Effect of Insecticide Treatments and Environmental Factors on Thrips Populations, Plant Growth and Yield of Cotton[1]

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Abstract Field experiments were conducted in 1997-1999 in Washington Co., NC, to examine how cotton, *Gossypium hirsutum*, is affected by thrips species composition and abundance, environmental factors, and insecticide applications. Populations of adult and juvenile thrips were monitored in seedling cotton treated with insecticide applications of either imidacloprid as a seed treatment, acephate as a foliar spray, or aldicarb applied in-furrow. The number of plants per 3.05 row-m, location of the first fruiting branch, number of open bolls per 1.52 row-m, yields, accumulated degree-d 60's (DD60's), and accumulated rainfall were recorded each year the studies were conducted. Aldicarb and acephate provided better thrips control than did imidacloprid in all 3 yrs. Thrips species ratios differed among years. In 1997, the aldicarb treatment resulted in a better "earliness profile" (lower fruit set and more early opening bolls) than either acephate or imidacloprid, while in 1998 and 1999 there were few differences in these plant parameters. In 1997, all insecticide treatments resulted in statistically higher yields compared with the untreated check. Accumulated DD60's were consistently higher in 1998 and 1999 than in 1997 after the first thrips sampling date. Cumulative rainfall appeared to be inversely associated with juvenile thrips populations.

Key Words *Frankliniella fusca, Frankliniella occidentalis, Frankliniella tritici, Thrips tabaci, Neohydatothrips variabilis, Gossypium hirsutum*

Most cotton producers consider thrips control on seedling cotton an essential production practice to minimize early-season stress on the cotton plant, thus enhancing earliness and yield. Although the deleterious effects of thrips feeding on cotton seedlings has been recognized and widely accepted for decades (Newsom et al. 1953), many researchers have reported no yield benefits from thrips control (Beckham 1970, Harp and Turner 1976, Lentz and Austin 1994, Cook 1998). Lambert (1985) stated that 80% of all cotton grown in Georgia received a prophylactic treatment for thrips despite the lack of information showing any yield benefit. In contrast, other investigators have reported yield losses from thrips feeding on cotton seedlings (Race 1961, Micinski et al. 1990, Roberts and Rechel 1996, Herbert 1998). The relationship between thrips control and cotton yield is a function of many factors including thrips numbers, temperatures from planting through the seedling stage, and other plant stressors (e.g., herbicides, seedling diseases).

The objective of this study was to document how the yield impact of thrips control

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on cotton varies annually with insecticide treatment, thrips species, thrips population levels, and environmental factors that impact cotton growth and phenology.

Materials and Methods

All studies were conducted on the Tidewater Research Station near Plymouth, Washington Co., NC. 'Deltapine 51' cotton was used in 1997 and 'Deltapine 436 RR' was used in both 1998 and 1999. Test 1 was planted on 9 May 1997, Test 2 on 29 April 1998, and Test 3 on 4 May 1999. The soil type at each test site was a Portsmouth silt loam soil (organic matter ≈3%). Commercial planters were used. All tests were planted in a randomized complete block design with four replicates. Each plot was 15.24 m in length and 4 rows wide. Rows were spaced 0.97 m apart.

Treatments included in each test were imidacloprid (Gaucho®; Gustafson, Inc., Dallas, TX) as a seed treatment, acephate (Orthene®; Valent USA Corp., Walnut Creek, CA) as a foliar spray, aldicarb (Temik®; Aventis Crop Science, Research Triangle Park, NC) as an in-furrow granule, and the untreated check. The imidacloprid treated seed (2.6 g [AI]/kg) was obtained from Delta and Pineland, Co. (Scott, MS) for Test 1. In Test 2 and Test 3, Gaucho was applied to seed utilizing the method described by Van Duyn et al. (1998). Aldicarb was applied from individually calibrated, gravity flow applicators as an in-furrow treatment (842 g [AI]/ha in Test 1 and Test 3 and at 644 g [AI]/ha in Test 2). Acephate was applied as a banded, foliar spray twice each year (≈14 and 28 d after planting) using a CO_2-pressurized, two row, backpack sprayer with hollow cone X-14 tips (Orthene 90 S at 281 g [AI]/ha in Test 1 and Orthene 75 S at 213 g [AI]/ha in Test 2 and Test 3). Sprayers were calibrated immediately prior to each application, with output ranging from 93.7 to 112.4 L/ha, at a pressure of 4.22 kg/cm^2. Crop maintenance including fertility, weed control and control of insects other than thrips was conducted as recommended by the North Carolina Cooperative Extension Service (Cotton Information 1997).

