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ARTHROPOD MANAGEMENT

Impact of Thrips Infesting Cotton Seedlings on Cotton Yield Distribution and Maturity

Donald R. Cook*, B. Rogers Leonard, E. Burris, and Jeffrey Gore

ABSTRACT

Studies conducted during 1996 through 1998 showed that the use of an at-planting insecticide significantly reduced densities of thrips (adults and immature) compared to the non-treated control. In these studies the use of an at-planting insecticide also resulted in significantly greater lint yield compared to the non-treated. Additional studies were conducted during 1999 and 2000 to determine how thrips infestations impact yield. Thrips densities were lower during 1999 and 2000 compared to those observed during 1996 through 1998. Fewer differences in thrips densities were observed between treated and non-treated plots. Analysis of yield components using plant mapping procedures did not detect any differences between the treated and non-treated plots and there were no significant differences in total yield observed. Results from these studies and previous studies indicate that environmental conditions might influence cotton response to thrips infestations. This interaction warrants further study.

Several species of thrips commonly infest cotton, *Gossypium hirsutum* (L.), seedlings in the mid-Southern U.S. These include tobacco thrips, *Frankliniella fusca* (Hinds); flower thrips, *Frankliniella tritici* (Fitch); onion thrips, *Thrips tabaci* (Lindeman); soybean thrips, *Neohydatothrips variabilis* (Beach); and western flower thrips, *Frankliniella occidentalis* (Pergande) (Cook et al. 2003).

Severe thrips infestations might result in damage or death of the plant terminal (Reed, 1988; Telford and Hopkins, 1957). Thrips-injured seedlings sometimes display proliferation of monopodial branches (Gaines, 1934). This development of an unusual growth pattern, commonly referred to as "crazy cotton", results from the loss of apical dominance, and often results in delayed crop maturity (Bourland et al., 1992; Dunham and Clark, 1937; Gaines, 1934; Watts, 1937). Thrips injury has delayed crop maturity to harvest by two weeks or more (Bourland et al., 1992; Dunham and Clark, 1937; Gaines, 1934; Watts, 1937). However, other studies have shown no effect on crop maturity (Harp and Turner, 1976; Leigh, 1963). Sadras and Wilson (1998) reported no delays in crop maturity following significant reductions in plant growth resulting from thrips injury during the seedling stage. Also, initial delays in flower bud (square) production have been observed (Davis et al., 1966; Race 1961).

Yield responses to thrips injury and thrips control strategies have varied among previous research. Several researchers have reported yield reductions associated with thrips injury and/or positive yield responses when thrips were controlled (Burris et al., 1994; Davis and Cowan, 1972; Davis et al., 1966; Leigh, 1963; Race, 1961; Watson, 1965; Watts, 1937). Other studies showed no significant effect on seed cotton yields when thrips infesting cotton seedlings were controlled (Beckham, 1970; Cowan et al., 1966; Harp and Turner, 1976; Hopkins and Taft, 1965; Leigh 1963). The objectives of these studies were to evaluate the efficacy of at-planting insecticides across production environments and to evaluate the impact of early-season thrips infestations on maturity and yield of cotton.

MATERIALS AND METHODS

Studies were conducted at the Northeast Research Station, near St. Joseph, LA and at the Macon Ridge Research Station, near Winnsboro, LA during 1996 through 2000. These sites represent two different production environments differing in soil types and localized agricultural landscapes. The test sites at the St. Joseph location consisted of a Commerce silt loam (fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquept) and a Sharkey Clay (very-fine, smectitic, thermic Chromic Epiaquert)

D.R. Cook, Mississippi State University, Delta Research and Extension Center, P.O. Box 197, Stoneville, MS 38776; B.R. Leonard, LSU AgCenter, Department of Entomology, Baton Rouge, LA 70803; E. Burris (retired), LSU AgCenter, Northeast Research Station, St. Joseph, LA 71366; J. Gore, Mississippi State University, Delta Research and Extension Center, Stoneville, MS 38776
*Corresponding author: dcook@drec.msstate.edu

(Anonymous, 2002; Weems et al., 1968) during 1996 through 1998 and a Commerce silt loam during 1998 through 2000. The Winnsboro location consisted of a Gigger silt loam (fine-silty, mixed, thermic, Typic Fragiudalf) (Anonymous, 2002; Martin et al., 1981) during 1996 through 2000. Average annual rainfall at the St. Joseph and Winnsboro locations is 136.96 cm (Weems et al., 1968) and 128.52 cm (Martin et al., 1981), respectively. Cultural practices and integrated pest management strategies recommended by the LSU AgCenter were utilized to maintain plots in a consistent manner within each trial.

