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ARTHROPOD MANAGEMENT & APPLIED ECOLOGY

Influence of *Lygus*-Traited Cotton Technology on Performance of Commonly Used Insecticides for Tarnished Plant Bug Management Prior to Bloom

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ABSTRACT

The tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), is the most economically damaging insect pest of cotton, *Gossypium hirsutum* L., production in the Mid-South region of the U.S. In Mississippi alone, tarnished plant bug caused approximately $270 in losses per hectare and accounted for nearly 70,000 lost bales per annum during 2021 and 2022. Insecticide use is the foundation of integrated pest management strategies for control of tarnished plant bug in the Mid-South. Prior to bloom, acephate, imidacloprid, and sulfoxaflor are commonly used insecticides for tarnished plant bug management. Research was conducted in the Mississippi Delta region with commonly used insecticides prior to bloom to evaluate their performance in non-ThryvOn^{TM} and ThryvOn cotton varieties. Research suggests that imidacloprid has a limited fit in non-ThryvOn cotton production. However, these data indicate that the additional mode of action provided by ThryvOn cotton could extend the longevity of imidacloprid, along with other commonly used insecticides in Mid-South cotton production.

Tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), has been the number one economic insect pest in cotton, *Gossypium hirsutum* L., for more than a decade in the mid-southern states of Mississippi, Louisiana, Arkansas, Tennessee, and Missouri (Cook and Threet, 2023; Williams, 2007). Boll weevil, *Anthonomus grandis grandis* Boheman, eradication and the widespread adoption of Bt, *Bacillus thuringiensis* Berliner, cotton reduced the need for foliar sprays and resulted in the tarnished plant bug becoming a major pest of cotton (Musser et al., 2007). Tarnished plant bug can damage cotton from plant emergence until boll maturation, five nodes above white flower plus 350 60 °F growing degree days (Layton, 1995; Russell, 1999). Although feeding can occur at any point during the growing season, tarnished plant bug prefers to feed on "young" squares (flower buds) that are less than 3.22 mm in diameter (Layton, 1995; Tugwell et al., 1976). A single tarnished plant bug adult can feed on 0.6 to 2.1 squares per day (Gutierrez et al., 1977). Feeding can cause abscission of the structure resulting in direct yield losses. Prior to bloom, plants are most vulnerable to yield losses during late squaring (Tugwell et al., 1976). With feeding preferences of small squares, most tarnished plant bug damage in cotton occurs from square emergence through the first few weeks of bloom (Black, 1973; Layton, 2000).

Pre-bloom tarnished plant bug insecticide applications often are used as standalone (non-tank-mixed), cost-effective control options. Eleven products across seven classes of insecticides are currently recommended by Mississippi State University Extension Insect Control Guide for Agronomic Crops. Chitin synthesis inhibitors, neonicotinoids, sulfoximines, and sometimes organophosphates are the four classes currently recommended before bloom (Crow et al., 2023). Insecticide-resistant tarnished plant bugs were first documented in the Mississippi Delta in the 1970s (Cleveland and Furr, 1979). Insecticide applications targeting boll weevil, and pests now controlled by Bt, bollworm, *Helicoverpa zea* (Boddie), and tobacco budworm, *Heliothis virescens* (Fabricius), might have caused selection pressure in tarnished plant bug (Snodgrass and Scott, 2003). Currently, widespread insecticide resistance has been documented to pyrethroids, carbamates, neonicotinoids, and organophosphates (Du et al., 2024; Pankey, 1996; Snodgrass, 1996; Snodgrass

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and Gore, 2007; Snodgrass and Scott, 1988, 2000; Snodgrass et al., 2009).

Acephate is an organophosphate with potential to provide up to seven days of tarnished plant bug efficacy (Huoni et al., 2022; Smith et al., 2023; Steckel et al., 2018). However, resistance has led to an increase in usage rates and therefore limits growers to fewer applications per growing season (Amvac, 2023; Snodgrass and Scott, 2000; Snodgrass et al., 2009). Imidacloprid is a neonicotinoid that has been used historically in cotton before bloom as a cost-effective product (Kagabu, 2011; Snodgrass and Scott, 2000), but a decline in tarnished plant bug efficacy has been observed in recent years (Blalock et al., 2023; Huoni et al., 2022; Smith et al., 2023; Steckel et al., 2018; Taillon et al., 2019). Sulfoxaflor is a sulfoximine compound (EPA, 2023). Sulfoxaflor exhibits good activity against tarnished plant bug and is recommended throughout the growing season for tarnished plant bug control (Blalock et al., 2023; Crow et al., 2023; Smith et al., 2023; Taillon et al., 2019).

Insecticide resistance has increased the difficulty of managing tarnished plant bugs. Various cotton and landscape management practices can reduce reliance on insecticides for tarnished plant bug control. Previous research has shown that planting early, using early maturing cultivars (Adams et al., 2013), optimizing nitrogen use rates (Samples et al., 2019), delaying irrigation until after bloom (Wood et al., 2019), and managing winter annuals (Snodgrass et al., 1984, 2005, 2006) can reduce tarnished plant bug populations. In general, these management practices have the potential to reduce pre-bloom infestation levels. When these practices are coupled with sound integrated pest-management strategies of rotating chemistries, following action thresholds, and using best insecticide tank mixes, growers have a chance to reduce the total number of insecticide applications for adequate control in a growing season (Adams et al., 2013; Samples et al., 2019; Snodgrass et al., 1984, 2005, 2006; Wood et al., 2019).

