/ha (χ2, *P*-value: 5.547, 0.0185), but was equal in frequency to acephate (χ2, *P*-value: 1.237, 0.2661). The frequency at which acephate reduced initial numbers at 2 to 5 d after application was significantly greater than 50 g ai/ha of sulfoxaflor (χ2, *P*-value: 4.299, 0.0381). At 6 to 8 d after application, sulfoxaflor applied at 75 g ai/ha significantly increased the number of occurrences of tarnished plant bug below the action threshold compared with 25 g ai/ha of sulfoxaflor (χ2, *P*-value: 9.874, 0.0017), 50 g ai/ha of sulfoxaflor (χ2, *P*-value: 4.142, 0.0418), and acephate (χ2, *P*-value: 4.002, 0.0454). The frequency at which 25 g ai/ha and 50 g ai/ha of sulfoxaflor and acephate reduced numbers below the action threshold was equal (paired comparison, χ2, *P*-value: 25 g ai/ha and 50 g ai/ha, 1.461, 0.2268; 25 g ai/ha and acephate, 1.222, 0.2689; 50 g ai/ha and acephate, 0.003, 0.9569). At 9 to 12 d after the initial application, there was no significant difference in frequency of reducing infestations below the action threshold among insecticide treatments applied once ($P > 0.05$).

At 2 to 5 d after the second application, all insecticide treatments applied twice reduced numbers below the action threshold more frequently than insecticides applied once, with one exception (Table 4). The frequency at which sulfoxaflor applied twice at 25 g ai/ha reduced numbers below the action threshold was not significantly different than 75 g ai/ha of sulfoxaflor applied once (Table 4). Among insecticide treatments applied twice at 2 to 5 d after the second application, the frequency of observations below the action threshold for sulfoxaflor applied twice at 25 g ai/ha was significantly less than 50 g ai/ha (χ2, *P*-value: 4.486, 0.0342) and 75 g ai/ha (χ2, *P*-value: 9.989, 0.0016) of sulfoxaflor, but equal to acephate (χ2, *P*-value: 2.036, 0.1536). Sulfoxaflor applied twice at 50 g ai/ha resulted in a frequency below the action threshold equal to both 75 g ai/ha of sulfoxaflor (χ2, *P*-value: 2.036, 0.1536) and acephate (χ2, *P*-value: 0.427, 0.5136). Tarnished plant bug numbers below threshold occurred at equal frequencies between 75 g ai/ha of sulfoxaflor and acephate ($\chi 2$, *P*-value: 3.144, 0.0762). At 6 to 8 d and 9 to 12 d after the second application, the frequencies at which mean densities were below the action threshold were equal among insecticide treatments applied twice, except for 25 g ai/ha sulfoxaflor at 6 to 8 d after the second application that reduced densities below the action threshold significantly less often than 75 g ai/ha of sulfoxaflor ($\chi 2$, *P*-value: 7.85, 0.0051).

Impact of Insecticide Treatments on Tarnished Plant Bug Mean Numbers in High Infestations. In high infestation levels, all rates of sulfoxaflor and acephate applied once significantly ($P < 0.05$) reduced mean tarnished plant bug nymph numbers relative to nontreated plots at 2 to 5 d and 6 to 8 d after the first application (Table 3). At 2 to 5 d after application, numbers of tarnished plant bugs were significantly less ($P < 0.05$) for plots treated with acephate compared to 25 or 50 g ai/ha of sulfoxaflor. There was no significant difference in the numbers ($P > 0.05$) of tarnished plant bugs between 75 g ai/ha of sulfoxaflor and acephate. At 6 to 8 d after a single application, there was no significant ($P > 0.05$) difference in the density of tarnished plant bug among insecticide treatments.

At 2 to 5 d after the second application (9 to 12 d after the first application), two applications of 50 or 75 g ai/ha of sulfoxaflor or acephate significantly reduced numbers compared with treatments applied once ($P < 0.05$). Among insect treatments applied twice at 2 to 5 d after the second application, number of nymphs was not significantly different between 75 g ai/ha of sulfoxaflor and acephate ($P < 0.05$) and both treatments had significantly fewer nymphs ($P < 0.05$) than 25 g ai/ha of sulfoxaflor. Number of tarnished plant bug in plots treated twice with 50 g ai/ha of sulfoxaflor was not significantly different than other insecticide treatments applied twice ($P > 0.05$).

