

Integrated Pest Management Strategies in Alabama Row Crops

by

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Abstract

Tobacco thrips (*Frankliniella fusca* Hinds) and nematodes are widespread pests of cotton (*Gossypium hirsutum* L.) across the Southeastern US. Recently, cotton varieties genetically modified with resistance to thrips (i.e., ThryvOn, Bayer CropScience, St. Louis, MO) have been released. Field experiments were conducted in 2022 and 2023 in Alabama to determine the effects of at-plant insecticides and ThryvOn cotton varieties on thrips management in nematode infested fields. A total of four tests were conducted in a *Meloidogyne incognita* (root-knot nematode) infested field at the Plant Breeding Unit in Tallassee, AL and in a *Rotylenchulus reniformis* (reniform nematode) infested field at the Tennessee Valley Research and Extension Center in Belle Mina, AL. Plots were sampled for thrips injury and populations at the 2nd, 4th and 6th true leaf stages. Additionally, plots were sampled for nematodes between 30 and 45 days after planting. Treatments included ThryvOn and non-ThryvOn cotton treated with AgLogic, Gaucho Insecticide Seed Treatment or Admire Pro + Velum fungicide/nematicide. Across years and locations, ThryvOn cotton provided consistent control of thrips. Similarly, at-plant insecticides provided consistent control compared to the non-treated, non-ThryvOn check. Additionally, both the ThryvOn and non-ThryvOn cotton benefited from the addition of the Admire Pro + Velum and AgLogic with reduced nematode populations.

Tarnished plant bug (TPB), *Lygus lineolaris*, is a key insect pest of cotton in the Midsouth and Southeast, and management programs increasingly rely on integrating host-plant resistance traits such as ThryvOn technologies with insecticide use strategies. This study evaluated the influence of low- and high-input insecticide

programs on TPB populations, plant injury, and yield in ThryvOn and non-ThryvOn cotton under large-plot field conditions. A non-replicated strip trial was conducted in 2023 and 2024 at the Tennessee Valley Research and Extension Center in Belle Mina, AL, using a ThryvOn variety (DP2131 B3XTF) and a non-ThryvOn variety (DP2038 B3XF) planted in eight-row × 175-ft strips and managed under non-treated, low-input or high-input insecticide programs. Weekly sampling of TPB included sweep nets, pinhead square retention, drop cloths, dirty bloom assessments, with additional internal boll examinations for stink bugs. Agronomic measurements were recorded at first bloom, and lint yield was quantified from the center two rows of each strip. ThryvOn cotton had significantly fewer small, large, and total TPB nymphs during bloom. High-input insecticide programs reduced total TPB regardless of variety. Dirty blooms and internal boll damage were lower in ThryvOn and treated plots. First-position fruit retention and node of first fruiting branch differed between varieties, and both insecticide programs increased yield relative to the control, with no yield differences between insecticide input levels. These results demonstrate that ThryvOn technology and insecticide inputs both contribute to TPB suppression and yield protection in Alabama cotton production systems.

Thrips, (*Frankliniella* spp.), are a key pest of seedling cotton throughout the Southeast. This study evaluated the impact of starter fertilizer and soil temperature on thrips management in ThryvOn and non-ThryvOn cotton. Field experiments were conducted in 2024 and 2025 at the Tennessee Valley Research and Extension Center in Belle Mina, AL, using a ThryvOn variety (DP2211 B3XTF) and a non-ThryvOn (DP2127 B3XF) variety planted at 4 planting dates based on soil temperature (55, 60,

65, and 70°F) with or without ammonium polyphosphate (10-34-0) fertilizer. Seedling data collection included stand counts, vigor and thrips injury ratings, and thrips population estimates were made at the 2nd and 4th true leaf stages. Plant heights and fresh shoot weights were obtained when the cotton began squaring, and lint yield was quantified from the center two rows of each plot. Vigor, thrips injury, thrips populations, and fresh shoot weight were each impacted by variety and soil temperature. Plant heights and yield were only influenced by soil temperature. The results demonstrate that ThryvOn technology and soil temperature both contribute to thrips pressure and plant growth, however, starter fertilizer has no impact on thrips management or any yield. Ultimately, soil temperature was the only yield limiting factor.

Tobacco Thrips (*Frankliniella fusca*) are a key early-season pest of peanut and vector tomato spotted wilt virus (TSWV) both of which can reduce yield when not managed effectively. This study evaluated the effects of peanut cultivar and at-plant insecticide on thrips injury, TSWV incidence, canopy development, nematode (*Meloidogyne arenaria*) infestation and yield in Alabama from 2023 to 2025. Two cultivars (GA 06-G and GA 12-Y) were planted with four treatments: a non-treated control and at-plant applications of aldicarb (7.8 kg/ha), phorate (5.6 kg/ha), and oxamyl (1.3 L/ha). Thrips injury (0-5), seedling vigor (0-10), fractional green canopy cover, TSWV incidence and nematode population estimates were done at various timings through 56 days after planting (DAP) and yield was collected at the end of the season. At-plant insecticides reduced thrips injury compared to the non-treated control. Seedling vigor was greatest in Georgia-12Y peanuts and where AgLogic was applied. TSWV was greater and FGCC was lower in non-treated plots and where GA-06G was used. Peanut

root knot nematode egg counts did not differ among treatments. Yield was greater in the GA-06G overall and where at-plant insecticides were applied. These results demonstrate that at-plant insecticides contribute to thrips and TSWV suppression and protect yield in Alabama peanut production.

Artificial Intelligence (AI) Use Disclosure

In preparation of this dissertation, the following Artificial Intelligence (AI) tools were used: Microsoft Co-Pilot. These are used as a tool to troubleshoot statistical code, provide example analysis scripts, and identify areas that require improved clarity. All final writing and analytical decisions were made independently by the author. The author acknowledges full responsibility for the intellectual content of this work and has ensured that all AI-assisted sections have been reviewed and revised for accuracy and appropriate academic style. All AI-generated content was reviewed and validated for relevance, appropriateness, and accuracy before incorporation into the final document to maintain scholarly integrity of this research.

Digital Accessibility Use Disclosure Statement

The author acknowledges full responsibility for the intellectual content of this work and has made a good faith effort to comply with digital accessibility requirements in publishing, wherein the nature of the content does not significantly change in order to do so. Furthermore, all content has been reviewed and revised to meet these requirements prior to final publication.

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List of Abbreviations

TVREC	Tennessee Valley Research and Extension Center
PBU	Plant Breeding Unit
NTO	Non-ThryvOn
TO	ThryvOn
TPB	Tarnished Plant Bug
DAP	Days After Plant
TSWV	Tomato Spotted Wilt Virus
FGCC	Fractional Green Canopy Cover
<i>Bt</i>	<i>Bacillus thuringiensis</i>

LITERATURE REVIEW

1. Cotton (*Gossypium Hirsutum* L.)

1.1 Thrips (*Frankliniella fusca* Hinds)

Thrips are an economically important pests of seedling cotton, *Gossypium hirsutum* (L.), causing significant damage throughout the U.S. cotton belt (Cook et al. 2011). With rasping and sucking mouthparts, thrips feed on the epidermal cells of cotton leaves (Cook et al. 2011). Correlating symptoms of thrips feeding include a silvery and dry appearance, curling of leaf edges (“cupping”), malformation and tearing of leaves, and even injury or death to the apical meristem (Cook et al. 2011, Telford and Hopkins 1957, Reed and Reinecke 1990). At-plant insecticides are an effective management option for thrips. These include in-furrow applications of aldicarb, acephate, and imidacloprid, as well as seed treatments such as acephate, imidacloprid, and thiamethoxam (Cook et al. 2011, Crow et al. 2018, Lawton et al. 2025). In addition to insecticides as a standard control option for thrips, a new trait technology, ThryvOn, also provides adequate thrips control by suppressing the population via adult non-preference and reduced egg lay (Graham et al. 2019, Huseeth et al. 2020).

1.2 Tarnished Plant Bug (*Lygus lineolaris*)

Alabama was ranked 7th nationally in the 2025 cotton growing season, producing approximately 600,000 bales of cotton (USDA, NASS 2025). Tarnished plant bug (TPB) (*Lygus lineolaris*) (Palisot de Beauvois) is a major pest of cotton in the Midsouthern US and has become an emerging pest in the past 5 years in Alabama. In 2017, TPB was responsible for an average of 0.39% yield loss and \$6.56 control cost in Alabama. This rose to 1.05% yield loss and \$24.50 control cost per acre in 2024 (Cook, 2024). With

the increase TPB pressure, 95% of Alabama's cotton acres were treated an average of 2.4 times in the 2022 growing season. Douglas et al. (2025) reported recent TPB pyrethroid resistance in south and central Alabama, along with Dorman et al. (2020), who confirmed pyrethroid resistance in northwest Alabama.

Adult TPB feed on pinhead squares with piercing and sucking mouthparts, often leading to aborted squares after injury (Burriss et al. 1997). During bloom, nymphs prefer to feed on larger squares. These damaged squares, known as 'blasted squares' turn into 'dirty' blooms as the fruiting structure flowers (George et al. 2021). White blooms are considered "dirty" if feeding injury appears on anthers, petals, or staining from TPB excretion (George et al. 2021). In return, TPB feeding leads to delayed crop maturity, malformed or abscised bolls and yield reduction (Layton, 2000 and George et al. 2021). The tarnished plant bug has several plant hosts, including over half of the cultivated plants grown in the U.S. (George et al., 2021). Most of the plant hosts are found along roadside ditches and field edges, allowing plant bugs to migrate into cotton fields once the weedy hosts are destroyed (Esquivel and Moery 2007, Snodgrass et al. 1984, Outward et al. 2008). Multiple generations of tarnished plant bugs are completed each year, with the first several generations occurring in the non-crop host and later generations moving into cotton fields (George et al. 2021, Fleischer and Gaylor 1987, Layton 2000). Tarnished plant bugs over winter as adults, inserting eggs inside plant tissues. After hatching, there are five nymphal instars during development before maturity (George et al. 2021).

When scouting for TPB, sweep nets are the most effective sampling method for tarnished plant bugs before peak bloom (Musser et al. 2007). After peak bloom, drop

cloth samples are most effective (Musser et al. 2007, Musser 2009). Avoiding automatic insecticide applications, only treating fields when populations approach economic thresholds and rotating insecticide modes of action also plays an important role in IRM (Graham, 2021).

1.3 Nematodes in Alabama Cotton

There are two species of nematodes that affect cotton grown in Alabama: southern root-knot (*Meloidogyne incognita*) and reniform (*Rotylenchulus reniformis*) nematode. Two races of Southern root-knot nematode are able to reproduce in cotton (Xiang et al. 2018). Cotton infected with *M. incognita* exhibit galls on the roots. Root damage (galling) prevents nutrient and water uptake of the cotton plant resulting in weak, stunted and poor-yielding plants (Abad et al. 2003). *M. incognita* resulted in 3.5% of yield loss in 2025 in cotton production throughout the U.S. (Faske, 2025). The reniform nematode is another major yield limiting pest of cotton in the U.S. (Lawrence, 2021). In 2025, the reniform nematode accounted for 2.4% of yield loss in cotton production nationally (Faske, 2025). Fields infested with reniform nematodes often have a 'wave effect' or irregular appearance (Lawrence, 2021). Infected root systems are often fragile, limiting root growth (Lawrence, 2021).

Management practices for reducing nematode populations of both *M. incognita* and *R. reniformis* include nematicides such as aldicarb (AgLogic 15G), fluopyram and imidacloprid (Velum Total) (Bayer Crop Science, Raleigh, NC), imidacloprid and thiodicarb (Aeris Seed-Applied System) (Bayer Crop Science, Raleigh, NC), Abamectin (Avicta 500 FS) (Syngenta, Greensboro, NC), and Oxamyl (Vydate L) (DuPont Crop

Protection, Wilmington, DE). Other control practices include crop rotation and the use of nematode resistant varieties (Xiang et al. 2018, Lawrence 2021).

1.4 ThryvOn Technology in Cotton

ThryvOn is a new technology introduced commercially in 2023 by Bayer CropScience (St. Louis, MO). ThryvOn consists of a new *Bacillus thuringiensis* (*Bt*) protein, Cry51Aa2.834_16 that has insecticidal activity against thrips and TPB (Graham and Stewart, 2018). ThryvOn is the first *Bt* crop to target any sucking pest (Yates-Stewart et al. 2023). Thrips populations were significantly reduced when using ThryvOn cotton compared to non-ThryvOn cotton (Graham and Stewart 2018, Whitfield 2023, Lawton et al. 2025, Lee et al. 2026,). ThryvOn reduced oviposition in thrips (*Frankliniella fusca* (Hinds) by 65% (Graham et al. 2019, Huseh et al. 2019, Yates-Stewart et al. 2023) due to thrips non-preference to ThryvOn over non-ThryvOn cotton (Whitfield 2023). Thrips preference to ThryvOn cotton directly correlates with thrips injury, where less plant damage occurs in the ThryvOn cotton (Graham et al. 2018, Whitfield 2023).

ThryvOn has also been documented to reduce the number of insecticide applications, damage and yield loss from TPB (Graham and Stewart 2018). Graham and Stewart, 2018 found that ThryvOn cotton required 1.25 fewer insecticide applications for TPB than non-ThryvOn cotton. A variant of the Cry51Aa2 protein, Cry51Aa2.834_16, is expressed in the ThryvOn variety, reducing TPB populations (Gowda et al. 2016). TPB that consume the Cry51Aa2.834_16 protein are documented to have damage to the midgut (Jerga et al. 2016). With adult TPB also having a non-preference to ThryvOn cotton, there is less damage due to reduced feeding and reduced oviposition of TPB in ThryvOn cotton (Graham et al. 2019).