Traditionally, tarnished plant bug management has been and continues to be reliant on chemical control (Snodgrass and Scott, 2000). On average, Mississippi cotton production required five insecticide applications targeting tarnished plant bug in 2022; reiterating that integrated pest management is critical for effective management (Cook and Threet, 2023). In 2023, Bayer Crop Science commercialized ThryvOn^{TM} cotton technology (Bayer Crop Science, St. Louis, MO). This technology introduced cultivars with a new *Bacillus thuringiensis* strain with *Lygus* spp. activity through the expression of the Cry51Aa2.834_16 protein. In cotton expressing this trait, fewer insecticide applications have been required to manage tarnished plant bug (Corbin et al., 2020; Graham and Stewart, 2018). Despite this trait having some activity against tarnished plant bug, foliar insecticide applications remain the foundation of their management. The objective of this study was to determine the efficacy of pre-bloom insecticides on migrating tarnished plant bug in both non-ThryvOn and ThryvOn cotton.

MATERIALS AND METHODS

Field Experiments Details. Field experiments were conducted at multiple locations throughout the Mississippi Delta to evaluate management of tarnished plant bug in cotton prior to bloom. Large-plot experiments were conducted in Glendora and Stoneville, MS, during 2022 and 2023, whereas small-plot experiments were only conducted in Stoneville during 2022 and 2023. Large-plot experiments were planted on 28 April in Stoneville and 10 May in Glendora in 2022, and on 22 May in Stoneville and 24 May in Glendora in 2023. Large plots were planted using Deltapine 2055 B3XF (Bollgard 3, non-ThryvOn, XtendFlex; Bayer Crop Science, St. Louis, MO). Small-plot studies were planted on 10 May 2022 and 16 May 2023 using Deltapine 2055 B3XF and Deltapine 2131 B3TXF (Bollgard 3, ThryvOn, XtendFlex; Bayer Crop Science, St. Louis, MO). ThryvOn was not evaluated in large-plot experiments because it was not fully commercialized when the experiments were initiated. All plots were planted at a seed population of 113,000 ha^{-1} at 2 cm in depth. All crop management practices were conducted based on the recommendations of the Mississippi State University Extension Service.

The large-plot trial was arranged as a randomized complete block design with four replications, two replications at each location. Plots were eight rows wide on 102-cm centers in Stoneville and on 97-cm centers in Glendora running approximately the length of the field. Each field was split down the middle using a 7.3-m fallow alley to separate replicates. Starting at the first week of squaring, treatments were sprayed weekly until the first week of bloom. Three pre-bloom insecticides were compared to an untreated control. Insecticide treatments included acephate (Orthene 90S, Amvac Chemical

Corporation, Newport Beach, CA) at 0.84 kg ai ha^{-1}, imidacloprid (Wrangler 4F, Loveland Products, Loveland, CO) at 0.07 kg ai ha^{-1}, sulfoxaflor (Transform 50WG, Corteva Agriscience, Wilmington, DE) at 0.053 kg ai ha^{-1}, and an untreated control.

Small-plot experiments were implemented as a randomized complete block design with a factorial arrangement of treatments with four replications. Plots were four rows wide on 102-cm centers by 12.2 m in length and were separated by 3-m fallow alleys. Factor A consisted of two cotton technologies: ThryvOn and non-ThryvOn cotton. Factor B consisted of three insecticide treatments: acephate at 0.84 kg ai ha^{-1}, imidacloprid at 0.07 kg ai ha^{-1}, and sulfoxaflor at 0.053 kg ai ha^{-1} compared to an untreated control. Plots were sprayed weekly beginning at the first week of squaring until the first week of bloom. After the second week of bloom, the entire test area was sprayed at threshold to manage late-season tarnished plant bugs until physiological maturity.

A Mudmaster^{TM}, 4WD Multi-Purpose Sprayer, (Bowman Manufacturing, Newport, AR) equipped with a compressed air high-clearance mounted multi-boom spray system calibrated to deliver 93.5 L ha^{-1} at 480 kPa through TX-6 ConeJet Visiflow Hollow Cone nozzles (TeeJet Technologies, Glendale, IL) was used for all insecticide applications.

Insecticide Efficacy. Tarnished plant bug densities, and damage ratings were determined weekly starting at the second week of squaring and continued through the first week of bloom. Samples were taken in four random locations per large plot in the center four rows and one random location in the center two rows of small plots, with plot ends being avoided. Square retention was evaluated by counting the number of missing fruit on the three uppermost nodes. Twenty-five fruiting sites were evaluated at each sample location within each plot. Fruit (squares) were considered missing if they were necrotic, flared bracts, or abscised. At 50% white flower (an average of one white flower on every other plant) and 100% white flower (when all plants averaged one white flower), whole-plant mapping was conducted on 100 total plants in large plots and 25 plants in small plots. Four sets of 25 plants from random locations on the centermost four rows per large plot and one set of 25 plants in the centermost two rows for small plots were mapped. Tarnished plant bug densities were evaluated by taking four sets of 25 sweeps using a 38.1-cm diameter sweep net from rows two or seven of each large plot. To avoid damaging plants and possibly influencing square retention, tarnished plant bug sweep net sampling was not conducted in the replicated small-plot trial. Instead, four sets of 25 sweeps were taken from an adjacent (directly behind) study that contained blocks of unsprayed ThryvOn and non-ThryvOn cotton. Cotton yield was measured only from the small-plot trials. Yield was determined by harvesting the center two rows with a modified cotton picker. Lint turnout was estimated to be 40%.

