The *Journal of Cotton Science 30:29–38* (*2026*)
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# ARTHROPOD MANAGEMENT & APPLIED ECOLOGY

## At-Planting Insecticide Efficacy for the Control of Tobacco Thrips (*Frankliniella fusca* Hinds) in the Mid-Southern U.S.

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### ABSTRACT

**Thrips, especially tobacco thrips, are the most prevalent seedling pest of cotton in the Mid-Southern U.S. Commonly used methods for controlling tobacco thrips in cotton include insecticidal seed treatments, at-planting in-furrow insecticide applications, and supplemental foliar insecticide applications. However, field-evolved resistance has been documented to neonicotinoid insecticides, which are primarily applied as seed treatments. Pyrethroid insecticides also provide poor control of tobacco thrips across much of the Mid-Southern U.S., due to widespread resistance. Recent field and lab experiments have shown a decrease in the efficacy of organophosphate insecticides, primarily acephate, which typically are applied as a foliar treatment to manage tobacco thrips. To evaluate the current performance of at-planting insecticide treatments, studies were conducted at 13 locations across the Mid-Southern U.S. from 2014 to 2023. Statistically significant declines in percent control over time were observed for select insecticide treatments at specific growth stages throughout the duration of the study. Additionally, significant increases in temporal trends of qualitative injury ratings were observed throughout the course of the study for multiple insecticide treatments.**

Thrips are a common early-season pest of cotton encountered across the U.S. (Cook et al., 2011). Estimates from 2024 indicated that 89.8% of all cotton acres in the U.S. were infested with thrips (Cook et al., 2025). Across these acres, the five most common species of thrips are: tobacco thrips, *Frankliniella fusca* (Hinds); flower thrips, *Frankliniella tritici* (Fitch); western flower thrips, *Frankliniella occidentalis* (Pergande); soybean thrips, *Neohydatothrips variabilis* (Beach); and onion thrips, *Thrips tabaci* (Lindeman) (Albeldano et al., 2008; Cook et al., 2003, 2011; Leigh et al., 1996; Reay-Jones et al., 2017; Stewart et al., 2013). Tobacco thrips are the most prevalent of these species occurring in Mississippi, comprising more than 90% of most collections from cotton seedlings (Cook et al., 2003, 2011; Layton and Reed, 2002; Stewart et al., 2013). Tobacco thrips are also the most commonly observed species in Tennessee cotton (Brown et al., 2023). Reay-Jones et al. (2017) found that tobacco thrips comprised 86.7% of all thrips identified to species on seedlings in eight out of nine trials in data from Alabama, Georgia, North Carolina, South Carolina, and Virginia. Wang et al. (2018) observed similar results in that tobacco thrips accounted for 76.8 to 94.3% of adults and 81.6 to 98.0% of immatures collected from locations in Alabama, Georgia, North Carolina, South Carolina, and Virginia.

Thrips injure cotton primarily during the seedling stage by feeding on the contents of the plant epidermal cells (Cook et al., 2011). This feeding causes death of the injured cells that can eventually result in twisting, distortion, malformation, and tearing of the injury site (Cook et al., 2011). Severe thrips infestations can kill the terminal buds or the entire

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seedling (Cook et al., 2011; Telford and Hopkins, 1957). Severe terminal bud damage may also result in what is referred to as "crazy cotton", where the loss of apical dominance results in excessive vegetative growth and branching (Cook et al., 2011).

The most common control methods for tobacco thrips in cotton have been insecticidal seed treatments, at-planting in-furrow insecticide applications, and supplemental foliar insecticide applications (Cook et al., 2011, 2022; Layton and Reed, 2002). Before the introduction of neonicotinoid seed treatments, aldicarb (Temik 15G, Bayer CropScience, Research Triangle Park, NC) was the standard for control of thrips in cotton (Cook et al., 2022). However, neonicotinoid seed treatments gained popularity quickly among growers due to their initial efficacy, ease of handling, and cheaper price. Between the removal of aldicarb from the market in 2010 and later reintroduction in 2016, neonicotinoid seed treatments combined with foliar applications became the recommended control practice (Cook et al., 2022; Huseth et al., 2016). The neonicotinoids used in these seed treatments are usually thiamethoxam (Cruiser, Syngenta U.S., Greensboro, NC) or imidacloprid (Gaucho 600, Bayer CropScience) (Cook et al., 2022; Huseth et al., 2016). Other at-planting insecticidal options for thrips control have included acephate (Orthene 97, Amvac Chemical Co., Newport Beach, CA) as a seed treatment or in-furrow spray, imidacloprid + thiodicarb as a seed treatment (Aeris, Bayer CropScience), and imidacloprid as an in-furrow spray (Admire Pro 4.6SC, Bayer CropScience).