Ten plants were randomly selected from each plot on the four sampling dates to obtain representative samples of juvenile and adult thrips populations. A washing, filtering technique similar to the Alexington Technique as described by Irwin and Yeargan (1979) was used to sample both adult and juvenile thrips. Data are presented for adult and juvenile thrips per 10 plants from 4 sampling dates for each year. In 1997 thrips were sampled at 18, 26, 33, and 40 d after planting (Test 1). In 1998 thrips were sampled at 19, 27, 33, and 40 d after planting (Test 2). Thrips were sampled at 20, 27, 35, and 42, and 47 d after planting in 1999. Additionally, a subsample of thrips adults (150+) was collected between the time of emergence to 47 d after planting in each year, prepared and mounted on glass slides, and identified to species. Stand counts were taken from the number of plants per 3.05 row-m per plot shortly following emergence, the location of the first fruiting branch was measured, and the number of open bolls per 1.52 row-m per plot was counted soon after boll opening began. Yields were obtained by harvesting the two center rows of each plot with a John Deere 9920 cotton harvester equipped with a bagger attachment. Harvested samples from each plot were weighed and recorded in the field. All data were subjected to standard analysis of variance ANOVA and Fisher's LSD means separation ($P \leq 0.05$) using Gyllings ARM version 7.2 software (Gylling Data Management, Inc. 1999).

High and low temperatures were obtained from a weather station within 1000 m of the experiments. From these data, degree-day 60's (DD60's) were calculated using the following equation: [(^{o}F Max + ^{o}F Min)/2]-60. All values less than 0 were discarded. Accumulated DD60's were recorded from planting until 47 d after planting in each test. Rainfall accumulation was also recorded for the same time interval.

Results

Thrips species composition. In 1997, the thrips identified were *Frankliniella fusca* (Hinds) (95%), *F. occidentalis* (Pergande) (2%), *Neohydatothrips variabilis* (Beach) (2%), and *F. tritici* (Fitch) (1%). In 1998, the thrips species composition was as follows: *N. variabilis* (56%), *F. fusca* (32%), *F. occidentalis* (5%), *F. tritici* (5%), and *Thrips tabaci* (Lindeman) (2%). The thrips species composition in 1999 consisted of *F. fusca* (58.2%), *T. tabaci* (26.2%), *N. variabilis* (8.6%), *F. tritici* (5.9%), and *F. occidentalis* (1.1%).

Contrasts of adult and juvenile thrips populations. In 1997 and 1999, there were 45.8 and 24.0 juvenile thrips per 10 plants, respectively, in the untreated control on the initial sampling dates (Table 1), whereas there were no juvenile thrips in the untreated control on the initial sampling date in 1998. Furthermore, juvenile thrips numbers per 10 plants peaked in the untreated control at 147.3 at 33 d after planting in 1997 (Table 1), at 324 at 42 d after planting in 1999 (Table 3), and at only 73 at 33 days after planting in 1998 (Table 2). Thus, overall thrips numbers were higher in 1997 and 1999 than in 1998 as there were at least twice as many juvenile thrips per 10 plants in the untreated control in these years (Fig. 1).

Aldicarb and acephate treated plots provided the most consistent thrips control as measured by reductions in juvenile thrips numbers in all years. Plants from imidacloprid-treated plots had significantly higher juvenile thrips numbers than plants from either the aldicarb or acephate treated plots at 26, 33, and 40 d after planting in 1997 (Table 1), at 33 and 40 d after planting in 1998, and at 27, 35, 42, and 49 d after planting in 1999. Also, the juvenile thrips numbers were statistically similar on plants from the imidacloprid-treated plots and the untreated control plots at approximately 4 wks after planting in each year. The juvenile thrips data suggest that the imidacloprid seed treatment will provide acceptable control of thrips reproduction for about 3 wks after planting, whereas aldicarb controls thrips reproduction for approximately 6 wks.

Adult thrips numbers followed a trend similar to that of the juvenile thrips as there were higher numbers of adult thrips from plants in the untreated control plots and imidacloprid-treated plots than in either the aldicarb and acephate treated plots after the initial sampling date (Table 1). However, adult thrips numbers were slightly lower overall in 1997 and in 1999 than in 1998, even though juvenile thrips numbers were much higher in 1997 and 1999.

Plant stands, fruiting branch, open bolls and yield. There were no differences in the plant populations among the treatments in any year (Table 2); thus, thrips and/or insecticide treatments did not cause measurable plant mortality.