Data Analysis. All data were analyzed using a generalized linear mixed model analysis of variance (Proc Glimmix, SAS version 9.4; SAS institute; Cary, NC). A separate analysis was conducted for the large-plot and small-plot experiments. In the large-plot, trial year, insecticide, and sample date were considered fixed effects for the square retention and sweep net count analysis. The random effect was replication. For the small-plot square retention study, cotton technology, insecticide, and sample date were considered fixed effects. Year and replication nested within year were considered random effects. Fixed effects in small-plot yield analysis were cotton technology and insecticide. Year and replication nested within with year were random effects for yield. Degrees of freedom were calculated using the Kenwood-Roger method. Means were calculated using LSMEANS and separated according to Fisher's Protected LSD at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Large-Plot Tarnished Plant Bug Sampling. Tarnished plant bug infestations can vary from year to year due to various environmental conditions. During 2022, tarnished plant bug densities were much lower than that observed during 2023. An interaction between year and sample date was observed for tarnished plant bug densities (Table 1). Tarnished plant bug densities remained below the current action threshold during 2022, and no differences were observed among sample dates (Fig. 1). In contrast, tarnished plant bug numbers were below the action threshold during the second week of square during 2023 but increased rapidly by the third week of squaring and peaked at 50% white flower (Fig. 1).

Because densities in all plots remained below threshold in 2022, no insecticide treatment was warranted. In 2023, none of the pre-bloom insecticide options alone achieved effective control throughout squaring and early bloom (Fig. 1). These data dem-

Table 1. Type III tests of fixed effects for large-plot TPB sweep net data analysis

Effect	Num. df	Den. df	*F*	*P*
Year	**1**	**445.9**	**197.29**	**<0.001**
Insecticide Performance	**3**	**445**	**2.15**	**0.093**
Year * Insecticide Performance	**3**	**445**	**0.60**	**0.618**
Sample Date	**3**	**445.7**	**20.19**	**<0.001**
Year * Sample Date	**3**	**445.7**	**14.52**	**<0.001**
Insecticide Performance * Sample Date	**9**	**445**	**1.50**	**0.146**
Year * Insecticide Performance * Sample Date	**9**	**445**	**0.62**	**0.784**

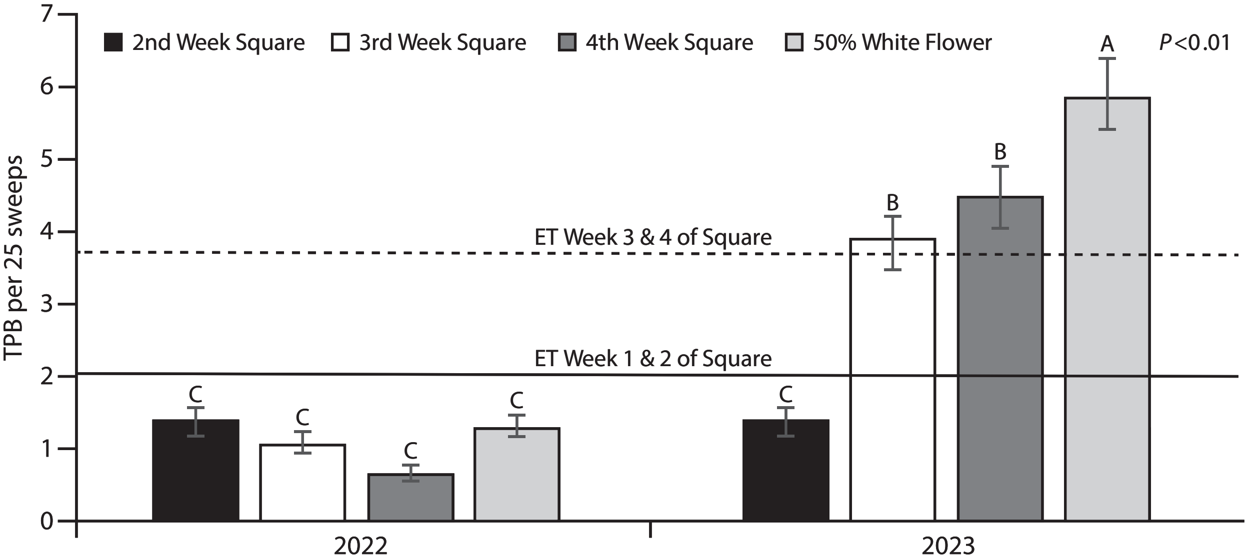

Figure 1. Impact of sample date and site year on tarnished plant bug densities, means + SEM, (adults plus nymphs per 25 sweeps) for large plots. Horizontal lines parallel to x-axis indicate tarnished plant bug density economic threshold. Bars with a common letter are not significantly different (FPLSD, *p* = 0.05, Error bars).