2. Peanuts (*Arachis hypogaea*)

2.1 Thrips and Tomato Spotted Wilt Virus

Tobacco thrips (*Frankliniella fusca* Hinds) transmit tomato spotted wilt virus (TSWV) in peanuts. Both larvae and adult thrips feed directly on the plants, transmitting the TSWV and causing leaf chlorosis, curling, yield loss (LaTora et al. 2022). Tomato spotted wilt virus induces several symptoms on infected peanut plants, including concentric ring spots, chlorotic patterns, general stunting on plants, and misshaped pegs and kernels (Srinivasan et al. 2017). Studies show that there is a correlation of thrips populations and TSWV incidence (Garcia et al. 2000, Shrestha et al. 2015). Research from the University of Georgia shows that for every 1% TSWV incidence in the Georgia-06G variety, yield is reduced by ≈ 20 pounds per acre (Abney, 2022). Several management strategies can be used to reduce thrips injury and potentially TSWV incidence, including pre-plant insecticides, planting date, seeding rates, and variety selection. Using pre-plant in-furrow insecticides, such as imidacloprid, phorate, and aldicarb are shown to effectively suppress thrips (Marasigan et al. 2015). Earlier planted peanuts have been found to have greater thrips injury and TSWV than later planted peanuts (Mahoney 2018, Cooke et al. 2025). Wright et al. (2016) noted that planting at higher seeding rates can reduce TSWV incidence. Variety selection is important due to differences in disease resistance (Wright et al. 2016). Branch et al. (2003) contends that TSWV resistant, runner-type peanut cultivars are the most important defense in management of TSWV.

2.2 Nematode Species in Alabama Peanuts

Several *Meloidogyne* species have been associated with peanuts, with three major species (*M. arenaria*, *M. javanica*, and *M. hapla*) capable of causing severe yield and fruit quality impacts (Minton and Baujard 1990, Dickson and De Waele 2005).

Meloidogyne arenaria (peanut root-knot nematode) is the most predominate nematode species in Alabama, causing the most economic damage (Hagan et al. 2025), with yield loss exceeding 50% in highly infested fields (Minton and Baujard, 1990). *Meloidogyne arenaria* juveniles enter the peanut roots, pegs and pods causing injury when present in large numbers (Minton and Baujard, 1990). Feeding of these nematodes result in malformations or “galls”, preventing infected roots from adequate nutrient and water uptake (Jones 1981, Dickson and De Waele 2005). Above ground symptoms of *M. arenaria* include stunted plant growth and premature plant death (Starr and Morgan 2002). Current nematode management for peanut producers consists of crop rotation, nematode resistant varieties, and nematicide applications, minimizing yield loss to *M. arenaria* (Grabau et al. 2020, Hagan et al. 2025).

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Title

Evaluation of ThryvOn Cotton for thrips management in nematode infested fields

Abstract

Tobacco thrips (*Frankliniella fusca* Hinds) and nematodes are widespread pests of cotton (*Gossypium hirsutum* L.) across the Southeastern US. Recently, cotton varieties genetically modified with resistance to thrips (i.e., ThryvOn, Bayer CropScience, St. Louis, MO) have been released. Field experiments were conducted in 2022 and 2023 in Alabama to determine the effects of at-plant insecticides and ThryvOn cotton varieties on thrips management in nematode infested fields. A total of four tests were done in a *Meloidogyne incognita* (root-knot nematode) infested field at the Plant Breeding Unit in Tallassee, AL and in a *Rotylenchulus reniformis* (reniform nematode) infested field at the Tennessee Valley Research and Extension Center in Belle Mina, AL. Plots were sampled for thrips injury and populations at the 2nd, 4th and 6th true leaf stages. Additionally, plots were sampled for nematodes between 30 and 45 days after planting. Treatments included ThryvOn and non-ThryvOn cotton treated with AgLogic, Gaucho Insecticide Seed Treatment or Admire Pro + Velum fungicide/nematicide. Across years and locations, ThryvOn cotton provided consistent control of thrips. Similarly, at-plant insecticides provided consistent control compared to the non-treated, non-ThryvOn check. Additionally, both the ThryvOn and non-ThryvOn cotton benefited from the addition of the Admire Pro + Velum and AgLogic with reduced nematode populations.

Keywords

Cotton, ThryvOn, Thrips, Nematodes

Introduction

Thrips (Thysanoptera: Thripidae), are the most economically important insect pest of seedling cotton across the US Cotton Belt (Cook, 2023). Adult and larval thrips injure cotton seedlings by feeding on plant cells with their rasping and sucking mouthparts. This feeding results in a silvery sheen along leaf veins and other feeding sites (Layton and Reed, 2002; Stewart and Lentz, 2010; Cook et al., 2011). As leaves grow, the silvery sheen is less obvious as damaged tissue becomes distorted and malformed. Growing leaves often curl upwards along leaf margins, sometimes referred to as “possum-eared cotton” (Layton and Reed, 2002). Heavy thrips populations may result in stunted growth, delayed fruiting, and a reduced stand (Layton and Reed, 2002). In some cases, thrips infestations damage the apical meristem, leading to unusual growth and excessive vegetative branching, commonly called “crazy cotton” (Gaines, 1934; Layton and Reed, 2002). Above ground stunting is also mirrored below ground in the roots (Roberts and Rechel, 1996; Sadras and Wilson, 1998). This stunting leaves cotton susceptible to below ground pests, such as plant parasitic nematodes.

Thrips are managed prophylactically by using at-plant insecticides, either seed-applied or in-furrow. Currently, the neonicotinoid class of insecticides, primarily imidacloprid, are the most used group of insecticides (Cooke et al., 2011). Previously, aldicarb was the most used insecticide, due to its efficacy against thrips and a spectrum of other pests (Smith et al., 2013) until it was removed from the market for several years (Hayes, 1982). In recent years, tobacco thrips (*Frankliniella fusca* Hinds), the most common thrips species in the southern US (Cook et al., 2003), have developed widespread resistance to the neonicotinoid class of insecticides (Huseth et al., 2016; Darnell-Crumpton et al., 2018). This resistance led to the reintroduction of aldicarb to

the market. Additionally, Bayer CropScience launched a new genetically modified (GM) cotton trait (ThryvOn) to the market in 2023. This new trait, Cry51Aa2, has activity against thrips (Graham and Stewart, 2018). Unlike most GM traits, ThryvOn does not result in high mortality of thrips, rather population suppression is provided via adult non-preference and reduced oviposition (Graham et al., 2019, Huseh et al., 2019). A study by Graham et al. (2019) documented that tobacco thrips, soybean thrips (*Neohydatothrips variabilis* Beach) and other thrips species respond similarly to ThryvOn cotton in replicated small plot field trials. Huseh et al. (2020) found that the presence of ThryvOn cotton suppressed oviposition for both tobacco thrips and western flower thrips (*Frankliniella occidentalis* Pergande) in no-choice cage studies.

In addition to thrips, ThryvOn cotton also has activity against tarnished plant bug (*Lygus lineolaris* Palisot De Beavouis) (Baum et al. 2012, Gowda et al. 2016, Graham and Stewart 2017). Field studies have shown that ThryvOn cotton require fewer insecticide applications based on recommended thresholds than non-ThryvOn Cotton (Graham and Stewart 2017, Corbin et al. 2020). Additionally, a study by Graham et al. (2019) reported tarnished plant bugs laid fewer eggs and caused less damage (i.e. dirty squares and blooms) with higher yields in ThryvOn cotton compared to non-ThryvOn. While it is not fully understood how ThryvOn cotton interacts with tarnished plant bug, adult avoidance appears to have an effect (Graham et al. 2019, Cervantes et al. 2019.)

The reniform nematode (*Rotylenchulus reniformis* Linford and Oliveira) and the southern root-knot nematode (*Meloidogyne incognita* Kofoid and White) are the most economically important nematodes in cotton (Robinson, 2007). Nematodes infect the root system of cotton seedlings and cause issues throughout the season. Stunted,

uneven plants randomly distributed across the field and chlorosis of the leaves are two general above ground symptoms of nematode infection (Lawrence, 2022). Cotton plants infected by reniform nematode do not have distinct symptoms; however, a general reduction in the overall root system is often observed. The cotton field will display areas of stunted and uneven plant growth, referred to as a wave effect, giving the field an irregular appearance (Lawrence, 2022) Reniform nematode infection often results in delayed crop maturity, and yield reductions have been documented at up to 50% (Robinson, 2007; Dyer et al., 2020). Cotton plants infected with root-knot nematode show the characteristic galling formed on the roots and is the only symptom caused solely by root-knot nematodes (Chitwood, 1949; Davis & Kemerait, 2022).

Several options, including crop rotation, seed-applied or in-furrow nematicides, foliar nematicides, or nematode specific resistant varieties are used to manage nematodes (Starr et al., 2007). Many at-plant options, such as the seed treatment (ST) Aeris, thiodicarb and imidacloprid, (Bayer CropScience, St. Louis, MO), Copeo Prime ST, fluopyram (BASF Corporation, Florham Park, NJ), Avicta Elite ST, thiamethoxam, imidacloprid and abamectin, (Syngenta Crop Protection, Greensboro, NC) and in-furrow AgLogic 15GG, aldicarb (AgLogic Chemical, Chapel Hill, NC) are insecticide/nematicides that provide control or suppression of thrips and/or nematodes. Foliar nematicides, such as Vydate C-LV, oxamyl (Corteva Agriscience, Wilmington, DE),, can be used in conjunction with at-plant nematicides to provide further suppression of nematode populations (Lawrence et al., 2015; Lawrence and McLean, 2002). Currently, high yielding varieties resistant to root-knot nematodes are available (Wheeler et al. 2020), while development of new varieties resistant to reniform

nematodes are entering the market (Turner et al., 2023). Before 2024, no nematode-resistant varieties had the ThryvOn trait. With the cost of at-plant insecticide/nematicides and ThryvOn cotton, research needs to be done to determine if growers should use ThryvOn varieties in fields infested with nematodes or use other varieties with premium insecticide/nematicides.

Materials and Methods

Experiments were done at the Plant Breeding Unit (PBU) in Tallahassee, AL, and Tennessee Valley Research and Extension Center (TVREC) near Belle Mina, AL, to determine the impacts of at-plant insecticide/nematicides on thrips and nematode management in ThryvOn and non-ThryvOn cotton. At both locations, in both years, plots consisted of 2 rows that were 7.6 m long with 1 m row spacing and seeds planted at 2.54 cm depth with a seeding rate of 13 seeds per row m. All plots were maintained throughout the season with standard herbicide, insecticide, and fertility production practices, and an overhead sprinkler irrigation system was used for watering as needed. Cotton was planted on 29 April 2022 and 25 April 2023 at PBU. The field was naturally infested with *Meloidogyne incognita* race 3. The soil type is Kalmia loamy sand, which contains 80% sand, 10% silt, and 10% clay. Cotton was planted on 9 May 2022 and 2 May 2023 at TVREC. The field was infested with *Rotylenchulus reniformis*. The soil type was Decatur silt loam soil type, which consists of 23% sand, 49% silt, and 28% clay. Treatments were organized in a randomized complete block design with four replications.

Treatments consisted of two varieties, a ThryvOn variety (DP2131 B3XTF; Bayer CropScience, St. Louis, MO) and a non-ThryvOn variety (DP1646 B2XF; Bayer

CropScience, St. Louis, MO), with at-plant insecticide/nematicides and a fungicide only untreated control. The tested insecticide/nematicides included imidacloprid at 0.375 mg/seed (Gaucho ST, Bayer CropScience, St. Louis, MO), or at 595 ml/ha (Admire Pro IFS, Bayer CropScience, St. Louis, MO) + Fluopyram at 455 ml/ha (Velum, imidacloprid, Bayer CropScience, St. Louis, MO) and aldicarb at 5.6 kg/ha (AgLogic 15GG, AgLogic Chemical, Chapel Hill, NC).

Stand counts were made between 14 and 21 days after planting for each trial by counting the total number of plants in one row. Thrips injury ratings and population densities were evaluated at the 2, 4 and 6 true leaf growth stages. Thrips injury was rated on a 0-5 scale following the methods of Kerns et al., 2018, where '0' was no thrips injury and '5' was death of the terminal growing point. Thrips populations densities were measured using destructive sampling methods. Five random plants were removed from each plot at each sample date and placed in a 0.45 kg jar of 70% ethyl alcohol. Jars with leaf material were then taken to the laboratory and washed over a sieve as described by Graham and Stewart (2018). Thrips were categorized as either adult or immature. Adult thrips were categorized as "dark" or "light" in color, however this is not always a reliable reference for species. However, tobacco thrips was considered the dominate species in our trial, as reported by Cook et al. (2003). At the same sample dates, whole-plot visual estimations of cotton seedling vigor were done on a 0-100 scale with '0' being no living plants and '100' being maximum vigor.

Four random, representative plants from each plot were excavated with roots intact to collect plant and nematode data. Plant data included plant height and fresh weights of shoot and roots. These data were collected between 30 and 45 days after

planting across years and locations. After collection of plant data, cotton roots were used to estimate nematode population levels. A modified method of Hussey and Barker (1973) was used to extract root-knot and reniform nematode eggs. Roots were placed in a 0.625% NaOCl solution and shaken for four minutes on a Barnstead Lab Line Max Q 5000 E Class shaker (Conquer Scientific, San Diego, CA). Roots were then washed with water and scrubbed. Eggs were rinsed with tap water, collected on a sieve (25- μ) and poured into a 50mL centrifuge tube, and processed by sucrose centrifugation-flotation at 240 g for 1 minutes (Jenkins, 1964). The supernatant was collected on a 25- μ sieve, rinsed with water. Eggs were counted using a Nikon TSX 100 inverted microscope at 40x magnification. All plots were machine harvested using a modified spindle-type cotton picker for small plot research.

Stand counts, seedling vigor, thrips injury, thrips population estimates, and plant growth parameters were analyzed using analysis of variance (PROC GLIMMIX, SAS 9.4; SAS Institute; Cary, NC). Variety and insecticide/nematicide (treatment) were designated as fixed effects. Sample date, year, location, year by location, and replication nested within year by location were designated as random effects to allow inferences to be made over a range of environments (Blouin et al., 2011; Carmer et al., 1989; Graham and Stewart, 2018). Because fields were infested with different nematode species, *M. incognita* (PBU) and *R. reniformis* (TVREC) and data did not follow similar trends across species, nematode data was analyzed by location across years, with year and replication as random effects. Means were estimated using LSMEANS and separated based on Fisher's protected least significant differences (LSD) ($\alpha=0.05$).