The mean plant node for the first fruiting branch and open boll counts were used to measure effects of treatments on earliness. In 1997, when juvenile thrips levels were highest, a significant effect on the mean node of first fruiting branch was observed. There were no differences among the insecticide treatments, as they ranged from 7.3 to 8.2 in 1997; however, the first fruiting branch was located significantly higher (node 11.3) in the untreated control. There were no significant differences in the location of the first fruiting branch among any of the treatments in 1998, coincident with the reduced number of juvenile thrips in that year. In contrast to 1997, the

Table 1. Adult and juvenile thrips populations in samples taken from cotton planted 9 May 1997 (Test 1), 29 April 1998 (Test 2), and 4 May 1999 (Test 3), in Washington Co., NC

				Mean number of thrips per 10 cotton seedlings							
				18-20 DAP		26-27 DAP		33-35 DAP		40-42 DAP	
Test	Treatment	Rate	Application	Adult	Juv.	Adult	Juv.	Adult	Juv.	Adult	Juv.
1 (1997)	Aldicarb	842 g [AI]/ha	in-furrow, at plant	1.8a	3.0b	6.3b	5.3b	5.8b	7.3b	28.3a	11.5b
1 (1997)	Imidacloprid	2.6 ml [AI]/kg	seed treatment	13.0a	6.5b	22.0a	88.8a	16.8a	90.3a	36.5a	76.0a
1 (1997)	Acephate	281 g [AI]/ha	foliar spray*	7.0a	22.3ab	2.8b	6.8b	1.8b	0.5b	6.3a	4.5b
1 (1997)	Untreated	—	—	12.0a	45.8a	31.3a	118.3a	18.8a	147.3a	39.5a	77.5a
2 (1998)	Aldicarb	842 g [AI]/ha	in-furrow, at plant	0.5b	0.0a	17.5c	0.5b	2.5b	5.0b	29.0ab	6.0b
2 (1998)	Imidacloprid	2.6 ml [AI]/kg	seed treatment	2.0ab	0.0a	102.5a	12.0ab	12.5ab	44.0a	32.0ab	52.5ab
2 (1998)	Acephate	281 g [AI]/ha	foliar spray*	2.0ab	0.0a	12.5c	7.0ab	3.0b	4.0b	10.5b	1.0b
2 (1998)	Untreated	—	—	6.5a	0.0a	46.5b	50.0a	23.5ab	73.0a	44.5a	63.5a
3 (1999)	Aldicarb	842 g [AI]/ha	in-furrow, at plant	6.6a	3.1b	5.6b	10.6b	9.6b	12.6b	7.6b	77.6b
3 (1999)	Imidacloprid	2.6 ml [AI]/kg	seed treatment	11.6a	4.6b	32.6a	134.6a	49.6a	143.6a	14.0ab	105.0a
3 (1999)	Acephate	213 g [AI]/ha	foliar spray*	3.0a	11.0b	9.0b	14.6b	5.6b	13.0b	14.6ab	30.0b
3 (1999)	Untreated	—	—	10.0a	24.0a	25.6a	169.0a	47.6a	156.0a	18.6a	324.0a

Means in the same column for each test followed by the same letter are not significantly different, Fisher's LSD ($P \leq 0.05$).

* Applications made on 23 May 1997 and 5 June 1997 for Test 1, 20 May 1998 and 2 June 1998 for Test 2, and 18 May 1999 and 3 June 1999 for Test 3.

Table 2. Insecticide treatment effects on cotton plant population, first sympodial branch, earliness, and yield taken from cotton was planted on 9 May 1997 (Test 1), 29 April 1998 (Test 2), and 4 May 1999 (Test 3) in Washington Co., NC

