8-2014

Potential Interactions of Early Season Herbicides and Insecticides in Cotton: Thrips Control and Plant Health

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A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Entomology

by

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University of Arkansas
Bachelor of Science in Agricultural Business, 2012

August 2014
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

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Abstract

Cotton growth early in the season is affected by damaging levels of thrips in many production fields in Arkansas. During this time, insecticides used to control thrips and herbicides used to control weeds are often present at the same time on the cotton plant. This research explores how various combinations of herbicides and insecticides influence thrips numbers and cotton plant growth parameters early in the growing season. Pathways evaluated included interactions between preemergence herbicides and insecticide seed treatments and interactions between common tank-mixed foliar herbicides and selected foliar insecticides. No interactions in thrips control or plant growth were observed when using preemergence herbicides in combination with insecticide seed treatments. However, efficacy varied between chosen insecticide seed treatments and it may be concluded that in this experiment imidacloprid seed treatments exhibited greater control of thrips numbers than thiamethoxam seed treatments. There were isolated herbicide-insecticide interactions affecting plant growth parameters, but overall the co-application of tested herbicides and insecticides offer cotton producers the ability to integrate thrips and weed control without loss of thrips efficacy or negative impact on plant growth. Herbicide-insecticide interactions examined in this study suggested that pesticide combinations present on the cotton plant simultaneously, early in the season, have no significant interaction which may affect thrips control and early season cotton plant growth.

Acknowledgments

The author wishes to express his appreciation and sincere thanks to his major professor, Dr. G.M. Lorenz, for his guidance, assistance and encouragement throughout the course of this research. The professional relationship and personal friendship developed with Dr. Lorenz over the course of four years is irreplaceable to the author. Special thanks are also extended to Dr. T.J. Kring and Dr. L.T. Barber for their support and assistance in reviewing this study. Also Entomology department head Dr. Wiedenmann and Mrs. N.M. Taillon provided overwhelming support during the course of this study.

University of Arkansas research facilities at both Marianna and Rohwer, AR are acknowledged for making available field plots in which this research was conducted.

A very special thanks is due to my significant other, Mary Kate, for her patience and long nights spent working by my side throughout my course of study. Gratitude is also due to Mr. and Mrs. R.F. Clarkson for their continuous support and encouragement.

Table of Contents

Introduction

Multiple chemical applications are often required for crop management and insect control throughout the growing season of upland cotton (*Gossypium hirsutum* L.). Thrips (Thysanoptera:Thripidae) are common insect pests during the early growth stages of cotton along with many species of early season weeds. Thrips are controlled chemically through the use of insecticide seed treatments (IST), insecticides applied into the soil at planting (in-furrow), or with foliar applications when needed. Early season weed control is achieved chemically through the application of preemergence (PRE) and/or post emergence (POST) herbicides. Because pesticide applications for early season weeds and thrips control coincide, there is potential for an interaction between the two types of pesticides. Herbicide-insecticide interactions in cotton have been previously reported. Shorter plants, stand reduction, increased or decreased toxicity and phytotoxicity have all been reported as effects due to herbicide-insecticide interactions (Putnam & Penner, 1974). Herbicide-insecticide interactions could explain reduced insecticide efficacy on thrips populations and slower growth of cotton plants under optimal growing conditions, observations sometimes seen by both extension and growers in the state of Arkansas.

There are two possible routes for early season herbicides and insecticides to be present simultaneously on the cotton plant. One route for this interaction to take place is through the use of PRE herbicides and IST's. This is especially interesting because of the major increase in PRE herbicide use across the cotton belt. Another potential route is through tank-mixing a thrips insecticide with a POST herbicide. As application costs increase for the grower, tank-mixing becomes more common, allowing the grower to become more efficient and reducing trips made across the field. Both of these practices are common in recent cotton production and more information is needed to determine if herbicide-insecticide interactions are affecting plant growth and/or pesticide efficacy in anyway. Therefore, this research was conducted to evaluate the

effects different pathways of herbicide-insecticide interactions have on thrips populations and cotton plant growth throughout the season.

Chapter I. Herbicide-Insecticide Interactions through the Combination of Preemergence Herbicides and Insecticide Seed Treatments

Abstract

Field studies were conducted in 2012 and 2013 to evaluate thrips control and cotton plant responses with the co-application of preemergence herbicides fluometuron (1122 g AI/ha), diuron (558 g AI/ha), and fomesafen (279 g AI/ha) alone or with insecticide seed treatments imidacloprid (0.75 mg AI/seed), imidacloprid (0.375 mg AI/seed), thiamethoxam (0.525 mg AI/seed), thiamethoxam (0.375 mg AI/seed), abamectin + thiamethoxam (0.15 mg AI/seed + 0.49 mg AI/seed), and abamectin + thiamethoxam (0.15 mg AI/seed + 0.375 mg AI/seed). There was no interaction between herbicides and insecticides on the number of thrips sampled or on seed cotton yield in 2012 or 2013. Significant differences in number of thrips sampled, plant growth parameters, and seed cotton yield were caused by insecticide seed treatments, but not preemergence herbicide applications. Imidacloprid treatments consistently exhibited greater control of thrips compared to thiamethoxam treatments. Seed cotton yield increased as thrips numbers decreased and imidacloprid treatments reduced thrips numbers, increasing seed cotton yield compared to thiamethoxam treatments.

Introduction

Thrips (Thysanoptera: Thripidae) are the most important group of insect pests in the early growth stages of Mid-south, U.S. cotton (*Gossypium hirsutum* L.). Reports in 2012 concluded that thrips were the overall second rated economically damaging insect pest in Arkansas cotton, with insecticide costs from both foliar treatments and insecticide seed treatments costing cotton growers over ten million dollars (Williams, 2012). Species of thrips that commonly infest cotton seedlings in the U.S. include tobacco thrips, *Frankliniella fusca* (Hinds); flower thrips, *Frankliniella tritici* (Fitch); western flower thrips, *Frankliniella occidentalis* (Pergande); onion thrips, *Thrips tabaci* (Lindeman); and soybean thrips, *Neohydatothrips variabilis* (Beach). Tobacco thrips in Arkansas are comprised of up to 84% of all thrips species found on seedling cotton. Western flower thrips were the second most common thrips species at 15.6% of the thrips populations (Stewart et al., 2013a). A thrips infestation during periods of cool weather and slow growth of cotton seedlings has been linked to several problems including stunting, delayed fruiting, loss of apical dominance, and possible loss of stand (Reed & Jackson, 2002). Increasing yields have been reported by several researchers when seedling thrips were controlled (Cook et al., 2013; Reed & Jackson, 2002; Stewart et al., 2013a).

Thrips are traditionally controlled with insecticides applied directly to the seed, into the soil at planting, or with foliar applications when needed. Currently, neonicotinoid seed treatments (imidacloprid and thiamethoxam) are the most widely adopted method for thrips control in the cotton belt and over 99% of Arkansas cotton acres are planted with insecticide treated seed (Williams, 2012). Several benefits result from the use of seed treatments including increased vigor and equivalent efficacy to alternative methods, cheaper method of application, convenience to the grower, and reduction in equipment cost (Taylor & Harman, 1990). Foliar

applications of insecticides are used in the absence of other control options or when seed treatment residual control declines (Studebaker et al., 2013). Foliar insecticide applications for thrips control were applied on 55% of Arkansas cotton acreage from 2006-2010, in addition to IST's. In contrast, 79.6% of Arkansas cotton acreage was treated with a foliar thrips insecticide application from 2011-2013 (Williams, 2006-2013). This increase of foliar applications suggests that IST's are not providing as much control of thrips as in previous years. By the year of 2012, 485,000 of 580,000 (83%) of cotton acres were treated with a supplemental foliar insecticide application for thrips control in Arkansas. On average, 1.8 foliar applications were made per acre, costing Arkansas producers an additional $4,306,000 to control thrips. With the cost of IST's in 2012 at $6,380,000, Arkansas growers spent around ~$10.7 million for thrips control in cotton.

A possible factor in the loss of thrips control with IST's may be related to issues in weed control. Historically, weed control in cotton relied heavily on a combination of tillage, soil-applied herbicides, post-emergence directed herbicides, and hand weeding. In recent years, weed control in cotton has become heavily reliant on transgenic technologies (Irby et al., 2013). Over 98% of Arkansas cotton was planted to Roundup Ready or Roundup Ready Flex (glyphosate) herbicide systems by 2010 (Smith & Scott, 2010). This adoption occurred because of glyphosate's effective means of controlling Palmer amaranth (*Amaranthus palmeri* S. Wats). However, widespread planting of glyphosate resistant cotton and the extensive use of glyphosate have placed intensive selection pressure on weed populations (Main et al., 2012). This selection pressure led to the glyphosate resistance in Palmer amaranth. Palmer amaranth is now considered the most difficult weed to control in Arkansas crop production (Smith & Scott, 2010). By 2012,

glyphosate resistant Palmer amaranth has spread throughout all crop growing counties in eastern and central Arkansas and much of the United States (Smith & Scott, 2010).

Because of glyphosate resistance in Palmer amaranth, growers rely more on residual herbicides applied at planting (pre-emerge) for proper weed control (Main et al., 2012). Herbicides such as fluometuron, prometryn, fomesafen, and pendimethalin are now used on all Mid-south cotton acres (Scott et al., 2014). However, cotton injury has been recorded with the use of preemergence herbicides (Culpepper, 2012). This injury especially occurs after excessive rainfall (above 1.5”) is coupled with cold temperatures allowing the developing cotton plant to become overly exposed to herbicide causing injury (Steckel, 2012). Cotton injury ranged up to 41% damage in some pre-emerge herbicide injury ratings (Whitaker et al., 2011). This injury physically harms and stresses the plant, slowing cotton growth and vigor.

Compared to many other plants, cotton’s early season growth is very slow. During this time period, pests and other stresses are often magnified. The thrips primary feeding site is young terminal of a cotton plant. The terminal of a cotton plant, during (60-80˚F) temperature, produces a node in about 2.5-3 days. If DD60’s decline to less than 5/day, the same terminal takes twice as long to produce that node (Robertson et al., 2007). This delayed growth allows thrips to cause injury to the same leaf structure for twice the normal length of time. PRE herbicide injury may stress the cotton plant, slowing cotton growth and sometimes reducing stand (Culpepper, 2012). Thrips will then have similar stressing circumstances as colder weather, exposing the slow growing cotton terminal for an increased period of time. Contrarily, a rapidly growing seedling can outgrow thrips injury, reducing economic damage (Cook et al., 2013).

Coinciding with the decreased efficacy of IST's, the use of PRE herbicides has increased to provide control of glyphosate resistant palmer amaranth. Within the last three years (2010-2012) the increased co-occurrence of IST's and preemergence herbicides increases the potential for an interaction between the pesticides. The possible interaction may result from PRE herbicides causing stress to the plant or slowing cotton growth and increasing exposure to thrips. Alternatively, PRE herbicides may antagonize the IST through a direct chemical interaction. However, exploring direct chemical interactions were not an objective of this study. The main objective of this study was to determine if there is an interaction between PRE herbicides and IST's that causes a decrease in efficacy of IST's. The second objective of this study was to determine if there is an interaction effect, PRE herbicide main effect, or no effect at all on early season plant growth.

Materials and Methods

Preemergence herbicide by insecticide seed treatments Trial I. Field trials were conducted in 2013 at the University of Arkansas Lonn Mann Cotton Branch Experiment Station near Marianna, AR and the Southeast Branch University of Arkansas Experiment Station near Rohwer, AR. Stoneville 4946GLB2 cotton cultivar, treated with the appropriate seed treatments (products and rates described in Table 1), was planted 15 May and 21 May at Marianna and Rohwer, respectively. Insecticide seed treatments (IST) evaluated were imidacloprid (Aeris) at 0.75 mg AI/seed, thiamethoxam (Avicta Cruiser) at 0.525 mg AI/seed, and an untreated control. All seed was treated with a fungicide package containing (Allegiance) at 13.3 mL./45.3 kg, (Spera) at 51.4 mL./45.3 kg, (Vertex) at 2.4 mL/45.3 kg, and (Trilex Advanced) at 47.31 mL/45.3 kg. Seed treatments were made with a UNICOAT 1200 ccs-m seed treating machine one week prior to planting. PRE herbicides evaluated were fluometuron (Cotoran) at 1122 g

AI/ha, Diuron (Direx) at 558 g AI/ha, fomesafen (Reflex) at 279 g AI/ha, and an untreated control. IST's were applied alone and in combination with all PRE herbicides. Trials were planted in a randomized complete block design with a John Deere Max Emergence 7300, four row planter. Plot design was a 3x4 factorial arrangement of IST's and preemergence (PRE) herbicides. The soils at these sites are a Loring silt loam (fine, silty, mixed, thermic Typic Fragiudalfs) and Hebert silt loam (fine silty, mixed, thermic Aeric Ochraqaulfs) at Marianna and Rohwer, respectively. All tests were conducted under furrow irrigated production practices at both locations. Plot size was four rows, 96.5 cm apart by 12.2 m long. Weed-free conditions were maintained throughout the growing season by manual removal of weeds and hand hoeing. In Marianna, one application of glufosinate herbicide was made 45 days after emergence (on 15 June) to control palmer amaranth escapes. Supplemental insecticide applications were made once insect pests other than thrips reached economic thresholds. However, no supplemental insecticide applications were made until the last sample of thrips was taken to avoid confounding results.