Results

Seedling Health. No differences in stand counts were observed for variety ($F=0.00$; $df=1, 83$; $p=0.9578$), treatment ($F=0.85$; $df=3, 83$; $p=0.4694$) or their interaction ($F=0.42$; $df=3, 83$; $p=0.7405$). For seedling vigor, there was no interaction of variety and treatment ($F=0.07$; $df=3, 111$; $p=0.9779$) or for variety alone ($F=0.39$; $df=1, 111$; $p=0.5340$). However, treatment did have a significant effect on seedling vigor ($F=2.79$; $df=3, 111$; $p=0.0438$). Regardless of variety, cotton treated with Gaucho ($=89.64 \pm 0.59$), AgLogic ($=89.55 \pm 0.62$), or Admire Pro + Velum ($= 88.96 \pm 0.68$) had significantly higher vigor compared to the non-treated control ($=82.24 \pm 1.74$).

Thrips. There was an interaction of variety and insecticide for thrips injury ($F=10.01$; $df=3, 335$; $p<0.0001$). Non-ThryvOn (NTO) cotton treated with fungicides only had significantly more thrips injury compared with all other treatments (Table 1). There was no difference in thrips injury between NTO cotton treated with Admire Pro + Velum, Gaucho, or AgLogic; however, all NTO cotton had significantly higher injury compared to the ThryvOn (TO) cotton. No differences in thrips injury were observed between treatments in TO cotton (Table 1.1).

There was a significant effect of variety on populations of adult thrips ($F=11.56$; $df=1, 348$; $p=0.0008$). Significantly more adult thrips were found on NTO cotton ($=10.68 \pm 1.04$) compared to the TO cotton ($=6.71 \pm 0.68$). No effect of treatment ($F=0.76$; $df=3, 348$; $p=0.5157$) or treatment by variety interaction ($F=0.83$; $df=3, 348$; $p=0.4797$) was observed. However, there was an interaction of variety and insecticide for immature thrips ($F=3.13$; $df=3, 364$; $p=0.0257$). Significantly more thrips were on the NTO non-treated control compared with all other treatments (Table 2). All TO cotton, regardless of

treatment, supported similar populations of immature thrips. Non-ThryvOn cotton treated with AgLogic was not different from TO cotton (Table 2). Similarly, there was a significant interaction of variety and insecticide for the total number of adult and immature thrips ($F=3.59$; $df=3, 366$; $p=0.0139$) observed. All treatments on NTO cotton resulted in significantly fewer total thrips compared to the NTO non-treated control (Table 2). No differences were observed between any treatment or the non-treated control in TO cotton (Table 1.2).

Plant Growth Parameters. No differences in plant heights were observed for variety ($F=0.39$; $df=1, 53$; $p=0.5364$), treatment ($F=0.55$; $df=1, 53$; $p=0.6527$), or their interaction ($F=0.38$; $df=1, 53$; $p=0.7680$). There were also no differences for above ground fresh shoot weight for variety ($F=0.03$; $df=1, 53$; $p=0.8681$), treatment ($F=0.70$; $df=1, 53$; $p=0.5542$), or their interaction ($F=0.50$; $df=1, 53$; $p=0.6853$). Similarly, no differences in fresh root weight were observed for variety ($F=0.09$; $df=1, 53$; $p=0.7609$), treatment ($F=0.52$; $df=1, 53$; $p=0.6712$), or their interaction ($F=0.38$; $df=1, 53$; $p=0.6805$) (Table 1.3).

Nematode Data. There were no significant differences for eggs per gram of root for variety ($F=0.69$; $df=1, 52$; $p=0.4106$) or the interaction of variety and insecticide ($F=0.41$; $df=3, 53$; $p=0.7500$) for *M. incognita* at PBU. However, insecticide did have a significant effect ($F=5.63$; $df=3, 53$; $p=0.0020$). Admire Pro + Velum and AgLogic supported significantly fewer *M. incognita* eggs per gram of root compared to the non-treated control or cotton treated with Gaucho (Table 1.3). No significant effects of variety ($F=0.77$; $df=1, 21$; $p=0.3898$), or their interaction of variety and insecticide ($F=2.64$; $df=3, 21$; $p=0.0761$) were observed for *R. reniformis* eggs per gram of root. Insecticide

did have a significant effect ($F=7.00$; $df=3, 21$; $p=0.0019$). AgLogic, Admire Pro + Velum, and Gaucho all supported lower populations of *R. reniformis* eggs per gram of root compared to the non-treated check (Table 1.4).

Yield. Plots were terminated prior to the initiation of bloom at TVREC in 2022, thus only year one of yield data was available at this location. There were no interactions between siteyear and variety ($F=9.43$; $df=2, 63$; $p=0.8615$), siteyear and treatment ($F=1.02$; $df=6, 63$; $p=0.4198$), or siteyear, variety and treatment ($F=0.27$; $df=6, 63$; $p=0.9496$), thus, yield data were analyzed across years and locations (Table 1.5). No differences in yield were observed for variety ($F=0.72$; $df=1, 78$; $p=0.3984$), treatment ($F=1.88$; $df=3, 78$; $p=0.1402$), or their interaction ($F=0.79$; $df=3, 78$; $p=0.5015$). When compared across treatments, including at-plant nematicides (Admire Pro + Velum, AgLogic), there was no effect of variety ($F=0.27$; $df=1, 83$; $p=0.6039$) or at-plant nematicide ($F=3.10$; $df=1, 83$; $p=0.0820$) or their interaction ($F=0.11$; $df=1, 83$; $p=0.7396$). When averaged across treatment types (i.e. insecticide/nematicide vs insecticide only), however, there was a significant impact on yield ($F=3.10$, $df=2, 80$; $p=0.0506$). Cotton that received an insecticide/nematicide (AgLogic or Admire Pro + Velum) yielded significantly higher compared to cotton receiving an insecticide only, or the non-treated control (Table 1.5).

Discussion

Our study explored the performance of ThryvOn and non-ThryvOn cotton with various at-plant insecticide/nematicides in reniform and root-knot infested fields in central and northern Alabama. There were no differences in variety or the interaction of variety and treatment for either *M. incognita* or *R. reniformis* for eggs per gram of root. However, treatment did have a significant effect. When using AgLogic and Admire Pro +

Velum, egg populations of both nematode species were reduced as compared to the non-treated control. Gaucho also reduced populations of *R. reniformis* eggs per gram of root, but not for *M. incognita*. A similar study in Mississippi found no interaction for nematodes in low- or high-pressure environments (Farmer, 2023). Dyer et al. (2020) found that an in-furrow spray of Velum Total reduced nematode density in roots and provided early season protection against nematodes.

ThryvOn provided greater thrips control, with less injury and thrips populations compared to the non-ThryvOn cotton, agreeing with Farmer (2023). No differences were observed between insecticide treatments for thrips in the ThryvOn cotton, which was also observed by Farmer (2023) in both low- and high-pressure environments. Reisig and Goldsworthy (2023) found that ThryvOn cotton treated with AgLogic 15G had significantly less thrips injury compared with ThryvOn cotton treated with Acephate 97S and Admire Pro 4.6SC. ThryvOn cotton alone or treated with Gaucho 600SC had significantly more injury compared to the ThryvOn with the aforementioned treatments (Reisig and Goldsworthy, 2023). The non-ThryvOn cotton had significantly more thrips injury, regardless of insecticide treatment, with the exception of AgLogic 15G (Reisig and Goldsworthy, 2023). Similarly, Graham and Stewart (2018) found higher thrips populations and thrips damage in non-ThryvOn cotton compared to cotton without an insecticide seed treatment. Graham and Stewart (2018) also found no differences between total thrips in ThryvOn cotton with an insecticide seed treatment and non-ThryvOn cotton with an insecticide seed treatment with an additional foliar application. Whitfield (2023) also saw similar results in the mid-Southern states, with reduced thrips populations and injury in ThryvOn compared to non-ThryvOn cotton. Overall, ThryvOn

cotton shows adequate control of thrips when compared to non-ThryvOn cotton. The findings in this study indicate ThryvOn provides good control of thrips, even in the absence of nematode control in nematode infested fields. These results are consistent with others (Graham and Stewart, 2018; Whitfield, 2023) documenting that ThryvOn cotton does not need additional insecticides for thrips control. In our study, however, we did not observe a yield response to thrips management. This could be a result of relatively “light” thrips injury. Non-treated, non-ThryvOn cotton only averaged a moderate thrips injury rating (2.95/5). While this rating may result in slight delays of maturity, yield impacts are not always expected. However, regardless of variety, when averaged across treatment types, cotton receiving an at-plant insecticide/nematicide out yielded cotton with no nematicide component in our study done in nematode infested fields.

With ThryvOn being a newer technology, further research is needed to understand how various stresses, like nematodes, drought, etc. may influence the performance of the trait against target insect pests. The objective of this study was to evaluate the performance of ThryvOn cotton against thrips in nematode infested fields. Our studies showed that while nematodes did not impact thrips control, yield was reduced in ThryvOn cotton if no nematicide component was applied. Since the focus of this study was on thrips/nematode interactions, we did not evaluate the performance of ThryvOn cotton against tarnished plant bug. To minimize tarnished plant bug effects, the trial area was monitored weekly and each variety was treated the same with respect to insecticide applications. Future research should evaluate the impact of ThryvOn cotton on all cotton pests. These findings are beneficial to growers who will potentially

use the ThryvOn technology. Currently, there are no ThryvOn varieties with nematode resistance available, thus further research specific to nematodes could be beneficial, particularly for performance against tarnished plant bugs.

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Figures and Tables

Table 1.1. Average thrips injury ratings for ThryvOn and Non-ThryvOn cotton treated with various insecticide/nematicides averaged across the 2, 4 and 6 true leaf stages in nematode infested fields in Tallassee and Belle Mina, AL, during 2022 and 2023.

Variety	Treatment	Rate	Thrips Injury 0-5 Scale
Non-ThryvOn	Fung. Only	-	2.95a (0.17) ²
Non-ThryvOn	Gaucho	0.375 mg	1.62b (0.16)
Non-ThryvOn	Admire Pro + Velum	595 ml + 455 ml	1.83b (0.20)
Non-ThryvOn	AgLogic 15GG	5.6 kg	1.59b (0.16)
ThryvOn	Fung. Only	-	1.06c (0.11)
ThryvOn	Gaucho	0.375 mg	0.98c (0.09)
ThryvOn	Admire Pro + Velum	595 ml + 455 ml	0.96c (0.11)
ThryvOn	AgLogic 15GG	5.6 kg	0.98c (0.10)

²Means within the column that are followed by the same letter are not different according to Fisher's Protected LSD ($\alpha = 0.05$).

Table 1.2. Average number of thrips per five plants for ThryvOn and Non-ThryvOn cotton treated with various insecticide/nematicide averaged across the 2, 4 and 6 true leaf stages in nematode infested fields in Tallassee and Belle Mina, AL, during 2022 and 2023.

Variety	Treatment	Rate	Immature Thrips	Adult Thrips	Total Thrips
Non-ThryvOn	Fung. Only	-	48.67 a (8.69) ^z	11.29 a (2.02)	58.39 a (8.88)
Non-ThryvOn	Gaucho	0.375 mg	25.72 b (6.29)	12.95 a (2.48)	38.01 b (6.73)
Non-ThryvOn	Admire Pro + Velum	595 ml + 455 ml	23.91 b (7.43)	10.48 a (2.17)	32.45 bc (8.21)
Non-ThryvOn	AgLogic 15GG	5.6 kg	11.65 bc (1.94)	8.55 a (1.54)	18.72 bcd (2.55)
ThryvOn	Fung. Only	-	12.42 bc (3.55)	5.63 a (0.93)	16.77 d (3.76)
ThryvOn	Gaucho	0.375 mg	8.00 c (1.93)	7.14 a (1.29)	14.38 d (2.24)
ThryvOn	Admire Pro + Velum	595 ml + 455 ml	12.43 bc (4.59)	6.99 a (1.74)	19.15 cd (4.82)
ThryvOn	AgLogic 15GG	5.6 kg	4.64 c (0.79)	6.67 a (1.46)	10.55 d (1.74)

^zMeans within the column that are followed by the same letter are not different according to Fisher's Protected LSD ($\alpha = 0.05$).

Table 1.3. Plant survival and growth parameters near 40 days after planting for ThryvOn and Non-ThryvOn cotton treated with various insecticide/nematicides in nematode infested fields in Tallassee and Belle Mina, AL, during 2022 and 2023.

Tallassee, AL; Root knot nematode				
Variety	Treatment	% Plant Stand	Plant Height (cm)	Fresh Shoot Weight (g)
Non-ThryvOn	Fung. Only	78 a (11.3) ^z	14.1 a (1.14)	27.3 a (5.53)
Non-ThryvOn	Gaucho	71a (10.9)	14.6 a (0.69)	29.2 a (3.03)
Non-ThryvOn	Admire Pro + Velum	88 a (13.5)	14.0 a (0.97)	24.2 a (3.80)
Non-ThryvOn	AgLogic 15GG	86 a (11.5)	14.7 a (0.69)	33.5 a (3.90)
ThryvOn	Fung. Only	66 a (10.5)	14.9 a (0.92)	27.7 a (3.44)
ThryvOn	Gaucho	76 a (10.5)	13.6 a (0.89)	21.1 a (2.74)
ThryvOn	Admire Pro + Velum	75 a (10.1)	15.9 a (0.68)	28.6 a (2.23)
ThryvOn	AgLogic 15GG	72 a (11.2)	15.4 a (0.47)	29.3 a (2.33)
Belle Mina, AL; Reniform nematode				
Variety	Treatment	% Plant Stand	Plant Height (cm)	Fresh Shoot Weight (g)
Non-ThryvOn	Fung. Only	55 a (6.7)	17.8 a (2.01)	6.3 a (1.89)
Non-ThryvOn	Gaucho	70 a (3.2)	18.9 a (1.77)	7.4 a (0.99)
Non-ThryvOn	Admire Pro + Velum	70 a (3.2)	20.1 a (0.99)	9.4 a (1.74)
Non-ThryvOn	AgLogic 15GG	66 a (1.6)	20.7 a (1.73)	10.1 a (2.20)
ThryvOn	Fung. Only	56 a (4.6)	18.8 a (1.77)	6.23 a (1.02)
ThryvOn	Gaucho	68 a (1.7)	19.0 a (1.43)	6.8 b a (1.18)
ThryvOn	Admire Pro + Velum	68 a (2.2)	20.9 a (0.55)	8.1 a (0.50)
ThryvOn	AgLogic 15GG	61 a (3.3)	21.9 a (0.86)	11.0 a (0.86)

^zMeans within the column that are followed by the same letter are not different according to Fisher's Protected LSD ($\alpha = 0.05$).

