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EFFECTS OF NEONICOTINOID INSECTICIDES AND IRRIGATION ON NUMBER OF COTTON APHIDS, *Aphis gossypii* GLOVER (HEMIPTERA: APHIDIDAE) AND FUNGUS-INFECTED APHIDS

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ABSTRACT

Experiments with the neonicotinoid insecticides, acetamiprid and thiamethoxam, were carried out at the Edisto REC., Clemson University, SC., USA. Cotton variety DP 458 BR was planted in plots of 12 rows x 15 m in both a dryland field and under irrigation on 6 and 7 May 2002, respectively. The experiment was arranged in a split-split plot design with four replications. There were 5 insecticide treatments which were based on cotton aphid infestation levels in cotton (AIL) at each location: (1) thiamethoxam (0.05 kg a.i./ha) for aphid-free plots, **thia1**, (2) thiamethoxam (0.05 kg a.i./ha) applied when 30% of plants were infested, **thia2**, (3) acetamiprid (0.05 kg a.i./ha) applied when 30% of plants were infested, **ace**, (4) thiamethoxam (0.05 kg a.i./ha) when 90% of plants were infested, **thia3**, and (5) untreated. Applications of insecticide were made as follows: treatments no. 1, 2, and 3 on 25 June, all treatments on 1 July, treatment no. 1 on 11 July 2002. Karate® was applied on 19 June 2002 and it was sprayed again on 16 July and 18 July 2002 to control bollworms.

There were significant differences in number aphids among location and insecticides treatment. Infection levels in aphid population by *N. fresenii* were significant different among insecticides treatments

INTRODUCTION

The cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae), has been considered as an important pest of cotton and many other crops around the world (*Blackman and Eastop 1985; Leclant and Deguine 1994*). The cotton aphid has been ranked as one of the most damaging pests on cotton in the US, especially in the southeastern and southwestern (Steinkraus *et al.* 1991). In 2002, this insect pest was regarded as the sixth most damaging pest of US cotton. The aphid infested 70.3% of US cotton, causing a 0.119% reduction in yield in 9,307,757 infested acres, resulting in a loss of 31,450 bales (Williams 2003).

The aphid problems have occurred especially after widespread use of insecticides for boll weevil (Frisbie *et al.* 1994). Outbreaks of cotton aphids have been associated with reductions in natural enemy populations and aphid resistance to pesticides (Grafton-Cardwell 1991). Before the mid-1980s, cotton aphids were considered as secondary pests of cotton because they rarely reached damaging levels. However, extensive insecticide treatments have destroyed natural enemies such as predators and parasitoids, and the cotton aphid has become an important pest of cotton. Additionally, this pest continues to be of concern because of its potential for rapid reproduction and ability to develop resistance to pesticides (Kern and Stewart 2000).

Cotton aphid population dynamics can be influenced by both agronomic and pest management practices. Irrigation management and cotton variety have been shown to be important factors in management of the cotton pests, *Lygus Hesperus* (Munk and Goodell 2002) and fleahopper, and in enhancing populations of predaceous bugs, and green lacewings (Bommireddy *et al*. 2003). High populations commonly occur as resurgent populations following applications of selected insecticides for other pests (Slosser *et al*. 1989). Also, chemical control is often ineffective due to cotton aphid resistance to many insecticides. Insecticides such as the synthetic pyrethroids , λ–cyhalothrin and tau-fluvalinate, are not effective against the cotton aphid (Martin and Workman 1997). However, use of insecticides for insect control is an essential component of most crop protection strategies in modern agriculture, although over reliance on insecticides has been reported to result in resistance problems, ecological disturbance, and higher cost to the growers (Horowitz *et al*. 2004). Use of either organophosphates or pyrethroids is often ineffective for cotton aphid due to resistance development.

Neonicotinoids, the most important new class of synthetic insecticides of the past three decades, are used to control sucking insects both on plants and animals. Imidacloprid, nitenpyram, acetamiprid, tiacloprid, thiamethoxam, and others act as agonists at the insect nicotine acetylcholine receptors (Tomizawa and Casida 2003; Horowitz *et al*. 2004) causing the insect to reduce or stop feeding, and reduce mobility (Gourment *et al*. 1994). These insecticides are active against species in the Hemiptera, Coleoptera, Diptera, and Lepidoptera. In agriculture, they are being used most intensively to control sucking pests such as aphids (Foster *et al*. 2003; Nauren *et al*. 1998), planthoppers, leafhoppers, and whiteflies (Mason *et al*. 2000).