PRE herbicide applications were made at planting on 16 May and 24 May at Marianna and Rohwer, respectively. In Marianna, PRE herbicide applications were made with a John Deere 5210, containing a compressed air multi-boom attachment. Green Leaf Air Mix 110001 tips were used at 10 gallons per acre at 50 psi. In Rohwer, PRE herbicide applications were made with the same spray apparatus. Thrips numbers were sampled three times at approximately 10, 20, and 25 days after planting. Each sample consisted of five plants taken from the center two rows of each plot. Plants were cut below the cotyledons and placed immediately into 1 quart glass jars, containing 70% ethyl alcohol. Samples were taken to the laboratory where thrips were washed from the plants onto a filter paper screen (Burris et al., 1989). Thrips were dislodged

from plants by rinsing each individual plant with 70% ethyl alcohol solution. Once rinsed thoroughly, plants were discarded and the remaining solution was filtered through a 9 cm Buchner funnel lined with a bowl-shaped coffee filter. Thrips were washed of the filter paper into a petri dish and counted with a Leica EZ4 dissecting microscope. Numbers of nymphs and adults were recorded. Stand counts were estimated in each plot by counting the number of plants in a random 10 foot section. In Marianna, stand counts were estimated once on 29 May (10 days after emergence). In Rohwer, stand counts were taken twice on 4 June and 11 June (8 and 15 days after emergence). Plant heights were taken weekly from emergence until first bloom by random selection of 5 plants per plot, measured from the ground surface to the tallest point of terminal growth. Preemergence herbicide injury ratings were visually estimated in Marianna on 29 May and 3 June in Rohwer. In Marianna, herbicide injury ratings were also taken after an application of glufosinate (Ignite) at 29 oz/acre caused visual injury on 20 June (35 days after emergence). Injury was divided into two categories (chlorosis and necrosis). A scale of 0-100% was used with 0 resulting in no apparent damage and 100 being plant death (Frans et al., 1986). Total main stem node counts were made weekly in each plot from emergence until first bloom. Nodes above white flower (NAWF) counts were taken once near physiological cut-out to determine differences in maturity. Yield was estimated by the use of a machine harvester, picking the center two rows of each plot.

Data were subjected to analysis of variance using the FIT MODEL procedure of JMP Pro 11 of SAS software. Copyright 2014 SAS Institute Inc. SAS and all other SAS institute Inc. product or service name are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA. Main effects consisting of IST and PRE herbicide and interaction effects between IST and PRE herbicides were tested. Block effects were analyzed as a random effect. Treatment means

were separated using Tukey’s option (α=0.05). Contrasts estimates were used to compare how IST’s effected plant growth and maturity alone vs. in the presence of an average of all three PRE herbicides.

Preemergence herbicide by insecticide seed treatment trial II. Field trials were conducted in 2013 at the University of Arkansas Lon Mann Cotton Branch Experiment Station near Marianna, AR and repeated at the Southeast Branch University of Arkansas Experiment Station, near Rohwer, AR. Phytogen 499 cotton cultivar was planted on 13 May and 21 May at Marianna and Rohwer, respectively. IST’s evaluated were thiamethoxam (Cruiser) at 0.375 mg AI/seed, abamectin at 0.15 mg AI/seed + thiamethoxam at 0.49 mg AI/seed (Avicta Duo) (high), abamectin at 0.15 mg AI/seed + thiamethoxam at 0.375 mg AI/seed (A20703) (low), and imidacloprid (Gaucho) at 0.375 mg AI/seed. PRE herbicides evaluated were fluometuron (Cotoran) at 1122 g AI/ha, Diuron (Direx) at 558 g AI/ha, and untreated control. Each IST was evaluated with each PRE herbicide and alone (Table 2). Packaged seed was sent directly from Syngenta Crop Protection (Greensboro, SC). Trials were planted in a randomized complete block design with a John Deere Max Emergence 7300, four row planter. Plot design was a 5x3 factorial arrangement of IST’s and PRE herbicides. Plot size was four rows, 96.5 cm apart by 12.2 m long. The soils at the sites are Loring silt loam (fine, silty, mixed, thermic Typic Fragiudalfs) at Marianna and Hebert silt loam (fine silty, mixed, thermic Aeric Ochraqaulfs) at Rohwer. Trials were conducted under furrow irrigated production practices at both locations. Weed-free conditions were maintained throughout the growing season by manual removal of weeds and hand hoeing. Supplemental insecticide applications were made once insect pests other than thrips reached economic thresholds. However, no supplemental insecticide applications were made until the last sample of thrips was taken to avoid confounding results.

PRE herbicide applications were made at planting on 16 May and 23 May at Marianna and Rohwer, respectively. In Marianna and Rohwer, PRE herbicide applications were made with the same spray application as describe in the previous trial. Thrips were sampled 3 times at 15, 20, and 28 day after planting. Each sample consisted of five plants taken from the center two rows of each plot and thrips were processed and counted as previously described. Stand counts were estimated on 7 June and 4 June in Marianna and Rohwer, respectively as previously described. Plant heights were taken weekly from emergence until first bloom as previously described. Herbicide injury ratings were visually estimated in Marianna on 29 May (10 days after emergence) and 3 June in Rohwer (7 days after emergence) as previously described. In Marianna, herbicide injury ratings were also taken after an application of glufosinate caused visual injury on 20 June (35 days after emergence). Total node counts were made weekly in each plot from emergence until first bloom. Nodes above white flower (NAWF) counts and yield were estimated for each plot as previously described.

Data were subjected to analysis of variance using the FIT MODEL procedure of JMP Pro 11 of SAS software. Copyright 2014 SAS Institute Inc. SAS and all other SAS institute Inc. product or service name are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA. Main effects consisting of IST alone, PRE herbicide alone, and interaction effects between IST and PRE herbicides were tested. Block effects were analyzed as a random effect. Treatment means were separated using Tukey's option (α=0.05). Contrasts estimates were used to compare how IST's effected plant growth and maturity alone vs. in the presence of an average of all three PRE herbicides.

Results Trial I

Thrips Response. The total numbers of thrips, over the season, were not significantly affected by an interaction between IST and PRE herbicides at either location (Marianna (p= 0.59), Rohwer (p= 0.76) Table 3). The main effect of PRE herbicide did not significantly affect thrips numbers at either location. However, the main effect of IST did significantly impact the number of thrips sampled at both locations (p= <0.0001). In both locations thiamethoxam reduced thrips numbers compared to an untreated seed and imidacloprid reduced thrips compared to both thiamethoxam and untreated control (Table 3).

Crop Response. In all locations, visual injury following seedling emergence was recorded as exhibiting no visible injury. Visual injury was apparent after the application of glufosinate at 45 days after emergence in Marianna (Table 3). Chlorosis damage ratings indicated no visual injury, post glufosinate application (data not shown). Necrosis damage ratings were significantly affected by the main effect IST in Marianna after the foliar application of glufosinate at 45 days after emergence (p= <0.0001). Necrosis damage ratings indicated imidacloprid treatments contained less damage than thiamethoxam which had less than untreated control.

Plant Growth and Maturity Marianna. There was no significant interaction effect between PRE herbicides and IST on plant growth and maturity parameters in Marianna. The main effect of PRE herbicide did not significantly affect plant stand, plant height, or NAWF (Table 4). There was a significant difference in the number of main stem nodes among herbicide treatments on 1 July (p= 0.022). Insecticide seed treatments did not significantly affect plant stand or NAWF. However, plant height and main stem node counts varied significantly among IST’s. Imidacloprid seed treatment resulted in significant increases in both plant heights and the

number of main stem nodes compared to an untreated seed. However, plant heights among the two IST's only differed on one day (20 June, Table 4). Contrasts were not significant when comparing IST alone to IST in combination with an average of all PRE herbicides (Table 5).

Plant Growth and Maturity Rohwer. There was no significant interaction effect between PRE herbicide and IST on plant growth and maturity parameters in Rohwer. The main effect of PRE herbicide did not significantly affect plant stand, main stem node counts, or NAWF (Table 6). Plant heights were significantly reduced on 12 July in fomesafen treated plots relative to fluometuron treatments. The main effect of IST did not significantly affect plant stand or NAWF. Plant heights and main stem node counts were significantly affected by IST on 12 July. Thiamethoxam and imidacloprid treatments contained taller plants than an untreated seed. Imidacloprid treatments contained plants with more main stem nodes than an untreated seed on 12 July. Isolated, significant contrasts existed in Rohwer 2013 when comparing IST alone to IST in combination with an average of all PRE herbicides (Table 7).

Seed Cotton Yield. Yield was not significantly affected by an interaction between IST and PRE herbicide in Marianna (p=0.93) or Rohwer (p= 0.59) (Table 3). The main effect of PRE herbicides also did not significantly affect yield in both locations. However, yield was significantly affected in Marianna (p= <0.0001) and Rohwer (p=0.0004) by IST. Yields were significantly higher in imidacloprid plots in both locations compared to both thiamethoxam and an untreated seed. In Marianna, thiamethoxam yields were significantly higher than the untreated seed however; this difference was not observed in Rohwer.

Results Trial II

Thrips Response. The total numbers of thrips, over the season, were not significantly affected by an interaction between IST and PRE herbicides at either location (Marianna (p= 0.09), Rohwer (p= 0.11) Table 8). The main effect of PRE herbicide did not significantly affect thrips samples at either location. However, IST significantly reduced numbers of thrips at both locations (p= <0.0001). In Marianna, imidacloprid decreased thrips numbers compared to thiamethoxam, abamectin + thiamethoxam (high), and an untreated seed. Abamectin + thiamethoxam (low) decreased thrips numbers compared to untreated seed only. In Rohwer, imidacloprid decreased thrips numbers compared to thiamethoxam and an untreated seed. Abamectin + thiamethoxam (high) and abamectin + thiamethoxam (low) decreased thrips numbers compared to untreated check only.

Crop Response. Chlorosis and necrosis injury ratings in both locations were not significantly affected by an interaction effect between PRE herbicides and IST's or the main effects of PRE herbicides and IST's.

Plant Growth and Maturity Marianna. There were no interaction effects between PRE herbicide and IST affecting plant growth and maturity in Marianna. PRE herbicides did not significantly affect plant stand, main stem nodes, or NAWF (Table 9). Plant heights differed among treatments on 26 June where plants in diuron treatments contained taller plants than those in both the untreated control and fluometuron plots. The main effect of IST did not significantly affect plant stand or NAWF. However, IST effected plant heights on 28 May and 26 June and NAG on 26 June. On 28 May, abamectin + thiamethoxam (high) plots contained taller plants than imidacloprid and thiamethoxam treatments. On 26 June, abamectin + thiamethoxam (high) plots contained taller plants than thiamethoxam and the untreated control treatments. On 26 June,

abamecticn + thiamethoxam (high) and abamectin + thiamethoxam (low) plots contained taller plants than the untreated control treatments. Significant plant growth and maturity contrasts were isolated (Table 10).

Plant Growth and Maturity Rohwer. There were no interaction effects between PRE herbicide and IST affecting plant growth or maturity in Rohwer. The main effect of PRE herbicide did not significantly affect plant stand, main stem nodes, or NAWF (Table 11). Plant heights were significantly affected by PRE herbicides on 17 June where fluometuron plots and the untreated control plots contained taller plants than diuron treatments. The main effect of IST significantly affected NAWF, where thiamethoxam treated plots contained plants with more NAWF compared to imidacloprid treatments. However, the main effect of IST did not significantly affect plant stand, plant height, or main stem nodes. Significant contrasts were isolated (Table 12).

Seed Cotton Yield. Yield in Marianna was not significantly affected by an interaction effect between PRE herbicides and IST's or the main effects of PRE herbicides or IST (Table 8). Yield in Rohwer was not significantly affected by an interaction effect of PRE herbicides or the main effect of PRE herbicide. However, Rohwer yield was significantly affected by IST ($p=0.0004$), where plots with untreated seed and thiamethoxam treated seed yielded significantly less than imidacloprid, abamectin + thiamethoxam (high), and abamectin + thiamethoxam (low) plots.

