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EFFICACY OF PRECISION-APPLIED IN-FURROW INSECTICIDE/NEMATICIDE AND SEED TREATMENTS ON POPULATIONS OF THRIPS AND NEMATODES IN COTTON

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EFFICACY OF PRECISION-APPLIED IN-FURROW INSECTICIDE/NEMATICIDE AND SEED TREATMENTS ON POPULATIONS OF THRIPS AND NEMATODES IN COTTON

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by
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ABSTRACT

Thrips and nematodes can be serious early-season pests of cotton grown on the highly variable soil types common in the southeastern United States. I examined the effects of precision-applied aldicarb (Temik® 15G) and seed treatments (Aeris® and Avicta Complete Pak®) on population dynamics of thrips and nematodes in management zones defined by soil texture as measured by soil electrical conductivity (EC). Research plots were established in cotton fields with variable soil types at the Clemson University Edisto Research and Education Center near Blackville, SC, during May of 2010 and 2011. Research plots were arranged in a three-way factorial design, with management zone (low EC, medium EC, or high EC), at-plant seed treatment (Aeris, Avicta Complete Pak, or none), and aldicarb rate (0, 0.51, or 0.86 kg/ha of active ingredient) as factors. Soil texture was significantly correlated with soil EC, indicating that using zone definition by soil EC provided distinct areas for applying differential control tactics for thrips and nematodes. Population densities of thrips (2010) and nematodes (2010 and 2011) were highest in the coarsest soils (low EC zones). Seed treatments were not as effective in controlling and suppressing thrips and nematodes as aldicarb. The addition of aldicarb to seed treatments increased the efficacy of these products. Although aldicarb under the trade name Temik 15G is no longer available for use in US agricultural fields, results from this study may serve as a model for future formulations of aldicarb that may become available.

DEDICATION

I would like to dedicate this thesis to my mother and father, Janice and Timothy Devinney. I would also like to dedicate this thesis to my sisters, LeChel Devinney Adkins and Kelly Devinney. I am grateful for the love and support that I have received from my family throughout my life. My academic and professional successes would not be possible without my supportive and loving family. I love you all with all of my heart.

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I would like to express sincere appreciation to my major advisor Dr. Jeremy Greene for his instruction and guidance during my graduate work. I would also like to thank the members of my committee, Dr. Francis Reay-Jones, Dr. John Mueller, and Dr. Paula Mitchell for their guidance with my research.

I would like to thank Dan Robinson, William Henderson, and members of the Bug Crew for their help with this research. I would also like to thank the faculty and staff of the former Department of Entomology, Soils, and Plant Sciences for their knowledge and assistance during my graduate study at Clemson University.

TABLE OF CONTENTS

LIST OF TABLES

List of Tables (Continued)

List of Tables (Continued)

LIST OF FIGURES

List of Figures (Continued)

List of Figures (Continued)

Figure | Page

List of Figures (Continued)

List of Figures (Continued)

Figure Page

INTRODUCTION

Overview

Thrips and nematodes can be serious early-season pests of cotton, *Gossypium hirsutum* L., grown on the highly variable soil types common in the southeastern United States. Feeding by thrips causes injury to cotton seedlings, such as yellowing and crinkling of leaves, the silvering of the underside of leaves, reduced stands, stunting of growth, and plant decline (Davidson and Lyon 1987; Layton and Reed 2002; Roberts et al. 2009). Nematodes can cause significant yield losses in cotton either alone or in combination with soil-borne diseases or early-season pests, such as thrips (Burris et al. 2008). Resistant cotton cultivars are not currently available in abundance for control of thrips and nematodes. Therefore, control or suppression of thrips and nematodes is reliant upon the application of insecticides and nematicides such as 1,3-dichloropropene (Telone II), aldicarb (Temik® 15G), or seed treatments (Aeris®, Avicta Complete Pak®) (Khalilian et al. 2001, 2002; Greene et al. 2007, 2008, 2009).

Aldicarb is an in-furrow granular insecticide/nematicide applied at-planting that can control thrips and nematodes for approximately four to six weeks after planting (Khalilian et al. 2001; Faircloth et al. 2002; Layton and Reed 2002). Aldicarb is a systemic carbamate insecticide/nematicide that was introduced in the 1960s (Hayes 1982; Howard 1991). Aldicarb is one of the most acutely poisonous pesticides and has the potential to leach into groundwater and pose health risks to humans and wildlife if used incorrectly (Hayes 1982; Howard 1991; Frye et al. 2009). Application rates range from 0.51 to 0.86 kg/ha of active ingredient. Studies have shown that 0.60 kg/ha of active ingredient provides the same amount of protection against thrips as 0.86 kg/ha of active ingredient (Vandiver et al. 2009). However, suppression and control of nematodes requires at least 0.86 kg/ha of active ingredient (Kemerait et al. 2004).

Seed treatments provide control and suppression of thrips and nematodes for three to four weeks after planting (Layton and Reed 2002). Avicta Complete Pak (ACP), a cotton seed treatment introduced by Syngenta Crop Protection, Inc., in 2006, contains a nematicide (abamectin) and an insecticide (thiamethoxam, trade name Cruiser®) (Carter 2003). Aeris, another cotton seed treatment introduced by Bayer CropScience in 2007, contains a nematicide (thiodicarb) and an insecticide (imidacloprid) (Hall et al. 2007; Riggs et al. 2007; Frye et al. 2009). Numerous efficacy trials have been completed since the release of these two products. Results from these studies showed that both seed treatments were not as effective in controlling populations of thrips and nematodes as the standard in-furrow aldicarb treatment (Temik 15G) (Brown et al. 2008; Greene et al. 2008). Some studies have shown that the addition of aldicarb (Temik 15G) to these seed treatments increased control of thrips and nematodes and subsequent yields (Kemerait et al. 2004; Greene et al. 2007, 2008, 2009).

Conventional control and suppression of thrips and nematodes has involved the application of nematicides/insecticides at a single rate over an entire field (Wrather et al. 2002; Overstreet et al. 2009). Studies have shown that densities of pests can be significantly affected by soil type and texture and do not have uniform distributions in fields (Khalilian et al. 2001, 2002; Wrather 2002). Root-knot nematode, *Meloidogyne incognita* and Columbia Lance nematode, *Hoplolaimus columbus* reproduce better in coarse textured soils than fine textured soils and are associated with sandy soils (Fassuliotis 1975; Khalilian et al. 2001; Koenning and Bowman 2005). Excessive inputs are wasted and environmental harm is caused when nematicides/insecticides are applied at one rate over an entire field (Wrather et al. 2002). Utilization of management zones, areas within a field that respond to management practices in a similar way (Fridgen et al. 2000), to apply variable pesticide rates for controlling of thrips and nematodes reduces economic inputs and environmental hazards while increasing yields (Khalilian et al. 2002; Lohmeyer et al. 2003).

Technologies are available that allow various inputs (insecticide/nematicide rates) to be site-specific, such as mapping of soil texture within fields by using soil electrical conductivity (EC) (Sullivan et al. 2004; Overstreet et al. 2009). Soil EC is a measurement that correlates with soil properties that affect crop productivity. These properties include texture, salinity, drainage conditions, and organic matter levels (Corwin and Lesch 2003; Sullivan et al. 2004). Soils with low, medium, or high EC values have sandy, silt, or clay textures, respectively (Khalilian et al. 2001, 2002; Sullivan et al. 2004).

Objectives

The first objective of this study was to determine the effects of site-specific variable rate applications of in-furrow insecticide/nematicide (Temik 15G) and seed treatments (Aeris and Avicta Complete Pak) on populations of thrips and nematodes in management zones defined by soil texture as measured by electrical conductivity. The second objective of this study was to examine the economic benefit or detriment of each management technique for thrips and nematodes either alone or in combination with other tactics.

CHAPTER ONE

EFFICACY OF PRECISION-APPLIED IN-FURROW INSECTICIDE/NEMATICIDE AND SEED TREATMENTS ON POPULATIONS OF THRIPS IN COTTON

Introduction

Thrips can be serious early-season pests of cotton, *Gossypium hirsutum* L., in the southeastern United States by feeding on the terminal of seedling cotton, which can lead to excessive vegetative growth, yellowing and silvering of leaves, stunting, stand loss, and yield reduction (Davidson and Lyon 1987; Layton and Reed 2002; Greene et al. 2007, 2008, 2009; Roberts et al. 2009; Cook et al. 2011). Thrips puncture leaf cells with their piercing-sucking mouthparts and feed on the meristematic tissue (terminal) of the cotton plant which contains tissues that develop into true leaves. Cotton seedlings are particularly susceptible to thrips injury when thrips feed on the terminal because the crop develops slowly during the first seven to ten days after emergence. The rate of plant growth increased after three to four true leaves have developed, resulting in reduced susceptibility to thrips injury (Cook et al. 2011).

Thrips pest species occurring in southeastern cotton production include, but are not limited to, tobacco thrips, *Frankliniella fusca* (Hinds), onion thrips, *Thrips tabaci* (Lind), soybean thrips, *Neohydatothrips variablis* (Beach), flower thrips, *Frankliniella tritici* (Fitch), and western flower thrips, *Frankliniella occidentalis* (Pergande) (Watts 1937; Kirk and Terry 2003; Cook et al. 2011). Most of the damage done to seedling cotton is caused by the feeding of immature thrips. Adult thrips will leave cotton fields to obtain protein from pollen, which aids in reproduction (Layton and Reed 2002).

Treatment thresholds in cotton vary from state to state, including one thrips per plant in Texas (Cook et al. 2011), two to three thrips per plant in Georgia (Cook et al. 2011), and two or more thrips per plant in Florida and South Carolina (Cook et al. 2011, Greene 2012). Treatments thresholds can also include the presence of immatures or signs of injury (Cook et al. 2011, Greene 2012). Control of thrips often involves both preventative and reactive measures. Preventative control tactics are typically applied at-planting and involve in-furrow liquid or granular insecticides or seed treatments (Layton and Reed 2002; Roberts et al. 2009). Reactive control tactics usually are in the form of broadcast foliar applications of insecticides, such as acephate, that are sprayed after thrips are infesting and damaging the plants (Cook et al. 2011). Across the United States Cotton Belt, control costs for the management of thrips in 2008, 2009, and 2010 were \$4.64, \$3.56, and \$5.73 per hectare, respectively (Williams 2009, 2010, 2011).

Conventional control and suppression of thrips has involved the application of insecticides at a single rate over an entire field (Wrather et al. 2002; Overstreet et al. 2009), leading to the use of excessive inputs (Wrather et al. 2002). Technologies are available that allow various inputs to be site-specific, such as mapping of soil texture within fields by using soil electrical conductivity (EC) (Corwin and Lesch 2003b). Soil EC is a measurement that correlates with soil properties that affect crop productivity. These properties include texture, salinity, drainage conditions, and organic matter levels (Corwin and Lesch 2003; Sullivan et al. 2004). Soils with low, medium, or high EC values have sandy, silt, or clay textures, respectively (Khalilian et al. 2001, 2002; Sullivan et al. 2004). Utilization of management zones, areas within a field that respond to management practices in a similar way (Fridgen et al. 2000), for control of thrips and nematodes reduce economic inputs (insecticide rates) and environmental hazards while increasing yields (Khalilian et al. 2002; Lohmeyer et al. 2003). Site-specific application of aldicarb has shown potential in controlling nematodes in cotton (Wrather et al. 2002). Because nematodes and thrips share similar control tactics, research is needed to address how site-specific application of aldicarb and the use of seed treatments may impact thrips, in addition to nematodes. The interactions of seed treatments, at-planting use of aldicarb and use of management zones have yet to be reported for thrips control on cotton. The objectives of this study were to determine the effects of site-specific variable rate applications of in-furrow insecticide/nematicide (Temik 15G) and seed treatments (Aeris and Avicta Complete Pak) on populations of thrips in management zones defined by soil texture as measured by electrical conductivity; and to examine the economic benefit or detriment of each management technique for thrips either alone or in combination with other tactics.

Materials and Methods

Research plots, located in fields with variable soil types at the Clemson University Edisto Research and Education Center near Blackville, SC, were mapped for soil texture using a soil electrical conductivity (EC) meter (Veris 3100) to define management zones within the fields. Management zones were delineated based on ranges of the difference between shallow and deep EC measurements. Low, medium, and high EC zones were determined by large, medium, and small differences between shallow and deep EC measurements, respectively. Soil texture analysis (% sand, silt, and clay) was completed by placing a stainless steel, conical probe 20.3-cm deep into the furrow of the middle two rows five or six times until the probe was full (Johnson et al. 2003). Research plots were arranged in a three-way factorial design, with management zone (low EC, medium EC, or high EC), seed treatment (Aeris® [imidacloprid at 0.375 mg of active ingredient per seed], Avicta Complete Pak® [thiamethoxam at 0.375 mg of active ingredient per seed], or no seed treatment), and rate of at-planting use of Temik® 15G (aldicarb at 0, 0.51, or 0.86 kg/ha of active ingredient) as factors. Seed treatments also contained nematicides and fungicides. Plots were eight rows by 12.2-meters with 96.5-cm centers. Each treatment was replicated four times. A Bollgard® 2, Roundup Ready Flex® cotton cultivar (DP 161 B2RF) from one seed lot was treated with both Aeris and Avicta Complete Pak seed treatments. Research plots were planted on 6 May 2010 and 3 May 2011.

Thrips were sampled by submerging ten randomly selected seedling plants removed from rows two and seven in 1.4-liter jars half filled with 70% isopropyl alcohol to dislodge thrips. The jars were taken to the laboratory and the alcohol mechanically suctioned through filter paper where adult and immature thrips were counted using dissecting scopes (Lohmeyer et al. 2003; Joost et al. 2004). The effects of thrips injury to seedling cotton plants were visually rated once per week for up to five weeks after planting on a 0-10 scale, where "0" described no damage and "10" described severe damage/dead plants (Hopkins et al. 2001). In 2010, vials containing thrips from several sample dates were sent to Dr. Jack Reed from Mississippi State University for species complex determination.

Populations of thrips were sampled twice weekly from each plot until five weeks after planting on the following dates: 18, 21, 24, and 27 May 2010; 1, 4, and 7 June 2010; 19, 23, 26, and 30 May 2011; and 1 June 2011. Injury ratings were taken on 26 May 2010; 2 and 18 June 2010; 19 and 27 May 2011; and 3 and 9 June 2011. Soil samples were taken to analyze percent composition the last week of July in 2010 and 28 October 2011.

Thrips counts (log [x + 1]) and injury ratings (arcsine [square root(x / 10)]) were transformed prior to ANOVA. Thrips counts and injury ratings were subjected to a repeated measures ANOVA (PROC MIXED, SAS Institute 2010) with sampling date, management zone (i.e., EC level), aldicarb rate, and seed treatment as fixed effects and replication as a random effect. Treatment means were separated using Least Significant Difference (LSD) (SAS Institute 2010). A simple correlation associated soil texture (percentages of sand, silt, clay) with soil EC (PROC CORR, SAS Institute 2010).

Results

EREC 2010:

Soil EC was negatively correlated with percentage of sand (r = -0.81, P < 0.0001) and positively correlated with percentage of silt (r = 0.31, P = 0.0009) and percentage of clay (r = 0.76, P < 0.0001). Tobacco thrips were the predominant species making up approximately 90% of the species complex. There were also some soybean thrips and flower thrips.

Population densities of adult and immature thrips were significantly the highest from 15 DAP to 26 DAP and from 21 DAP to 32 DAP, respectively (Figure 1.1). Population densities of immature thrips were significantly lower in high EC management zones (1.91 ± 0.37 b) compared to medium (4.30 ± 0.76 a) and low (5.73 ± 1.08 a) EC zones. Population densities of thrips were significantly lower in treatments with 0.51 (adults = 1.24 ± 0.11 b, immature = 1.27 ± 0.24 b) or 0.86 (adults = 1.28 ± 0.12 b, immature = 0.97 ± 0.15 b) kg/ha of aldicarb than the untreated control (adults = 6.85 ± 0.46 a, immature = 9.69 ± 1.28 a). Population densities of immature thrips were significantly lower in treatments with either Aeris (2.97 ± 0.68 b) or Avicta (2.19 ± 0.39 b) than the untreated control (6.79 ± 1.11 a). The addition of aldicarb to seed treatments significantly reduced population densities of immature thrips (Figure 1.2). Treatments with either Aeris (3.48 ± 1.65 c) or Avicta (2.19 ± 0.74 bc) in low EC management zones had significantly lower population densities of immature thrips than the untreated control (4.18 ± 2.60 a). Population densities of immature thrips were highest in low EC management zones at 29 DAP (Figure 1.3). Population densities of adult and immature thrips were significantly lower in treatments with aldicarb averaged across sample dates (Figure 1.4).

Ratings of injury to cotton plants by thrips were significantly higher at 27 DAP (3.04 ± 0.12 a) compared with 20 DAP (2.58 ± 0.10 b) and 43 DAP (2.00 ± 0.10 c). Ratings of injury to cotton plants by thrips were significantly higher in high EC management zones (2.95 ± 0.12 a) compared to medium (2.44 ± 0.10 b) and low EC zones (2.21 ± 0.11 b). Treatments with either 0.51 (2.01 ± 0.10 b) or 0.86 (2.07 ± 0.10 b) kg/ha of aldicarb had significantly lower ratings of injury by thrips than the untreated control (3.54 ± 0.10 a). Treatments with either Aeris (2.35 ± 0.11 b) or Avicta (2.24 ± 0.11 b) had significantly lower ratings of injury by thrips than the untreated control (3.02 ± 0.12 a). Ratings of injury to cotton plants by thrips decreased over time with an increase in sand content (Figure 1.5). Treatments with aldicarb in common had the significantly lowest ratings of injury to cotton plants by thrips across all sample dates (Figure 1.6).

<u>EREC 2011</u>:

Soil EC was negatively correlated with percentage of sand (r = -0.26, P = 0.0058) and positively correlated with percentage of silt (r = 0.05, P = 0.6338) and percentage of clay (r = 0.24, P = 0.0116).

Population densities of adult and immature thrips were significantly higher from 16 DAP to 27 DAP and from 23 DAP to 29 DAP, respectively (Figure 1.7). Population densities of adult thrips were significantly lower in low EC management zones (7.11 ±

0.64 b) compared to high (7.30 ± 0.54 a) and medium (8.35 ± 0.62 a) EC zones. Population densities of adult and immature thrips were significantly lower in aldicarb treated plots (Figure 1.8). The addition of aldicarb to both seed treatments significantly lowered population densities of adult and immature thrips (Figure 1.9). Population densities of adult thrips were significantly lower in treatments with aldicarb across all sample dates (Figure 1.10). Population densities of immature thrips were significantly lower in treatments with aldicarb 29 DAP (Figure 1.10).

Ratings of injury to cotton plants by thrips were significantly the highest at 16 DAP (3.48 ± 0.08 a) and the lowest at 37 DAP (2.36 ± 0.11 c). Treatments with either 0.51 (2.54 ± 0.08 b) or 0.86 (2.50 ± 0.07 b) kg/ha of aldicarb had significantly lower ratings of injury by thrips than the untreated control (3.65 ± 0.06 a). Ratings of injury by thrips were significantly the lowest in treatments with Aeris (2.63 ± 0.08 c) compared with treatments with Avicta (2.91 ± 0.07 b) and the untreated control (3.12 ± 0.09 a). Ratings of injury by thrips were significantly lower in treatments with aldicarb in common across sample dates (Figure 1.11). Ratings of injury by thrips were significantly lower at 16 DAP in treatments with a seed treatment (Figure 1.12).

Table 1.1. Statistical comparisons of treatment effects on population densities of immature thrips, adult thrips, and ratings of injury by thrips to cotton in plots near Blackville, SC, 2010.

Management factor combination	Population Densities of Immature Thrips			Population Densities of Adult Thrips			Ratings of Injury to Cotton Seedlings		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 564	5.82	**0.0032**	2, 564	2.09	0.1244	2, 240	18.69	**<0.0001**
Aldicarb rate	2, 564	60.30	**<0.0001**	2, 564	128.10	**<0.0001**	2, 240	99.10	**<0.0001**
Seed treatment	2, 564	9.51	**<0.0001**	2, 564	1.78	0.1702	2, 240	24.08	**<0.0001**
Sample date	6, 564	66.83	**<0.0001**	6, 564	18.46	**<0.0001**	2, 240	61.53	**<0.0001**
Soil texture × aldicarb rate	4, 564	0.71	0.5863	4, 564	0.82	0.5114	4, 240	0.74	0.5628
Soil texture × seed treatment	4, 564	3.30	**0.0109**	4, 564	0.79	0.5349	4, 240	1.04	0.3863
Aldicarb rate × seed treatment	4, 564	2.74	**0.0281**	4, 564	1.88	0.1120	4, 240	0.24	0.9164
Sample date × soil texture	12, 564	2.32	**0.0067**	12, 564	1.02	0.4301	4, 240	4.72	**0.0011**
Sample date × aldicarb rate	12, 564	15.57	**<0.0001**	12, 564	5.25	**<0.0001**	4, 240	3.66	**0.0065**
Sample date × seed treatment	12, 564	2.50	**0.0034**	12, 564	0.89	0.5521	4, 240	1.73	0.1450
Soil texture × aldicarb rate × seed treatment	8, 564	1.75	0.0848	8, 564	1.28	0.2503	8, 240	0.73	0.6670
Sample date × soil texture × aldicarb rate	24, 564	1.04	0.4096	24, 564	1.00	0.4680	8, 240	0.72	0.6731
Sample date × soil texture × seed treatment	24, 564	1.39	0.1040	24, 564	0.73	0.8277	8, 240	1.74	0.0904
Sample date × aldicarb rate × seed treatment	24, 564	1.46	0.0737	24, 564	0.61	0.9257	8, 240	0.77	0.6319
Sample date × soil texture × aldicarb rate × seed treatment	48, 564	0.90	0.6713	48, 564	0.98	0.5220	16, 240	0.58	0.8984

Table 1.2. Statistical comparisons of treatment effects on immature thrips, adult thrips, and ratings of injury in cotton by thrips in plots near Blackville, SC, 2011.

Management factor combination	Population Densities of Immature Thrips			Population Densities of Adult Thrips			Ratings of Injury to Cotton Seedlings		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 402	1.10	0.3351	2, 402	7.35	**0.0007**	2, 321	2.34	0.0980
Aldicarb rate	2, 402	109.19	**<0.0001**	2, 402	131.29	**<0.0001**	2, 321	123.48	**<0.0001**
Seed treatment	2, 402	1.14	0.3212	2, 402	1.33	0.2661	2, 321	15.89	**<0.0001**
Sample date	4, 402	43.50	**<0.0001**	4, 402	19.02	**<0.0001**	3, 321	63.13	**<0.0001**
Soil texture × aldicarb rate	4, 402	1.47	0.2111	4, 402	4.23	**0.0023**	4, 321	0.19	0.9454
Soil texture × seed treatment	4, 402	0.16	0.9582	4, 402	1.27	0.2806	4, 321	0.87	0.4822
Aldicarb rate × seed treatment	4, 402	5.61	**0.0002**	4, 402	5.95	**0.0001**	4, 321	2.03	0.0901
Sample date × soil texture	8, 402	0.42	**<0.0001**	8, 402	4.04	**0.0001**	6, 321	4.89	**<0.0001**
Sample date × aldicarb rate	8, 402	10.35	**<0.0001**	8, 402	7.25	**<0.0001**	6, 321	9.48	**<0.0001**
Sample date × seed treatment	8, 402	0.92	0.5007	8, 402	3.93	**0.0002**	6, 321	3.73	**0.0013**
Soil texture × aldicarb rate × seed treatment	8, 402	1.03	0.4096	8, 402	2.16	**0.0298**	8, 321	0.94	0.4816
Sample date × soil texture × aldicarb rate	16, 402	0.62	0.8669	16, 402	0.84	0.6392	12, 321	1.17	0.3004
Sample date × soil texture × seed treatment	16, 402	0.44	0.9727	16, 402	1.11	0.3411	12, 321	0.39	0.9681
Sample date × aldicarb rate × seed treatment	16, 402	2.26	**0.0038**	16, 402	1.15	0.3088	12, 321	1.27	0.2346
Sample date × soil texture × aldicarb rate × seed treatment	32, 402	0.55	0.9781	32, 402	0.67	0.9142	24, 321	0.57	0.9494

A

B

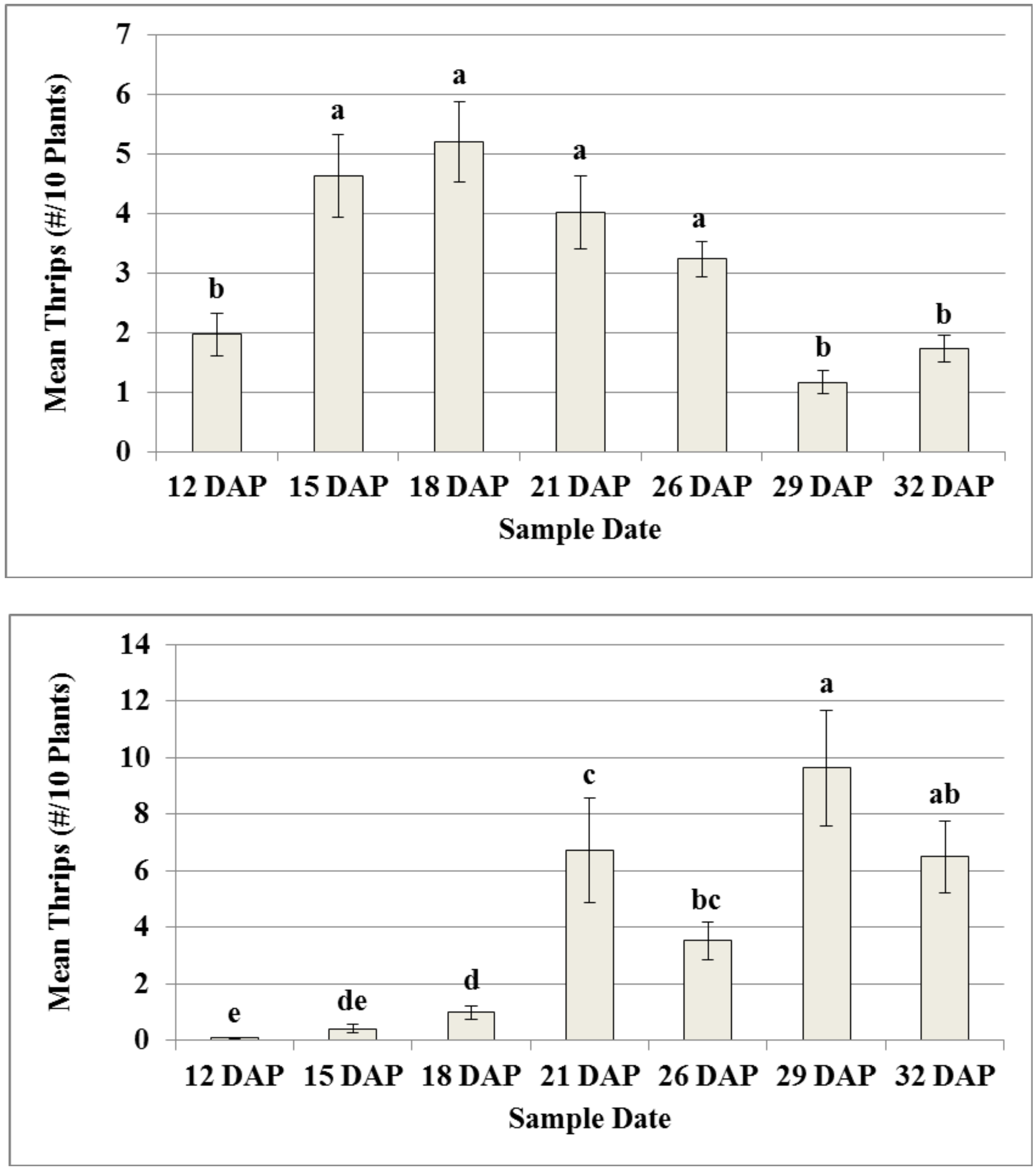


Figure 1.1. Effect of sample date on mean population densities of (A) adult and (B) immature thrips in cotton plots near Blackville, SC, 2010. Ten plants examined per treatment. Bars with a letter in common across dates are not significantly different, P>0.05, LSD. DAP, days after planting.

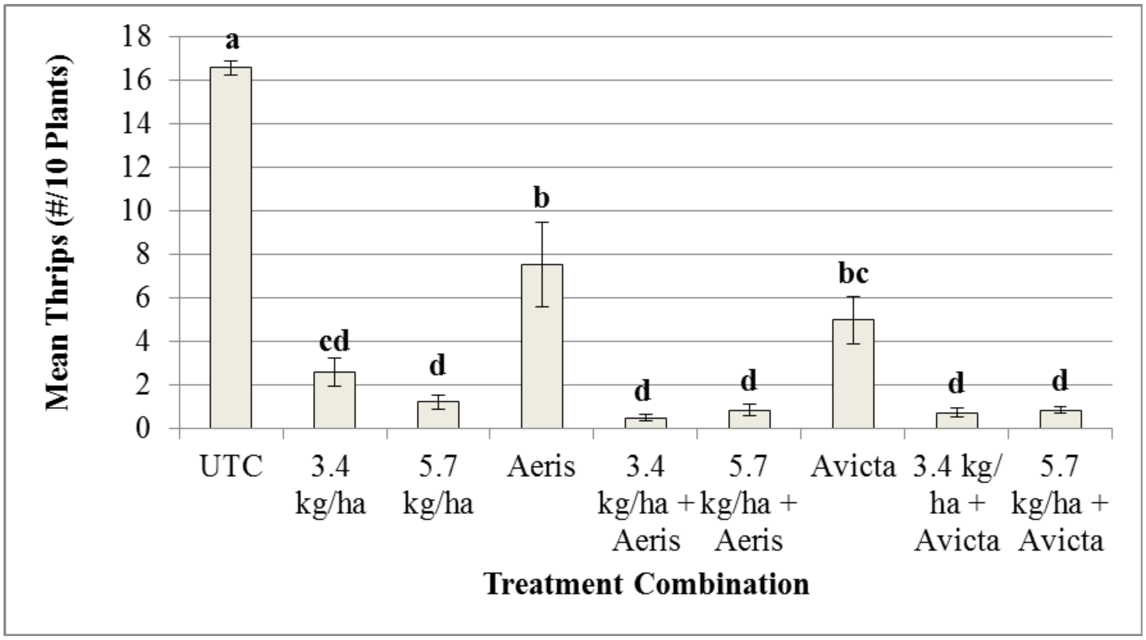


Figure 1.2. Effect of aldicarb rate and seed treatment on mean population densities of immature thrips in cotton plots near Blackville, SC, 2010. Ten plants examined per treatment. Bars with a letter in common across treatment combinations are not significantly different, P>0.05, LSD.

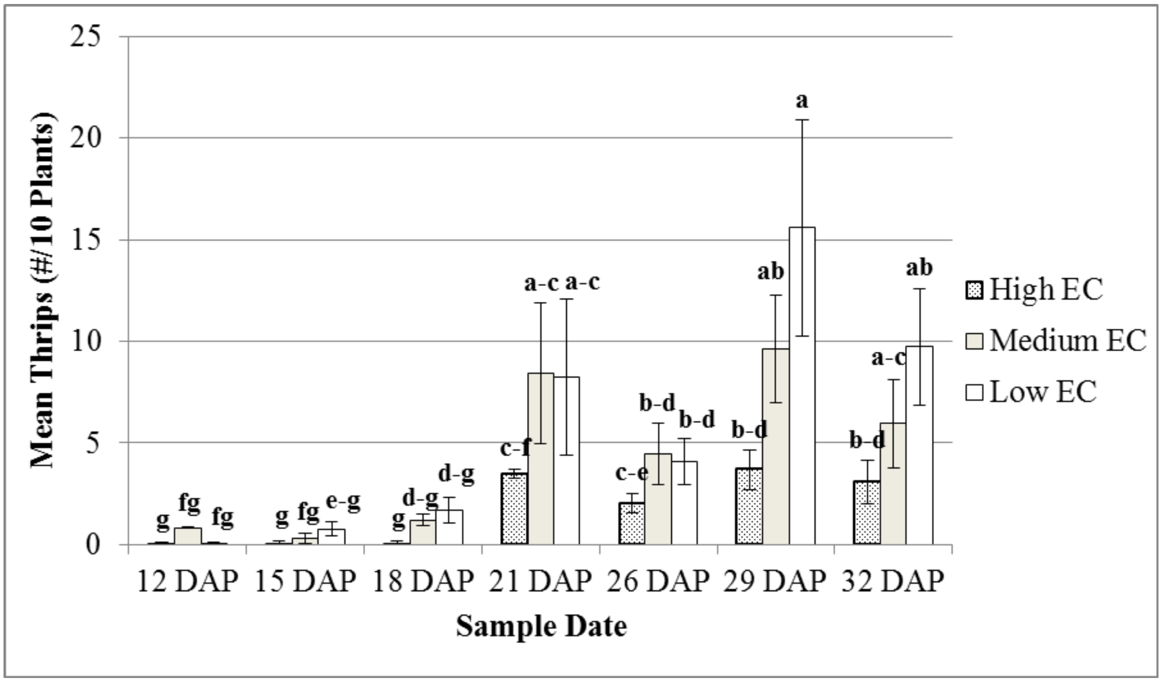


Figure 1.3. Effect of sample date and soil texture on mean population densities of immature thrips from cotton plots near Blackville, SC, 2010. Bars with a letter in common are not significantly different, P>0.05, LSD. DAP, day after plant. EC, electrical conductivity.