At 6 to 8 d after the second application, mean nymph numbers were not significantly different and below the action threshold among 50 g ai/ha and 75 g ai/ha of sulfoxaflor and acephate ($P > 0.05$). Numbers of tarnished plant bug were significantly less ($P < 0.05$) for plots treated with 50 g ai/ha and 75 g ai/ha of sulfoxaflor than 25 g ai/ha of sulfoxaflor, which exceeded the action threshold. There was no significant difference in the number of nymphs between acephate and 25 g ai/ha of sulfoxaflor ($P > 0.05$). At 9 to 12 d and 13 to 15 d after the second application, mean number of nymphs were not significantly different among insecticide treatments ($P > 0.05$) and all insecticide treatments except acephate at 13 to 15 d after the second application had significantly lower mean numbers than nontreated plots.

Impact of Insecticide Treatments on Tarnished Plant Bug Frequency Below Threshold in High Infestations. A single application of sulfoxaflor or acephate reduced numbers ≤ 52% of the time below the action threshold at 2 to 5 d after the first application (Fig. 2). The frequency at which numbers of nymphs were reduced below the action threshold for acephate was greater compared to 25 g ai/ha ($\chi 2$, *P*-value: 8.393, 0.0038) or 50 g ai/ha ($\chi 2$, *P*-value: 8.156, 0.0043) of sulfoxaflor. There was no significant difference in the frequency at which means were below the action threshold between 75 g ai/ha of sulfoxaflor and acephate at 2 to 5 d after application ($\chi 2$, *P*-value: 2.613, 0.1060). At 6 to 8 d after a single application there was no significant difference in the frequency at which numbers of nymphs were reduced below the action threshold, with one exception. Sulfoxaflor applied at 25 g ai/ha did not reduce infestations below the action threshold as frequently as 75 g ai/ha of sulfoxaflor ($\chi 2$, *P*-value: 7.652, 0.0057) or acephate ($\chi 2$, *P*-value: 3.893, 0.0485).

Table 4. Results of contrasts comparing single and sequential application treatments (rate) for reduction of tarnished plant bug numbers below the action threshold under moderate infestation levels at 2 to 5 d after the second application.

Single Application	Sequential Applications			
	Sulfoxaflor (25gai/ha)	Sulfoxaflor (50 gai/ha)	Sulfoxaflor (75 gai/ha)	Acephate (1121 g ai/ha)
Sulfoxaflor (25gai/ha)	6.79, 0.009[z]	18.04, <0.001	25.24, <0.001	13.62. <0.001
Sulfoxaflor (50 gai/ha)	4.74, 0.029	14.48, <0.001	21.09, <0.001	10.62, 0.001
Sulfoxaflor (75 gai/ha)	1.68, 0.194	8.32, 0.004	13.62, <0.001	5.57, 0.018
Acephate (1121 g ai/ha)	4.74, 0.029	14.48, <0.001	21.09, <0.001	10.62, 0.001

[z] χ^2, *P*-value.