Test	Treatment	Rate	Application	Plants per 3.05 row-m	Mean node of 1st fruiting branch	Open bolls per 1.52 row-m	Yields kg seedcotton per ha
				5-21-97	9-26-97	9-26-97	11-22-97
1 (1997)	Aldicarb	842 g [AI]/ha	in-furrow, at plant	27.8a	7.3b	22.3a	4327a
1 (1997)	Imidacloprid	2.6 ml [AI]/kg	seed treatment	30.0a	7.4b	10.0b	3830a
1 (1997)	Acephate	281 g [AI]/ha	foliar spray*	31.5a	8.2b	11.3b	3515a
1 (1997)	Untreated	—	—	30.5a	11.3a	4.3b	2120b
				5-26-98	10-14-98	9-18-98	10-19-98
2 (1998)	Aldicarb	842 g [AI]/ha	in-furrow, at plant	27.3a	6.3a	36.8a	2703a
2 (1998)	Imidacloprid	2.6 ml [AI]/ha	see treatment	29.8a	7.4a	35.3a	2416a
2 (1998)	Acephate	281 g [AI]/ha	foliar spray*	33.0a	7.2a	28.0a	2531a
2 (1998)	Untreated	—	—	32.5a	7.2	22.8a	2627a
				5-28-99	10-20-99	10-20-99	11-5-99
3 (1999)	Aldicarb	842 g [AI]/ha	in-furrow, at plant	20.0a	6.7a	39.8a	1196.5a
3 (1999)	Imidacloprid	2.6 ml [AI]/kg	seed treatment	20.5a	6.0b	40.0a	1181.0a
3 (1999)	Acephate	213 g [AI]/ha	foliar spray*	20.8a	5.9b	39.5a	1196.7a
3 (1999)	Untreated	—	—	21.3a	5.9b	44.5a	998.3a

Means in the same column for each test followed by the same letter are not significantly different, Fisher's LSD ($P \leq 0.05$).

* Applications made on 23 May 1997 and 5 June 1997 for Test 1, 20 May 1998 and 2 June 1998 for Test 2, and 18 May 1999 and 3 June 1999 for Test 3.

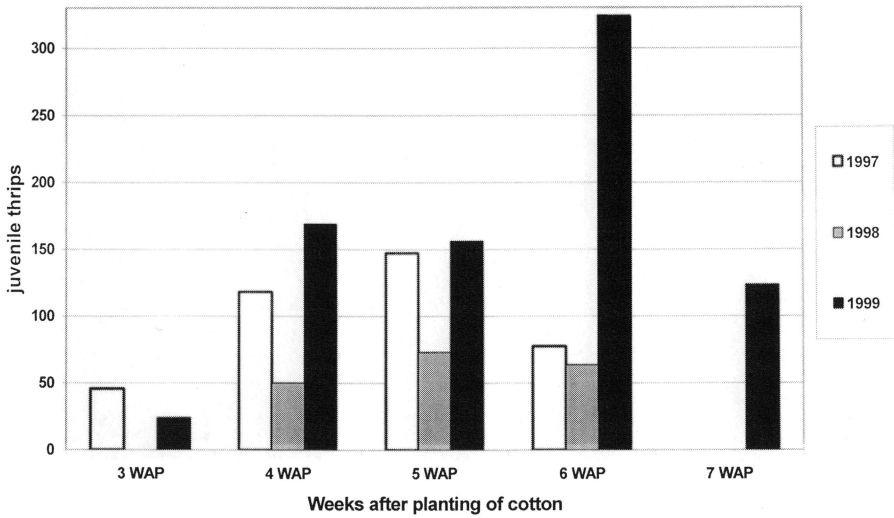

Fig. 1. Mean number of juvenile thrips per ten plants sampled in untreated control plots at 3, 4, 5, 6, and 7 weeks after planting in Washington Co., NC.

aldicarb-treated plots in 1999 had a significantly higher node of first fruiting branch than did all other treatments.

In 1997, there were significantly more open bolls on plants in the aldicarb treated plots than on plants in the other treated plots; the aldicarb treated plants had approximately 5 times as many open bolls as the untreated control (Table 2). Although the aldicarb treatment had numerically the highest number of open bolls in 1998, there were no significant differences among treatments. In 1999, excessive rainfall caused field flooding that delayed open boll assessments until 20 October at which time the effects on boll opening could not be assessed.

Yields in 1997 were very high for the site and all insecticide-treated plots had significantly higher yields than the untreated control plots (Table 2). The seedcotton yield in the aldicarb-treated plots was more than twice that in the untreated control plots, but there were no significant yield differences among the insecticide treatments. In 1998 and 1999, yields were statistically similar among all treatments, including the untreated check.

Weather relationships. During the first 47 d after planting, a numerically higher number of DD60's (approximately 100) accumulated during 1997 than during the same period in 1998 and 1999 (Fig. 2). During the first 47 d after planting, rainfall was >10 cm in all three years. In 1999, from day 40 to 47, over 11 cm of rainfall accumulated increasing cumulative amounts to the highest of all 3 yrs.

