The *Journal of Cotton Science 29:7–15* (*2025*)
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ARTHROPOD MANAGEMENT & APPLIED ECOLOGY

Evaluation of ThryvOn Cotton for Thrips Management in Nematode-Infested Fields

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ABSTRACT

Tobacco thrips (*Frankliniella fusca*) and nematodes are widespread pests of cotton (*Gossypium hirsutum*) across the southeastern U.S. Recently, cotton varieties genetically modified with resistance to thrips (i.e., ThryvOn) 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 near 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 thrips control compared with the non-treated, non-ThryvOn untreated control. Additionally, both ThryvOn and non-ThryvOn cotton benefited from the addition of the Admire Pro + Velum and AgLogic with reduced nematode populations.

Thrips (Thysanoptera: Thripidae) are the most economically important insect pests of seedling cotton (*Gossypium hirsutum* L.) across the U.S. 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 (Cook et al., 2011; Layton and Reed, 2002; Stewart and Lentz, 2010). 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 can 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, is the most used group of insecticides (Cook 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 U.S. (Cook et al., 2003), have developed widespread resistance to the neonicotinoid class of insecticides (Darnell-Crumpton et al., 2018; Huseth et al., 2016). This resistance led to the reintroduction of aldicarb to the market. Additionally, Bayer CropScience launched a new genetically modified cotton trait (ThryvOn) to the market in 2023. This new trait, Cry51Aa2, has activity against thrips (Graham and Stewart, 2018). Unlike most genetically modified 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; Huseth et al., 2020). A study by Graham et al. (2019) documented that tobacco thrips, soybean

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thrips (*Neohydatothrips variabilis* Beach) and other thrips species respond similarly to ThryvOn cotton in replicated small-plot field trials. Huseth 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, 2018). Field studies have shown that ThryvOn cotton require fewer insecticide applications based on recommended thresholds than non-ThryvOn Cotton (Corbin et al., 2020; Graham and Stewart, 2018). 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. Although it is not fully understood how ThryvOn cotton interacts with tarnished plant bug, adult avoidance appears to have an effect (Cervantes et al., 2019; Graham 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 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 up to 50% yield reductions have been documented (Dyer et al., 2020; Robinson, 2007). 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 and 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 and McLean, 2002; Lawrence et al., 2015). Currently, high yielding cotton 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 cotton variety 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 Tallassee, 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 was 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: ThryvOn variety (DP2131 B3XTF; Bayer CropScience, St. Louis, MO) and 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 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 d 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 to 5 scale following the methods of Kerns et al. (2019), where 0 was no thrips injury and 5 was death of the terminal growing point. Thrips population 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 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 was not always a reliable reference for species. However, tobacco thrips were 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 to 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 shoots and roots. These data were collected between 30 and 45 d after planting across years and locations. After plant data were collected, 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 4 min 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 50-mL centrifuge tube, and processed by sucrose centrifugation-flotation at 240 g for 1 min (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 were 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 ± 0.59), AgLogic (89.55 ± 0.62), or Admire Pro + Velum (88.96 ± 0.68) had significantly higher vigor compared to the non-treated control (82.24 ± 1.74).

Thrips. There was an interaction of variety and treatment 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).

Table 1. Average thrips injury ratings (0-5 scale) 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
Non-ThryvOn	Fung. Only	-	2.95 a[z] (0.17)
Non-ThryvOn	Gaucho	0.375 mg	1.62 b (0.16)
Non-ThryvOn	Admire Pro + Velum	595 ml + 455 ml	1.83 b (0.20)
Non-ThryvOn	AgLogic 15GG	5.6 kg	1.59 b (0.16)
ThryvOn	Fung. Only	-	1.06 c (0.11)
ThryvOn	Gaucho	0.375 mg	0.98 c (0.09)
ThryvOn	Admire Pro + Velum	595 ml + 455 ml	0.96 c (0.11)
ThryvOn	AgLogic 15GG	5.6 kg	0.98 c (0.10)

[z]Means within the column that are followed by the same letter are not different according to Fisher's Protected LSD (α = 0.05).

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 ± 1.04) compared to the TO cotton (6.71 ± 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 treatment 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 treatment 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 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 aboveground 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 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

Table 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[z] (8.69)	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)

[z]Means within the column that are followed by the same letter are not different according to Fisher's Protected LSD (α = 0.05).