Table 1.4. Root-knot and Reniform nematode populations near 40 days after planting for ThryvOn and Non-ThryvOn cotton treated with various insecticide/nematicides near Tallassee and Belle Mina, AL during 2022 and 2023.

Variety	Treatment	Rate	Root-knot eggs / g root	Reniform eggs / g root
Non-ThryvOn	Fung. Only	-	3440 b (1901) ^z	4318 ab (3014)
Non-ThryvOn	Gaucho	0.375 mg	2484 c (1092)	3686 ab (2007)
Non-ThryvOn	Admire Pro + Velum	595 ml + 455 ml	3379 b (3027)	1595 b (681)
Non-ThryvOn	AgLogic 15GG	5.6 kg	259 g (82)	562 b (199)
ThryvOn	Fung. Only	-	3819 a (2225)	2493 ab (997)
ThryvOn	Gaucho	0.375 mg	1395 d (559)	9565 a (4337)
ThryvOn	Admire Pro + Velum	595 ml + 455 ml	825 e (569)	986 b (411)
ThryvOn	AgLogic 15GG	5.6 kg	388 f (151)	716 b (354)

^zMeans within the column that are followed by the same letter are not different according to Fisher's Protected LSD ($\alpha = 0.05$). (Poisson distribution in SAS)

Table 1.5. Yield for ThryvOn and Non-ThryvOn cotton with various at-plant insecticide/nematicides in nematode infested fields in Tallassee (2022, 2023) and Belle Mina, AL during (2023).

Variety	Treatment	Lint yield (kg/ha)
Non-ThryvOn	Fung. Only	849.8 a (98.9) ²
Non-ThryvOn	Gaucho	1,077.5 a (115.3)
Non-ThryvOn	Admire Pro + Velum	1,015.5 a (140.9)
Non-ThryvOn	AgLogic 15GG	1,155.8 a (171.6)
ThryvOn	Fung. Only	978.2 a (127.7)
ThryvOn	Gaucho	946.7 a (137.4)
ThryvOn	Admire Pro + Velum	1,129.4 a (150.1)
ThryvOn	AgLogic 15GG	1,059.5 a (120.3)
Treatment Type ²	Lint Yield (kg/ha)	
Insecticide/Nematicide	978.5 a (88.7)	
Insecticide Only	892.2 ab (70.5)	
Non-Treated Check	784.1 b (79.3)	

¹Insecticide/Nematicide = AgLogic 15GG and Gaucho + Velum; Insecticide Only = Gaucho

²Means within the column that are followed by the same letter are not different according to Fisher's Protected LSD ($\alpha = 0.05$).

Title

Management of Tarnished Plant Bugs (*Lygus Lineolaris*) in ThryvOn and Non-ThryvOn Cotton

Abstract

Tarnished plant bug (TPB), *Lygus lineolaris*, is a key insect pest of cotton in the Midsouth and Southeast, and management programs increasingly rely on integrating host-plant resistance traits such as ThryvOn technologies with insecticide use strategies. This study evaluated the influence of low- and high-input insecticide programs on TPB populations, plant injury, and yield in ThryvOn and non-ThryvOn cotton under large-plot field conditions. A non-replicated strip trial was conducted in 2023 and 2024 at the Tennessee Valley Research and Extension Center in Belle Mina, AL, using a ThryvOn variety (DP2131 B3XTF) and a non-ThryvOn variety (DP2038 B3XF) planted in eight-row × 175-ft strips and managed under non-treated, low-input or high-input insecticide programs. Weekly sampling of TPB included sweep nets, pinhead square retention, drop cloths, dirty bloom assessments, with additional internal boll examinations for stink bugs. Agronomic measurements were recorded at first bloom, and lint yield was quantified from the center two rows of each strip. ThryvOn cotton had significantly fewer small, large, and total TPB nymphs during bloom. High-input insecticide programs reduced total TPB regardless of variety. Dirty blooms and internal boll damage were lower in ThryvOn and treated plots. First-position fruit retention and node of first fruiting branch differed between varieties, and both insecticide programs increased yield relative to the control, with no yield differences between insecticide input levels. These results demonstrate that ThryvOn technology and insecticide inputs both contribute to TPB suppression and yield protection in Alabama cotton production systems.

Keywords

Cotton, ThryvOn, Tarnished Plant Bug

Introduction

Tarnished plant bug (TPB), *Lygus lineolaris* (Palisot de Beauvois), is a major pest of cotton, *Gossypium hirsutum* (L.), across the Mid-Southern US and has become an increasing significant pest in the Southeastern US over the last 5 years. According to the Cotton Insect Loses Report (Cook 2024) substantial increases in yield loss and control costs associated with TPB have been observed in Alabama over the last several years. From 2017-2020, TPB was responsible for an average of 0.39% yield loss and control costs of \$6.56 per acre with a total of \$3.7M in loss plus cost. From 2021-2024, this number has increased to 1.05% yield loss and \$24.50 per acre in control costs and cost-plus loss estimated at \$13.4M (Cook 2024). With this consistent increase in TPB pressure, 95% of Alabama's cotton acres were treated an average of 2.4 times in the 2022 growing season. This trend continued in 2023, when many entomologists across the Southeast claimed the highest TPB pressure ever (Graham and Smith 2023). Along with increased pest pressure, there has been recent TPB pyrethroid resistance documented in south and central Alabama (Douglas et al. 2025), coinciding with the previously reported pyrethroid resistance in the Northwestern part of the state (Dorman et al. 2020). Adult TPB generally infest the earliest planted fields in June in Alabama (pre-bloom) and feed on pinhead squares, which may be aborted after injury (Burriss et al. 1997). During bloom, nymphs prefer to feed on larger squares, where damage is referred to as 'blasted squares', and then a few weeks later as 'dirty' blooms (George et al. 2021). White blooms are considered "dirty" if feeding injury appears on anthers, petals, or staining from TPB excretion (George et al. 2021). In return, TPB feeding leads

to delayed crop maturity, malformed or abscised bolls and yield reduction (Layton, 2000 and George et al. 2021).

ThryvOn is a new technology introduced commercially by Bayer CropScience in 2023 (St. Louis, MO) that has been documented to reduce the number of insecticide applications, damage and yield loss from TPB (Graham and Stewart 2018). The Cry51Aa2.834_16 is a variant of the Cry51Aa2 protein that is expressed in this ThryvOn cotton that reduces populations of TPB (Gowda et al. 2016). TPB that consume the Cry51Aa2.834_16 protein are documented to have damage to the midgut (Jerga et al. 2016). In a study by Jerga et al. (2016), TPB mortality reached 100% within three days after TPB were fed a diet containing the Cry51Aa2.834_16 protein. Jerga et al. (2016) also observed that TPB had a significant reduction in the anterior section of the midgut when fed the Cry51Aa2.834_16 protein diet. Baum et al. (2012) found that nymph mortality and nymph body mass decreased when the expression of the Cry51Aa2.834_16 protein increased. Akbar et al. (2018) noted that not all life stages of the TPB are equally damaging. Larger nymphs are considered to be more damaging to cotton than smaller nymphs (Greene et al. 1999). With adults having a non-preference to ThryvOn cotton, there is less damage due to reduced feeding and reduced oviposition of TPB in ThryvOn cotton (Graham et al. 2019). These findings are important because TPB are polyphagous insects with piercing and sucking mouthparts, that feed mainly on the squares and bolls of cotton (George et al. 2021). Gowda et al. (2016) found that transgenic cotton expressing the Cry51Aa2.834_16 (i.e., ThryvOn) protein reduced TPB populations up to 30-fold in a caged field trial. The authors also noted that protein accumulation was most abundant in squares, followed by bolls and leaves.

Graham et al. (2019) found more TPB nymphs in non-ThryvOn flowers compared to ThryvOn squares and bolls but found that the trait had no effect on the size of the nymphs. However, other studies found a reduction in the number of large nymphs (4th-5th instars) as well as the total number of nymphs in ThryvOn cotton compared to non-ThryvOn cotton (Bachman et al. 2017, Graham and Stewart 2018, Akbar et al. 2018). In a laboratory test, Graham et al. (2019) noted that the TPB preferred to feed on diet packs and abscised squares that did not contain the ThryvOn protein compared to those that did.

Several studies conducted across the cotton belt have shown less injury from not only TPB, but also another key pest: thrips (*Frankliniella* spp.) in ThryvOn cotton compared to non-ThryvOn cotton (Graham and Stewart, 2018, Bachman et al. 2017, Whitfield, 2023). Bachman et al. (2017) reported high thrips pressure and injury in a non-ThryvOn variety compared to a ThryvOn variety. Graham et al. (2019) documented lower populations of adult thrips in ThryvOn cotton compared to non-ThryvOn cotton. Similarly, Farmer et al. (2025) found reduced number of thrips in ThryvOn cotton compared to non-ThryvOn cotton, where the ThryvOn non-treated plots had similar numbers of thrips populations as the non-ThryvOn plots treated with the trial's best at-plant insecticide, aldicarb (AgLogic 15GG, AgLogic Chemical, Chapel Hill, NC). Regardless of insect pressure levels, Yates-Stewart et al. (2023) observed a greater reduction in the number of immature thrips in ThryvOn cotton compared to the non-ThryvOn control cotton, while the reduction in the number of adults were variable. Yates-Stewart et al. (2023) also noted that the ThryvOn cotton had less thrips damage than the non-ThryvOn cotton in all cases. Lawton et al. (2025) found significantly fewer

adult thrips in ThryvOn cotton compared to non-ThryvOn cotton, regardless of at-plant insecticide used. Our objectives for this study were to evaluate how low- and high-input insecticide programs influence TPB populations, plant injury, and yield in ThryvOn and non-ThryvOn cotton under large-plot field conditions.

The objective of this study was to evaluate management strategies of TPB on ThryvOn and non-ThryvOn cotton.

Materials and Methods

Research was conducted at the Tennessee Valley Research and Extension Center (TVREC) near Belle Mina, AL in 2023 and 2024. A ThryvOn variety (DP 2131 B3XTF) and a non-ThryvOn variety (DP 2038 B3XF) were planted on 17 May 2023 and 8 May 2024. The study consisted of non-replicated strips 8 rows by 175 ft long.

Insecticide treatments of 2023 (Table 2.1) and 2024 (Table 2.2) consisted of low input systems ('economic' insecticides, reduced insecticide rates, etc.), high input systems (full rates of insecticides, tank-mixtures, etc.), and no insecticide inputs for each variety.

Insect populations were quantified throughout the growing season using various sampling methods. Within each insecticide input, samples were replicated in four areas (plots) distributed across each plot and a minimum of 40 feet apart. Cotton was scouted weekly beginning at the pinhead square stage through cutout (five nodes above white flower) (Oosterhuis, 1992). Prior to bloom, pinhead square retention was monitored by examining the first position fruiting site on the top two nodes, excluding the terminal node, of plants until 25 sites were examined in each plot. The number of retained squares was recorded. A square was considered damaged if it was missing or if it abscised when touched or the bracts were flared. TPB densities were determined by

making 25 sweeps with a 38.1-cm diameter sweep-net in each plot. At the initiation of bloom, TPB densities were determined using a black drop cloth. The drop cloth was laid between two rows of cotton, and each row was shaken vigorously to dislodge any insects on plants. One sample resulted in 1.52 m of row being sampled. Two drop cloth samples were done between the center 2 rows of each plot, for a total of 3.04 m of row sampled. Tarnished plant bug nymphs were classified as either small (1-3 instar) or large (4-5 instar). The number of dirty blooms per 10 flowers were also counted. Flowers were considered injured (dirty) if anthers were black or brown or if yellow staining was observed on the surface of the flower. Due to the lack of data available on ThryvOn efficiency on stink bugs, 15 quarter-sized (≈ 1 inch diameter) bolls were sampled from each plot for internal boll damage as a scouting method for stink bugs. First position retention was obtained during the first week of bloom along with other agronomic counts, such as node of first fruiting branch, total node counts and plant heights. The center two rows of each plot were harvested to obtain yield, and lint was estimated at 40% turnout. Yield was not replicated in 2023 due to miscommunication; therefore, the entire 175 ft was harvested in 2 passes. In 2024 plots were divided into 5 blocks (30 ft) to allow for replication.

Sample date was excluded from the analysis because insecticide applications were triggered independently within each treatment based on TPB incidence, resulting in non-comparable treatment conditions across dates. Including sample date would have confounded treatment effects with insecticide timing, following the guidance of Blouin et al. (2011), who note that only factors corresponding to valid experimental units should be included in combined analyses. Thus, season-long responses (square

retention, TPB densities from sweep-net and drop-cloth sampling, dirty blooms, and internal boll injury) were pooled across sample dates to quantify the overall effect of each management strategy. Additionally, the number of insecticide applications was evaluated by analyzing preboom sprays, bloom sprays, and total seasonal sprays separately.

All data were analyzed using a linear mixed model in PROC GLIMMIX (SAS 9.4). Variety (ThryvOn vs. non-ThryvOn) and insecticide input level (no, low, and high input) were treated as fixed effects. Year, replication and replication nested within year were treated as random effects to allow inference across environments, consistent with recommendations for multi-environment experiments from Blouin et al. (2011). Degrees of freedom were estimated using the Kenward–Roger method. Means were obtained using LSMEANS and separated using Fisher’s protected LSD at $\alpha = 0.05$, following the mean-comparison framework described by Carmer et al. (1989).