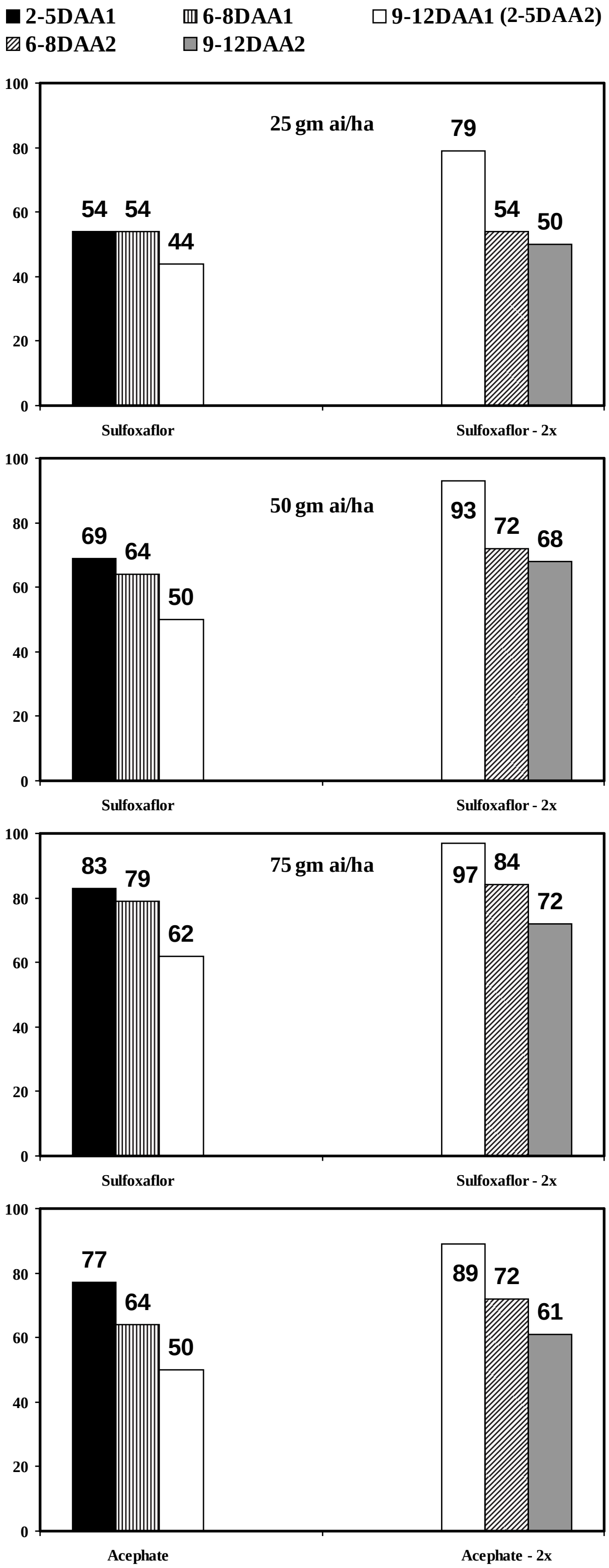

Figure 1. Frequency (denoted above each bar) in which tarnished plant bug mean numbers are below the action threshold of 3 per 1.5 row-m in moderate infestation levels.