Table 3. Plant survival and growth parameters approximately 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

Variety	Treatment	Plant Stand	Plant Height	Fresh Shoot Weight
		(%)	(cm)	(g)
Tallassee, AL; Root-knot nematode				
Non-ThryvOn	Fung. Only	78 a[z] (11.3)	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				
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 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)

[z]Means within the column that are followed by the same letter are not different according to Fisher's Protected LSD (α = 0.05).

and treatment (F = 0.41; df = 3, 53; p = 0.7500) for *M. incognita* at PBU. However, treatment 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 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 control (Table 4).

Yield. Plots were terminated prior to the initiation of bloom at TVREC in 2022, thus only year one of yield data were available at this location. There were no interactions between site-year and variety (F = 9.43; df = 2, 63; p = 0.8615); site-year and treatment (F = 1.02; df = 6, 63; p = 0.4198); or site-year, variety, and treatment (F = 0.27; df = 6, 63; p = 0.9496); thus, yield data were analyzed across years and locations (Table 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), 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), 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 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 cotton 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

Table 4. Root-knot and Reniform nematode populations approximately 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	Reniform
			(eggs / g root)	
Non-ThryvOn	Fung. Only	-	3440 b[z] (1901)	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)

[z]Means within the column that are followed by the same letter are not different according to Fisher's Protected LSD (α = 0.05). (Poisson distribution in SAS)

Table 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 (2023)

Variety	Treatment	Lint Yield
		(kg/ha)
Non-ThryvOn	Fung. Only	849.8 a[z] (98.9)
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[y]		
Insecticide/Nematicide		978.5 a (88.7)
Insecticide Only		892.2 ab (70.5)
Non-Treated Control		784.1 b (79.3)

[z]Means within the column that are followed by the same letter are not different according to Fisher's Protected LSD (α = 0.05).

[y]Insecticide/Nematicide = AgLogic 15GG and Gaucho + Velum; Insecticide Only = Gaucho

a significant effect. When using AgLogic and Admire Pro + Velum, egg populations of both nematode species were reduced, as compared with 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 cotton 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 (2024) 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, 2024). The non-ThryvOn cotton had significantly more thrips injury, regardless of insecticide treatment, except for AgLogic 15G (Reisig and Goldsworthy, 2024). 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 with non-ThryvOn cotton. Overall, ThryvOn cotton shows adequate control of thrips when compared with non-ThryvOn cotton. The findings in this study indicate ThryvOn cotton 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 averaged a moderate thrips injury rating (2.95/5). Although this rating can 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.

Further research is needed to understand how various stresses, such as nematodes and drought can influence the performance of ThryvOn cotton 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 although nematodes did not impact thrips control, yield was reduced in ThryvOn cotton if no nematicide component was applied. Because 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.

ACKNOWLEDGMENTS

This research and publication were supported by industry funds and the Alabama Cotton Commission under Hatch Act ALA015-1-19917 and ALA15-2-14003.

REFERENCES

Baum, J.A., U.R. Sukuru, S.R. Penn, S.E. Meyer, S. Subbarao, X. Shi, S. Flasinski, G.R. Heck, R.S. Brown, and T.L. Clark. 2012. Cotton plants expressing a hemipteran-active *Bacillus thuringiensis* crystal protein impact the development and survival of *Lygus hesperus* (Hemiptera: Miridae) nymphs. J. Econ. Entomol. 105(2):616–624. https://doi.org/10.1603/EC11207

Blouin, D.C., E.P. Webster, and J.A. Bond. 2011. On the analysis of combined experiments. Weed Tech. 25(1):165–169. https://doi.org/10.1614/WT-D-10-00047.1

Carmer, S.G., W.E. Nyquist, and W.M. Walker. 1989. Least significant differences for combined analyses of experiments with two- or three- factor treatment designs. Agron. J. 81(4):665–672. https://doi.org/10.2134/agronj1989.00021962008100040021x

Cervantes, F.A., E.A. Backus, L. Godfrey, M.G. Rojas, W. Akbar, and T.L. Clark. 2019. Quantitative differences in feeding behavior of *Lygus lineolaris* (Hemiptera: Miridae) on transgenic and nontransgenic cotton. J. Econ. Entomol. 112(4):1920–1925. https://doi.org/10.1093/jee/toz054

Chitwood, B.G. 1949. Root-knot nematodes part I. A revision of the genus *Meloidogyne* Goeldi, 1887. Proc. Helminthological Soc. Washington. 16: 90–104.

Cook, D. 2023. Cotton insect losses. [Online] Available at https://www.biochemistry.msstate.edu/resources/cotton-crop.php (verified 10 Jan. 2025).