Treatments were arranged in a randomized complete block design with four replications during all years. Plots were four rows (1.02 m wide) x 13.72 m in length during 1996 through 1998 and eight rows (1.02 m wide) x 13.72 m in length during 1999 and 2000. An early maturity cotton variety, Stoneville 474, was used in all years, and planted at a seeding rate of 13.1 seed/row m. Insecticides for thrips management included in these studies were acephate (Orthene 80S, Valent USA, Walnut Creek, CA), aldicarb (Bayer CropScience, Research Triangle Park, NC), and a non-treated control. Acephate was applied as a seed treatment at a rate of 2.5 gm AI/kg seed. Aldicarb was applied as an in-furrow granule at planting at a rate of 0.56 kg AI/ha.

Seed treatments were applied to the outer coat of the seed. Acephate (2.5 gm AI/kg.) was mixed with 15 ml of water per kg of seed and applied to 4.54 kg of cottonseed in a plastic bag. The bag containing treated seed was agitated vigorously to evenly distribute the insecticide: water solution on the seed. The seeds were allowed to dry and placed in a clean bag before planting. Each year 4.54 kg of cottonseed was treated with acephate prior to planting and this treated seed was used to plant acephate-treated plots at both locations.

At both locations, cottonseed were planted with a row crop planter (John Deere, Inc. Moline, IL) equipped with 25.4-cm seed cone units (Almaco, Nevada, IA) mounted to replace the standard seed hoppers. At the St. Joseph location, granular in-furrow treatments were applied with 20.32-cm belt cone applicators (Almaco, Nevada, IA) mounted to replace the standard granular applicators. At the Winnsboro location, granular in-furrow treatments were applied with standard granular applicators.

Planting dates, crop emergence dates, and soil temperatures on dates of planting are detailed in Table 1. Mean heat unit accumulation from planting until harvest across locations and years for 1996 through 1998 and 1999 through 2000 is illustrated in Figs. 1 and 2. Heat units (HU) were calculated as: HU = [(maximum daily temperature + minimum daily temperature)/2] – 15.5, where 15.5°C (60°F) is the minimum adequate temperature for cotton plant development (Supak, 1984).

Table 1. List of planting dates, emergence dates, soil temperatures at planting, and dates of mechanical harvest

Year	Location	Soil Type	Planting Date	Emergence Date	Soil Temperature at Planting[z]	Date of Mechanical Harvest
1996	St. Joseph	Commerce Silt Loam	7 May	13 May	25.6°C	8 October
	St. Joseph	Sharkey Clay	6 May	13 May	26.1°C	8 October
	Winnsboro	Gigger Silt Loam	7 May	13 May	21.7°C	10 October
1997	St. Joseph	Commerce Silt Loam	6 May	13 May	20.0°C	2 October
	St. Joseph	Sharkey Clay	5 May	12 May	20.6°C	2 October
	Winnsboro	Gigger Silt Loam	7 May	13 May	16.1°C	20 October
1998	St. Joseph	Commerce Silt Loam	5 May	8 May	25.0°C	17 September
	St. Joseph	Sharkey Clay	6 May	11 May	21.1°C	5 October
	Winnsboro	Gigger Silt Loam	7 May	12 May	16.7°C	25 September
1999	St. Joseph	Commerce Silt Loam	7 May	13 May	21.7°C	4 October
	Winnsboro	Gigger Silt Loam	6 May	12 May	20.0°C	17 September
2000	St. Joseph	Commerce Silt Loam	10 May	18 May	24.4°C	15 September
	Winnsboro	Gigger Silt Loam	11 May	18 May	21.7°C	25 September

[z] At at a depth of 5 cm. Soil temperature data provided by the Southern Regional Climate Center, Louisiana State University, Baton Rouge, LA.

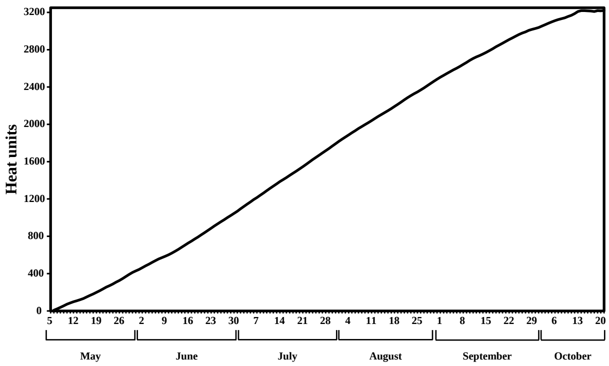

Figure 1. Mean heat unit accumulation from planting until the end of harvest at Winnsboro and St. Joseph, LA during 1996 through 1998.

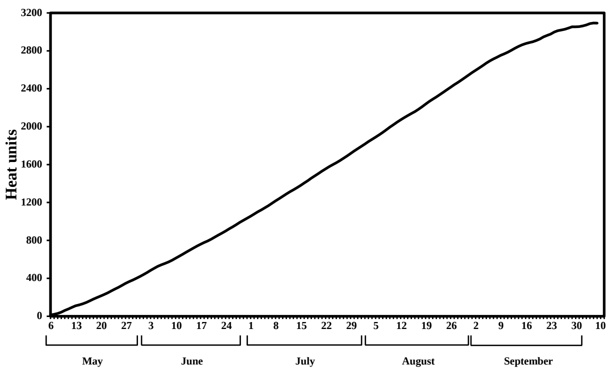

Figure 2. Mean heat unit accumulation from planting until the end of harvest at Winnsboro and St. Joseph, LA during 1999 and 2000.