A

B

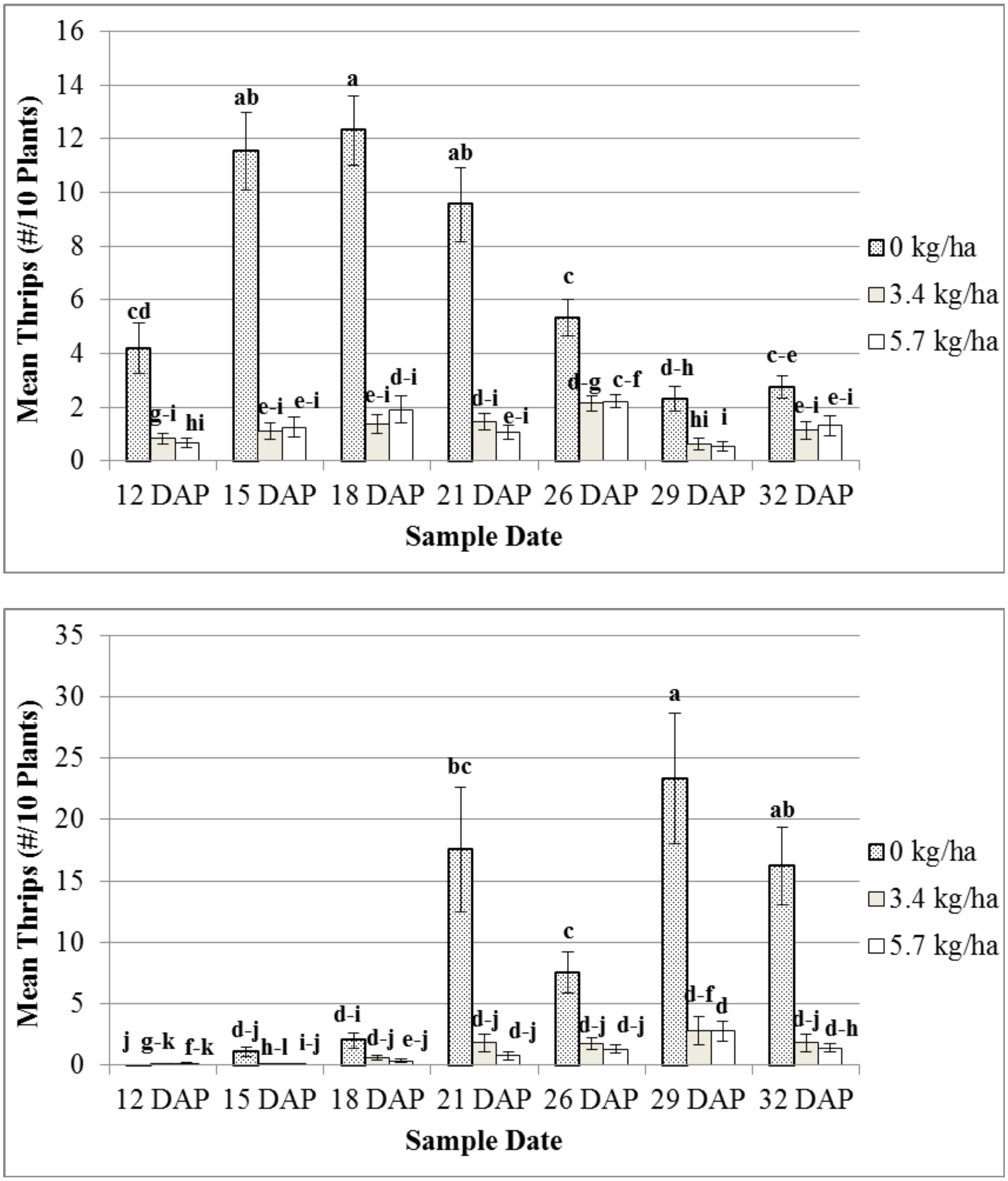


Figure 1.4. Effect of sample date and aldicarb rate on mean population densities of (A) adult and (B) immature thrips in cotton plots near Blackville, SC, 2010. Ten plants examined per treatment. Bars with a letter in common across sample dates and aldicarb rates are not significantly, P>0.05, LSD.

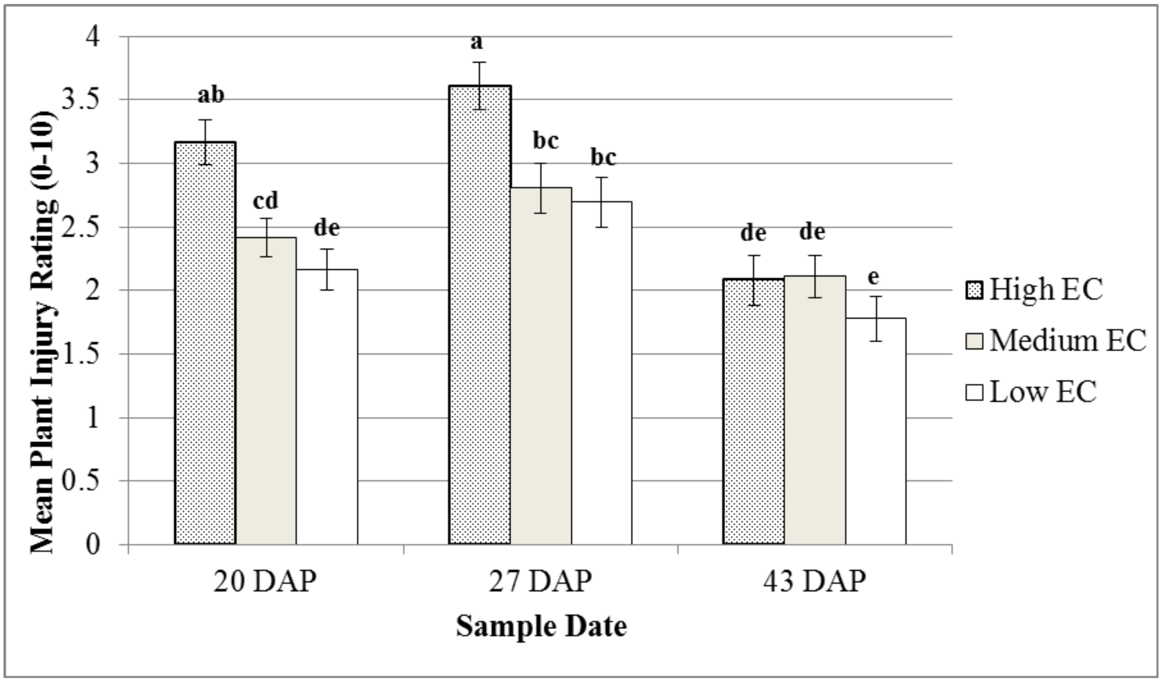


Figure 1.5. Effect of sample date and soil texture on mean cotton plant injury ratings by thrips in plots near Blackville, SC, 2010. 0, no injury; 10, severe damage/dead plants. Bars with a letter in common are not significantly different, P>0.05, LSD. DAP, day after plant. EC, electrical conductivity.

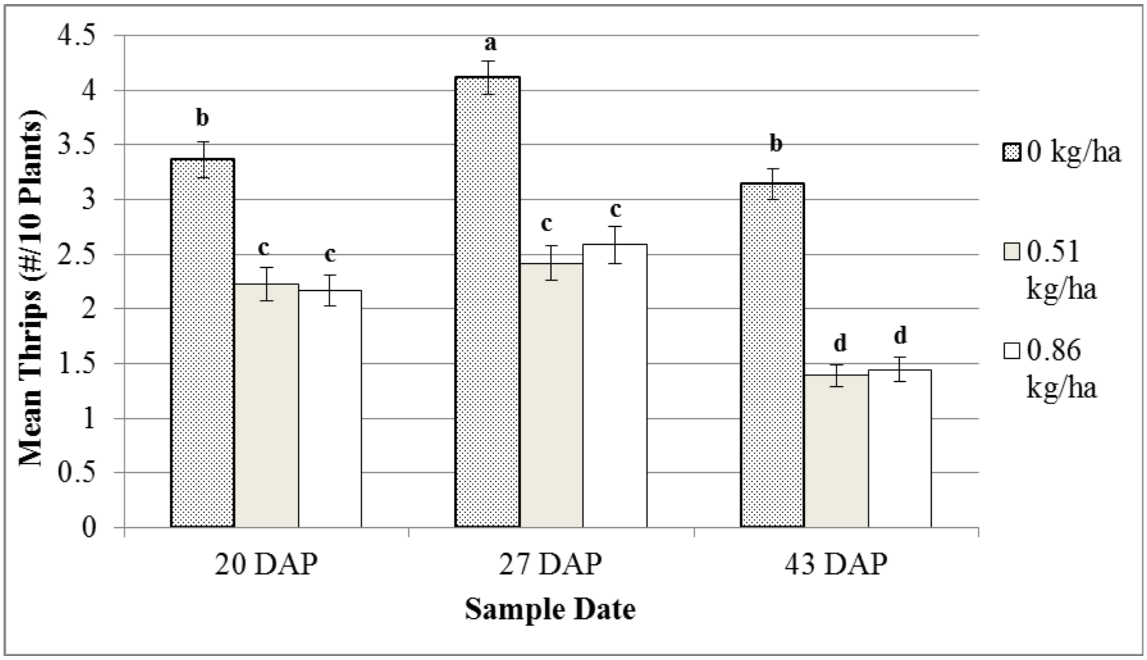


Figure 1.6. Effect of sample date and aldicarb rate on mean cotton plant injury ratings by thrips in plots near Blackville, SC, 2010. 0, no injury; 10, severe damage/dead plants. Bars with a letter in common are not significantly different, P>0.05, LSD. DAP, day after plant.

A

B

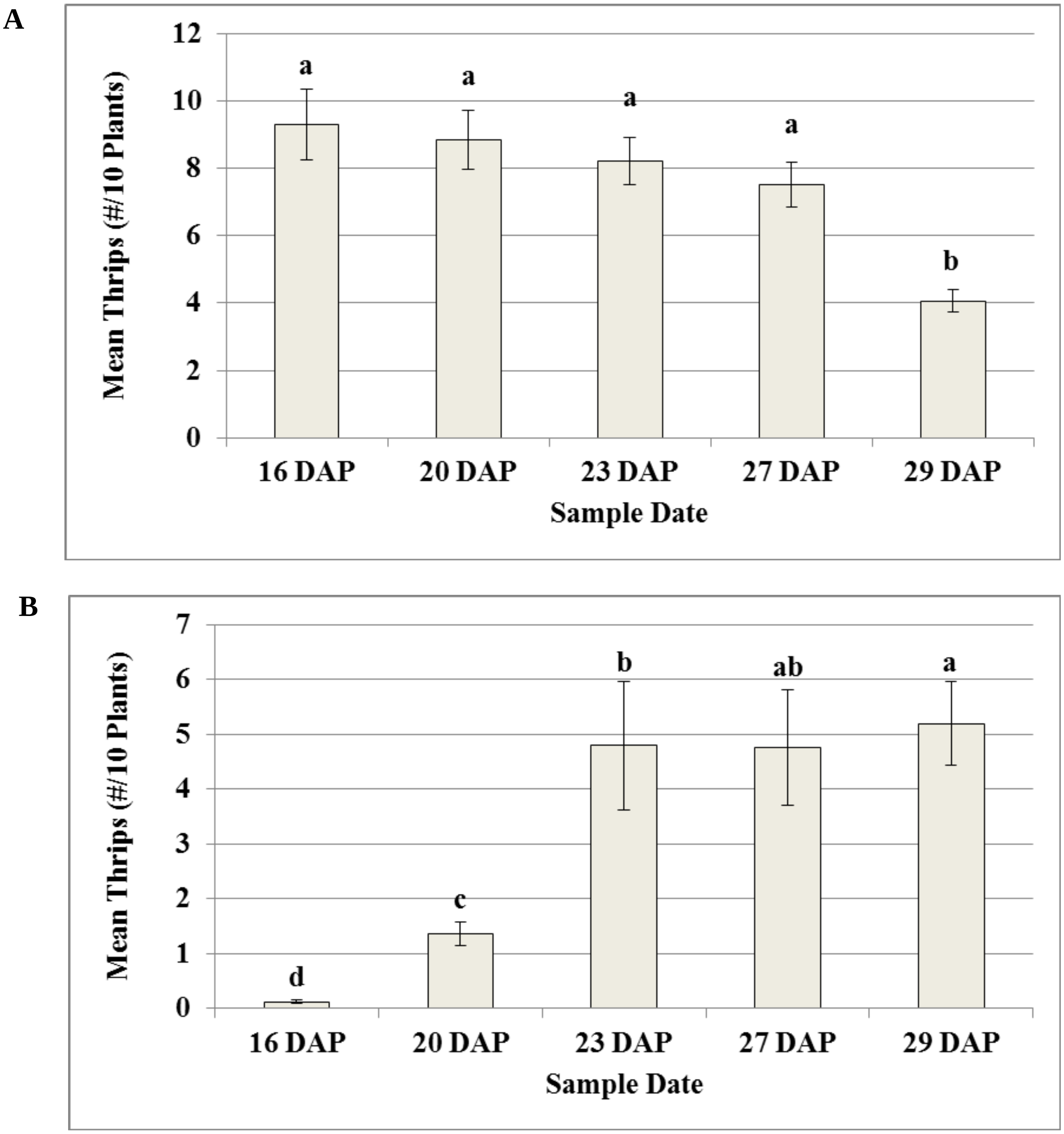


Figure 1.7. Effect of sample date on mean population densities of (A) adult and (B) immature thrips in cotton plots near Blackville, SC, 2011. Ten plants examined per treatment. Bars with a letter in common across dates are not significantly different, P>0.05, LSD. DAP, days after planting.

A

B

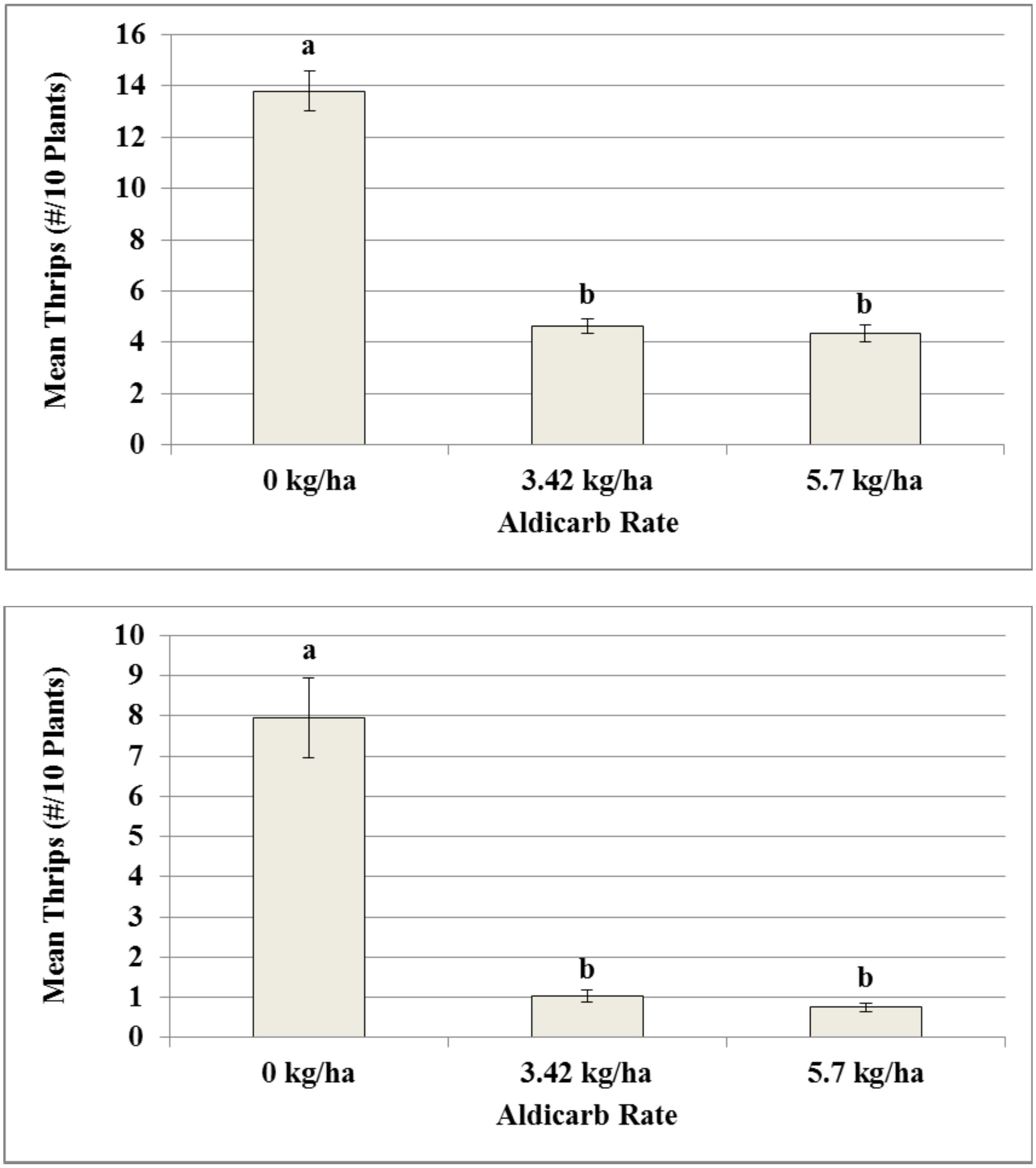
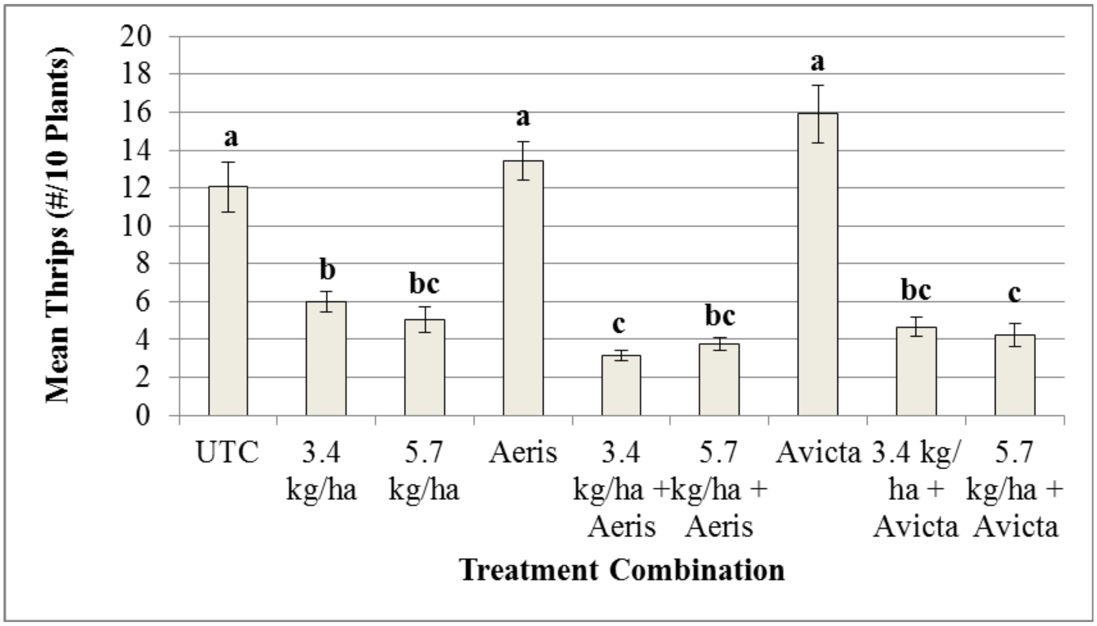


Figure 1.8. Effect of aldicarb rate on mean population densities of (A) adult and (B) immature thrips in cotton plots near Blackville, SC, 2011. Ten plants examined per treatment. Bars with a letter in common across aldicarb rate are not significantly different, P>0.05, LSD.

A



B

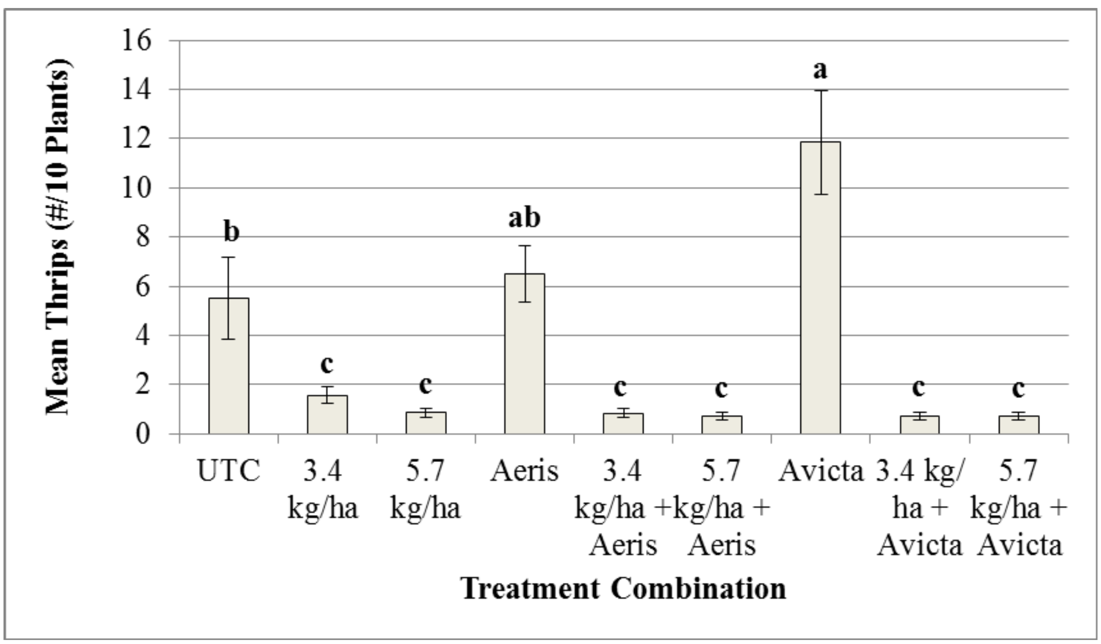


Figure 1.9. Effect of treatment regime on mean population densities of (A) adult and (B) immature thrips in cotton plots near Blackville, SC, 2011. Ten plants examined per treatment. Bars with a letter in common across treatment combinations are not significantly different, P>0.05, LSD.

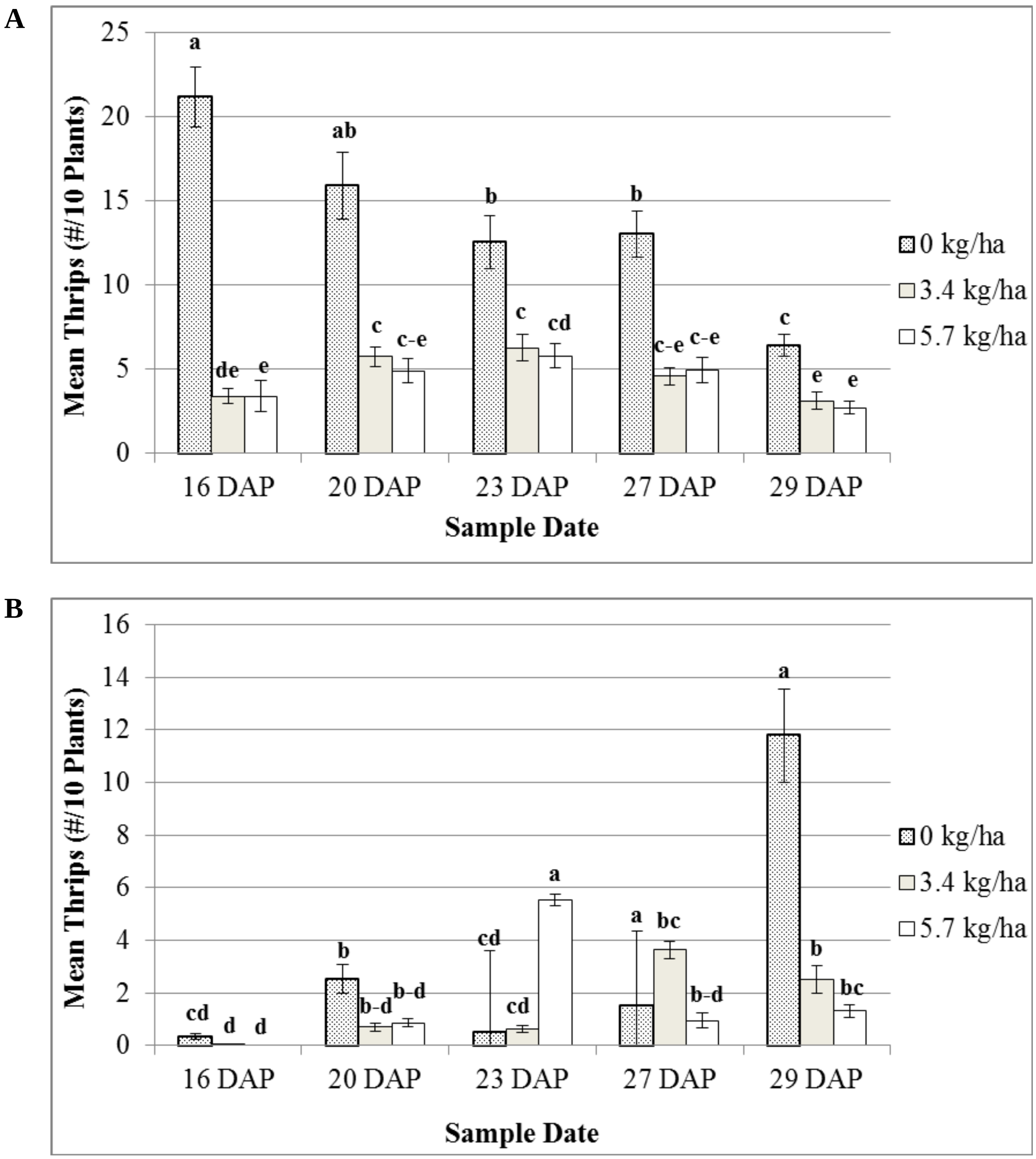


Figure 1.10. Effect of sample date and aldicarb rate on mean population densities of (A) adult and (B) immature thrips in cotton plots near Blackville, SC, 2011. Ten plants examined per treatment. Bars with a letter in common across sample dates and aldicarb rates are not significantly different, P > 0.05, LSD. DAP, days after plant.

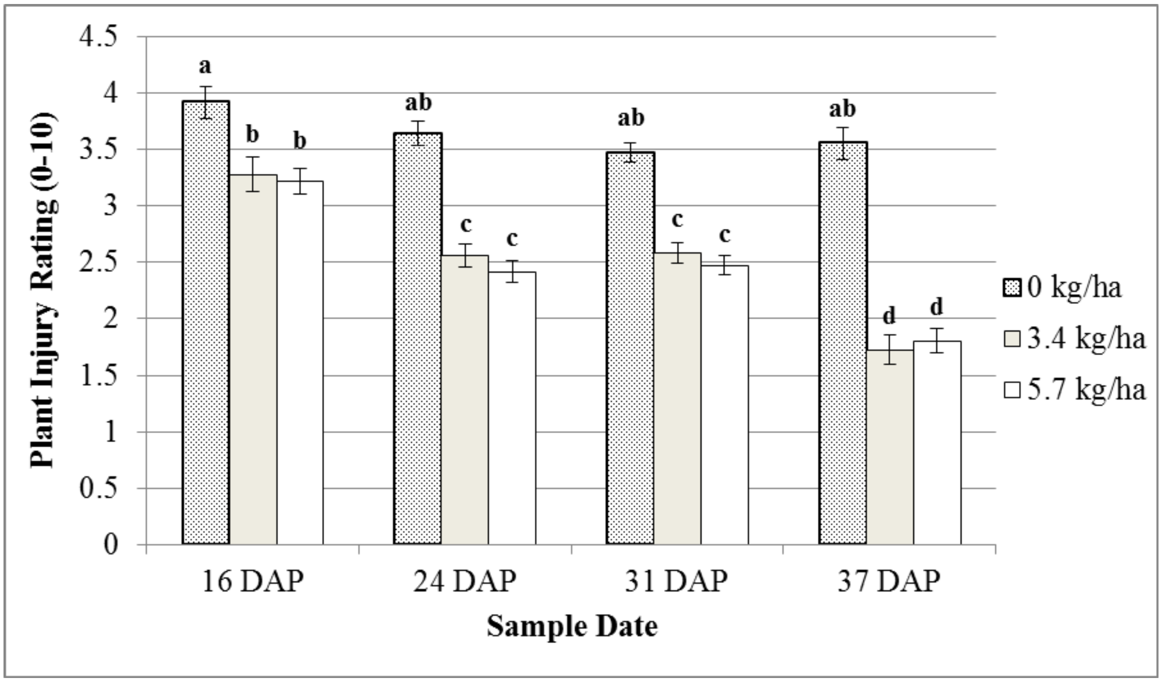


Figure 1.11. Effect of sample date and aldicarb rate on ratings of injury to cotton plants by thrips in plots near Blackville, SC, 2011. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P>0.05, LSD. DAP, days after plant.

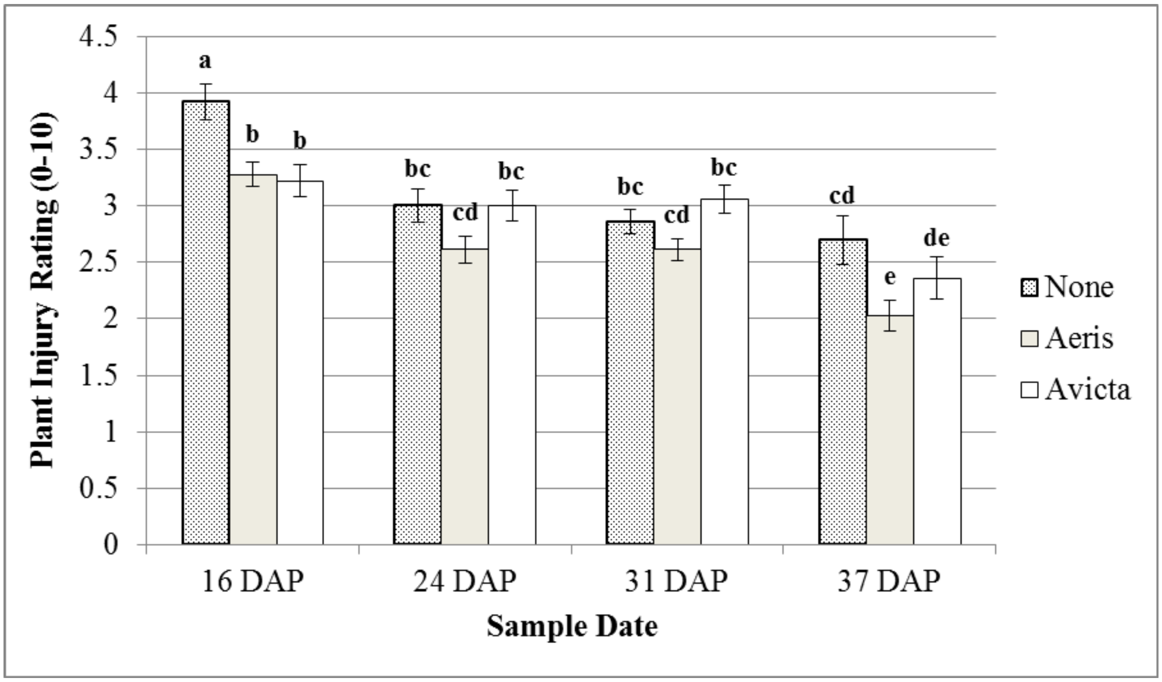


Figure 1.12. Effect of sample date and seed treatment on ratings of injury to cotton plants by thrips in plots near Blackville, SC, 2011. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P>0.05, LSD. DAP, days after plant.

Discussion

In this study, soil texture was strongly correlated with soil EC. Soils with low, medium, or high EC management zones had sandy, silt, or clay textures, respectively. These results reaffirmed that using zone definition by soil EC provides distinct areas for applying differential control tactics for thrips control. Soil texture had significant effects on population densities of thrips in this study. However, densities of thrips were inconsistent within management zones. Other environmental factors, such as soil properties (e.g., water content, pH, salinity, etc.) may influence spatial variability of population densities of thrips within cotton production fields.

In this study, population densities of thrips were moderate to light. Densities of adult thrips were high during the first few sample dates as overwintered, adult thrips moved into cotton fields from surrounding wild and cultivated vegetation (Davidson and Lyon 1987; Layton and Reed 2002; Greene et al. 2007, 2008, 2009; Roberts et al. 2009; Cook et al. 2011). Population densities of adult thrips then decreased as adult thrips left cotton fields to obtain nourishment from other sources, which can assist in their reproduction (Layton and Reed 2002). Because adult thrips leave cotton fields, most of the damage done to seedling cotton is caused by the feeding of immature thrips (Layton and Reed 2002). As population densities of adult thrips decreased, population densities of immature thrips increased in this study. Injury ratings to cotton seedling were highest when the population density of immature thrips peaked. Injury ratings decreased over time because the plant becomes less susceptible as the rate of growth increases after three or four true leaves develop (Davidson and Lyon 1987; Layton and Reed 2002; Greene et al. 2007, 2008, 2009; Roberts et al. 2009; Cook et al. 2011).

Plots with aldicarb had the lowest densities of adult and immature thrips and associated injury to cotton plants across all sample dates and management zones. In this study, 0.51 kg/ha of aldicarb provided the same amount of protection against thrips as 0.86 kg/ha of aldicarb. Similar results were found in a study by Vandiver et al. (2009). Control of thrips and associated injury to cotton seedlings was achieved for up to five weeks after planting with aldicarb. Both seed treatments provided control and suppression of thrips and lowered associated injury to cotton seedling compared with the untreated control ultimately increasing yields. While both seed treatments also provided up to five weeks of control of thrips and associated injury after planting, neither seed treatment achieved the level of protection of aldicarb as shown by Brown et al. (2008) in Georgia and Greene et al. (2008) in South Carolina. The addition of aldicarb to both seed treatments increased protection against thrips. These results are similar to studies completed by Kemerait et al. in Georgia (2004) and Greene et al. (2007, 2008, 2009) in South Carolina.

CHAPTER TWO

EFFICACY OF PRECISION-APPLIED IN-FURROW INSECTICIDE/NEMATICIDE AND SEED TREATMENTS ON POPULATIONS OF NEMATODES IN COTTON

Introduction

Nematodes can cause significant yield losses in cotton either alone or in combination with soil-borne diseases or early-season insect pests, such as thrips (Burris et al. 2008). Plant-parasitic nematodes are equipped with a stylet, a needle-like structure located at the top of the head that is inserted into a host cell to obtain nourishment by sucking out the contents of the cell (Veech 1990). Among nematodes, Southern root-knot nematode, *Meloidogyne incognita*, the Columbia lance nematode, *Hoplolaimus columbus*, and the reniform nematode, *Rotylenchulus reniformis*, cause the most damage to the southeastern US cotton crop (Veech 1990; Mai et al. 1996). Columbia lance nematodes are migratory, endo/ecto-parasites that are very damaging to the root system. Symptoms of Columbia lance nematode infections include stunting and excessive branching of the tap-root system. Symptoms of root-knot nematode infections include stunting of the cotton plant and the presence of galls on the root systems. Mature female root-knot nematodes are sedentary endo-parasites which can establish permanent feeding sites via the formation of giant cells resulting in root galling. Mature reniform nematodes are semi-endo parasitic and establish permanent feeding sites via the formation of syncytia. Plant-parasitic nematodes are obligate parasites and typically do not kill their host plants (Veech 1990).