Cook, D., A. Herbert, D.S. Akin, and J. Reed. 2011. Biology, crop injury, and management of thrips (Thysanoptera: Thripidae) infesting cotton seedlings in the United States. J. Integ. Pest Manag. 2(2):1–9. https://doi.org/10.1603/IPM10024

Cook, D.R., C.T. Allen, E. Burris, B.L. Freeman, G.A. Herzog, G.L. Lentz, B.R. Leonard, and J.T. Reed. 2003. A survey of thrips (Thysanoptera) species infesting cotton seedlings in Alabama, Arkansas, Georgia, Louisiana, Mississippi, and Tennessee. J. Entomol. Sci. 38(4):669–681. https://doi.org/10.18474/0749-8004-38.4.669

Corbin, J.C., T.B. Towles, W.D. Crow, A.L. Catchot, D.R. Cook, D.M. Dodds, and J. Gore. 2020. Evaluation of current tarnished plant bug (Hemiptera: Miridae) thresholds in transgenic MON 88702 cotton expressing the Bt Cry51Aa2.834_16 trait. J. Econ. Entomol. 113:1816–1822. https://doi.org/10.1093/jee/toaa075

Darnell-Crumpton, C., A.L. Catchot, D.R. Cook, J. Gore, D.M. Dodds, S.C. Morsello, and F.R. Musser. 2018. Neonicotinoid insecticide resistance in tobacco thrips (Thysanoptera: Thripidae) of Mississippi. J. Econ. Entomol. 111(6):2824–2830. https://doi.org/10.1093/jee/toy298

Davis, R.F., and R.C. Kemerait. 2022. Integrated management of *Meloidogyne incognita*, the most economically damaging pathogen of cotton in the southeastern United States. pp. 87–93 *In* R. Sikora, J. Desaeger, and L. Molendijk (eds.), Integrated Nematode Management: State-of-the-Art and Visions for the Future. CABI Digital Library. https://doi.org/10.1079/9781789247541.0013

Dyer, D.R., W. Groover, and K.S. Lawrence. 2020. Yield loss of cotton cultivars due to *Rotylenchulus reniformis* and the added benefit of a nematicide. Plant Health Prog. 21(2):113–118. https://doi.org/10.1094/PHP-10-19-0073-RS

Farmer, W.B. 2023. The influence of at-plant insecticide treatments on tobacco thrips, (Thysanoptera: Thripidae), and reniform nematode (Tylenchida: Hoplolaimidae), in conventional and ThryvOn cotton systems. M.S. Thesis. Mississippi State Univ., Mississippi State, MS.

Gaines, J.C. 1934. A preliminary study of thrips on seedling cotton with special reference to the population, migration, and injury. J. Econ. Entomol. 27(4):740–743. https://doi.org/10.1093/jee/27.4.740

Gowda, A., T.J. Rydel, A.M. Wollacott, R.S. Brown, W. Akbar, T.L. Clark, S. Flasinski, J.R. Nageotte, A.C. Read, X. Shi, B.J. Werner, M.J. Pleau, and J.A. Baum. 2016. A transgenic approach for controlling *Lygus* in cotton. Nat. Commun. 7:12213. https://doi.org/10.1038/ncomms12213

Graham, S.H., and S.D. Stewart. 2018. Field Study Investigating Cry51Aa2.834_16 in cotton for control of thrips (Thysanoptera: Thripidae) and tarnished plant bugs (Hemiptera: Miridae). J. Econ. Entomol. 111(6):2717–2726. https://doi.org/10.1093/jee/toy250

Graham, S.H., F.M. Musser, A.L. Jacobson, A. Chitturi, B. Catchot, and S.D. Stewart. 2019. Behavioral responses of thrips (Thysanoptera: Thripidae) and tarnished plant bug (Hemiptera: Miridae) to a new Bt toxin, Cry51Aa2.834_16 in cotton. J. Econ. Entomol. 112(4):1695–1704. https://doi.org/10.1093/jee/toz058

Hayes, W.J. 1982. Pesticides Studied in Man. Williams & Wilkins, Philadelphia, PA.

Huseth, A.S., D.A. D'Ambrosio, B.T. Yorke, G.P. Head, and G.G. Kennedy. 2020. Novel mechanism of thrips suppression by Cry51Aa2.834_16 *Bt* toxin expressed in cotton. Pest Manag. Sci. 76(4):1492–1499. https://doi.org/10.1002/ps.5664

Huseth, A.S., T.M. Chappell, K. Langdon, S.C. Morsello, S. Martin, J.K. Greene, A. Herbert, A.L. Jacobson, F.P. Reay-Jones, T. Reed, D.D. Reisig, P.M. Roberts, R. Smith, and G.G. Kennedy. 2016. *Frankliniella fusca* resistance to neonicotinoid insecticides: an emerging challenge for cotton pest management in the eastern United States. Pest Manag. Sci. 72(10):1934–1945. https://doi.org/10.1002/ps.4232

Hussey, R.S., and K.R. Barker. 1973. A comparison of methods of collecting inocula of *Meloidogyne* spp. including a new technique. Plant Disease Reporter. 57(12):1025–1028.

