The influence of at-planting insecticide treatments on tobacco thrips, (Thysanoptera:Thripidae), and reniform nematode, (Tylenchida:Hoplolaimidae), in conventional and ThryvOn cotton systems

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The influence of at-planting insecticide treatments on tobacco thrips, (Thysanoptera:Thripidae), and reniform nematode, (Tylenchida:Hoplolaimidae), in conventional and ThryvOn cotton systems

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A Thesis
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Mississippi State, Mississippi

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One of the objectives of this research was to evaluate the need for an additional imidacloprid seed treatment on ThryvOn® (Bayer Crop Science®, St. Louis, MO) cotton to effectively manage tobacco thrips, *Frankliniella fusca* (Hinds). While evaluating thrips densities and damage ratings, ThryvOn cotton continued to display reduced damage and thrips populations than non-ThryvOn. Thrips populations and damage ratings were consistently reduced when incorporating a higher rate of imidacloprid, but they were not reduced enough to justify the higher rates of imidacloprid. Another objective of this research was to evaluate the impact of aldicarb (AgLogic Chemical®, LLC; Chapel Hill, NC) and ThryvOn on reniform nematode, *Rotylenchulus reniformis* (Linford & Oliveira). The impact of aldicarb and ThryvOn technology had no impact on reniform nematode densities in Mississippi cotton throughout this study. The reduced thrips populations and damage ratings provided by ThryvOn cotton has the potential to improve integrated pest management in the southern U.S.
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CHAPTER I
INTRODUCTION

1.1 Cotton and Pest Introduction

One of the most important agricultural commodities produced across the United States is cotton, *Gossypium* spp. In 2022, the U.S. planted about 5.1 million hectares of cotton; of these hectares about 5 million were upland cotton, *Gossypium hirsutum* L. (USDA-NASS 2022). Thrips are often the first insect pest cotton growers encounter at the start of the growing season. While most cotton insect pests are localized, thrips are an issue across the cotton belt and may need to be controlled using pesticides to help safeguard cotton (Akbar et al. 2019). Many different species of thrips can infest cotton seedlings in the United States, including flower thrips, *Frankliniella tritici* (Fitch), tobacco thrips, *Frankliniella fusca* (Hinds), soybean thrips, *Neohydatothrips variabilis* (Beach), onion thrips, *Thrips tabaci* (Lindeman), and western flower thrips, *Frankliniella occidentalis* (Pergande) (Leigh et al. 1996, Albeldano et al. 2008). Tests conducted in the states of Arkansas, Georgia, Louisiana, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, Texas, and Virginia revealed a wide variety of adult thrips species infesting cotton (Stewart et al. 2013). Prior studies confirmed that the most frequent species in Mississippi were flower thrips, soybean thrips, and tobacco thrips (Dunham and Clark 1937, Cook et al. 2003).
1.2 Thrips Description & Life Cycle

Thrips measure less than 3.2 mm in length (Bethke et al. 2014). Adult thrips have long, slender bodies and are usually darker in color. Immature thrips appear similar to full-grown adults, but they are smaller, paler, and do not have wings. Female thrips can lay eggs that develop into either males or females, although practically all thrips observed on cotton seedlings are females (Bourland et al. 1992). A few species, including *Frankliniella* species, can reproduce by parthenogenesis, in which unfertilized eggs develop into males and fertilized eggs develop into females. From egg to adult, there are six distinct life stages (Lentz et al. 2000). Prepupal and pupal thrips are found in the soil or, very rarely, on a plant, and neither stage feeds (DuRant et al. 1994). Field scouts need to be able to distinguish between thrips larvae and adults. Larvae are always less developed and lighter in color than their adult counterparts. Many species of thrips have long, fringed wings at adulthood, but others are wingless. The thrips’ life span is diminished by rising temperatures. The average time it takes for an egg to develop into an adult is approximately 30 days but, can be as little as 15 days at warmer temperatures (Parker et al. 1992). This suggests that immature thrips may persist for an extended period of time on seedling plants before molting into adults that can migrate off plants (Newsom et al. 1953). Female thrips adults that develop on cotton seedlings typically move off plants in search of pollen because they require a high-protein diet for successful oviposition. Juvenile thrips may be the primary stage attacking cotton seedlings, as they often outnumber the adult stage in untreated fields (Graves et al. 1987). Under ideal conditions, one female can lay up to 100 eggs during her 60-day lifespan (about 20 degrees Celsius).

As soon as cotton seedlings emerge from the soil, they are susceptible to infestation by thrips. Thrips lay their eggs in plant tissue with a sharp ovipositor. Thrips can overwinter in one
of three stages: as a hibernating adult, a larva on winter plants, or a pupa in the soil. During late winter to early spring, thrips begin multiplying on non-cultivated hosts and other available plants like winter wheat (Lentz et al. 2000). Towards the end of April, adults that developed on winter annual hosts begin migrating to better food sources, such as cotton (Herbert 1998). Thrips can fly short distances, but long-range migration is usually facilitated by prevailing winds (Bourland et al. 1992). During times of strong wind velocity during planting, thrips pressure in cotton seedlings is often high. Thrips populations can be so dense that the winds continually blow adult thrips into cotton fields and thus become evenly dispersed across large areas (Gaines 1965). Damage done to young plants by windblown sand can often be mistaken for thrips damage in cotton. Cotton seedlings that have been mechanically damaged by windblown sand are also more prone to injury by thrips. Because thrips adults are constantly being blown into fields, even unplanted fields, they are usually present in most fields before cotton is sown (Lambert et al. 1985). The constant threat from thrips, due to their large populations at such an early stage, can have a detrimental effect on cotton.

1.3 Thrips Impact on Cotton

Unlike most other row crops, cotton is highly susceptible to damage from thrips. Thrips can have a significant impact on cotton growth and development. Thrips injury to seedling cotton can result in delayed fruiting. The damage potential of thrips in cotton is greater than in other crops because cotton seedlings take seven to ten days following emergence to begin developing their terminal bud (Kerns et al. 2009). This slow rate of seedling development provides more time for thrips to cause damage. The cells that will eventually develop into fully formed leaves and fruits make up the terminal bud (Bachelor and Reisig 2010). Thrips tend to concentrate feeding on this terminal bud, causing the leaves to become crinkled and distorted as they expand.
As the plant matures, the damage becomes more evident because of tearing and abnormal growth (Akin et al. 2012). Growth in the terminal bud becomes more rapid once cotton seedlings have three or four true leaves. Because of that, cotton plants become more resistant to damage from thrips (Leigh et al. 1996). Thrips can cause significant damage to cotton from emergence to the four-leaf stage; thus, it is important to scout for thrips and protect the cotton plant during this time. Damage from thrips can cause up to a two-week delay in maturity resulting in a delayed harvest of cotton (Gaines 1934, Dunham and Clark 1937, Bourland et al. 1992, Parker et al. 1992, Herbert 1998, Lentz et al. 2000). Even a short delay in maturity at the beginning of the season can result in the crop being susceptible to other pests for a longer period of time and a greater delay in harvest due to cooler temperatures between defoliation and harvest (Gipson and Johan 1968).