North et al. (2017) studied neonicotinoid cotton seed treatment efficacy on thrips from 1996 to 2014 and noted that both imidacloprid and thiamethoxam seed treatments decreased thrips densities and increased cotton yields compared to a fungicide-only seed treatment. However, Huseth et al. (2016) found that 65 and 57% of tobacco thrips populations assayed from 86 different locations in 10 different cotton-producing states were classified as resistant to thiamethoxam and imidacloprid, respectively. Additionally, Darnell-Crumpton et al. (2018) found 57 and 16% of the tested tobacco thrips populations in Mississippi were resistant to thiamethoxam and imidacloprid, respectively. Darnell-Crumpton et al. (2018) noted that two different definitions of resistance were used between these two studies, offering some explanation of variation in findings.

The definition and method used by Darnell-Crumpton et al. (2018) consisted of quantitative dose-response bioassays to determine $LC_{50}$ values to each insecticide, with populations whose $LC_{50}$ was ≥ 10x the $LC_{50}$ of the susceptible population deemed resistant. Huseth et al. (2016) classified a population as resistant using a qualitative discriminating-dose bioassay with a 12% survival threshold deemed as having a high probability of conferring resistance. Additionally, Darnell-Crumpton et al. (2018) found no variation in resistance due to host plant, whereas Huseth et al. (2016) noted that thrips assay survival rates were greater when populations were collected from crop hosts, suggesting the potential for subpopulations of tobacco thrips that are predominantly found on certain hosts. Darnell-Crumpton et al. (2018) further concluded that neither paper had balanced data or paired comparisons in which insect populations from different host plants were collected from the same locations and evaluated under identical conditions, so the impact of host plant on resistance levels could have been confounded by other variables such as geographic location, population history, insecticide exposure, and environmental conditions, leading to contradictory conclusions. Regardless of the different methodologies, resistance often varies spatially and temporally, and these papers indicate that resistance is present in field populations, and that populations exhibit a greater degree of resistance to thiamethoxam relative to imidacloprid.

Further research by Huseth et al. (2017) found their neonicotinoid-resistant population of tobacco thrips had a five-fold greater resistance to thiamethoxam compared to imidacloprid. This study also observed that the average percent survival of immature thrips on cotton with an imidacloprid seed treatment was significantly lower than the percent survival of immature thrips on cotton with a thiamethoxam seed treatment, 21.8 (±4.9) and 82.4 (±4.6), respectively. Additionally, imidacloprid was found to cause higher oviposition disturbance than thiamethoxam, resulting in fewer eggs laid in imidacloprid-treated cotton (Huseth et al., 2017). However, it should be noted that Huseth et al. (2017) used a single field-collected colony from Weldon, NC, so the difference in resistance levels to imidacloprid and thiamethoxam might not be consistent or widespread throughout the cotton belt.

Due to thiamethoxam resistance in tobacco thrips, Mississippi, Arkansas, Louisiana, and Tennessee no longer recommend thiamethoxam-based seed treatments for the control of thrips (Bateman et al., 2025; Brown et al., 2023; Crow et al., 2025; Davis et al., 2024). For this reason, thiamethoxam-treated seed is no longer commercially available in the Mid-Southern U.S. (Cook et al., 2022). However, imidacloprid is still recommended for cotton seed treatments, and nearly all commercial cotton seed treatments include imidacloprid (Cook et al., 2022). With the current levels of neonicotinoid resistance, growers have adopted other means of thrips control. Because aldicarb has been reintroduced to the market under the trade name AgLogic 15GG (AgLogic Chemical, Chapel Hill, NC), it has become a recommended in-furrow control method (Cook et al., 2022).

Currently recommended foliar insecticides for use on thrips in the Mid-South include acephate (Orthene 97), dicrotophos (Bidrin 8E, Amvac Chemical Co.), dimethoate (Dimethoate 4EC, Drexel Chemical Co., Memphis, TN), methoxyfenozide and spinetoram (Intrepid Edge, Corteva AgriScience, Indianapolis, IN), and spinetoram (Radiant, Corteva AgriScience) (Bateman et al., 2025; Brown et al., 2023; Crow et al., 2025; Davis et al., 2024). Foliar-applied broad-spectrum organophosphate insecticides such as acephate, dimethoate, and dicrotophos, often applied for control of thrips in cotton, put producers at risk of flaring secondary arthropod pests of cotton such as cotton aphids and spider mites due to suppression of beneficial insect populations that provide natural population control of these pests (Brown et al., 2012; Toews et al., 2012). Across the Mid-Southern U.S., many growers used acephate as a seed treatment or in-furrow spray to help control thrips (Cook et al., 2022). However, recent field observations have suggested decreased efficacy of organophosphates, primarily acephate (Cook et al., 2022; Krob et al., 2022). Due to cotton's short susceptibility window to thrips injury, foliar insecticide applications in Tennessee and Arkansas are recommended only prior to the third true-leaf stage (Bateman et al., 2025; Brown et al., 2023), whereas Louisiana and Mississippi recommend treatment until the fourth true-leaf stage (Crow et al., 2025; Davis et al., 2024). With the development of resistance, changes in market offerings, and field observations from entomologists, a study was conducted to monitor at-planting insecticide efficacy for the control of thrips.