Thrips densities were determined by randomly selecting five plants per plot at 7, 14, 21, and 28 d after emergence. Plant samples were processed using whole plant washing procedures to remove insects (Burris et al., 1990). Insects were counted with the aid of a dissecting microscope. Thrips population density data for individual sample dates were pooled to determine mean treatment effects across the entire sampling period.

During 1999 and 2000 plant density and number of plants with aborted terminals were recorded from rows five and six of each plot after the plots had been defoliated. Rows three and four of each plot were mechanically harvested with a spindle-type cotton harvester (John Deere, Inc., Moline, IL) in all years. Lint percent and lint yield of each plot were determined from a seed cotton sample collected during mechanical harvest operations and ginned using a 10-saw laboratory cotton gin. Dates of mechanical harvest are listed in Table 1.

Crop earliness was evaluated by hand harvesting all open bolls weekly within a 1-m section of row in each plot during 1998 through 2000. Boll samples were separated according to plot and week of harvest and ginned to separate the seed and lint with a 10-saw laboratory cotton gin.

Yield distribution and fruiting patterns at each location were determined by plant mapping all the plants within 1 m of row (approximately 11 to 12 plants) in each plot after all bolls were open and plots had been defoliated during 1999 and 2000 using methods similar to those described by Jenkins et al. (1990). The first mainstem node above the cotyledonary node was designated as mainstem node one. Yield distribution data from plant mapping procedures were partitioned into fruiting zones, which are illustrated in Fig. 3. These included fruiting zone 1 position 1 (first fruiting positions on mainstem nodes 8 and below), fruiting zone 1 position 2 (second fruiting positions on mainstem nodes 8 and below), fruiting zone 1 position 3 (third and beyond fruiting positions on mainstem nodes 8 and below), zone 2 position 1 (first fruiting positions on mainstem nodes 9 through 12), fruiting zone 2 position 2 (second fruiting positions on mainstem nodes 9 through 12), fruiting zone 2 position 3 (third and beyond fruiting positions on mainstem nodes 9 through 12), zone 3 position 1 (first fruiting positions on mainstem nodes 13 and above), fruiting zone 3 position 2 (second fruiting positions on mainstem nodes 13 and above), fruiting zone 3 position 3(third and beyond fruiting positions on mainstem nodes 13 and above), and the vegetative fruiting zone (all fruiting positions on vegetative branches).

Mean thrips density, lint yield from mechanical harvest, plant density, numbers of plants with damaged terminals, percentage of plants with damaged terminals, boll distribution, boll retention, and mainstem location of first fruiting branch were subjected to analysis of variance using the mixed procedure (SAS Institute, 2010). Type III statistics were used to test all possible fixed effects (at-planting insecticide treatment) or interactions among the fixed effects. Random effects were years, locations, and replications nested with years by location (Blouin et al., 2011). Years and locations were considered as environmental or random as effects; this allowed inferences about treatments to be made over a range of environments (Blouin et al. 2011; Carmer et al., 1989). Orthogonal contrasts were used to compare means from insecticide-treated (acephate + aldicarb) plots to the non-treated plots. Crop earliness measurements (open bolls/m and lint/m) and boll weight were analyzed using procedures similar to those described above, except that week of harvest was included as a repeated measure to allow comparisons over time (Blouin et al., 2004). Least square means were calculated and mean separation ($P \leq 0.05$) was produced using PDMIX800 in SAS (SAS Institute, 2010), which is a macro for converting mean separation output to letter groupings (Saxton, 1998).