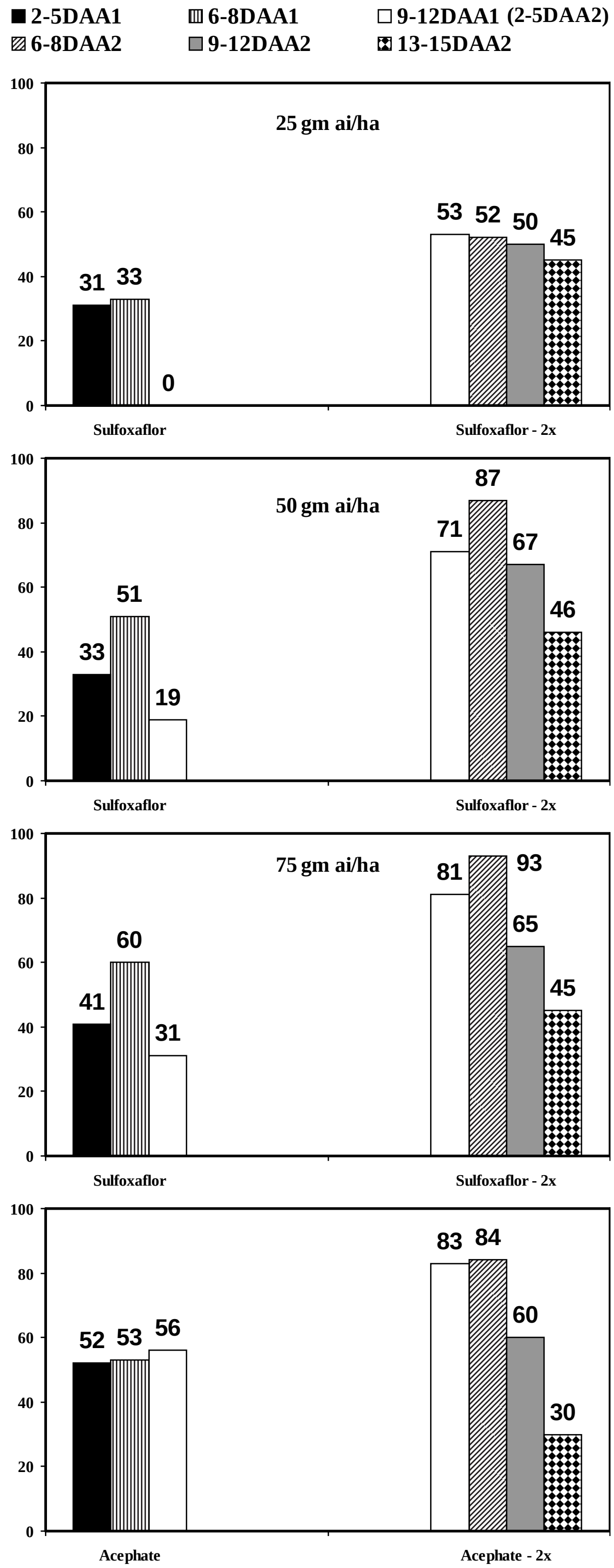

Figure 2. Frequency (denoted above each bar) in which tarnished plant bug mean numbers are below the action threshold of 3 per 1.5 row-m in high infestation levels.

At 2 to 5 d after the second application (9 to 12 d after the first application) the frequency at which numbers of tarnished plant bug were reduced below the action threshold for treatments applied twice was significantly greater compared with insecticide treatments applied once, except for 25 and 50 g ai/ha of sulfoxaflor applied twice, which provided similar frequencies to acephate applied once (Table 5, Fig. 2). Among insect treatments applied twice at 2 to 5 d after the second application, the frequency of tarnished plant bug numbers below the action threshold was not significantly different between 50 g ai/ha and 75 g ai/ha of sulfoxaflor and acephate ($\chi 2$, *P*-value: 50 g ai/ha twice and 75 g ai/ha twice, 2.549, 0.1103; 50 g ai/ha twice and acephate twice, 3.286, 0.0699; 75 g ai/ha twice and acephate twice, 0.135, 0.7133). These treatments had significantly higher frequency below the action threshold than 25 g ai/ha of sulfoxaflor (paired comparison, $\chi 2$, *P*-value: 25 g ai/ha twice and 50 g ai/ha twice, 5.256, 0.0219; 25 g ai/ha twice and 75 g ai/ha twice, 13.757, 0.0002; 25 g ai/ha twice and acephate, 13.908, 0.0002).

At 6 to 8 d after the second application, sulfoxaflor applied twice at 50 g ai/ha and 75 g ai/ha and acephate reduced numbers below the action threshold at equal frequencies (paired comparison, $\chi 2$, *P*-value: 50 g ai/ha twice and 75 g ai/ha twice, 1.221, 0.2691; 50 g ai/ha twice and acephate, 0.136, 0.7127; 75 g ai/ha and acephate, 1.925, 0.1653). Plots receiving 25 g ai/ha of sulfoxaflor applied twice exceeded the action threshold more often than other insecticides applied twice (paired comparison, $\chi 2$, *P*-value: 25 g ai/ha twice and 50 g ai/ha twice, 16.670, < 0.0001; 25 g ai/ha twice and 75 g ai/ha twice, 24.834, < 0.0001; 25 g ai/ha twice and acephate twice, 11.642, 0.0006).

The frequency at which treatments reduced numbers below the action threshold was not significantly different at 9 to 12 d (paired comparison, $\chi 2$, *P*-value: 25 g ai/ha twice and 50 g ai/ha twice, 3.410, 0.0648; 25 g ai/ha twice and 75 g ai/ha twice, 2.680, 0.1016; 25 g ai/ha twice and acephate twice 0.9843, 0.3314; 50 g ai/ha twice and 75 g ai/ha twice, 0.066, 0.7970; 50 g ai/ha twice and acephate twice, 0.552, 0.4576; 75 g ai/ha twice and acephate twice, 0.257, 0.6125) and 13 to 15 d after the second application (paired comparison, $\chi 2$, *P*-value: 25 g ai/ha twice and 50 g ai/ha twice, 0.003, 0.9559; 25 g ai/ha twice and 75 g ai/ha twice, 0, 1.000; 25 g ai/ha twice and acephate twice, 0.965, 0.3259; 50 g ai/ha twice and 75 g ai/ha twice, 0.367, 0.5445; 50 g ai/ha twice and acephate twice, 1.165, 0.2803; 75 g ai/ha twice and acephate twice, 0.965, 0.3259).