Because resistant cotton cultivars are not abundantly available, control of nematodes relies on crop rotation or nematicide applications (Khalilian et al. 2001, 2002; Koenning and Bowman 2005). Peanut is an economically important rotation crop for control of *M. incognita* and *H. columbus* because it is not a host for these two species (Khalilian et al. 2002; Koenning and Bowman 2005; Mueller 2011). Nematicides used for control are applied in-furrow at-planting as granular or liquid, as a pre-plant in-furrow fumigant, or as a seed-treatment (Burris et al. 2008). In-furrow nematicides have been used for over forty years and are very effective at controlling nematodes. Seed treatments have recently become available for the control of nematodes (Mueller 2011).

Conventional control and suppression of nematodes has involved the application of nematicides at a single rate over an entire field (Wrather et al. 2002; Overstreet et al. 2009). Excessive inputs are wasted when nematicides are applied at one rate over an entire field (Wrather et al. 2002). Technologies, such as mapping of soil texture within fields by using soil electrical conductivity (EC), are available that allow various inputs to be site-specific (Corwin and Lesch 2003b; Sullivan et al. 2004; Overstreet et al. 2009). Soil EC correlates highly to soil properties including texture, salinity, drainage, and organic matter levels (Corwin and Lesch 2003; Sullivan et al. 2004). Soils with low, medium, or high EC values have sandy, silt, or clay textures, respectively (Khalilian et al. 2001, 2002; Sullivan et al. 2004). Studies have shown that nematodes are significantly affected by soil type and texture and do not have uniform distributions in fields (Khalilian et al. 2001, 2002; Wrather 2002). Root-knot nematode (SRK) and Columbia Lance nematode (CLN) reproduce better in soil with coarse texture than in soil with fine texture and are associated with sandy soils (Fassuliotis 1975; Khalilian et al. 2001; Koenning and Bowman 2005). Management zones, areas within a fields that respond to management practices in a similar way (Fridgen et al. 2000), for control of nematodes reduce economic inputs (nematicide rates) and environmental hazards while increasing yields (Khalilian et al. 2002; Lohmeyer et al. 2003). Site-specific application of aldicarb has shown potential in controlling nematodes in cotton (Wrather et al. 2002). The interactions of seed treatments, at-planting use of aldicarb and use of management zones have yet to be reported for nematode control on cotton. The objectives of this study were to determine the effects of precision-applied, in-furrow insecticide/nematicide (Temik 15G) and seed treatments (Aeris and Avicta Complete Pak) on populations of thrips in management zones defined by soil texture as measured by electrical conductivity; and to examine the economic benefit or detriment of each management technique for nematodes either alone or in combination with other tactics.

Materials and Methods

Research plots, located in fields with variable soil types at the Clemson University Edisto Research and Education Center near Blackville, SC, were mapped for soil texture using a soil electrical conductivity (EC) meter (Veris 3100) to define management zones within the fields. Management zones were delineated based on ranges of the difference between shallow and deep EC measurements. Low, medium, and high EC zones were determined by large, medium, and small differences between shallow and deep EC measurements, respectively. Soil texture analysis (% sand, silt, and clay) was completed by placing a stainless steel, conical probe 20.3-cm deep into the furrow of the middle two rows five or six times until the probe was full the last week of July in 2010 and 28 October 2011 (Johnson et al. 2003). Research plots were arranged in a three-way factorial design, with management zone (low EC, medium EC, or high EC), seed treatment (Aeris® [thiodicarb at 0.375 mg of active ingredient per seed], Avicta Complete Pak® [abamectin at 0.15 mg of active ingredient per seed], or no seed treatment), and rate of at-planting use of Temik® 15G (aldicarb at 0, 0.51, or 0.86 kg/ha of active ingredient) as factors. Seed treatments also contained insecticides and fungicides. Plots were eight rows by 12.2-meters with 96.5-cm centers. Each treatment was replicated four times. A Bollgard® 2, Roundup Ready Flex® cotton cultivar (DP 161 B2RF) from one seed lot was treated with both Aeris and Avicta Complete Pak seed treatments. Research plots were planted on 6 May 2010 and 3 May 2011.

Nematode samples were taken from each plot near planting (11 May 2010 and 12 May 2011), approximately seven-weeks-after planting (6 July 2010 and 23 June 2011), and at harvest (30 September 2010 and 28 October 2011) to determine the density of each nematode species and potential effects of nematodes on plant growth and vigor. These samples were taken from soil cores obtained by placing a conical, stainless steel probe 20.3-cm deep into the furrow of the middle two rows of each plot five or six times until the probe was full. Nematode samples were extracted by a differential sieving and centrifugal flotation technique (Jenkins 1964). For this technique, 100 cm^3 of soil from each plot were placed in a large beaker and water added until the beaker was about 75% full. The soil was stirred by hand to allow the nematodes to separate from the soil. Once the water in the beaker stopped swirling, the water was passed through two sieves (# 20 and 400). The soil and nematodes caught on the bottom sieve were rinsed into centrifuge tubes and centrifuged for five minutes. Water was decanted off and replaced with a sugar solution and centrifuged for an additional minute. The solution was placed through a # 400 sieve to capture nematodes. The sugar solution was washed off the nematodes, and the nematodes were then rinsed into vials for storage. Nematodes were identified to genus and counted (Jenkins 1964).

Nematode gall ratings were taken approximately seven-to-eight-weeks-after planting (30 June 2010 and 23 June 2011). Gall ratings were taken by excavating the root systems of ten random plants from each plot from rows one and seven. Galls were rated on a scale from zero to five, where “0” described no galls, and “5” described severe galling on the entire root system (Caldwell et al. 2003). These roots were cut into 2-cm pieces and placed into cups for measurement of fresh weight. Cups filled with root pieces were placed into a mist chamber for approximately five days, and then placed into a drying oven for seventy-two hours for measurement of dry weight (Vrain 1977). Nematodes recovered from the mist chamber were identified to genus and counted.

Nematode counts (log [x + 1]) and gall ratings (arcsine [square root(x / 5)]) were transformed prior to ANOVA. Nematodes recovered from soil were subjected to a repeated measures ANOVA (PROC MIXED, SAS Institute 2010) with sampling date, management zone (i.e., EC level), aldicarb rate, and seed treatment as fixed effects and replication as a random effect. Gall ratings and nematodes recovered from a mist chamber were subjected to a three-way ANOVA (PROC MIXED, SAS Institute 2010) with soil texture, aldicarb rate, and seed treatment as fixed effects and replication as a random effect. Treatment means were separated using Least Significant Difference (LSD) (SAS Institute 2010). A simple correlation associated soil texture (percentages of sand, silt, clay) with soil EC (PROC CORR, SAS Institute 2010).

Results

EREC 2010:

Soil EC was negatively correlated with percentage of sand (r = -0.81, $P < 0.0001$) and positively correlated with percentage of silt (r = 0.31, $P = 0.0009$) and percentage of clay (r = 0.76, $P < 0.0001$).

Population densities of CLN and SRK nematodes recovered from soil were significantly the highest at-harvest (CLN = 31.70 ± 4.93 a, SRK = 95.46 ± 10.82 a) compared with at-planting (CLN = 3.01 ± 0.42 c, SRK = 1.47 ± 0.32 b) and mid-season (CLN = 9.82 ± 1.34 b, SRK = 0.74 ± 0.43 b). There were significantly lower population densities of CLN and SRK nematodes recovered from soil in high EC management zones (CLN = 2.76 ± 0.74 b, SRK = 13.84 ± 3.47 b) compared with medium (CLN = 15.25 ± 2.81 a, SRK = 44.67 ± 9.21 a) and low (CLN = 26.52 ± 4.44 a, SRK = 39.52 ± 8.49 a) EC zones. Population densities of CLN recovered from soil were significantly higher in medium and low EC management zones mid-season and at-harvest compared with high EC zones (Figure 2.1). Population densities of SRK nematodes recovered from soil were significantly highest in medium and low EC management zones at-harvest compared with high EC zones (Figure 2.1).

Population densities of CLN from mist chamber recovery were significantly higher in low EC management zones (5.03 ± 6.26 a) compared with high EC zones (2.25 ± 3.11 b). Treatments with either 0.51 (22.69 ± 53.21 b) or 0.86 (27.47 ± 47.02 b) kg/ha of aldicarb had significantly lower population densities of SRK nematodes from mist chamber recovery than the untreated control (65.11 ± 95.41 a). Treatments with Aeris (2.94 ± 6.31 b) had significantly lower population densities of CLN from mist chamber recovery than Avicta (4.86 ± 8.48 a) and the untreated control (4.47 ± 4.88 a). In low EC management zones, higher population densities of CLN from mist chamber recovery were in treatments with 0.86 kg/ha of aldicarb compared with 0.51 kg/ha of aldicarb (Figure 2.2).

Gall ratings of cotton root systems were significantly higher in medium EC management zones (0.37 ± 0.31 a) compared with high (0.23 ± 0.17 b) and low (0.20 ± 0.22 b) EC zones. Gall ratings of cotton root systems were significantly lower in treatments with 0.51 kg/ha of aldicarb (0.19 ± 0.19 b) compared with the untreated control (0.34 ± 0.29 a), but not 0.86 kg/ha of aldicarb (0.27 ± 0.23 ab).

<u>EREC 2011</u>:

Soil EC was negatively correlated with percentage of sand (r = -0.26, P = 0.0058) and positively correlated with percentage of silt (r = 0.05, P = 0.6338) and percentage of clay (r = 0.24, P = 0.0116).

Population densities of CLN recovered from soil were significantly lower mid-season (2.16 ± 0.58 b) compared with at-planting (6.88 ± 1.55 a), but not at-harvest (7.32 ± 1.78 ab). Population densities of SRK nematodes were significantly higher at-harvest (38.79 ± 9.39 a) compared with at-planting (7.51 ± 1.46 b) and mid-season (14.18 ± 3.96 b). Population densities of CLN recovered from soil were significantly higher in low EC management zones (8.59 ± 1.64 a) compared with high (2.80 ± 1.07 b) and medium (4.97 ± 1.45 b) EC zones. Population densities of CLN recovered from soil were significantly higher in low EC management zones compared with medium and high EC zones at-planting (Figure 2.3). Population densities of SRK nematodes recovered from soil were significantly higher at-harvest in high EC management zones in treatments with Aeris in common (Figure 2.4).

Treatments with Aeris in common (1.67 ± 2.87 b) had significantly lower population densities of SRK nematodes from mist chamber recovery than Avicta (2.81 ± 4.03 a), but not the untreated control (1.89 ± 1.60 ab). Gall ratings of cotton root systems were significantly lower in treatments with a seed treatment in high EC management zones and highest in treatments with a seed treatment in medium EC management zones (Figure 2.5).

Table 2.1. Statistical comparison of population densities of Columbia lance and root-knot nematodes recovered from soil (100 cm^3) in plots of cotton near Blackville, SC, 2010.

Management factor combination	Population Densities of Columbia Lance Nematodes			Population Densities of Root-knot Nematodes		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 240	38.75	**<0.0001**	2, 240	11.48	**<0.0001**
Aldicarb rate	2, 240	0.28	0.7567	2, 240	0.09	0.9096
Seed treatment	2, 240	1.25	0.2897	2, 240	0.56	0.5721
Sample date	2, 240	35.99	**<0.0001**	2, 240	185.34	**<0.0001**
Soil texture × aldicarb rate	4, 240	1.11	0.3542	4, 240	0.63	0.6413
Soil texture × seed treatment	4, 240	0.40	0.8053	4, 240	0.36	0.8382
Aldicarb rate × seed treatment	4, 240	0.20	0.9367	4, 240	0.38	0.8247
Sample date × soil texture	4, 240	5.39	**0.0004**	4, 240	5.06	**0.0006**
Sample date × aldicarb rate	4, 240	0.19	0.9441	4, 240	0.07	0.9907
Sample date × seed treatment	4, 240	2.29	0.0603	4, 240	0.54	0.7064
Soil texture × aldicarb rate × seed treatment	8, 240	0.89	0.5250	8, 240	0.22	0.9866
Sample date × soil texture × aldicarb rate	8, 240	0.75	0.6487	8, 240	0.75	0.6462
Sample date × soil texture × seed treatment	8, 240	1.83	0.0720	8, 240	0.73	0.6682
Sample date × aldicarb rate × seed treatment	8, 240	1.11	0.3539	8, 240	0.40	0.9187
Sample date × soil texture × aldicarb rate × seed treatment	16, 240	1.22	0.2520	16, 240	0.53	0.9280

Table 2.2. Statistical comparisons of population densities of Columbia lance and root-knot nematodes recovered using a mist chamber and ratings of galling to root systems in cotton plots near Blackville, SC, 2010.

Management factor combination	Population Densities of Columbia Lance Nematodes			Population Densities of Root-knot Nematodes			Ratings of Galling to Cotton Root Systems		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 78	4.78	**0.0110**	2, 78	1.12	0.3300	2, 78	6.03	**0.0037**
Aldicarb rate	2, 78	0.41	0.6674	2, 78	7.63	**0.0009**	2, 78	3.78	**0.0272**
Seed treatment	2, 78	4.42	**0.0153**	2, 78	1.53	0.2235	2, 78	0.93	0.4008
Soil texture × aldicarb rate	4, 78	3.29	**0.0153**	4, 78	0.79	0.5382	4, 78	1.14	0.3433
Soil texture × seed treatment	4, 78	0.24	0.9135	4, 78	0.71	0.5862	4, 78	0.60	0.6632
Aldicarb rate × seed treatment	4, 78	0.34	0.8468	4, 78	0.94	0.4459	4, 78	1.18	0.3251
Soil texture × aldicarb rate × seed treatment	8, 78	1.25	0.2833	8, 78	0.68	0.7076	8, 78	0.64	0.7448

Table 2.3. Statistical comparison of population densities of Columbia lance and root-knot nematodes recovered from soil (100 cm^3) in plots of cotton near Blackville, SC, 2011.

Management factor combination	Population Densities of Columbia Lance Nematodes			Population Densities of Root-knot Nematodes		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 240	9.02	**0.0002**	2, 240	0.14	0.8733
Aldicarb rate	2, 240	1.22	0.2969	2, 240	0.22	0.8020
Seed treatment	2, 240	0..01	0.9855	2, 240	1.55	0.2142
Sample date	2, 240	3.74	**0.0250**	2, 240	14.86	**<0.0001**
Soil texture × aldicarb rate	4, 240	0.70	0.5967	4, 240	0.60	0.6612
Soil texture × seed treatment	4, 240	0.77	0.5446	4, 240	0.75	0.5575
Aldicarb rate × seed treatment	4, 240	1.98	0.0990	4, 240	0.98	0.4198
Sample date × soil texture	4, 240	3.54	**0.0080**	4, 240	1.24	0.2927
Sample date × aldicarb rate	4, 240	0.46	0.7639	4, 240	0.31	0.8698
Sample date × seed treatment	4, 240	1.99	0.0965	4, 240	0.60	0.6610
Soil texture × aldicarb rate × seed treatment	8, 240	0.77	0.6332	8, 240	1.04	0.4079
Sample date × soil texture × aldicarb rate	8, 240	0.13	0.9980	8, 240	0.61	0.7684
Sample date × soil texture × seed treatment	8, 240	1.19	0.3053	8, 240	2.64	**0.0087**
Sample date × aldicarb rate × seed treatment	8, 240	0.51	0.8464	8, 240	0.53	0.8331
Sample date × soil texture × aldicarb rate × seed treatment	16, 240	1.44	0.1256	16, 240	2.01	**0.0135**

Table 2.4. Statistical comparisons of population densities of Columbia lance and root-knot nematodes recovered using a mist chamber and ratings of galling to root systems in cotton plots near Blackville, SC, 2011.

Management factor combination	Population Densities of Columbia Lance Nematodes			Population Densities of Root-knot Nematodes			Ratings of Galling to Cotton Root Systems		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 78	2.00	0.1422	2, 78	0.76	0.4702	2, 78	0.02	0.9828
Aldicarb rate	2, 78	0.50	0.6085	2, 78	0.19	0.8273	2, 78	0.67	0.5165
Seed treatment	2, 78	0.50	0.6085	2, 78	3.17	**0.0475**	2, 78	1.63	0.2033
Soil texture × aldicarb rate	4, 78	0.50	0.7358	4, 78	0.95	0.4396	4, 78	0.80	0.5316
Soil texture × seed treatment	4, 78	0.50	0.7358	4, 78	1.39	0.2451	4, 78	5.88	**0.0003**
Aldicarb rate × seed treatment	4, 78	1.25	0.2969	4, 78	1.34	0.2628	4, 78	0.63	0.6393
Soil texture × aldicarb rate × seed treatment	8, 78	1.25	0.2820	8, 78	0.97	0.4679	8, 78	0.77	0.6259

A

B

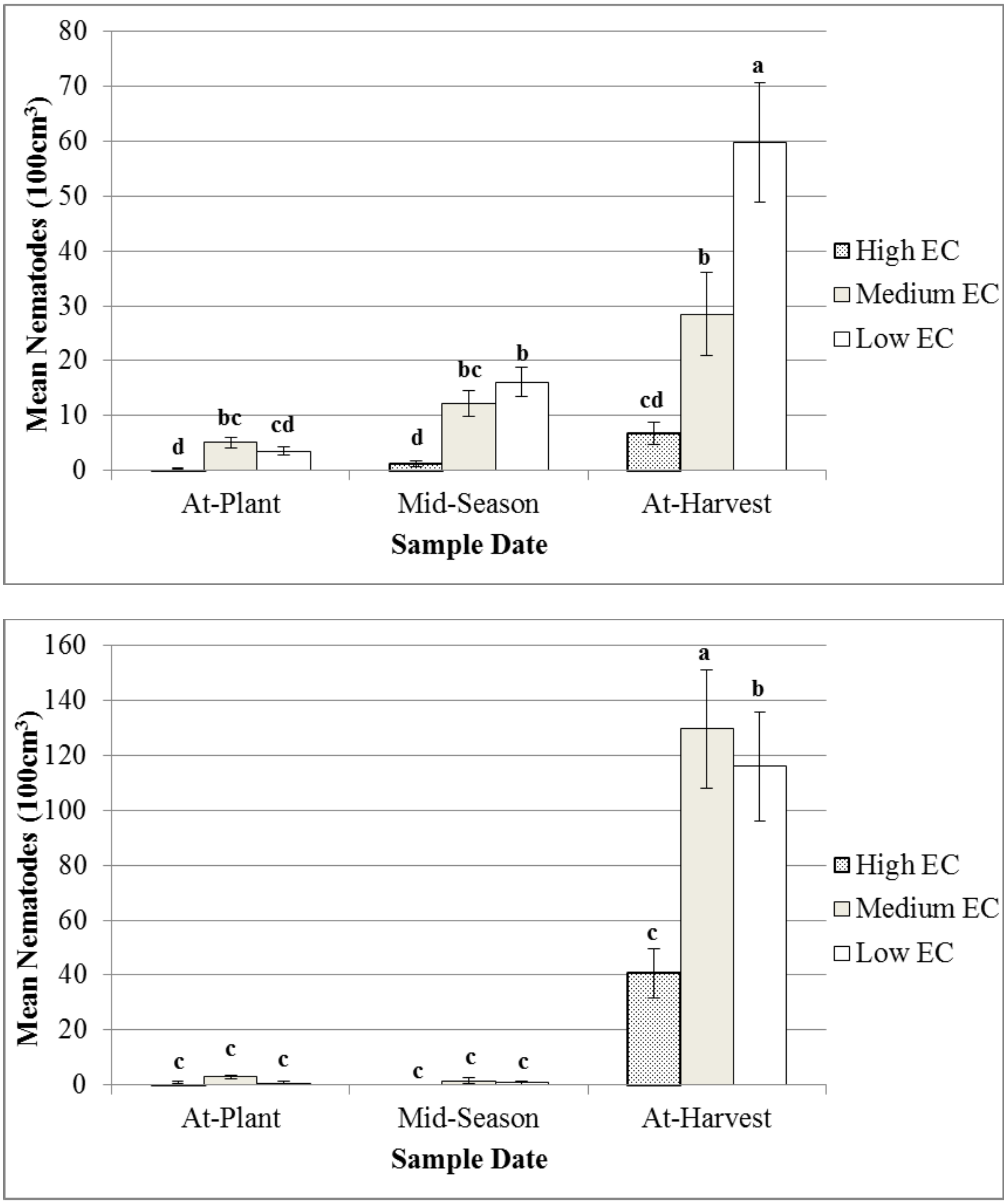


Figure 2.1. Effect of sample date and soil texture on mean population densities of (A) Columbia lance and (B) root-knot nematodes recovered from soil (100 cm^3) in cotton plots near Blackville, SC, 2010. Bars with a letter in common are not significantly different, P>0.05, LSD. EC, electrical conductivity.

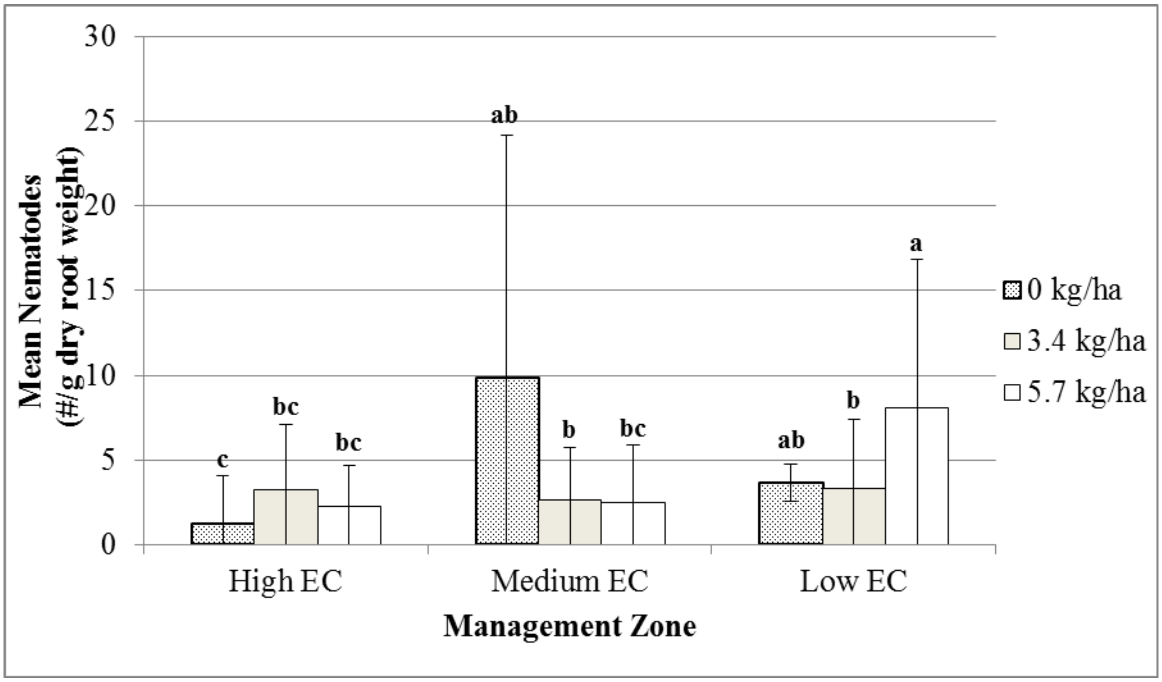


Figure 2.2. Effect of soil texture and aldicarb rate on mist chamber recovery of Columbia lance nematodes from field zones defined by electrical conductivity of soil from cotton plots near Blackville, SC, 2010. Bars with a letter in common are not significantly different, $P > 0.05$, LSD. EC, electrical conductivity.

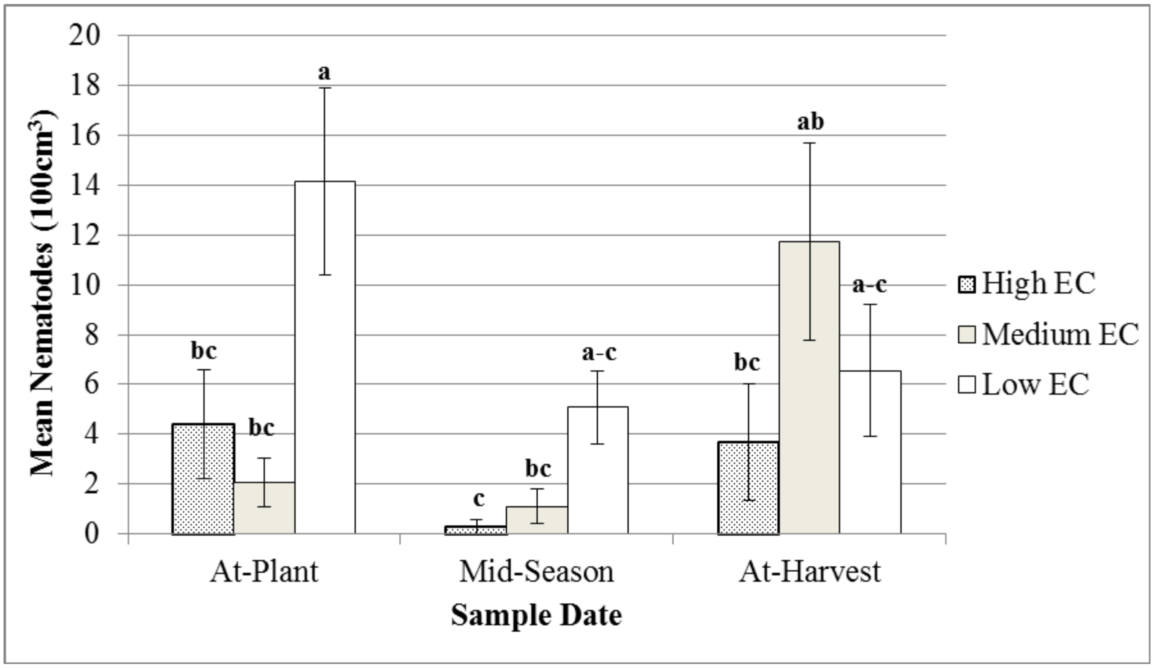


Figure 2.3. Effect of sample date and soil texture on mean population densities of Columbia lance nematodes recovered from soil (100 cm^3) in cotton plots near Blackville, SC, 2011. Bars with a letter in common are not significantly different, P>0.05, LSD. EC, electrical conductivity.

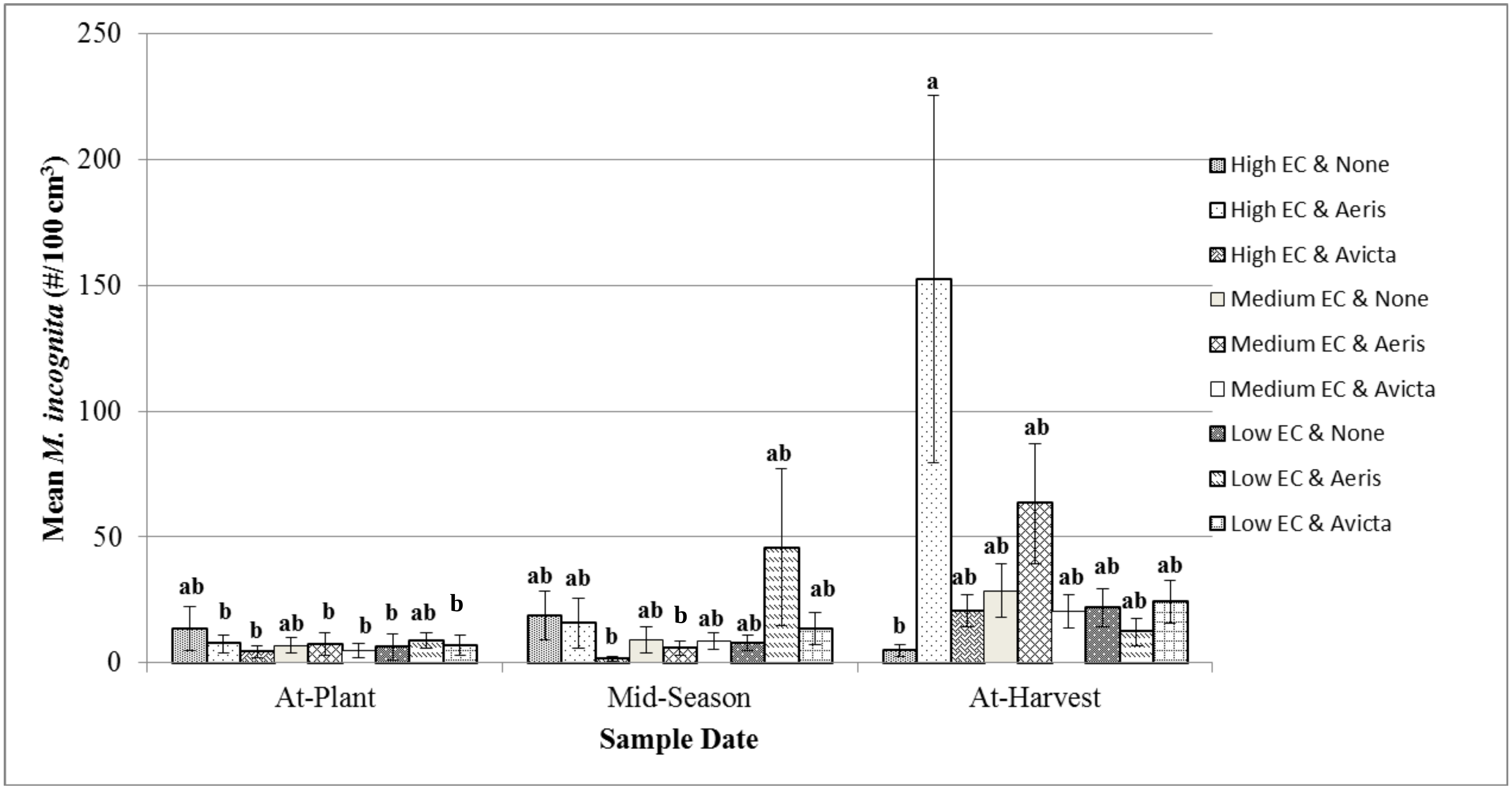


Figure 2.4. Effect of seed treatment, soil texture, and sample date on mean population densities of southern root-knot nematodes from plots in zones defined by electrical conductivity of soil (100 cm^3) in cotton near Blackville, SC, 2011. Bars with a letter in common are not significantly different, P > 0.05, LSD.

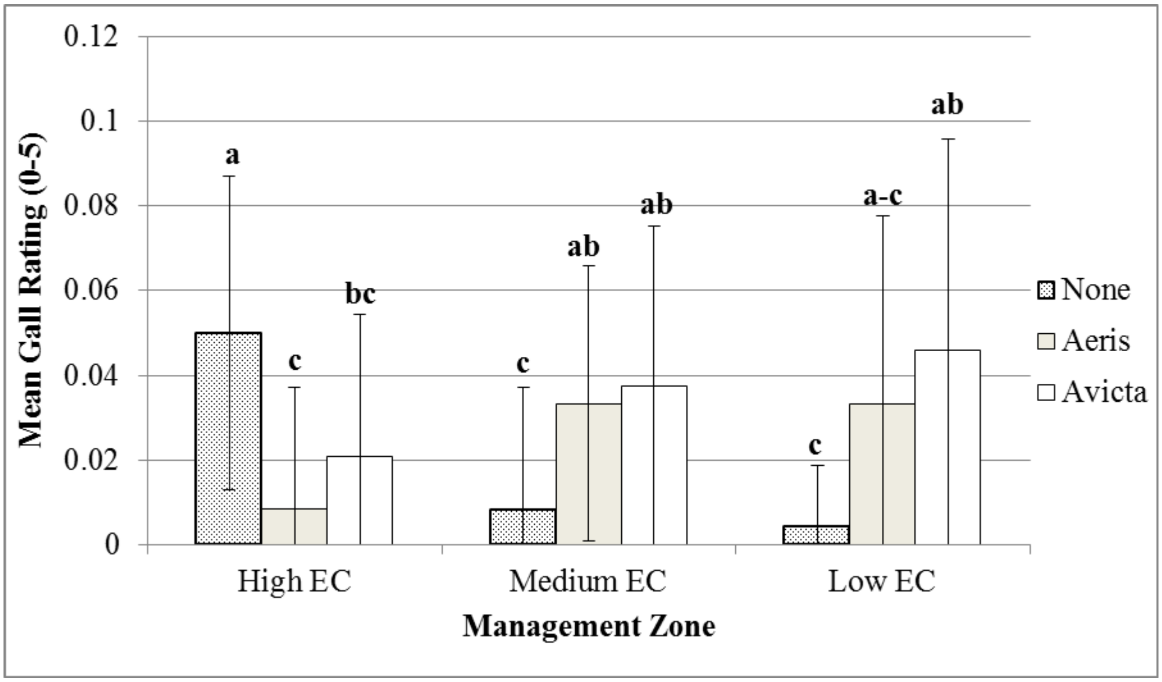


Figure 2.5. Effect of soil texture and seed treatment on ratings of galling to root systems in plots near Blackville, SC, 2011. 0, no galls; 5, severe galling. Bars with a letter in common across management zones are not significantly different, P > 0.05, LSD. EC, electrical conductivity.

Discussion

Population densities of Columbia lance and root-knot nematodes were higher at-harvest than at-planting and mid-season in 2010 (Figure 2.1). Seed treatments and aldicarb have been shown to control and suppress nematodes for three-to-six-weeks-after planting (Layton and Reed 2002). Increases in population densities of nematodes after mid-season indicate that aldicarb and seed treatments did not control and suppress nematode populations from seven weeks after planting to harvest.

An increase in population densities of nematodes as soil EC decreased showed that nematodes do not have a uniform distribution in fields. Other studies have also shown that nematodes are significantly affected by soil type and texture and do not have a uniform distribution in fields (Khalilian et al. 2001, 2002; Wrather 2002). Columbia lance and root-knot nematodes reproduce better in soil with coarse texture associated with sandy soils (Fassuliotis 1975; Khalilian et al. 2011; Koenning and Bowman 2005).

Aldicarb was common in treatments with the lowest population densities of nematodes and the lowest gall ratings across all management zones. There were no differences between the efficacy of 0.51 kg/ha of aldicarb and 0.86 kg/ha of aldicarb. Results from a study completed by Kemerait et al. (2004) indicated that suppression and control of nematodes requires at least 0.86 kg/ha.