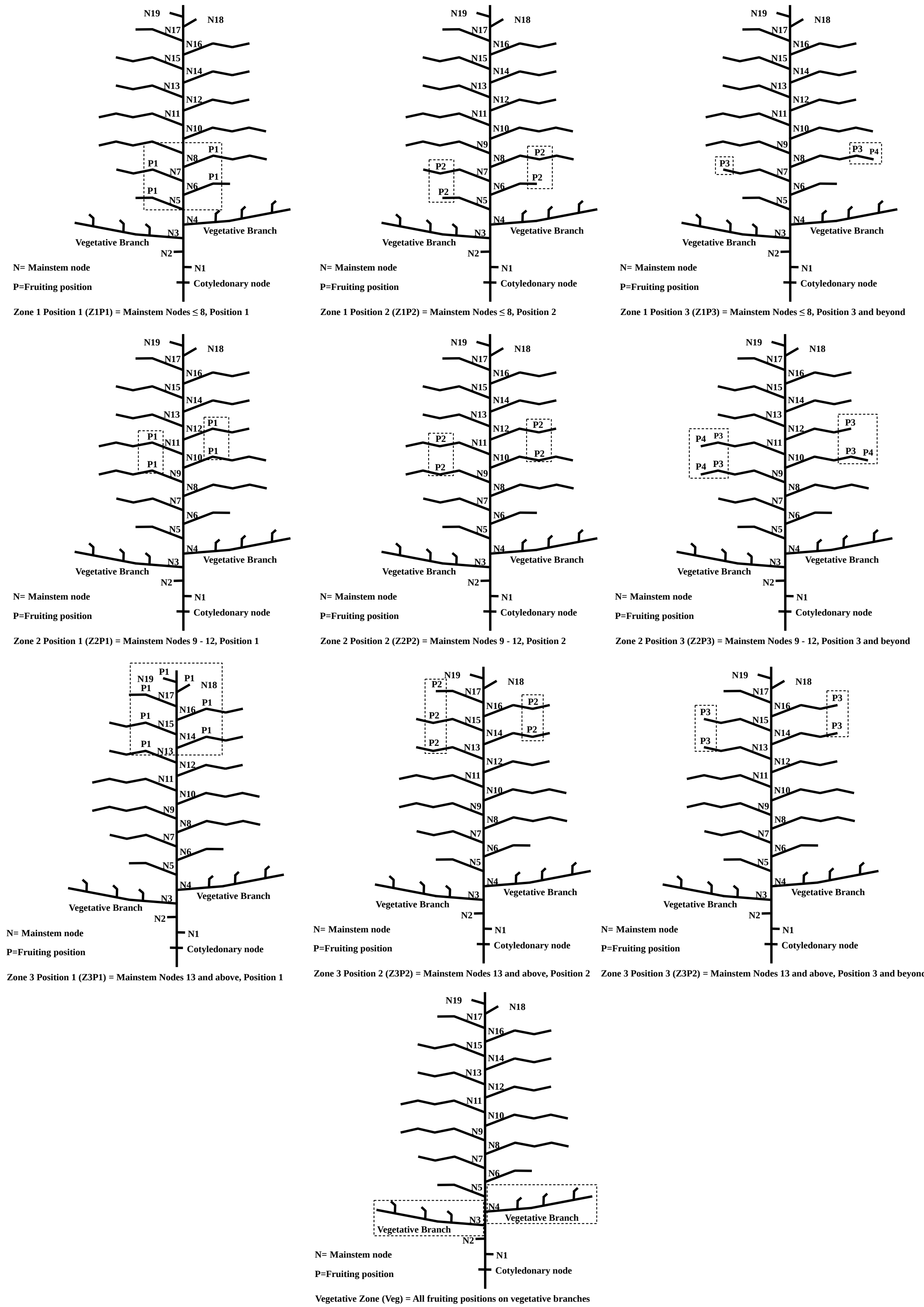

Figure 3. Cotton plant schematics detailing partitioning of yield at Winnsboro and St. Joseph, LA during 1999 and 2000.

RESULTS AND DISCUSSION

Thrips Densities and Yield, 1996 Through 1998. During 1996 through 1998, the use of an at-planting insecticide significantly reduced densities of thrips adults during weeks 1 through 4 after emergence and the mean across weeks (week 1 T = -6.45, df = 70, P < 0.01; week 2 T = -4.24, df = 70, P < 0.01; week 3 T = -2.98, df = 70, P < 0.01; week 4; T = -2.22, df = 70, P < 0.01; mean T = -7.05, df = 70, P < 0.01) compared to the non-treated control (Table 2). During weeks 1 and 3 and the mean across weeks plots treated with aldicarb had significantly fewer thrips adults than plots treated with acephate. The use of an at-planting insecticide significantly reduced densities of thrips larvae during weeks 1 through 4 after emergence and the mean across weeks (week 1 T = -4.79, df = 70, P < 0.01; week 2 T = -7.98, df = 70, P < 0.01; week 3 T = -5.15, df = 70, P < 0.01; week 4; T = -3.52, df = 70, P < 0.01; mean T = -7.97, df = 70, P < 0.01) compared to the non-treated control (Table 2). During weeks 2 through 4 and the mean across weeks, aldicarb provided significantly greater control of thrips larvae than acephate. The addition of an at-planting insecticide resulted in significantly greater lint yield compared to the non-treated control (T = 3.45, df = 69, P < 0.01) (Table 2).