Results

High thrips pressure in 2023 delayed crop maturity by 5 days. For the 2024 season, aldicarb was used to eliminate similar maturity delays. Prior to bloom, there were no significant differences in square retention across either insecticide treatment ($F = 0.91$; $df = 2, 93$; $p = 0.4063$), variety ($F = 3.40$; $df = 1, 93$; $p = 0.0683$), or their interaction ($F = 2.40$; $df = 2, 93$; $p = 0.0959$). Square retention was maintained above threshold (80%) throughout the pre-bloom window. Similarly, there were no differences in the number of adult TPB within insecticide ($F = 0.43$; $df = 2, 111$; $p = 0.6491$), variety ($F = 0.05$; $df = 1, 111$; $p = 0.8259$), or their interaction ($F = 0.42$; $df = 2, 111$; $p = 0.6610$) during the pre-bloom stage (Table 2.3).

For agronomic data, there was no significant difference in total nodes by insecticide ($F = 1.21$; $df = 2, 35$; $p = 0.3109$), variety ($F = 0.00$; $df = 1, 35$; $p = 1.0000$), or their interaction ($F = 1.37$; $df = 2, 35$; $p = 0.2668$). Similarly, there was no significant difference in plant heights by insecticide ($F = 0.82$; $df = 2, 39$; $p = 0.4496$), variety ($F = 0.13$; $df = 1, 39$; $p = 0.7158$), or their interaction ($F = 1.72$; $df = 2, 39$; $p = 0.1930$). There were no significant differences in node of first fruiting branch by insecticide ($F = 0.12$; $df = 2, 35$; $p = 0.8885$), variety ($F = 0.297$; $df = 1, 35$; $p = 0.0939$), or their interaction ($F = 1.70$; $df = 2, 35$; $p = 0.1974$). However, first position retention was significantly different between variety ($F = 15.41$; $df = 2, 35$; $p = 0.0004$) with DP2131B3XTF retaining over 88% of the bolls (Table 2.3).

The average number of TPB observed during bloom was significantly different for insecticide ($F = 4.70$; $df = 2, 67$; $p = 0.0123$) and variety ($F = 13.02$; $df = 1, 67$; $p = 0.0006$), but not their interaction ($F = 0.01$; $df = 2, 67$; $p = 0.9852$). Fewer TPB were found in the ThryvOn variety (2.63 ± 0.59) compared to the non-ThryvOn variety (5.93 ± 0.93). There was a 37% increase in control where we used low input insecticide systems, and a 54% increase in the high input insecticide systems, as compared to the non-treated control. The number of small TPB nymphs was significantly different by variety ($F = 10.75$; $df = 1, 67$; $p = 0.0017$), but not by insecticide ($F = 3.09$; $df = 2, 67$; $p = 0.0519$) or their interaction ($F = 0.67$; $df = 2, 67$; $p = 0.5155$). The number of large TPB nymphs was also significantly different by variety ($F = 6.15$; $df = 1, 67$; $p = 0.0157$), where there were fewer small and large nymphs in the ThryvOn variety compared to the non-ThryvOn variety (Table 2.4).

There was an interaction of variety and insecticide for bloom damage ($F = 6.76$; $df = 2, 67$; $p = 0.0021$) and boll damage ($F = 3.48$; $df = 2, 67$; $p = 0.0366$). The non-ThryvOn non-treated cotton had significantly more bloom damage (59.6 ± 0.47) compared with the ThryvOn cotton and the insecticide systems. Boll damage in the ThryvOn high input cotton (18.3 ± 0.50) was significantly less than all other treatments. (Table 5). There was no significant difference in yield for variety ($F = 0.48$; $df = 1, 20$; $p = 0.4985$) or an interaction between variety and insecticide ($F = 3.23$; $df = 2, 20$; $p = 0.0607$). However, insecticide did impact yield ($F = 4.62$; $df = 2, 20$; $p = 0.0225$), with significantly less yield in the non-treated control (868.2 ± 79.0) as compared to the low input system (1061.5 ± 73.0) and high input system (1146.3 ± 61.7) (Table 2.5).

The number of insecticide applications required to manage TPB throughout the season was significantly impacted by variety ($F = 22.09$; $df = 1, 21$; $p = 0.0001$). Prior to bloom, more applications were made in the ThryvOn cotton (3.0 ± 0.0) than non-ThryvOn cotton (1.8 ± 0.2). During bloom, more applications were made in non-ThryvOn cotton (3.0 ± 0.2) than ThryvOn cotton (1.0 ± 0.0). Overall, significantly more sprays were needed in non-ThryvOn cotton (4.8 ± 0.2) compared to the ThryvOn cotton (4.0 ± 0.0).

Discussion

Overall, ThryvOn cotton significantly impacted TPB populations and injury compared to a non-ThryvOn variety, while yield was driven by insecticide applications regardless of trait background. Prior to bloom, square retention remained above threshold (80%) across all insecticide inputs and varieties. While not significant ($p=0.0683$), ThryvOn cotton tended to have higher square retention than non-ThryvOn

cotton in our study. This agrees with Houni et al. (2025) and Whitfield (2023) who found generally higher square retention in ThryvOn cotton compared to non-ThryvOn cotton.

Our study showed no differences in plant height between the ThryvOn and non-ThryvOn varieties at first bloom, disagreeing with Permenter et al. (2025) who observed taller plants in ThryvOn cotton compared to non-ThryvOn cotton during late bloom. This could be explained by a difference in the non-ThryvOn variety in our study (DP 2038 B3XF) and the one used by Permenter et al. (2025) (DP 2055 B3XF), while both studies used DP 2131 B3TXF for the ThryvOn variety. We also saw no differences in total node counts or node of first fruiting branch. However, in our trial, first position retention was significantly different between variety, with the ThryvOn cotton retaining first position fruit (93%) more than the non-ThryvOn cotton (75%) at first bloom. This result was interesting, because we did not observe differences in square retention during the pre-bloom window. A similar observation was made by Huoni et al. (2025), who attributed this shift to the way square loss accumulates as the plant develops. Older damage is covered by the development of new nodes and squares, which form every ~3 days (Ritchie et al. 2007), making differences between varieties more apparent as squaring progresses. By first bloom, node-specific scouting methods tended to underestimate whole-plant damage, allowing true differences in injury to surface. These findings document the importance of monitoring whole plant retention occasionally during the season, as more square loss than anticipated may be observed, as early set squares tend to provide significant portions of yield. Oosterhuis (1990) noted the importance of fruiting positions on fruiting branches, with first position bolls contributing approximately 60% of the total seedcotton yield, agreeing with Jenkins et al. (1990) who noted 66 to

75% of the total lint yield produced from first position bolls. First position bolls have greater lint quality than bolls further from the mainstem (Oosterhuis, 1990). Our trial suggests that ThryvOn cotton retains greater “money bolls” (Pitman, 2000) with greater fiber quality than non-ThryvOn cotton.

During bloom, overall TPB populations differed by insecticide and variety but not their interaction. Foliar programs reduced TPB relative to the non-treated control by 37% (low input) and 54% (high input). Similar trends were observed for bloom and boll damage. Total (55%), small (70%), and large (48%) nymph populations were significantly lower in ThryvOn cotton than non-ThryvOn. These results support previous reports (Graham and Stewart 2018, Whitfield et al. 2022) that found ThryvOn cotton reduced immature plant bugs (especially large) and provided some level of protection from injury. Our lower TPB densities and injury in ThryvOn cotton are consistent with the behavioral deterrence documented for ThryvOn cotton; adults exhibit reduced feeding and host acceptance of ThryvOn plants (Graham et al. 2019). Additionally, we saw no differences in boll damage between ThryvOn (38%) and non-ThryvOn (42%) varieties, which was expected because ThryvOn has not been documented to impact stink bugs in the field (Vyavhare and Kerns, 2024).

In this study, lint yield was driven by insecticide program, not by ThryvOn trait. Across varieties, cotton treated for plant bugs (low and high inputs) out-yielded non-treated cotton across varieties. Within varieties, non-ThryvOn cotton lint yield increased stepwise with inputs (none < low < high), whereas ThryvOn cotton lint yield was numerically higher in the low-input program, reinforcing that TPB management is more important than ThryvOn alone for yield effects. These findings were consistent with

Graham and Stewart (2018) who found that ThryvOn cotton reduces TPB injury and nymphs compared to non-treated ThryvOn cotton but still benefits from timely insecticide applications to preserve yield. Another study found that ThryvOn cotton required fewer TPB insecticide applications and sometimes showed little yield separation among spray regimes, while non-ThryvOn cotton gained more yield protection from foliar sprays (Whitfield et al. 2022). Our trials found that more TPB insecticide applications were made on the ThryvOn cotton during pre-bloom (3.0) and fewer applications in the ThryvOn during bloom (1.0), compared to non-ThryvOn cotton. Overall, ThryvOn cotton required approximately 20% fewer applications across both years (4.0) than the non-ThryvOn cotton (4.8). These findings are consistent with both Graham and Stewart (2018) and Lipsey (2024), who found that ThryvOn plots required fewer insecticide applications to control TPB than the non-ThryvOn plots. Though ThryvOn does help reduce TPB feeding, the technology does not prevent TPB feeding completely. Insecticide applications will still be required to control TPB populations, though the number of timeliness sprays can potentially be reduced with the adoption of ThryvOn technology. With the ability to not only reduce the number of plant bug applications, but also potentially eliminate thrips applications, ThryvOn technology proves to be beneficial for growers by saving on input costs from cotton in the seedling stage that is susceptible to thrips, all the way to TPB pressure in throughout the growing season.

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Figures and Tables

Table 2.1. Insecticide application date and insecticide rate for each input system at TVREC near Belle Mina, AL during 2023.

Variety and Treatment	Date 1	Application 1	Date 2	Application 2	Date 3	Application 3	Date 4	Application 4	Date 5	Application 5
DP 2038 B3XF Low	18- Jul	0.5 lb Acephate	25- Jul	1.7 oz Imidacloprid + 0.5 lb Acephate	11- Aug	0.5 lb Acephate	23- Aug	4 oz Bidrin	-	-
DP 2131 B3XTF Low	28- Jun	1.7 oz Imidacloprid	12- Jul	1.7 oz Imidacloprid	18- Jul	0.5 lb Acephate	31- Jul	0.75 lb Acephate	-	-
DP 2038 B3XF High	12- Jun	2 oz Centric	18- Jul	1.5 oz Transform + 6 oz Diamond	31- Jul	6 oz Bidrin + 6 oz Diamond	11- Aug	0.75 lb Acephate	-	-
DP 2131 B3XTF High	28- Jun	2 oz Centric	12- Jul	2 oz Centric	18- Jul	1.5 oz Transform + 6 oz Diamond	31- Jul	6 oz Bidrin + 6 oz Diamond	-	-

Table 2.2. Insecticide application date and insecticide rate for each input system at TVREC near Belle Mina, AL during 2024.

Variety and Treatment	Date 1	Application 1	Date 2	Application 2	Date 3	Application 3	Date 4	Application 4	Date 5	Application 5
DP 2038 B3XF Low	21-Jun	1.7 oz Imidacloprid	28-Jun	1.7 oz Imidacloprid	3-Jul	0.5 lb Acephate	1-Aug	0.75 lb Acephate	9-Aug	0.67 lb Acephate
DP 2131 B3XTF Low	21-Jun	1.7 oz Imidacloprid	3-Jul	0.5 lb Acephate	1-Aug	0.75 lb Acephate	-	-	-	-
DP 2038 B3XF High	21-Jun	2 oz Centric	3-Jul	1.5 oz Transform + 6 oz Diamond	-	-	1-Aug	6 oz Bidrin + 6 oz Diamond	9-Aug	0.75 lb Acephate + 6.4 oz Bifenthrin
DP 2131 B3XTF High	21-Jun	2 oz Centric	3-Jul	1.5 oz Transform + 6 oz Diamond	-	-	1-Aug	6 oz Bidrin + 6 oz Diamond	9-Aug	0.75 lb Acephate + 6.4 oz Bifenthrin

Table 2.3. Pre-Bloom square retention, adult plant bugs populations, and agronomic counts (first position retention, node of first fruiting branch, total node counts, and plant heights) for ThryvOn (DP2131 B3XTF) and non-ThryvOn (DP2038 B3XF) cotton treated with various input levels of insecticides at TVREC near Belle Mina, AL during 2023 and 2024.

Variety	Input Level	Square Retention (%)	# Adult TPB (per 25 sweeps)	% First Position Retention	Node of First Fruiting Branch	Total Node Counts	Plant Heights (cm)
DP2038 B3XF	None	87.5 AB ^z	4.6 A	81.2 ABC (0.07)	7.0 AB (0.65)	15.4 A (0.78)	37.6 A (4.07)
	Low	84.0 AB	4.0 A	70.3 C (0.07)	6.5AB (0.42)	14.3 A (0.49)	30.0 A (2.31)
	High	87.0 AB	3.7 A	73.4 BC (0.09)	7.5 A (0.38)	14.9 A (0.55)	34.0 A (1.40)
DP2131 B3XTF	None	90.1 A	3.8 A	95.9 A (0.03)	6.3 AB (0.25)	15.1 A (0.61)	35.3 A (3.78)
	Low	90.1 A	4.6 A	87.7 AB (0.05)	6.8 AB (0.41)	15.1 A (0.64)	37.1 A (3.18)
	High	85.8 A	3.6 A	95.0 A (0.03)	6.1 B (0.48)	14.3 A (0.59)	31.9 A (1.73)

^zMeans within the column that are followed by the same letter are not different according to Fisher's Protected LSD ($\alpha = 0.05$).

Table 2.4. Average number of thrips per five plants during bloom for ThryvOn (DP2131 B3XTF) and non-ThryvOn (DP2038 B3XF) cotton treated with various input levels of insecticides at TVREC near Belle Mina, AL during 2023 and 2024.

Variety	Small Nymphs (1-2 instar)	Large Nymphs (3-5 instar)	Total TPB
DP2038 B3XF	1.29 A ^z (0.27)	3.96 A (0.76)	5.93 A (0.93)
DP2131 B3XTF	0.37 B (0.14)	2.06 B (0.53)	2.63 B (0.59)

^zMeans within the column that are followed by the same letter are not different according to Fisher's Protected LSD ($\alpha = 0.05$).