onstrated that large infestations of adult tarnished plant bug can be difficult to control, and applications of single products at intervals less than seven days might be necessary. Previous research conducted in the Mississippi Delta during bloom also suggested that a single application of imidacloprid, sulfoxaflor, or acephate could not achieve satisfactory tarnished plant bug control six days after treatment (Lytle et al., 2023). These data indicated that there are occurrences where chemical control is warranted multiple times per week to maintain tarnished plant bug densities below the action threshold during heavy pressure situations. High, sustained levels of tarnished plant bugs are most likely why insecticide treatments did not separate from the untreated control.

Large-Plot Square Retention. There was a significant three-way interaction between year, insecticide, and sample date (Table 2) for square retention (Fig. 2). During 2022 all treatments maintained cotton at or above 80% square retention on all sample dates (Fig. 2). This suggests that no insecticide treatments were needed for pre-bloom management and corresponds with tarnished plant bug densities observed. During 2023, square retention in the untreated plots and those treated with imidacloprid dropped below 80% beginning the third week of squaring. During the third week of squaring, square retention in plots treated with acephate or sulfoxaflor was greater than that in plots treated with imidacloprid and the untreated plots (Fig. 2). During the fourth week of squaring, square retention in the untreated control dropped to 60%, whereas square retention in all insecticide-treated plots was similar and remained above 80% (Fig. 2). At 50 and 100% white flower, none of the treatments maintained whole-plant square retention above 80%. Cotton treated with acephate or sulfoxaflor had higher whole-plant square retention at these sample dates compared to cotton treated with imidacloprid and untreated cotton.

Table 2. Type III tests of fixed effects for large-plot square retention data analysis

Effect	Num. df	Den. df	*F*	*P*
Year	**1**	**567.3**	**502.79**	**<0.001**
Insecticide Performance	**3**	**565**	**132.60**	**<0.001**
Year * Insecticide Performance	**3**	**565**	**32.23**	**<0.001**
Sample Date	**4**	**566.4**	**99.47**	**<0.001**
Year * Sample Date	**4**	**566.4**	**90.67**	**<0.001**
Insecticide Performance * Sample Date	**12**	**565**	**9.38**	**<0.001**
Year * Insecticide Performance * Sample Date	**12**	**565**	**5.80**	**<0.001**

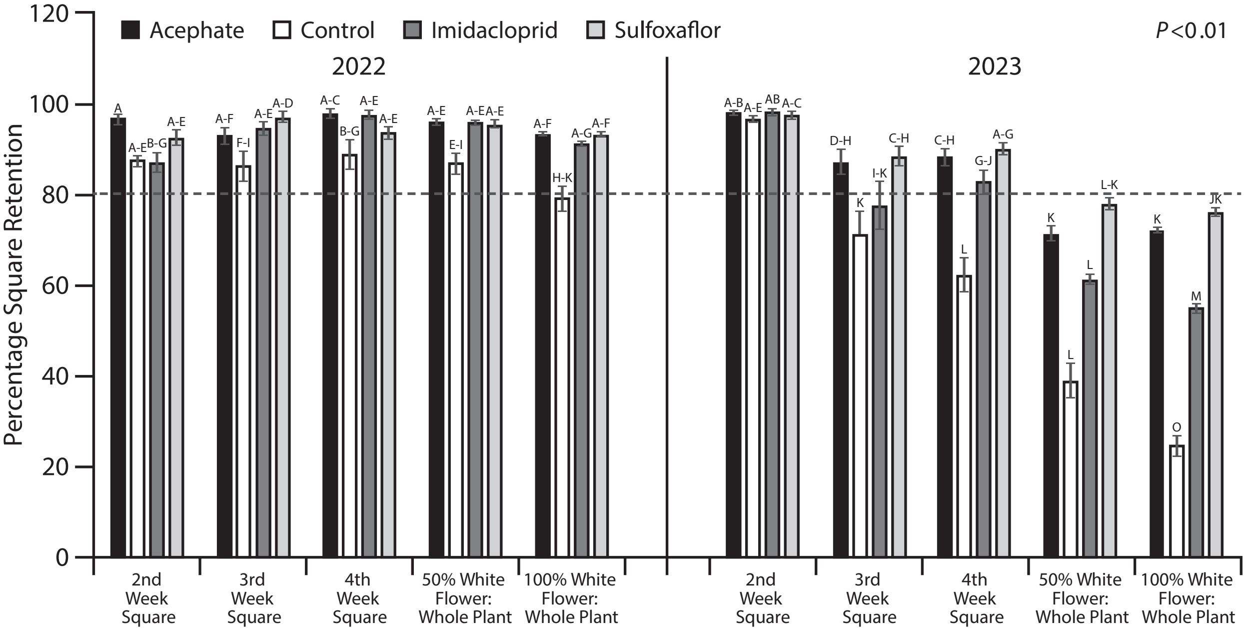

Figure 2. Impact of sample date, insecticide performance, and location on square retention in top three nodes of cotton plants during 2nd, 3rd, and 4th week of squaring. Whole-plant square retention was determined at 50 and 100% white flower for large plots. The figure presents 2022 and 2023 on separate sides of figure, but data were analyzed together. Horizontal lines parallel to x-axis indicate the square retention economic threshold. Bars with a common letter are not significantly different (FPLSD, *p* = 0.05).