Thrips Densities, Plant Growth Parameters, and Yield, 1999 and 2000. After observing significant impacts on cotton yield from thrips infestations during 1996 through 1998 additional studies were conducted to try to determine how thrips infestations impact yield by examining crop maturity during 1998 through 2000, yield components, and yield distribution during 1999 and 2000. During 1999 and 2000, the addition of an at-planting insecticide significantly reduced densities of thrips adults during weeks 1 and 2 after emergence and the mean across weeks (week 1 T = 2.71, df = 30, P = 0.01; week 2 T = 2.43, df = 30, P = 0.02; mean T = 3.67, df = 30, P < 0.01) compared to the non-treated control (Table 3). Also during week 1 and 2 and the mean across weeks, aldicarb provided significantly better control of thrips adults compared to acephate. The addition of an at-planting insecticide significantly reduced densities of thrips larvae during weeks 1, 2, and 3 after emergence and the mean across weeks (week 1 T = 2.94, df = 30, P < 0.01; week 2 T = 3.12, df = 30, P < 0.01; week 3 T = 3.07, df = 30, P < 0.01; mean T = 4.57, df = 0, P < 0.01) compared to the non-treated control (Table 3). The use of an at-planting insecticide did not significantly influence main stem node location of the first fruiting branch (T = 1.65, df = 508, P = 0.10), total nodes per plant (T = 0.06, df = 508, P = 0.96), plant density (T = -1.11, df = 30, P = 0.28), numbers of plant with damaged terminals (T = -0.17, df = 30, P = 0.87), percentage of plants with damaged terminals (T = -0.15, df = 30, P = 0.88), or lint yield (T = -1.90, df = 30, P = 0.07) (Table 4).

Table 2. Impact of at-planting insecticides on densities of thrips adults and thrips larvae, and lint yield during 1996-1998

Treatment	Adults Plant^{-1} Week 1	Adults Plant^{-1} Week 2	Adults Plant^{-1} Week 3	Adults Plant^{-1} Week 4	Adults Plant^{-1} Mean	Larvae Plant^{-1} Week 1	Larvae Plant^{-1} Week 2	Larvae Plant^{-1} Week 3	Larvae Plant^{-1} Week 4	Larvae Plant^{-1} Mean	Lint Yield kg/ha
Acephate	1.0b	1.8a	1.3ab	0.7b	1.2b	1.2b	3.8b	5.4b	3.2a	3.4b	1480a
Aldicarb	0.6c	1.2b	1.0b	0.6b	0.8c	0.8b	1.7c	2.6c	1.4b	1.6c	1464a
Non-treated	2.5a	1.9a	1.6a	1.0a	1.7a	15.0a	13.5a	7.7a	2.5a	10.0a	1383b
F	42.68	9.13	6.40	5.39	38.83	41.82	78.5	16.64	7.21	72.52	5.91
df	2,70	2,70	2,70	2,70	2,70	2,70	2,70	2,70	2,70	2,70	2,68
P>F	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Non-treated vs. Treated[z]											
T	-6.45	-4.24	-2.98	-2.22	-7.05	-4.79	-7.98	-5.15	-3.52	-7.97	3.45
df	70	70	70	70	70	70	70	70	70	70	69
P>F	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Means within columns followed by a common letter are not significantly different (*P* = 0.05).

[z] Orthogonal contrasts *P* = 0.05, Treated = All insecticide treatments.

Table 3. Impact of at-planting insecticides on densities of thrips adults and thrips larvae, lint yield, plant density, damaged terminals, and percent damaged terminals during 1999-2000

Treatment	Adults Plant^{-1} Week 1	Adults Plant^{-1} Week 2	Adults Plant^{-1} Week 3	Adults Plant^{-1} Week 4	Adults Plant^{-1} Mean	Larvae Plant^{-1} Week 1	Larvae Plant^{-1} Week 2	Larvae Plant^{-1} Week 3	Larvae Plant^{-1} Week 4	Larvae Plant^{-1} Mean
Acephate	0.8ab	0.7ab	0.5	0.5	0.6b	1.4b	1.5b	1.2b	0.9	1 .2b
Aldicarb	0.4b	0.4b	0.3	0.5	0.4c	0.6b	1.1b	0.7b	0.7	0.8b
Non-treated	1.1a	0.9a	0.6	0.6	0.8a	3.8a	2.7a	2.1a	1.1	2.4a
F	5.19	3.93	2.48	0.20	8.82	4.61	5.15	5.28	1.46	11.27
df	2,30	2,30	2,30	2,30	2,30	2,30	2,30	2,30	2,30	2,30
P>F	0.01	0.03	0.10	0.82	<0.01	0.02	0.01	0.01	0.25	<0.01
Non-treated vs. Treated[z]										
T	2.71	2.43	1.93	0.62	3.67	2.94	3.12	3.07	1.52	4.57
df	30	30	30	30	30	30	30	30	30	30
P>F	0.01	0.02	0.06	0.54	<0.01	<0.01	<0.01	<0.01	0.14	<0.01

Means within columns followed by a common letter are not significantly different (*P* = 0.05).

[z] Orthogonal contrasts *P* = 0.05, Treated = All insecticide treatments.