1.4 Thrips Impact on Cotton Yield

There is considerable debate in the literature about the impact of thrips on yield of cotton. Multiple studies have documented improved yields from early season thrips management in cotton (Davis et al. 1966, Davis and Cowan 1972, Burris et al. 1980, Herbert 1998, Lentz et al. 2000, Cook et al. 2013). In extreme circumstances, thrips can kill seedlings which can drastically reduce production. Yield losses due to thrips, have been seen in Louisiana; the untreated cotton yielded 224-672.5 kg. per ha. less than cotton that was treated (Burris et al. 1989). The average yield gain from thrips management in Virginia was 380 kg lint per ha compared to non–treated controls from 1997-2001 (Herbert 2002). Increases of 483-614 kg lint per ha, on average, have been seen in recent years in North Carolina and Virginia following seed treatments with imidacloroprid and in–furrow applications of aldicarb (Herbert et al. 2007). The consistently greater yield reductions from thrips on cotton in those states may be because there are more
thrips hosts per unit area in these small fields than in the rest of the cotton belt, and because the cooler weather delays the growth of seedlings, magnifying the consequences of thrips injury (Herbert et al. 2012).

1.5 Preventative Strategies in Cotton

Thrips injury can be prevented with insecticides placed in the furrow (such as aldicarb, acephate or imidacloprid), applied to the seed (such as acephate, imidacloprid, or thiamethoxam), or applied as a foliar spray (Kerns et al. 2009). In various regions of the cotton belt, neonicotinoid seed treatments, such as thiamethoxam and imidacloprid, have been adopted by farmers to control thrips (Pollet al. 2010, Stewart et al. 2013). Even with the use of an insecticide seed treatment for thrips management, historical research suggests that supplemental foliar sprays may be required in high-risk situations (Cook et al. 2011). The high-risk situations include planting into conventionally tilled fields. Reports of successful pesticide applications targeting thrips are common, however, the species being sprayed is rarely discussed. According to Cook et al., thrips species composition was more diverse in untreated cotton than in cotton that had been treated with insecticides (2003). After spraying, the proportion of thrips species changed dramatically. These findings suggest that Frankliniella fusca were particularly susceptible to these insecticides at the time of those studies (Cook et al. 2003). With regards to reducing adult populations, aldicarb was more effective than other treatments, especially imidacloprid.

Emerging Frankliniella fusca populations in the southeastern United States that are resistant to neonicotinoids pose a threat to cotton (Huseth et al. 2017, Darnell-Crumpton et al. 2018, Huseth et al. 2018). Huseth et al. emphasized that the widespread use of preventive neonicotinoid seed treatments in soybean and cotton was the primary source of neonicotinoid resistance in Frankliniella fusca (2018). About 87 to 90 percent of soybean and cotton hectares
in the United States have a neonicotinoid seed treatment, respectively (Hurley and Mitchell 2017).

Even though neonicotinoid seed treatments (NST) in cotton are not as effective at killing adults of tobacco thrips as they once were, they do have non-lethal effects on the feeding and oviposition behavior of adults (Huseth et al. 2017). Susceptible tobacco thrips lay over 60% fewer eggs on cotton plants treated with imidacloprid compared to untreated cotton plants and only 2.1% of larvae survived on imidacloprid-treated plants, compared to 79.6% on untreated plants (Huseth et al. 2017). This would suggest that thrips populations are susceptible to imidacloprid-treated plants versus untreated. Aldicarb was superior to other treatments, particularly imidacloprid, in lowering adult populations. While at-planting pesticides are generally accepted for thrips management, previous studies have shown that additional foliar sprays may be necessary for high-risk circumstances (Stewart et al. 2013). Planting on conventionally tilled fields or the burning down of overwintering potential plant hosts are examples of risky strategies. Although reports of pesticide efficacy against thrips are prevalent, the species composition of treated populations is rarely mentioned (Reay-Jones et al. 2017). Despite the widespread occurrence of resistance, imidacloprid remains to be one of the most effective insecticides for managing thrips (Reisig et al. 2012).

### 1.6 Alternative Thrips Management

There are other ways to manage thrips in cotton that are being introduced. The thrips prediction model from NC State University provides insight to growers for potential thrips injury depending on planting date. This model uses weather data based on a particular location to make predictions of thrips dispersal, injury risk, and cotton growth affecting seedling susceptibility (Chappell et al. 2020). This is an innovative tool that can be utilized by growers and researchers
across the industry to minimizing thrips injury by adjusting planting dates to avoid periods with more intense thrips pressure.

Another alternative strategy for thrips management is Bt technology, which has been used to target lepidopteran pests for several years (Siebert et al. 2008). This breakthrough technology developed by Bayer Crop Science® is known as ThryvOn® technology, which expresses a newly discovered Bt protein, Cry51Aa2.834_16. This Bt trait targets tobacco thrips, western flower thrips, and tarnished plant bugs, which provides growers with additional protection (Yates-Stewart et al. 2023). Cotton that has ThryvOn technology reduces the number of thrips vs. non-ThryvOn cotton by interacting with their behavior and deterring oviposition (Huseth et al. 2020). Additionally, other studies conducted by researchers have found that thrips densities were significantly reduced in seedling cotton that contained the Bt protein (Graham and Stewart 2018). By using this technology, we could reduce or possibly eliminate the need for foliar insecticide applications and at-planting insecticides, which are currently being used to control thrips. Because the ThryvOn technology is relatively new, information is limited about its utility for thrips management. Therefore, the current studies were conducted to help our understanding of the need for supplemental control measures in ThryvOn cotton.
1.7 References


Burris, E. 1980. Observations on tobacco thrips (Frankliniella fusca) and soybean thrips (Sericothrips variabilis) damage to and control in cotton. p. 204-206. Northeast Louisiana Agricultural Experiment Station Progress Report. LSU AgCenter, Baton Rouge, LA.