Compared to acephate and sulfoxaflor, imidacloprid resulted in lower square retention during the third and fourth weeks of squaring, as well as whole-plant square retention at 50 and 100% white flower. With an increase in neonicotinoid resistance (Du et al., 2024), the decline in imidacloprid efficacy is consistent with other studies in the Mid-South region (Blalock et al., 2023; Huoni et al., 2022; Smith et al., 2023; Steckel et al., 2018; Taillon et al., 2019).

Overall, large-plot data indicate the importance of insecticide use, particularly acephate and sulfoxaflor, to Mid-South cotton producers for preserving fruit retention in pre-bloom cotton. These data indicate that when large, adult tarnished plant bug infestations occur, individual insecticide products applied at seven-day intervals provided less than adequate control. Therefore, when square retention falls below 80% or sweep net thresholds are exceeded under large migrations of plant bug adults, cotton should continue to be scouted twice a week and insecticide applications might need to occur every three to four days instead of once a week (Gore et al., 2010). Large infestations might warrant insecticide applications in shortened intervals, or tank-mixed insecticide applications might also be justified. Ideally, mixtures of products with both adult and nymph activity would best mitigate migrating adult tarnished plant bug. However, previous research has demonstrated the value of novaluron, an insect growth regulator with lethal effects on nymphs and reduced reproductive capacity of adults (Catchot, 2020), (Diamond 0.83EC, ADAMA USA, Raleigh, NC) as a tank-mix component. The best results have been obtained when novaluron was applied week three or four of squaring, or at peak adult migration (Gore et al., 2010; Graham, 2016; Owen et al., 2011).

Small-Plot Square Retention. Tarnished plant bug densities in adjacent blocks were monitored for the small-plot study to observe migration over time, but densities were not analyzed. Densities among each technology were close in non-ThryvOn and ThryvOn cotton until the fourth week of squaring. At this time, densities in non-ThryvOn cotton averaged greater than one tarnished plant bug more per 25 sweeps than in ThryvOn cotton (Fig. 3). There was an interaction between cotton technology, insecticide treatment, and sample date for square retention in the small-plot study (Table 3). In non-ThryvOn cotton, no differences in square retention were observed among treatments until the fourth week of squaring (Fig. 4). During the fourth week of squaring, all cotton treated with insecticides had higher square retention than the untreated control in non-ThryvOn. At 50% white flower, cotton treated with acephate or sulfoxaflor had higher whole-plant square retention than cotton treated with imidacloprid, which had greater square retention than the untreated control (Fig. 4). At 100% white flower, cotton sprayed with imidacloprid had greater whole-plant square retention than the untreated control, whereas cotton treated with acephate or transform had the highest overall square retention. This is similar to the 2023 large-plot study in which acephate and transform resulted in higher overall square retention at 50 and 100% white flower compared to imidacloprid and the untreated control. These data are also consistent