Populations of cotton aphids are limited by a complex of natural enemies that includes predators, parasitoids, and pathogens. One of the most important insect pathogen infecting the cotton aphid is *Neozygites fresenii* (Nowakowski) Batko (Entomophthorales: Neozygitaceae) (Harper and Carner 1996). This fungus is an important natural enemy of the cotton aphid, *A. gossypii*, and is known to cause rapid declines of aphid populations in cotton. The fungus has occurred in the Midsouth and Southeast of the United States during June-August each year since 1989 (Steinkraus *et al*. 2002). The large quantities of fungus *N. fresenii* produced during natural epizootics in cotton fields represent a valuable resource as large quantities of fungus can be harvested from the field and stored for future use (Steinkraus and Boys 2005).

The purpose of this research was to determine effects of interaction among neonicotinoid insecticide treatments based on aphid infestation levels and irrigation on number of cotton aphids and fungus-Infected aphids.

MATERIALS AND METHOD

Experiments with the neonicotinoid insecticides, acetamiprid (Intruder 70WP, Dupont, Wilmington, DE) and thiamethoxam (Centric 40WG, Syngenta Crop Protection, Greensboro, NC), were carried out at the Edisto REC, Clemson University, Blackville, South Carolina, USA. Cotton variety DP 458 BR was planted in plots of 12 rows x 15 m in both a dryland field and under irrigation on 6 and 7 May 2002, respectively. The experiment was arranged in a split-split plot design with four replications. The date of sampling was the main plot; locations were the subplot and neonicotinoid insecticides were sub subplots. There were 5 insecticide treatments which were based on cotton aphid infestation levels in cotton at each location (AIL): (1) thiamethoxam (0.05 kg a.i./ha) for aphid-free plots, thia1, (2) thiamethoxam (0.05 kg a.i./ha) applied when 30% of plants were infested, thia2, (3) acetamiprid (0.05 kg a.i./ha) applied when 30% of plants were infested, ace, (4) thiamethoxam (0.05 kg a.i./ha) when 90% of plants were infested, thia3, and (5) untreated. Applications of insecticide were made as follows: treatments no. 1, 2, and 3 on 25 June, all treatments on 3 July, treatment no. 1 on 11 July. Karate® was applied on 19 June 2002 and it was sprayed again on 16 July and 18 July 2002 to control bollworms.

Cotton aphids were sampled twice weekly between 28 June and 31 July 2002. Treatment effects were monitored by counting the number of aphids on the top two leaves from 18 plants that were selected systematically in each plot. Leaves were preserved in 30 ml screw cup vials filled with 70% alcohol. These were later processed in the laboratory to confirm presence of *N. fresenii*. Other variables that were examined were percentage of fungus infection levels, percentage of winged aphids in aphid populations, and fungus infection levels in winged aphids. Aphid numbers for each plot were determined by counting from samples in each plot. Percent of winged aphids in the populations was obtained by dividing the number winged aphids in each plot by the total number of sampled aphids in each plot x100. Percent of aphid infection was determined from numbers of all aphids including winged aphids per plot by dividing the numbers of aphids with fungus by the total numbers of aphids sampled, then multiplying by 100. Percent of fungus infection in winged aphids was obtained by dividing the number of infected winged aphids by number of winged aphids in each plot.

Microscope slide squash mounts in lactophenol fuchsin were made for all aphids collected each date sampling. and each aphid was examined with a microscope to determine if secondary conidia, hyphal bodies, conidiophores, primary conidia, and resting spores were present (Steinkraus *et al.* 1991). This method was used to determine percent of aphid infection (fungus infection levels) and percent of fungus infection in winged aphids. Aphids were classified into one of the following six categories based on Steinkraus *et al.* (1995): (1) with secondary conidia attached to aphid's leg, antennae or body, (2) with hyphal bodies, (3) with conidiophores and primary conidia, (4) with resting spores, (5) with saprophytic fungi, and (6) no fungus (healthy aphids). The first five categories will be fungus-infected aphid.