Discussion

Thrips populations exceeded the recommended threshold of an average of 5 thrips per plant and injury present in the non-insecticide treated plots. Thrips samples were measured and

analyzed using a season total sum of three sampling period means throughout the 2-4 leaf stage of cotton. This extended evaluation was done to determine if main effects and interaction effects affected thrips populations throughout the period of time that thrips damage cotton rather than single point in time. Interaction effects between preemergence herbicides and IST's were non-existent in analyses of the number of thrips sampled. Similarly, preemergence herbicide treatments alone did not alter the number of thrips sampled across all trials. All insecticide seed treatments significantly reduced the number of thrips sampled compared to the untreated control across all trials (Table 3, Table 8). However, insecticide seed treatments did not perform similarly. Imidacloprid treated seed consistently provided the greater control of thrips across trials compared to plots planted to thiamethoxam treated seed. The data shown here now suggests that reduced efficacy of IST is not through the interaction of IST and PRE herbicides, but may actually be the loss of control of IST. While we believe this could be a product of resistance/tolerance to thiamethoxam seed treatments, no data has been reported. More research will be conducted in the following year to determine if thrips are exhibiting a tolerance to specific neonicotinoid seed treatments.

Preemergence herbicide injury on seedling cotton has been directly linked to rainfall that occurs from planting through cotton emergence (Main et al., 2012). Cotton typically emerges in five to seven days after planting, and rainfall during this period totaled 3.46 inches and 1.46 inches in Marianna and Rohwer, respectively. Rohwer received the amount of rainfall desired when applying a PRE herbicide, while Marianna received excessive amounts. Excessive rainfall typically coupled with cooler temperatures causes the developing cotton seedling to become overly exposed to the herbicide causing injury (Steckel, 2012). However, herbicide injury was not grossly evident in 2013. Visual injury was not recorded immediately following seedling

emergence. There were significant differences in phytotoxicity injury after the application of glufosinate, 35 DAE (Table 3). After the application of glufosinate, there was a direct correlation between increased necrosis damage and treatments supporting higher numbers of thrips. This observation has been speculated before, where higher thrips populations magnify glufosinate injury (Stewart et al., 2013b). Additional experiments to isolate this observation would be beneficial for the Arkansas grower.

Plant parameters were sporadically affected by main effects of IST and PRE herbicides but were never significantly affected by the interaction between the two. Plant growth was strongly influenced by the main effect of IST within Trial I in Marianna 2013 (Table 4) thus indicating higher thrips populations may cause plant stunting. This was not the case in other research, where the use of an at planting insecticide did not influence plant growth parameters (Cook et al., 2013). Other observations have been made that thrips injury may delay crop maturity (Bourland et al., 1992). This observation occurred within trial II in Rohwer 2013, where thiamethoxam treatments that contained higher thrips numbers also had more NAWF in contrast to imidacloprid treatments with less thrips numbers and less NAWF (Table 11). However, three of the other four trials showed no change in cotton maturity associated with changes in thrips densities. Therefore, the hypothesis that PRE herbicides are slowing cotton seedling growth and therefore increasing the length of time thrips have to damage the cotton plant was not supported by this research. Additional studies that alter irrigation (as a surrogate for rainfall) could better assess injury to the cotton seedling as a result of delays in plant growth.

Yield responses to thrips injury vary among previous studies. Reductions in yield are often associated with increased thrips damage (Cook et al., 2013; Reed & Jackson, 2002; Stewart et al., 2013a), although other studies show no significant effect on seed cotton yield associated

with thrips control (Beckham, 1970; Harp & Turner, 1976; Leigh, 1963). Across all trials within this study, decreased thrips numbers were associated with increases in seed cotton yield. Imidacloprid treatments which significantly reduced thrips numbers compared to thiamethoxam and untreated control, also showed significant yield increases over thiamethoxam and untreated control in trial I (Table 3). However, increased yields resulted when thrips were significantly decreased in one of two locations in trial II (Table 8). Yields were not significantly affected across all trials by PRE herbicides alone or the interaction of PRE herbicides and insecticide seed treatments. The lack of impact on yield was expected because treatments only sporadically affected plant growth parameters.

The goal of this study was designed to determine if a significant interaction between preemergence herbicides and insecticide seed treatments induced changes in plant growth parameters or thrips control. Non-significant interaction effects that were observed in these studies may have been significant with increased replication or under different growing circumstances. Similar studies are being repeated across the mid-south. These studies showed that observations of reduced IST efficacy were not caused by an interaction between IST and PRE herbicides but may be attributed to reduced efficacy of specific IST's, consistent with tolerance/resistance in thrips populations. Understanding and documenting thrips tolerance/resistance to thiamethoxam will be vital in prevention of the complete loss of the entire neonicotinoid insecticide class being used for thrips control. Neonicotinoid use is at risk in the future in years with the current production practices utilizing neonicotinoid seed treatments in many mid-southern crops.

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Table 1. Trial I, insecticide seed treatment and PRE herbicide treatments.

Treatment #	Insecticide Seed Treatment	PRE Herbicide
1	Control	Control
2	Control	fluometuron 1122 g AI/ha
3	Control	diuron 558 g AI/ ha
4	Control	fomesafen 279 g AI/ ha
5	imidacloprid 0.75 mg AI/seed	Control
6	imidacloprid 0.75 mg AI/seed	fluometuron 1122 g AI/ha
7	imidacloprid 0.75 mg AI/seed	diuron 558 g AI/ ha
8	imidacloprid 0.75 mg AI/seed	fomesafen 279 g AI/ ha
9	thiamethoxam 0.525 mg AI/seed	Control
10	thiamethoxam 0.525 mg AI/seed	fluometuron 1122 g AI/ha
11	thiamethoxam 0.525 mg AI/seed	diuron 558 g AI/ ha
12	thiamethoxam 0.525 mg AI/seed	fomesafen 279 g AI/ ha

Table 2. Trial II, insecticide seed treatment and PRE herbicide treatments.

Treatment #	Insecticide Seed Treatment	PRE Herbicide
1	Control	Control
2	Control	fluometuron 1122 g AI/ha
3	Control	diuron 558 g AI/ha
4	thiamethoxam 0.375 mg AI/seed	Control
5	thiamethoxam 0.375 mg AI/seed	fluometuron 1122 g AI/ha
6	thiamethoxam 0.375 mg AI/seed	diuron 558 g AI/ha
7	abamectin + thiamethoxam (High)	Control
8	abamectin + thiamethoxam (High)	fluometuron 1122 g AI/ha
9	abamectin + thiamethoxam (High)	diuron 558 g AI/ha
10	abamectin + thiamethoxam (Low)	Control
11	abamectin + thiamethoxam (Low)	fluometuron 1122 g AI/ha
12	abamectin + thiamethoxam (Low)	diuron 558 g AI/ha
13	imidacloprid 0.375 mg AI/seed	Control
14	imidacloprid 0.375 mg AI/seed	fluometuron 1122 g AI/ha
15	imidacloprid 0.375 mg AI/seed	diuron 558 g AI/ha

Table 3. Preemergence herbicide by insecticide seed treatment trial I, mean season total thrips, mean necrosis injury, and mean seed cotton yield (±SE) by main effects and significance of interaction effect.

Main Effect	Treatment	Marianna Thrips[1]	Marianna Injury %[2]	Marianna Seed cotton yield (lbs/ac)	Rohwer Thrips[1]	Rohwer Injury %[2]	Rohwer Seed cotton yield (lbs/ac)
Herbicide	fluometuron	570.8 ± 35.1	27.5 ± 2.6	4231.4 ± 98.5	639.2 ± 47.8	0	4226 ± 241.8
	diuron	640.1 ± 35.1	29.2 ± 2.6	4020.7 ± 98.5	576.6 ± 47.8	0	4312 ± 241.8
	fomesafen	650.9 ± 35.1	31.3 ± 2.6	3843.7 ± 98.5	648.4 ± 47.8	0	4438 ± 241.8
	untreated control	612.2 ± 35.1	25.4 ± 2.6	4016.5 ± 98.5	496.2 ± 47.8	0	4654 ± 241.8
	Factorial analysis	*P= 0.3854*	*P= 0.4517*	*P= 0.0693*	*P= 0.3860*	*x*	*P= 0.6252*
Insecticide	imidacloprid	438.4 ± 30.3 c	8.7 ± 2.3 c	4464.2 ± 85.3 c	384.1 ± 41.1 c	0	5127.4 ± 209.4 a
	thiamethoxam	610.0 ± 30.3 b	24.7 ± 2.3 b	4145.1 ± 85.3 b	618.7 ± 41.1 b	0	4290.4 ± 209.4 b
	untreated control	806.8± 30.3 a	51.6 ± 2.3 a	3475.0 ± 85.3 a	779.1 ± 41.1 a	0	3804.6 ± 209.4 b
	Factorial analysis	*P= 0.0001**	*P= 0.0001**	*P= 0.0001**	*P=0.0001**	*x*	*P= 0.0004**
Herbicide*Insecticide	Factorial analysis	*p= 0.59*	*p= 0.99*	*p= 0.93*	*p= 0.71*	*x*	*p= 0.59*

[1] Mean thrips season total

[2] Necrosis injury ratings (%) after application of glufosinate at 45 days after emergence

[3] Means with a column followed by the same letter are not significantly different (p= 0.05).

Table 4. Preemergence herbicide by insecticide seed treatment trial I Marianna 2013, mean plant stand, mean plant heights, mean nodes above ground, and mean nodes above white flower (±SE) by main effects.

Main Effect	Treatment	Stand[1]	Plant heights (in.) 29-May	Plant heights (in.) 20-Jun	Plant heights (in.) 1-Jul	Total Nodes 20-Jun	Total Nodes 26-Jun	Total Nodes 1-Jul	NAWF 15-Aug
Herbicide	fluometuron	30.3 ± 1.3	2.7 ± 0.1	7.9 ± 0.2	11.8 ± 0.4	6.42 ± 0.2	8.7 ± 0.3	9.5 ± 0.2 ab	4.3 ± 0.1
	diuron	33.2 ± 1.3	2.8 ± 0.1	7.5 ± 0.2	12.9 ± 0.4	5.9 ± 0.2	8.5 ± 0.3	10.1 ± 0.2 a	4.4 ± 0.1
	fomesafen	30.2 ± 1.3	2.7 ± 0.1	7.1 ± 0.2	12.0 ± 0.4	6.15 ± 0.2	8.2 ± 0.3	9.0 ± 0.2 b	4.3 ± 0.1
	Untreated control	33 ± 1.3	2.7 ± 0.1	7.2 ± 0.2	12.1 ± 0.4	5.82 ± 0.2	8.0 ± 0.3	9.3 ± 0.2 ab	4.0 ± 0.1
	Factorial Analysis	P= 0.18	*P= 0.83*	*P= 0.07*	*P= 0.223*	*P= 0.20*	*P= 0.35*	*P= 0.022**	*P= 0.13*
Insecticide	imidacloprid	31.1 ± 1.1	2.9 ± 0.1 a	8.4 ± 0.2 a	13.8 ± 0.3 a	6.5 ± 0.2 a	8.8 ± 0.2	9.9 ± 0.2 a	4.1 ± 0.1
	thiamethoxam	31.3 ± 1.1	2.7± 0.1 ab	7.6 ± 0.2 b	13.0 ± 0.3 a	6.4 ± 0.2 a	8.2 ± 0.2	9.5 ± 0.2 ab	4.4 ± 0.1
	Untreated Control	32.6 ± 1.1	2.6 ± 0.1 b	6.3 ± 0.2 c	9.8 ± 0.3 b	5.4 ± 0.2 b	8.0 ± 0.2	8.9 ± 0.2 b	4.1 ± 0.1
	Factorial Analysis	P= 0.56	*P= 0.03**	*P= 0.001**	*P= 0.001**	*P= 0.004**	*P= 0.07*	*P= 0.002**	*P= 0.30*

[1] Plant Stand per 10 feet

[2] Means with a column followed by the same letter are not significantly different (p= 0.05).

Table 5. Preemergence herbicide by Insecticide Seed Treatment Trial I Marianna 2013, plant growth and maturity contrast estimates established from contrast analysis results.

	Treatment	Stand[1]	Plant height			Total Nodes			NAWF
			29-May	20-Jun	1-Jul	20-Jun	26-Jun	1-Jul	15-Aug
Contrasts	imidacloprid Vs.	1.5 [2]	0.08	-0.73	-0.6	-0.22	0.02	0.17	-0.15
	imidacloprid + PRE	*P= 0.59*	*P= 0.66*	*P= 0.15*	*P= 0.46*	*P= 0.61*	*P= 0.97*	*P= 0.72*	*P= 0.56*
	thiamethoxam Vs.	2	-0.02	0.3	-0.4	-0.4	-0.68	-0.22	-0.23
	thiamethoxam + PRE	*P= 0.43*	*P= 0.89*	*P= 0.54*	*P= 0.61*	*P= 0.35*	*P= 0.25*	*P= 0.64*	*P= 0.37*
	Untreated Vs.	1.8	-0.01	-0.5	0.6	-0.4	-0.68	-0.62	-0.45
	Untreated + PRE	*p= 0.53*	*P= 0.93*	*P= 0.31*	*P= 0.45*	*P= 0.35*	*P= 0.25*	*P= 0.19*	*P= 0.09*

[1] Plant Stand per 10 feet
[2] Contrast estimate above and corresponding p-value below

Table 6. Preemergence herbicide by insecticide seed treatment trial I Rohwer 2013, mean plant stand, mean plant heights, mean nodes above ground, and mean nodes above white flower (± SE) by main effects.