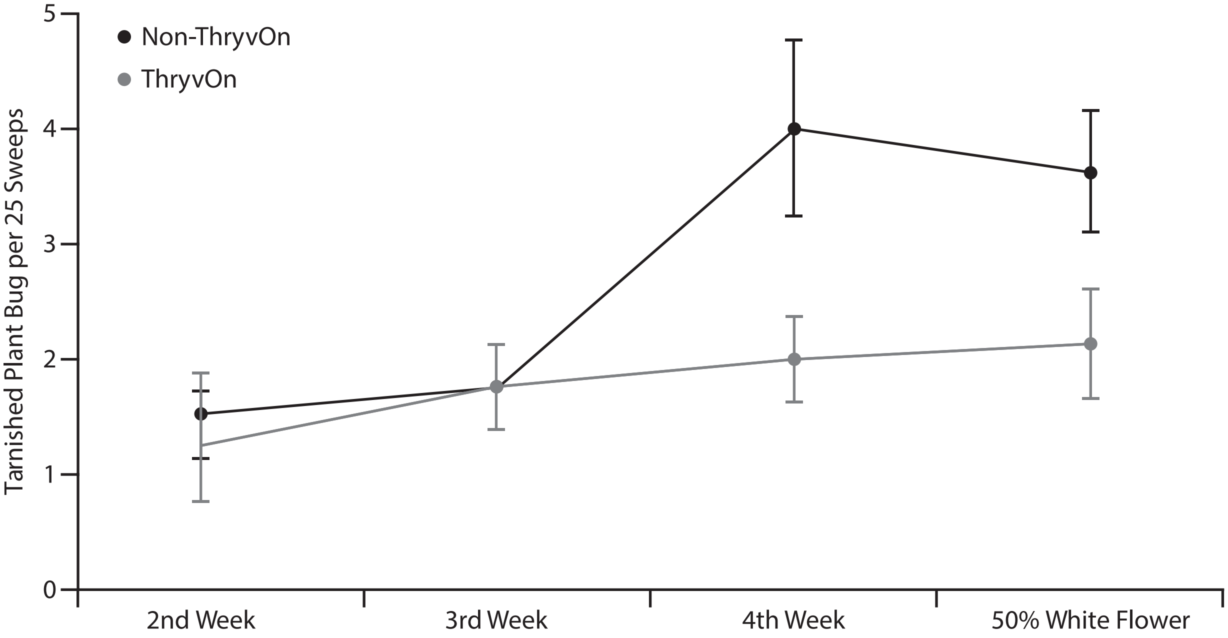

Figure 3. Tarnished plant bug densities, means + SEM, (adults plus nymphs per 25 sweeps) in cotton adjacent to small-plot trials.

Table 3. Type III tests of fixed effects for small-plot square retention data analysis

Effect	Num. df	Den. df	*F*	*P*
Insecticide Performance	**3**	**273**	**27.23**	**<0.001**
Sample Date	**4**	**273**	**56.20**	**<0.001**
Sample Date * Insecticide Performance	**12**	**273**	**4.89**	**<0.001**
Cotton Technology	**1**	**273**	**77.90**	**<0.001**
Cotton Technology * Insecticide Performance	**3**	**273**	**4.97**	**0.002**
Cotton Technology * Sample Date	**4**	**273**	**8.32**	**<0.001**
Cotton Technology * Sample Date * Insecticide Performance	**12**	**273**	**1.89**	**0.0351**

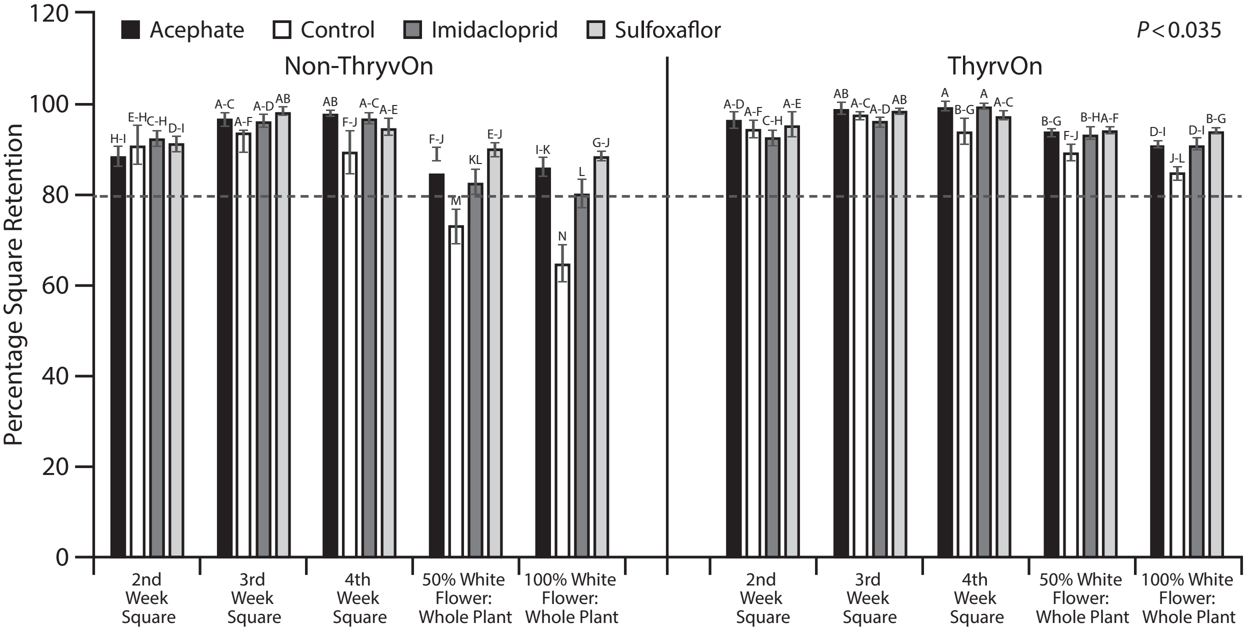

Figure 4. Impact of sample date, insecticide performance, and cotton technology on square retention, means + SEM, in top three nodes of cotton plants during 2nd, 3rd, and 4th week of squaring. Whole-plant square retention, means + SEM, was determined at 50 and 100% white flower for small plots. Non-ThryvOn and ThryvOn are presented on separate sides of the figure, but data were analyzed together. Horizontal lines parallel to x-axis indicate the square retention economic threshold. Bars with a common letter are not significantly different (FPLSD, *p* = 0.05).

with other studies from the Mid-South region that illustrate a decline in imidacloprid efficacy (Blalock et al., 2023; Huoni et al., 2022; Smith et al., 2023; Steckel et al., 2018; Taillon et al., 2019).