Evaluating control within a treatment over time in high infestations, the frequency of below threshold numbers for plots treated twice with 50 g ai/ha or 75 g ai/ha of sulfoxaflor significantly increased between 2 to 5 d and 6 to 8 d after the first application (rate from 2-5 d to 6-8 d, $\chi 2$, *P*-value: 50 g ai/ha, 5.512, 0.0189; 75 g ai/ha, 6.591, 0.0103) and also after the second application (rate from 2-5 d to 6-8 d, $\chi 2$, *P*-value: 50 g ai/ha, 5.552, 0.0185; 75 g ai/ha, 4.212, 0.0401). In comparison, the frequency at which mean numbers were reduced below the action threshold was not significantly different for 25 g ai/ha of sulfoxaflor and acephate from 2 to 5 d to 6 to 8 d after first application (rate from 2-5 d to 6-8 d, $\chi 2$, *P*-value: 25 g ai/ha, 0.063, 0.8019; acephate, 0.04, 0.8287) and second application (rate from 2-5 d to 6-8 d, $\chi 2$, *P*-value: 25 g ai/ha, 0.012, 0.9119; acephate, 0.011, 0.9177) in high infestations.

Impact of Insecticide Treatments on Cotton Lint Yield. In moderate tarnished plant bug infestation levels, lint yields were significantly greater for plots treated twice with 50 g ai/ha and 75 g ai/ha of sulfoxaflor and acephate as compared with nontreated plots ($P < 0.05$) (Table 6). There was no significant difference in lint yield between 25 g ai/ha of sulfoxaflor and nontreated plots ($P > 0.05$). In high tarnished plant bug infestation levels, there was no significant ($P > 0.05$) difference in lint yield among insecticide treatments and all resulted in significantly greater yield than nontreated plots ($P < 0.05$).

Table 5. Results of contrasts comparing single and sequential application treatments (rate) for reduction of tarnished plant bug numbers below the action threshold under high infestation levels at 2 to 5 d after the second application.

Single Applications	Sequential Applications			
	Sulfoxaflor (25gai/ha)	Sulfoxaflor (50 gai/ha)	Sulfoxaflor (75 gai/ha)	Acephate (1121 g ai/ha)
Sulfoxaflor (25gai/ha)	20.29, <0.0001[z]	33.47, <0.0001	42.98, <0.0001	42.63, <0.0001
Sulfoxaflor (50 gai/ha)	8.33, 0.0038	17.37, <0.0001	24.88, <0.0001	25.11, <0.0001
Sulfoxaflor (75 gai/ha)	4.26, 0.0388	10.62, 0.0011	16.73, <0.0001	17.46, <0.0001
Acephate (1121 g ai/ha)	1.45, 0.2273	2.64, 0.1040	5.45, 0.0195	6.93, 0.0084

[z] χ^2, *P*-value.

Table 6. Lint yield of sulfoxaflor and acephate applied twice as sequential applications in moderate and high infestation levels of tarnished plant bug nymphs, 2008-2010.

	Kg lint / ha	
	Moderate Infestation[z]	**High Infestation**
Sulfoxaflor (25 g ai/ha) – 2x[y]	**1008.7 (950.3 – 1006.1)**	**993.8 (891.6 – 1096.4)**
Sulfoxaflor (50 g ai/ha) – 2x	**1186.4 (1124.7 – 1247.0)**	**1107.1 (1010.5 – 1203.2**
Sulfoxaflor (75 g ai/ha) – 2x	**1175.2 (1129.2 – 1222.3)**	**1081.6 (982.8 – 1179.7)**
Acephate (1121 g ai/ha) – 2x	**1184.2 (1088.0 – 1282.9)**	**1090.4 (967.4 – 1213.3)**
Nontreated	**942.8 (864.9 – 1020.2)**	**745.2 (652.2 – 838.1)**

[z] χ^2, *P*-value.

Means within columns are significantly different if 95% confidence intervals do not overlap (α = 0.05).

[z] Trials with Area Under Insect Pressure Curve average <3x action threshold and ≥3x action threshold within the non-treated treatment was categorized as moderate and high infestation, respectively.

[y] Insecticides applied twice at a 3- to 7-d interval between applications.