Main Effect	Treatment	Stand[1]	Plant heights (in.)			Total Nodes			NAWF
			4-Jun	17-Jun	12-Jul	24-Jun	2-Jul	12-Jul	19-Aug
Herbicide	fluometuron	30.2 ± 2.1	2.3 ± 0.1	5.1 ± 0.2	17.9 ± 0.3 a	6.5 ± 0.1	8.2 ± 0.2	10.3 ± 0.2	4.3 ± 0.2
	diuron	30.5 ± 2.1	2.2 ± 0.1	4.9 ± 0.2	17.7 ± 0.3 ab	6.6 ± 0.1	8.4 ± 0.2	9.9 ± 0.2	4.1 ± 0.2
	fomesafen	26.8 ± 2.1	2.3 ± 0.1	5.1 ± 0.2	16.6 ± 0.3 b	6.7 ± 0.1	8.5 ± 0.2	10.0 ± 0.2	4.5 ± 0.2
	untreated control	25.6 ± 2.1	2.4 ± 0.1	5.5 ± 0.2	17.3 ± 0.3 ab	7 ± 0.1	8.7 ± 0.2	10.3 ± 0.2	4.2 ± 0.2
	Factorial Analysis	*P= 0.28*	*P= 0.69*	*P= 0.12*	*P= 0.028**	*P= 0.17*	*P= 0.39*	*P= 0.42*	*P= 0.66*
Insecticide	imidacloprid	27.4 ± 1.8	2.3 ± 0.1	5.3 ± 0.1	18.2 ± 0.2 a	6.9 ± 0.1	8.5 ± 0.1	10.5 ± 0.2 a	4.3 ± 0.2
	thiamethoxam	28.9 ± 1.8	2.4 ± 0.1	5.3 ± 0.1	17.5 ± 0.2 a	6.9 ± 0.1	8.3 ± 0.1	10.2 ± 0.2 ab	4.3 ± 0.2
	untreated control	28.4 ± 1.8	2.2 ± 0.1	4.9 ± 0.1	16.4 ± 0.2 b	6.5 ± 0.1	8.7 ± 0.1	9.7 ± 0.2 b	4.1 ± 0.2
	Factorial Analysis	*P= 0.85*	*P= 0.58*	*P= 0.09*	*P= 0.0001**	*P= 0.08*	*P= 0.23*	*P= 0.0149**	*P= 0.69*

[1] Plant Stand per 10 feet

[2] Means within a column followed by the same letter are not significantly different (p= 0.05).

Table 7. Preemergence herbicide by Insecticide Seed Treatment Trial I Rohwer 2013, plant growth and maturity contrast estimates established from contrast analysis results.

	Treatment	Stand	Plant height			Total Nodes			NAWF
			4-Jun	17-Jun	12-Jul	24-Jun	2-Jul	12-Jul	19-Aug
Contrasts	imidacloprid vs.	0.42	0.03	0.81	0.05	0.18	0.33	0.05	-0.12
	imidacloprid + PRE	*p= 0.93*	*p= 0.91*	*p= 0.04**	*p= 0.94*	*p= 0.54*	*p= 0.37*	*p= 0.91*	*p= 0.81*
	thiamethoxam vs.	-5.58	0.37	0.35	0.19	0.25	0.45	0.46	-0.12
	thiamethoxam + PRE	*p= 0.19*	*p= 0.15*	*p= 0.37*	*p= 0.76*	*p= 0.40*	*p= 0.22*	*p= 0.27*	*p= 0.81*
	Untreated vs.	-5.5	0.08	0.29	-0.47	0.6	0.13	0.22	-0.17
	Untreated + PRE	*p= 0.206*	*p= 0.76*	*p= 0.45*	*p= 0.46*	*p= 0.05**	*p= 0.72*	*p= 0.61*	*p= 0.73*

[1] Plant Stand per 10 feet
[2] Contrast estimate above and corresponding p-value below

Table 8. Preemergence herbicide by insecticide seed treatment trial II, mean season total thrips and mean seed cotton yield (± SE) by main effects and significance of interaction effect.

Main Effect	Treatment	Marianna Thrips[z]	Marianna Seed Cotton Yield(lbs/acre)	Rohwer Thrips[z]	Rohwer Seed Cotton Yield(lbs/acre)
Herbicide	fluometuron	156.1 ± 5.8	3388.2 ± 80.5	510.5 ± 29.4	3587.6 ± 279.9
	diuron	161.5 ± 5.8	3610.8 ± 80.5	525.4 ± 29.4	3806.7 ± 279.9
	Untreated control	150.5 ± 5.8	3420.4 ± 80.5	487.7 ± 29.4	3762.8 ± 279.9
	Factorial analysis	*p= 0.43*	*p= 0.14*	*p= 0.66*	*p= 0.84*
IST	thiamethoxam	159.6 ± 7.6 ab	3367.6 ± 103.9	540.0 ± 37.9 ab	2690.1 ± 361.4 c
	abamectin + thiamethoxam (high)	158.4 ± 7.6 ab	3693.2 ± 103.9	512.3 ± 37.9 bc	4408.9 ± 361.4 a
	abamectin + thiamethoxam (low)	148.8 ± 7.6 bc	3483.5 ± 103.9	433.5 ± 37.9 bc	4216.5 ± 361.4 ab
	imidacloprid	126.1 ± 7.6 c	3560.8 ± 103.9	374.1 ± 37.9 c	4513.7 ± 361.4 a
	Untreated control	187.3 ± 7.6 a	3260.7 ± 103.9	679.5 ± 37.9 a	2766.1 ± 361.4 bc
	Factorial analysis	*p= 0.0001**	*p= 0.078*	*p= 0.0001**	*p= 0.0004**
Herbicide*Insecticide	Factorial analysis	*p= 0.095*	*p= 0.24*	*p= 0.11*	*p= 0.28*

[1] Mean Thrips Season Total

[2] Means within a column followed by the same letter are not significantly different (p= 0.05).

Table 9. Preemergence herbicide by insecticide seed treatment trial II Marianna 2013, mean plant stand, mean plant heights, mean nodes above ground, and mean nodes above white flower (± SE) by main effects.

Main Effect	Treatment	Stand	Plant Height (in)			Total Nodes		NAWF
			28-May	12-Jun	26-Jun	20-Jun	26-Jun	15-Aug
Herbicide	fluometuron	36.7 ± 1.3	2.2 ± 0.0	4.7 ± 0.1	9.9 ± 0.3 b	6.3 ± 0.1	7.4 ± 0.2	3.9 ± 0.1
	diuron	37.6 ± 1.3	2.2 ± 0.0	4.7 ± 0.1	11.2 ± 0.3 a	6.3 ± 0.1	7.5 ± 0.2	3.8 ± 0.1
	Untreated control	34.8 ± 1.3	2.2 ± 0.0	4.9 ± 0.1	9.7 ± 0.3 b	6.3 ± 0.1	7.4 ± 0.2	3.9 ± 0.1
	Factorial analysis	*p= 0.34*	*p= 0.85*	*p= 0.53*	*p= 0.008**	*p= 0.88*	*p= 0.86*	*p= 0.79*
IST	thiamethoxam	35.3 ± 1.7	2.1 ± 0.1 b	4.7 ± 0.2	9.8 ± 0.4 b	6.3 ± 0.1	7.3 ± 0.2 ab	4.0 ± 0.2
	abamectin + thiamethoxam (high)	34.3 ± 1.7	2.4 ± 0.1 a	5.0 ± 0.2	11.4 ± 0.4 a	6.5 ± 0.1	7.9 ± 0.2 a	3.7 ± 0.2
	abamectin + thiamethoxam (low)	35.8 ± 1.7	2.2 ± 0.1 ab	4.8 ± 0.2	10.4 ± 0.4 ab	6.2 ± 0.1	7.7 ± 0.2 a	3.8 ± 0.2
	imidacloprid	40.1 ± 1.7	2.0 ± 0.1 b	4.9 ± 0.2	10.5 ± 0.4 ab	6.1 ± 0.1	7.5 ± 0.2 ab	3.8 ± 0.2
	Untreated control	36.4 ± 1.7	2.2 ± 0.1 ab	4.5 ± 0.2	9.4 ± 0.4 b	6.4 ± 0.1	6.8 ± 0.2 b	4.2 ± 0.2
	Factorial analysis	*p= 0.18*	*p= 0.013**	*p= 0.43*	*p= 0.004**	*p= 0.19*	*p= 0.009**	*p= 0.29*

[1] Plant Stand per 10 feet

[2] Means within a column followed by the same letter are not significantly different (p= 0.05)

Table 10. Preemergence herbicide by Insecticide Seed Treatment Trial II Marianna 2013, plant growth and maturity contrast estimates established from contrast analysis results.

	Treatment	Stand[1]	Plant Height			Total Nodes		NAWF
			28-May	12-Jun	26-Jun	20-Jun	26-Jun	15-Aug
Contrasts	thiamethoxam vs.	-3.38[2]	-0.01	-0.6	-1.7	0.33	-0.6	-0.05
	thiamethoxam + PRE	*p= 0.37*	*p= 0.92*	*p= 0.18*	*p= 0.049**	*p= 0.30*	*p= 0.24*	*p= 0.90*
	abamectin +thiamethoxam (high) vs.	-5.63	0.06	0.49	-0.55	0.08	0.13	-0.08
	abamectin + thiamethoxam (high) + PRE	*p=0.14*	*p= 0.63*	*p= 0.24*	*p= 0.52*	*p= 0.81*	*p= 0.80*	*p= 0.85*
	abamectin + thiamethoxam (low) vs.	0	0.03	0	-0.38	0.03	-0.18	0.45
	abamectin + thiamethoxam (low) + PRE	*p= 1*	*p= 0.85*	*p= 1*	*p= 0.66*	*p= 0.94*	*p= 0.72*	*p= 0.27*
	imidacloprid vs.	-1.25	0.04	0.35	-1.25	0.1	-0.15	0.33
	imidacloprid + PRE	*p= 0.74*	*p= 0.77*	*p= 0.40*	*p= 0.14*	*p= 0.75*	*p= 0.76*	*p= 0.42*

[1] Plant Stand per 10 feet
[2] Contrast estimate above and corresponding p-value below

Table 11. Preemergence herbicide by insecticide seed treatment trial II Rohwer 2013, mean plant stand, mean plant heights, mean nodes above ground, and mean nodes above white flower (± SE) by main effects.

Main Effect	Treatment	Stand[1]	Plant Height (in)			Total Nodes	NAWF
			4-Jun	17-Jun	28-Jun	20-Jun	19-Aug
Herbicide	fluometuron	29.1 ± 1.8	2.3 ± 0.1	5.0 ± 0.1	8.6 ± 0.2	6.2 ± 0.1	5.0 ± 0.2
	diuron	29.1 ± 1.8	2.4 ± 0.1	4.5 ± 0.1	8.5 ± 0.2	6.2 ± 0.1	5.1 ± 0.2
	untreated control	28.1 ± 1.8	2.5 ± 0.1	5.2 ± 0.1	8.8 ± 0.2	6.3 ± 0.1	4.9 ± 0.2
	Factorial analysis	*p= 0.91*	*p= 0.41*	*p= 0.0025**	*p= 0.69*	*p= 0.89*	*p= 0.83*
IST	thiamethoxam	25.7 ± 2.4	2.5 ± 0.1	4.9 ± 0.2	8.4 ± 0.3	5.9 ± 0.2	5.6 ± 0.2 a
	abamectin + thiamethoxam (high)	29.3 ± 2.4	2.4 ± 0.1	4.9 ± 0.2	8.8 ± 0.3	6.3 ± 0.2	4.8 ± 0.2 ab
	abamectin + thiamethoxam (low)	33.3 ± 2.4	2.5 ± 0.1	4.8 ± 0.2	8.6 ± 0.3	6.6 ± 0.2	4.7 ± 0.2 ab
	imidacloprid	31.1 ± 2.4	2.5 ± 0.1	5.3 ± 0.2	9.2 ± 0.3	6.3 ± 0.2	4.7 ± 0.2 b
	untreated control	24.3 ± 2.4	2.2 ± 0.1	4.7 ± 0.2	7.9 ± 0.3	6.0 ± 0.2	5.3 ± 0.2 ab
	Factorial analysis	*p= 0.056*	*p= 0.33*	*p= 0.29*	*p= 0.09*	*p= 0.07*	*p= 0.019**

[1] Plant Stand per 10 feet

[2] Means within a column followed by the same letter are not significantly different (p= 0.05).

Table 12. Preemergence herbicide by Insecticide Seed Treatment Trial II Rohwer 2013, plant growth and maturity contrast estimates established from contrast analysis results.

