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ARTHROPOD MANAGEMENT & APPLIED ECOLOGY

Impact of Aldicarb and ThryvOn® on Tobacco Thrips (*Frankinella fusca*) and Reniform Nematode (*Rotylenchus reniformis*)

Walker Brett Farmer*, Jeffrey Gore, Angus L. Catchot Jr., Whitney D. Crow, Donald R. Cook, Brian K. Pieralisi, and Tyler Towles

ABSTRACT

In 2022, 98% of U.S. cotton hectares were infested with thrips, which amounts to more than 2.8 million hectares. In the Mid-South, most cotton hectares are treated with some type of preventative insecticide treatment, most commonly imidacloprid and acephate seed treatments are used on Mississippi cotton. In addition to insecticide seed treatment, approximately 40 to 45% of the planted area requires an additional foliar application to effectively control thrips. All cotton hectares in Mississippi are infested with tobacco thrips, *Frankliniella fusca* (Thysanoptera: Thripidae), and some areas might also be infested by reniform nematodes, *Rotylenchulus reniformis* (Tylenchida: Hoplolaimidae). Depending on the year and environmental conditions, nematodes cause varying levels of damage to cotton plants. Reniform nematodes and thrips have been controlled in the past using aldicarb, a granular insecticide and/or other soil-incorporated nematicides plus insecticide seed treatments. The overall impact of aldicarb and the new ThryvOn® technology on reniform nematodes and tobacco thrips in Mississippi cotton production systems has yet to be seen. In this study, ThryvOn and non-ThryvOn varieties were used along with different rates of at-planting insecticides to evaluate their effectiveness against early season thrips and nematode management

W.B. Farmer*, and W.D. Crow, Mississippi State Univ. Dept. of Biochemistry, Molecular Biology, Entomology & Plant Pathology, Mississippi State, MS 39762; J. Gore, D.R. Cook, and T. Towles, Mississippi State Univ. Delta Research & Extension Center, Stoneville, MS 38776; A.L. Catchot, Mississippi State Univ. Extension Service, Mississippi State, MS 39762; and B.K. Pieralisi, Mississippi State Univ. Dept. of Plant & Soil Science, Mississippi State, MS 39762.
*Corresponding author: wbf44@msstate.edu

Cotton, *Gossypium hirsutum* L., has many economically important early season pests such as tobacco thrips, *Frankliniella fusca* (Thysanoptera: Thripidae) (Hinds), and the reniform nematode, *Rotylenchulus reniformis* (Tylenchida: Hoplolaimidae) (Linford and Oliveira). Tobacco thrips damage plants from above by feeding on the leaves, which can cause deformed leaves with a silverish appearance (Layton and Reed, 2014; Telford and Hopkins, 1957). Reniform nematodes feed below the soil surface on the cortex of cotton roots (Crow et al., 2018). Both pests have the potential to severely damage cotton by reducing yield potential, reducing root growth, and delaying maturity (Brown et al., 2008; Crow, 2018; Gazaway et al., 1992; Kirkpatrick, 2001; Monfort, 2005; Roberts and Rechel, 1996). For the 2022 growing season in Mississippi, thrips infested 100% of the 214,400 cotton hectares. As a result, 50% of those hectares were treated with insecticide for thrips management and incurred a yield loss of more than twelve million dollars (Cook et al., 2023). To combat thrips, most Mississippi cotton is treated with some type of at-planting insecticide. These include imidacloprid applied as a seed treatment or granular aldicarb applied in the seed furrow. Aldicarb was implemented into this study due to its broad spectrum use in controlling thrips and nematodes. In addition to an at-planting insecticide, some of the more heavily infested cotton fields could require an additional foliar application for effective thrips control. A new technology, ThryvOn®, offers a *Bacillus thuringiensis* Berliner trait in cotton that eliminates the need for foliar insecticide applications for thrips.

Reniform nematode is an early season pest in cotton that limits nutrient and water uptake through the roots (Koenning et al., 2004). These nematodes are considered stress pathogens that could compound potential yield losses from other environmental stresses (Crow, 2018). Some researchers have estimated seven to eight percent yield loss due to reniform nematode

(Birchfield and Jones, 1961; Blasingame et al., 2006, 2009; Davis et al., 2003). Fluopyram is a narrow spectrum nematicide that was used in this study to analyze its effects on nematodes in ThryvOn and non-ThryvOn cotton. To effectively analyze the impact of at-planting insecticides and nematicides and ThryvOn on both pests, trials were conducted throughout Mississippi in three locations over two years.