Neither seed treatment provided better suppression and control of nematodes than the untreated control. However, Aeris provided more control of nematodes than Avicta. Results from numerous efficacy trials of both seed treatments have shown that neither seed treatment is as effective at controlling populations of nematodes as aldicarb (Brown et al. 2008; Greene et al. 2008). Some studies have shown that the addition of aldicarb to these seed treatments increased control of nematodes (Kemerait et al. 2004; Greene et al. 2007, 2008, 2009). However, the addition of aldicarb to these seed treatments did not provide significant suppression and control of nematodes.

CHAPTER THREE

EFFICACY OF PRECISION-APPLIED IN-FURROW INSECTICIDE/NEMATICIDE AND SEED TREATMENTS ON COTTON PLANT VIGOR AND YIELD

Introduction

Thrips and nematodes can be serious early-season pests of cotton grown on the highly variable soil types common in the southeastern United States. Thrips feed on the terminal of seedling cotton, which negatively effects growth and maturity. Negative effects include excessive vegetative growth, yellowing and silvering of leaves, stunting, and stand loss, and yield reduction (Davidson and Lyon 1987; Layton and Reed 2002; Greene et al. 2007, 2008, 2009; Roberts et al. 2009; Cook et al. 2011). Thrips puncture leaf cells with their piercing-sucking mouthparts and feed on the meristematic tissue (terminal) of the cotton plant which contains tissues that develop into true leaves. Cotton seedlings are particularly susceptible to thrips injury when thrips feed on the terminal because the crop develops slowly during the first seven to ten days after emergence. The rate of plant growth increases after three to four true leaves have developed, resulting in reduced susceptibility to thrips injury.

Thrips have the potential to reduce yields by about 114 kg of lint per hectare (100 lb of lint per acre) (Layton and Reed 2002). In the United States, yield losses due to thrips in 2008, 2009, and 2010 were 16,481 metric tons (50,465 bales), 45,136 metric tons (138,207 bales), and 15,011 metric tons (45,964 bales), respectively (Williams 2009, 2010, 2011). South Carolina had yield reductions of 0.5% in response to thrips damage during 2008 and 2010, with 379 and 512 metric tons (1,740 and 2,350 bales) lost, respectively (Williams 2009, 2011). In the United States, control costs for the management of thrips in 2008, 2009, and 2010 were $4.64, $3.56, and $5.73 per hectare, respectively (Williams 2009, 2010, 2011).

Nematodes can cause significant yield losses in cotton either alone or in combination with soil-borne diseases or early-season pests, such as thrips (Burris et al. 2008). Fifty percent of cotton fields in South Carolina are infested with plant-parasitic nematodes. In 2010, plant-parasitic nematodes caused a yield reduction of 8.5% in South Carolina, resulting in a loss of $4.4 million (Mueller 2011).

Plant parasitic nematodes are equipped with a stylet, a needle-like structure located at the top of the head, that is inserted into a host cell to obtain nourishment by sucking out the contents. In addition to nematode densities, factors such as soil texture, nutrient availability, and pH affect potential damage to the cotton plant and yield (Khalilian et al. 2001, 2002; Overstreet et al. 2008). Soil type has a significant effect on population density of nematodes. It has been shown that the greatest yield losses caused by nematodes in cotton occur in coarse textured, sandy soil. This is due to nematodes being more common in areas of a field with coarse-textured soils (Sullivan et al.2004; Overstreet et al. 2009) and that coarse textured soils do not retain moisture as well as finer textured soils or soil with higher clay, silt, and organic matter contents. Therefore, plants grown in coarse-textured soils are under more moisture and nutrient stress before they become infected with nematodes.

Conventional control and suppression of thrips and nematodes has involved the application of insecticides and nematicides at a single rate over an entire field (Wrather et al. 2002; Overstreet et al. 2009), leading to the use of excessive inputs (Wrather et al 2002). Technologies are available that allow various inputs to be site-specific, such as mapping of soil texture within fields by using soil electrical conductivity (EC) (Corwin and Lesch 2033b). Soil EC is a measurement that correlates with soil properties that affect crop productivity. These properties include texture, salinity, drainage conditions, and organic matter levels (Corwin and Lesch 2003a; Sullivan et al. 2004). Soils with low, medium, or high EC values have sandy, silt, or clay textures respectively (Khalilian et al. 2001, 2002; Sullivan et al. 2004). Management zones, areas within a field that respond to management practices in a similar way (Fridgen et al. 2000), for control of thrips and nematodes reduce economic inputs (insecticide/nematicide rates) and environmental hazards while increasing yields (Khalilian et al. 2002; Lohmeyer et al. 2003). The interactions of seed treatments, at-planting use of aldicarb and use of management zones have yet to be reported for thrips and nematode control on cotton. The objectives of this study were to determine the effects of precision-applied, in-furrow insecticide/nematicide (Temik 15G) and seed treatments (Aeris and Avicta Complete Pak) on populations of thrips and nematodes in management zones defined by soil texture as measured by electrical conductivity; and to examine the economic benefit or detriment of each management technique for thrips and nematodes alone or in combination with other tactics.

Materials and Methods

Research plots, located in fields with variable soil types at the Clemson University Edisto Research and Education Center near Blackville, SC, were mapped for soil texture using a soil electrical conductivity (EC) meter (Veris 3100) to define management zones within the fields. Management zones were delineated based on ranges of the difference between shallow and deep EC measurements. Low, medium, and high EC zones were determined by large, medium, and small differences between shallow and deep EC measurements, respectively. Soil texture analysis (% sand, silt, and clay) was completed by placing a stainless steel, conical probe 20.3-cm deep into the furrow of the middle two rows five or six times until the probe was full the last week of July in 2010 and 28 October 2011 (Johnson et al. 2003). Research plots were arranged in a three-way factorial design, with management zone (low EC, medium EC, or high EC), seed treatment (Aeris® [imidacloprid at 0.375 mg and thiodicarb at 0.375 mg of active ingredient per seed], Avicta Complete Pak® [thiamethoxam at 0.34 mg and abamectin at 0.15 mg of active ingredient per seed], or no seed treatment), and rate of at-planting use of Temik® 15G (aldicarb at 0, 0.51, or 0.86 kg/ha of active ingredient) as factors. Seed treatments also contained fungicides. Plots were eight rows by 12.2-meters with 96.5-cm centers. Each treatment was replicated four times. A Bollgard® 2, Roundup Ready Flex® cotton cultivar (DP 161 B2RF) from one seed lot was treated with both Aeris and Avicta Complete Pak seed treatments. Research plots were planted on 6 May 2010 and 3 May 2011.

Nodes above white flower (NAWF) counts, stand counts, plant heights, and fresh and dry weights of the shoot systems were measured to determine plant vigor and maturity. The number of nodes above the highest first position white flower for five plants per plot was counted to determine NAWF counts. Stand counts were taken by randomly placing a stick that was 0.91 m (one yard) in length on the ground four separate times in the middle two rows of each plot. Plant heights were measured from the base to the terminal of five plants per plot. Five plants per plot were clipped at the base of the stem to determine fresh weights of shoots. Dry weight was also determined after placing plants into a drying oven for seventy-two hours. Yields were determined by machine-harvesting the four center rows of each plot.

Nodes above white flower counts were taken on the following dates: 16 and 28 July 2010; 5 August 2010; 7 and 25 July 2011. Stand counts were taken on 28 May 2010, 10 June 2010, and 1 June 2011. Plant heights were taken on 10 June 2010, 1, 13, and 20 June 2011. Plant weights were taken on 23 June 2010 and 15 June 2011. The middle four rows from each plot were harvested on 12 October 2010 and 24 October 2011.

Nodes above white flower counts and stand counts were transformed (log [x+1]) prior to ANOVA. Node above white flower counts, stand counts, fresh weight, dry weight, and plant height were subjected to a repeated measures ANOVA (PROC MIXED, SAS Institute 2010) with soil texture, aldicarb rate, seed treatment, and sampling date as fixed effects and replication as a random effect. Yields were subject to a three-way ANOVA (PROC MIXED, SAS Institute 2010) with soil texture, aldicarb rate, and seed treatment as fixed effects and replication as a random effect. Treatment means were separated using Least Significant Difference (LSD) (SAS Institute 2010). A simple correlation associated soil texture (percentages of sand, silt, clay) with soil EC (PROC CORR, SAS Institute 2010).

Results

EREC 2010:

Soil EC was negatively correlated with percentage of sand (r = -0.81, P < 0.0001) and positively correlated with percentage of silt (r = 0.31, P = 0.0009) and percentage of clay (r = 0.76, P < 0.0001).

Node above white flower counts were significantly higher at 71 DAP (6.91 ± 0.10 a) than at 83 DAP (3.22 ± 0.08 b) and 91 DAP (3.30 ± 0.07 b). Node above white flower counts were significantly higher in high EC management zones (4.90 ± 0.20 a) compared with medium (4.43 ± 0.19 b) and low (4.10 ± 0.16 b) EC zones. Node above white flower counts were significantly higher in high (7.69 ± 0.11 a), medium (6.92 ± 0.11 ab), and low (6.13 ± 0.19 c) EC management zones at 71 DAP.

Stand counts were significantly higher at 68 DAP (5.88 ± 0.17 a) than at 86 DAP (6.79 ± 0.12 b). Stand counts were significantly lower in high EC management zones (5.18 ± 0.13 b) compared with medium (6.90 ± 0.20 a) and low (6.93 ± 0.15 a) EC zones. Stand counts were significantly higher in treatments with either Aeris (6.40 ± 0.18 a) or Avicta (6.83 ± 0.17 a) compared with the untreated control (5.77 ± 0.20 b). Across all plots, stand counts were significantly lower in high EC management zones at 68 (4.75 ± 0.19 d) and 86 (5.61 ± 0.15 c) DAP. Stand counts were significantly lower at 68 DAP in treatments with no seed treatment (5.02 ± 0.30 c).

Cotton plant heights were significantly higher in medium EC management zones (23.09 ± 1.23 a) compared with high (18.63 ± 0.44 b) and low (17.06 ± 0.85 b) EC zones. Based on the seed treatment and management zone interaction, cotton plant heights were significantly higher in treatments with Avicta (26.34 ± 1.78 bc) in medium EC management zones than the untreated control (18.82 ± 2.82 a). Cotton plant fresh and dry weights were significantly lower in low EC management zones (fresh weight = 292.16 ± 0.845 b, dry weight = 52.76 ± 0.19 b) compared with high (fresh weight = 433.91 ± 0.86 a, dry weight = 88.986003 ± 0.2821482 a) and medium (fresh weight = 515.02 ± 1.18 a, dry weight = 108.67 ± 0.32 a) EC zones.

Yields and returns were significantly the highest in high EC management zones (yield (kg/ha) 1808.04 ± 33.02 a, return (US $) 2144.03 ± 44.72 a) and then decreased with an increase in percent sand content (medium EC: yield (kg/ha) 1612.31 ± 47.09 b, return (US $) 1890.54 ± 62.91 b; Low EC: yield (kg/ha) 1137.67 ± 61.13 c, return (US $) 1380.69 ± 87.08 c).

EREC 2011:

Soil EC was negatively correlated with percentage of sand (r = -0.26, P = 0.0058) and positively correlated with percentage of silt (r = 0.05, P = 0.6338) and percentage of clay (r = 0.24, P = 0.0116).

Node above white flower counts were significantly higher at 65 DAP (5.79 ± 0.07 a) than at 83 DAP (4.17 ± 0.08 b). Node above white flower counts were lower in low EC management zones (4.67 ± 0.12 b) compared with high (5.07 ± 0.14 a) and medium (5.21 ± 0.13 a) EC zones. Based on the sample date and management zone interaction, NAWF were significantly higher at 65 DAP in high (6.10 ± 0.09 a), and medium (6.01 ± 0.11 a) EC management zones. Stand counts were significantly lower in high EC management zones (7.13 ± 0.14 b) compared with medium (8.07 ± 0.53 a) and low (7.89 ± 0.16 a) EC zones. Stand counts were significantly lower in the untreated control (7.17 ± 0.12 b) compared with treatments with Aeris (8.02 ± 0.53 a) or Avicta (7.90 ± 0.16 a) in common.

Cotton plant heights were significantly lower at 29 DAP (15.21 ± 0.38 c) and increased over time (41 DAP 31.92 ± 0.58 b; 48 DAP 44.04 ± 0.77 a). Cotton plant heights were significantly lower in high EC management zones (26.01 ± 1.07 b) compared with medium (32.28 ± 1.36 a) and low (32.88 ± 1.32 a) EC zones. Cotton plant heights were significantly higher in Avicta treated seeds (31.21 ± 1.32 a) compared with the untreated control (29.21 ± 1.22 b). Cotton plant heights were significantly higher in treatments with either 0.51 (31.38 ± 1.33 a) or 0.86 (31.81 ± 1.33 a) kg/ha of aldicarb compared with the untreated control (28.00 ± 1.17 b). Based on the sample date and management zone interaction, plant heights were significantly higher at 48 DAP in medium EC management zones (46.98 ± 1.38 a). Cotton plant heights were significantly higher in treatments with 0.86 kg/ha of aldicarb (34.08 ± 1.13 c) than the untreated control (29.62 ± 0.76 d) 41 DAP. Based on the aldicarb rate and sample date interaction, cotton plant heights were also higher in treatments with either 0.51 (46.20 ± 1.23 a) or 0.86 (45.41 ± 1.37 a) kg/ha of aldicarb than the untreated control (40.53 ± 1.22 b) at 48 DAP.

Cotton dry plant weights were significantly lower in high EC management zones (28.55 ± 1.33 c) and then increased as percent sand content increased (Medium EC 44.29 ± 2.73 b, Low EC 50.64 ± 2.32 a). Cotton dry plant weights were significantly higher with either 0.51 (43.73 ± 3.11 a) or 0.86 (44.59 ± 2.46 a) kg/ha of aldicarb compared with the untreated control (35.16 ± 2.18 b).

Yields and returns were significantly lower in high EC management zones (yield (kg/ha) 1540.27 ± 25.66 b, return (US $) 1210.51 ± 23.07 b) compared with medium (yield (kg/ha) 1772.38 ± 30.29 a, return (US $) 1394.88 ± 27.86 a) and low (yield 1835.21 ± 27.06 a, return (US $) 1445.95 ± 24.56 a) EC zones.

Table 3.1. Statistical comparison of nodes above white flower counts and stand counts in plots of cotton near Blackville, SC, 2010.

Management factor combination	Node Above White Flower Counts			Stand Counts		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 240	16.60	**<0.0001**	2, 159	32.00	**<0.0001**
Aldicarb rate	2, 240	0.13	0.8814	2, 159	1.08	0.3437
Seed treatment	2, 240	0.39	0.6793	2, 159	10.97	**<0.0001**
Sample date	2, 240	524.58	**<0.0001**	1, 159	49.38	**<0.0001**
Soil texture × aldicarb rate	4, 240	0.63	0.6411	4, 159	0.40	0.8100
Soil texture × seed treatment	4, 240	0.37	0.8267	4, 159	2.36	0.0560
Aldicarb rate × seed treatment	4, 240	1.54	0.1918	4, 159	0.87	0.4823
Sample date × soil texture	4, 240	2.32	0.0575	2, 159	3.64	**0.0286**
Sample date × aldicarb rate	4, 240	0.94	0.4395	2, 159	1.16	0.3169
Sample date × seed treatment	4, 240	1.52	0.1981	2, 159	7.77	**0.0006**
Soil texture × aldicarb rate × seed treatment	8, 240	0.94	0.4830	8, 159	1.20	0.3025
Sample date × soil texture × aldicarb rate	8, 240	0.94	0.4881	4, 159	1.04	0.3898
Sample date × soil texture × seed treatment	8, 240	0.74	0.6539	4, 159	4.04	**0.0038**
Sample date × aldicarb rate × seed treatment	8, 240	1.13	0.3444	4, 159	0.34	0.8537
Sample date × soil texture × aldicarb rate × seed treatment	16, 240	1.19	0.2795	8, 159	0.35	0.9439

Table 3.2. Statistical comparison of plant heights (cm) and fresh and dry weights (g) in cotton plots near Blackville, SC, 2010.

Management factor combination	Cotton Plant Heights			Cotton Plant Fresh Weights			Cotton Plant Dry Weights		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 78	12.54	**<0.0001**	2, 78	17.40	**<0.0001**	2, 78	15.92	**<0.0001**
Aldicarb rate	2, 78	1.67	0.1943	2, 78	2.00	0.1423	2, 78	0.79	0.4595
Seed treatment	2, 78	1.46	0.2377	2, 78	0.21	0.8079	2, 78	0.53	0.5920
Soil texture × aldicarb rate	4, 78	0.81	0.5247	4, 78	0.56	0.6912	2, 78	1.00	0.4126
Soil texture × seed treatment	4, 78	2.75	**0.0340**	4, 78	1.12	0.3532	4, 78	1.13	0.3490
Aldicarb rate × seed treatment	4, 78	0.15	0.9602	4, 78	0.65	0.6320	4, 78	1.35	0.2590
Soil texture × aldicarb rate × seed treatment	8, 78	0.81	0.5965	8, 78	1.79	0.0918	8, 78	2.41	**0.0221**

Table 3.3. Statistical comparison of yield (kg of lint per ha) and economic return (US $) of cotton in plots near Blackville, SC, 2010.

Management factor combination	Yield			Return		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 78	43.46	**<0.0001**	2, 78	33.06	**<0.0001**
Aldicarb rate	2, 78	0.75	0.4768	2, 78	0.19	0.8242
Seed treatment	2, 78	2.43	0.0945	2, 78	2.80	0.0671
Soil texture × aldicarb rate	4, 78	0.97	0.4304	4, 78	0.61	0.6545
Soil texture × seed treatment	4, 78	0.82	0.5176	4, 78	0.52	0.7230
Aldicarb rate × seed treatment	4, 78	0.96	0.4339	4, 78	0.73	0.5771
Soil texture × aldicarb rate × seed treatment	8, 78	2.06	0.0501	8, 78	1.81	0.0883

Table 3.4. Statistical comparison of nodes above white flower counts and plant heights (cm) of cotton in plots near Blackville, SC, 2011.

Management factor combination	Node Above White Flower Counts			Cotton Plant Heights		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 159	8.44	**0.0003**	2, 240	45.05	**<0.0001**
Aldicarb rate	2, 159	0.69	0.5025	2, 240	13.57	**<0.0001**
Seed treatment	2, 159	2.07	0.1291	2, 240	3.41	**0.0346**
Sample date	1, 159	269.83	**<0.0001**	2, 240	1153.27	**<0.0001**
Soil texture × aldicarb rate	4, 159	0.05	0.9947	4, 240	1.37	0.2461
Soil texture × seed treatment	4, 159	0.45	0.7721	4, 240	1.37	0.2447
Aldicarb rate × seed treatment	4, 159	0.22	0.9259	4, 240	0.27	0.8981
Sample date × soil texture	2, 159	4.75	**0.0100**	4, 240	5.68	**0.0002**
Sample date × aldicarb rate	2, 159	0.98	0.3791	4, 240	2.98	**0.0199**
Sample date × seed treatment	2, 159	0.78	0.4619	4, 240	1.90	0.1106
Soil texture × aldicarb rate × seed treatment	8, 159	1.26	0.2682	8, 240	0.34	0.9486
Sample date × soil texture × aldicarb rate	4, 159	0.92	0.4516	8, 240	0.30	0.9664
Sample date × soil texture × seed treatment	4, 159	0.83	0.5052	8, 240	1.36	0.2135
Sample date × aldicarb rate × seed treatment	4, 159	0.26	0.9020	8, 240	0.53	0.8321
Sample date × soil texture × aldicarb rate × seed treatment	8, 159	0.25	0.9815	16, 240	0.46	0.9618

Table 3.5. Statistical comparisons of stand counts and fresh and dry weights (g) of cotton in plots near Blackville, SC, 2011.

Management factor combination	Stand Counts			Cotton Plant Fresh Weights			Cotton Plant Dry Weights		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 78	4.63	**0.0126**	2, 78	0.45	0.6396	2, 78	31.64	**<0.0001**
Aldicarb rate	2, 78	1.23	0.2978	2, 78	0.60	0.5515	2, 78	6.65	**0.0022**
Seed treatment	2, 78	3.74	**0.0281**	2, 78	1.91	0.1553	2, 78	1.66	0.1963
Soil texture × aldicarb rate	4, 78	1.30	0.2759	4, 78	1.26	0.2945	4, 78	0.38	0.8188
Soil texture × seed treatment	4, 78	0.56	0.6928	4, 78	0.54	0.7070	4, 78	0.36	0.8385
Aldicarb rate × seed treatment	4, 78	0.57	0.6867	4, 78	0.52	0.7229	4, 78	0.35	0.8419
Soil texture × aldicarb rate × seed treatment	8, 78	1.39	0.2154	8, 78	1.23	0.2944	8, 78	0.75	0.6451

Table 3.6. Statistical comparison of yield (kg of lint per ha) and economic return (US $) of cotton in plots near Blackville, SC, 2011.

Management factor combination	Yield			Return		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 78	21.90	**<0.0001**	2, 78	21.77	**<0.0001**
Aldicarb rate	2, 78	0.02	0.9830	2, 78	0.09	0.9098
Seed treatment	2, 78	0.37	0.6944	2, 78	0.24	0.7879
Soil texture × aldicarb rate	4, 78	0.39	0.8140	4, 78	0.39	0.8185
Soil texture × seed treatment	4, 78	0.54	0.7074	4, 78	0.52	0.7230
Aldicarb rate × seed treatment	4, 78	0.26	0.9013	4, 78	0.27	0.8953
Soil texture × aldicarb rate × seed treatment	8, 78	0.98	0.4550	8, 78	0.97	0.4676

Discussion

Plant vigor, maturation, yield, and return increased as soil EC increased in 2010. Studies have shown that crop productivity increases as soil EC increases (Corwin and Lesch 2003; Sullivan et al. 2004). Nematodes are more common in areas of a field with coarse-textured soils causing stresses to plants in these areas (Sullivan et al. 2004; Overstreet et al 2009). In addition to nematode densities, factors such as nutrient availability affect potential damage to the cotton plant and yield (Khalilian et al. 2001, 2002; Overstreet et al. 2008). Coarse textured soils do not retain moisture as well as finer textured soils; therefore, plants grown in coarse-textured soils are under more moisture and nutrient stress (Mueller 2011). Plant vigor, yield, and return were lowest in high EC management zones in 2011. This was in response to the erosion of the layer of top soil in these areas of the field.

Treatments with aldicarb in common had positive effects on plant vigor. Studies have shown that aldicarb at the rate of 4.0-5.7 kg/ha controls thrips and nematodes, ultimately increasing yields (Kemerait et al. 2004; Vandiver et al. 2009). Treatments with a seed treatment in common also had positive effects on plant vigor and returns. Seed treatments provide control and suppression of thrips, which increases yields (Layton and Reed 2002).

CONCLUSION

My studies reaffirmed that zone definition by soil EC is a viable approach to characterize field variability for the application of site-specific management. Soil within low, medium, or high EC management zones had sandy, silt, or clay textures, respectively. Soil texture had significant effects on population densities of thrips in this study. However, densities of thrips were inconsistent within management zones. Population densities of nematodes were highest in areas of fields with an increase in sand content. An increase in population densities of nematodes as soil EC decreased showed that nematodes do not have a uniform distribution in fields.

Plots with aldicarb had the lowest numbers of thrips and nematodes. Aldicarb provided protection against thrips and nematodes for up to five weeks after planting. Plant vigor, yields, and returns were higher in treatments with aldicarb in common. Although both seed treatments also provided protection against thrips and nematodes for up to five weeks after planting, neither was comparable to aldicarb. The addition of aldicarb to both seed treatments increased the efficacy of these products.

Population densities of thrips and nematodes were low to moderate in this two year study. Further studies under higher pressures from these pests need to be conducted to determine effects of the interactions of aldicarb rate, seed treatments, and management zones. Although aldicarb under the trade name Temik 15G is no longer available for use in U.S. agricultural fields, this study may serve as a model for future formulations of aldicarb that may become available.

APPENDICES

Appendix A

Marlboro County 2008

Table A-1. Statistical comparison of treatment effects on population densities of immature thrips, adult thrips, and ratings of injury to cotton in plots in Marlboro County, SC, 2008.

Management factor combination	Population Densities of Immature Thrips			Population Densities of Adult Thrips			Ratings of Injury to Cotton Seedlings		
	df	*F*	*P > F*	df	*F*	*P > F*	df	*F*	*P > F*
Soil texture	2, 402	4.73	**0.0094**	2, 402	0.50	0.6048	2, 78	0.43	0.6503
Aldicarb rate	2, 402	8.29	**0.0003**	2, 402	3.21	**0.0413**	2, 78	36.46	**<0.0001**
Seed treatment	2, 402	0.02	0.9809	2, 402	0.27	0.7661	2, 78	4.68	**0.0121**
Sample date	4, 402	176.31	**<0.0001**	4, 402	156.11	**<0.0001**	-	-	-
Soil texture × aldicarb rate	4, 402	1.97	0.0989	4, 402	1.40	0.2328	4, 78	3.42	**0.0126**
Soil texture × seed treatment	4, 402	2.24	0.0641	4, 402	0.75	0.5613	4, 78	0.80	0.5306
Aldicarb rate × seed treatment	4, 402	0.45	0.7755	4, 402	0.81	0.5181	4, 78	4.83	**0.0016**
Sample date × soil texture	8, 402	1.08	0.3780	8, 402	1.01	0.4276	-	-	-
Sample date × aldicarb rate	8, 402	3.73	**0.0003**	8, 402	3.73	**0.0003**	-	-	-
Sample date × seed treatment	8, 402	1.10	0.3655	8, 402	0.96	0.4701	-	-	-
Soil texture × aldicarb rate × seed treatment	8, 402	0.74	0.6584	8, 402	0.62	0.7613	8, 78	0.70	0.6875
Sample date × soil texture × aldicarb rate	16, 402	2.02	**0.0111**	16, 402	1.39	0.1401	-	-	-
Sample date × soil texture × seed treatment	16, 402	1.54	0.0822	16, 402	1.12	0.3364	-	-	-
Sample date × aldicarb rate × seed treatment	16, 402	1.29	0.1984	16, 402	1.20	0.2668	-	-	-
Sample date × soil texture × aldicarb rate × seed treatment	32, 402	1.28	0.1433	32, 402	1.36	0.0968	-	-	-

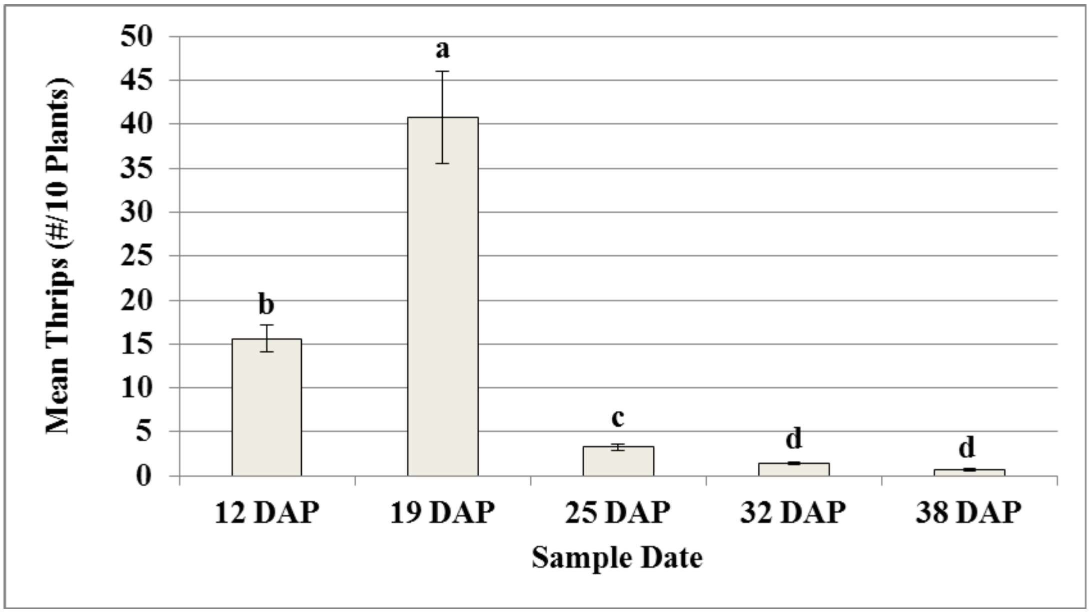
Table A-2. Statistical comparison of treatment effects on population densities of Columbia lance, root-knot, and reniform nematodes recovered from soil (100 cm^3) in cotton plots in Marlboro County, SC, 2008.

Management factor combination	Population Densities of Columbia Lance Nematodes			Population Densities of Root-knot Nematodes			Population Densities of Reniform Nematodes		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 78	3.12	**0.0495**	2, 78	1.48	0.2339	2, 78	0.23	0.7914
Aldicarb rate	2, 78	1.05	0.3536	2, 78	0.35	0.7093	2, 78	0.27	0.7664
Seed treatment	2, 78	0.32	0.7290	2, 78	2.39	0.0980	2, 78	0.86	0.4289
Soil texture × aldicarb rate	4, 78	0.40	0.8076	4, 78	0.42	0.7916	4, 78	2.15	0.0826
Soil texture × seed treatment	4, 78	0.09	0.9848	4, 78	1.65	0.1698	4, 78	1.63	0.1741
Aldicarb rate × seed treatment	4, 78	1.13	0.3501	4, 78	0.49	0.7448	4, 78	0.47	0.7580
Soil texture × aldicarb rate × seed treatment	8, 78	0.99	0.4508	8, 78	1.08	0.3827	8, 78	0.53	0.8322

Table A-3. ANOVA table for cotton yield (kg of lint per ha) in plots located in Marlboro County, SC, 2008.

Management factor combination	Yields		
	df	*F*	*P* > *F*
Soil texture	2, 78	2.02	0.1401
Aldicarb rate	2, 78	5.08	**0.0084**
Seed treatment	2, 78	0.03	0.9657
Soil texture × aldicarb rate	4, 78	1.49	0.2129
Soil texture × seed treatment	4, 78	0.69	0.6022
Aldicarb rate × seed treatment	4, 78	0.29	0.8867
Soil texture × aldicarb rate × seed treatment	8, 78	0.52	0.8357

A



B

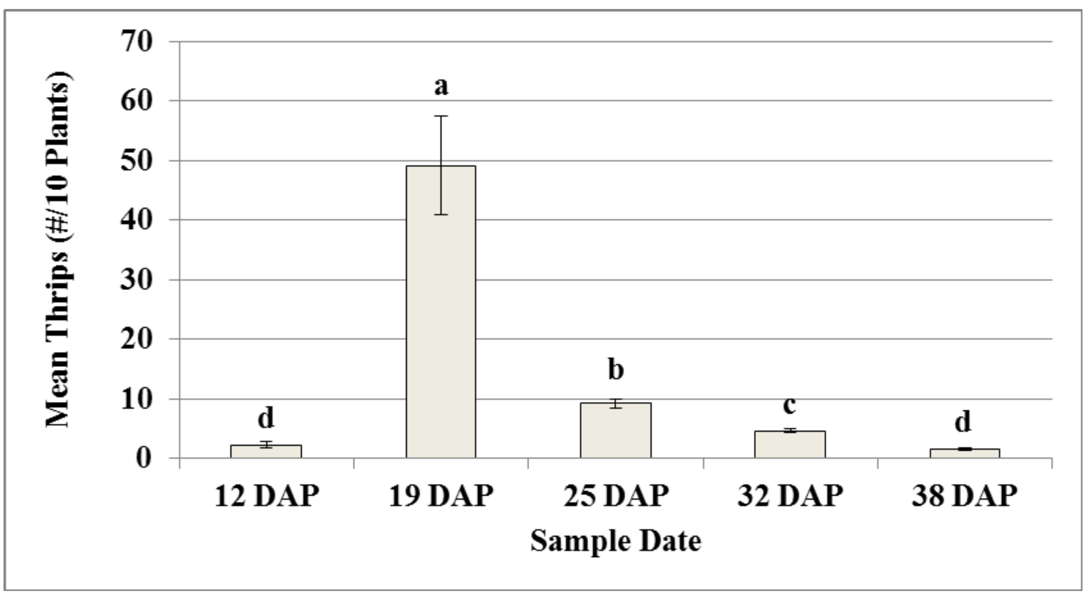


Figure A-1. Effect of sample date on mean population densities of (A) adult and (B) immature thrips in cotton plots in Marlboro County, SC, 2008. Ten plants examined per treatment. Bars with a letter in common across dates are not significantly different, P>0.05, LSD. DAP, days after planting.