In ThryvOn cotton, all cotton treated with insecticides had similar square retention compared to untreated cotton until 100% white flower (Fig. 4). Untreated ThryvOn cotton had 6.5 and 16% higher whole-plant square retention than non-ThryvOn cotton treated with imidacloprid and untreated non-ThryvOn cotton at 50% white flower, respectively. Untreated ThryvOn cotton had similar whole-plant square retention compared to non-ThryvOn cotton treated with acephate or sulfoxaflor at this sample date. At 100% white flower, untreated ThryvOn cotton had greater whole-plant square retention than unsprayed non-ThryvOn cotton. At this sample date, unsprayed ThryvOn cotton had similar whole-plant square retention compared to all non-ThryvOn cotton treated with insecticides (Fig. 4).

Imidacloprid performed better when applied to ThryvOn cotton compared to non-ThryvOn cotton based on whole-plant square retention at 50 and 100% white flower. ThryvOn cotton sprayed with imidacloprid had almost 11% higher whole-plant square retention at 50 and 100% white flower compared to non-ThryvOn cotton sprayed with imidacloprid at the same sample dates (Fig. 4). No differences were observed between ThryvOn and non-ThryvOn cotton that were treated with acephate or sulfoxaflor, across the same sample dates. At 100% white flower, untreated ThryvOn cotton averaged approximately 20% higher whole-plant square retention compared to untreated non-ThryvOn cotton (Fig. 4). In the Mid-South, differences in seasonal pre-bloom square retention of 6.5 to 14% between untreated ThryvOn cotton to untreated non-ThryvOn cotton have been observed (Corbin et al., 2020; Graham and Stewart, 2018; Whitfield, 2023).

Similar to the large-plot 2023 data, these data suggest that insecticide selection in non-ThryvOn cotton is important. The non-ThryvOn data implies that rigorous scouting is paramount and conservative control methods can be warranted prior to bloom. However, these data also indicate that ThryvOn cotton has the potential to require fewer insecticide applications than non-ThryvOn cotton, which could alleviate some reliance on current insecticides used for chemical control. Scouting should still occur twice a week to monitor tarnished plant bug migration because sweep net numbers were comparable between technologies (Fig. 3) and ThryvOn technology has little activity against adults. However, when thresholds determine insecticide applications are needed, these data indicate there were no differences between insecticide treatments observed through square retention in ThryvOn cotton. Also, reductions in the number of insecticide applications for tarnished plant bug needed in ThryvOn cotton have been observed for the pre-bloom period and the entire season when compared to non-ThryvOn cotton (Corbin et al., 2020; Graham and Stewart, 2018). This reduction in applications could reduce insecticide inputs, and potentially allow for a wider application window when insecticide applications are needed. This would allow growers the opportunity to make applications when environmental conditions are optimal. Unlike non-ThryvOn cotton, ThryvOn technology has the potential for single insecticide products to perform over longer periods. This would help to reduce input costs for growers.

Small-Plot Yield. There was an interaction between cotton technology and insecticide (Table 4) for cotton yield (Fig. 5). ThryvOn cotton treated with sulfoxaflor had the highest yield compared to all other insecticide and cotton technology combinations, except ThryvOn sprayed with imidacloprid (Fig. 5). ThryvOn cotton treated with imidacloprid yielded higher than non-ThryvOn cotton treated with imidacloprid and untreated non-ThryvOn cotton. Untreated ThryvOn cotton yielded 235 kg ha^{-1} more than unsprayed non-ThryvOn cotton. Yields of untreated ThryvOn cotton were similar to that of non-ThryvOn cotton sprayed with acephate, sulfoxaflor, or imidacloprid, and ThryvOn cotton treated with acephate (Fig. 5).

Based on cotton market prices from October and November of 2023, cotton was valued at $1.92 and 1.69 per kg, respectively (USDA AMS, 2023a, b). With either of these prices, and growing conditions similar to the ones during 2022 and 2023, the increased yields from ThryvOn technology could offset the $60 to 100 ha^{-1} differences in seed costs (technology fee is an estimate of the price increase of ThryvOn cotton compared to three gene cotton cultivars). In plots that received no insecticides prior to bloom, ThryvOn cotton averaged 235 kg more lint ha^{-1} than non-ThryvOn (Fig. 4). Mid-South cotton producers could see a $351.20 ha^{-1} economic return using ThryvOn technology with October prices

Table 4. Type III tests of fixed effects for small-plot yield analysis

Effect	Num. df	Den. df	*F*	*P*
Cotton Technology	**1**	**55**	**10.69**	**0.0019**
Insecticide Performance	**3**	**55**	**4.23**	**0.0093**
Cotton Technology * Insecticide Performance	**3**	**55**	**3.33**	**0.0260**