## MATERIALS AND METHODS

Studies were conducted from 2014 to 2023 at 13 locations across Arkansas, Louisiana, Mississippi, Tennessee, Missouri, and Texas to evaluate the performance of selected at-planting insecticide treatments against thrips in cotton. Locations used throughout this trial included: University of Arkansas Northeast Research and Extension Center, Keiser, AR; University of Arkansas Lon Mann Cotton Research Station, Marianna, AR; University of Arkansas Rohwer Research Station, Rohwer, AR; commercial field, Tillar, AR; LSU AgCenter Dean Lee Research & Extension Center, Alexandria, LA; LSU AgCenter Macon Ridge Research Station, Winnsboro, LA; LSU AgCenter Northeast Research Station, St. Joseph, LA; University of Missouri T.E. "Jake" Fisher Delta Research, Extension and Education Center, Portageville, MO; USDA-ARS Southern Insect Management Research Unit Farm, Leland, MS; Mississippi State University R. R. Foil Plant Science Research Center, Starkville, MS; Mississippi State University Delta Research and Extension Center, Stoneville, MS; University of Tennessee West Tennessee AgResearch and Education Center, Jackson, TN; and a commercial field in Snook, TX.

Each trial was arranged in a randomized complete block design with four replicate blocks. Variables including row spacing, plot sizes, and planting dates varied across locations; however, plot sizes were typically 4 rows wide and planting dates were targeted to coincide with local recommended cotton planting windows. Cotton varieties varied across years and locations due to seed availability, but a single variety was used for all treatments within each location. All seeds were treated with a fungicide seed treatment, which also varied throughout the years of the study.

Treatments in this study included: (1) imidacloprid in-furrow (IF) spray (Admire Pro 4.6SC) at a rate of 0.37 kg ai per hectare, (2) imidacloprid + thiodicarb seed treatment (IST) (Aeris, Bayer CropScience) at a rate of 0.75 mg ai per seed (0.375 mg ai imidacloprid + 0.375 mg ai thiodicarb), (3) aldicarb IF granule (AgLogic 15GG) at a rate of 0.67 kg ai per hectare, (4) imidacloprid IST (Gaucho 600) at a rate of 0.375 mg ai per seed, (5) imidacloprid IST (Gaucho 600) at 0.375 mg ai per seed + acephate IF spray (Orthene 97) at a rate of 1.12 kg ai per hectare, (6) acephate IF spray (Orthene 97) at a rate of 1.12 kg ai per hectare, (7) acephate IST (Orthene 97) at a rate of 181.44 g wt. product per cwt. + imidacloprid IST (Gaucho 600) at a rate of 0.375 mg ai per seed, and (8) acephate IST (Orthene 97) at a rate of 181.44 g wt. product per cwt. Treatment combinations were tested to determine the efficacy of including additional modes of action for the control of tobacco thrips. Liquid in-furrow insecticides (Admire Pro 4.6SC and Orthene 97) were applied using a planter-mounted in-furrow spray system calibrated to deliver 46.74 liters per hectare at 110.32 kPa through TeeJet (TeeJet Spray Solutions, Glendale Heights, IL) 2501 flat fan nozzles rotated at a 45-degree angle to maximize delivery into the furrow. The granular in-furrow insecticides (AgLogic) were applied using a planter-mounted granular chemical application system.

Plant injury was estimated at the 1-, 2-, 3-, and 4-leaf growth stages using a 0-5 scale, with a rating of 0 = no injury and 5 = severe injury or plant death. Thrips population densities were also determined by sampling 5 plants per plot at each rating timing using a similar version of the whole plant washing procedure developed by Burris et al. (1990). Briefly, plants were clipped above the soil line and placed into plastic self-sealing bags or glass jars. Plants were washed with ethanol over a series of sieves, allowing thrips to pass through and be collected separately from soil and other debris. Following the washing process, the thrips were transferred to filter paper via Büchner funnels to be quantified under a microscope. Thrips density assessments and injury ratings were targeted to occur at the 1-, 2-, 3-, and 4–true-leaf stages.