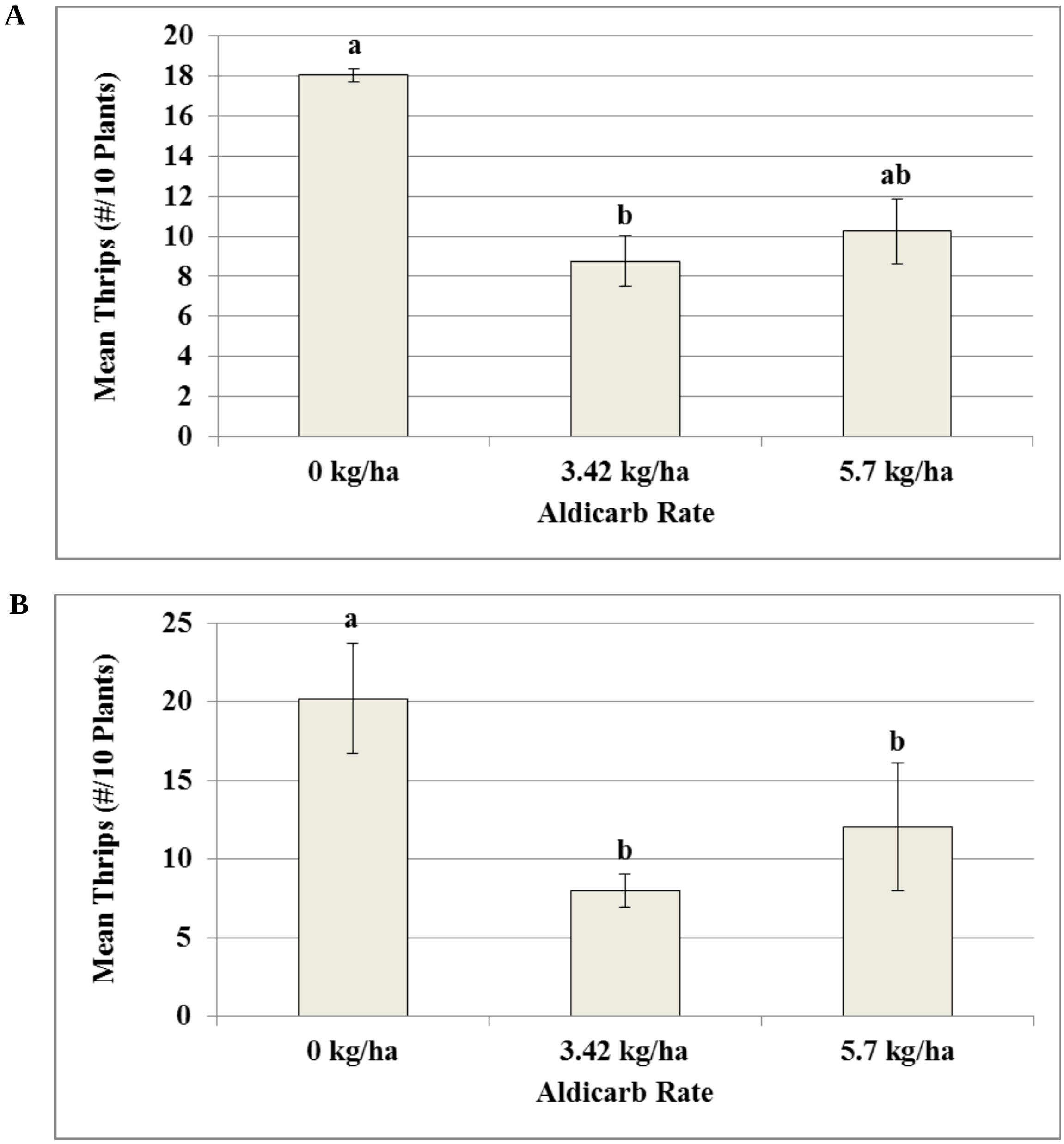
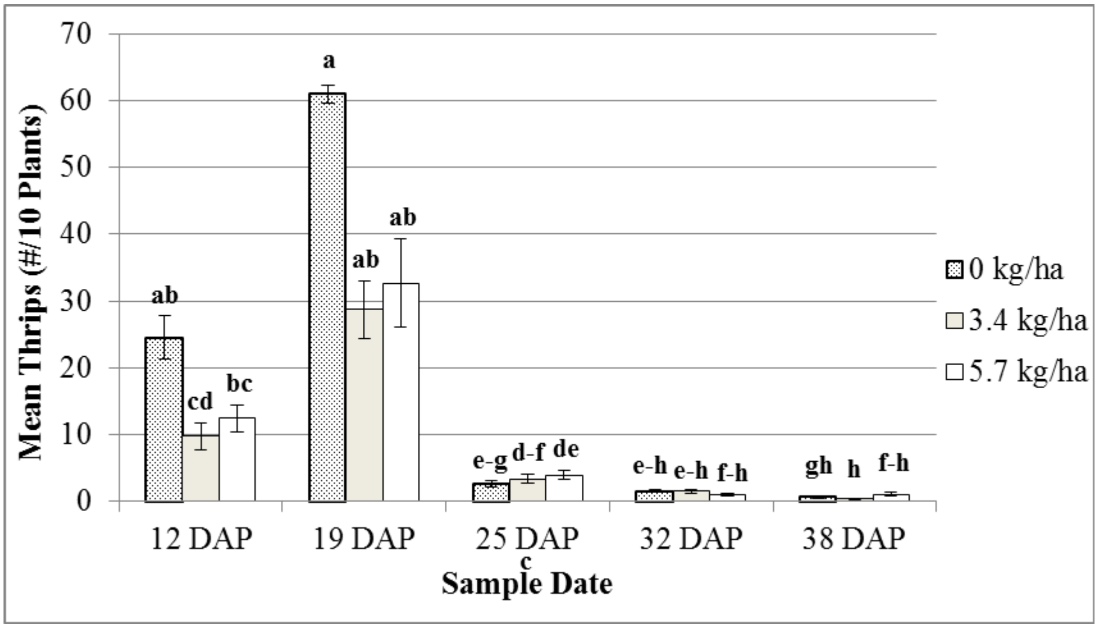


Figure A-2. Effect of aldicarb rate on mean population densities of (A) adult and (B) immature thrips in cotton plots in Malboro County, SC, 2008. Ten plants examined per treatment. Bars with a letter in common across aldicarb rate are not significantly different, P>0.05, LSD.

A



B

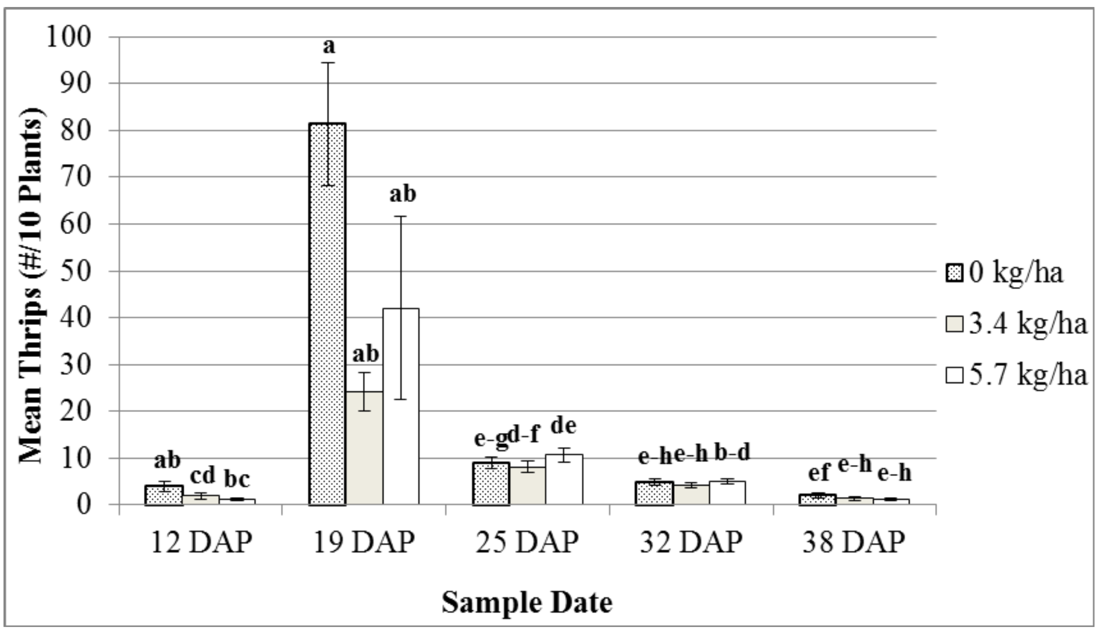


Figure A-3. Effect of sample date and aldicarb rate on mean population densities of (A) adult and (B) immature thrips in cotton plots in Marlboro County, SC, 2008. Ten plants examined per treatment. Bars with a letter in common across sample dates and aldicarb rates are not significantly different, P > 0.05, LSD. DAP, days after plant.

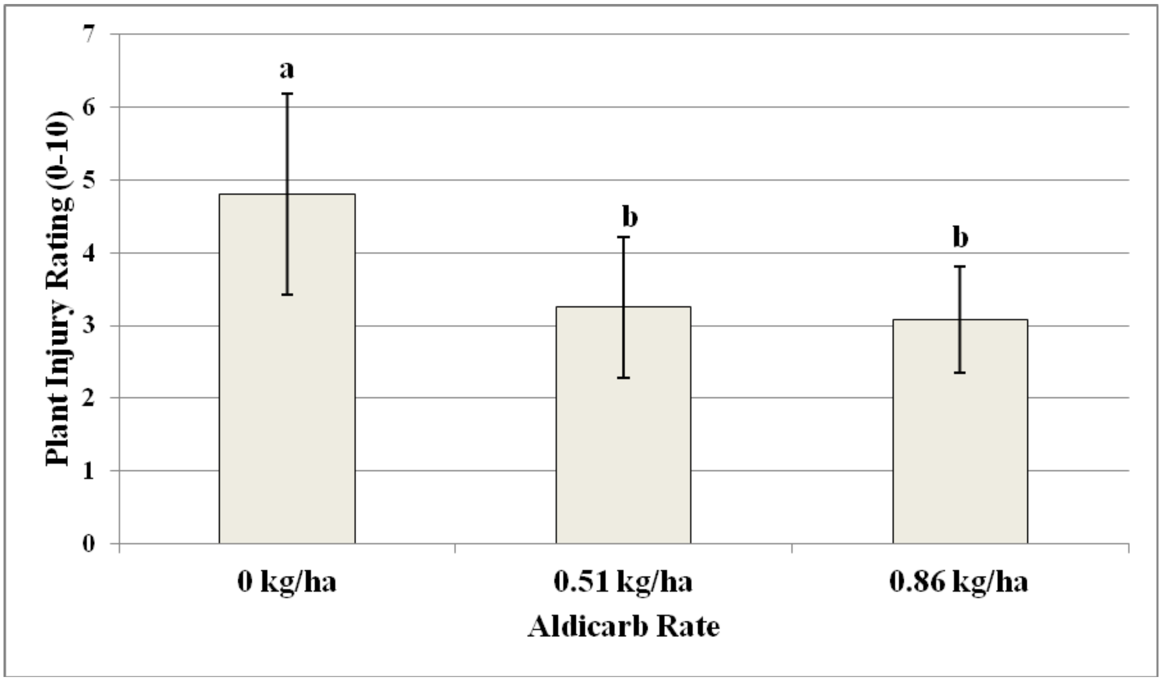


Figure A-4. Effect of aldicarb rate on mean ratings of injury to cotton plants by thrips in plots in Marlboro County, SC, 2008. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD.

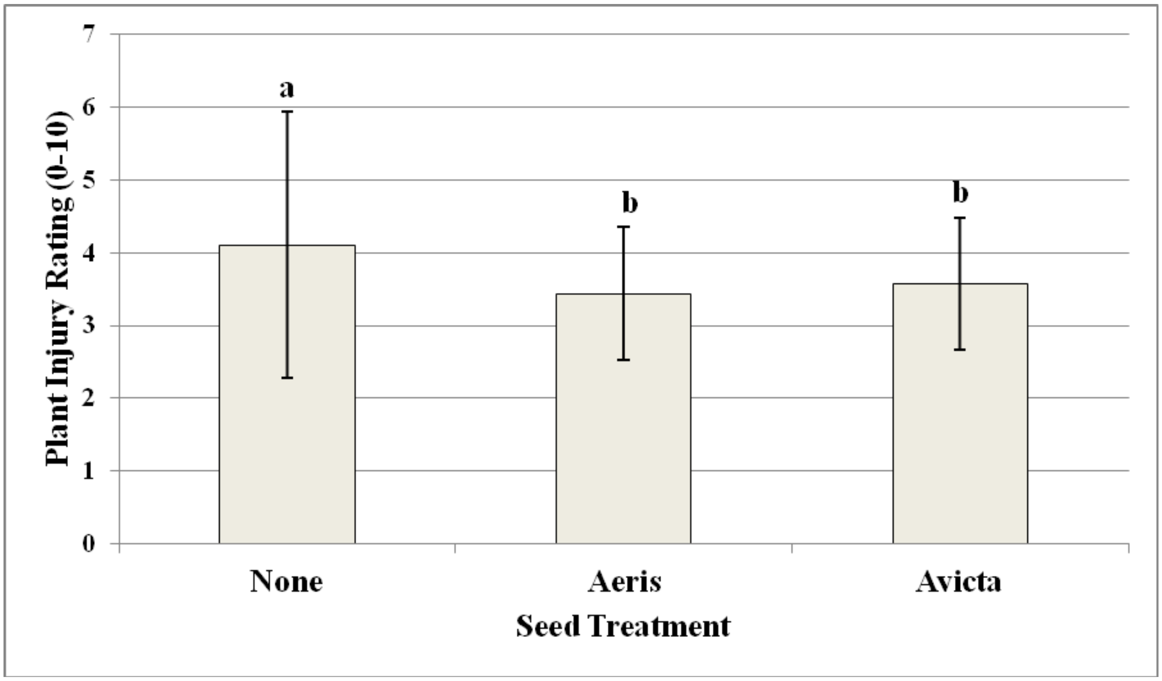


Figure A-5. Effect of seed treatment on mean ratings of injury to cotton plants by thrips in plots in Marlboro County, SC, 2008. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD.

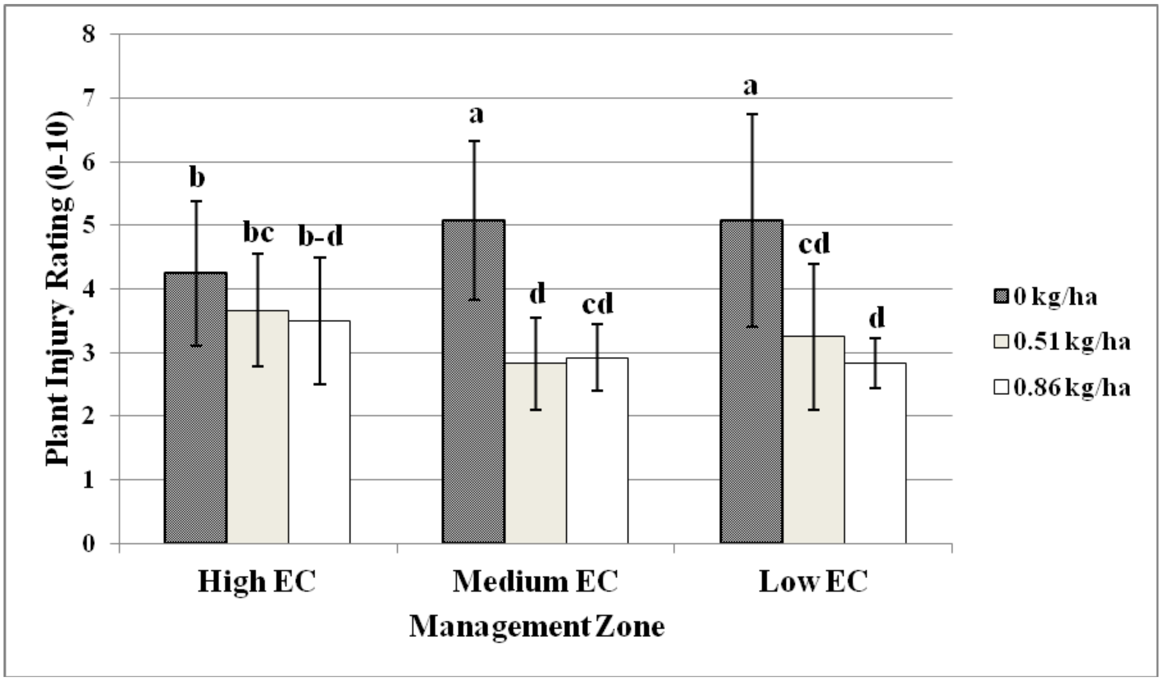


Figure A-6. Effect of soil texture and aldicarb rate on mean ratings of injury to cotton plants by thrips in plots in Marlboro County, SC, 2008. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD. EC, electrical conductivity.

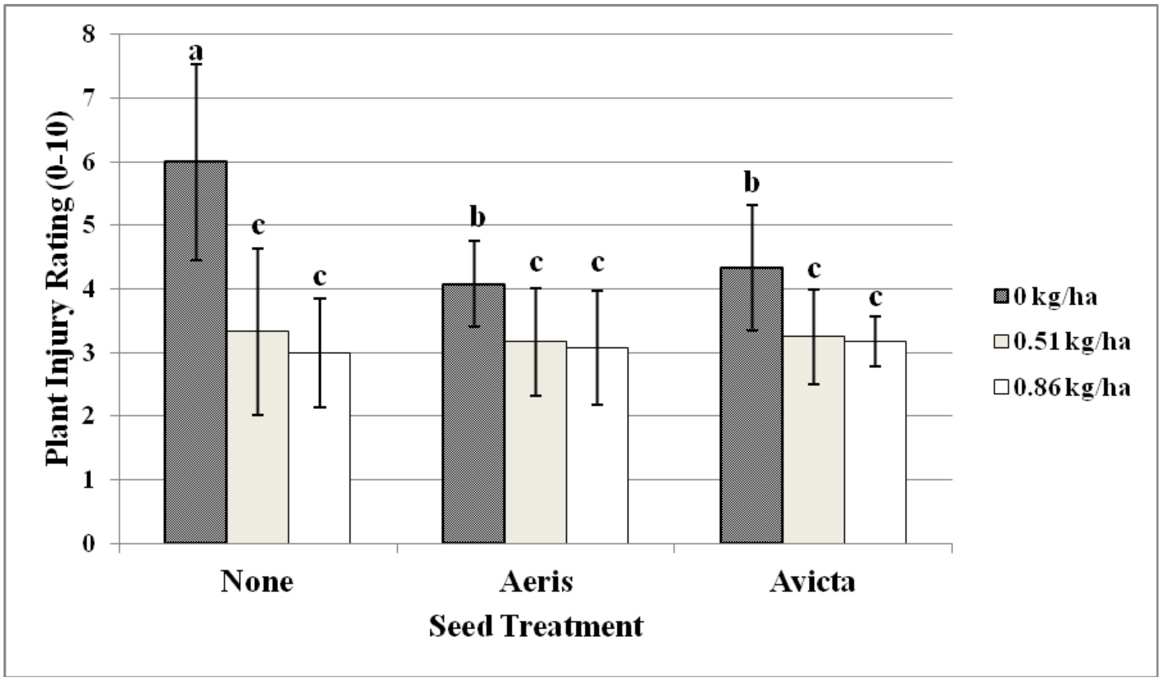


Figure A-7. Effect of aldicarb rate and seed treatment on mean ratings of injury to cotton plants by thrips in plots in Marlboro County, SC, 2008. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD.

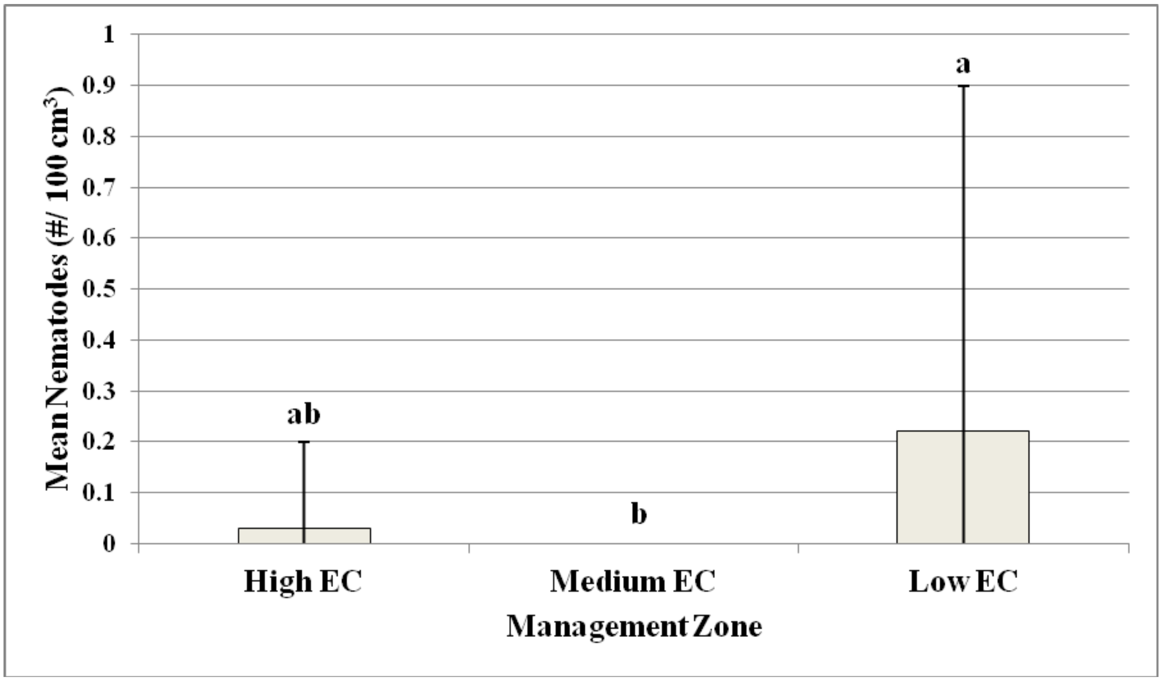


Figure A-8. Effect of soil texture on mean population densities of Columbia lance nematodes recovered from soil (100 cm3) in cotton plots in Marlboro County, SC, 2008. Bars with a letter in common are not significantly different, P > 0.05, LSD. EC, electrical conductivity.

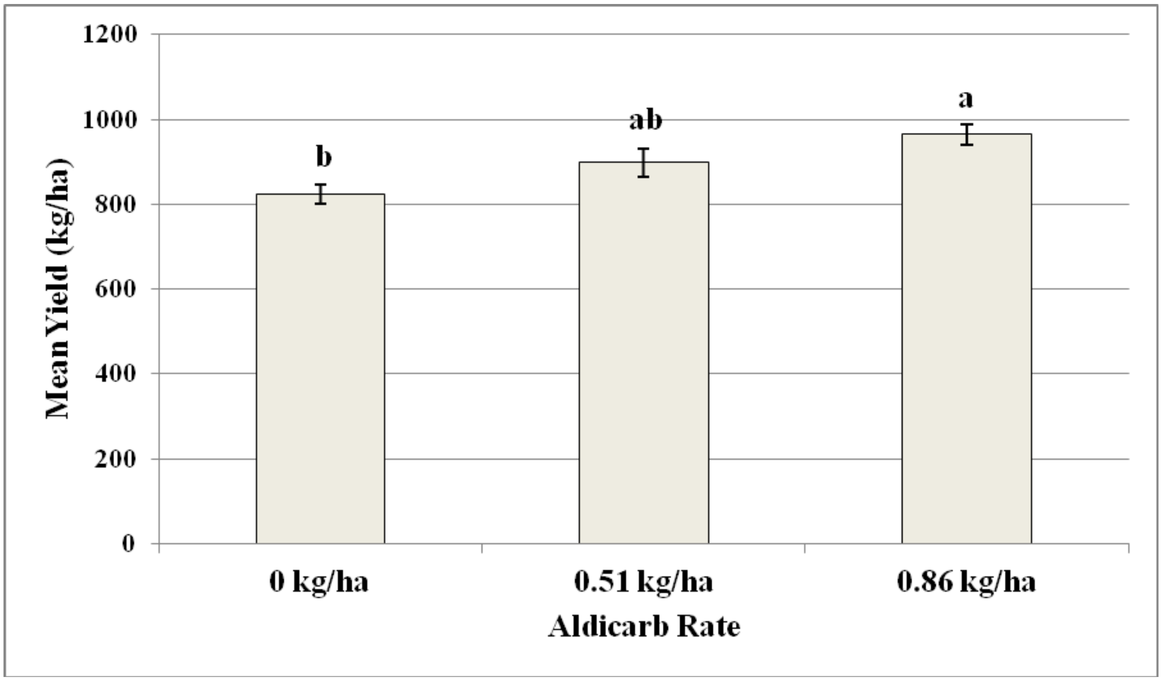


Figure A-9. Effect of aldicarb rate on mean yield (kg/ha) in cotton plots in Marlboro County, SC, 2008. Bars with a letter in common are not significantly different, P > 0.05, LSD.

Appendix B

Hampton County 2008

Table B-1. Statistical comparison of treatment effects on population densities of immature thrips, adult thrips, and ratings of injury to cotton in plots in Hampton County, SC, 2008.

Management factor combination	Population Densities of Immature Thrips			Population Densities of Adult Thrips			Ratings of Injury to Cotton Seedlings		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 483	5.55	**0.0041**	2, 483	6.63	**0.0014**	2, 159	1.73	0.1812
Aldicarb rate	2, 483	29.90	**<0.0001**	2, 483	26.25	**<0.0001**	2, 159	84.73	**<0.0001**
Seed treatment	2, 483	9.43	**<0.0001**	2, 483	3.71	**0.0251**	2, 159	61.39	**<0.0001**
Sample date	4, 483	21.32	**<0.0001**	4, 483	34.27	**<0.0001**	1, 159	106.42	**<0.0001**
Soil texture × aldicarb rate	4, 483	0.49	0.7452	4, 483	1.60	0.1732	4, 159	0.88	0.4778
Soil texture × seed treatment	4, 483	1.05	0.3784	4, 483	2.00	0.0929	4, 159	0.30	0.8770
Aldicarb rate × seed treatment	4, 483	5.65	**0.0002**	4, 483	5.90	**0.0001**	4, 159	22.27	**<0.0001**
Sample date × soil texture	10, 483	1.11	0.3551	10, 483	2.41	**0.0085**	2, 159	0.18	0.8388
Sample date × aldicarb rate	10, 483	2.00	**0.0315**	10, 483	2.66	**0.0036**	2, 159	8.34	**0.0004**
Sample date × seed treatment	10, 483	1.84	0.0510	10, 483	2.97	**0.0012**	2, 159	0.98	0.3784
Soil texture × aldicarb rate × seed treatment	8, 483	0.54	0.8264	8, 483	0.67	0.7145	8, 159	1.10	0.3675
Sample date × soil texture × aldicarb rate	20, 483	0.95	0.5187	20, 483	0.57	0.9311	4, 159	0.22	0.9281
Sample date × soil texture × seed treatment	20, 483	1.05	0.4036	20, 483	0.89	0.6023	4, 159	0.55	0.7023
Sample date × aldicarb rate × seed treatment	20, 483	2.47	**0.0004**	20, 483	2.19	**0.0022**	4, 159	2.82	**0.0271**
Sample date × soil texture × aldicarb rate × seed treatment	40, 483	0.61	0.9738	40, 483	1.02	0.4409	8, 159	0.27	0.9748

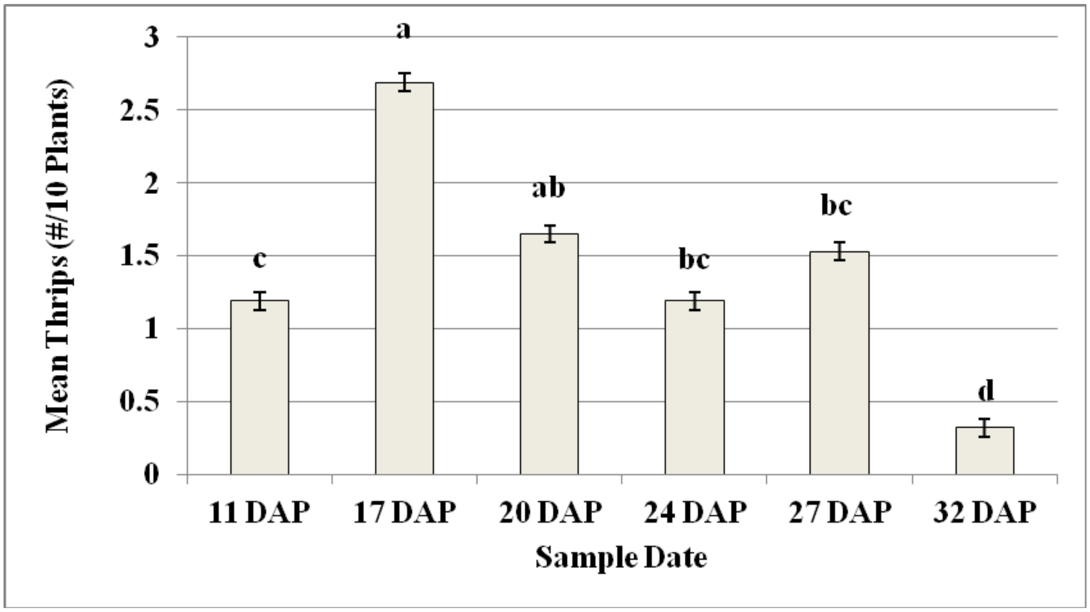
Table B-2. Statistical comparison of treatment effects on population densities of Columbia lance and root-knot nematodes recovered from soil (100 cm^3) in cotton plots in Hampton County, SC, 2008.

Management factor combination	Population Densities of Columbia Lance Nematodes			Population Densities of Root-knot Nematodes		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 78	11.73	**<0.0001**	2, 78	0.58	0.5596
Aldicarb rate	2, 78	0.38	0.6868	2, 78	0.70	0.4996
Seed treatment	2, 78	1.87	0.1608	2, 78	0.81	0.4484
Soil texture × aldicarb rate	4, 78	1.95	0.1105	4, 78	0.08	0.9893
Soil texture × seed treatment	4, 78	1.58	0.1866	4, 78	1.03	0.3950
Aldicarb rate × seed treatment	4, 78	0.72	0.5777	4, 78	0.18	0.9497
Soil texture × aldicarb rate × seed treatment	8, 78	0.94	0.4866	8, 78	0.64	0.7419

Table B-3. Statistical comparison of treatment effects on stand counts and yield (lint kg per ha) in cotton plots in Hampton County, SC, 2008.

Management factor combination	Stand Counts			Yield		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 78	0.69	0.5038	2, 78	7.73	**0.0009**
Aldicarb rate	2, 78	1.17	0.3166	2, 78	0.01	0.9861
Seed treatment	2, 78	1.29	0.2798	2, 78	4.81	**0.0107**
Soil texture × aldicarb rate	4, 78	0.92	0.4568	4, 78	0.45	0.7743
Soil texture × seed treatment	4, 78	3.76	**0.0075**	4, 78	0.24	0.9140
Aldicarb rate × seed treatment	4, 78	0.81	0.5229	4, 78	0.72	0.5784
Soil texture × aldicarb rate × seed treatment	8, 78	1.66	0.1215	8, 78	0.88	0.5393

A



B

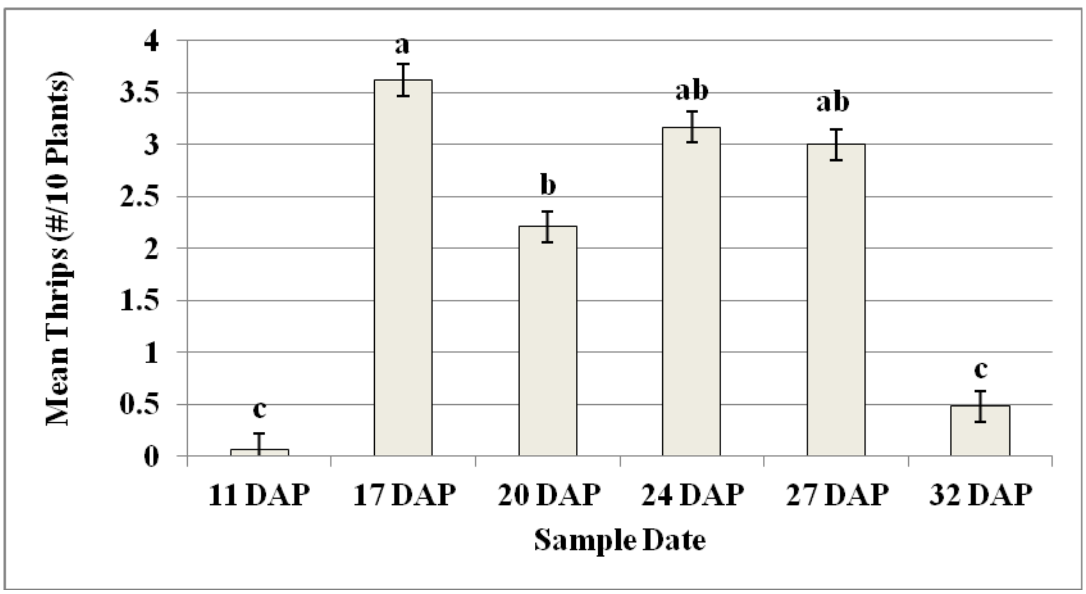


Figure B-1. Effect of sample date on mean population densities of (A) adult and (B) immature thrips in cotton plots in Hampton County, SC, 2008. Ten plants examined per treatment. Bars with a letter in common across dates are not significantly different, P>0.05, LSD. DAP, days after planting.