Table 4. Impact of at-planting insecticides on densities of thrips adults and thrips larvae, lint yield, plant density, damaged terminals, and percent damaged terminals during 1999-2000

Treatment / Year	Main Stem Node Location of First Fruiting Branch	Total Nodes per Plant	Plant Density Plants ha^{-1}	Damaged Terminals ha^{-1}	Percent Damaged Terminals	Lint Yield Kg ha^{-1}
Acephate	6.9	16.5	104,470	9,254a	8.9a	775
Aldicarb	6.7	16.4	104,037	4,741b	4.7b	761
Non-treated	7.0	16.5	101,842	6,800ab	6.6ab	691
F	2.22	0.08	0.63	5.54	4.95	1.86
df	2,508	2,508	2,30	2,30	2,30	2,30
P>F	0.11	0.93	0.54	<0.01	0.01	0.17
Non-treated vs. Treated[z]						
T	1.65	0.06	-1.11	-0.17	-0.15	-1.90
df	508	508	30	30	30	30
P>F	0.10	0.96	0.28	0.87	0.88	0.07

Means within columns followed by a common letter are not significantly different (*P* = 0.05).

[z] Orthogonal contrasts *P* = 0.05, Treated = All insecticide treatments.

Crop Maturity and Yield Distribution. The application of an at-planting insecticide did not significantly influence the number of open bolls (F = 0.14, df =12,444, P = 0.99) during weeks 1 through 7 of harvest (Fig. 4). A significant effect of week (F = 38.97, df = 6,444, P < 0.01) was observed while the effect of at-planting insecticide treatment was not significant (F = 0.14, df = 2,444, P = 0.99) (data for week and at-planting insecticide treatment not shown). Also, the application of an at-planting insecticide did not significantly influence boll weight (F = 0.33, df = 12,444, P = 0.72) during weeks 1 through 7 of harvest (Fig. 5). A significant effect of week (F = 7.1, df = 6,444, P < 0.01) was observed whereas the effect of at-planting insecticide treatment was not significant (F = 0.47, df = 2,444, P = 0.62) (data for week and at-planting insecticide treatment not shown). The application of an at-planting insecticide did not significantly influence lint yield (F = 0.25, df = 12,444, P = 0.99) during weeks 1 through 7 of harvest (Fig. 6). A significant effect of week (F = 43.00, df = 6,444, P < 0.01) was observed whereas the effect of at-planting insecticide treatment was not significant (F = 0.34, df = 2,444, P = 0.71) (data for week and at-planting insecticide treatment not shown).

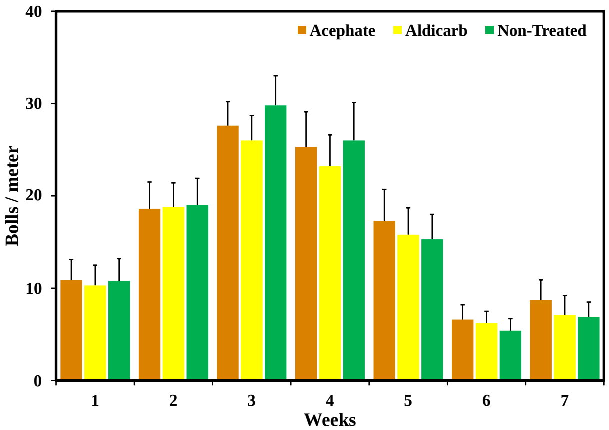

Figure 4. Influence of at-planting insecticides on number of open bolls over time at Winnsboro and St. Joseph, LA during 1998 through 2000.

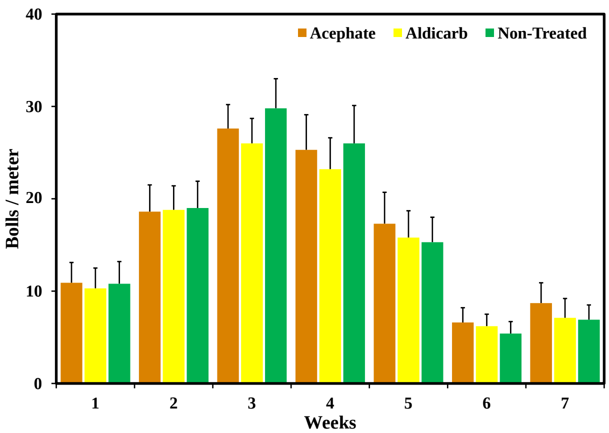

Figure 5. Influence of at-planting insecticides on boll weight over time at Winnsboro and St. Joseph, LA during 1998 through 2000.

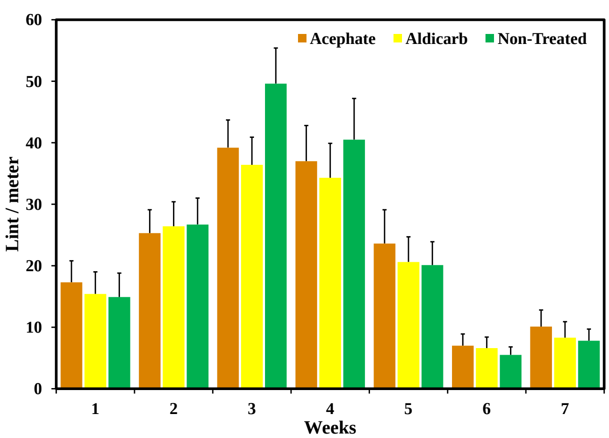

Figure 6. Influence of at-planting insecticides on lint yield over time at Winnsboro and St. Joseph, LA during 1998 through 2000.