Burris E., K. J. Ratchford, A. M. Pavloff, D. J. Boquet, B. R. Williams, and R. L. Rogers. 1989. Thrips on seedling cotton: Related problems and control. Louisiana Agricultural Experiment Station Bulletin 811. LSU AgCenter, Baton Rouge, LA.


Gaines, J. C. 1965. Cotton insects. Texas Agricultural Experiment Station Serial Bulletin 933. Texas A&M University, College Station, TX.


CHAPTER II
THE INFLUENCE OF IMIDACLOPRID SEED TREATMENT ON NON-THRYVON AND THRYVON COTTON

2.1 Abstract

In the Mid-South, thrips are an important early season pest on cotton. Mississippi planted over 400,000 hectares of cotton in 2021 and 2022, all of which were infested with tobacco thrips, *Frankliniella fusca* (Hinds) resulting in about $20 million of economic losses plus cost. A new *Bacillus thuringiensis* trait, ThryvOn® (Bayer Crop Science®, St. Louis, MO), has been developed that provides good control of thrips. Currently, there is some debate about the need for an insecticide seed treatment to improve thrips control with ThryvOn. Research was conducted to determine if the addition of an imidacloprid seed treatment improves efficacy against tobacco thrips and to determine if reduced rates of seed treatments (100, 75, 50, 25, and 0% of the labeled rate) provide benefits for thrips control in ThryvOn cotton. Results suggest that a 50% seed treatment rate of imidacloprid provided similar control compared to the 100% rate of imidacloprid seed treatment. These data suggest that ThryvOn cotton could be utilized with a reduced rate of imidaclorpid compared to other current commercial varieties, drastically decreasing the amount of neonicotinoids released in the environment.

2.2 Introduction

Thrips (Thysanoptera: Thripidae) are the most important and the most damaging insect pests of seedling cotton in the U.S. (Graham et al. 2018, Cook et al. 2011). *Frankliniella fusca*
(Hinds), makes up about 90% of thrips found on cotton in the Mid-South region of the U.S. that includes Arkansas, Mississippi, Louisiana, Tennessee, and Missouri (Cook et al. 2011). Bayer Crop Science® has developed a new biotechnology trait in cotton, ThryvOn, that targets thrips and two species of tarnished plant bugs, *Lygus hesperus* (Knight) and *L. lineolaris* (Palisot de Beauvois), (Hemiptera: Miridae) (Graham et al. 2018). ThryvOn expresses a *Bacillus thuringiensis* (Bt) crystalline protein, Cry51Aa2.834_16, that deters thrips and plant bugs (Bachman et al. 2017, Akbar et al. 2019). Along with this Bt trait, ThryvOn also contains the XtendFlex® technology which protects the cotton from over-the-top applications of glyphosate, glufosinate and dicamba allowing growers to manage difficult weed species. The Bollgard 3® trait also protects the cotton from lepidopteran pests such as bollworm, *Helicoverpa* zea (Boddie); tobacco budworm, *Chloridea virescens* (F.); and other common lepidopteran species. ThryvOn technology was released commercially for the 2023 growing season with a full rate of imidacloprid (Gaucho 600, 0.375 mg a.i./seed, Bayer Crop Science®, St. Louis, MO) on the seed.

Thrips injury to cotton seedlings is more severe than any other agronomic crop in the southern U.S. Thrips adults and larvae feed on the cellular contents of cotton seedlings with rasping-sucking mouthparts (Layton and Reed 2014). This feeding can lead to damaged cotton seedlings resulting in reduced root growth, plant height, and leaf area (Burris et al. 1989, Roberts and Rechel 1996, Brown et al. 2008, Grey et al. 2016). The impact of thrips injury on cotton yield has been seen in some studies showing improved yields when thrips are controlled (Herbert 1998, Lentz and Van Tol 2000). Other studies have found that cotton yield was not affected by thrips feeding injury (Roberts 1994). Those studies have shown that the impact of thrips feeding on cotton yield is dependent on several factors such as weather patterns that can vary among locations, years, and planting dates.
Historically, protection from thrips has relied on the use of at-planting in-furrow insecticides such as aldicarb (AgLogic® 15G, AgLogic Chemical®, LLC; Chapel Hill, NC) or by using neonicotinoid seed treatments such as thiamethoxam (Cruiser® 5FS, Syngenta Crop Protection®, Greensboro, NC) or imidacloprid (Gaucho®, Bayer Crop Science®, St. Louis, MO) (Catchot et al. 2010). In addition to these at-planting insecticides, certain conditions may require an additional foliar insecticide spray such as spinetoram plus methoxyfenozide to manage thrips populations, especially in areas where resistance to neonicotinoids occurs (Cook et al. 2011).

Resistance to neonicotinoids and organophosphates from thrips has become a problem over the past ten years across the Southeastern U.S., so there is considerable concern about the additional value they provide for ThryvOn cotton. In 2014 and 2015, researchers found that 57-65% of the thrips populations collected had decreased susceptibility to neonicotinoids (Huseth et al. 2016). A more recent study found that 16 and 57% of tobacco thrips populations in Mississippi were resistant to neonicotinoids (Darnell-Crumpton et al. 2018). Both studies are crucial to the fact that resistance to neonicotinoids in tobacco thrips is prevalent. Some researchers question the need for a supplemental insecticide seed treatment on ThryvOn cotton. At 0.375 mg a.i. of imidacloprid per seed, there is concern about the additional cost to growers for the use of an insecticide seed treatment on ThryvOn cotton. The objective of this study was to determine if at-planting insecticides provide value on ThryvOn cotton and to determine the optimum rate of imidacloprid.

2.3 Materials and Methods

To determine the impact of imidacloprid rate applied on the seed of ThryvOn and non-ThryvOn cotton, an experiment was established at six locations across two years in the southern U.S. The locations included Starkville, MS, Stoneville, MS, Glendora, MS, Sidon, MS, Jackson,
TN, and Clayton, NC. There were multiple trials at each location that were each replicated four times. The number of trials at each location was six in Starkville, six in Stoneville, three in Glendora, three in Sidon, two in Jackson, and two in Clayton for a total of twenty-two trials. Planting dates varied across locations from early to late May and were planted at a rate of four seeds per 0.31 m and depth between 1.91 cm to 2.54 cm. The experimental design at each location was 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, which included imidacloprid (Gaucho®, Bayer Crop Science®, St. Louis, MO) at 0.375 (100%), 0.281 (75%), 0.188 (50%), and 0.094 (25%) mg a.i. per seed. Aldicarb (AgLogic® 15G, AgLogic Chemical®, LLC; Chapel Hill, NC) was included as an at-planting granular application as a positive control at 3.92 kg per hectare. Additionally, a non-treated control of each variety was included in all trials that did not receive any insecticide treatment. At each location, plot size varied. All plots were four rows with plot length ranging from 9.14 to 12.19 meters and row spacing was 96.52 or 101.6 centimeters depending on location.