MATERIALS AND METHODS

In 2021 and 2022, four trials were conducted in Starkville, Glendora, and Stoneville, MS. Planting dates for each trial varied across the month of May depending on location, but each trial was replicated four times and had a row spacing of 96.52 to 101.6 cm. Plots were four rows wide and 12.19 m in length. Trials were implemented as a randomized complete block design with a factorial arrangement of treatments. Factor A was technology and included non-ThryvOn (Deltapine 1646 B2XF) and ThryvOn (Deltapine 2131 B3TXF) (Bayer Crop Science, St. Louis, MO). Factor B was at-planting insecticide treatment, which consisted of two different rates of aldicarb (AgLogic 15G; AgLogic Chemical, LLC, Chapel Hill, NC) applied as a granular in-furrow at 3.92 and 5.60 kg per ha., imidacloprid (Gaucho; Bayer Crop Science, St. Louis, MO) plus fluopyram (Velum Total; Bayer Crop Science, St. Louis, MO) applied as an in-furrow spray at 4.11 kg per ha., along with an untreated control.

To assess the impacts of aldicarb, fluopyram, and ThryvOn, thrips densities were determined by randomly selecting five plants per plot from each trial at both the two- and four-leaf stage. Each plant was cut at the soil level and placed into a 0.95-L mason jar. These mason jars contained a 70% water to 30% ethanol mixture and were filled to approximately 25% capacity. The contents of the jars were washed using a whole-plant wash method (Burris et al., 1989). The contents of each jar were rinsed with water and poured into a 300-mesh metal sieve (C-E Tyler Inc., Gastonia, NC). All contents were collected on a ruled P5 filter paper (9 cm diameter) with a medium porosity and a slow flow rate (Fisher Scientific Inc., Hampton, NH). A Buchner funnel connected to a vacuum was used to drain the moisture from the filter paper. Each piece of filter paper was then transferred to a petri dish, where it was counted for thrips numbers categorized as black adult, yellow adult, or immature. The microscopes used to count thrips densities was a Leica EZ4 microscope at 25x magnification.

Plant damage ratings were determined on a scale of zero to five from each plot at both the two- and four-leaf stages. A healthy cotton plant with no signs of thrips injury was rated zero, severe damage that would cause significant economic injury was rated three, and a dead cotton plant that would not recover was rated five. Thrips damage ratings were used to categorize locations into low and high pressure. Each location's pressure was determined by comparing it to the damage rating from the non-ThryvOn with no at-planting insecticide treatment at the two-leaf stage. A low-pressure location was selected if the damage rating was below three on the thrips injury scale. If four plots in a trial averaged above three on the thrips injury scale, that location was categorized as a high-pressure location. Between 2020 and 2021, two locations were designated as low-pressure environments and two locations as high-pressure environments.

In addition to thrips densities and damage ratings, plant biomass per 10 plants and nematode numbers per 568 ml of soil were recorded at the four-leaf stage. Biomass was determined to assess plant vigor by using a gardening spade to dig up 10 plants per plot. The plants were then washed in an 18.93-L bucket containing water to remove any soil or debris and then placed into brown paper bags. After collecting all the samples from a trial, these bags were placed into an industrial dryer oven at 50 °C for 48 h. The samples were taken out of the dryer and weighed in grams individually on an OHAUS PR Series scale. Nematode soil samples were taken from each plot approximately 40 d after emergence to assess the effectiveness of aldicarb treatments on nematode populations. Soil samples were sent to the Extension Plant Diagnostic Laboratory at Mississippi State University to determine the number of reniform nematodes per 568 mL of soil.

Statistical Analysis. All data were analyzed using analysis of variance (PROC GLIMMIX, SAS 9.4; SAS Institute; Cary, NC). Technology, insecticide, and their interaction were considered fixed effects in the model. Replication nested in year by location, location nested in year, and location by technology nested in year were considered random effects. Means were separated using Fisher's Protected LSD procedure at the 0.05 level of significance.