Discussion

The variations in thrips species compositions seen in these studies may have been an important factor in the relationship of thrips numbers to earliness measured by counting open bolls and yield in cotton. For example, in 1998 there were higher

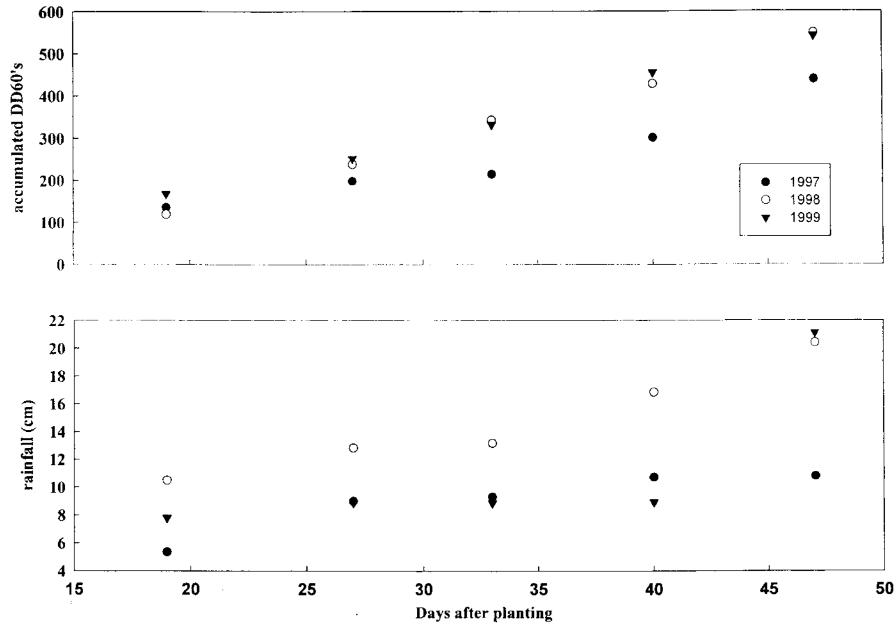

Fig. 2. Accumulated DD60's and rainfall from planting to one week after termination of sampling in Washington Co., NC.

numbers of adult thrips overall, but much lower numbers of juvenile thrips developed in any of the treatments, including the untreated check. This phenomenon may have been the result of a much higher proportion of the total adult population being represented by *N. variabilis,* a pest we suspect that does not utilize cotton as a host as effectively as does *F. fusca.* Most of the literature on thrips control in cotton does not include identification of the thrips species involved, thus the relative importance of most thrips species that colonize cotton seedlings is unknown. However, it has been demonstrated that various species of thrips do possess different levels of damage potential (Faircloth et al. 2001, Hightower 1958).

Lower temperatures during the seedling period in 1997, as compared to 1998, may have resulted in reduced open boll counts and yield. In 1997, the impact of thrips on plant productivity was great as yields were reduced by >50% in the untreated control when all other production factors were equal among the treatments. In contrast, thrips had little impact on earliness or yield in 1998 when juvenile thrips numbers were lower and temperatures and rainfall were higher. In late summer of 1999, a series of hurricanes that passed over eastern and northeastern North Carolina compromised growth measurements and yield data.

The lower temperatures during 1997 placed additional stress on the cotton plants and possibly made them more susceptible to thrips feeding effects, particularly in the untreated check. Cumulative rainfall appeared to be inversely associated with juvenile thrips populations, because in 1998 rainfall was numerically greater (Fig. 2) and juvenile thrips numbers were lower (Fig. 1). While most data suggest an inverse relationship between thrips numbers and rainfall, it was especially apparent in 1999 when coincident with a sharp decline in juvenile thrips numbers in untreated control plots between 6 and 7 weeks after planting (Fig. 1), the test received rainfall in excess of 10.2 cm. The combination of the physical removal of juvenile thrips by the rain and the rapid growth afforded by the soil moisture allowed seedlings to quickly outgrow the threat of thrips injury and compensate for prior thrips injury.

Our data suggest that thrips control during the first 3 wks after planting is the most important period for preventing yield loss. The imidacloprid seed treatment, which did not effectively control thrips beyond 3 wks in the 1997 test, had a statistically similar node of first fruiting branch and produced seedcotton yields statistically comparable to those of the aldicarb treatment. However, the earliness advantage measured by the number of open bolls in the aldicarb treatment in 1997 may have been a result of more effective thrips control throughout cotton seedling development.

At the same site in the 3 study years, there were differences among insecticide treatments in the proportions of thrips species, rates of colonization, juvenile adult thrips numbers, accumulated heat units, accumulated rainfall, earliness as measured by open bolls, and in cotton yields. Our data demonstrate the need to evaluate thrips control technologies over several years in order to determine relative efficacy.

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