Because insecticide seed treatments provide the greatest efficacy during the first three weeks after planting (approximately the 1-2–true-leaf stage) (Roberts and Toews, 2014; Steckel et al., 2023), and because environmental conditions occasionally prevented complete sampling at all growth stages, data were pooled into early (1-2 leaf) and late (3-4 leaf) growth-stage categories for analysis. Thrips densities vary widely among environments, which can confound comparisons of raw counts across site-years. Therefore, densities were converted to immature percent control relative to the untreated check within each site-year to standardize treatment effects. Immature thrips were used to estimate percent control because adults are highly mobile and capable of flight, whereas immature stages are largely confined to the plant on which they are developing, providing a more stable estimate of treatment effects. Although immature thrips were not identified to species, adult thrips were identified to confirm that tobacco thrips comprised the predominant species present during the study. Although this approach improves comparability across environments, it can exaggerate apparent declines under high-pressure conditions or mask reduced susceptibility under low-pressure conditions; results were interpreted with these limitations in mind.

**Data Analysis**. Temporal trends in percent control of immature thrips and injury ratings were analyzed within each growth stage and treatment using PROC GLIMMIX in SAS Version 9.4 (SAS Institute Inc., Cary, NC). Linear mixed models were fit with year treated as a continuous fixed effect. Models were fit using restricted pseudo-likelihood assuming normally distributed residuals. For each treatment-by-stage subset, location × year and replication nested within location × year were specified as random effects.

For each growth stage and treatment, the estimated annual slope (percentage point change in control per year or qualitative change in injury rating), its standard error, t-value, Kenward-Roger denominator degrees of freedom, and p-value were extracted from the model output for inference. Because analyses were conducted separately for each treatment within each growth stage, the year slope represents the within-treatment temporal trend rather than a treatment × year interaction. Year was centered at the mean study year to improve model stability and facilitate interpretation of intercept estimates.

To illustrate temporal patterns, model-predicted percent control and injury ratings were generated from fixed-effect estimates across the range of study years. Predicted trends are presented with 95% confidence intervals reflecting uncertainty in the estimated mean response, not prediction intervals for individual observations.

## RESULTS

At the 1-2–leaf growth stage, acephate IST was the only insecticide that showed a significant change in percent control (Fig. 1). Percent control for this insecticide declined significantly over time (slope = -1.79 ± 0.86 % per year; t = -2.07; $p = 0.04$), indicating a reduction in insecticide performance across the study period. At the 3-4–leaf growth stage, percent control in acephate + imidacloprid seed treatment (slope = -4.85 ± 1.74 % per year; t = -2.78; $p < 0.01$) (Fig. 2) and imidacloprid + thiodicarb seed treatment

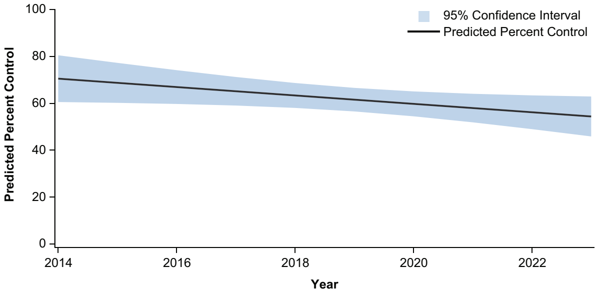

**Figure 1. Model-predicted temporal trends in percent control of immature thrips for acephate seed treatment at the 1-2–leaf growth stage. Lines represent predicted percent control derived from linear mixed models fit separately for each treatment and growth stage. Shaded bands indicate 95% confidence intervals for the model-predicted mean response. Calendar year is shown on the x-axis. Slope = -1.79 ± 0.86 % per year; t = -2.07; $p = 0.04$.**

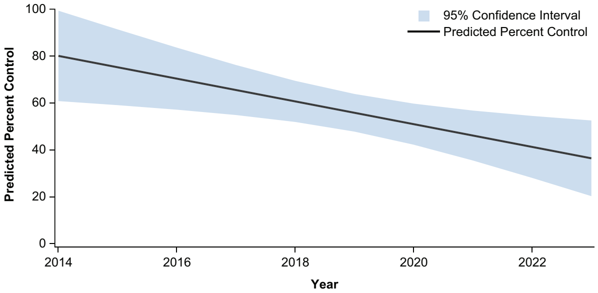

**Figure 2. Model-predicted temporal trends in percent control of immature thrips for the acephate + imidacloprid seed treatment at the 3-4–leaf growth stage. Lines represent predicted percent control derived from linear mixed models fit separately for each treatment and growth stage. Shaded bands indicate 95% confidence intervals for the model-predicted mean response. Calendar year is shown on the x-axis. Slope = -4.85 ± 1.74 % per year; t = -2.78; $p < 0.01$.**