RESULTS

Low Thrips Pressure Environments. There was an interaction between technology and insecticide for the mean number of thrips (F = 4.38; df = 3,48; $p < 0.01$) at the two-leaf stage. The non-ThryvOn untreated control had a higher mean number of thrips than any of the other insecticide treatments (Table 1). The non-ThryvOn, aldicarb insecticide treatments were not significantly different from one another, but they resulted in lower mean numbers of thrips than the untreated control and imidacloprid plus fluopyram insecticide treatments. All insecticide treatments in the ThryvOn cotton were not significantly different from one another regarding mean number of thrips. There was an interaction between technology and insecticide for mean damage ratings (F = 9.33; df = 3,48; $p < 0.01$) in low thrips pressure environments at the two-leaf stage. Non-ThryvOn cotton without an at-planting insecticide had a higher mean damage rating than any of the other insecticide treatments across both technologies (Table 1). Mean damage ratings in all insecticide treatments in ThryvOn cotton were not significantly different from one another.

There was an interaction between technology and insecticide for the mean number of thrips (F = 6.61; df = 3,48; $p < 0.01$) at the four-leaf stage in low thrips pressure environments. The untreated and the imidacloprid plus fluopyram insecticide treatments in the non-ThryvOn cotton had the highest mean number of thrips (Table 1). In the ThryvOn cotton, there were no differences among insecticide treatments for the mean number of thrips, except for the aldicarb 5.60-kg treatment, which had a significantly lower mean number of thrips than the untreated control (Table 1). There was an interaction between technology and insecticide at the four-leaf stage for the mean damage ratings (F = 14.98; df = 3,48; $p < 0.01$). The non-ThryvOn untreated control, imidacloprid plus fluopyram, and the ThryvOn untreated control insecticide treatments resulted in higher mean damage ratings than all the other insecticide treatments, and they were significantly different from one another. Regardless of technology, all the aldicarb insecticide treatments were not significantly different from one another.

There was no significant interaction between technology and insecticide for biomass (F = 1.65; df = 3,18; $p = 0.21$) in low thrips pressure environments (Table 2). There was also no main effect for technology (F = 6.85; df = 1,3; p = 0.08) or insecticide (F = 0.86; df = 3,18; $p = 0.48$) for biomass in low thrips pressure environments. There was no interaction between technology and insecticide for nematode numbers (F = 0.90; df = 3,18; $p = 0.46$) in low thrips pressure environments at the four-leaf stage (Table 2). There was no main effect for technology (F = 0.99; df = 1,3; $p = 0.39$) or insecticide (F = 1.46; df = 3,18; $p = 0.26$) for nematode densities in low thrips pressure environments.

High Thrips Pressure Environments. There was no interaction between technology and insecticide for the mean number of thrips per 10 plants (F = 1.54; df = 3,48; $p = 0.22$) at the two-leaf stage). There was also no main effect for technology (F = 1.29; df = 1,3; $p = 0.46$), but there was a main effect for insecticide (F = 5.58; df = 3,48; $p = 0.0023$) at the two-leaf stage for the mean number of thrips. The untreated control had the highest mean number of thrips (Table 3). All the other insecticide treatments were not significantly different

Table 1. Mean (SEM) number of thrips and damage ratings at the 2-leaf and 4-leaf stage of ThryvOn and non-ThryvOn cotton averaged across all low-pressure environments in 2021 and 2022

	Mean (SEM) at 2-Leaf Stage[z]		Mean (SEM) at 4-Leaf Stage[z]	
	Thrips	Damage Rating	Thrips	Damage Rating
	No. per 5 plants	0-5 Scale	No. per 5 plants	0-5 Scale
ThryvOn UTC	5.50 (1.79)bc	0.81 (0.18)bc	32.13 (8.85)b	1.44 (0.12)c
ThryvOn + 3.92 kg Aldicarb	0.88 (0.35)c	0.75 (0.18)bc	9.25 (2.83)bc	0.84 (0.10)d
ThryvOn + 5.60 kg Aldicarb	1.00 (0.38)c	0.84 (0.14)bc	6.25 (2.23)c	0.84 (0.12)d
ThryvOn + 4.11 kg Velum Total	2.88 (0.85)bc	0.78 (0.14)bc	19.00 (5.68)bc	1.06 (0.13)d
Non-ThryvOn UTC	17.62 (4.86)a	1.97 (0.21)a	89.75 (18.11)a	2.84 (0.15)a
Non-ThryvOn + 3.92 kg Aldicarb	1.38 (0.53)c	0.69 (0.15)bc	10.75 (1.99)bc	1.16 (0.10)cd
Non-ThryvOn + 5.60 kg Aldicarb	1.25 (0.49)c	0.56 (0.14)c	9.63 (2.38)bc	0.94 (0.13)d
Non-ThryvOn + 4.11 kg Velum Total	9.63 (3.25)b	1.03 (0.16)b	72.88 (21.29)a	2.31 (0.24)b

[z]Means within a column followed by the same letter are not different according to Fisher's Protected LSD test within an alpha of 0.05.