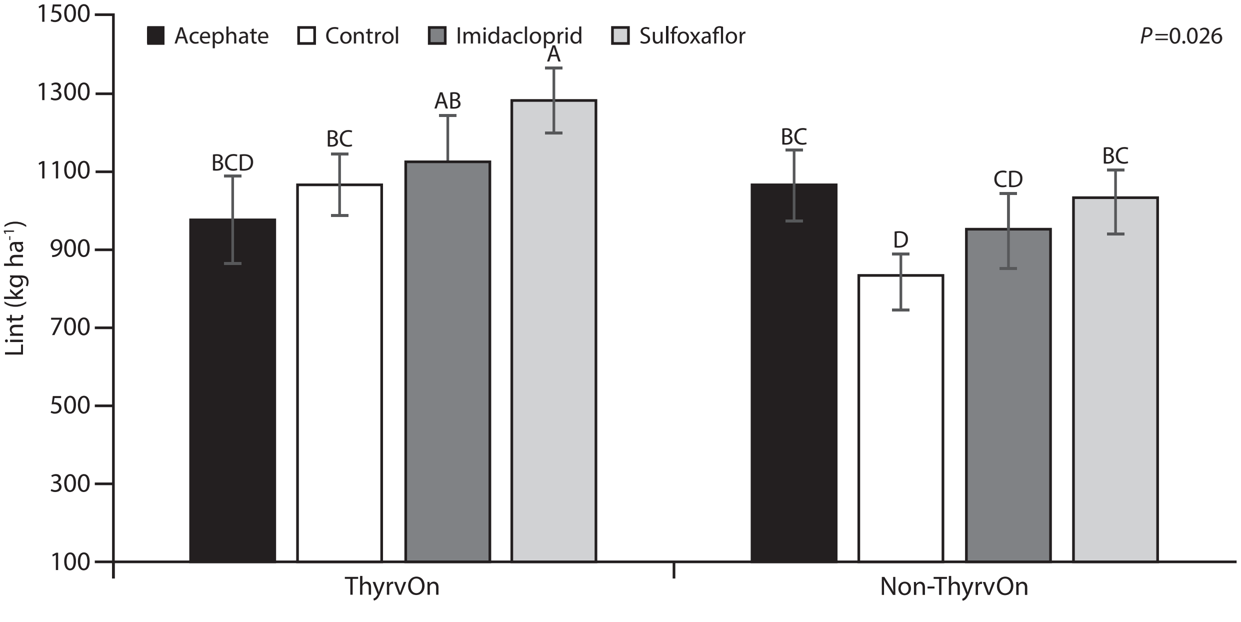

Figure 5. Effect of insecticide performance and cotton technology on cotton lint yield, means + SEM, (kg/ha). Bars with a common letter are not significantly different (FPLSD, $p = 0.05$).

and \$297.15 ha^{-1} economic return with November prices, without applying any pre-bloom insecticides [(235kg×respective cotton price kg^{-1}) - \$100 ha^{-1} tech fee estimate]. These differences could vary with different ThryvOn and non-ThryvOn varieties.

This technology can offer the potential to eliminate one or two pre-bloom insecticide applications, delay insecticide usage entirely when plant bug infestations are low prior to bloom or delay the time interval between insecticide applications. This all could be achieved through the extended duration of efficacy that ThryvOn technology offers in conjunction with currently used insecticides (Corbin et al., 2020; Graham and Stewart, 2018; Whitfield, 2023). Producers in the Mid-South also have the potential to be more flexible with insecticide options when managing tarnished plant bugs in ThryvOn production systems. In some circumstances, ThryvOn might not require tank mixes of insecticides for plant bug management. Prior to first flower, single product applications would be more cost effective than tank-mixed insecticide applications, or single chemistry applications at shortened intervals that might be necessary in non-ThryvOn cotton when large, tarnished plant bug infestations occur. Overall, higher yield potential (could be due to cultivar instead of trait), fewer potential insecticide applications, and flexibility in choosing cost-effective insecticides during the pre-bloom period are attributes of ThryvOn cotton that could lead to positive economic benefits.

These data suggest that imidacloprid has a limited fit in tarnished plant bug management in Mid-South non-ThryvOn cotton production, while reiterating the importance of acephate and sulfoxaflor (Blalock et al., 2023; Huoni et al., 2022; Smith et al., 2023; Steckel et al., 2018; Taillon et al., 2019). This study reiterates that tarnished plant bug management can vary from year to year and is largely dependent on the environmental conditions that favor tarnished plant bug development, and as a result, dictate pressure that stems from migratory events. Also, this study suggests that large, tarnished plant bug infestations in non-ThryvOn cotton can warrant insecticide applications sooner than every six to seven days. When these applications are made, insecticide tank mixes might be warranted due to evidence that no single mode of action appears to control tarnished plant bug for this duration in non-ThryvOn cotton. In ThryvOn cotton, as indicated by square retention and yield data, imidacloprid can remain a viable option for tarnished plant bug management during the pre-flowering period. The increase in imidacloprid efficacy observed in ThryvOn cotton during this study might warrant further research regarding other insecticidal options including pyrethroids and organophosphates, which have become less efficacious over time due to resistance development. Under moderate-to-heavy tarnished plant bug pressure, ThryvOn technology can have the potential to use a single mode of action to target tarnished plant bug, while having the potential to extend the duration of control up to six or seven days. In ThryvOn cotton, these properties could eliminate the need for tank-mixed insecticides for pre-bloom tarnished plant bug control (except for novaluron plus an adulticide at peak adult migration), lower the number of tarnished plant bug applications pre-bloom, and decrease the dependence on chemical control for tarnished plant bug management, especially when coupled with sound cultural integrated pest-management strategies. Decreases in the need for chemical control can also extend the longevity of efficacy for currently used insecticides by lowering selection pressure for insecticide resistance in Mississippi Delta tarnished plant bug populations.

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