	Treatment	Stand[1]	Plant Height			Total Nodes	NAWF
			29-May	20-Jun	1-Jul	20-Jun	19-Aug
Contrasts	thiamethoxam vs.	-3.25 [2]	0.51	0.69	1.4	-0.05	0.53
	thiamethoxam + PRE	*p= 0.52*	*p= 0.037**	*p= 0.08*	*p= 0.059*	*p= 0.89*	*p= 0.25*
	abamectin +thiamethoxam (high) vs.	-0.13	0.23	0.64	0.6	0.33	0.03
	abamectin + thiamethoxam (high) + PRE	*p= 0.98*	*p= 0.35*	*p= 0.11*	*p= 0.41*	*p= 0.39*	*p= 0.96*
	abamectin + thiamethoxam (low) vs.	-4.25	-0.18	0.35	0.21	0.13	-0.25
	abamectin + thiamethoxam (low) + PRE	*p= 0.40*	*p= 0.47*	*p= 0.37*	*p= 0.77*	*p= 0.74*	*p= 0.58*
	imidacloprid vs.	2.13	-0.01	-0.01	-0.26	-0.15	-0.7
	imidacloprid + PRE	*p= 0.67*	*p= 0.96*	*p= 0.97*	*p= 0.72*	*p= 0.69*	*p= 0.13*

[1] Plant Stand per 10 feet
[2] Contrast estimate above and corresponding p-value below

Chapter II. Herbicide-Insecticide Interactions Through the Process of Tank-mixing

Abstract

Studies were conducted in 2012 and 2013 at the University of Arkansas Experiment Stations in Marianna, AR and Rohwer, AR to evaluate thrips control and cotton plant responses to glyphosate or a tank mix of glufosinate and s-metolachlor alone or when tank mixed with selected insecticides used for thrips control. Small plot field studies were organized in randomized complete block design and tank mix applications were made using a Bowman Mudmaster. Glyphosate applications increased thrips numbers in plots when in combination with the insecticides acephate and dicrotophos vs. insecticides alone in one of a total of three Roundup trials. Numbers of thrips in Liberty Link trials after the application of an insecticide alone were no different than that in plots with the addition of glufosinate or glufosinate + s-metolachlor. Visual injury did not exceed 10% with all tank mix combinations 5 days after application and injury was no longer present 14 days after application. Seed cotton yield was not affected by an interaction between insecticides and herbicides. These data suggested that maturity was not delayed and yield was not decreased by an early season application of glyphosate or glufosinate in combination with selected insecticides. Seed cotton yield was affected by different with the combinations of glyphosate and s-metolachlor vs. glufosinate and s-metolachlor. Results indicated that when applied according to pesticide labels, the co-application of tested herbicide-insecticide tank-mixtures offered cotton producers the ability to integrate thrips and weed control.

Introduction

Thrips (Thysanoptera: Thripidae) are the most important group of insect pests in the early growing season of Mid-south, U.S. cotton (*Gossypium hirsutum* L.). Reports in 2012 concluded that thrips were the second most economically damaging insect pest in Arkansas cotton, with insecticide costs from both foliar treatments and insecticide seed treatments costing cotton growers over ten million dollars (Williams, 2012). Species of thrips that commonly infest cotton seedlings in the U.S. include tobacco thrips, *Frankliniella fusca* (Hinds); flower thrips, *Frankliniella tritici* (Fitch); western flower thrips, *Frankliniella occidentalis* (Pergande); onion thrips, *Thrips tabaci* (Lindeman); and soybean thrips, *Neohydatothrips variabilis* (Beach). In Arkansas, tobacco thrips comprised 84% of all thrips species found on seedling cotton. Eastern flower thrips and western flower thrips together comprise the remaining 15.6% of the thrips populations (Stewart et al., 2013a). The significance of thrips species composition is important when decisions are made regarding thrips control with insecticides (Stewart et al., 2013a). A thrips infestation coupled with cool weather and slow growth of cotton seedlings has been linked to several problems including stunting, delayed fruiting, loss of apical dominance, and possible loss of stand (Reed & Jackson, 2002). Increasing yields have been reported by several researchers when seedling thrips were controlled (Cook et al., 2013; Reed & Jackson, 2002; Stewart et al., 2013a).

Thrips are traditionally controlled with insecticides applied directly to the seed, into the soil at planting, or with foliar applications when needed. Currently, neonicotinoid seed treatments (e.g., imidacloprid and thiamethoxam) are the most widely adopted method for thrips control in the cotton belt and over 99 percent of Arkansas cotton acres are planted with an insecticide treated seed (Williams, 2012). Benefits of seed treatments include increased vigor and

equivalent thrips control efficacy to alternative methods, cheaper method of application, convenience to the grower, and reduction in equipment cost (Taylor & Harman, 1990). Foliar applications of insecticides are used in the absence of other control options or when seed treatment residual control declines (Studebaker et al., 2013). Foliar insecticide applications for thrips control were applied on 55% of Arkansas cotton acreage from 2006-2010, in addition to IST's. During this time period an average of 0.89 applications were made per acre and the average spent on foliar thrips insecticides was ~$2 million per year. However, foliar insecticide applications increased to 79.6% in Arkansas cotton from 2011-2013. (Williams, 2006-2013). During this time period, an average of 1.53 applications were made per acre and the average money spent on foliar thrips insecticides increased to ~$2.4 million. During the year of 2012 alone, 485,000 of 580,000 (84%) acres of cotton were treated with a supplemental foliar insecticide application for thrips control in Arkansas. On average, 1.8 foliar applications were made per acre, resulting in a cost of > $4.3 million to Arkansas cotton growers. In addition to the > $6.3 million was spent on ISTs in Arkansas cotton (Williams, 2013).

Weed control in cotton depends on a combination approach including tillage, preemergence herbicides (PRE), post emergence directed herbicides (POST), and hand weeding. With the advent of Roundup Ready technology (and later Liberty link technology) growers have become more reliant on transgenic cotton to aid in weed control (Irby et al., 2013). Primarily, there are two main systems within U.S. cotton using an herbicide resistant gene. The first is glyphosate resistant cotton under the trade name of Roundup Ready and the second is glufosinate resistant cotton, under the trade name Liberty Link cotton. Each system requires the use of foliar herbicide applications which target small, actively growing weeds.

Herbicide Systems. Monsanto's introduction of glyphosate resistant cotton in 1997 dramatically changed weed control methodologies in cotton. Roundup Ready cotton was developed by inserting GR (glyphosate resistant) clone CP4-EPSPS into the cotton plant. This transgene allows for glyphosate to be applied POST over the crop canopy from the time of emergence until fifth leaf expansion without reproductive damage or yield loss (Dill et al., 2008). Second generation Roundup Ready cotton (Roundup Ready Flex) was introduced in 2006 (Young, 2006). Roundup Ready Flex technology allowed for a more flexible window of POST applications from cotton emergence to seven days prior to harvest (Murdock, 2006). Roundup Ready cotton was planted on 3.6% of total U.S. cotton acreage in 1997 and by 2009, 92% of U.S. cotton was planted to Roundup Ready or Roundup Ready Flex technology (Irby et al., 2013). The rapid adoption Roundup Ready technology occurred because of glyphosate's effective means of controlling Palmer amaranth (*Amaranthus palmeri* S. Wats), and economic benefits including production efficiency and flexibility, enhanced weed control, and facilitation of conservation tillage (Dill et al., 2008). However, widespread planting of Roundup Ready cotton and the extensive use of glyphosate has placed intensive selection pressure on weed populations (Main et al., 2012). As of 2010, glyphosate is the number one pesticide used on U.S. cotton, with 68% of cotton acres treated and 10.6 million pounds of active ingredient applied (USDA-NASS, 2010). Reliance on glyphosate has caused a major reduction in the use of herbicides with different modes of action (Shaner, 2000). This selection pressure led to glyphosate resistance in Palmer amaranth, making it the single most troublesome weed in Arkansas crop production (Smith & Scott, 2010).

Glufosinate resistant cotton (Liberty Link) was introduced by Bayer CropScience in the year of 2004. Glufosinate tolerant cotton utilizes a bialaphos acetyltransferase gene designated as

LLCotton25 with a CaMV35S promoter. Glufosinate is a non-selective herbicide that has activity on both grass and broadleaf weeds which can be applied to Liberty Link cotton POST from emergence through early bloom (Irby et al., 2013). One advantage of a glufosinate based system is that glufosinate can effectively manage glyphosate resistant Palmer amaranth (Miller et al., 2012). However, the adoption rate of glufosinate resistant cotton vs. GR cotton has been much slower. In 2004, Liberty Link cotton was only planted on 1.7% of U.S. cotton acres, increasing only to 5.9%, in 2012 (Irby et al., 2013). This slow adoption rate is attributed to poor agronomic performance of available varieties (Irby et al., 2013).

With the introduction of a new gene, labeled *2mepsps*, Bayer CropScience is now marketing a glyphosate resistant variety under the trade name GlyTol® (Wallace et al., 2011). Bayer then added their glufosinate resistant gene integrating both the GlyTol and Liberty Link traits into one commercial variety. GlyTol + Liberty Link cotton can now be treated with a POST application of glyphosate and glufosinate without crop injury. Trial results indicate that GlyTol + LibertyLink cotton is highly resistant to glyphosate, glufosinate, or glyphosate plus glufosinate applied multiple times throughout the growing season (Wallace et al., 2011).

In Arkansas, herbicide costs ranged from $56.76-$75.93 per acre, depending on the herbicide system used (Bryant et al., 2012). However, the grower must also account for the cost of transgenic technology that allows the application of these herbicide systems when purchasing seed.

More foliar insecticide applications for thrips have resulted in an increased probability of growers taking a dual approach in order to control weeds and insects at the same time. Both applications of herbicides for Roundup Ready, Liberty Link, GlyTol, and GlyTol + Liberty Link

varieties and foliar application of thrips insecticides can occur around the 2-4 leaf stage. When early season applications for pests coincide, there are obvious economic reasons for the use of tank-mixing or combinations of various insecticides and herbicides. Tank-mixing results in fewer trips across the field via aerial or ground application, resulting in decreases in both labor and equipment costs. At the same time, combinations of chemicals frequently control the desired pest more so than the use of one chemical alone (Putnam & Penner, 1974). However, problems arising from tank-mixing of herbicides and insecticides have been recognized for several decades. Four results have been observed after the combination of insecticides, herbicides, and fungicides: synergism, addition, independence, and antagonism. Synergism is the cooperative action of two components of a mixture, such that the total effect is greater or more prolonged than the sum of the effects of the two taken independently. Addition is the cooperative action of two components of a mixture, such that the total effect is equal to the sum of the effects taken independently. A mixture of two components can have an independent effect where the total effect is equal to the effect of the most active component alone. Antagonism is the action of two components such that the total effect is less than the impact of the most effective component alone (Tammes, 1964). These terms are applicable when referring to commonly used insecticide-herbicide combinations during the early growth stages of cotton. In addition to possibly changing the efficacy insecticides through a chemical interaction, mixtures of pesticides may also cause increased phytotoxicity in the cotton plant and cause changes in cotton growth and maturity.

As a result of the widespread adoption of herbicide resistant cotton, commonly used tank-mixes of insecticides and herbicides were developed for both the glyphosate and glufosinate systems. These trials were designed to determine if there were any effects of the mixtures on the

efficacy of insecticides used for thrips control. Other factors evaluated included analysis of these mixtures on phytotoxicity, plant growth and development, and yield.

Materials and Methods

Roundup Foliar Tank-mix Field Trial. Field trials were conducted during 2012 at the University of Arkansas Lon Mann Cotton Branch Experiment Station near Marianna, AR and repeated in 2013 at both the Lon Mann Station and the Rohwer Research Station, a division of the Southeast Research and Extension Center. DP 0912 B2RF cotton cultivar was planted on 31 May in Marianna 2012. Stoneville 4946 GLB2 cotton cultivar was planted 15 May and 21 May in Marianna and Rohwer, respectively during the 2013 season. All trials were planted in a randomized complete block design using 4 replications with a John Deere Max Emerge 7300, four row planter. Plot size was four rows, 96.5 cm apart by 12.2 m long. The soils at these sites are a Loring silt loam (fine, silty, mixed, thermic Typic Fragiudalfs) and Hebert silt loam (fine silty, mixed, thermic Aeric Ochraqaulfs) at Marianna and Rohwer, respectively. All tests were conducted under furrow irrigated production practices at both locations. Weed-free conditions were maintained throughout the growing season by manual removal of weeds and hand hoeing. Supplemental insecticide applications were made once insect pests other than thrips reached economic thresholds. No supplemental insecticide applications were made before the last sample of thrips was taken to avoid confounding results.