Thrips numbers were estimated at each location at the two- and four-leaf stages. Thrips collections were taken from each plot by cutting five random cotton plants at the soil level and immediately placing them into a 0.95 L mason jar. Each mason jar was filled a quarter of the way full of a 70% water to 30% ethanol solution. The jars were then transported to the laboratory and carefully washed using a whole plant wash method (Burris et al. 1989). The contents of each jar were poured into a 300-mesh metal sieve (W.S. Tyler, Mentor, OH) and plants were rinsed with water. 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). The filter paper was placed
on a Buchner funnel and a vacuum was used to drain excess moisture. After all the moisture had been removed from the filter paper, it was then transferred to a petri dish to count the number of adult and immature thrips under a Leica EZ4™ microscope at 25x magnification. Each petri dish was counted, and thrips numbers were recorded by each plot number on a sheet of paper.

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 a 0, while severe damage that could cause significant economic injury was rated a 3, and a dead cotton plant that would not recover was rated a 5. Thrips damage rating was used to categorize locations with low and high pressure. Pressure was determined based on the plots damage ratings at the two-leaf stage from the non-ThryvOn 0% seed treatment rate. A location was considered a low-pressure location if the damage rating was below a three on the thrips injury scale. If plots at a location averaged three or higher on the thrips injury scale, that location was categorized as a high-pressure location. In total there were 12 low pressure locations and 10 high pressure locations.

Plant biomass was recorded at the four-leaf stage. Biomass was taken by carefully digging up ten plants per plot with a gardening spade. The ten plants were then washed in an 18.9 L bucket containing water and placed in paper bags. After collecting all the samples from a trial, these bags with plants were placed into an industrial dryer oven for forty-eight hours at 48 degrees Celsius. The samples were then taken out of the dryer and weighed individually on an OHAUS® PR Series scale. All these trials were regulated by USDA-APHIS and had to be destroyed prior to flowering so yields were not recorded.
2.4 Statistical Analysis

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, location by technology nested in year, location by insecticide nested in year, and location by technology by insecticide nested in year were considered random effects. Means were separated using Fisher’s Protected LSD procedure at the 0.05 level of significance.

2.5 Results

Low Pressure Environments. There was an interaction between technology and insecticide for mean number of thrips ($F= 5.21; df= 5.55; P<0.01$) at the two-leaf stage. At the two-leaf stage, the non-ThryvOn with no additional insecticide had more thrips than all other treatment combinations (Table 2.1). All insecticides applied with non-ThryvOn cotton resulted in fewer thrips than non-ThryvOn with no additional insecticide. In contrast, no differences were observed among any of the insecticide treatments (including the no insecticide) on ThryvOn cotton. On non-ThryvOn cotton, the addition of aldicarb at planting resulted in fewer thrips than non-ThryvOn cotton with 25% and 50% rates of imidacloprid. ThryvOn cotton with no additional insecticide had similar numbers of thrips to the best insecticide treatment, aldicarb, on non-ThryvOn cotton.

There was an interaction between technology and insecticide for mean damage ratings ($F= 8.01; df= 5.55; P<0.01$) at the two-leaf stage. Mean damage ratings on ThryvOn were generally lower than on non-ThryvOn regardless of insecticide treatment (Table 2.1). All insecticide treatments resulted in lower thrips damage ratings than the no insecticide treatment on either ThryvOn or non-ThryvOn cotton (Table 2.1). Aldicarb resulted in lower mean damage
ratings than the insecticide seed treatments on non-ThryvOn cotton. ThryvOn cotton with no insecticide treatment had a lower mean damage rating than non-ThryvOn cotton with any rate of imidacloripid. Both the non-ThryvOn and ThryvOn damage ratings resulted in no imminent advantage after the 50% insecticide rate of imidacloripid.

There was a significant interaction between technology and insecticide for mean number of thrips \((F= 5.30; df= 5.55; P<0.01)\) at the four-leaf stage. ThryvOn cotton with no insecticide had fewer thrips than non-ThryvOn with no insecticide (Table 2.1). Aldicarb was the only insecticide treatment in non-ThryvOn cotton that resulted in fewer thrips than the non-ThryvOn with no additional insecticide (Table 2.1). Similar results were observed in ThryvOn cotton where aldicarb was the only insecticide treatment that resulted in fewer thrips than the no insecticide treatment. Imidacloripid seed treatments did not provide a reduction in thrips compared to the no insecticide in either non-ThryvOn or ThryvOn cotton.

There was a significant interaction between technology and insecticide for mean damage ratings \((F= 24.29; df= 5.55; P<0.01)\) at the four-leaf stage. Mean damage ratings on ThryvOn were lower than on non-ThryvOn regardless of insecticide treatments other than aldicarb (Table 2.1). The untreated ThryvOn control resulted in lower mean damage ratings than any of the imidacloripid insecticide rates in non-ThryvOn (Table 2.1). In the ThryvOn technology, mean damage ratings were not significantly different after the 25% insecticide rate. However, in the non-ThryvOn technology, mean damage ratings were not significantly different after the 75% insecticide rate.

There was not an interaction between technology and insecticide for mean total biomass at the four-leaf stage \((F= 1.91; df= 5.50; P=0.11)\). There was also no main effect on mean total biomass by technology \((F= 0.69; df= 1.10; P=0.42)\). Insecticide was the only factor that had an
effect on biomass ($F = 3.67; df = 5.50; P < 0.01$). Aldicarb was the only insecticide that resulted in greater biomass than the untreated control averaged across both ThryvOn and non-ThryvOn cotton (Figure 2.1).

**High Pressure Environments.** There was a significant interaction between technology and insecticide for mean number of thrips ($F = 2.71; df = 5.35; P = 0.04$) at the two-leaf stage. Mean number of thrips was lower in ThryvOn cotton than non-ThryvOn cotton for each insecticide treatment, except the 100% imidacloprid rate and aldicarb (Table 2.2). On non-ThryvOn cotton, imidacloprid seed treatment at the 100% rate and aldicarb were the only insecticide treatments that resulted in fewer thrips than non-ThryvOn cotton with no insecticide. In contrast, there were no differences among insecticide treatments for ThryvOn cotton including the untreated control.