Jenkins, W.R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Dis. Reporter. 48(9):692.

Kerns, C.D., J.K. Greene, F.P. Reay-Jones, and W.C. Bridges. 2019. Effects of planting date on thrips (Thysanoptera:Thripidae) in cotton. J. Econ. Entomol. 112(2):699-707.

Lawrence, G.W., and K.S. McLean. 2002. Foliar applications of oxamyl with aldicarb for the management of *Meloidogyne incognita* on cotton. Nematropica. 32(2):103–112.

Lawrence, K.S. 2022. Reniform nematode (*Rotylenchulus reniformis*) and its interactions with cotton (*Gossypium hirsutum*). pp. 94–99 *In* R. Sikora, J. Desaeger, and L. Molendijk (eds.), Integrated Nematode Management: State-of-the-Art and Visions for the Future. CABI Digital Library. https://doi.org/10.1079/9781789247541.0014

Lawrence, K.S., G.W. Lawrence, T. Faske, C. Overstreet, T. Wheeler, H. Young, B. Kemerait, and H. Mehl. 2015. Beltwide nematode research and education committee 2014 nematode research report cotton varietal and nematicide responses in nematode soils. pp. 739–742 *In* Proc. Beltwide Cotton Conf., San Antonio, TX. 5-7 Jan. 2015. Natl. Cotton Counc. Am., Memphis, TN.

Layton, B., and J.T. Reed. 2002. Biology and control of thrips in seedling cotton. Publ. 2302. Mississippi State Univ. Ext. Serv., Starkville, MS.

Reisig, D., and E. Goldsworthy. 2024. Efficacy of selected insecticides on thrips in cotton, 2023. Arthropod Manag. Tests. 49(1):tsae070. https://doi.org/10.1093/amt/tsae070

Roberts, B.A., and E.A. Rechel. 1996. Effects of early season thrips feeding on root development, leaf area, and yield. pp. 939–941 *In* Proc. Beltwide Cotton Conf., Nashville, TN. 9-12 Jan. 1996. Natl. Cotton Counc. Am., Memphis, TN.

Robinson, A.F. 2007. Reniform in U.S. cotton: when, where, why, and some remedies. Ann. Rev. Phytopathol. 45:263–288. https://doi.org/10.1146/annurev.phyto.45.011107.143949

Sadras, V.O., and L.J. Wilson. 1998. Recovery of cotton crops after early season damage by thrips (Thysanoptera). Crop Sci. 38(2):399–409. https://doi.org/10.2135/cropsci1998.0011183X003800020022x

Smith, J.F., A.L. Catchot, F.R. Musser, and J. Gore. 2013. Effects of aldicarb and neonicotinoid seed treatments on twospotted spider mite on cotton. J. Econ. Entomol. 106(2):807–815. https://doi.org/10.1603/EC10125

Starr, J.L., S.R. Koenning, T.L. Kirkpatrick, A.F. Robinson, P.A. Roberts, and R.L. Nichols. 2007. The future of nematode management in cotton. J. Nematol. 39(4):283–294. https://pmc.ncbi.nlm.nih.gov/articles/PMC2586512/

Stewart, S.D., and G.L. Lentz. 2010. Cotton insects: thrips. Publ. W026. Univ. of Tennessee Agric. Ext. Serv., Knoxville, TN.

Turner, A.K., S.H. Graham, N. Potnis, S.M. Brown, P. Donald, and K.S. Lawrence. 2023. Evaluation of *Meloidogyne incognita* and *Rotylenchulus reniformis* nematode-resistant cotton cultivars with supplemental Corteva Agriscience nematicides. J. Nematol. 55(1):1–21. https://doi.org/10.2478/jofnem-2023-0001

Wheeler, T.A., K. Siders, C. Monclova-Santana, and J.K. Dever. 2020. The relationship between commercial cotton cultivars with varying *Meloidogyne incognita* resistance genes and yield. J. Nematol. 52(1):1–8. https://doi.org/10.21307/jofnem-2020-064

Whitfield, A.Y. 2023. Evaluation of thresholds, control, and behavioral responses of tobacco thrips, *Frankliniella fusca* (Hitch), and tarnished plant bugs, *Lygus lineolaris* (Beauvoris), in ThryvOn cotton. M.S. Thesis. Univ. of Arkansas, Fayetteville, AR.