Table 2.5. Tarnished plant bug damaged blooms (number of dirty blooms out of 10 blooms), boll damage (number of damaged bolls out of 15 bolls), and yield for ThryvOn (DP2131 B3XTF) and non-ThryvOn (DP2038 B3XF) cotton treated with various input levels of insecticides at TVREC near Belle Mina, AL during 2023 and 2024

Variety	Input level	Bloom damage (%)	Boll damage (%)	Lint cotton yield (lb/A)
DP2038 B3XF	None	59.6 A ^z (0.47)	29.8 AB (0.56)	783 C (86.41)
	Low	23.8 B (0.26)	27.5 ABC (0.75)	954 BC (53.62)
	High	20.6 B (0.45)	27.9 ABC (0.50)	1260 A (16.78)
DP2131 B3XTF	None	20.4 B (0.58)	38.7 A (0.73)	953 BC (130.44)
	Low	11.3 B (0.26)	20.3 BC (0.87)	1169 AB (123.82)
	High	25.0 B (0.96)	18.3 C (0.50)	1033 ABC (88.46)

^zMeans within the column that are followed by the same letter are not different according to Fisher's Protected LSD ($\alpha = 0.05$).

Title

Evaluating the Impact of Starter Fertilizer and Soil Temperature on Thrips Management in ThryvOn Cotton

Abstract

Thrips, (*Frankliniella* spp.), are a key pest of seedling cotton throughout the Southeast. This study evaluated the impact of starter fertilizer and soil temperature on thrips management in ThryvOn and non-ThryvOn cotton. Field experiments were conducted in 2024 and 2025 at the Tennessee Valley Research and Extension Center in Belle Mina, AL, using a ThryvOn variety (DP2211 B3XTF) and a non-ThryvOn (DP2127 B3XF) variety planted at 4 planting dates based on soil temperature (55, 60, 65, and 70°F) with or without ammonium polyphosphate (10-34-0) fertilizer. Seedling data collection included stand counts, vigor and thrips injury ratings, and thrips population estimates were done at the 2nd and 4th true leaf stages. Plant heights and fresh shoot weights were obtained when the cotton began squaring, and lint yield was quantified from the center two rows of each plot. Vigor, thrips injury, thrips populations, and fresh shoot weight were each impacted by variety and soil temperature. Plant heights and yield were only influenced by soil temperature. The results demonstrate that ThryvOn technology and soil temperature both contribute to thrips pressure and plant growth; however, starter fertilizer has no impact on thrips management or any yield. Ultimately, soil temperature was the only yield limiting factor.

Keywords

Cotton, ThryvOn, Thrips

Introduction

Upland Cotton, *Gossypium hirsutum*, is a major contributor to Alabama's agricultural economy. Alabama was ranked 7th nationally in the 2025 growing season, harvesting 285,00 total acres and producing 1011 lbs per acre of cotton (USDA, NASS 2025). Cotton is grown through the state of Alabama with the majority of the crop

produced in the Tennessee River Valley of northwest Alabama and Wiregrass Region of southeast Alabama (USDA, NASS 2023). In an attempt to improve early season growth and development, some growers throughout the southeast have found that the use of starter fertilizer can be beneficial, especially for early planted cotton (Touchton et al. 1986). The use of P-containing starter fertilizer, such as ammonium polyphosphate (10-34-0), are an adequate source of phosphorus for cotton planted in cool environmental conditions (Bednarz et al. 2000, Collins and Edmisten 2025). The use of starter fertilizer can occasionally aid in seedling vigor (Collins and Edmisten, 2025) and result in greater early season biomass (Toews et al. 2012). Gatiboni and Hardy (2023) note that starter fertilizers can enhance early season growth, promote earlier fruiting, and increase yields. Bednarz et al. (2000) found that yield only increased where a starter fertilizer was used when the crop experienced cool weather immediately after planting. Other studies show no benefit of starter fertilizers in regard to yield (Toews et al. 2012, Egbedi et al. 2020).

Thrips are a consistent and economically important pest of seedling cotton throughout the US Cotton Belt (Cook et al. 2011). Thrips feed on leaf epidermal cells using rasping and sucking mouthparts (Cook et al. 2011). Symptoms of thrips feeding include a silvery and dry appearance, curling of leaf edges (“cupping”), malformation and tearing of leaves, and even injury or death to the apical meristem (Cook et al. 2011, Telford and Hopkins 1957, Reed and Reinecke 1990). Thrips management consists of the use of at-plant insecticides, either seed-applied or in-furrow (Lawton et al. 2025). Effective at-plant insecticides to control thrips include in-furrow applications of aldicarb, acephate, and imidacloprid, as well as seed treatments such as acephate, imidacloprid,

and thiamethoxam (Cook et al. 2011, Crow et al. 2018, Lawton et al. 2025). In addition to insecticides as a standard control option for thrips, a new trait technology also provides adequate thrips control.

In 2023, a new trait, ThryvOn, was commercially introduced by Bayer CropScience (St. Louis, MO). ThryvOn consists of a new *Bt* protein, Cry51Aa2.834_16 that has insecticidal activity against thrips and tarnished plant bug (Graham and Stewart, 2018). ThryvOn is the first *Bt* crop to target any sucking pest (Yates-Stewart et al. 2023). Several studies have shown significantly less thrips densities in ThryvOn cotton compared to non-ThryvOn cotton (Graham and Stewart 2018, Whitfield 2023, Lawton et al. 2025, Lee et al. 2026,). ThryvOn has also been shown to reduce oviposition in thrips (*Frankliniella fusca* (Hinds) by 65% (Graham et al. 2019, Huseeth et al. 2019, Yates-Stewart et al. 2023). In a study by Whitfield (2023), thrips were shown to prefer non-ThryvOn cotton over non-ThryvOn in a controlled environment. Thrips preference to ThryvOn cotton directly correlates with thrips injury, where there is greater plant damage in the non-ThryvOn cotton in which thrips prefer (Graham et al. 2018, Whitfield 2023).

The objective of this study was to evaluate how soil temperature at-planting and the use of starter fertilizer influence thrips pressure, plant growth and yield in ThryvOn and non-ThryvOn cotton.

Materials and Methods

Experiments were conducted at the Tennessee Valley Research and Extension Center in Belle Mina, AL (2024-25), the Coastal Plain Station in Tifton, GA (2024-25), and the Delta Research Extension Center in Stoneville, MS (2024), to evaluate the

impact of starter fertilizer and planting date on thrips management in ThryvOn and non-ThryvOn cotton. Treatments were arranged in a split-split-plot experimental design within a randomized complete block with four replications. Main plots consisted of 8 rows that were based on soil temperatures of 55, 60, 65, and 70°F. Sub-plots consisted of 4 rows with or without ammonium polyphosphate (10-34-0) fertilizer that was applied at a rate of 10 gallons per acre in a 2x2 method, placing the nutrients 5 cm to the side and 5 cm below the seed at planting. Sub-sub plots consisted of 2 rows of either a ThryvOn variety (DP2211 B3XTF) or a non-ThryvOn (DP2127 B3XF) variety provided by Bayer CropScience. Cotton was planted when the soil temperature 0-10 cm below the soil surface averaged the target temperature for a 5-day period. Prior to planting, seed were treated with standard commercial rates of an insecticide seed treatment (Gaucho 600; Bayer CropScience, St. Louis, MO) and fungicide seed treatment (Trilex Advanced; Bayer CropScience, St. Louis, MO). Cotton was planted at the recommended seeding rate for each location.

Stand counts were made approximately 15 days after planting (DAP) by counting the total number of plants in 18 row feet and converted to number of plants per acre. Thrips injury ratings, vigor ratings, and thrips population densities were evaluated at the 2nd and 4th true leaf stage. Thrips injury was evaluated on a 0-5 scale, following the methods of Kerns et al. (2019), where 0 was no thrips injury and 5 was death of the plant terminal. Whole plot vigor was evaluated on a 0-10 scale, with 0 being no living plants and 10 being maximum vigor. Thrips populations were collected by obtaining 5 plants per plot and placing into a jar of 70% ethyl alcohol. Thrips were collected from the sampled plants using the wash and sieve method as described by Graham and Stewart

(2018) and were further categorized as adult or immature. Plant heights were obtained from 10 random plants per plot at the beginning of squaring, measuring from the soil line to the upper most expanded leaf. 5 plants per plot were clipped at the soil line and weighed to obtain fresh shoot weights 30 DAP. Both rows of each plot were harvested to obtain yield. Lint was estimated at 40% turnout, which is representative of a commercial cotton gin (Mulvaney et al. 2021).

In order to evaluate the overall impact of each factor, vigor ratings, thrips injury ratings and thrips populations estimates were analyzed across all sample dates. All data were analyzed using a linear mixed model in PROC GLIMMIX of SAS (Version 9.4, SAS Institute, Cary, NC). Soil temperature, fertilizer, variety and their interactions were considered fixed effects in the model. Year, location, year by location and replication nested within year by location were designated as random effects to allow for inferences to be made over a range of environments (Carmer et al. 1989, Blouin et al. 2011). Degrees of freedom were estimated using the Kenward–Roger method (Kenward and Roger 2009). Means were obtained using LSMEANS and separated using Fisher's protected least significance difference (LSD) ($\alpha = 0.05$). Only significant interactions are discussed; non-significant two- and three-way interaction are omitted for clarity. Due to weather impacts, the only data included from the Mississippi location was yield.

Results

Stand. There was no significant difference in plant population per acre between variety ($F = 0.56$; $df = 1, 169$; $p = 0.4552$), fertilizer ($F = 0.36$; $df = 1, 169$; $p = 0.5476$), soil temperature ($F = 1.22$; $df = 3, 169$; $p = 0.3043$).

Vigor. There was a significant difference in plant vigor between variety ($F = 60.83$; $df = 1, 393$; $p < 0.0001$) and soil temperature ($F = 9.32$; $df = 3, 393$; $p < 0.0001$), but not fertilizer ($F = 0.95$; $df = 1, 393$; $p = 0.3306$). ThryvOn cotton had significantly greater vigor (8.0 ± 0.1) compared to the non-ThryvOn cotton (7.2 ± 0.1). The 70°F soil moisture plots had significantly greater vigor (8.0 ± 0.1) than all other treatments (Table 3.1).

Thrips injury. There was a significant difference in thrips injury between variety ($F = 499.85$; $df = 1, 425$; $p < 0.0001$), soil temperature ($F = 9.00$; $df = 3, 425$; $p < 0.0001$), and their interaction ($F = 9.33$; $df = 3, 425$; $p < 0.0001$). The non-ThryvOn cotton had significantly more thrips injury (2.2 ± 0.06) than the ThryvOn cotton (0.8 ± 0.04). The 70°F soil moisture plots had significantly less injury (1.2 ± 0.07) than all other soil temperatures. There was no impact of fertilizer ($F = 1.64$; $df = 1, 425$; $p = 0.2017$) on thrips injury (Table 3.1).

Immature thrips populations. There was a significant difference in the number of immature thrips between variety ($F = 76.80$; $df = 1, 440$; $p < 0.0001$), soil temperature ($F = 13.04$; $df = 3, 440$; $p < 0.0001$), and their interaction ($F = 5.29$; $df = 3, 440$; $p = 0.0014$). The non-ThryvOn cotton had significantly more immature thrips (14.7 ± 1.3) than the ThryvOn cotton (4.1 ± 0.3). The 60°F soil moisture plots had significantly more immature thrips (15.22 ± 1.8) than the 65°F (9.2 ± 1.6) and 55°F (8.7 ± 0.9) soil temperatures, with the least amount in the 70°F (4.5 ± 0.7) soil temperature. There was no impact of fertilizer ($F = 0.04$; $df = 1, 440$; $p = 0.8374$) on thrips injury (Table 3.1).

Adult thrips populations. There was a significant difference in the number of adult thrips between variety ($F = 47.42$; $df = 1, 440$; $p < 0.0001$) and soil temperature (F

= 4.27; df = 3, 440; p = 0.0055), but not fertilizer (F = 0.01; df = 1, 440; p = 0.9304) or their interaction (F = 1.02; df = 3, 440; p = 0.3823). The non-ThryvOn cotton had significantly more adult thrips (6.9 ± 0.6) than the ThryvOn cotton (2.7 ± 0.2). The 60°F soil moisture plots had significantly more adult thrips (6.3 ± 0.6) than the 65°F (5.3 ± 0.5) and 55°F (4.4 ± 0.8) soil temperatures, with the least amount in the 70°F (3.3 ± 0.4) soil temperature (Table 3.1).

Total thrips populations. There was a significant difference in the total number of thrips between variety (F = 98.15; df = 1, 441; p < 0.0001), soil temperature (F = 14.12; df = 3, 441; p < 0.0001), and their interaction (F = 5.11; df = 3, 441; p = 0.0017). The non-ThryvOn cotton had significantly more total thrips (21.6 ± 1.6) than the ThryvOn cotton (6.8 ± 0.4). The 60°F soil moisture plots had significantly more thrips (21.5 ± 2.1) than the 65°F (14.5 ± 2.0) and 55°F (12.9 ± 1.3) soil temperatures, with the least amount in the 70°F (7.9 ± 1.0) soil temperature. There was no impact of fertilizer (F = 0.02; df = 1, 441; p = 0.8758) on thrips injury (Table 3.1).

Fresh shoot weight. There was a significant difference in fresh shoot weight between variety (F = 13.46; df = 1, 169; p = 0.0003) and soil temperature (F = 19.37; df = 3, 169; p < 0.0001), but not fertilizer (F = 1.88; df = 1, 169; p = 0.1717). ThryvOn cotton had significantly greater fresh shoot weight (31.9 ± 2.1) compared to the non-ThryvOn cotton (25.6 ± 1.6). The 65°F soil temperature plots had the greatest fresh shoot weight (37.6 ± 3.5) with significant reductions in the 60°F (27.9 ± 2.5) and 70°F (30.4 ± 2.0), which were greater than plants in the 55°F (19.1 ± 1.8) (Table 3.2).

Plant height. There was a significant difference in plant height between soil temperature (F = 9.43; df = 3, 217; p < 0.0001), but not variety (F = 1.72; df = 1, 217; p

= 0.1916) or fertilizer ($F = 0.33$; $df = 1, 217$; $p = 0.5692$). The 70°F soil temperature had significantly greater plant height (27.0 ± 2.8) than all other soil temperatures (Table 3.2).