The application of an at-planting insecticide did not significantly influence the number of bolls present within any fruiting zones, except the monopodial zone (Table 5). Plots that received an at-planting insecticide application had significantly more bolls at monopodial zone (T = -2.36, df = 30, P = 0.02) compared the non-treated plots. The application of an at-planting insecticide did not significantly influence boll retention within any of the fruiting zones (Table 6).

The application of an at-planting insecticide significantly reduced densities of thrips adult and thrips larvae during 1996 through 1998, with few exceptions. During 1999 and 2000, the at-planting insecticide treatments resulted in lower densities of thrips adults and larvae compared to the non-treated less often than during 1996 through 1998. Many studies have reported thrips density reduction with the use of at-planting insecticides (Beckam, 1970; Cowan et al., 1966; Davis et al., 1966; Harp and Turner, 1976; Leigh, 1963; Race 1961; Watson 1965). During 1999 and 2000, thrips densities were considerably lower than that observed during 1996 through 1998. The mean number of thrips larvae/plant for the non-treated plots was 2.4 during 1999 and 2000 compared to 10.0 during 1996 through 1998.

During1999 and 2000, thrips infestations did not significantly reduce plant density. Davis et al. (1966), Davis and Cowan (1972), and Harp and Turner (1976) also reported that thrips infestations did not significantly reduce plant density.

Telford and Hopkins (1957), Klein et al. (1986), and Reed (1988) reported that thrips feeding resulted in damage to and/or abortion of plant terminals. In our studies, the use of an at-planting insecticide did not significantly influence the number or percentage of plants with damaged/aborted terminals compared to the non-treated.

During 1999 and 2000, the use of an at-planting insecticide did not affect the location of the first fruiting branch indicating that thrips infestations did not delay the initiation of fruiting. Also, there were no significant differences in the total number of nodes per plant indicating that internode length was affected.

Thrips infestations did not significantly affect crop maturity. Studies by Bourland et al. (1992), Herbert (1998), and Van Duyn et al. (1998), reported that application of an at-planting insecticide to control thrips, significantly improved crop maturity. Whereas, Leigh (1963) and Harp and Turner (1976) observed no significant improvement in crop maturity associated with thrips control with at-planting insecticides. Burris et al. (1994) reported variable results from thrips control with at-planting insecticides with respect to crop maturity.

Table 5. Influence of at-planting insecticides on boll number at fruiting positions one, two, and three within each fruiting zone, fruiting positions on monopodial branches, total boll number, mainstem location of first fruiting branch, and plant density during 1999 and 2000

Treatment	Bolls / m											
	Z1P1[z]	Z1P2[y]	Z1P3[x]	Z2P1[w]	Z2P2[v]	Z2P3[u]	Z3P1[t]	Z3P2[s]	Z3P3[r]	Mon[q]	Total	Plants m^{-1}
Acephate	7.4	3.9	1.5	18.4	8.3	4.6	13.4	4.4	1.1	13.2	71.7	12.3
Aldicarb	9.1	3.6	1.8	16.6	9.1	4.9	14.1	4.6	1.9	12.1	73.2	11.6
Non-treated	8.6	3.5	1.4	19.3	7.9	3.4	13.3	4.6	1.6	6.7	65.5	11.9
F	0.65	0.12	0.38	0.81	0.52	0.68	0.11	0.02	1.28	2.86	1.04	0.45
df	2,30	2,30	2,30	2,30	2,30	2,30	2,30	2,30	2,30	2,30	2,30	2,30
P>F	0.53	0.89	0.69	0.45	0.60	0.51	0.90	0.98	0.29	0.07	0.36	0.64
Non-treated vs. Treated[p]												
T	0.30	-0.35	-0.63	0.96	-0.75	-1.14	-0.32	0.11	0.13	-2.36	-1.42	0.01
df	30	30	30	30	30	30	30	30	30	30	30	30
P>F	0.76	0.73	0.53	0.35	0.46	0.26	0.75	0.91	0.90	0.02	0.17	0.99

[z] Z1P1 = Fruiting position 1 on mainstem nodes ≤ 8.
[y] Z1P2 = Fruiting position 2 on mainstem ≤ 8.
[x] Z1P3 = Fruiting positions 3 and beyond on mainstem nodes ≤ 8.
[w] Z2P1 = Fruiting position 1 on mainstem nodes 9, 10, 11, and 12.
[v] Z2P2 = Fruiting position 2 on mainstem nodes 9, 10, 11, and 12.
[u] Z2P3 = Fruiting positions 3 and beyond on mainstem nodes 9, 10, 11, and 12.
[t] Z3P1 = Fruiting position 1 on mainstem nodes 13 and above.
[s] Z3P2 = Fruiting position 2 on mainstem nodes 13 and above.
[r] Z3P3 = Fruiting positions 3 and beyond on mainstem nodes 13 and above.
[q] Mon = All fruiting positions on monopodial branches.
[p] Orthogonal contrasts *P* = 0.05, Treated = All insecticide treatments.