There was a significant interaction between technology and insecticide for mean damage ratings ($F = 23.52; df = 5.40; P < 0.01$) at the two-leaf stage. Mean damage ratings on ThryvOn were generally lower than those for non-ThryvOn, regardless of insecticide treatment. All insecticide treatments resulted in lower thrips damage ratings than the no insecticide treatment on either ThryvOn or non-ThryvOn cotton (Table 2.2). The 75% and 100% imidacloprid seed treatment rates had a similar damage rating as the aldicarb treatment on ThryvOn cotton, but aldicarb resulted in a lower thrips damage rating than all imidacloprid seed treatment rates on non-ThryvOn cotton. ThryvOn cotton with no insecticide treatment had a lower damage rating than non-ThryvOn cotton with any rate of imidacloprid.

There was an interaction between technology and insecticide for mean total thrips ($F = 6.58; df = 5.45; P < 0.01$) at the four-leaf stage. On ThryvOn cotton, aldicarb was the only insecticide treatment that resulted in fewer mean thrips than the no insecticide treatment (Table 2.2). In contrast, all insecticide treatments resulted in fewer mean thrips than the no insecticide
treatment on non-ThryvOn cotton. All insecticide treatments (including the untreated) on ThryvOn cotton resulted in fewer mean thrips than all imidacloprid seed treatment rates and the no insecticide treatment on non-ThryvOn. Aldicarb applied in furrow was the only insecticide treatment on non-ThryvOn cotton that resulted in similar numbers of thrips as any of the insecticide treatments on ThryvOn cotton at the four-leaf stage. 

There was an interaction between technology and insecticide for mean damage ratings ($F= 35.44; df= 11.45; P<0.01$) at the four-leaf stage. Mean damage ratings on ThryvOn cotton were lower than damage ratings on non-ThryvOn cotton regardless of insecticide treatment except that aldicarb applied to non-ThryvOn cotton had a similar damage rating to ThryvOn cotton with a 25% rate of imidacloprid and the no insecticide treatment (Table 2.2). On ThryvOn cotton, imidacloprid rates of 50% or greater and aldicarb resulted in a lower thrips damage rating than the no insecticide treatment. In contrast, all insecticide treatments resulted in lower thrips damage ratings than the no insecticide treatment on non-ThryvOn cotton. All mean thrips damage ratings on ThryvOn cotton were below a 2.0 at the two-leaf and four-leaf stages. The only treatment that resulted in a mean damage rating less than 2.0 on non-ThryvOn cotton was the aldicarb treatment at the two and four-leaf stages.

There was an interaction between technology and insecticide for mean total biomass ($F= 3.82; df= 5.40; P<0.01$) at the four-leaf stage. When comparing technologies, ThryvOn had greater mean total biomass compared to non-ThryvOn for the untreated control, the 75% and 100% imidacloprid rates (Figure 2.2). On non-ThryvOn cotton, all insecticide treatments resulted in greater biomass than the no insecticide treatment. In contrast, only imidacloprid at the 75% and 100% rates, and aldicarb resulted in greater biomass than the no insecticide treatment on ThryvOn cotton. On non-ThryvOn cotton, aldicarb resulted in greater biomass than all other
treatments, while biomass was not different between 75-100% imidacloprid rates and aldicarb on ThryvOn cotton.

2.6 Discussion

Thrips management in cotton has always relied on prophylactic at-planting insecticides such as aldicarb or acephate. Most growers have adopted the use of neonicotinoid seed treatments such as imidacloprid and thiamethoxam (Cook et al. 2011). Through this research, non-ThryvOn and ThryvOn at different seed treatment rates proved to show both advantages and disadvantages of each insecticide treatment rate. Thrips numbers were significantly reduced by ThryvOn when compared to non-ThryvOn. ThryvOn has continued to provide better control of thrips than non-ThryvOn as was found in a study in Arkansas (Whitfield et al. 2021). Thrips have also shown to prefer non-ThryvOn when it comes to oviposition (Graham et al. 2019). On ThryvOn cotton, at-planting insecticides did not provide a substantial advantage in terms of thrips numbers at both the two- and four-leaf stages in low- and high-pressure environments. Thrips damage ratings were significantly reduced when increasing the rate of imidacloprid in the non-ThryvOn variety. However, in ThryvOn there was no significant difference in damage ratings across any of the rates of imidacloprid. ThryvOn continued to show significantly lower damage ratings with all seed treatment rates other than aldicarb compared to non-ThryvOn. ThryvOn has continued to show decreased mean damage ratings when compared to non-ThryvOn cotton technology (Yates-Stewart et al. 2023). As with any insecticide, resistance is always a concern. Thrips resistance has occurred with acephate, which is one of our most common insecticides (Krob et al. 2022). From a management perspective, thrips are being controlled with the use of the Bt gene in ThryvOn and the one hundred percent imidacloprid seed treatment rate that is being added to ThryvOn may not be needed. Aldicarb was the only
insecticide that provided any benefit for thrips management in ThryvOn cotton. ThryvOn provides the opportunity to reduce insecticide use in cotton providing an economic benefit to growers and an environmental benefit from fewer insecticides being used. Based on these data, a better integrated pest management approach would be to limit the insecticide seed treatment to fifty percent (0.188 mg a.i./seed) to provide some benefit for resistance management and to continue scouting and spraying based on established thresholds.
Table 2.1  Mean (SEM) number of thrips and damage ratings at the 2-leaf stage and 4-leaf stage of ThryvOn and non-ThryvOn cotton averaged across all low-pressure environments (12) in 2021 and 2022.