Insecticides evaluated included acephate (Orthene) at 368 g/ha, spinetoram (Radiant) at 109 mL/ha, dicrotophos (Bidrin) 225 g/ha, and spinetoram combined with the organosilicone surfactant (Dyne-Amic) at 1%. Herbicides evaluated included glyphosate (Roundup) at 651 L/ha, s-metolachlor (Dual Magnum) at 1.2 L/ha, and clethodim (Sequence) at 2.91 L/ha. Insecticides

were applied alone, in combination with glyphosate, and in combination with both glyphosate and s-metolachlor (Table 13).

Tank-mixed applications were made on 5 June in Marianna, 2012. Tank-mixed applications were made on 5 June in Marianna 2013 and 12 June in Rohwer 2013. All tank-mix applications were made using a Bowman Mudmaster fitted with Tee Jet Hollow Cone TX-VS6 nozzles at 10 gallons per acre, under a pressure of 40 psi.

Thrips samples were collected once in 2012, 5 days after tank-mix applications on 11 June. Thrips numbers were sampled three times within each plot during 2013. In Marianna thrips were sampled on 27 May, 6 June, and 10 June. In Rohwer, thrips were sampled on 3 June, 11 June, and 17 June. The second thrips sample was taken just before tank-mix applications and the last sample was taken 5-7 days after application. Each sample consisted of five plants taken from the center two rows of each plot. Plants were cut below the cotyledons and placed immediately into one quart glass jars, containing 70% ethyl alcohol. Samples were taken to the laboratory where thrips were washed from the plants onto a filter paper screen (Burris et al., 1989). Thrips were dislodged from plants by rinsing individual plants with 70% ethyl alcohol solution. Once rinsed thoroughly, plants were discarded and the remaining solution was filtered through a 9 cm Buchner funnel, lined with a bowl-shaped coffee filter. Thrips were washed off the filter paper into a petri dish and counted with a Leica EZ4 dissecting microscope. Numbers of nymph and adult thrips were recorded.

Stand counts were estimated in each plot by randomly counting the number of plants in a 10 foot section. In the 2012 Marianna trial, stand counts were estimated once on 5 June. In Marianna 2013, stand counts were estimated twice on 29 May and 12 June. Rohwer 2013, stand

counts were taken twice on 4 June and 11 June. Plant heights were taken weekly from the time of emergence until first bloom, by random selection of 5 plants per plot measured from the ground surface to the tallest point of terminal growth. Estimations of cotton injury (chlorosis and necrosis) were recorded 5-7 days post application on a scale of 0 to 100, where 0 indicates no cotton injury and 100 indicates cotton death (Frans et al., 1986). Total node counts were taken weekly in each plot from the time of emergence until first bloom. Nodes above white flower (NAWF) counts were made once near physiological cut-out to determine differences in maturity. Yield was taken using a machine harvester, picking the center two rows of each plot.

Data were subjected to analysis of variance using the FIT MODEL procedure of JMP Pro 11 (SAS Institute, Cary, NC). Two treatments, consisting of s-metolachlor alone and clethodim + spinetoram were removed, so that data could be analyzed as a complete factorial. Main effects, consisting of insecticide alone and herbicide alone and interaction effects between insecticides and herbicides were tested. Block effects were analyzed as a random effect. Treatment means were separated using Tukey's option (a=0.05). Contrasts estimates were used to compare how insecticides affected plant growth and maturity alone vs. in the presence of glyphosate or glyphosate + s-metolachlor.

Liberty Link Foliar Tank-mix Field Trial. Field trials were conducted in 2012 and 2013 at the same locations (Marianna and Rohwer) as previously described for the Roundup Foliar Trial. Phytogen 499 cotton cultivar was planted on 21 May and 14 May in 2012 and 2013, respectively in Marianna and 21 May in Rohwer in 2013. Trials were planted with the same equipment, plot sizes, and crop management strategies as previously described for the Roundup Ready Foliar Trial.

Herbicides evaluated included glufosinate (Liberty) at 2.1 L/ha, s-metolachlor (Dual Magnum) at 1.2 L/ha, and acetochlor (Warrant) at 3.5 L/ha. Insecticides evaluated included acephate (Orthene) at 368 g/ha, spinetoram (Radiant) at 109 mL/ha, dicrotophos (Bidrin) at 225 g/ha, and spinetoram combined with the organosilicone surfactant (Dyne-Amic) at 1%. Insecticides were applied alone, in combination with glufosinate, and in combination with both glufosinate and s-metolachlor (Table 14).

Tank-mixed applications were made on 1 June, 2012 in Marianna and 6 June and 12 June, 2013 in Marianna and Rohwer, respectively. All tank-mix applications were made with equipment as previously described.

Thrips were sampled as previously described on 6 June, 2012 in Marianna. Thrips were sampled three times in 2013 on 28 May, 6 June, and 10 June in Marianna and 3 June, 11 June, and 17 June in Rohwer. The second thrips sample was taken just before tank-mix applications and the last sample was taken 5-7 days after application. Thrips samples were processed and counted as previously described.

Plant measurement (stand counts, plant heights, total node counts, NAWF counts, plant injury ratings, and plot yields were taken on the same dates using the same methods as previously described.

Data from both trials were subjected to analysis of variance using the FIT MODEL procedure of JMP Pro 11 of SAS software. Copyright 2014 SAS Institute Inc. SAS and all other SAS institute Inc. product or service name are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA. Two treatments within the Liberty Link Trial, consisting of s-metolachlor alone and acetochlor + spinetoram + glufosinate were removed, so that data could be

analyzed as a complete factorial. Two treatments within the Roundup Trial, consisting of s-metolachlor alone and clethodim + spinetoram were removed, so that data could be analyzed as a complete factorial. Main effects, consisting of insecticide alone and herbicide alone and interaction effects between insecticides and herbicides were tested. Block effects were analyzed as a random effect. Treatment means were separated using Tukey's option (a=0.05). Contrasts estimates were used to compare how insecticides effected plant growth and maturity alone vs. in the presence of glufosinate or glufosinate + s-metolachlor.

Results

Liberty Link tank-mix 2012-2013 The total number of thrips were significantly affected by an interaction between tank-mixed insecticides and herbicides at Rohwer 2013 (p= 0.0373), where glufosinate + s-metolachlor with no insecticide, significantly increased thrips numbers compared to all other treatments (Table 15). However, this interaction effect was not observed in other locations. The main effect of herbicide affected thrips numbers in Marianna during 2013, but means did not separate using Tukey's HSD analysis. The main effect of insecticide affected thrips numbers in all locations (p= 0.0001). All insecticide treatments reduced thrips numbers compared to untreated check. Insecticide treatments did not separate from each other at Rohwer 2013. However, in Marianna during 2012 and 2013, spinetoram decreased thrips numbers compared to dicrotophos. In Marianna during 2012, acephate also reduced thrips numbers compared to dicrotophos. Thrips numbers were not significantly different among treatments when comparing insecticides alone vs. insecticides tank-mixed with herbicides of glufosinate and glufosinate + s-metolachlor (Table 16).

Visual injury following tank-mixed applications ranged from 0 to 6.75 % (Table 17). In Marianna during 2012, spinetoram + organosilicone surfactant treatments caused significantly

more chlorosis damage than all other treatments (p= 0.0060) although damage did not exceed 3.5 %. In Marianna during 2013, necrosis damage was also significant (p= 0.0001) but did not exceed 8.75%. Increased necrosis damage was observed in treatments with glufosinate + s-metolachlor and glufosinate + s-metolachlor + acephate compared to all other treatments. In Rohwer during 2013, no visual injury was observed for all treatments.

No interaction between insecticides and herbicides, with respect to plant height and main stem node counts, was observed. There was a significant interaction among pesticide groups in the ratings of NAWF in Marianna 2013 (p= 0.0001). The presence of glufosinate with dicrotophos increased NAWF vs. dicrotophos alone (data not shown). All other means were not significantly different among treatment combinations. Main effects of herbicides and insecticides were not significant across all plant growth information collected.

Yield was not significantly affected by the interactions of tank-mixed insecticides and herbicides in Marianna (p= 0.47) or Rohwer (p= 0.22) (Table 15). The main effect of herbicide significantly affected yield in Marianna 2013 (p= 0.0365) where the tank-mix of glufosinate and s-metolachlor increased yield compared to untreated check. The main effect of insecticide did not significantly affect yield in Marianna (p= 0.77) or Rohwer (p= 0.22). Yield contrast estimates were not significant when comparing insecticides alone vs. insecticides tank-mixed with herbicides of glufosinate and glufosinate + s-metolachlor (Table 16).

Roundup tank-mix 2012-2013 The total number of thrips, after tank-mix application, were not significantly affected by an interaction between tank-mixed insecticides and herbicides in Marianna (p= 0.18 and p= 0.70) or Rohwer (p= 0.72) (Table 19). The main effect of herbicide significantly affected thrips numbers in Marianna 2012 (p= 0.0180), where higher numbers of

thrips were observed in glyphosate treatments compared to glyphosate + s-metolachlor and untreated check treatments. The main effect of insecticide significantly affected thrips numbers in all locations (p= 0.0001). Thrips numbers were significantly reduced by spinetoram only in Marianna during 2012. However, in Marianna during 2013 and Rohwer during 2013, all insecticide treatments reduced thrips numbers compared to the untreated check. Contrast estimates of thrips numbers were significant when comparing insecticides alone vs. insecticides tank-mixed with herbicides of glyphosate and glyphosate + s-metolachlor (Table 20). The presence of glyphosate in combination with acephate or dicrotophos reduced thrips efficacy vs. the insecticide alone in Marianna during 2012 (p= 0.0055 & p = 0.0403). However, reduced or increased thrips efficacy caused by tank-mixing was not observed in other locations or years.

Visual injury following tank-mixed applications ranged from 0 to 6.25% (Table 21). Tank-mix application of glyphosate + s-metolachlor + acephate and glyphosate + s-metolachlor + spinetoram resulted in significantly more necrosis damage than all other treatments in Marianna during 2012 (p= 0.0001). Chlorosis damage was also significantly influenced by treatments in Marianna during 2013 (p=0.0002). All other damage ratings were not significantly different by treatment.

None of the plant growth parameters were significantly influenced by an interaction between insecticides and herbicides (Table 22). Furthermore, main effects of herbicides and insecticides did not significantly affect any of the measured plant growth parameters.

Yield was not significantly affected by an interaction between tank-mixed insecticides and herbicides in Marianna (p= 0.79) or Rohwer (p= 0.26) (Table 15). However, the main effect of herbicide significantly affected yield in both locations. Glyphosate treatments yielded

significantly more than glyphosate + s-metolachlor treatments, but no difference occurred relative to the untreated check in Rohwer during 2013. Glyphosate treatments yielded significantly more than the untreated check in Rohwer during 2013, but no separation occurred when relative to glyphosate + s-metolachlor treatments. The main effect of insecticide significantly affected yield in Rohwer during 2013 ($p= 0.0357$), where spinetoram treatments yielded significantly more than the untreated check. However, the main effect of insecticide did not significantly affect yield in Marianna during 2013 ($p= 0.93$). Contrasts estimates of yield were significant when comparing insecticides alone vs. insecticides tank-mixed with herbicides of glyphosate and glyphosate + s-metolachlor (Table 16). The presence of glyphosate in combination with spinetoram significantly increased yield vs. spinetoram alone in Rohwer during 2013. Yield was not significantly affected by tank-mixes within any other location or year.

Discussion

Thrips populations exceeded the recommended threshold of an average of 5 thrips per plant and injury present in the non-insecticide treated plots. All insecticide treatments reduced the number of thrips sampled compared to untreated check and insecticide performance varied throughout replicated tests. Herbicide-insecticide interactions affected thrips numbers in only one of a total of six trials (Table 15). In this trial, glufosinate + s-metolachlor, with no insecticide present, increased thrips numbers compared to all other interaction treatments. Most reports indicate that herbicides alone, at field use rates do not adversely affect insects (Messersmith & Adkins, 1995), although no literature testing glyphosate or glufosinate alone on thrips was found. From our observations, herbicides alone did not alter numbers of thrips compared to untreated treatments. However, when s-metolachlor was co-applied with glufosinate or glyphosate small,

insignificant decreases in thrips numbers were observed compared to glyphosate alone or glufosinate alone (Table 15 & 19).

Because of treatment structure, a contrast analysis was appropriate. Thus, even when the overall ANOVA analysis is not significant, contrast analysis could identify differences between selected treatments. Previous research demonstrated that thrips control with an insecticide was not reduced by co-application with glyphosate when compared with individual insecticides applied alone (Pankey et al., 2004). However, isolated contrasts estimates found in the Roundup trial located in Marianna during 2012 showed increases in numbers of thrips sampled with the addition of glyphosate to the insecticides acephate and dicrotophos vs. insecticides alone (Table 20). Acephate treatments in this trial showed a mean increase of 89.8 thrips when in combination with glyphosate. Decreased efficacy of acephate while in combination with glyphosate was repeated in other locations, but contrast estimates were not significant. Dicrotophos treatments in combination with glyphosate showed a mean increase of 64.5 thrips. However this increase in thrips numbers was only observed in Marianna during 2012. (Table 20). These differences were isolated in these studies, so one cannot conclude that the co-application of glyphosate with insecticides acephate and dicrotophos decreases thrips efficacy. However, this has not been observed in previous research. The number of thrips sampled in Liberty Link trials after the application of an insecticide alone, was no different than with the addition of glufosinate or glufosinate + s-metolachlor. Therefore, co-application of glufosinate with insecticides did not influence the efficacy of insecticides used to control thrips.