RESULTS AND DISCUSSION

This experiment was arranged in a split-split plot design with four replications. There were significant differences in numbers of aphids among locations and among insecticide treatments (F=4.23, DF=36, $p<0.0001$). Significance difference comparisons for aphid numbers on Table 1 are among treatments by date. Significant differences among

Table 1. Effect of neonicotinoid insecticides and irrigation on cotton aphid populations (mean±SE) (treatments based on AIL) at Edisto REC, 2002

Date	Location	Numbers of aphids in each insecticide treatment and irrigation (aphids/leaf)				
		thia1	thia2	ace	thia3	untreated
6/28	Irrigation	17.44±33.71ab	0.00±0.00c	0.36±0.09c	0.00±0.00c	17.76±7.15a
	Dryland	1.58±0.66bc	0.00±0.00c	1.58±0.97bc	0.00±0.00c	12.68±1.86a
7/3	Irrigation	0.21±0.11c	1.32±2.43c	0.10±0.16c	4.61±2.33c	22.84±3.57b
	Dryland	1.24±0.35c	0.65±0.26c	0.46±0.23c	3.40±3.07c	75.57±22.10a
7/6	Irrigation	0.78±0.35d	1.13±0.48d	0.73±0.20d	10.64±7.80c	62.17±44.19a
	Dryland	2.15±0.93cd	1.56±1.12cd	1.79±0.59cd	1.80±0.54cd	20.16±6.08b
7/10	Irrigation	3.58±1.54c	2.32±0.95c	4.18±1.10c	2.52±1.02c	31.05±24.06a
	Dryland	8.38±2.79bc	6.59±3.49c	5.78±1.55c	4.75±2.64c	20.76±9.41ab
7/13	Irrigation	2.74±1.02	2.76±2.12	4.20±1.93	1.43±0.39	3.34±2.18
	Dryland	4.53±0.95	3.65±1.29	2.43±1.08	5.36±1.04	30.39±8.51
7/17	Irrigation	1.21±0.34b	1.17±0.72b	2.30±1.59b	0.99±0.48b	2.30±3.41b
	Dryland	0.73±0.36b	1.46±0.89b	1.49±1.30b	5.43±4.39b	6.31±8.84a
7/20	Irrigation	2.51±0.72	4.72±2.54	5.25±3.75	3.73±2.50	1.80±0.85
	Dryland	0.56±0.13	1.04±0.31	1.12±0.77	4.73±1.55	3.38±3.41
7/24	Irrigation	2.21±0.98	4.52±2.46	4.08±2.20	3.52±0.72	2.39±0.09
	Dryland	1.01±0.76	1.45±2.13	1.48±1.40	2.27±1.11	3.03±1.99
7/27	Irrigation	0.94±0.67	1.25±0.69	2.64±2.46	1.87±1.77	1.59±0.83
	Dryland	0.27±0.13	1.55±2.01	0.65±0.21	0.58±0.36	0.89±0.35
7/31	Irrigation	0.82±0.62	0.55±0.33	0.84±0.65	1.08±0.91	1.39±0.63
	Dryland	0.05±0.04	0.07±0.07	0.12±0.13	0.14±0.10	0.16±0.04

thia1= thiamethoxam 0.05 kg/ha for free-aphid treatment, thia2= thiamethoxam 0.05 kg/ha when 5 or more aphid per plant, ace= acetamiprid 0.05 kg/ha when 30% of plant infested, thia3= thiamethoxam 0.05 kg/ha when 90% of plant infested. Means within a row followed by the same letter are not significantly different $p>0.05$. Means without letters in the same row are not significantly different $p>0.05$ insecticide treatments at both locations occurred from 28 June through 10 July and on 17 July. On 28 June, numbers of aphids in untreated plots in the dryland field were not significantly different from the irrigation fields. Aphid numbers in these untreated plots were significantly higher than in the neonicotinoid insecticide tested plots, except for the thia1 treatment in the irrigation field. The thia1 treatment in the irrigation field had aphid numbers higher than in other neonicotinoid treatments, except for the ace and thia1 treatments in the dryland field.

On 3 and 17 July, aphid numbers in the untreated dryland plots were higher than in the untreated irrigation plots. On 3 July, untreated plots in both fields had significantly higher aphid numbers than those in the neonicotinoid plots. However, on 17 July, only untreated plots in the dryland field had significantly higher aphid numbers than insecticide treated plots. On those days, there were no significant differences in numbers of aphids among neonicotinoid treatments in both dryland and irrigation field. On 6 and 10 July, aphid numbers in untreated irrigation plots were significantly higher than those in untreated dryland plots. Aphid numbers in all untreated plots were significantly higher than in neonicotinoid treatment plots, except thia1 in the dryland fields on 10 July (Table 1). Data in this Table shows that there were no differences in aphid numbers among neonicotinoid insecticide treatments based on AIL, indicating that growers could possibly delay insecticide treatment in the field even until 90% of the plants are infested.