<table>
<thead>
<tr>
<th></th>
<th>Mean (SEM) at 2-Leaf Stage&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Mean (SEM) at 4-Leaf Stage&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thrips No. per 5 plants</td>
<td>Damage Rating 0-5 Scale</td>
</tr>
<tr>
<td>ThryvOn UTC</td>
<td>14.36 (2.16)bcde</td>
<td>0.96 (0.08)de</td>
</tr>
<tr>
<td>ThryvOn 25%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.46 (1.90)cd</td>
<td>0.87 (0.08)ef</td>
</tr>
<tr>
<td>ThryvOn 50%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.49 (1.01)cd</td>
<td>0.90 (0.07)ef</td>
</tr>
<tr>
<td>ThryvOn 75%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.39 (1.15)cd</td>
<td>0.76 (0.06)ef</td>
</tr>
<tr>
<td>ThryvOn 100%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.09 (0.79)d</td>
<td>0.77 (0.07)ef</td>
</tr>
<tr>
<td>ThryvOn + 3.92 kg. AgLogic</td>
<td>5.26 (1.10)d</td>
<td>0.70 (0.07)f</td>
</tr>
<tr>
<td>Non-ThryvOn UTC</td>
<td>48.31 (7.68)a</td>
<td>1.91 (0.11)a</td>
</tr>
<tr>
<td>Non-ThryvOn 25%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>27.40 (4.07)b</td>
<td>1.56 (0.08)b</td>
</tr>
<tr>
<td>Non-ThryvOn 50%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23.46 (4.85)bc</td>
<td>1.40 (0.10)bc</td>
</tr>
<tr>
<td>Non-ThryvOn 75%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.91 (2.93)bcd</td>
<td>1.28 (0.08)c</td>
</tr>
<tr>
<td>Non-ThryvOn 100%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.57 (3.00)bc</td>
<td>1.20 (0.07)cd</td>
</tr>
<tr>
<td>Non-ThryvOn + 3.92 kg. AgLogic</td>
<td>8.70 (2.80)d</td>
<td>0.87 (0.11)ef</td>
</tr>
</tbody>
</table>

<sup>a</sup>Percentages represent the amount of imidacloprid on the seed relative to the currently labeled rate of 0.375 mg a.i./seed.

<sup>b</sup>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 2.2  Mean (SEM) number of thrips and damage ratings at the 2-leaf stage and 4-leaf stage of ThryvOn and non-ThryvOn cotton averaged across all high-pressure environments (10) in 2021 and 2022.

<table>
<thead>
<tr>
<th></th>
<th>Mean (SEM) at 2-Leaf Stage&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Mean (SEM) at 4-Leaf Stage&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thrips No. per 5 plants</td>
<td>Damage Rating 0-5 Scale</td>
</tr>
<tr>
<td>ThryvOn UTC</td>
<td>26.88 (3.83)b-f</td>
<td>1.68 (0.09)e</td>
</tr>
<tr>
<td>ThryvOn 25%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22.28 (4.28)c-f</td>
<td>1.42 (0.07)f</td>
</tr>
<tr>
<td>ThryvOn 50%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20.91 (3.45)def</td>
<td>1.25 (0.07)fg</td>
</tr>
<tr>
<td>ThryvOn 75%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>17.22 (2.61)ef</td>
<td>1.18 (0.06)gh</td>
</tr>
<tr>
<td>ThryvOn 100%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.41 (2.12)ef</td>
<td>1.15 (0.06)gh</td>
</tr>
<tr>
<td>ThryvOn + 3.92 kg. AgLogic</td>
<td>5.97 (0.76)f</td>
<td>0.98 (0.07)h</td>
</tr>
<tr>
<td>Non-ThryvOn UTC</td>
<td>72.41 (11.73)a</td>
<td>3.47 (0.08)a</td>
</tr>
<tr>
<td>Non-ThryvOn 25%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>65.44 (13.09)ab</td>
<td>2.84 (0.09)b</td>
</tr>
<tr>
<td>Non-ThryvOn 50%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>61.97 (15.64)abc</td>
<td>2.58 (0.10)c</td>
</tr>
<tr>
<td>Non-ThryvOn 75%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>58.25 (12.82)a-d</td>
<td>2.36 (0.11)cd</td>
</tr>
<tr>
<td>Non-ThryvOn 100%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>46.63 (9.75)b-e</td>
<td>2.26 (0.11)d</td>
</tr>
<tr>
<td>Non-ThryvOn + 3.92 kg. AgLogic</td>
<td>15.59 (4.17)ef</td>
<td>1.35 (0.12)fg</td>
</tr>
</tbody>
</table>

<sup>a</sup>Percentages represent the amount of imidacloprid on the seed relative to the currently labeled rate of 0.375 mg a.i./seed.

<sup>b</sup>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.
Figure 2.1  Mean (SEM) total biomass in grams at the 4-leaf stage of ThryvOn and non-ThryvOn cotton averaged across all low-pressure environments in 2021 and 2022.

a Percentages represent the amount of imidacloprid on the seed relative to the currently labeled rate of 0.375 mg a.i./seed. IST-insecticide seed treatment.

b 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.
Figure 2.2  Mean (SEM) total biomass in grams at the 4-leaf stage of ThryvOn and non-ThryvOn cotton averages across all high-pressure environments in 2021 and 2022.

\( ^a \) Percentages represent the amount of imidacloprid on the seed relative to the currently labeled rate of 0.375 mg a.i./seed. IST-insecticide seed treatment.

\( ^b \) Means within a column followed by the same letter are not different according to Fisher’s Protected LSD test within an alpha pf 0.05.
2.7 References


CHAPTER III
IMPACT OF ALDICARB AND THRYVON ON TOBACCO THRIPS AND RENIFORM NEMATODES

3.1 Abstract
In 2022, 100% of Mississippi Cotton hectares were infested with tobacco thrips, Frankliniella fusca (Hinds). Most cotton was treated with some type of at-planting insecticide treatment, most commonly an imidacloprid and acephate seed treatment is used in Mississippi cotton. In addition to an insecticide seed treatment, about 40-45% of the hectares require an additional foliar application to effectively control thrips. Cotton fields in some areas of Mississippi may also be infested by reniform nematode, Rotylenchulus reniformis (Linford & Oliveira). Depending on the year and environment nematodes may cause varying levels of damage to cotton plants. However, reniform nematode and thrips have been controlled in the past using aldicarb, a granular insecticide and/or other soil incorporated nematicides plus insecticide seed treatments. The impact of aldicarb (AgLogic® 15G, AgLogic Chemical®, LLC; Chapel Hill, NC) and the new ThryvOn® technology (Bayer Crop Science®; St. Louis, MO) on reniform nematodes and tobacco thrips in Mississippi cotton production systems has yet to be seen.