The cotton cultivar ST4946GlB$_2$ was chosen for tank-mixing trials because of its flexibility and crop safety to full labeled rates of glufosinate and glyphosate. Previous studies have indicated GlyTol + LibertyLink cotton contained no visual injury after the application of

glyphosate and/or glufosinate (Irby et al., 2013). However, other research has shown with the addition of an insecticide to herbicide combinations, cotton injury can reach up to 38% (Steckel et al., 2012). Visual assessment of cotton injury 5 days after application did not exceed 10% in both herbicide systems with herbicides alone or with herbicides co-applied with insecticide. Visual injury observed within treatments 5 days after application was no longer present 14 days after application.

Plant growth parameters including plant heights, total node counts, and NAWF were not affected by an herbicide-insecticide interaction or herbicides and insecticides alone in the Roundup tank-mix study. This observation agrees with previous findings where herbicide-insecticide interactions in tank-mixes had no effect on plant growth parameters or yield (Miller et al., 2008; Stewart et al., 2013b). Liberty link trials paralleled these results in all but one location where the presence of glufosinate with dicrotophos contained more NAWF and therefore delayed maturity compared to all other treatments.

Seed cotton yield was not affected by an interaction affect between co-applied insecticides and herbicides. Small amounts of visual injury recorded at 5 days after application did not affect seed cotton yield, which was also seen in previous studies (Miller et al., 2008). Seed cotton yield was not affected by different insecticide treatments even though thrips control was achieved at different rates. This response likely was due to thrips stressing the cotton plant before tank-mix applications. Thrips numbers averaged no less than 13 per plant at the time of evaluation 5 days after application in treatments that exhibited the greatest control. This is well over the recommended Arkansas threshold of 5 thrips per plant. Seed cotton yield was affected by herbicide differently in each herbicide system. In the absence of an insecticide, glyphosate + s-metolachlor treatments yielded less seed cotton than glyphosate alone. However, glufosinate +

s-metolachlor treatments yielded more seed cotton than glufosinate alone. In previous research it was shown that differences in yield response occurs due to stress caused by thrips before glufosinate application (Stewart et al., 2013b). Our findings showed no differences in numbers of thrips and therefore the observed variance in yield was not due to thrips damage being compounded by herbicide.

Overall, negative effects of herbicide insecticide tank-mixtures in this study to GlyTol + LibertyLink cotton at the 2-4 leaf stage were limited. Visual injury occurred, but did not last longer than 14 days after application and rarely resulted in delayed maturity or yield loss. Results indicated that when applied according to the pesticide label, co-application of the tested herbicide-insecticide tank-mixtures offer cotton producers the ability to integrate thrips and weed control. The use of these mixtures limits application costs without sacrificing loss of insecticide control on thrips or crop tolerance. The impact that foliar tank mixed applications have on seedling cotton is likely to vary from year to year due to diverse environmental conditions. Growers must remember to take caution when tank-mixing pesticides and only do so when economic thresholds for insects and weeds are reached.

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Table 13. Roundup tank-mix study 2012 and 2013, treatments.

Tank mixture	Rate
acephate	368 g/ha
spinetoram + dyne-amic	109 mL/ha + 1%
dicrotophos	225 g/ha
glyphosate + acephate	651 L/ha + 368 g/ha
glyphosate + spinetoram	651L/ha + 109 mL/ha
glyphosate + dicrotophos	651 L/ha + 225 g/ha
glyphosate + s-metolachlor + acephate	651 L/ha + 1.2 L/ha + 368 g/ha
glyphosate + s-metolachlor + spinetoram	651 L/ha + 1.2 L/ha + 109 mL/ha
glyphosate + s-metolachlor + dicrotophos	651 L/ha + 1.2 L/ha + 22 g/ha
glyphosate	651 L/ha
glyphosate + s-metolachlor	651 L/ha + 1.2 L/ha
control	x
clethodim + spinetoram [1]	2.91 L/ha + 109 mL/ha
glyphosate + s-metolachlor [1]	651 L/ha + 1.2 L/ha

1 Treatments removed for factorial analysis

Table 14. Liberty Link tank-mix study 2012 and 2013, treatments.

Tank mixture	Rate
acephate	368 g/ha
spinetoram + dyne-amic	109 mL/ha + 1%
dicrotophos	225 g/ha
glufosinate + acephate	2.1 L/ha + 368 g/ha
glufosinate + spinetoram	2.1 L/ha + 109 mL/ha
glufosinate + dicrotophos	2.1 L/ha + 225 g/ha
glufosinate + s-metolachlor + acephate	2.1 L/ha + 1.2 L/ha + 368 g/ha
glufosinate + s-metolachlor + spinetoram	2.1 L/ha + 1.2 L/ha + 109 mL/ha
glufosinate + s-metolachlor + dicrotophos	2.1 L/ha + 1.2 L/ha + 225 g/ha
glufosinate	2.1 L/ha
glufosinate + s-metolachlor	2.1 L/ha + 1.2 L/ha
Control	x
glufosinate + acetochlor + spinetoram [1]	2.1 L/ha + 3.5 L/ha + 109 mL/ha
glufosinate + s-metolachlor [1]	2.1 L/ha + 1.2 L/ha

[1] Treatments removed for factorial analysis

Table 15. Liberty Link tank-mix study 2012 and 2013, thrips total after tank-mix application and seed cotton yield (± SE), by main effects and significance of interaction effect.

Main Effect	Treatment	Thrips POST tank-mix			Seed Cotton yield (lbs.)	
		M[1] 2012	M 2013	R[2] 2013	M 2013	R 2013
Herbicide	glufosinate	89.5 ± 10.1	142.9 ± 11.9 b	173.9 ± 18.1	4122.5 ± 101.8 ab	3876.5 ± 209.0
	glufosinate+ s-metolachlor	63.2 ± 10.1	103.8 ± 11.9 a	158.7 ± 18.1	4311.7 ± 101.8 a	4137.6 ± 209.0
	untreated	97.2 ± 10.1	101.9 ± 11.9 a	149.4 ± 18.1	3921.5 ± 101.8 b	3499.6 ± 209.0
	Factorial analysis	*p= 0.0586*	*p= 0.0338**	*p= 0.63*	*p= 0.0365**	*p= 0.11*
Insecticide	dicrotophos	92.3 ± 11.7 b	122 ± 13.8 b	111.3 ± 20.8 b	4181.3 ± 117.6	3352.0 ± 241.3
	acephate	69.6 ± 11.7 c	90.3 ± 13.8 bc	125.3 ± 20.8 b	4162.6 ± 117.6	4002.0 ± 241.3
	spinetoram	34.0 ± 11.7 c	65.5 ± 13.8 c	96.7 ± 20.8 b	4109.6 ± 117.6	4133.7 ± 241.3
	untreated	137.4 ± 11.7 a	187.1 ± 13.8 a	309.6 ± 20.8 a	4020.8 ± 117.6	3863.9 ± 241.3
	Factorial analysis	*p= 0.0001**	*p= 0.0001**	*p= 0.0001**	*p= 0.77*	*p= 0.13*
Herbicide*Insecticide	Factorial analysis	*p= 0.32*	*p= 0.26*	*p= 0.0373**	*p= 0.47*	*p= 0.22*

[1]Marianna
[2]Rohwer
[3]Means within a column followed by the same letter are not significantly different (p= 0.05).

Table 16. Liberty Link tank-mix study 2012 and 2013, thrips and yield contrast estimates established from contrast analysis results.

	Thrips POST tank-mix			Seed Cotton yield (lbs.)	
Contrasts	M[1] 2012	M 2013	R[2] 2013	M 2013	R 2013
acephate vs.	36.25[3]	16	-39.5	-180.6	821.7
acephate + glufosinate	*p= 0.21*	*p= 0.64*	*p= 0.44*	*p= 0.54*	*p= 0.17*
spinetoram vs.	-32.25	-16.25	-13.25	-150.4	-186.8
spinetoram + glufosinate	*p= 0.27*	*p= 0.63*	*p= 0.80*	*p= 0.61*	*p= 0.75*
dicrotophos vs.	-1.5	-54.25	28.25	-537.3	-582
dicrotophos + glufosinate	*p= 0.96*	*p= 0.12*	*p= 0.58*	*p= 0.07*	*p= 0.33*
acephate vs.	32.5	28	47	-739.4	278.4
acephate + glufosinate + s-metolachlor	*p= 0.26*	*p= 0.41*	*0.36*	*p= 0.015*	*p= 0.64*
spinetoram vs.	9	-1.75	50.25	-249.3	-622.8
spinetoram + glufosinate + s-metolachlor	*p= 0.75*	*p= 0.96*	*p= 0.33*	*p= 0.39*	*p= 0.30*
dicrotophos vs.	9.25	8.5	36.25	-283.7	-809.6
dicrotophos + glufosinate + s-metolachlor	*p= 0.75*	*p= 0.80*	*p= 0.48*	*p= 0.33*	*p= 0.18*

[1] Marianna
[2] Rohwer
[3] Contrast estimate above and corresponding p-value below

Table 17. Liberty Link tank-mix study 2012 and 2013, mean chlorosis and necrosis injury (± SE) ratings by treatment.

Main effect	Damage Ratings %					
	M[1]-2012		M[1]-2013		R[2]-2013	
	Chlor	Nec	Chlor	Nec	Chlor	Nec
acephate	0 ± 0.6 b	0 ± 1.1	0 ± 0.7	0 ± 1.3 d	0 ± 0	0 ± 0
spinetoram + dyne-amic	3.5 ± 0.6 a	2.5 ± 1.1	0 ± 0.7	0.5 ± 1.3 d	0 ± 0	0 ± 0
dicrotophos	0 ± 0.6 b	0 ± 1.1	1.3 ± 0.7	0.7 ± 1.3 cd	0 ± 0	0 ± 0
glufosinate + acephate	0 ± 0.6 b	0 ± 1.1	0.7 ± 0.7	0.7 ± 1.3 cd	0 ± 0	0 ± 0
glufosinate + spinetoram	0 ± 0.6 b	0 ± 1.1	0 ± 0.7	0.5 ± 1.3 d	0 ± 0	0 ± 0
glufosinate + dicrotophos	0 ± 0.6 b	0 ± 1.1	0 ± 0.7	0.7 ± 1.3 cd	0 ± 0	0 ± 0
glufosinate + s-metolachlor + acephate	0 ± 0.6 b	0 ± 1.1	0 ± 0.7	8.0 ± 1.3 ab	0 ± 0	0 ± 0
glufosinate + s-metolachlor + spinetoram	0 ± 0.6 b	2.5 ± 1.1	2.7 ± 0.7	6.7 ± 1.3 abc	0 ± 0	0 ± 0
glufosinate + s-metolachlor + dicrotophos	2.0 ± 0.6 ab	0 ± 1.1	0 ± 0.7	5.2 ± 1.3 abcd	0 ± 0	0 ± 0
Untreated Control	0 ± 0.6 b	0 ± 1.1	0 ± 0.7	0.5 ± 1.3 d	0 ± 0	0 ± 0
glufosinate	0 ± 0.6 b	0 ± 1.1	0 ± 0.7	2.2 ± 1.3 bcd	0 ± 0	0 ± 0
glufosinate + s-metolachlor	0 ± 0.6 b	2.5 ± 1.1	0.7 ± 0.7	8.7 ± 1.3 a	0 ± 0	0 ± 0
Factorial analysis	*p= 0.0060**	*p= 0.45*	*p= 0.91*	*p= 0.0001**	*p= 1.0*	*p= 1.0*

[1] Marianna
[2] Rohwer
[3] Means within a column followed by the same letter are not significantly different (p= 0.05).

Table 18. Liberty Link tank-mix study 2012 and 2013, changes in plant height, changes in total plant nodes, and nodes above white flower counts (± SE), by main effects and significance of interaction effect.