A

B

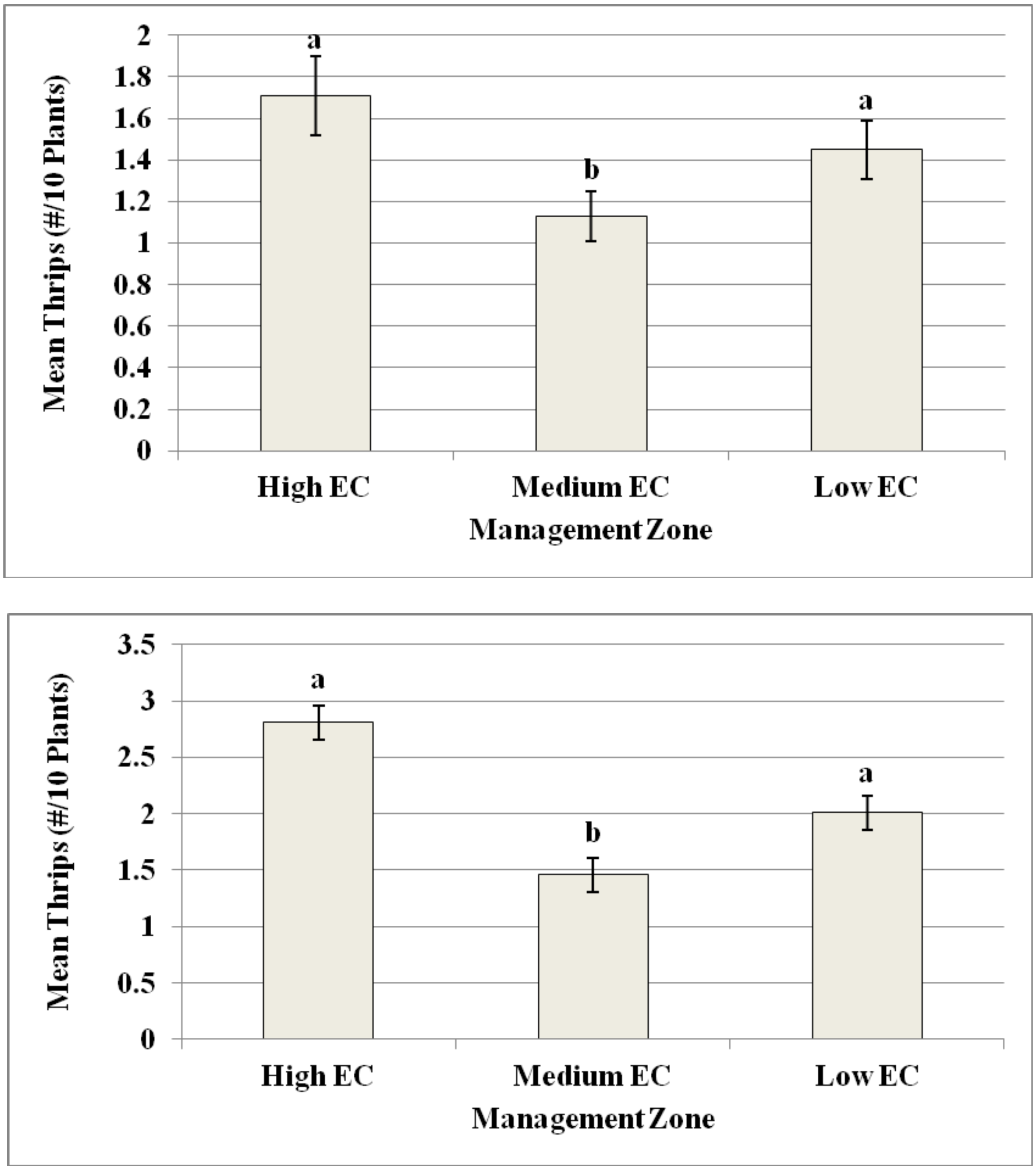
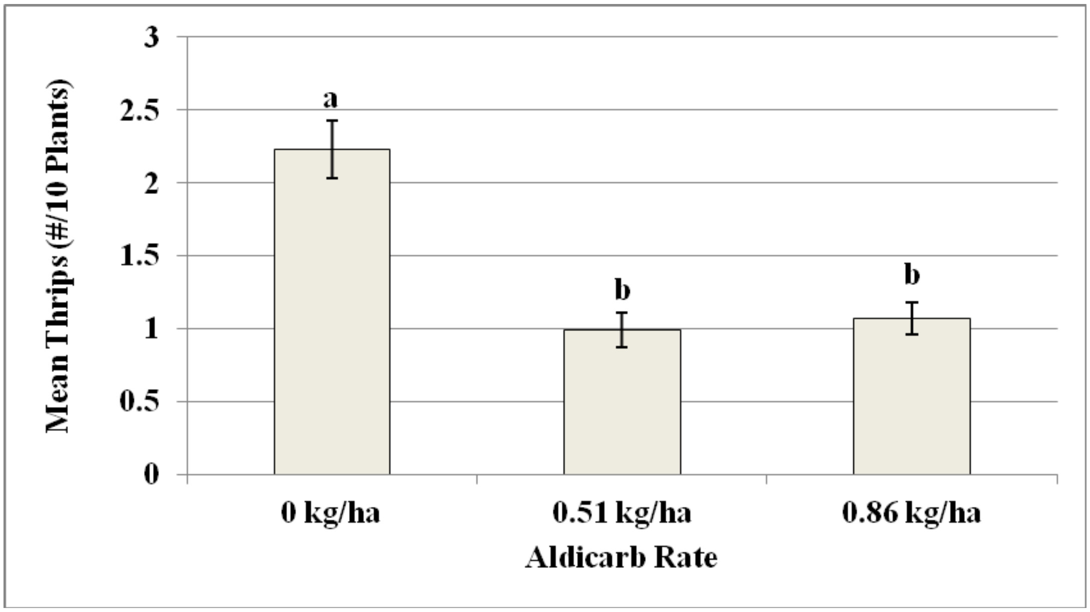


Figure B-2. Effect of soil texture on mean population densities of (A) adult and (B) immature thrips in cotton plots in Hampton County, SC, 2008. Ten plants examined per treatment. Bars with a letter in common across dates are not significantly different, P>0.05, LSD. DAP, days after planting.

A



B

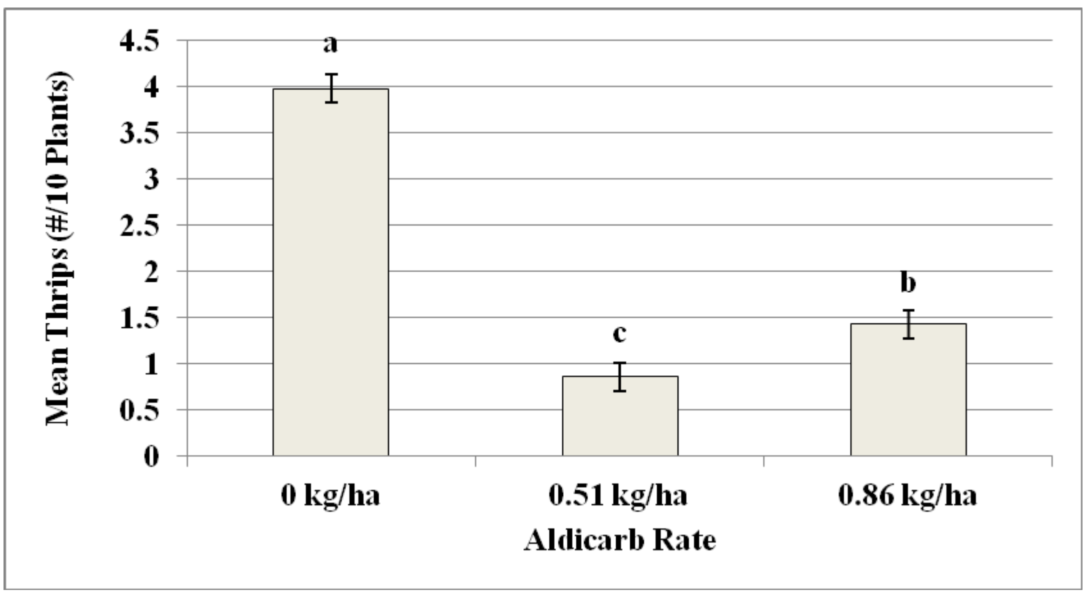
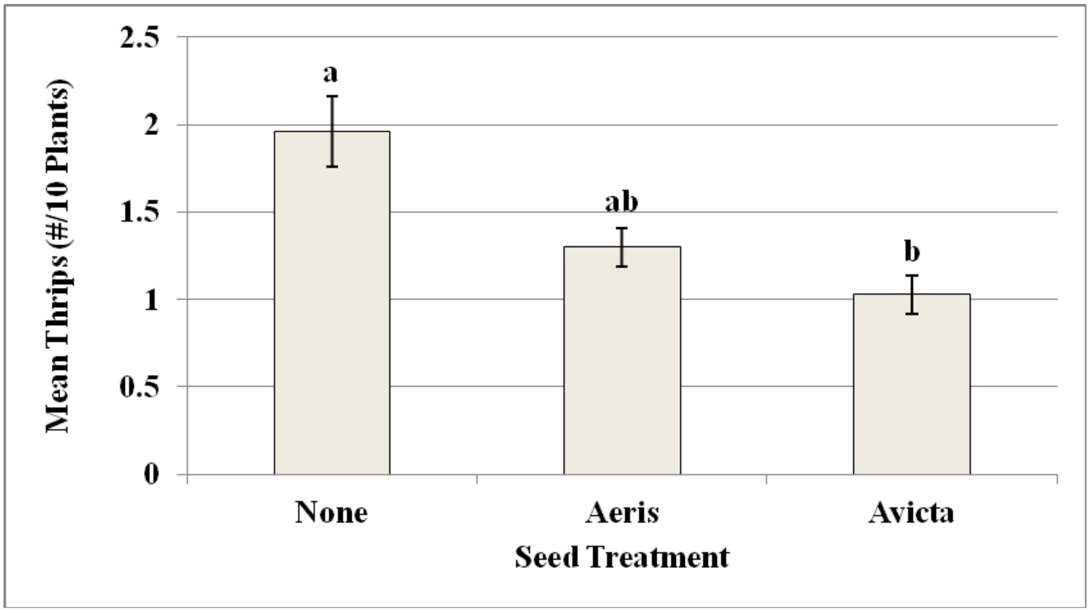


Figure B-3. Effect of aldicarb rate on mean population densities of (A) adult and (B) immature thrips in cotton plots in Hampton County, SC, 2008. Ten plants examined per treatment. Bars with a letter in common across dates are not significantly different, P>0.05, LSD. DAP, days after planting.

A



B

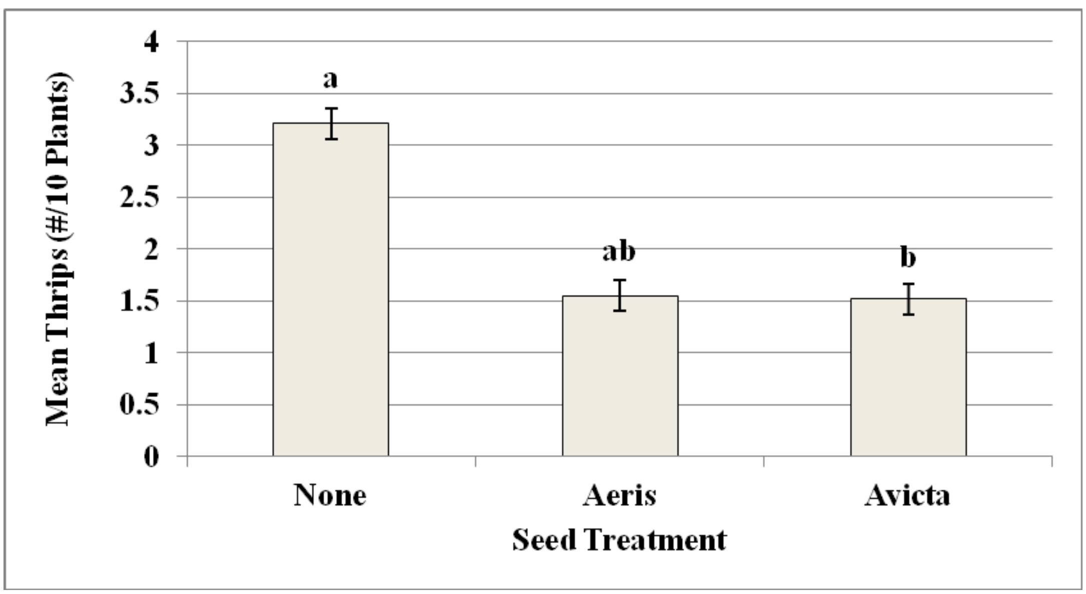
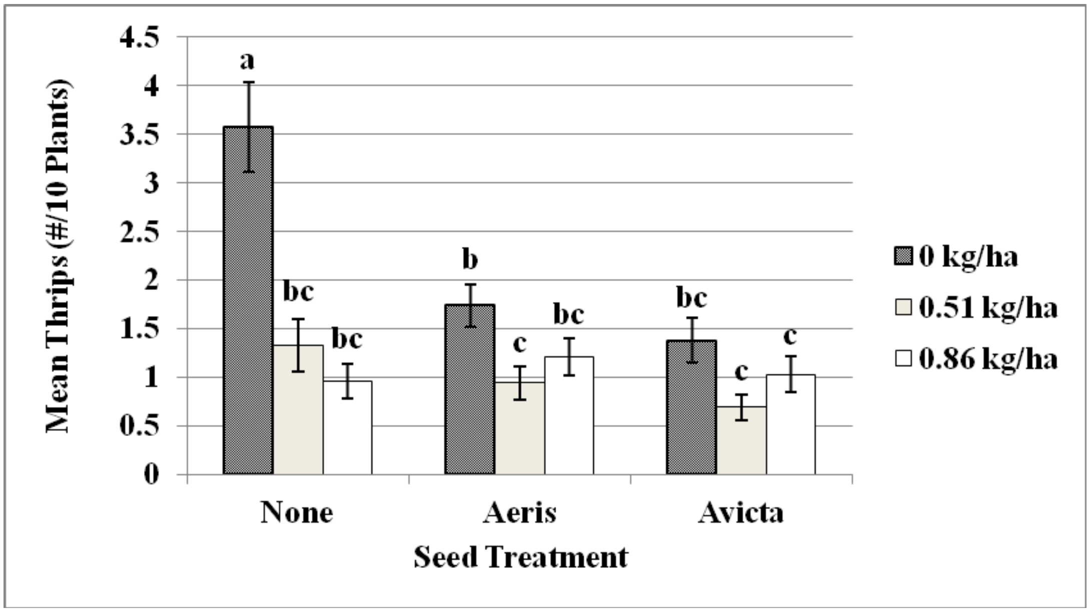


Figure B-4. Effect of seed treatment on mean population densities of (A) adult and (B) immature thrips in cotton plots in Hampton County, SC, 2008. Ten plants examined per treatment. Bars with a letter in common across dates are not significantly different, P>0.05, LSD. DAP, days after planting.

A



B

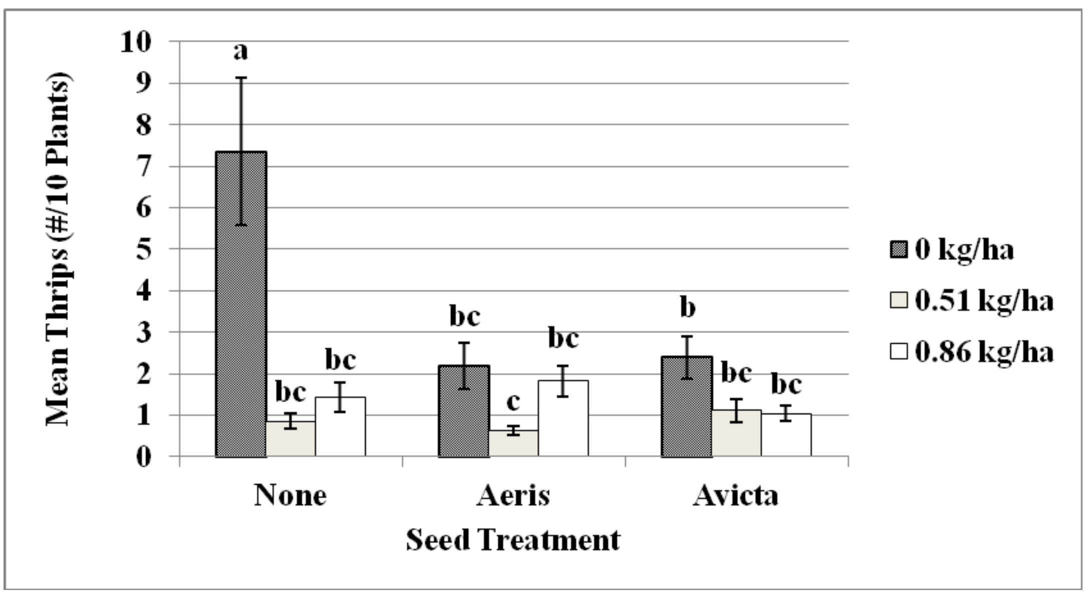
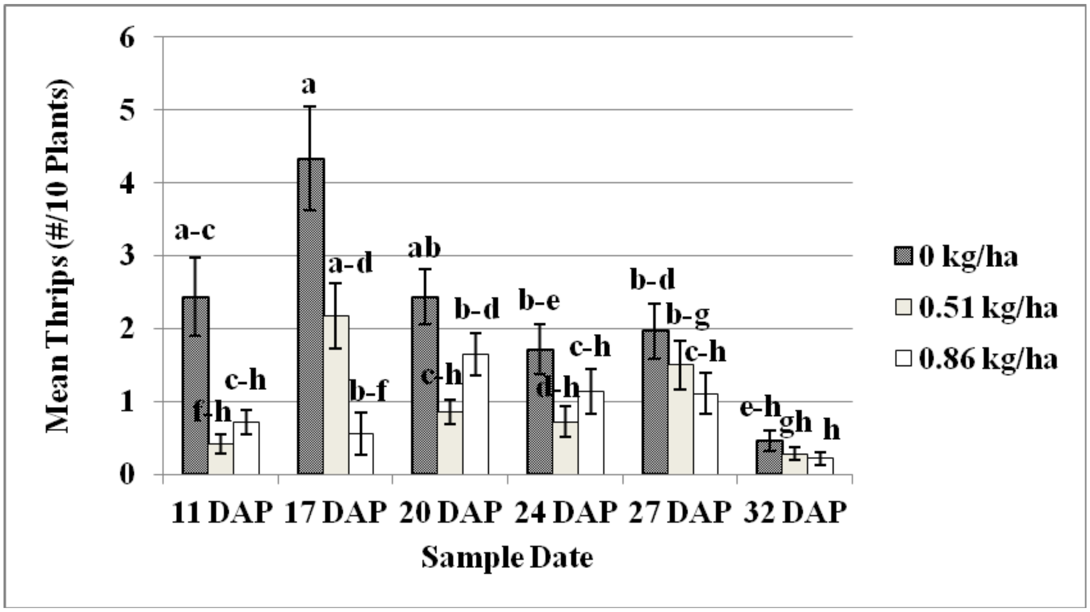


Figure B-5. Effect of aldicarb rate and seed treatment on mean population densities of (A) adult and (B) immature thrips in cotton plots in Hampton County, SC, 2008. Ten plants examined per treatment. Bars with a letter in common across dates are not significantly different, P>0.05, LSD. DAP, days after planting.

A



B

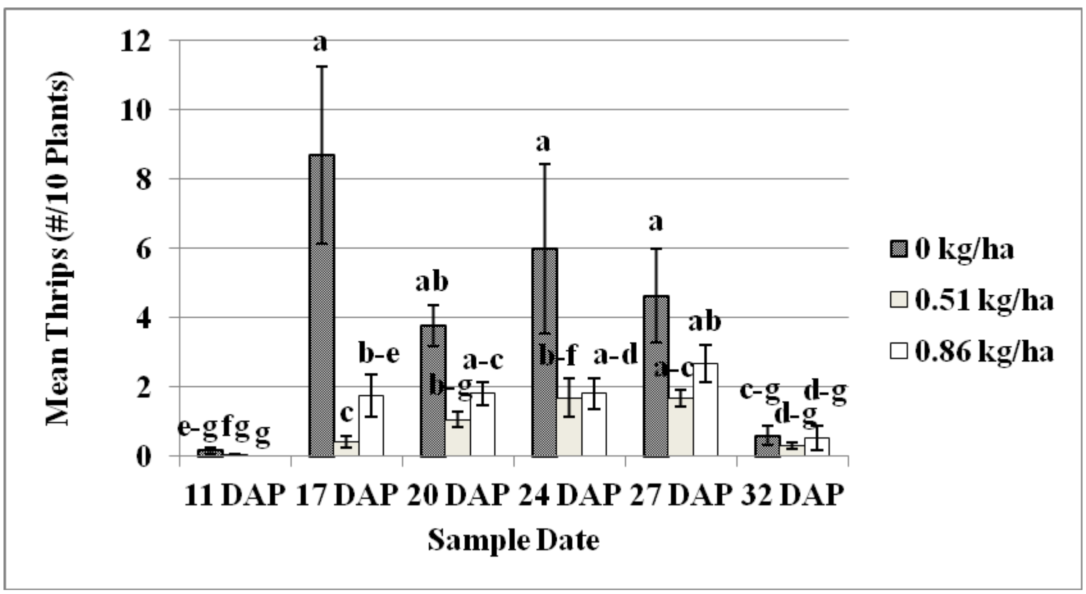


Figure B-6. Effect of sample date and aldicarb rate on mean population densities of (A) adult and (B) immature thrips in cotton plots in Hampton County, SC, 2008. Ten plants examined per treatment. Bars with a letter in common across dates are not significantly different, P>0.05, LSD. DAP, days after planting.

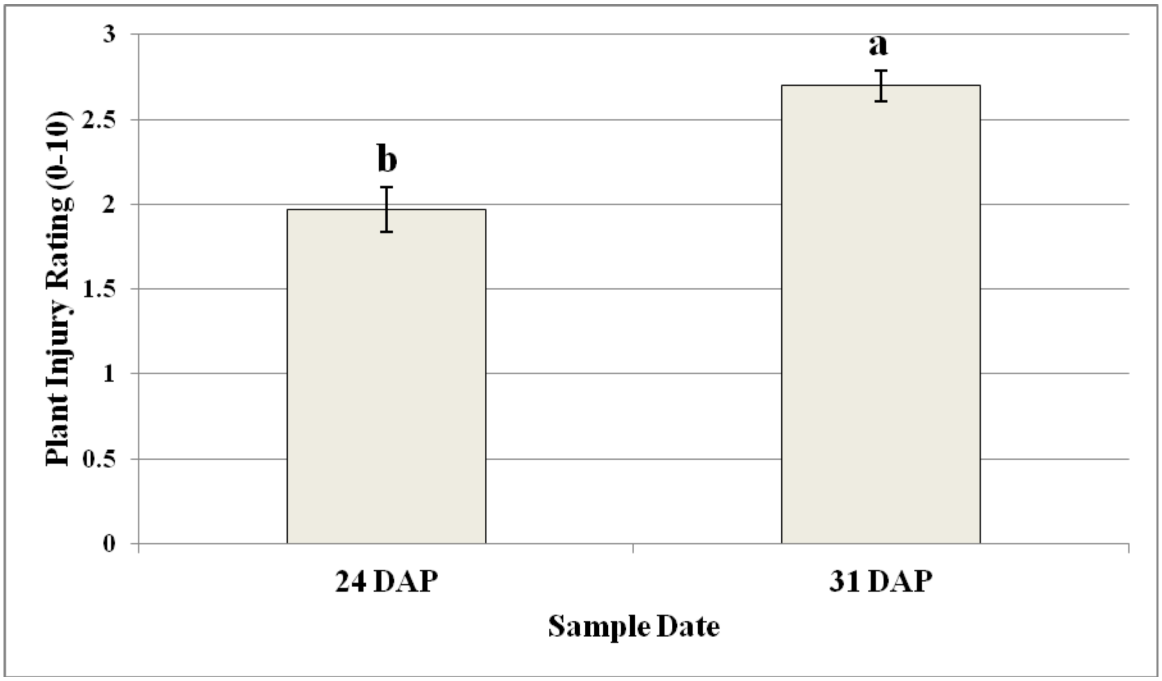


Figure B-7. Effect of sample date on mean ratings of injury to cotton plants by thrips in plots in Hampton County, SC, 2008. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD.

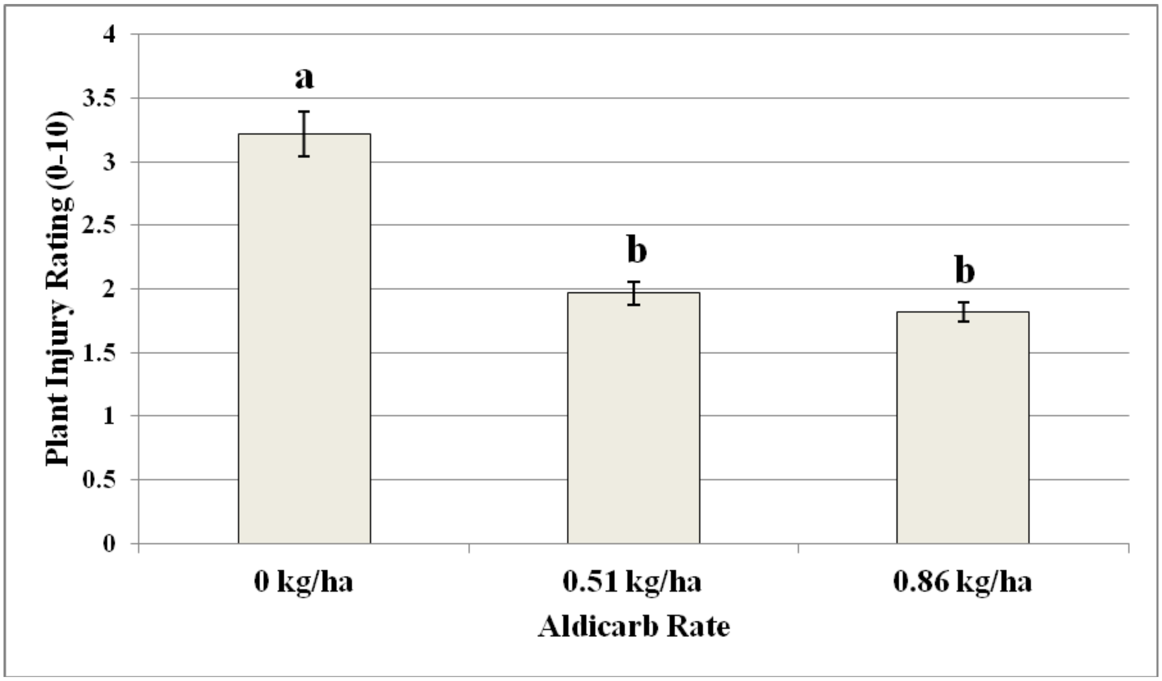


Figure B-8. Effect of aldicarb rate on mean ratings of injury to cotton plants by thrips in plots in Hampton County, SC, 2008. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD.

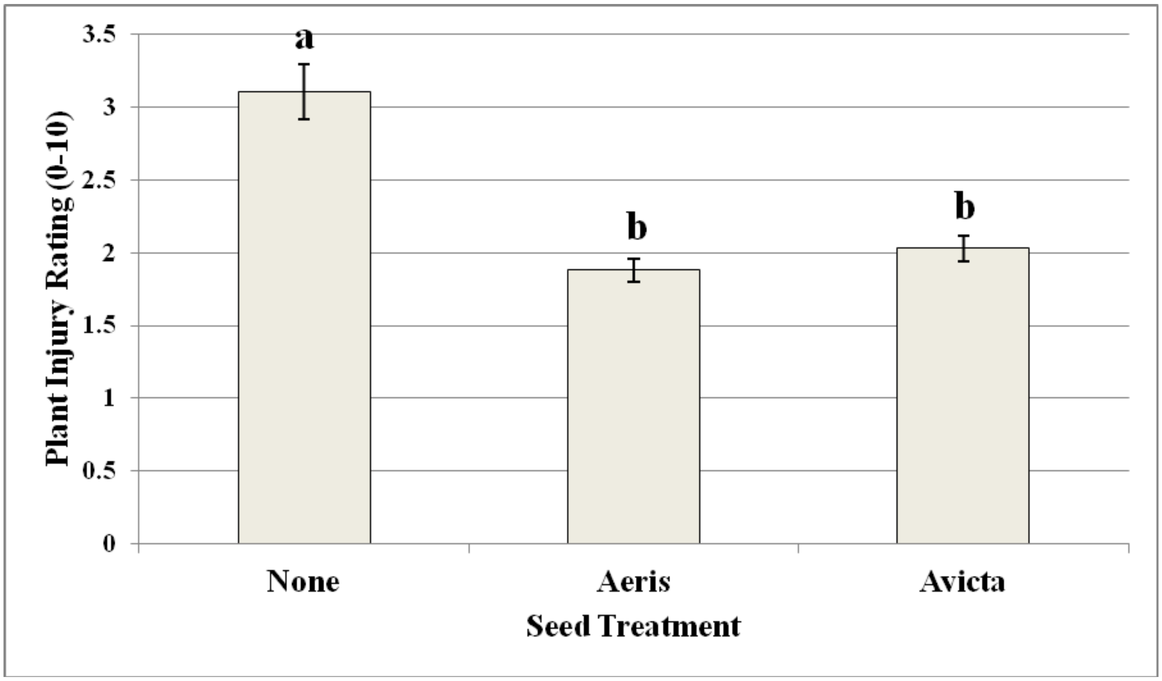


Figure B-9. Effect of seed treatment on mean ratings of injury to cotton plants by thrips in plots in Hampton County, SC, 2008. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD.

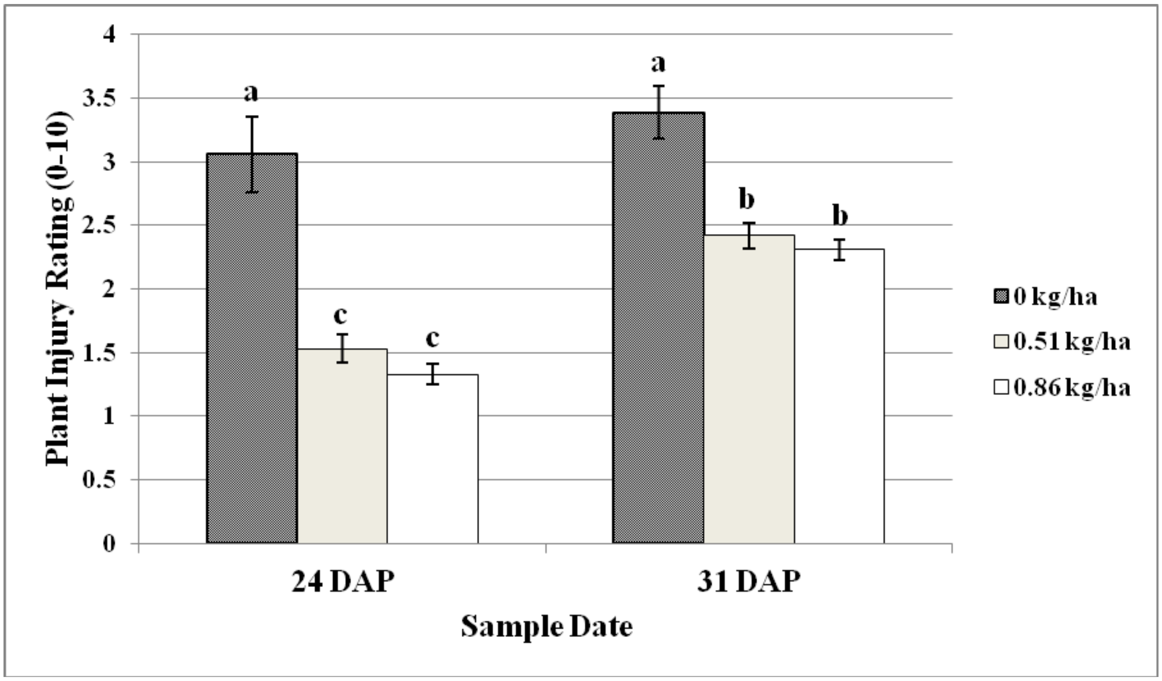


Figure B-10. Effect of sample date and aldicarb rate on mean ratings of injury to cotton plants by thrips in plots in Hampton County, SC, 2008. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD.

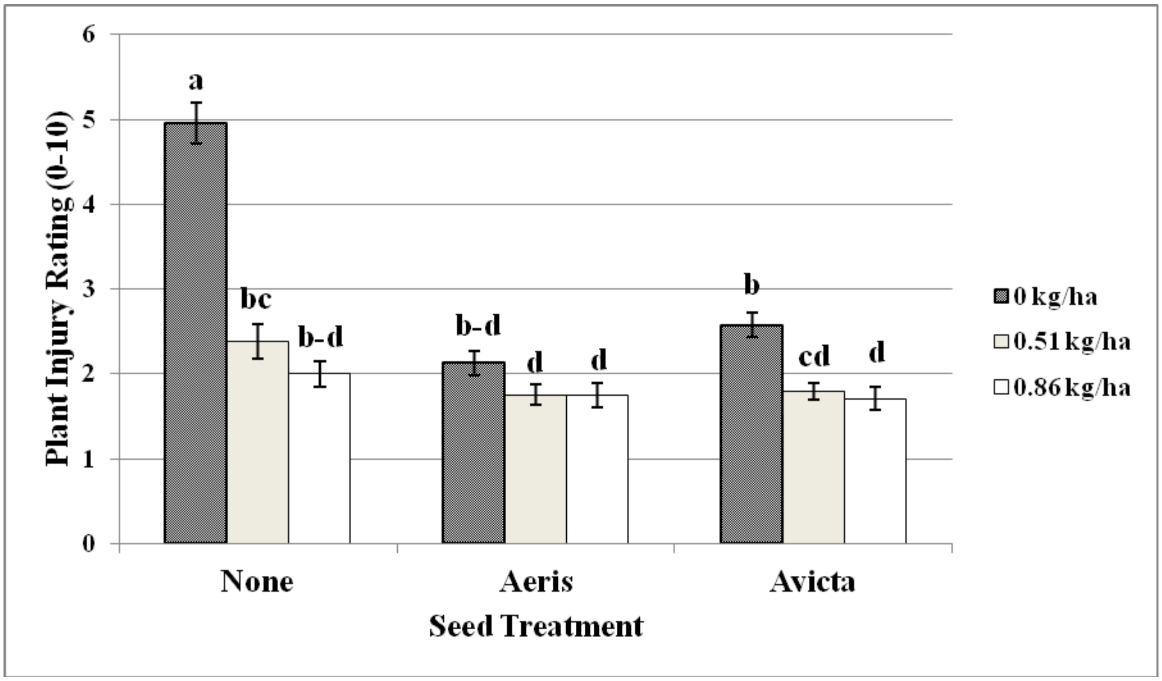


Figure B-11. Effect of aldicarb rate and seed treatment on mean ratings of injury to cotton plants by thrips in plots in Hampton County, SC, 2008. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD.

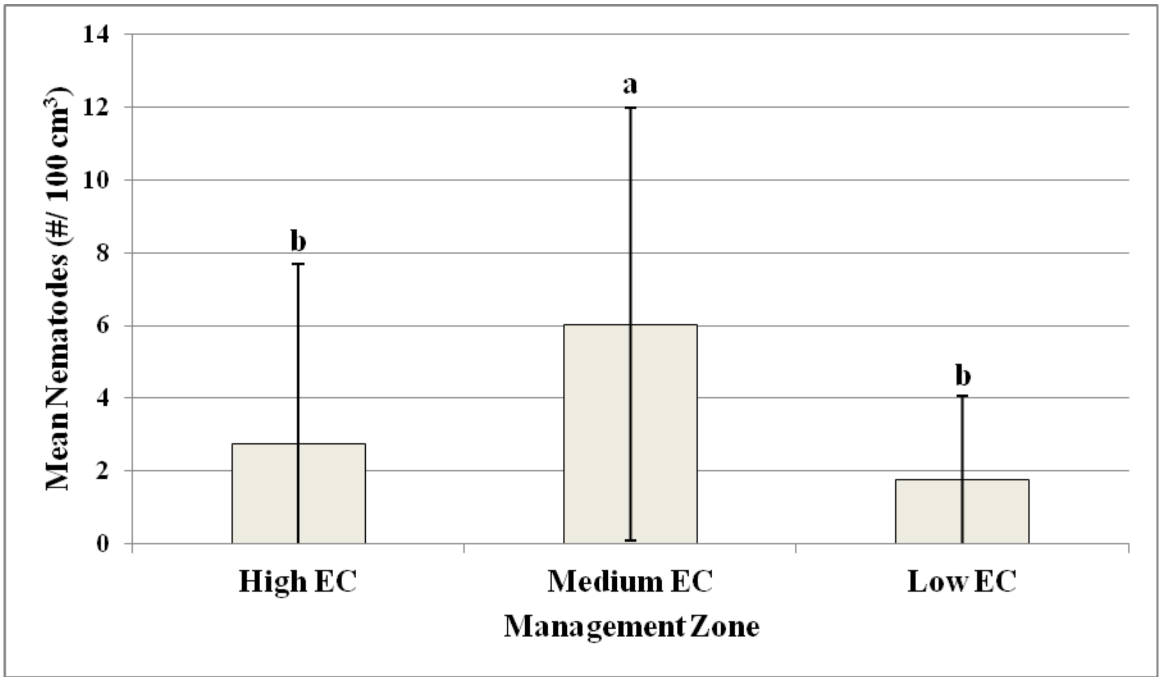


Figure B-12. Effect of soil texture on mean population densities of Columbia lance nematodes recovered from soil (100 cm3) in cotton plots in Hampton County, SC, 2008. Bars with a letter in common are not significantly different, P > 0.05, LSD. EC, electrical conductivity.