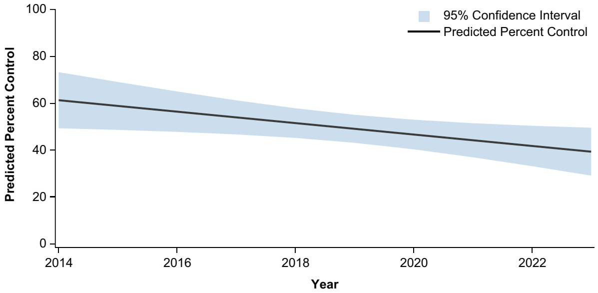

**Figure 3. Model-predicted temporal trends in percent control of immature thrips for the imidacloprid + thiodicarb seed treatment at the 3-4–leaf growth stage. Lines represent predicted percent control derived from linear mixed models fit separately for each treatment and growth stage. Shaded bands indicate 95% confidence intervals for the model-predicted mean response. Calendar year is shown on the x-axis. Slope = -2.44 ± 1.04 % per year; t = -2.35; $p = 0.02$.**

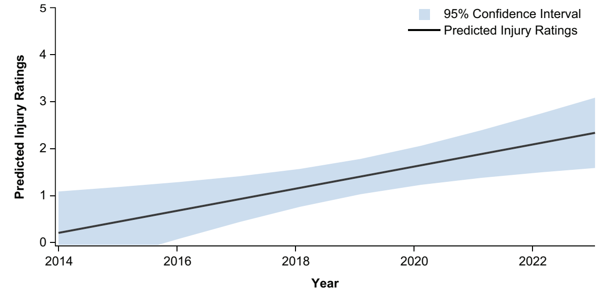

**Figure 4. Model-predicted temporal trends in thrips injury ratings (0-5 scale) for the imidacloprid in-furrow treatment at the 1-2–leaf growth stage. Lines represent fixed-effect predictions from linear mixed models, and shaded bands indicate 95% confidence intervals for the model-predicted mean response. Slope = 0.24 ± 0.08; t = 2.99; $p < 0.01$.**

(slope = -2.44 ± 1.04 % per year; t = -2.35; $p = 0.02$) (Fig. 3) declined significantly over time, indicating a significant temporal decline in observed control. No other treatments showed significant changes in percent control across the study period.

In the analysis of injury ratings, slope values represent annual changes in qualitative injury rating units. Significant, positive values indicate qualitative observed injury ratings have increased throughout the duration of the study. Significant increases in rating values were observed in five of the eight treatments at the 1-2–leaf stage. Treatments with significant changes in injury ratings included: imidacloprid in-furrow (slope = 0.24 ± 0.08; t = 2.99; $p < 0.01$; Fig. 4), imidacloprid seed treatment + acephate in-furrow (slope = 0.48 ± 0.16; t = 3.09; $p < 0.01$; Fig. 5), acephate in-furrow (slope = 0.27 ± 0.09; t = 2.87; $p < 0.01$; Fig. 6), acephate seed treatment + imidacloprid seed treatment (slope = 0.11 ± 0.05; t = 2.48; $p = 0.02$; Fig. 7), and imidacloprid + thiodicarb seed treatment (slope = 0.06 ± 0.03; t = 2.19; $p = 0.03$; Fig. 8).

At the 3-4–leaf stage, six of the eight treatments showed significant increases in injury ratings and included: acephate seed treatment (slope = 0.12 ± 0.03; t = 3.70; $p < 0.01$; Fig. 9), imidacloprid + thiodicarb seed treatment (slope = 0.10 ± 0.03; t = 3.27; $p < 0.01$; Fig. 10), acephate in-furrow (slope = 0.28 ± 0.09; t = 3.02; $p < 0.01$; Fig. 11), imidacloprid in-furrow (slope = 0.22 ± 0.07; t = 2.95; $p < 0.01$; Fig. 12), acephate seed treatment + imidacloprid seed treatment (slope = 0.13 ± 0.05; t = 2.54; $p = 0.01$; Fig. 13), and imidacloprid seed treatment + acephate in-furrow (slope = 0.33 ± 0.13; t = 2.46; $p = 0.02$; Fig. 14).

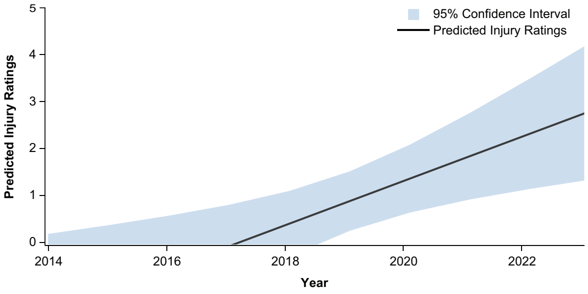

**Figure 5.** Model-predicted temporal trends in thrips injury ratings (0-5 scale) for the imidacloprid IST + acephate in-furrow treatment at the 1-2–leaf growth stage. Lines represent fixed-effect predictions from linear mixed models, and shaded bands indicate 95% confidence intervals for the model-predicted mean response. Slope = 0.48 ± 0.16; t = 3.09; $p < 0.01$.