Table 2. Mean (SEM) number of nematodes per 568 mL of soil and grams of biomass per 10 plants at the 4-leaf stage of ThryvOn and non-ThryvOn cotton averaged across all low- and high-pressure environments in 2021 and 2022

	Mean (SEM) at Low Pressure[z]		Mean (SEM) at High Pressure[z]	
	Biomass	Nematodes	Biomass	Nematodes
	Grams per 10 plants	No. per 568 mL of soil	Grams per 10 plants	No. per 568 mL of soil
ThryvOn UTC	4.56 (0.50)	2125.75 (406.37)	4.16 (0.25)b	1174.00 (743.60)
ThryvOn + 3.92 kg Aldicarb	5.81 (0.15)	1789.00 (306.73)	4.74 (0.21)ab	949.50 (656.17)
ThryvOn + 5.60 kg Aldicarb	5.50 (0.29)	1948.00 (487.28)	4.52 (0.46)ab	1186.25 (661.28)
ThryvOn + 4.11 kg Velum Total	5.10 (0.48)	3774.00 (1632.84)	4.42 (0.28)b	868.75 (659.13)
Non-ThryvOn UTC	6.47 (0.25)	4485.75 (2196.69)	3.23 (0.23)c	1765.25 (505.00)
Non-ThryvOn + 3.92 kg Aldicarb	6.02 (0.35)	1115.25 (727.30)	4.48 (0.27)b	973.25 (323.71)
Non-ThryvOn + 5.608 kg Aldicarb	6.10 (0.22)	3721.75 (2328.03)	5.34 (0.49)a	793.75 (331.63)
Non-ThryvOn + 4.11 kg Velum Total	5.51 (0.78)	3465.00 (686.35)	4.94 (0.17)ab	606.75 (138.49)

[z]Means within a column followed by the same letter are not different according to Fisher's Protected LSD test within an alpha of 0.05.

Table 3. Mean (SEM) number of thrips and damage ratings at the 2-leaf and 4-leaf stage of ThryvOn and non-ThryvOn cotton averaged across all high-pressure environments in 2021 and 2022

	Mean (SEM) at 2-Leaf Stage[z]		Mean (SEM) at 4-Leaf Stage[z]	
	Thrips	Damage Rating	Thrips	Damage Rating
	No. per 5 plants	0-5 Scale	No. per 5 plants	0-5 Scale
ThryvOn UTC	21.38 (10.22)b	1.41 (0.23)c	13.75 (2.44)c	1.03 (0.17)c
ThryvOn + 3.92 kg Aldicarb	4.38 (1.36)b	1.03 (0.18)cd	7.63 (1.61)c	0.84 (0.13)c
ThryvOn + 5.608 kg Aldicarb	5.88 (0.93)b	0.94 (0.16)d	11.75 (1.60)c	0.81 (0.12)c
ThryvOn + 4.11 kg Velum Total	3.13 (0.91)b	1.13 (0.17)cd	12.75 (2.78)c	0.78 (0.11)c
Non-ThryvOn UTC	68.75 (30.36)a	3.44 (0.14)a	64.00 (9.02)a	4.03 (0.12)a
Non-ThryvOn + 3.92 kg Aldicarb	10.88 (3.79)b	1.44 (0.25)c	17.13 (3.39)c	1.00 (0.17)c
Non-ThryvOn + 5.608 kg Aldicarb	17.50 (8.30)b	1.38 (0.26)cd	13.38 (3.02)c	1.03 (0.20)c
Non-ThryvOn + 4.11 kg Velum Total	22.00 (8.80)b	2.28 (0.16)b	33.50 (7.54)b	2.28 (0.23)b