3.2 Introduction
Cotton, Gossypium hirsutum L., has many economically important early season pests such as tobacco thrips, Frankliniella fusca (Hinds), and reniform nematode, Rotylenchulus reniformis (Linford and Oliveira). Tobacco thrips damage the plant from above by feeding on the
leaves which can cause deformed leaves with a silverish appearance. Reniform nematodes tend to feed below the surface on the cortex of cotton roots (Crow et al. 2018). Both pests have the potential to severely damage a cotton plant by reducing yield potential, reducing root growth, and by delaying maturity (Gazaway and Edisten 1993, Roberts and Rechel 1996, Kirkpatrick 2001, Monfort 2005, Brown et al. 2008, Crow 2018). For the 2022 growing season in Mississippi, thrips infested 100% of the 214,400 cotton hectares causing 50% of those hectares to be treated for thrips which resulted in over twelve million dollars in losses (Cook 2022). To combat these infestations, most Mississippi cotton is treated with some type of at-planting insecticide. These include imidacloprid (Gaucho®, Bayer Crop Science®; St. Louis, MO) applied as a seed treatment or granular aldicarb applied in the seed furrow (AgLogic® 15G, AgLogic Chemical®, LLC; Chapel Hill, NC). In addition to an at-planting insecticide, some of the more heavily infested cotton fields may require an additional foliar application for effective thrips control. A new product called ThryvOn® from (Bayer Crop Science®; St. Louis, MO) will offer a Bacillus thuringiensis trait in cotton that may eliminate the need for foliar thrips applications.

Reniform nematode is an early season pest in cotton that limits nutrient and water uptake through the roots (Koenning et al. 2004). For growers, these nematodes are considered stress pathogens that may compound potential yield losses from other environmental stresses (Crow 2018). Some researchers have estimated anywhere from seven to eight percent yield loss due to reniform nematode (Birchfield and Jones 1961, Davis et al. 2003, Blasingame et al. 2006, 2009). To effectively analyze the impact of aldicarb and ThryvOn on both pests, trials were conducted throughout Mississippi in various locations.
3.3 Materials and Methods

In 2021 and 2022, four trials were conducted in Starkville, Glendora, and Stoneville, Mississippi. 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 96.52-101.6 cm. Plots were four rows wide and 12.19 meters 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. and included a 4.11 kg. per ha. rate of imidacloprid plus fluopyram (Velum Total®, Bayer Crop Science®; St. Louis, MO) applied as an in-furrow spray, along with an untreated control.

To assess the impact of aldicarb and ThryvOn, thrips populations were taken 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 at about 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, N.C.). 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 and placed into a category of
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 a zero, while severe damage that would cause significant economic injury was rated a three, and a dead cotton plant that would not recover was rated a five. Thrips damage ratings were used to categorize locations into low and high pressure. Each location’s pressure was determined by taking the damage rating from the non-ThryvOn no at-planting insecticide treatment at the two-leaf stage. A low-pressure location was selected if the damage rating was below a three on the thrips injury scale. If the four plots in a trial averaged above a three on the thrips injury scale, that location was categorized as a high-pressure location. Between 2020 and 2021, there were two locations designated as low-pressure environments and two locations designated as high-pressure environments.

In addition to thrips densities and damage ratings, plant biomass per ten plants and nematode numbers per 568 mL of soil were also recorded at the four-leaf stage. Biomass was determined to assess plant vigor by using a gardening spade to dig up ten 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 then placed into an industrial dryer oven at fifty degrees Celsius for forty-eight hours. The samples were then taken out of the dryer and weighed in grams individually on an OHAUS® PR Series scale. Nematode soil samples were taken from each plot ~40 days 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.

3.4 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.

3.5 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 in the trial (Table 3.1). In the non-ThryvOn, the aldicarb insecticide treatments were not significantly different from one another, however, they resulted in lower mean numbers of thrips than the untreated control and imidacloprid plus fluopyram insecticide treatments. All the insecticide treatments in the ThryvOn 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-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 3.1). All the insecticide treatments in the 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-pressure environments. The untreated and the imidacloprid plus fluopyram insecticide treatments in the non-ThryvOn cotton had the highest mean number of thrips. In the ThryvOn, 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 3.1). 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 not a significant interaction between technology and insecticide for biomass \((F = 1.65; df = 3.18; P = 0.21)\) in low-pressure environments (Table 3.2). 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-pressure environments. Also, there was not an interaction between technology and insecticide for nematode numbers \((F = 0.90; df = 3.18; P = 0.46)\) in low pressure environments at the four-leaf stage (Table 3.2). There was also 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 per 568 mL of soil in low pressure environments.

**High Thrips Pressure Environments.** There was not an interaction between technology and insecticide for the mean number of thrips per ten plants \((F = 1.54; df = 3.48; P = 0.22)\) at the two-leaf stage (Table 3.3). There was also no main effect for technology \((F = 1.29; df = 1.3; P = 0.29)\)
P=0.46), however, there was a main effect for insecticide ($F= 5.58; df= 3,48; P=0.0023$) at the two-leaf stage regarding the mean number of thrips. The untreated control had the highest mean number of thrips. All the other insecticide treatments were not significantly different from one another. However, it is worth noting that much lower thrips numbers occurred in the ThryvOn insecticide treatments compared to non-ThryvOn even though they are not significantly different 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-pressure environments (Table 3.3). The non-ThryvOn untreated control had a higher mean damage rating than any other insecticide treatments. The non-ThryvOn plus Velum Total insecticide treatment also 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-pressure environments (Table 3.3). Non-ThryvOn untreated control had the highest mean number of thrips than any other plots that received an insecticide treatment. All other insecticide treatments were not significantly different from one another, 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 3.3). The non-ThryvOn untreated control mean damage rating was greater than any other insecticide treatments. The non-ThryvOn with imidacloprid plus fluopyram insecticide
treatment had the second highest mean damage rating (Table 3.3). 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 3.2). 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 3.2). There was not an interaction between insecticide and technology for nematode numbers per 568 mL of soil ($F=0.34; df=3.18; P=0.81$) in high-pressure environments (Table 3.2). 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 per 568 mL of soil in high-pressure environments.

### 3.6 Discussion

Overall, the objective of this study was to assess the impact of aldicarb 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 (Crow 2018). When comparing mean damage ratings in this study, ThryvOn technology does have generally lower ratings than non-ThryvOn. The imidacloprid plus fluopyram insecticide
treatment in the ThryvOn variety consistently displayed lower mean numbers of thrips and lower mean damage ratings at the four-leaf stages. Another study conducted found that all non-ThryvOn plots had greater damage ratings than the 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, while 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. While no significant interaction was observed for nematodes in low- or high-pressure environments, this could be explained by the lack of adequate nematode populations. Given the data, we can conclude that the addition of aldicarb provides 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.
Table 3.1  Mean (SEM) number of thrips and damage ratings at the 2-leaf stage and 4-leaf stage of ThryvOn and non-ThryvOn cotton averaged across all low-pressure environments in 2021 and 2022.