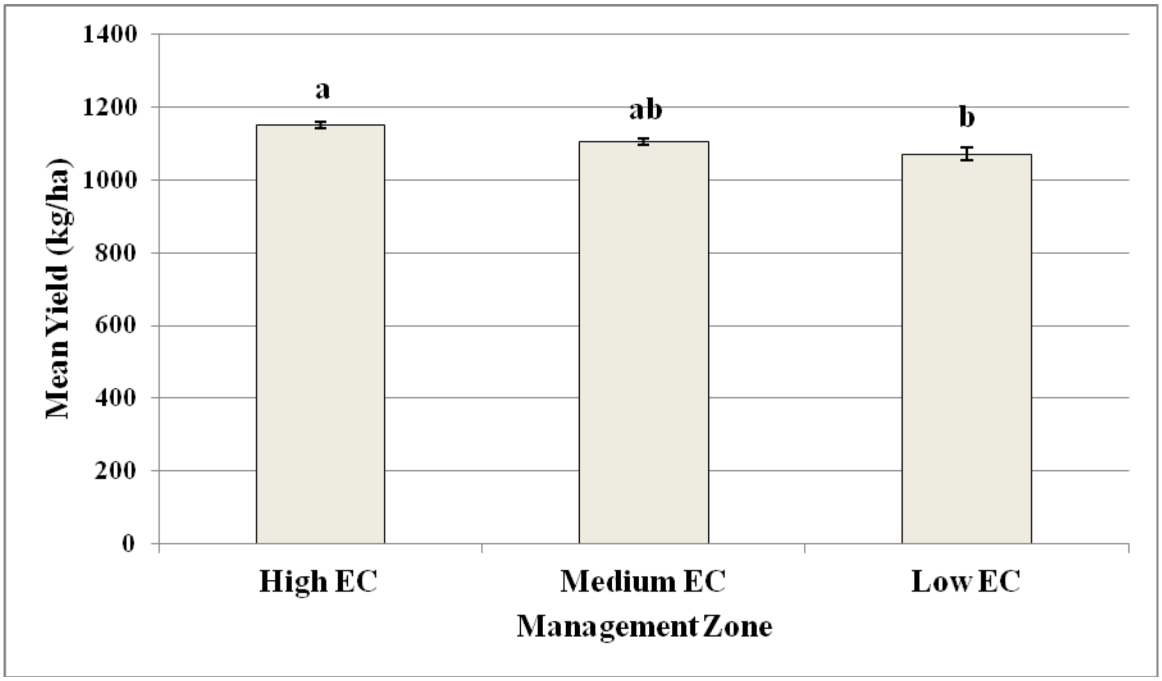


Figure B-13. Effect of soil texture on mean yield (kg/ha) in cotton plots in Hampton County, SC, 2008. Bars with a letter in common are not significantly different, P > 0.05, LSD. EC, electrical conductivity.

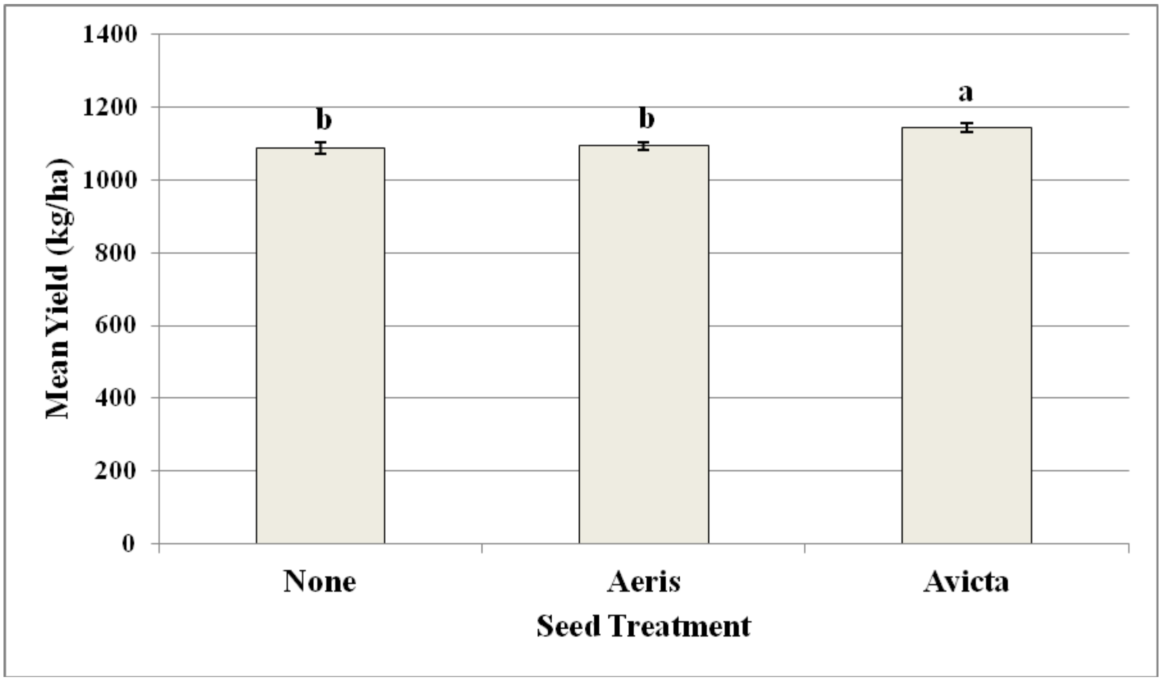


Figure B-14. Effect of seed treatment on mean yield (kg/ha) in cotton plots in Hampton County, SC, 2008. Bars with a letter in common are not significantly different, P > 0.05, LSD. EC, electrical conductivity.

Appendix C

PDREC 2009

Table C-1. Statistical comparison of treatment effects on population densities of immature thrips, adult thrips, and ratings of injury to cotton in plots in Florence, SC, 2009.

Management factor combination	Population Densities of Immature Thrips			Population Densities of Adult Thrips			Ratings of Injury to Cotton Seedlings		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 482	3.16	**0.0433**	2, 482	12.44	**<0.0001**	2, 240	9.87	**<0.0001**
Aldicarb rate	2, 482	19.04	**<0.0001**	2, 482	13.60	**<0.0001**	2, 240	28.46	**<0.0001**
Seed treatment	2, 482	7.41	**0.0007**	2, 482	0.76	0.4670	2, 240	43.56	**<0.0001**
Sample date	5, 482	5.55	**<0.0001**	5, 482	24.87	**<0.0001**	2, 240	9.77	**<0.0001**
Soil texture × aldicarb rate	4, 482	1.76	0.1350	4, 482	0.43	0.7840	4, 240	0.15	0.9640
Soil texture × seed treatment	4, 482	0.96	0.4266	4, 482	1.33	0.2592	4, 240	0.89	0.4693
Aldicarb rate × seed treatment	4, 482	1.69	0.1501	4, 482	1.09	0.3627	4, 240	20.20	**<0.0001**
Sample date × soil texture	10, 482	0.80	0.6247	10, 482	3.31	**0.0004**	4, 240	10.16	**<0.0001**
Sample date × aldicarb rate	10, 482	4.01	**<0.0001**	10, 482	2.46	**0.0071**	4, 240	0.92	0.4528
Sample date × seed treatment	10, 482	3.35	**0.0003**	10, 482	1.34	0.2043	4, 240	4.84	**0.0009**
Soil texture × aldicarb rate × seed treatment	8, 482	0.81	0.5939	8, 482	1.11	0.3536	8, 240	1.30	0.2459
Sample date × soil texture × aldicarb rate	20, 482	1.13	0.3159	20, 482	0.75	0.7788	8, 240	0.17	0.9949
Sample date × soil texture × seed treatment	20, 482	1.13	0.3164	20, 482	1.33	0.1561	8. 240	0.93	0.4936
Sample date × aldicarb rate × seed treatment	20, 482	2.23	**0.0018**	20, 482	1.59	**0.0500**	8, 240	1.10	0.3671
Sample date × soil texture × aldicarb rate × seed treatment	40, 482	0.96	0.5496	40, 482	0.94	0.5838	16, 240	0.85	0.6289

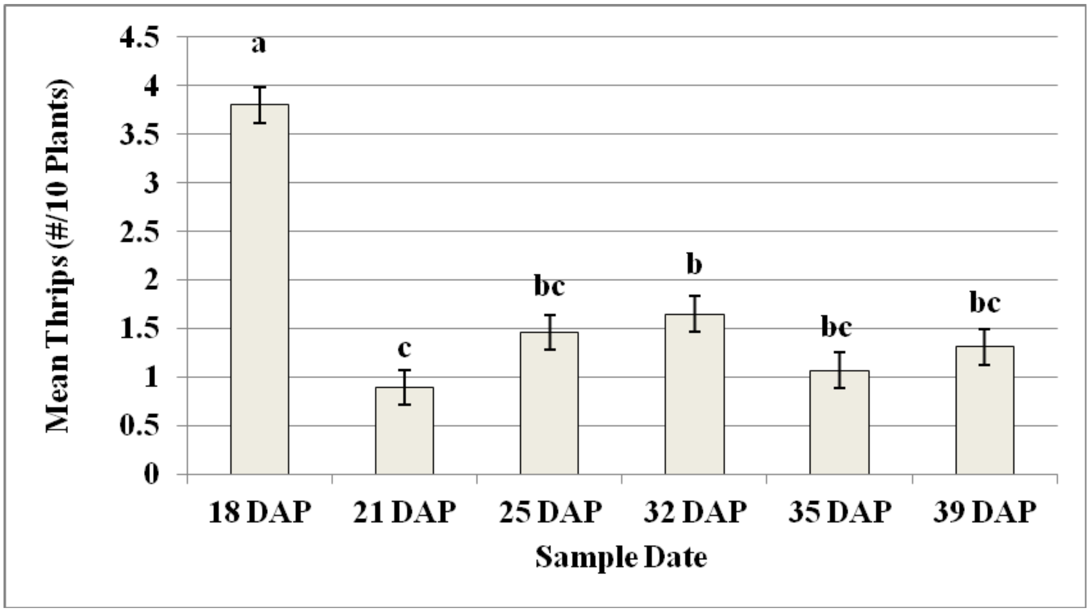
Table C-2. Statistical comparison of treatment effects on population densities of Columbia lance and root-knot nematodes recovered from soil (100 cm^3) in cotton plots and gall ratings to cotton root systems in Florence, SC, 2009.

Management factor combination	Population Densities of Columbia Lance Nematodes			Population Densities of Root-knot Nematodes			Ratings of Galling to Cotton Root Systems		
	df	*F*	*P* > *F*	df	*F*	*P* > *F*	df	*F*	*P* > *F*
Soil texture	2, 240	3.95	**0.0205**	2, 240	24.81	**<0.0001**	2, 78	9.89	**0.0001**
Aldicarb rate	2, 240	1.52	0.2280	2, 240	3.08	**0.0479**	2, 78	4.57	**0.0133**
Seed treatment	2, 240	3.95	0.0800	2, 240	2.50	0.0843	2, 78	0.62	0.5393
Sample date	2, 240	12.13	**<0.0001**	2, 240	285.67	**<0.0001**	-	-	-
Soil texture × aldicarb rate	4, 240	1.46	0.2139	4, 240	3.65	**0.0065**	4, 78	1.25	0.2977
Soil texture × seed treatment	4, 240	1.69	0.1527	4, 240	0.50	0.7370	4, 78	0.31	0.8712
Aldicarb rate × seed treatment	4, 240	1.26	0.2858	4, 240	0.59	0.6680	4, 78	0.69	0.6001
Sample date × soil texture	4, 240	0.79	0.5297	4, 240	9.24	**<0.0001**	-	-	-
Sample date × aldicarb rate	4, 240	0.42	0.7928	4, 240	3.18	**0.0142**	-	-	-
Sample date × seed treatment	4, 240	0.76	0.5501	4, 240	0.19	0.9429	-	-	-
Soil texture × aldicarb rate × seed treatment	8, 240	0.49	0.8629	8, 240	0.98	0.4495	8, 78	0.73	0.5939
Sample date × soil texture × aldicarb rate	8, 240	1.18	0.3087	8, 240	0.90	0.5184	-	-	-
Sample date × soil texture × seed treatment	8, 240	1.38	0.2073	8, 240	0.46	0.8823	-	-	-
Sample date × aldicarb rate × seed treatment	8, 240	0.86	0.5542	8, 240	0.44	0.8961	-	-	-
Sample date × soil texture × aldicarb rate × seed treatment	16, 240	0.62	0.8624	16, 240	0.99	0.4662	-	-	-

Table C-3. Statistical comparison of treatment effects on stand counts, plant heights (cm), and yield (lint kg/ha) of cotton in plots in Florence, SC, 2009.

Management factor combination	Stand Counts			Cotton Plant Heights			Yield		
	df	*F*	*P > F*	df	*F*	*P > F*	df	*F*	*P > F*
Soil texture	2, 78	1.36	0.2634	2, 159	11.44	**<0.0001**	2, 77	32.34	**<0.0001**
Aldicarb rate	2, 78	0.49	0.6151	2, 159	6.36	**0.0022**	2, 77	4.52	**0.0139**
Seed treatment	2, 78	0.44	0.6475	2, 159	5.12	**0.0070**	2, 77	2.27	0.1104
Sample date	-	-	-	1, 159	420.58	**<0.0001**	-	-	-
Soil texture × aldicarb rate	4, 78	0.26	0.9006	4, 159	2.65	**0.0353**	4, 77	0.22	0.9268
Soil texture × seed treatment	4, 78	0.31	0.8728	4, 159	0.90	0.4666	4, 77	0.51	0.7276
Aldicarb rate × seed treatment	4, 78	1.31	0.2751	4, 159	1.05	0.3832	4, 77	0.87	0.4834
Sample date × soil texture	-	-	-	2, 159	12.38	**<0.0001**	-	-	-
Sample date × aldicarb rate	-	-	-	2, 159	2.76	0.0665	-	-	-
Sample date × seed treatment	-	-	-	2, 159	5.05	**0.0075**	-	-	-
Soil texture × aldicarb rate × seed treatment	8, 78	1.73	0.0984	8, 159	0.21	0.9886	8, 77	0.36	0.9406
Sample date × soil texture × aldicarb rate	-	-	-	4, 159	5.15	**0.0006**	-	-	-
Sample date × soil texture × seed treatment	-	-	-	4, 159	2.85	**0.0258**	-	-	-
Sample date × aldicarb rate × seed treatment	-	-	-	4, 159	1.36	0.2511	-	-	-
Sample date × soil texture × aldicarb rate × seed treatment	-	-	-	8, 159	0.83	0.5794	-	-	-

A



B

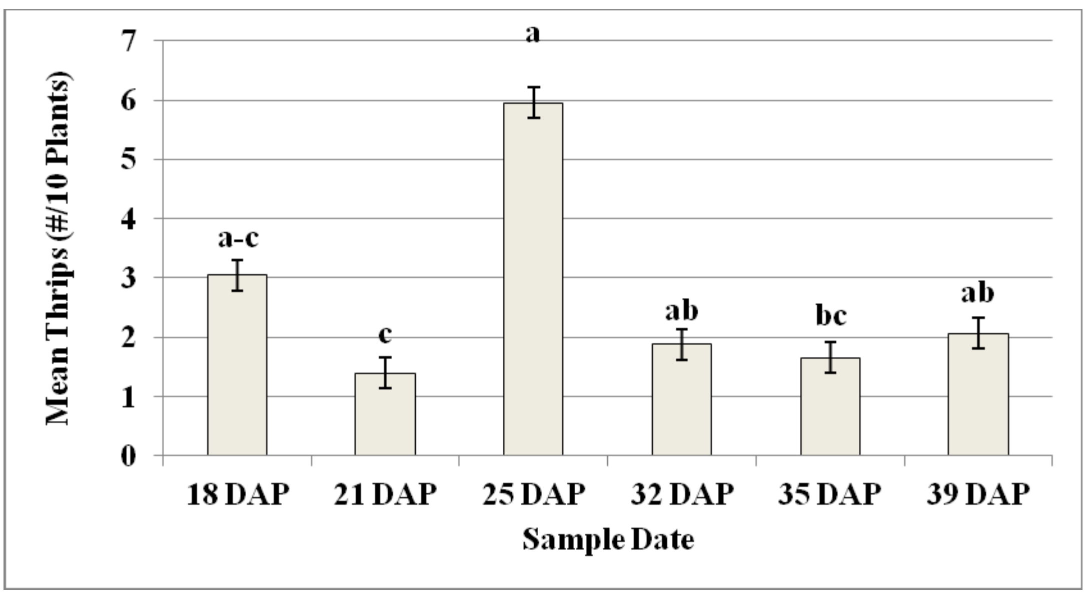
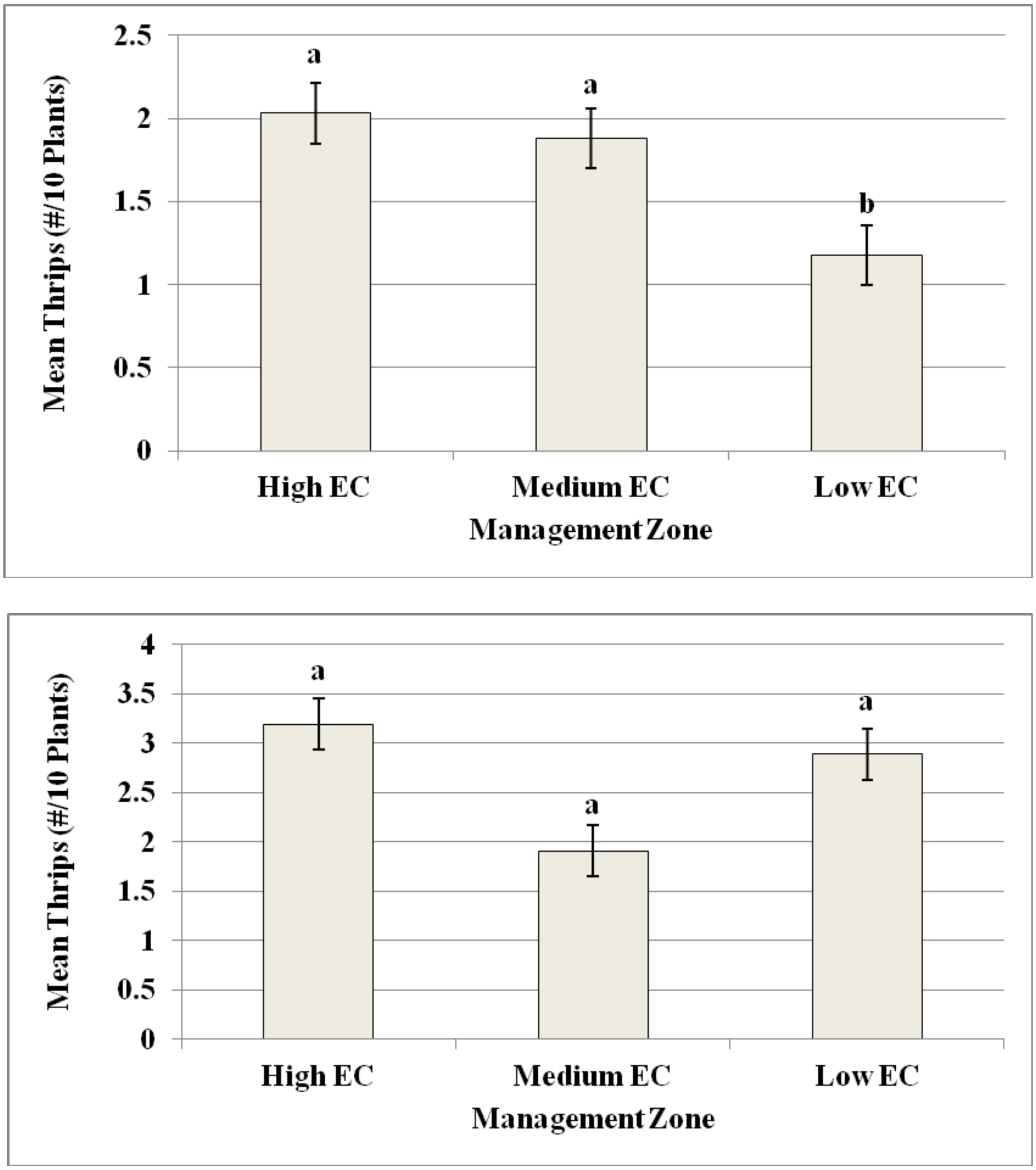


Figure C-1. Effect of sample date on mean population densities of (A) adult and (B) immature thrips in cotton plots in Florence, SC, 2009. Ten plants examined per treatment. Bars with a letter in common across dates are not significantly different, P>0.05, LSD. DAP, days after planting.

A



B

Figure C-2. Effect of soil texture on mean population densities of (A) adult and (B) immature thrips in cotton plots in Florence, SC, 2009. Ten plants examined per treatment. Bars with a letter in common across dates are not significantly different, P>0.05, LSD. EC electrical conductivity.

A

B

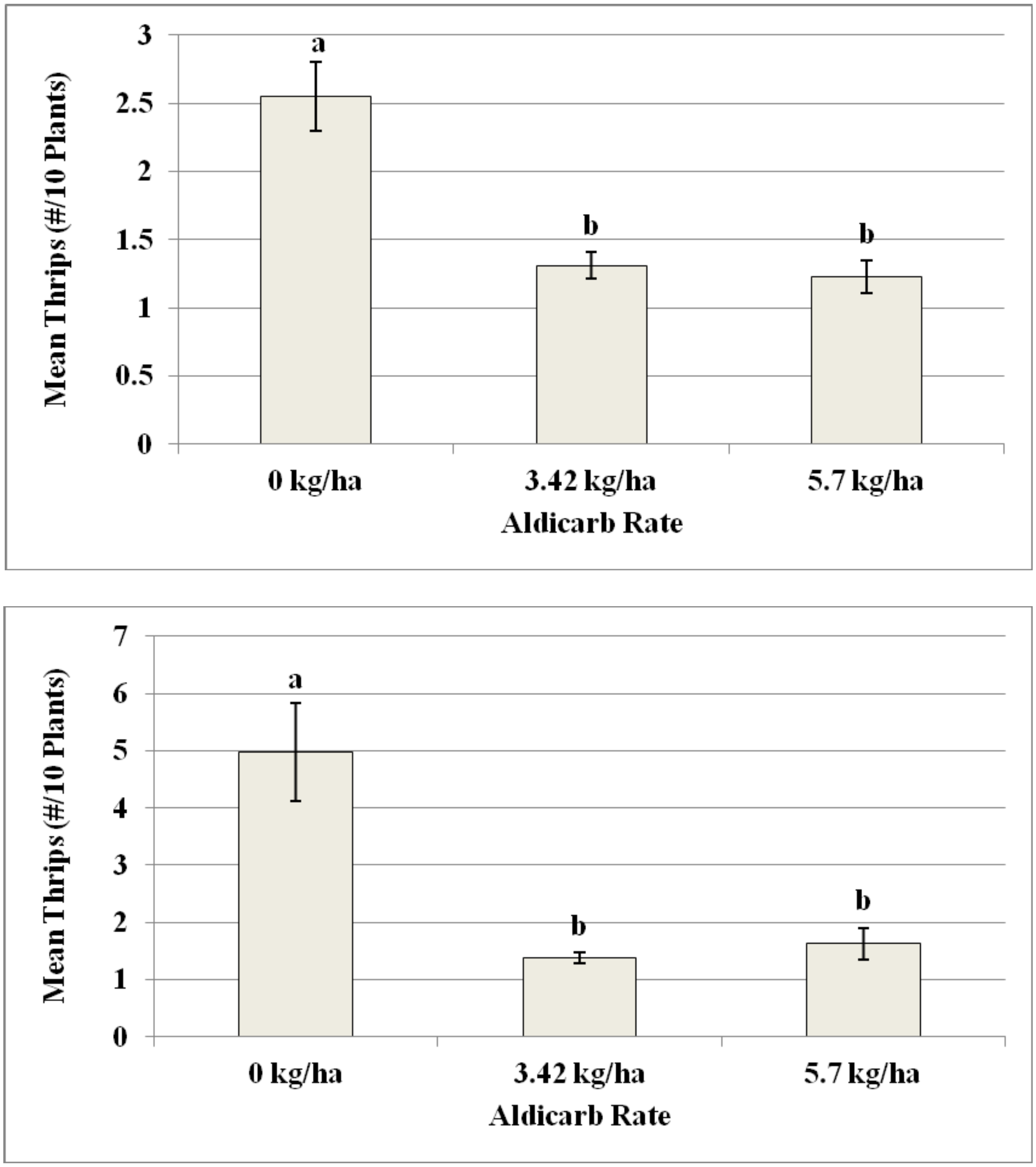
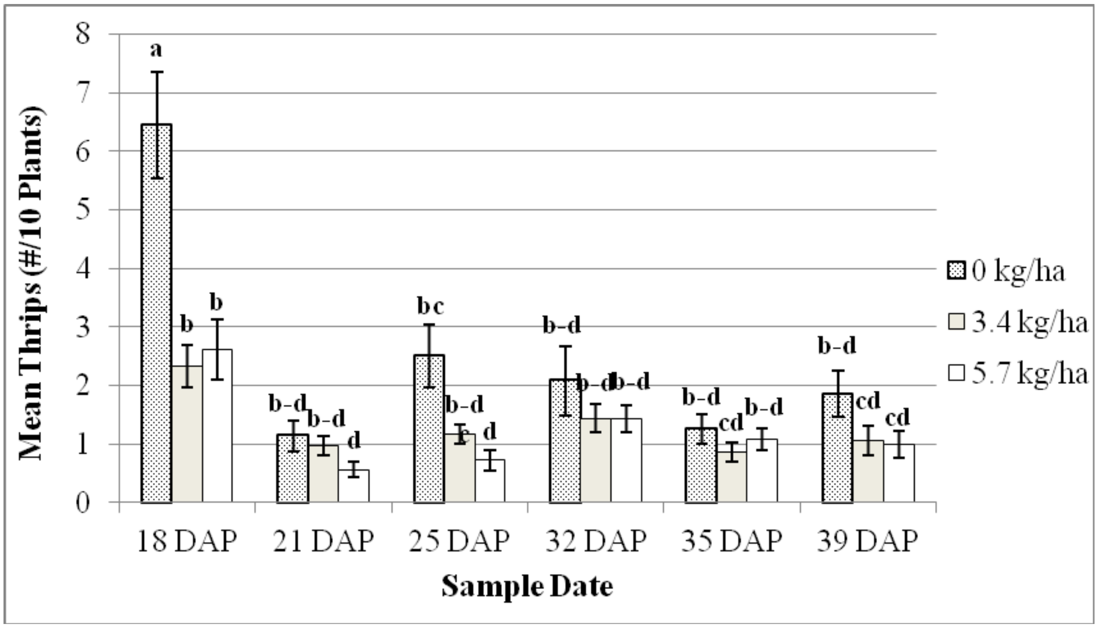


Figure C-3. Effect of aldicarb rate on mean population densities of (A) adult and (B) immature thrips in cotton plots in Florence, SC, 2009. Ten plants examined per treatment. Bars with a letter in common across aldicarb rate are not significantly different, P>0.05, LSD.

A



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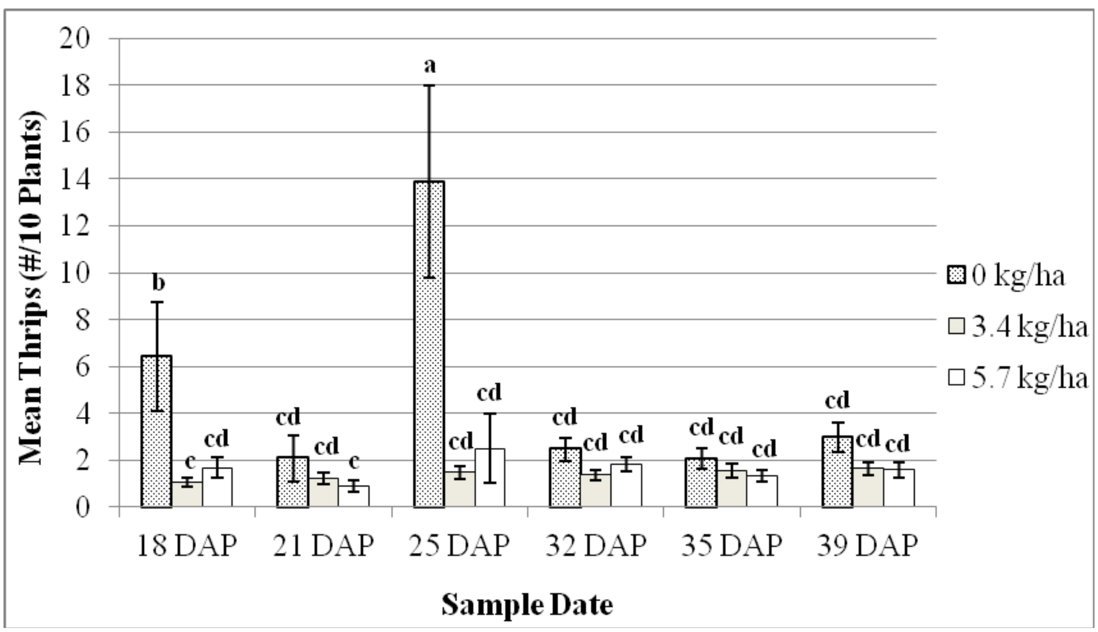


Figure C-4. Effect of sample date and aldicarb rate on mean population densities of (A) adult and (B) immature thrips in cotton plots in Florence, SC, 2009. Ten plants examined per treatment. Bars with a letter in common across sample dates and aldicarb rates are not significantly different, P > 0.05, LSD. DAP, days after plant.

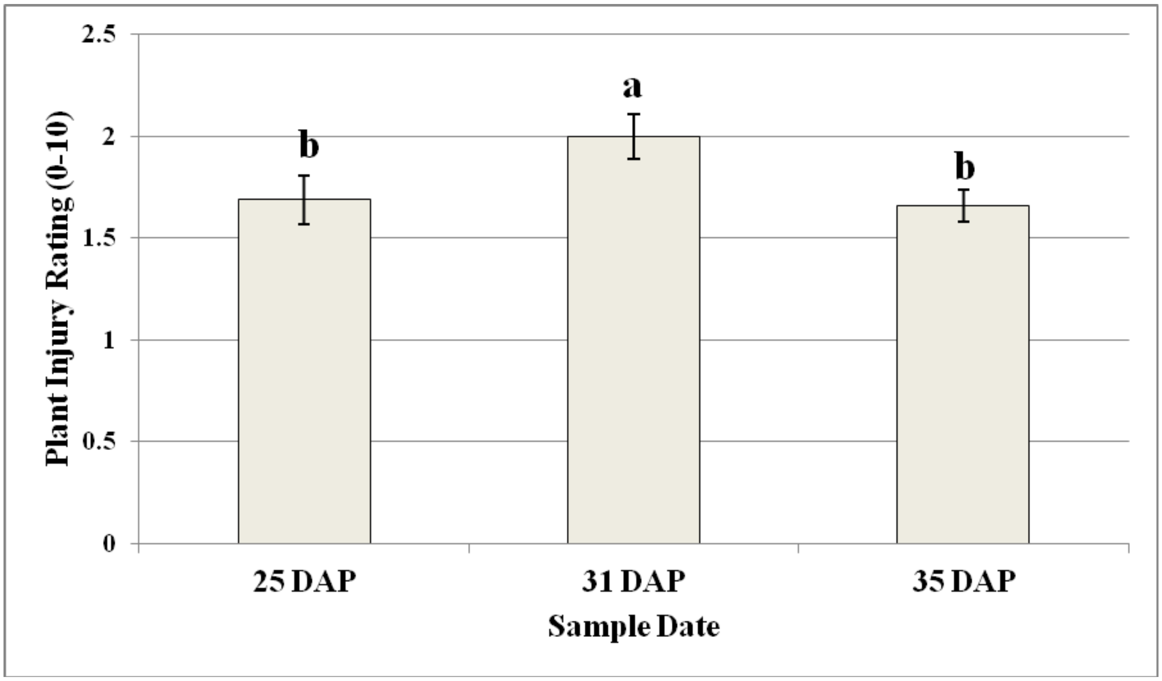


Figure C-5. Effect of sample date on mean ratings of injury to cotton plants by thrips in plots in Florence, SC, 2009. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD. DAP, days after planting.