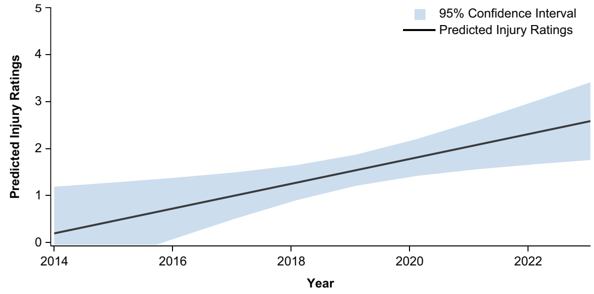

**Figure 6.** Model-predicted temporal trends in thrips injury ratings (0-5 scale) for the acephate in-furrow treatment at the 1-2–leaf growth stage. Lines represent fixed-effect predictions from linear mixed models, and shaded bands indicate 95% confidence intervals for the model-predicted mean response. Slope = 0.27 ± 0.09; t = 2.87; p < 0.01.

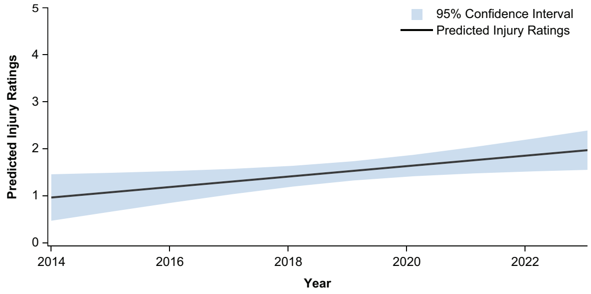

**Figure 7.** Model-predicted temporal trends in thrips injury ratings (0-5 scale) for the acephate + imidacloprid IST treatment at the 1-2–leaf growth stage. Lines represent fixed-effect predictions from linear mixed models, and shaded bands indicate 95% confidence intervals for the model-predicted mean response. Slope = 0.11 ± 0.05; t = 2.48; $p = 0.02$.

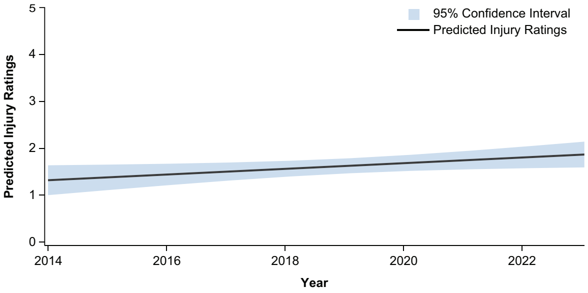

**Figure 8.** Model-predicted temporal trends in thrips injury ratings (0-5 scale) for the imidacloprid + thiodicarb IST treatment at the 1-2–leaf growth stage. Lines represent fixed-effect predictions from linear mixed models, and shaded bands indicate 95% confidence intervals for the model-predicted mean response. Slope = 0.06 ± 0.03; t = 2.19; $p = 0.03$.

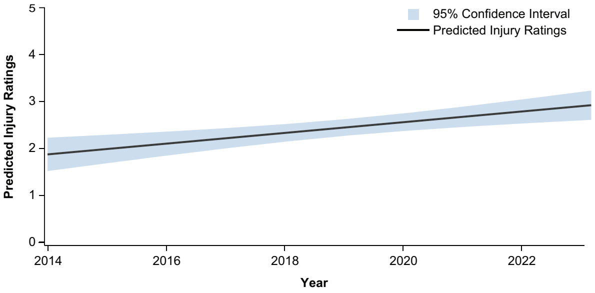

**Figure 9.** Model-predicted temporal trends in thrips injury ratings (0-5 scale) for the acephate IST treatment at the 3-4–leaf growth stage. Lines represent fixed-effect predictions from linear mixed models, and shaded bands indicate 95% confidence intervals for the model-predicted mean response. Slope = 0.12 ± 0.03; t = 3.70; $p < 0.01$.

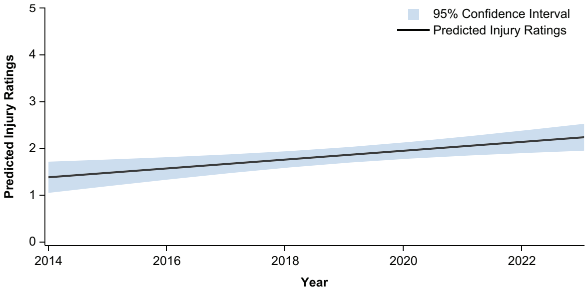

**Figure 10.** Model-predicted temporal trends in thrips injury ratings (0-5 scale) for the imidacloprid + thiodicarb IST treatment at the 3-4–leaf growth stage. Lines represent fixed-effect predictions from linear mixed models, and shaded bands indicate 95% confidence intervals for the model-predicted mean response. Slope = 0.10 ± 0.03; t = 3.27; $p < 0.01$.