Yield. There was a significant difference in yield between soil temperature ($F = 5.22$; $df = 3, 274$; $p = 0.0016$), but not variety ($F = 0.12$; $df = 1, 274$; $p = 0.7312$) or fertilizer ($F = 0.67$; $df = 1, 274$; $p = 0.4123$). The 55°F soil temperature plots had significantly greater yield (1197.1 ± 35.7) than the 70°F (1043.6 ± 39.5) soil temperature, with the 60°F (1186.2 ± 32.7) and 65°F (1112.4 ± 31.7) soil temperatures having similar yields (Table 3.2).

Discussion

Soil temperature and ThryvOn cotton significantly influenced thrips populations and early season plant responses in this study, while the use of starter fertilizer had no measurable impact on any data collected. Across years and locations, ThryvOn cotton consistently reduced thrips injury and populations relative to non-ThryvOn cotton, documenting this trait provides good control regardless of early season environmental conditions.

The lack of response to starter fertilizer we observed agrees with other findings that starter fertilizer provides inconsistent benefits and are likely dependent on cool soil conditions combined with phosphorus deficiency (Bednarz et al. 2000, Toews et al. 2012, Egbedi et al. 2020). In our study, starter fertilizer did not improve stand establishment, vigor, thrips injury or yield at any soil temperature, suggesting that under the soil fertility conditions evaluated, starter fertilizer did not provide any agronomic benefits. This further supports Extension recommendations that starter fertilizer should

only be in specific cases, such as nutrient limitations and poor environmental conditions at-planting.

ThryvOn cotton had significantly lower thrips injury and thrips populations compared to the non-ThryvOn cotton across all soil temperatures. Reductions in thrips populations were particularly high ($\approx 70\%$), consistent with other research showing that ThryvOn suppresses thrips reproduction and oviposition, rather than relying only on direct mortality (Graham et al. 2019, Huseeth et al. 2020, Yates-Stewart et al. 2023). Our results agree with other studies documenting significantly greater thrips pressure in non-ThryvOn varieties compared to ThryvOn (Graham and Stewart 2019, Whitfield 2023, Lawton et al. 2025, Lee et al. 2026).

Soil temperature strongly impacted thrips populations, with the greatest immature populations, adult populations, and total thrips populations observed at the 60°F soil temperature the lowest thrips populations consistently found at 70°F. This is consistent with other findings that showing that cooler planting conditions are associated with higher thrips colonization and injury, while warmer planting conditions favor faster plant development, which reduces the susceptibility of cotton seedlings to thrips injury (Kerns et al. 2019). Reduced thrips pressure under warmer soil temperatures is likely due to increased cotton growth and development under these conditions (Morsello et al. 2008).

Despite reduced thrips injury and populations, yield was lowest at the 70°F planting date and highest at the 55°F planting date. This is consistent with Kerns et al. (2020) who reported that later planting dates corresponded with less thrips pressure, but not necessarily higher yields. Other factors outside of the scope of our data, such as rainfall patterns at key points during cotton growth and development, could be a factor.

Often, thrips injury results in delayed maturity (Cook et al. 2011). These delays may or may not result in yield loss depending on factors throughout the rest of the year. Earlier planted cotton has a long period to compensate for maturity delays than later planted cotton does (Lee et al. 2026).

Starter fertilizer had no impact on any measured variable in this study, which agrees with previous findings showing no yield impact from starter fertilizer use in cotton under similar production systems (Toews et al. 2012, Egbedi et al. 2020). Stand establishment was not affected by variety or soil temperature. Plant height, however, was significantly impacted by both soil temperature and variety, with the tallest plants occurring at 65°F soil temperature and in the ThryvOn cotton. In our seedling cotton, there was no differences in plant populations between variety or soil temperature. This agrees with the findings of Lee et al. (2026), who found significantly greater plant heights in both treated and non-treated ThryvOn cotton and in treated non-ThryvOn cotton compared to non-treated non-ThryvOn cotton. In contrast, fresh shoot weight was influenced by soil temperature, but not variety, aligning with findings from Graham and Stewart (2018), who found no effect of the ThryvOn technology on seedling biomass. We also had significantly greater vigor in the 70°F soil temperature as well as the ThryvOn variety. These results along with other findings (Graham and Stewart 2018, Lee et al. 2026) show that improved seedling growth does not always result in increased yields.

Overall, our findings reinforce the value of ThryvOn cotton for a reliable tool for thrips management across a wide range of planting conditions. While warmer soil temperatures reduced thrips pressure, soil temperature effects on yield were

independent of thrips management. This shows the importance of other factors, such as soil moisture at-planting, on yield. Under the conditions of this study, starter fertilizer did not enhance thrips control, plant growth or yield, suggesting limited value for its use when soils are not nutrient-limited.

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Figures and Tables

Table 3.1. Vigor, thrips injury, and thrips populations (immature, adult, and total) at the 2nd and 4th true leaf stage for ThryvOn (DP2211 B3XTF) and non-ThryvOn (DP 2127 B3XF) cotton planted at various soil temperatures (55, 60, 65, and 70°F).

Variety	Soil Temperature (°F)	Vigor	Thrips Injury (0-5)	Immature Thrips	Adult Thrips	Total Thrips
DP 2127 B3XF	55	6.7 (0.23) D ^z	2.3 (0.11) B	13.6 (1.51) B	6.5 (1.59) A	19.9 (2.28) B
	60	7.2 (0.17) C	2.6 (0.08) A	24.2 (3.05) A	9.2 (1.08) A	33.4 (3.41) A
	65	77.0 (0.23) CD	2.4 (0.12) AB	14.3 (2.92) B	7.3 (0.93) A	21.7 (3.59) B
	70	7.8 (0.12) B	1.7 (0.09) C	6.7 (1.30) C	4.7 (0.69) A	11.5 (1.84) C
DP 2211 B3XTF	55	7.8 (0.13) B	0.9 (0.88) D	3.7 (0.47) C	2.2 (0.26) B	5.9 (0.61) CD
	60	8.0 (0.13) AB	0.7 (0.73) D	6.2 (0.79) C	3.5 (0.43) B	9.7 (0.99) CD
	65	7.9 (0.11) AB	0.9 (0.89) D	4.1 (0.70) C	3.2 (0.38) B	7.3 (0.89) CD
	70	8.3 (0.13) A	0.8 (0.79) D	2.3 (0.24) C	2.0 (0.38) B	4.3 (0.49) D

^zMeans within the column that are followed by the same letter are not different according to Fisher's Protected LSD ($\alpha = 0.05$).

Table 3.2. Plant heights, fresh shoot weights, and yield for ThryvOn (DP2211 B3XTF) and non-ThryvOn (DP 2127 B3XF) cotton planted at various soil temperatures (55, 60, 65, and 70°F) in Alabama and Georgia in 2024 and 2025.

Variety	Soil Temperature (°F)	Fresh Shoot Weight (g)	Plant Height (cm)	Yield (lbs/ac) ^y
DP 2127 B3XF	55	16.9 (2.13) D ^z	17.8 (0.54) B	1186.1 (44.52) AB
	60	23.5 (2.61) CD	17.9 (1.04) B	1175.4 (41.31) AB
	65	33.6 (4.11) B	18.1 (0.99) B	1137.4 (47.62) ABC
	70	28.3 (2.69) BC	26.5 (3.94) A	1020.3 (59.41) C
DP 2211 B3XTF	55	21.3 (2.86) D	20.4 (0.71) B	1208.0 (56.18) A
	60	32.4 (4.10) B	19.8 (1.13) B	1197.0 (51.16) A
	65	41.7 (5.61) A	19.1 (0.81) B	1087.4 (42.13) BC
	70	32.4 (3.05) B	27.5 (4.01) A	1066.8 (52.68) BC

^zMeans within the column that are followed by the same letter are not different according to Fisher's Protected LSD ($\alpha = 0.05$).

^yYield includes Alabama, Georgia and Mississippi locations in 2024 and 2025.

Title

Evaluating the Impact of Peanut Variety and Insecticide on Thrips Management in Nematode Infested Fields

Abstract

Tobacco Thrips (*Frankliniella fusca*) are a key early-season pest of peanut and transmit tomato spotted wilt virus (TSWV), both of which can reduce yield when not managed effectively. This study evaluated the effects of peanut cultivar and at-plant insecticide on thrips injury, TSWV incidence, canopy development, nematode (*Meloidogyne arenaria*) infestation and yield in Alabama from 2023 to 2025. Two cultivars (GA 06-G and GA 12-Y) were planted with four treatments: a non-treated control and at-plant applications of aldicarb (7.8 kg/ha), phorate (5.6 kg/ha), and oxamyl (1.3 L/ha). Thrips injury (0-5), seedling vigor (0-10), fractional green canopy cover, TSWV incidence and nematode population estimates were done at various timings through 56 days after planting (DAP) and yield was collected at the end of the season. At-plant insecticides reduced thrips injury compared to the non-treated control. Seedling vigor was greatest in Georgia-12Y peanuts and where AgLogic was applied. TSWV was greater and fractional green canopy cover was lower in non-treated plots and where GA-06G was used. Peanut root knot nematode egg counts did not differ among treatments. Yield was greater in GA-06G overall and where at-plant insecticides were applied. These results demonstrate that at-plant insecticides contribute to thrips and TSWV suppression and protect yield in Alabama peanut production.

Keywords

Peanut, Thrips, Tomato Spotted Wilt Virus, Nematodes

Introduction

Peanut (*Arachis hypogaea* L.) became a major money crop planted in rotation with cotton, especially when the boll weevil was a widespread concern across the cotton belt (Beattie, 1920). Today, peanut ranks 7th in Alabama's agricultural commodity crops (USDA NASS, 2022). Nationally, Alabama ranks 2nd in peanut production, with 564 million pounds (3000 lb/ac) of peanuts produced in 2024 (USDA NASS, 2025). Peanuts are a major contribution both nationally and locally to the economy, with a farm value of \$1 billion across the U.S. (National Peanut Board).

Thrips (Thysanoptera: Thripidae) are a common pest in multiple crops across the Southeastern U.S., vectoring several Tospovirus diseases. Specifically in peanuts, tobacco thrips (*Frankliniella fusca* Hinds) vector the tomato spotted wilt virus (TSWV). Both larvae and adult thrips can transmit the virus when feeding directly on the plant, causing leaf chlorosis, curling, and yield loss (LaTora et al. 2022), especially when thrips populations are high early in the growing season (Srinivasan et al. 2018). Thrips damage appears as "silvering" on the leaves, which is a result of empty epidermal cells in leaves fed upon by thrips (Srinivasan et al. 2018). Tomato spotted wilt virus induces several symptoms on infected peanut plants, including concentric ring spots, chlorotic patterns, general stunting on plants, and also misshaped pegs and kernels (Srinivasan et al. 2017). These symptoms, at the time of initial appearance, have been correlated with more symptoms earlier in the season incur more severe yield losses compared to plants that show symptoms later in the season (Culbreath et al. 1992, Garcia et al. 2000). Studies show that there is a correlation between thrips populations and TSWV incidence (Garcia et al. 2000, Shrestha et al. 2015). Research from the University of

Georgia shows that for every 1% TSWV incidence in the Georgia-06G variety, yield is reduced by \approx 20 pounds per acre (Abney, 2022).

Several management strategies, including both chemical and cultural practices, can reduce thrips injury and potentially TSWV incidence. Using pre-plant in-furrow insecticides, such as imidacloprid, phorate, and aldicarb are shown to effectively suppress thrips (Marasigan et al. 2015). Marasigan et al. 2015 found that the use of alternative insecticides, including foliar applications of thiamethoxam, spinetoram and cyantraniliprole, were effective at reducing thrips feeding regardless of variety, but injury in plots treated with these alternative insecticides were no different than the non-treated plots. Studies show planting date reduces thrips incidence and TSWV severity (Mahoney et al. 2018, Cooke et al. 2025). Mahoney et al. (2018) observed peanuts planted late had less thrips injury. Cooke et al. (2025) found similar results, with greater thrips injury and TSWV incidence in early planted peanuts compared to late planted peanuts. Variety selection is another important cultural factor in managing TSWV. According to Wright et al. (2016), varieties differ in their resistance to diseases. Branch et al. (2003) noted that TSWV-resistant, runner-type peanut cultivars are the most important defense to control spotted wilt disease. Along with variety selection, Wright et al. (2016) also noted that higher seeding rates reduce TSWV incidence. Though thrips pressure can have a substantial impact on yield, other pests such as nematodes can also impact peanut production.

Nematodes are another significant pest of peanuts in the southeast. Several *Meloidogyne* species have been associated with peanuts, with three major species capable of causing severe yield and quality losses (Minton and Baujard 1990, Dickson

and De Waele 2005), but with *Meloidogyne arenaria* (peanut root-knot nematode) the most predominate and damaging species in Alabama (Hagan et al. 2025). Yield loss due to *M. arenaria* can exceed 50% in highly infested fields (Minton and Baujard, 1990). *Meloidogyne arenaria* juveniles enter the peanut roots, pegs and pods and cause injury to the plant when present in large numbers in a limited area (Minton and Baujard, 1990). Once penetrated into the root tissue, these nematodes induce giant cells that result in malformations known as “galls”, preventing infected roots from adequate nutrient and water uptake (Jones 1981, Dickson and De Waele 2005). Above ground symptoms of *M. arenaria* include stunted plant growth and premature plant death (Starr and Morgan 2002). Infected pegs are often weaker than non-infected pegs and will break off in the soil during harvest, contributing to additional yield loss (Starr and Morgan 2002). Infected pods also contribute to yield quality reductions (Starr and Morgan 2002).

Current nematode management for peanut producers consists of crop rotation, nematode resistant varieties, and nematicide applications, minimizing yield loss to *M. arenaria* (Grabau et al. 2020, Hagan et al. 2025). Crop rotation is one of the oldest and most effective methods of managing diseases caused by nematodes (Rodríguez-Kábana and Canullo, 1992). Planting resistant varieties is less costly than using nematicides and provides greater flexibility than crop rotation (Grabau et al. 2025). Hagan et al. 2025 found that cultivar had a significant impact on *M. arenaria* juvenile populations, but nematicides did not. However, Grabau et al. 2020 found that the use of nematicides such as fluopyram, aldicarb, and 1,3-D can effectively increase yield when nematode pressure is present. Our objectives for this study were to evaluate the impacts of variety and insecticide on thrips management in nematode infested fields.