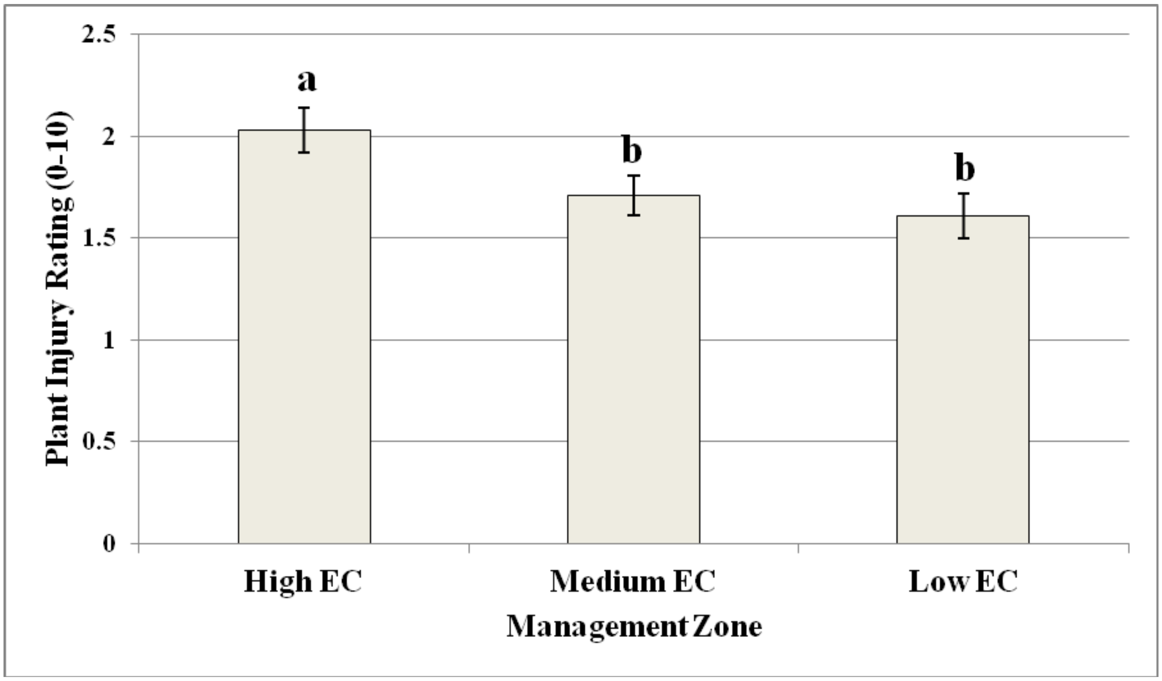


Figure C-6. Effect of soil texture on mean ratings of injury to cotton plants by thrips in plots in Florence, SC, 2009. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD. EC, electrical conductivity.

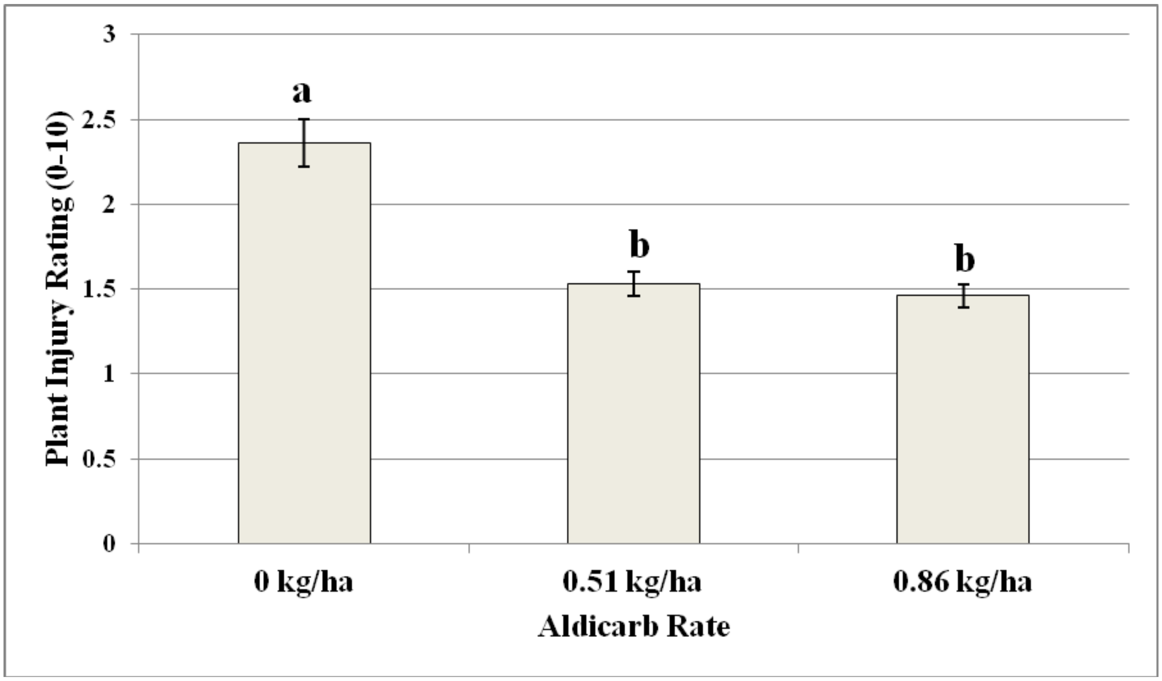


Figure C-7. Effect of aldicarb rate on mean ratings of injury to cotton plants by thrips in plots in Florence, SC, 2009. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD.

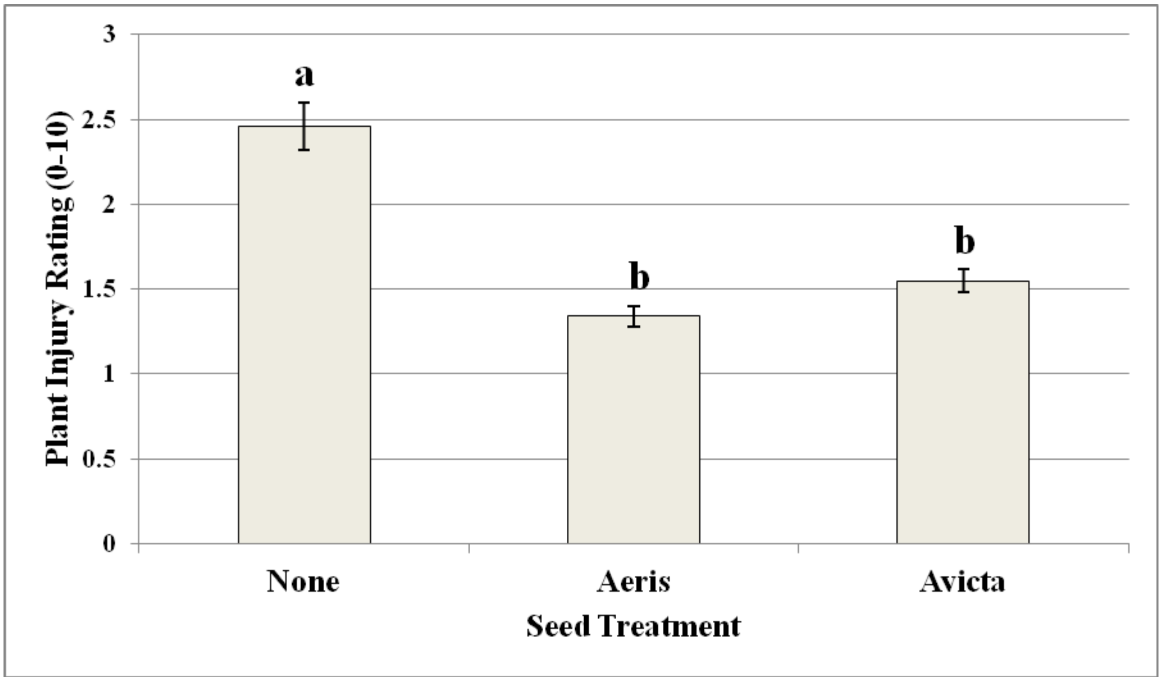


Figure C-8. Effect of seed treatment on mean ratings of injury to cotton plants by thrips in plots in Florence, SC, 2009. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD.

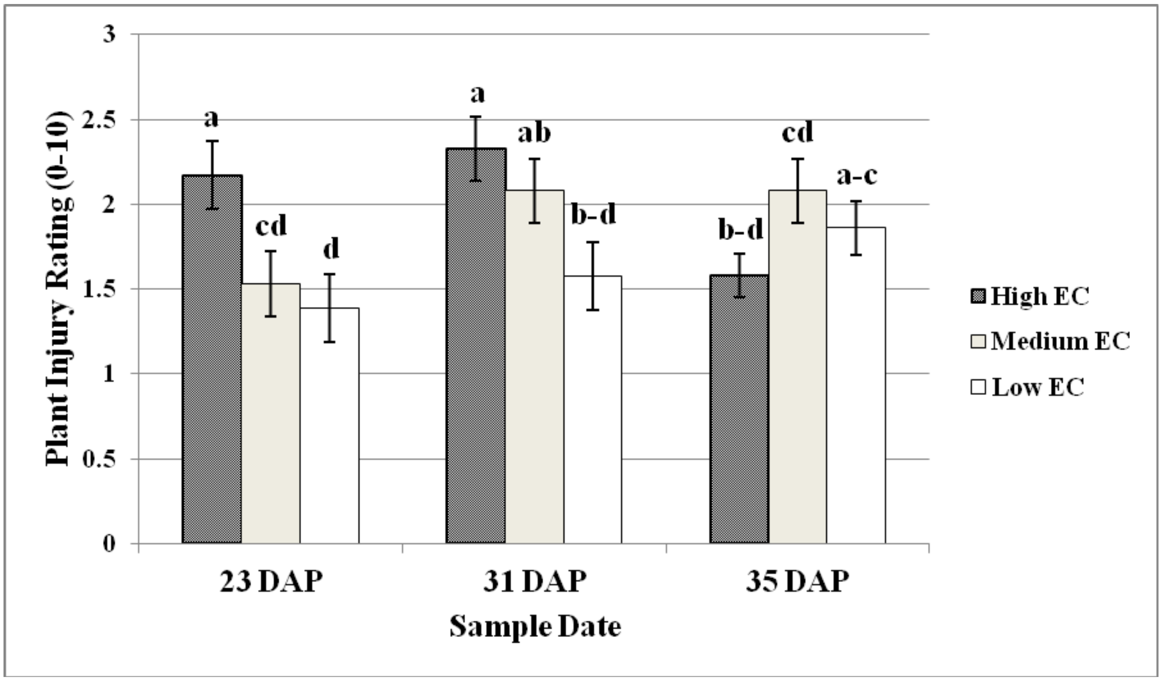


Figure C-9. Effect of sample date and soil texture on mean ratings of injury to cotton plants by thrips in plots in Florence, SC, 2009. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD. EC, electrical conductivity. DAP, days after planting.

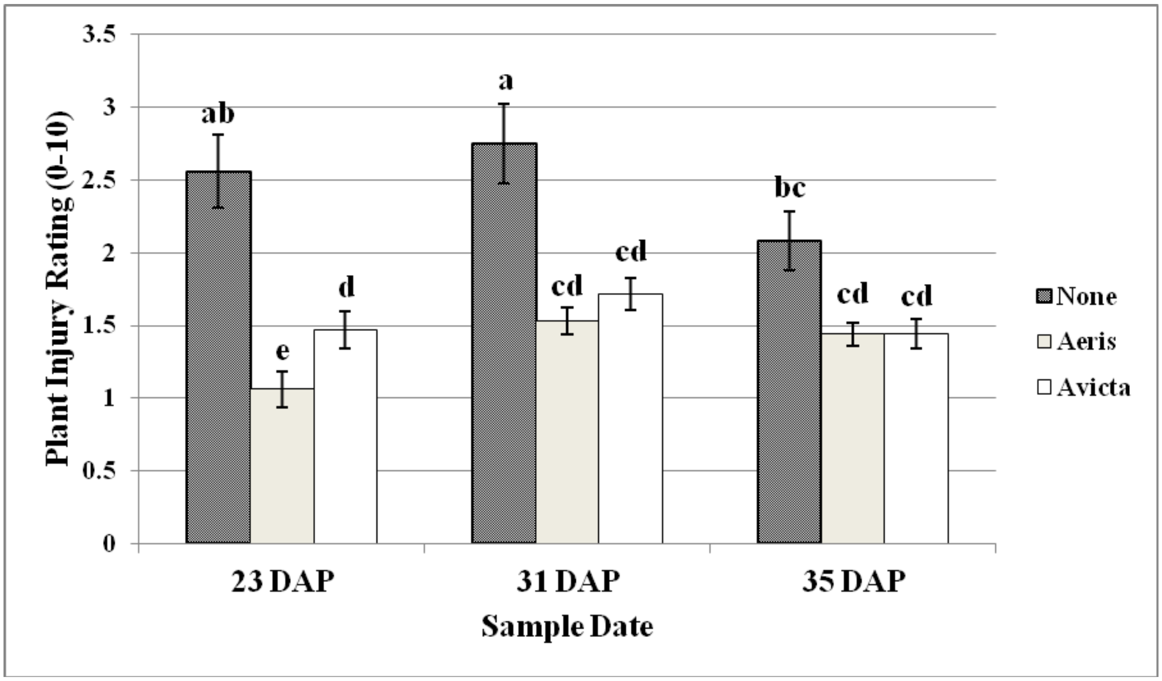


Figure C-10. Effect of sample date and seed treatment on mean ratings of injury to cotton plants by thrips in plots in Florence, SC, 2009. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD. EC, electrical conductivity. DAP, days after planting.

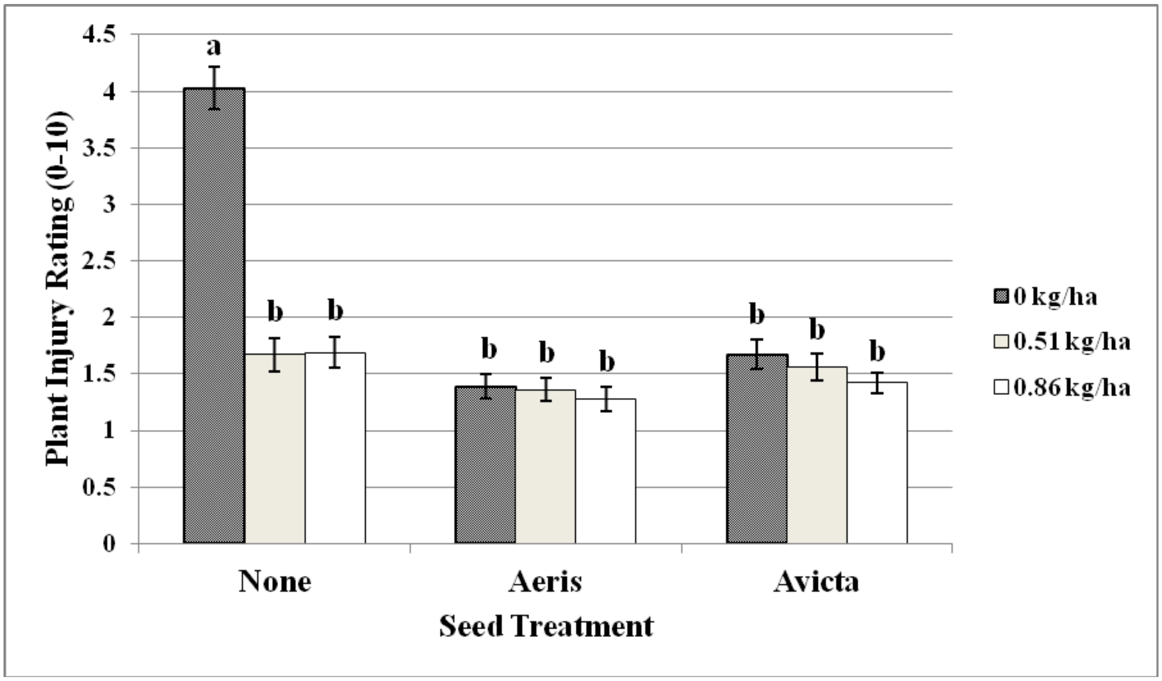


Figure C-11. Effect of aldicarb rate and seed treatment on mean ratings of injury to cotton plants by thrips in plots in Florence, SC, 2009. 0, no injury; 10, dead plants. Bars with a letter in common are not significantly different, P > 0.05, LSD.

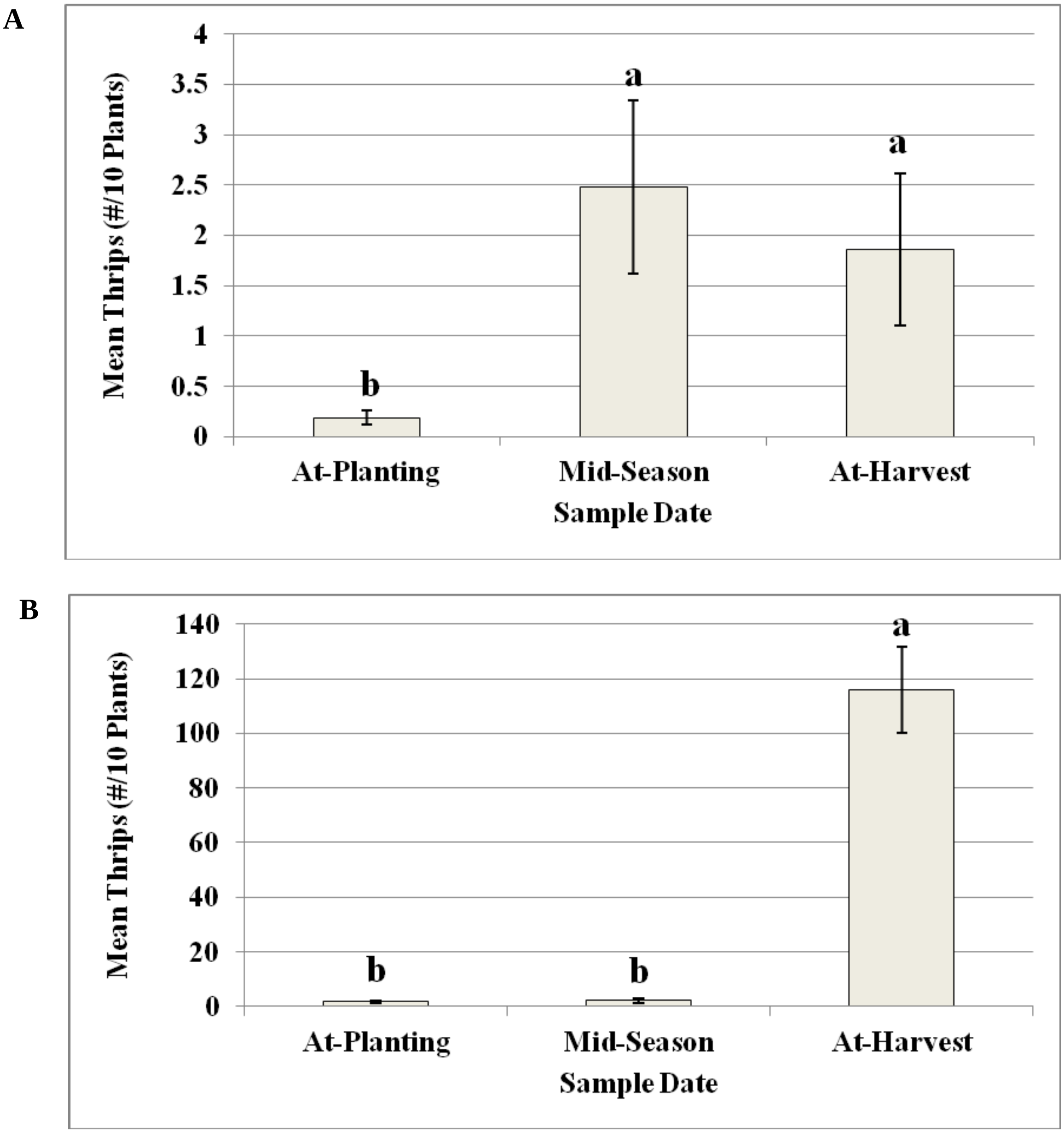
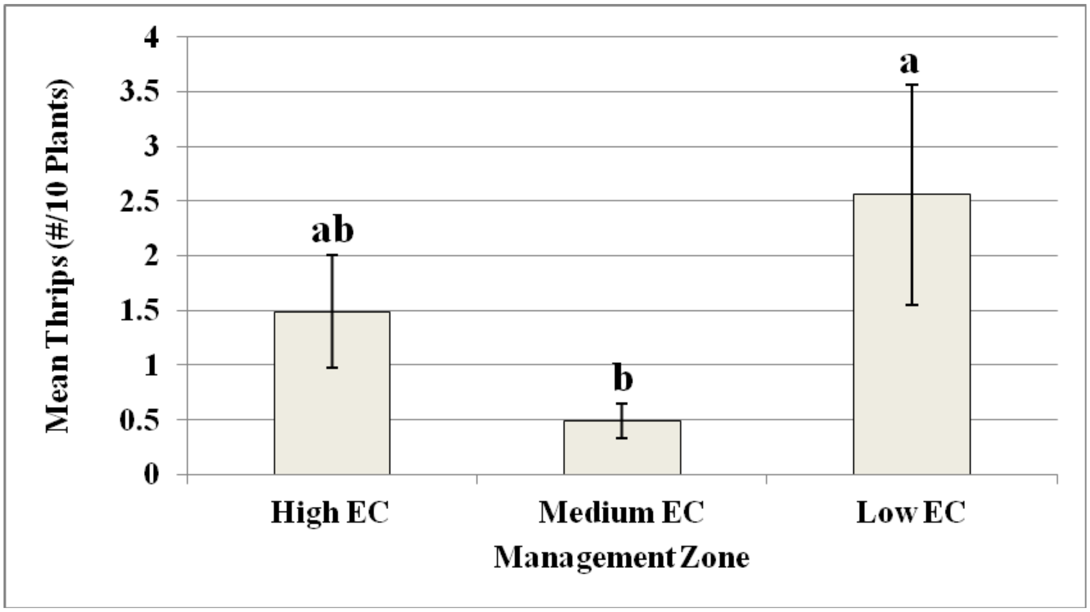


Figure C-12. Effect of sample date on mean population densities of (A) Columbia lance and (B) southern root-knot nematodes recovered from soil (100 cm^3) in cotton plots in Florence, SC, 2009. Bars with a letter in common across dates are not significantly different, P>0.05, LSD. DAP, days after planting.

A



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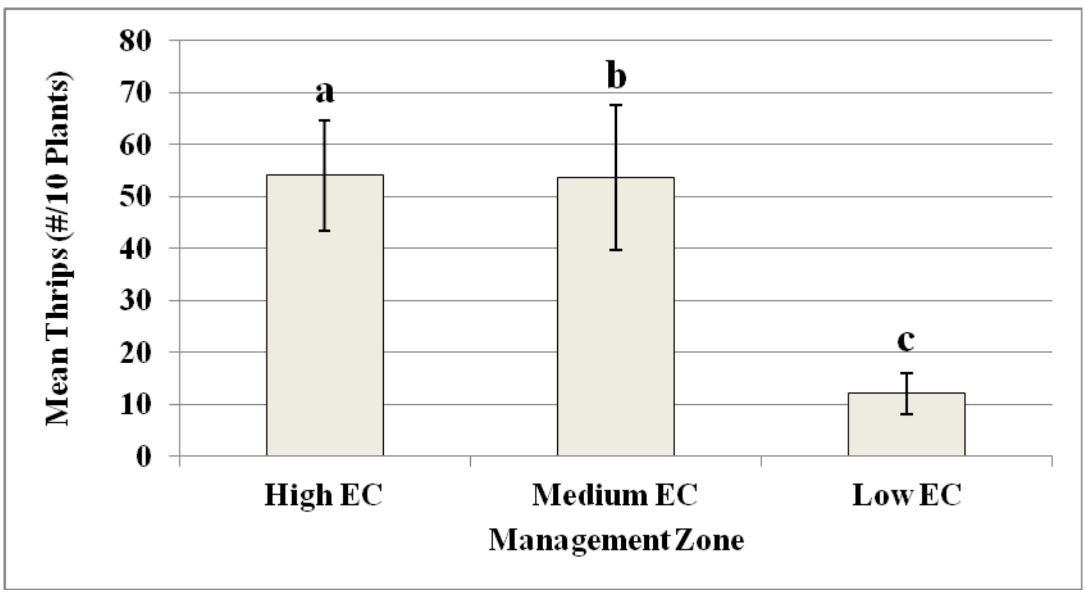

Figure C-13. Effect of soil texture on mean population densities of (A) Columbia lance and (B) southern root-knot nematodes from soil (100 cm^3) in cotton plots in Florence, SC, 2009. Bars with a letter in common across dates are not significantly different, P>0.05, LSD. EC, electrical conductivity.

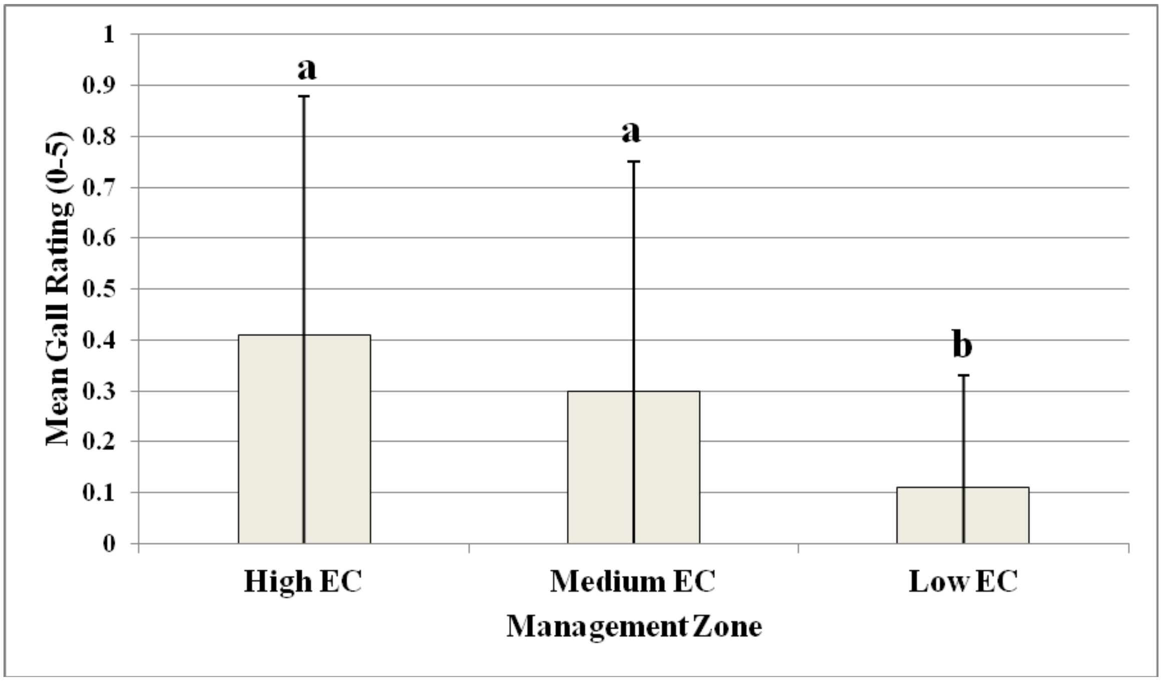

Figure C-14. Effect of soil texture on mean ratings of galling to cotton root systems in plots in Florence, SC, 2009. 0, no galls; 5, severe galling. Bars with a letter in common are not significantly different, P > 0.05, LSD. EC, electrical conductivity.

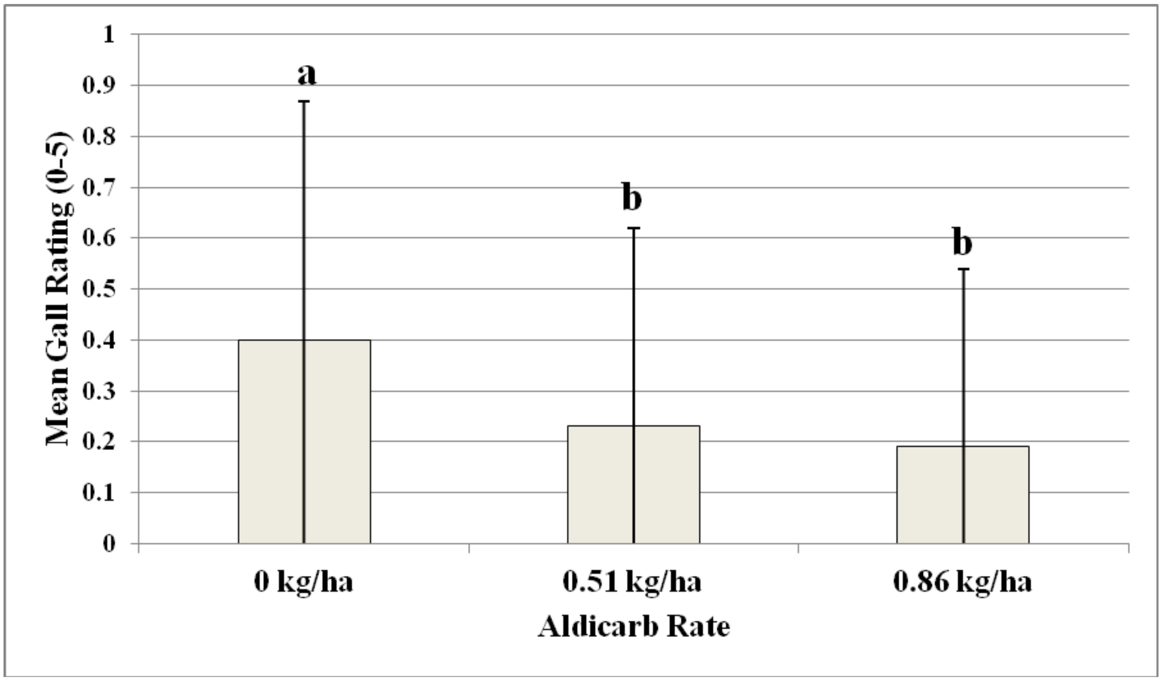

Figure C-15. Effect of aldicarb rate on mean ratings of galling to cotton root systems in plots in Florence, SC, 2009. 0, no galls; 5, severe galling. Bars with a letter in common are not significantly different, P > 0.05, LSD.

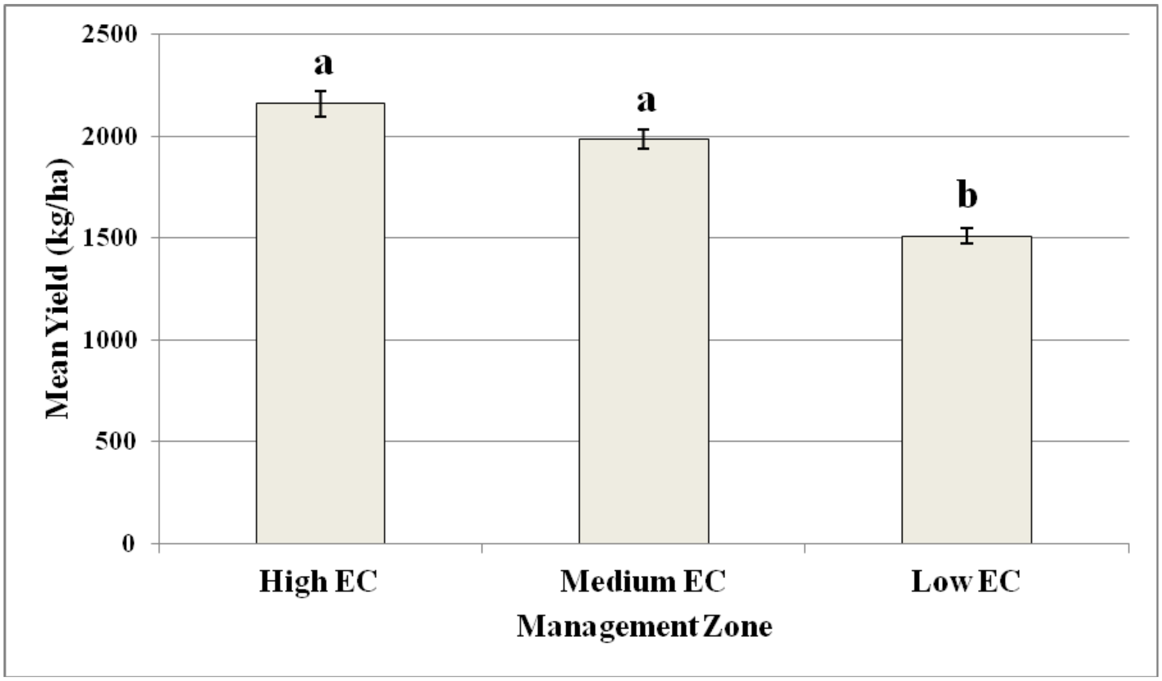

Figure C-16. Effect of soil texture on mean yield (kg/ha) in cotton plots in Florence, SC, 2009. Bars with a letter in common are not significantly different, P > 0.05, LSD. EC, electrical conductivity.

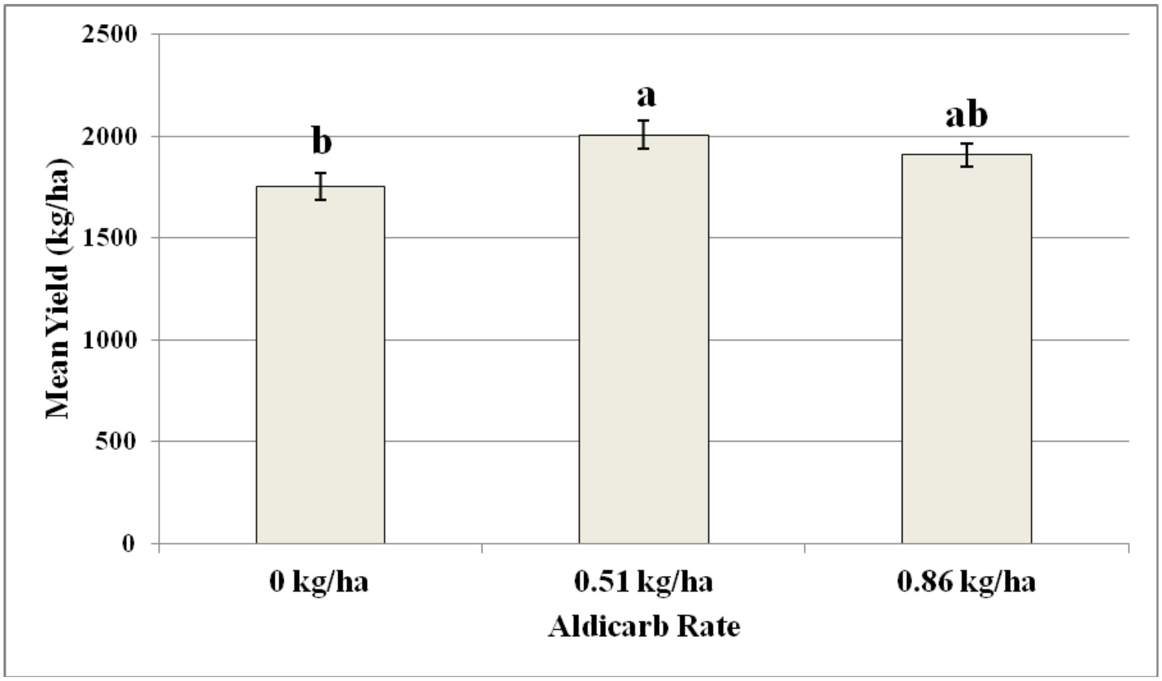

Figure C-17. Effect of aldicarb rate on mean yield (kg/ha) in cotton plots in Florence, SC, 2009. Bars with a letter in common are not significantly different, P > 0.05, LSD.

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