DISCUSSION

The activity of sulfoxaflor insecticide was characterized across a range of field environments and tarnished plant bug infestation levels likely to occur in the mid-southern U.S., including the Delta region of the Mississippi River. The relative ecological simplicity (i.e., lower host diversity) that is typical of heavily cropped delta areas during the growing season can lead to high numbers of tarnished plant bugs (Layton, 2000). These are the areas where tarnished plant bugs cause the greatest concern (Layton, 2000). Infestations in the present studies were categorized from moderate (< 3x action threshold) to high (≥ 3x action threshold) levels, and insecticide applications were applied to large-canopied cotton plants during flowering stages to target the most difficult to control infestations. Insecticide coverage and efficacy of a product applied to pre-flowering cotton would be expected to exceed that of the same product applied during the flowering stage, with all other factors such as infestation levels and population dynamics being equal.

Segmentation of the results from different locations based on per-day densities (AUIPC average) for tarnished plant nymphs in nontreated plots and using a 3x action threshold to delineate moderate and high infestation levels was a reliable means of understanding efficacy. Mean number of tarnished plant bug nymphs in nontreated plots were 2.1- to 2.3-fold greater in high infestations as compared with moderate infestations. Similarly, the frequency at which number of tarnished plant bug nymphs was below the action threshold (three adults and/or nymphs per 1.5 row-m) in nontreated plots under moderate and high infestations ranged from 13 to 30% and 0 to 10%, respectively.

In the present studies, treatment means were compared as one method for evaluating the efficacy of insecticides against tarnished plant bug. These data are valuable for understanding the magnitude at which an insecticide reduces populations relative to other treatments and nontreated plots. However, populations of tarnished plant bugs are characteristically high in cotton and cause direct damage to plants, and the ability of an insecticide to reduce infestations below the action threshold becomes equally important. Insecticides currently used for tarnished plant bug management frequently demonstrate significant reductions in post-treatment numbers compared to nontreated areas, but it is less common that insecticides reduce tarnished plant bug numbers below a prescribed action threshold, thus leading to repeated treatments (Sharp et al., 2010). Examination of the frequency of a treatment to maintain number of nymphs below the action threshold in these studies provides insight into the how often a level of performance might be expected (i.e., consistency) from an insecticide. Careful review of these results can reveal variability that might be masked if only comparing mean numbers, and thus provide growers and pest management advisors insight into the potential to reduce insecticide applications and well as how to best rotate different classes of chemistry in an overall program.

For moderate and high infestation levels, all rates of sulfoxaflor demonstrated activity against tarnished plant bug nymphs based on reduced infestations relative to nontreated plots. Sulfoxaflor efficacy against tarnished plant bugs in the present study confirms initial laboratory results that evaluated sulfoxaflor against western tarnished plant bug, *Lygus hesperus* (Babcock et al., 2011). Babcock et al. (2011) demonstrated sulfoxaflor activity against western tarnished plant bug to be similar to that of imidacloprid, acetamiprid, and dinotefuran. Efficacy in the present small-plot studies was assessed based on densities of nymphs because they are less mobile than adults and more reliably collected on drop cloths, which is the sampling method that is emphasized in flowering cotton (Catchot, 2012; Layton, 2000; Snodgrass, 1993). However, sulfoxaflor also has demonstrated activity against tarnished plant bug adults. Numbers of tarnished plant bug adults have been reduced in sulfoxaflor-treated plots relative to nontreated plots in large-plot studies and evaluated using the sweep net sampling method, which is considered the most reliable method for sampling adults (Walton et al., 2012).

In comparing rates of sulfoxaflor against moderate and high infestations, 50 g ai/ha was the minimum rate that consistently reduced infestations below the action threshold and demonstrated efficacy levels most similar to the commercial standard acephate. Sulfoxaflor applied at 25 g ai/ha demonstrated activity against tarnished plant bug nymphs and in many instances provided control comparable to acephate or 50 g ai/ha of sulfoxaflor. However, when differences among sulfoxaflor rates were detected, 25 g ai/ha of sulfoxaflor was generally less consistent in reducing densities below the action threshold. Sulfoxaflor applied at 25 g ai/ha was most similar to other rates of sulfoxaflor only when applied twice under moderate infestations. Common use of a lower than effective rate (i.e., 25 g ai/ha of sulfoxaflor) that provides inconsistent control may compromise a resistance management plan for sulfoxaflor. An important strategy for minimizing the fitness of resistant insect genotypes is applying effective rates of insecticides that provide higher kill (Phillips et al., 1989; Roush, 1989).