[z]Means within a column followed by the same letter are not different according to Fisher's Protected LSD test within an alpha of 0.05.

from one another. There was an interaction between technology and insecticide for mean damage ratings ($F = 11.40$; df = 3,48; $p < 0.01$) at the two-leaf stage in high thrips pressure environments (Table 3). The non-ThryvOn untreated control had a higher mean damage rating than any other insecticide treatment. The non-ThryvOn plus Velum Total insecticide treatment had a higher mean damage rating than all the other insecticide treatments except for the non-ThryvOn untreated control. All the other insecticide treatments were not significantly different from one another other than the ThryvOn aldicarb 5.60 kg insecticide treatment, which had the lowest mean damage rating overall.

There was an interaction between technology and insecticide for the mean number of thrips ($F = 10.31$; df = 3,48; $p < 0.01$) at the four-leaf stage in high thrips pressure environments (Table 3). Non-ThryvOn untreated control had the highest mean number of thrips compared to all other treatments. Mean number of thrips were not different among all other insecticide treatments, except for the non-ThryvOn with imidacloprid plus fluopyram, which resulted in the second highest mean number of thrips. There was an interaction between technology and insecticide for the mean damage ratings ($F = 52.23$; df = 3,48; $p < 0.01$) at the four-leaf stage (Table 3). Mean damage rating in the non-ThryvOn untreated control was greater than all other treatments. The non-ThryvOn with imidacloprid plus fluopyram insecticide treatment had the second highest mean damage rating (Table 3). All the other insecticide treatments were not significantly different from one another regardless of technology.

There was an interaction between technology and insecticide for biomass (F = 4.60; df = 3,18; p = 0.01) at the four-leaf stage (Table 2). All ThryvOn insecticide treatments (including the untreated control) were not significantly different from one another for total biomass. The non-ThryvOn untreated control resulted in the lowest biomass and was significantly different from all the insecticide treatments across both technologies. The ThryvOn untreated control resulted in significantly higher biomass than any insecticide treatment with non-ThryvOn cotton, except when 3.92 kg aldicarb was applied (Table 2). There was no interaction between insecticide and technology for nematode numbers (F = 0.34; df = 3,18; p = 0.81) in high thrip pressure environments (Table 2). There was also no main effect for technology (F = 0.00; df = 1,3; p = 0.98) or insecticide (F = 0.67; df = 3,18; p = 0.59) for nematode number in high thrips pressure environments.

DISCUSSION

The objective of this study was to assess the impact of aldicarb, fluopyram, and ThryvOn on tobacco thrips and reniform nematodes. The higher rate of aldicarb did not provide any additional benefits to ThryvOn technology for thrips control when looking at both the low- and high-pressure locations for thrips densities and mean damage ratings at both leaf stages. When incorporating an effective insecticide treatment such as aldicarb, the technology aspect of the study can be overshadowed by the insecticide treatment when comparing mean thrips numbers. However, studies have shown that aldicarb provides additional control of tobacco thrips in non-ThryvOn cotton (Crow, 2018). When comparing mean damage ratings in this study, ThryvOn had lower thrips damage ratings than non-ThryvOn. The imidacloprid plus fluopyram insecticide treatment in ThryvOn variety consistently displayed lower mean numbers of thrips and lower mean damage ratings at the four-leaf stages than the non-ThryvOn variety with the imidacloprid plus fluopyram insecticide treatment. Another study conducted found that all non-ThryvOn plots had greater damage ratings than ThryvOn plots (Yates-Stewart et al., 2023). In this study, biomass increased with the addition of a higher rate of aldicarb in the non-ThryvOn cotton, whereas there were no differences among the insecticide treatments in the ThryvOn cotton. This could be an attribute of ThryvOn technology, giving growers a healthier root system without the additional cost of an at-planting insecticide. Another study showed significant increases in biomass in cotton that was treated with an insecticide treatment versus cotton that was left untreated (Krob et al., 2022). Although no significant interaction was observed for nematodes in low- or high-pressure environments, this could be explained by the lack of adequate nematode populations. In the current study, the addition of aldicarb provided little to no benefit to ThryvOn when comparing thrips and nematodes numbers. Thrips and nematode management practices should also be considered on a field-to-field basis. Additional research is needed to continue to evaluate the impact of aldicarb and ThryvOn on tobacco thrips and reniform nematodes.

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