Methods and Materials

Experimental Design. Experiments were conducted at the Wiregrass Research and Extension Center in Headland, AL from 2023 to 2025 to evaluate the management of tobacco thrips and the transmission of tomato spotted wilt virus. Two peanut varieties, GA-06G and GA-12Y, were planted in late April at a seeding rate of 20 seed per m on 0.9 m rows in four row plots 9.1 m long with four replications. Treatments consisted of a non-treated control, and in-furrow applications of 7.8 kg/ha of Aldicarb (AgLogic, AgLogic Chemical, Chapel Hill, NC), 5.6 kg/ha of Phorate (Thimet, AMVAC Chemical corporation, Newport Beach, CA), and 1.3 l/ha of Oxamyl (Vydate, Corteva Agriscience, Indianapolis, IN).

Data Collection. Stand counts were made 15 days after planting (DAP) by counting the number of plants in the center two rows of each plot. Whole plot seedling vigor and thrips injury ratings were made at 15, 22, and 29 DAP. Vigor was rated on a 0-10 scale where 0 is no vigor and 10 is maximum vigor. Thrips injury was rated on a 0-5 scale as described in Cooke et al. 2025 (Figure 4.1). Percent TSWV incidence was estimated by determining the number of row meters that showed symptoms of TSWV, such as stunted growth, leaf chlorosis or ringspots, divided by the total number of row meters in the middle two rows of each plot at 50 and 56 DAP. Fractional green canopy cover (FGCC) was also obtained at 50 and 56 DAP. FGCC was determined using the Canopeo application on iPhone following the methods described in Cooke et al. 2025.

Additionally, *Meloidogyne arenaria* were collected. Four random, representative plants from each plot were dug up to collect plant and nematode data. Plant parameters included plant height, shoot and root fresh weight. These data were collected between

30 and 45 days after planting across years. After collecting plant parameters, peanut roots were used to obtain nematode population levels. A modified method of Hussey and Barker (1973) was used to extract the root-knot nematode eggs in this study. Roots were weighed and then placed in a 0.625% NaOCl solution and shaken for four minutes on a Barnstead Lab Line Max Q 5000 E Class shaker (Conquer Scientific, San Diego, CA). Roots were then washed with water and rubbed by hand. Eggs were rinsed with tap water, collected on a sieve (25- μ) and poured into a 50mL centrifuge tube, and processed by a modified sucrose centrifugation-flotation at 240 g for 1 minute (Jenkins 1964). The supernatant was collected on a 25- μ sieve, rinsed with water. Eggs were enumerated using a Nikon TSX 100 inverted microscope at 40x magnification. Peanuts were machine harvested on September 19, 2023, and October 2, 2024. Data were subjected to ANOVA and an F-protected Least Significant Difference (LSD, $P < 0.05$) was used to distinguish treatment mean differences using SAS PROC GLIMMIX (PROC GLIMMIX, SAS 9.4; SAS Institute; Cary, NC).

Results

Seedling Health. There were no differences in stand counts between variety ($F = 0.14$; $df = 1, 82$; $p = 0.7140$), treatment ($F = 0.53$; $df = 3, 82$; $p = 0.6625$), or their interaction ($F = 1.07$; $df = 3, 82$; $p = 0.3650$). For seedling vigor, there was a significant difference between variety ($F = 7.83$; $df = 1, 171$; $p = 0.0057$) and treatment ($F = 12.94$; $df = 3, 171$; $p < 0.0001$), but not their interaction ($F = 0.61$; $df = 3, 171$; $p = 0.6096$). Vigor was significantly greater in Georgia-12Y (88.1 ± 0.5) compared to Georgia-06G (86.8 ± 0.4). Peanuts treated with AgLogic (89.1 ± 0.6) and Vydate (88.4 ± 0.6) had

significantly greater vigor than peanuts treated with Thimet (87.1 ± 0.7). Non-treated peanuts had significantly less vigor (85.3 ± 0.6) than all other treatments (Table 4.1).

Thrips. There was a significant difference in thrips injury between treatments ($F = 10.50$; $df = 3, 265$; $p < 0.0001$), but not between variety ($F = 0.147$; $df = 1, 265$; $p = 0.2262$) or their interaction ($F = 0.19$; $df = 3, 265$; $p = 0.9042$). The non-treated peanuts had significantly greater thrips injury (1.9 ± 0.1) than plots treated with Vydate (1.5 ± 0.1), Thimet (1.4 ± 0.1), or AgLogic (1.2 ± 0.1) (Table 4.1).

Tomato Spotted Wilt Virus. There was a significant difference in percent of TSWV incidence between variety ($F = 17.63$; $df = 1, 171$; $p < 0.0001$) and treatment ($F = 5.12$; $df = 3, 171$; $p = 0.0020$), but not their interaction ($F = 0.68$; $df = 3, 171$; $p = 0.5638$). Georgia-06G peanuts had significantly higher percent of TSWV incidence (5.0 ± 0.6) compared to the Georgia-12Y peanuts (2.4 ± 0.4). The non-treated peanuts had significantly greater percent of virus (5.6 ± 1.0) than all other treatments (Table 4.1).

Canopy Data. There was a significant difference in canopy ratings between variety ($F = 9.53$; $df = 1, 76$; $p = 0.0028$) and treatment ($F = 3.80$; $df = 3, 76$; $p = 0.0136$), but not their interaction ($F = 0.48$; $df = 3, 76$; $p = 0.6941$). GA-12Y had significantly higher fractional green canopy closure (46.4 ± 3.1) than GA-06G (39.5 ± 3.4) which was higher than the non-treated peanuts (36.4 ± 4.2) (Table 4.1).

Nematode Data. No differences in root knot nematode eggs per gram of root were observed for variety ($F = 1.78$; $df = 1, 52$; $p = 0.1881$), treatment ($F = 2.39$; $df = 3, 52$; $p = 0.0791$), or their interaction ($F = 0.66$; $df = 3, 52$; $p = 0.5824$) (Table 4.2).

Yield. There was a significant difference in yield between variety ($F = 8.50$; $df = 1, 63$; $p = 0.0049$), and treatment ($F = 7.28$; $df = 3, 63$; $p = 0.0003$) but not their

interaction ($F = 1.15$; $df = 3, 63$; $p = 0.3361$). Yield was significantly greater in Georgia-06G peanuts (4564.9 ± 158.5) compared to the Georgia-12Y peanuts (4033.6 ± 140.2), which was significantly higher than the non-treated check (3600.1 ± 211.9) (Table 4.2).

Discussion

Overall, peanuts that were treated with an at-plant insecticide were healthier, with less thrips injury and virus, ultimately producing greater yields than untreated peanuts. Though variety did have an impact in some of the data collected, yield was driven by insecticide application. In our trials, plant populations were similar across treatments and varieties. Zurweller et al. (2023) found that planting date and variety had an impact on plant population, while insecticide treatment did not affect plant stand. Our data also indicated that untreated peanuts had less vigor than those treated with an at-plant insecticide. This agreed with Moor et al. (2021) who observed increased plant vigor when an insecticide was used.

Previous research has documented a clear relationship between thrips abundance and TSWV incidence (Garcia et al. 2000, Shrestha et al. 2015). Although we did not directly quantify thrips populations, thrips injury ratings provide a reliable indicator of feeding activity, which is the mechanism by which TSWV is spread. We observed this correlation in our study, where non-treated peanuts had greater thrips injury (thus higher thrips activity) and correspondingly higher incidence of TSWV compared peanuts treated with an at-plant insecticide. We also saw a reduction in TSWV in the GA-12Y variety, which aligns with the documented TSWV resistance of this cultivar (Branch et al. 2023) and with findings from Cooke et al. (2025), who reported that GA-12Y had lower incidence of TSWV than GA-06G. These results agree

with research showing that peanut genotypes often express tolerance rather than complete resistance to TSWV, showing less severe symptoms despite still being infested with thrips(Shrestha et al. 2013). Broader germplasm evaluations have found that genotypic differences significantly influence both thrips feeding injury and TSWV infection levels (Chen et al. 2023), supporting our interpretation that genetic background of GA-12Y contributed to reduced virus impact and improved canopy maintenance.

Fractional green canopy coverage (FGCC) was influenced by treatment and variety in our study. FGCC reflects cumulative early-season stress, including plant vigor, thrips injury, and TSWV symptom expression, so reduced thrips injury from at-plant insecticides likely contributed to more rapid and complete canopy development (Funderburk et al. 1998). Similarly, the TSWV tolerance of GA-12Y would be expected to maintain canopy growth even when infected, resulting in fuller canopies relative to more susceptible cultivars. Greater canopy coverage was observed in GA-12Y and where an at-plant insecticide was used. Due to the aforementioned tolerance in GA-12Y, we could expect these plots to have a fuller canopy due to less TSWV incidence. Because FGCC shows the impacts of early season stresses mentioned above, the higher FGCC observed in GA-12Y, and insecticide-treated plots reflects both reduced early season stress and greater genetic resilience under TSWV pressure.

Our data showed no differences in peanut root-knot nematode eggs between variety or treatment. This study suggests that nematode pressure was limited due to the dry, drought-like conditions in South Alabama during the duration of the trial. Soil moisture is the driver of nematode activity because nematodes rely on soil moisture for movement, feeding and host infection. Nematode abundance, biomass and activity

have been shown to decline under drought conditions (Zhao et al. 2018, Zhao et al. 2024). Because environmental conditions can override management and varietal influences, drought years often mask differences among treatments, making it difficult to detect biological responses (Hajihassani, Lawrence and Jadale 2018, Nyaku et al. 2016).

Regardless of treatment, GA-06G outyielded GA-12Y by ≈ 531 lbs per acre in our study. There are varying results in the literature between the yield potential of these two varieties. Similarly, Standish et al. (2019) found that GA-06G had superior yield over GA-12Y under high fungicide input programs. However, Sidhu et al. (2019) found that GA-12Y outyielded GA-06G across multiple planting dates in a three-year study. Finally, Cooke et al. (2025) found no differences in yield between these cultivars across multiple planting dates in a two-year study. Although we saw differences in TSWV incidence between varieties, overall infection was low (0.8-3.8%). All other disease and later season insect pressure was low, maximizing the yield potential for each cultivar, similar to findings from Standish et al. (2019).

We also found a significant increase in yield for at-plant insecticide treatment. Regardless of treatment, peanuts that received an at-plant insecticide treatment yielded ≈ 931 lbs per acre over the non-treated check. These results are in line with other studies evaluating the impact of at-plant insecticides on yield (Cooke et al. 2025, Zurweller et al. 2023, Brandenburg et al. 2021, Mahoney et al. 2018). Overall, our results confirm that protecting seedling peanut from early thrips injury can meaningfully improve yield, even in years with minimal TSWV, emphasizing that at-plant insecticide

use remains a reliable, yield-protective management practice for April planted peanuts in Alabama.

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Tables and Figures

Figure 4.1. In-field visual of how thrips injury ratings were rated on a scale of 0-5, with 0 being no thrips injury to 5 representing dead growing terminal.



0: no injury



1: slight flecking/crinkling



2: moderate flecking/crinkling



3: beginning necrosis



4: necrosis, terminal damage



5: dead terminal

Table 4.1. Peanut stand, thrips injury rating (0-5), percent of tomato spotted wilt virus incidence, vigor rating (0-100) and canopeo measurements on Georgia-06G and Georgia-12Y peanut varieties treated with various at-plant insecticides/nematicides in Headland, AL from 2023 to 2025.

Variety	Treatment	Stand	Thrips Injury	% TSWV Incidence	Vigor	% Fractional Green Canopy Cover
Georgia-06G	Check	74.8 A ^z (7.42)	2.0 A (0.16)	3.8 A (0.79)	84.6 B (0.66)	34.1 D (6.16)
	Thimet	77.5 A (7.58)	1.4 CD (0.12)	2.3 B (0.38)	86.0 B (0.75)	41.0 ABCD (6.34)
	Vydate	75.5 A (8.34)	1.5 BC (0.13)	2.2 B (0.51)	88.0 A (0.82)	39.3 BCD (7.18)
	AgLogic	80.2 A (7.21)	1.3 CD (0.13)	1.7 BC (0.32)	88.6 A (0.77)	43.4 ABC (7.21)
Georgia-12Y	Check	79.4 A (7.00)	1.9 AB (0.17)	1.9 BC (0.41)	86.0 B (0.98)	38.8 CD (5.31)
	Thimet	73.0 A (10.55)	1.4 CD (0.09)	1.5 BC (0.37)	88.2 A (1.05)	49.3 A (4.34)
	Vydate	80.8 A (7.04)	1.4 CD (0.13)	0.8 C (0.24)	88.7 A (0.92)	49.9 A (5.43)
	AgLogic	78.4 A (9.71)	1.2 D (0.10)	0.8 C (0.23)	89.5 A (0.88)	47.7 AB (7.34)

^zMeans within the column that are followed by the same letter are not different according to Fisher's Protected LSD ($\alpha = 0.05$).

Table 4.2. Number of root knot nematode eggs per gram of root and yield of Georgia-06G and Georgia-12Y peanut varieties treated with various at-plant insecticides/nematicides in Headland, AL from 2023 to 2025.

Variety	Treatment	Root knot (eggs/g root)	Yield (lbs/ac)
Georgia-06G	Check	60.3 AB ^z (37.5)	4068.8 (316.7) -
	Thimet	29.3 B (4.8)	4421.4 (371.6) -
	Vydate	17.3 B (3.5)	4867.7 (316.7) -
	AgLogic	24.5 B (6.9)	4901.9 (276.1) -
Georgia-12Y	Check	152.3 A (94.8)	3131.4 (291.1) -
	Thimet	57.5 AB (14.8)	4322.5 (305.4) -
	Vydate	31.9 B (5.9)	4092.7 (233.5) -
	AgLogic	23.8 B (6.9)	4587.7 (297.3) -

^zMeans within the column that are followed by the same letter are not different according to Fisher's Protected LSD ($\alpha = 0.05$).