		Plant Height Δ (in.)		Total Node Δ		NAWF		
Main Effect	Treatment	M[1]-2013	R[2]-2013	M-2013	R-2013	M-2012	M-2013	R-2013
Herbicide	untreated	11.0 ± 0.3	8.2 ± 0.3	3.7 ± 0.2	3.1 ± 0.2	4.5 ± 0.1	2.7 ± 0.1	4.2 ± 0.2
	glufosinate	10.4 ± 0.3	8.3 ± 0.3	3.9 ± 0.2	3.5 ± 0.2	4.3 ± 0.1	2.9 ± 0.1	4.6 ± 0.2
	glufosinate + s-metolachlor	10.1 ± 0.3	8.1 ± 0.3	3.9 ± 0.2	3.4 ± 0.2	4.3 ± 0.1	2.8 ± 0.1	4.6 ± 0.2
	Factorial analysis	*p= 0.16*	*p= 0.81*	*p= 0.71*	*p= 0.41*	*p= 0.34*	*p= 0.67*	*p= 0.40*
Insecticide	untreated	9.9 ± 0.4	8.3 ± 0.3	3.9 ± 0.2	3.2 ± 0.3	4.5 ± 0.2	2.6 ± 0.1	4.3 ± 0.3
	acephate	10.7 ± 0.4	8.4 ± 0.3	3.9 ± 0.2	3.6 ± 0.3	4.3 ± 0.2	2.7 ± 0.1	4.8 ± 0.3
	spinetoram	10.6 ± 0.4	8.4 ± 0.3	3.8 ± 0.2	3.4 ± 0.3	4.3 ± 0.2	2.9 ± 0.1	4.4 ± 0.3
	dicrotophos	10.7 ± 0.4	7.8 ± 0.3	3.7 ± 0.2	3.3 ± 0.3	4.4 ± 0.2	2.9 ± 0.1	4.4 ± 0.3
	Factorial analysis	*p= 0.52*	*p= 0.47*	*p= 0.89*	*p= 0.76*	*p= 0.81*	*p= 0.22*	*p= 0.56*
Herbicide*Insecticide	Factorial analysis	*p= 0.75*	*p= 0.15*	*p= 0.81*	*p= 0.35*	*p= 0.48*	*p= 0.001**	*p= 0.69*

Δ change in growth between application time and reading 20 days after application
[1] Marianna
[2] Rohwer
[3] Means within a column followed by the same letter are not significantly different (p= 0.05).

Table 19. Roundup tank-mix study 2012 and 2013, thrips total and seed cotton yield (± SE) after tank-mix application, by main effect and significance of interaction effect.

Main Effect	Treatment	Thrips POST tank-mix			Seed Cotton yield (lbs.)	
		M[1] 2012	M 2013	R[2] 2013	M 2013	R 2013
Herbicide	glyphosate	154.8 ± 10.7 a	173.1 ± 12.3	172.9 ± 22.8	5071.4 ± 124.1 a	6974.8 ± 215.9 a
	glyphosate + s-metolachlor	117.3 ± 10.7 b	140.7 ± 12.3	161.1 ± 22.8	4621.2 ± 124.1 b	6563.0 ± 215.9 ab
	untreated	113.7 ± 10.7 b	176.7 ± 12.3	145.9 ± 22.8	4882.7 ± 124.1 ab	5860.3 ± 215.9 b
	Factorial analysis	p= 0.0180*	p= 0.09	p= 0.71	p= 0.0488*	p= 0.0033*
Insecticide	dicrotophos	184 ± 12.3 a	151.8 ± 14.2 b	120.3 ± 26.4 b	4787.9 ± 143.4	6163.8 ± 249.3 ab
	acephate	155.4 ± 12.3 a	152.3 ± 14.2 b	103.8 ± 26.4 b	4904.9 ± 143.4	6606.7 ± 249.3 ab
	spinetoram	14.7 ± 12.3 b	106.9 ± 14.2 b	129.7 ± 26.4 b	4840.4 ± 143.4	7033.6 ± 249.3 a
	untreated	160.3 ± 12.3 a	243.0 ± 14.2 a	286.2 ± 26.4 a	4900.6 ± 143.4	6060 ± 249.3 b
	Factorial analysis	p= 0.0001*	p= 0.0001*	p= 0.0001*	p= 0.93	p= 0.0357*
Herbicide*Insecticide	Factorial analysis	p= 0.18	p= 0.70	p= 0.72	p= 0.79	p= 0.26

[1] Marianna

[2] Rohwer

[3] Means within a column followed by the same letter are not significantly different (p= 0.05).

Table 20. Roundup tank-mixing study 2012 and 2013, thrips and yield contrast estimates established from contrast analysis results.

	Thrips POST tank-mix			Seed Cotton (lbs.)	
Contrasts	M[1] 2012	M 2013	R[2] 2013	M 2013	R 2013
acephate vs.	-89.753[3]	-37.25	-18.5	-206.3	-401.2
acephate + glyphosate	*p= 0.0055**	*p= 0.29*	*p= 0.78*	*p= 0.56*	*p= 0.52*
spinetoram vs.	3.5	29	-62	-124.7	-1405
spinetoram + glyphosate	*p= 0.91*	*p= 0.41*	*p= 0.34*	*p= 0.72*	*p= 0.0279**
dicrotophos vs.	-64.5	26.25	40.75	147.88	-439.5
dicrotophos + glyphosate	*p= 0.0403**	*p= 0.46*	*p= 0.53*	*p= 0.68*	*p= 0.47*
acephate vs.	7.5	-12.25	-2.75	322.4	-182.6
acephate + glyphosate + s-metolachlor	*p= 0.81*	*p= 0.73*	*p= 0.97*	*p= 0.37*	*p= 0.77*
spinetoram vs.	-3.25	54.5	-83.25	214.95	-454.5
spinetoram + glyphosate + s-metolachlor	*p= 0.92*	*p= 0.13*	*p= 0.21*	*p= 0.54*	*p= 0.46*
dicrotophos vs.	-37.5	69	5.75	233.82	-298.7
dicrotophos + glyphosate + s-metolachlor	*p= 0.22*	*p= 0.0555**	*p= 0.93*	*p= 0.51*	*p= 0.63*

[1] Marianna
[2] Rohwer
[3] Contrast estimate above and corresponding p-value below

Table 21. Roundup tank-mixing study 2012 and 2013, mean chlorosis and necrosis injury ratings (± SE) by treatment.

Tank Mixture	Damage Ratings %					
	M[1]-2012		M[1]-2013		R[2]-2013	
	Chlor	Nec	Chlor	Nec	Chlor	Nec
acephate	3.5 ± 0.9	0.7 ± 1.0 b	0 ± 0.4 c	0 ± 0.6	1.2 ± 1.3	0 ± 0.5
spinetoram + dyne-amic	2.5 ± 0.9	0.7 ± 1.0 b	0.2 ± 0.4 bc	0 ± 0.6	1.7 ± 1.3	0 ± 0.5
dicrotophos	1.7 ± 0.9	0.7 ± 1.0 b	0.2 ± 0.4 bc	0 ± 0.6	2.5 ± 1.3	0 ± 0.5
glyphosate + s-metolachlor + acephate	2.7 ± 0.9	6 ± 1.0 a	0.7 ± 0.4 abc	2 ± 0.6	4.7 ± 1.3	0.7 ± 0.5
glyphosate + s-metolachlor + spinetoram	2.5 ± 0.9	6.2 ± 1.0 a	2.0 ± 0.4 abc	0.7 ± 0.6	5.2 ± 1.3	0 ± 0.5
glyphosate + s-metolachlor + dicrotophos	3 ± 0.9	4.5 ± 1.0 ab	2.5 ± 0.4 a	2.5 ± 0.6	4.2 ± 1.3	0 ± 0.5
glyphosate + spinetoram	2 ± 0.9	0.7 ± 1.0 b	0 ± 0.4 c	0.7 ± 0.6	5.7 ± 1.3	2.0 ± 0.5
glyphosate + acephate	2.7 ± 0.9	2.0 ± 1.0 ab	0 ± 0.4 c	0 ± 0.6	4.0 ± 1.3	1.0 ± 0.5
glyphosate + dicrotophos	5.5 ± 0.9	1.0 ± 1.0 b	0 ± 0.4 c	1.2 ± 0.6	3.7 ± 1.3	0.7 ± 0.5
untreated control	1.2 ± 0.9	1.0 ± 1.0 b	2.2 ± 0.4 ab	1.7 ± 0.6	5.2 ± 1.3	0 ± 0.5
glyphosate	2.0 ± 0.9	1.5 ± 1.0 ab	0 ± 0.4 c	0.5 ± 0.6	6.5 ± 1.3	0.5 ± 0.5
glyphosate + s-metolachlor	2.0 ± 0.9	5.2 ± 1.0 ab	0.2 ± 0.4 bc	1.5 ± 0.6	7.0 ± 1.3	0.5 ± 0.5
Factorial analysis	*p=0.19*	*p= 0.0001**	*p= 0.0002**	*p= 0.08*	*p= 0.66*	*p= 0.77*

[1] Marianna
[2] Rohwer
[3] Means within a column followed by the same letter are not significantly different ($p = 0.05$).

Table 22. Roundup tank-mix study 2012 and 2013, plant height differences, total plant node differences, and nodes above white flower counts (± SE), by main effects and significance of interaction effect.

Main effect	Treatment	Plant Height Δ (in.) M[1]-2013	Plant Height Δ (in.) R[2]-2013	Total Nodes Δ M-2013	Total Nodes Δ R-2013	NAWF M-2012	NAWF M-2013	NAWF R-2013
Herbicide	untreated	12.4 ± 0.3	8.2 ± 0.3	2.8 ± 0.2	3.5 ± 0.2	4.6 ± 0.1	3.6 ± 0.2	4.4 ± 0.2
	glyphosate	11.9 ± 0.3	8.2 ± 0.3	3.2 ± 0.2	4.1 ± 0.2	4.7 ± 0.1	3.6 ± 0.2	4.6 ± 0.2
	glyphosate + s-metolachlor	11.9 ± 0.3	8.3 ± 0.3	3.4 ± 0.2	3.7 ± 0.2	4.6 ± 0.1	3.6 ± 0.2	4.6 ± 0.2
	Factorial analysis	*p= 0.51*	*p= 0.92*	*p= 0.22*	*p= 0.13*	*p= 0.73*	*p= 0.76*	*p= 0.79*
Insecticide	untreated	12.1 ± 0.4	8.2 ± 0.3	3.6 ± 0.3	4.1 ± 0.2	4.6 ± 0.1	3.6 ± 0.2	4.1 ± 0.2
	acephate	12.1 ± 0.4	8.1 ± 0.3	3.3 ± 0.3	3.6 ± 0.2	4.6 ± 0.1	3.6 ± 0.2	5.0 ± 0.2
	spinetoram	12.1 ± 0.4	8.1 ± 0.3	2.7 ± 0.3	3.9 ± 0.2	4.7 ± 0.1	3.3 ± 0.2	4.6 ± 0.2
	dicrotophos	12.2 ± 0.4	8.6 ± 0.3	2.8 ± 0.3	4.1 ± 0.2	4.7 ± 0.1	3.7 ± 0.2	4.5 ± 0.2
	Factorial analysis	*p= 0.87*	*p= 0.67*	*p= 0.09*	*p= 0.32*	*p= 0.85*	*p= 0.45*	*p= 0.14*
Herbicide*Insecticide	Factorial analysis	*p= 0.95*	*p= 0.88*	*p= 0.32*	*p= 0.89*	*p= 0.41*	*p= 0.20*	*p= 0.59*

Δ change in growth between application time and reading 20 days after application
[1]Marianna
[2]Rohwer
[3]Means within a column followed by the same letter are not significantly different (p= 0.05).

Conclusion

Two possible pathways of herbicide-insecticide interactions were identified and tested. These pathways consisted of possible interactions between preemergence herbicides in combination with insecticide seed treatments and early season foliar herbicides tank-mixed with foliar thrips insecticides. The goal of this study was not to clearly define the mechanisms of an interaction between insecticides and herbicides, but to illustrate if a significant interaction was present on some of the parameters tested. The majority of research documenting herbicide-insecticide interactions in cotton has a focused on the impact of weed control. The focus of the trials in the current study was largely on thrips control and if herbicides were affecting the efficacy of thrips insecticides in anyway. Potential impacts of combinations of these pesticides and their interaction on cotton plant growth parameters were also taken into consideration. These studies showed that herbicide-insecticide interactions rarely occurred within these pathways and when they did they were sporadic in nature. Observations of reduced IST efficacy in this study were not caused by an interaction between IST and PRE herbicides but appear to be the result of reduced efficacy of specific IST's, consistent with resistance in thrips populations. Prior to this study, tobacco thrips tolerance/resistance to thiamethoxam was unknown. Preliminary resistance testing of tobacco thrips collected from Marianna Arkansas has indicated what appears to be some form of resistance (data not shown). If confirmed by formal evaluation, thrips resistance would have serious implications for the cotton growers of Arkansas and the Mid-south. Trials testing co-application of foliar herbicides with thrips insecticides have indicated that growers could safely tank-mix these pesticides at labeled rates without sacrificing loss of insecticide efficacy or risk crop injury. Cotton under stress or various environmental factors may influence the interaction of herbicides and insecticides affecting the tested parameters differently than results recorded in this study. Therefore, growers must always exercise caution in extreme

environmental conditions when there is a potential for herbicides and insecticides to be present on the cotton plant at the same time.