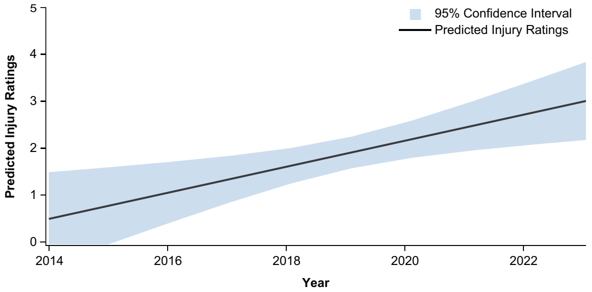

**Figure 11. Model-predicted temporal trends in thrips injury ratings (0-5 scale) for the acephate in-furrow treatment at the 3-4–leaf growth stage. Lines represent fixed-effect predictions from linear mixed models, and shaded bands indicate 95% confidence intervals for the model-predicted mean response. Slope = 0.28 ± 0.09; t = 3.02; *p* < 0.01.**

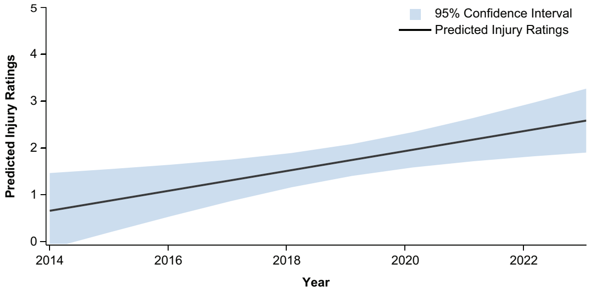

**Figure 12. Model-predicted temporal trends in thrips injury ratings (0-5 scale) for the imidacloprid in-furrow treatment at the 3-4–leaf growth stage. Lines represent fixed-effect predictions from linear mixed models, and shaded bands indicate 95% confidence intervals for the model-predicted mean response. Slope = 0.22 ± 0.07; t = 2.95; *p* < 0.01.**

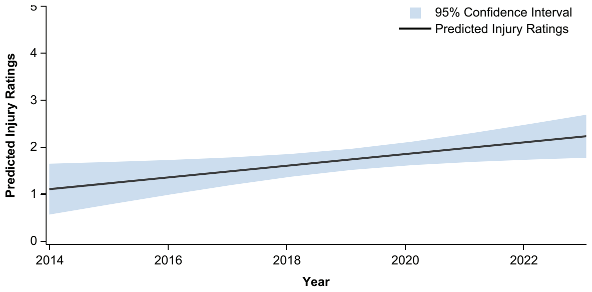

**Figure 13. Model-predicted temporal trends in thrips injury ratings (0-5 scale) for the acephate + imidacloprid IST treatment at the 3-4–leaf growth stage. Lines represent fixed-effect predictions from linear mixed models, and shaded bands indicate 95% confidence intervals for the model-predicted mean response. Slope = 0.13 ± 0.05; t = 2.54; *p* = 0.01.**

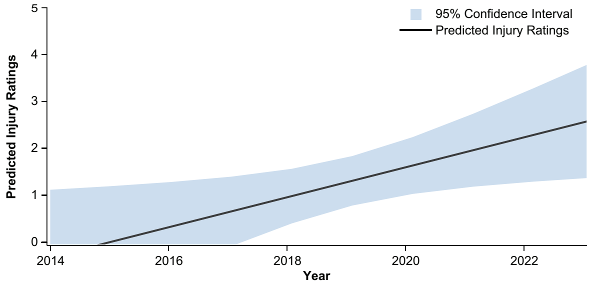

**Figure 14. Model-predicted temporal trends in thrips injury ratings (0-5 scale) for the imidacloprid IST + acephate in-furrow treatment at the 3-4–leaf growth stage. Lines represent fixed-effect predictions from linear mixed models, and shaded bands indicate 95% confidence intervals for the model-predicted mean response. Slope = 0.33 ± 0.13; t = 2.46; *p* = 0.02.**

## DISCUSSION

Evaluation of immature thrips control across multiple years provided valuable insight into temporal patterns of insecticide performance, with consistent trends in efficacy observed among some of the tested treatments. Results also estimated that injury ratings associated with some insecticides increased over time. The significant decrease in percent control observed for some insecticides, combined with the increase in observed injury ratings, can suggest increasing prevalence of reduced susceptibility within thrips populations across the Mid-Southern U.S. Although direct resistance assays were not conducted as part of this study and causal mechanisms cannot be isolated from these data, the consistency of temporal changes across site-years suggest that shifts in susceptibility can be contributing to the observed trends. It must be noted, however, that thrips densities, planting date, crop growth rate, weather, and other environmental factors can affect percent control, suggesting alternate explanations for these changes.