Mean numbers of nymphs were similar between 50 g ai/ha and 75 g ai/ha of sulfoxaflor across moderate and high infestations within each respective (single or sequential) application timing. However, sulfoxaflor at 75 g ai/ha was more consistent in reducing numbers of tarnished plant bug than 50 g ai/ha in moderate infestations from 2 to 8 d after the first application. Numbers of nymphs for plots treated with 50 g ai/ha and 75 g ai/ha were always similar to those from plots treated with acephate within respective (single or sequential) timings.

Differences in the consistency of initial (2-5 d) and residual (≥ 6 d) control among effective sulfoxaflor treatments (≥ 50 g ai/ha) and acephate were detected. The frequency at which numbers of nymphs were reduced below the action threshold at 2 to 5 d after the first or second application with 75 g ai/ha of sulfoxaflor was always equal to or significantly greater than acephate in both moderate and high infestations. In contrast, consistency of initial control (2-5 d) with 50 g ai/ha of sulfoxaflor was significantly lower compared with acephate in all instances except 2 to 5 d after the second application under moderate infestations. Although 50 g ai/ha of sulfoxaflor provided slower initial control relative to acephate, the frequency of reduction below the action threshold was similar to that of acephate at the subsequent evaluation interval. Evidence for slower activity and increasing activity through time with sulfoxaflor was observed in high infestations where effective rates (50 g ai/ha and 75 g ai/ha) of sulfoxaflor significantly increased in consistency between the 2 to 5 d and 6 to 8 d evaluation intervals after the first and second applications. In comparison, frequency of reductions below the action threshold was not significantly different for 25 g ai/ha of sulfoxaflor and acephate from 2 to 5 d to 6 to 8 d after first and second application in high infestations. Slower initial activity observed with sulfoxaflor could be due to the greater contribution feeding has to resulting mortality as compared to primarily contact activity with acephate. Laboratory bioassays that expose tarnished plant bugs to sulfoxaflor through feeding have been observed to be more reliable than exposure through contact to residues on glass vials (D.R. Cook, unpublished data). Lack of increasing consistency through time with 25 g ai/ha of sulfoxaflor provides additional evidence for lower efficacy at this rate as compared with 50 g ai/ha or 75 g ai/ha of sulfoxaflor.

Consistency in residual control was equal to or significantly greater (6- 8 d after the first application) with 75 g ai/ha sulfoxaflor as compared to acephate against moderate populations. In contrast, 50 g ai/ha of sulfoxaflor and acephate demonstrated similar residual efficacy levels at evaluation intervals > 6 d after application. Greater consistency with 75 g ai/ha of sulfoxaflor suggests that in some situations the re-treatment interval may be longer compared with either 50 g ai/ha of sulfoxaflor or acephate. Extending the interval between applications in the management of tarnished plant bug has the potential to reduce the frequency of insecticide applications targeting tarnished plant bug and reduce the selection pressure placed on any insecticide.

In these studies, the ability of sulfoxaflor and acephate to reduce nymphs below the action threshold differed between moderate and high infestations. In moderate infestations, ≥ 50 g ai/ha of sulfoxaflor and acephate reduced infestations below the action threshold from 69 to 83% of the time at the initial evaluation interval. In contrast, 33 to 52% of mean observations were below the action threshold for ≥ 50 g ai/ha of sulfoxaflor and acephate at the initial evaluation interval in high infestations. Sequential applications of sulfoxaflor and acephate were required in these studies to increase the frequency of observations below the action threshold to 71 to 83% in high infestations. For moderate infestations following a single application or in high infestations following two applications, tarnished plant bug nymphs remained below the action threshold from 64 to 79% and 84 to 93%, respectively, of occurrences at the 6 to 8 d evaluation interval. The level and consistency of control for both sulfoxaflor and acephate declined at evaluation intervals ≥ 9 d after the first and second application in moderate and high infestations, respectively. However, based upon the frequency of observations below the action threshold, some infestations treated with sulfoxaflor might experience extended residual control and a lengthened re-treatment interval as compared with acephate.