Table 6. Influence of at-planting insecticides on boll retention at fruiting positions one, two, and three within each fruiting zone, fruiting positions on monopodial branches, and total boll retention during 1999 and 2000

Treatment	Percent Boll Retention										
	Z1P1[z]	Z1P2[y]	Z1P3[x]	Z2P1[w]	Z2P2[v]	Z2P3[u]	Z3P1[t]	Z3P2[s]	Z3P3[r]	Mon[q]	Total
Acephate	32.9	25.3	17.1	42.7	25.4	25.2	25.6	22.1	14.8	26.3	29.2
Aldicarb	37.5	23.2	18.6	41.1	28.2	28.6	29.9	18.0	16.0	25.7	30.8
Non-treated	40.2	22.9	20.2	44.5	23.9	26.0	24.8	19.1	20.5	26.0	29.2
F	1.32	0.11	0.12	0.36	0.80	0.14	1.59	0.29	0.17	0.01	0.31
df	2,30	2,30	2,29	2,30	2,30	2,30	2,30	2,30	2,23	2,30	2,30
P>F	0.28	0.89	0.89	0.70	0.46	0.87	0.22	0.75	0.85	0.99	0.73
Non-treated vs. Treated[p]											
T	1.27	-0.28	0.42	0.75	-0.98	-0.03	-1.11	-0.19	0.50	-0.01	-0.41
df	30	30	29	30	30	29	30	30	23	30	30
P>F	0.22	0.78	0.68	0.46	0.33	0.98	0.27	0.85	0.56	0.99	0.69

[z] Z1P1 = Fruiting position 1 on mainstem nodes ≤ 8.
[y] Z1P2 = Fruiting position 2 on mainstem ≤ 8.
[x] Z1P3 = Fruiting positions 3 and beyond on mainstem nodes ≤ 8.
[w] Z2P1 = Fruiting position 1 on mainstem nodes 9, 10, 11, and 12.
[v] Z2P2 = Fruiting position 2 on mainstem nodes 9, 10, 11, and 12.
[u] Z2P3 = Fruiting positions 3 and beyond on mainstem nodes 9, 10, 11, and 12.
[t] Z3P1 = Fruiting position 1 on mainstem nodes 13 and above.
[s] Z3P2 = Fruiting position 2 on mainstem nodes 13 and above.
[r] Z3P3 = Fruiting positions 3 and beyond on mainstem nodes 13 and above.
[q] Mon = All fruiting positions on monopodial branches.
[p] Orthogonal contrasts *P* = 0.05, Treated = All insecticide treatments.

During 1996 through 1998, the addition of an at-planting insecticide significantly improved lint yield. Several researchers have reported significant reductions in thrips densities following applications of at-planting insecticides, but no impact on lint yield (Beckham 1970; Cowan et al. 1966; Harp and Turner, 1976). Others reported significant positive yield responses to thrips control provided by at-planting insecticides (Burris et al. 1989; Davis and Cowan, 1972; Davis et al., 1966; Herbert, 1998, 2002; Herbert et al., 2007; Race, 1961). Some studies have reported mixed results with significant yield responses to thrips control with at-planting insecticides at some locations or during some years and no differences at/during others (Burris et al., 1994; Faircloth et al., 1999; Leigh, 1963; Van Duyn et al., 1998).

After observing significant impacts from thrips infestations on lint yield during 1996 through 1998, we attempted to determine how yield is impacted by thrips infestations through plant mapping and yield partitioning. However during 1999 and 2000, thrips infestations did not significantly affect lint yield, distribution of bolls, or boll retention, with one exception (monopodial branches). Yields were substantially lower during 1999 and 2000 compared to 1996 through 1998. This, along with the differences in thrips infestations between the two periods, might be responsible for the discrepancies in yield response.

The impact of thrips injury on maturity and yield would probably be more dramatic for earlier plantings in which less favorable growing conditions would be experienced. In the U.S., thrips infesting cotton seedlings have been ranked in importance from first to seventh with regard to yield loss during 1979 to 2010, with yield loss estimates ranging from 0.12% to 0.88% (King et al. 1988; Williams 1994). However, in Virginia, which represents the more northern portion of the cotton belt, thrips infesting cotton seedlings were responsible for more yield losses than any other insect pest in 9 of the 12 yrs from 1999 to 2010 (Williams, 1999, 2000, 2002a, 2002b, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011). In the more northern portions of the cotton belt, environmental conditions (i.e. temperature) during seedling development are generally less favorable than those further south, also the growing season is shorter. These environmental conditions would limit cotton's ability to compensate for thrips injury that occurred during seedling development. Additional research is needed to identify which environmental parameters interact with thrips injury to affect cotton yield and maturity, when during the growing season these interactions occur, and how production practices (i.e. date of planting, length of growing season, etc.) contribute to these interactions.

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