Weather also can play a role in injury ratings, as warmer temperatures favor increased cotton vigor, shortening the susceptibility window and reducing observed injury compared to cotton developing in cooler temperatures. Soil moisture can affect at-planting insecticide efficacy, as limited soil moisture reduces the plant's ability to absorb the insecticide, whereas over-saturation in the soil can cause the insecticide to leach out of the root zone. The number of site-years analyzed across a wide geographic range strengthens confidence in the consistency of the observed temporal trends; however, these results do not isolate the underlying cause of these changes. These findings are further supported by other research documenting resistance development during the time of this experiment. This includes resistance to neonicotinoids, pyrethroids, and organophosphates (Cook et al., 2022; Darnell-Crumpton et al., 2018; D'Ambrosio et al., 2019; Huseth et al., 2016; Krob et al., 2022).

Although aldicarb provides excellent control of tobacco thrips in cotton and was used extensively before the introduction of neonicotinoid seed treatments in the mid-1990s, it is not widely used in the current Mid-Southern cotton production systems. This is primarily due to two reasons: the high cost of aldicarb, and the lack of aldicarb in-furrow granular hopper boxes on newer generation planter equipment required for applications. These additional hopper boxes were common on planters before the mid-1990s, as both aldicarb and fungicide treatments were applied in-furrow. However, the introduction of seed-applied neonicotinoid seed treatments and fungicides provided the option to eliminate the need for granular hopper units, allowing for easier planting practices. Due to the relatively low cost of neonicotinoid seed treatments, they are used on more than 95% of cotton planted in the Mid-Southern U.S. regardless of neonicotinoid resistance (Cook et al., 2022).

The use of neonicotinoid seed treatments typically provides adequate control of tobacco thrips through the 1-2–leaf stage depending on injury. Following this, supplemental foliar applied insecticides are often required to mitigate thrips injury until cotton grows out of the susceptible growth stages. Although data suggested decreased efficacy in some neonicotinoid treatments, in years of lower thrips densities, adequate thrips control can be achieved solely with a neonicotinoid seed treatment. In high-pressure years, one to two foliar applications might be required to mitigate thrips injury and prevent delays in maturity, depending on insecticide selection.

The introduction of ThryvOn cotton technology (Bayer CropScience) provides an additional Bt mode of action (MPP 51Aa2.834_16), suppressing *Lygus* spp. and thrips populations (Bachman et al., 2017; Graham and Stewart, 2018). Current research has demonstrated that ThryvOn cotton technology typically does not require supplemental insecticide intervention to mitigate thrips injury (Farmer et al., 2025; Graham and Stewart, 2018; Whitfield, 2023). Neonicotinoid seed treatments have been observed to significantly reduce susceptible immature thrips densities in ThryvOn cotton compared to untreated seed (Farmer et al., 2025). However, the authors of this study noted that adequate control was achieved from the ThryvOn trait alone, and the imidacloprid did not provide an additional benefit.

Based on that research, current university guidelines recommend that no foliar insecticide applications be made targeting thrips in seedling ThryvOn cotton, unless warranted by excessive thrips injury (Bateman et al., 2025; Brown et al., 2023; Crow et al., 2025; Davis et al., 2024). Currently, ThryvOn cotton also comes standard with an imidacloprid seed treatment as part of resistance management strategies. Neonicotinoids have been the foundation of thrips management in seedling cotton for the last decade and are likely to continue to be the main control strategy going forward in cotton, regardless of technology.

## CONCLUSIONS

Various research and extension entomologists have reported reduced efficacy of multiple insecticides based on field observations of insecticide performance over the years and across the Mid-Southern U.S. Data from this research support these observations, as statistically significant decreases in percent control of immature thrips were observed for select insecticide treatments at specific growth stages throughout the duration of the study. Additionally, significant increases in injury ratings were observed throughout the course of the study for multiple insecticide treatments. Additional research published during this study has documented thrips resistance to several of the tested insecticides, supporting the findings of this study and field observations by various agricultural personnel. Furthermore, ThryvOn cotton technology will need to be a continual treatment in this research going forward to generate a baseline value for thrips control and more efficiently track its efficacy as a thrips control measure compared to the products missing baseline control ratings. Findings of this research also highlight the importance of region-wide trial work.

## ACKNOWLEDGMENTS

The authors are thankful to Cotton Incorporated for providing funding to carry out this research.

The authors would also like to thank all individuals who helped accomplish this research throughout the years.

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