For all evaluation intervals in moderate infestations or after the second application in high infestations, the frequency of sulfoxaflor applied at ≥ 50 g ai/ha was numerically equal to or greater than acephate. The frequency at which densities were below the action threshold at 9 to 12 d after the first application in moderate infestations and from 9 to 15 d after the second application in high infestations was 50 to 62% and 45 to 67%, respectively. The studies demonstrate the length of control of tarnished plant bug expected following a sulfoxaflor application will vary and control is not absolute (i.e., 100% of mean densities below the action threshold). As with any insecticide, control will be dependent on the operational quality of the application, field conditions (plant height, wind, etc), dynamics of local tarnished plant bug populations, and level and time of re-infestation. Thus, routine scouting practices will be necessary for determining the timing of insecticide treatments following a sulfoxaflor insecticide. Similarly, Snodgrass and Scott (2002) described situations where control of large tarnished plant bug populations in cotton with acephate might not occur and scouting after each application is recommended to determine if additional treatments are necessary.

These data provide evidence for the typical population dynamics in a cotton agro-ecosystem and also support the observed benefit of applying sequential applications against moderate infestations. Large numbers of tarnished plant bug constantly move into cotton fields when dry conditions, natural senescence, mowing, and/or tillage causes decline in blooms on alternate wild or cultivated hosts (Cleveland, 1982; Jackson et al., 2010; Layton, 2000; Snodgrass et al., 2006). Continual movement of tarnished plant bug in and out of cotton fields from squaring stage through flowering results in the need to apply multiple insecticide applications to manage infestations. In Mississippi, extension guidelines state that multiple applications applied at a 4- to 5-d interval might be required and are most effective to manage infestations because of immigration from adjacent hosts, difficulty in obtaining adequate coverage in large cotton, and/or insecticide resistance (Catchot, 2012; Gore et al., 2009). Insecticide resistance would not be considered as reason for the need for a sequential treatment of sulfoxaflor to manage an infestation.

The yield results reflect a reduction in tarnished plant bug nymphs provided by sulfoxaflor applied at ≥ 50 g ai/ha. Sulfoxaflor applied at 50 g ai/ha and 75 g ai/ha produced nearly identical yields that were comparable to that of acephate across both moderate and high infestation levels of tarnished plant bug. The lower and less consistent efficacy observed with 25 g ai/ha of sulfoxaflor against high infestations of tarnished plant bugs did not translate to significant reductions in lint yield. Fruit compensation by cotton plants under high tarnished plant bug infestation levels might have minimized the differences in consistency observed in-season among sulfoxaflor treatments. The ability of cotton to compensate for fruit loss from insects has been widely documented (Brook et al., 1992; Heitholt, 1999; Jones et al., 1996). Compensation in cotton is best facilitated if growing conditions are optimal and other pests are managed appropriately, especially if the injury being compensated for occurs during the initial period of flowering (Musser et al., 2009; Willrich et al., 2004). In the present studies initiated during the first week of flowering, treated and nontreated plots were oversprayed after the last sample to remove tarnished plant bugs and other pests capable of causing injury and yield loss for the remaining two to three weeks of flowering. Gore et al. (2009) demonstrated the greatest yield losses associated with tarnished plant bug during the flowering period occurred during the third through sixth week of flowering. Similarly, Musser et al. (2009) demonstrated that yield losses in cotton by tarnished plant bug were more strongly associated with infestations during late flowering than the early flowering period. The single timing of harvest aid applications in these studies did not make it possible to account for any delays in plant maturity due to earlier tarnished plant bug infestations.

Results from 3 yr of testing demonstrated sulfoxaflor applied at ≥ 50 g ai/ha reduced tarnished plant bugs and protected cotton yield similar to the commercial standard acephate. Mean numbers of tarnished plant bug were reduced to levels at or below the action threshold with one and two applications of sulfoxaflor for moderate and high infestations, respectively. Sulfoxaflor applied at 50 g ai/ha demonstrated less consistent initial control compared with acephate, whereas 75 g ai/ha demonstrated more consistent residual control compared with acephate when differences were evident. As with most insecticides, the performance of sulfoxaflor in cotton will be dependent upon population levels of tarnished plant bug and duration of infestation. Multiple applications of sulfoxaflor may be required to manage an initial infestation, and the interval between applications might vary in cotton based upon dynamics of local tarnished plant bug populations. Currently recommended action thresholds and scouting techniques should still be utilized in management programs incorporating sulfoxaflor applications. The new mode of action and efficacy provided by sulfoxaflor will have an excellent fit in cotton Integrated Pest Management and can be used in rotation with other insecticides to improve programs that manage tarnished plant bug.

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