<table>
<thead>
<tr>
<th></th>
<th>Mean (SEM) at 2-Leaf Stage&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean (SEM) at 4-Leaf Stage&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thrips No. per 5 plants</td>
<td>Damage Rating 0-5 Scale</td>
</tr>
<tr>
<td>ThryvOn UTC</td>
<td>5.50 (1.79)bc</td>
<td>0.81 (0.18)bc</td>
</tr>
<tr>
<td>ThryvOn + 3.92 kg. AgLogic&lt;sup&gt;®&lt;/sup&gt;</td>
<td>0.88 (0.35)c</td>
<td>0.75 (0.18)bc</td>
</tr>
<tr>
<td>ThryvOn + 5.60 kg. AgLogic&lt;sup&gt;®&lt;/sup&gt;</td>
<td>1.00 (0.38)c</td>
<td>0.84 (0.14)bc</td>
</tr>
<tr>
<td>ThryvOn + 4.11 kg. Velum Total&lt;sup&gt;®&lt;/sup&gt;</td>
<td>2.88 (0.85)bc</td>
<td>0.78 (0.14)bc</td>
</tr>
<tr>
<td>Non-ThryvOn UTC</td>
<td>17.62 (4.86)a</td>
<td>1.97 (0.21)a</td>
</tr>
<tr>
<td>Non-ThryvOn + 3.92 kg. AgLogic&lt;sup&gt;®&lt;/sup&gt;</td>
<td>1.38 (0.53)c</td>
<td>0.69 (0.15)bc</td>
</tr>
<tr>
<td>Non-ThryvOn + 5.60 kg. AgLogic&lt;sup&gt;®&lt;/sup&gt;</td>
<td>1.25 (0.49)c</td>
<td>0.56 (0.14)c</td>
</tr>
<tr>
<td>Non-ThryvOn + 4.11 kg. Velum Total&lt;sup&gt;®&lt;/sup&gt;</td>
<td>9.63 (3.25)b</td>
<td>1.03 (0.16)b</td>
</tr>
</tbody>
</table>

<sup>a</sup>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 3.2  Mean (SEM) number of nematodes per 568 mL of soil and grams of biomass per ten plants at the 4-leaf stage of ThryvOn and non-ThryvOn cotton averaged across all low- and high-pressure environments in 2021 and 2022.

<table>
<thead>
<tr>
<th></th>
<th>Mean (SEM) at Low Pressure&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean (SEM) at High Pressure&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Biomass (Grams per 10 plants)</td>
<td>Nematodes (No. per 568 mL of soil)</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------------------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>ThryvOn UTC</td>
<td>4.56 (0.50)</td>
<td>2125.75 (406.37)</td>
</tr>
<tr>
<td>ThryvOn + 3.92 kg. AgLogic®</td>
<td>5.81 (0.15)</td>
<td>1789.00 (306.73)</td>
</tr>
<tr>
<td>ThryvOn + 5.60 kg. AgLogic®</td>
<td>5.50 (0.29)</td>
<td>1948.00 (487.28)</td>
</tr>
<tr>
<td>ThryvOn + 4.11 kg. Velum Total®</td>
<td>5.10 (0.48)</td>
<td>3774.00 (1632.84)</td>
</tr>
<tr>
<td>Non-ThryvOn UTC</td>
<td>6.47 (0.25)</td>
<td>4485.75 (2196.69)</td>
</tr>
<tr>
<td>Non-ThryvOn + 3.92 kg. AgLogic®</td>
<td>6.02 (0.35)</td>
<td>1115.25 (727.30)</td>
</tr>
<tr>
<td>Non-ThryvOn + 5.608 kg. AgLogic®</td>
<td>6.10 (0.22)</td>
<td>3721.75 (2328.03)</td>
</tr>
<tr>
<td>Non-ThryvOn + 4.11 kg. Velum Total®</td>
<td>5.51 (0.78)</td>
<td>3465.00 (686.35)</td>
</tr>
</tbody>
</table>

<sup>a</sup> 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 3.3  Mean (SEM) number of thrips and damage ratings at the 2-leaf stage and 4-leaf stage of ThryvOn and non-ThryvOn cotton averaged across all high-pressure environments in 2021 and 2022.

<table>
<thead>
<tr>
<th></th>
<th>Mean (SEM) at 2-Leaf Stage&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean (SEM) at 4-Leaf Stage&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thrips No. per 5 plants</td>
<td>Damage Rating 0-5 Scale</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>ThryvOn UTC</td>
<td>21.38 (10.22)b</td>
<td>1.41 (0.23)c</td>
</tr>
<tr>
<td>ThryvOn + 3.92 kg. AgLogic®</td>
<td>4.38 (1.36)b</td>
<td>1.03 (0.18)cd</td>
</tr>
<tr>
<td>ThryvOn + 5.608 kg. AgLogic®&lt;sup&gt;®&lt;/sup&gt;</td>
<td>5.88 (0.93)b</td>
<td>0.94 (0.16)d</td>
</tr>
<tr>
<td>ThryvOn + 4.11 kg. Velum Total&lt;sup&gt;®&lt;/sup&gt;</td>
<td>3.13 (0.91)b</td>
<td>1.13 (0.17)cd</td>
</tr>
<tr>
<td>Non-ThryvOn UTC</td>
<td>68.75 (30.36)a</td>
<td>3.44 (0.14)a</td>
</tr>
<tr>
<td>Non-ThryvOn + 3.92 kg. AgLogic®</td>
<td>10.88 (3.79)b</td>
<td>1.44 (0.25)c</td>
</tr>
<tr>
<td>Non-ThryvOn + 5.608 kg. AgLogic®&lt;sup&gt;®&lt;/sup&gt;</td>
<td>17.50 (8.30)b</td>
<td>1.38 (0.26)cd</td>
</tr>
<tr>
<td>Non-ThryvOn + 4.11 kg. Velum Total&lt;sup&gt;®&lt;/sup&gt;</td>
<td>22.00 (8.80)b</td>
<td>2.28 (0.16)b</td>
</tr>
</tbody>
</table>

<sup>a</sup>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.
3.7 References


Crow, Whitney D. The Compounding Stresses of Tobacco Thrips, Frankliniella Fusca (Hinds), and Reniform Nematode, Rotylenchulus Reniformis (Linford & Oliveira), on the Growth and Development of Cotton, Gossypium Hirsutum L, Mississippi State University, United States -- Mississippi, 2018.