In comparing infection levels in aphid populations by *N. fresenii*, there were no significant differences among locations on any given date (F=1.29, DF=36, p=0.1364). However, there were differences among treatments on certain dates (F=1.66, DF=36, p=0.0134). Significance difference comparisons for aphid numbers on Table 2 are among treatments by date. Table 2 shows that cotton aphid infection occurred for the first time on 3 July and continued through 24 July, 2002. Only on 3, 10, and 24 July, infection levels were significant different among insecticide treatments. On 3 July, infection levels in untreated plots were significantly higher than in thia1 and ace plots. On 10 and 24 July, only in the ace treated plots, the infection levels were lower than in untreated plots (Table 2). Figures B1-B4 that are shown in the appendices show that during the early stages of the epizootic of *N. fresenii*, most aphids contained only the hyphal body stage of the fungus. Infection levels were less than 50% until 17 July. At the end of the season, all fungus stages were found in the field including resting spores and saprophytic fungi.

Winged aphid numbers differed significantly among locations and among treatments (F=2.61, DF=36, p<0.0001). Significance difference comparisons for aphid

Table 2. Effect of neonicotinoid insecticides and irrigation on levels of fungus infection in cotton aphids (mean±SE) (treatments based on AIL) at Edisto REC, 2002

Date	Location	% infection by *N. fresenii* in each insecticide treatment				
		thia1	thia2	ace	thia3	untreated
6/28	Irrigation	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	Dryland	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	average	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7/3	Irrigation	8.33±16.67	6.73±13.46	0.00±0.00	6.00±5.19	9.07±4.49
	Dryland	0.00±0.00	11.29±11.49	0.00±0.00	6.11±4.34	23.95±9.19
	average	4.17±11.78b	9.01±11.84ab	0.00±0.00b	6.05±4.43ab	16.51±10.40a
7/6	Irrigation	34.55±44.56	29.51±20.58	13.02±16.17	7.96±5.66	8.36±3.92
	Dryland	12.08±14.18	20.42±16.69	18.75±21.92	13.96±13.94	38.89±16.76
	average	23.31±32.88	24.97±18.01	15.89±18.09	10.96±10.36	23.63±19.83
7/10	Irrigation	19.02±10.20	14.11±7.23	17.45±6.68	18.82±12.99	34.12±20.46
	Dryland	25.02±8.61	25.81±12.07	23.74±16.09	38.86±15.54	60.45±11.80
	average	22.02±9.31ab	19.96±11.13ab	20.59±11.89b	28.84±17.05ab	47.29±20.91a
7/13	Irrigation	32.03±16.98	27.16±14.68	18.19±4.42	13.15±2.87	30.85±12.27
	Dryland	24.65±12.48	24.95±9.02	17.62±3.80	33.17±3.85	39.87±7.33
	average	28.34±14.35	26.05±11.35	17.90±3.38	23.16±11.16	35.36±10.52
7/17	Irrigation	39.73±14.05	37.50±12.58	21.28±12.50	17.12±4.88	48.41±18.58
	Dryland	32.43±14.06	39.05±15.20	34.53±9.67	33.78±23.08	49.82±12.31
	average	36.08±13.59	38.28±12.95	27.90±12.54	25.45±17.83	49.12±14.61
7/20	Irrigation	36.00±9.73	40.56±14.69	48.99±11.85	39.26±12.46	42.84±7.05
	Dryland	27.43±12.29	46.65±19.32	57.74±11.60	64.07±19.26	70.03±18.61
	average	31.71±11.24	43.60±16.22	53.37±11.82	51.66±20.04	56.44±19.52
7/24	Irrigation	80.87±10.41	66.59±21.41	80.56±14.19	74.61±16.40	79.25±5.01
	Dryland	60.80±32.39	67.27±22.74	29.17±20.97	82.36±16.85	82.39±21.98
	average	70.84±24.72ab	66.93±20.45ab	54.86±32.09b	78.48±15.94a	80.82±14.86a
7/27	Irrigation	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	Dryland	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	average	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7/31	Irrigation	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	Dryland	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	average	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

thia1= thiamethoxam 0.05 kg/ha for free-aphid treatment, thia2= thiamethoxam 0.05 kg/ha when 5 or more aphid per plant, ace= acetamiprid 0.05 kg/ha when 30% of plant infested, thia3= thiamethoxam 0.05 kg/ha when 90% of plant infested. Means within a row followed by the same letter are not significantly different p >0.05. Means without letters in the same row are not significantly different p > 0.05 numbers on Table 20 are among treatments by date. Winged aphids were first observed on 3 July and increased to peak levels on 6 and 10 July (Table 3). There were differences among treatments in levels of winged aphids from 3 July through 17 July. On 3 July, in the irrigated field, percentages of winged aphids were higher in the thia1 and ace treatments than in the untreated plots. On 6 and 10 July, winged aphid levels in all insecticide treatments in the dryland field and the thia1 and ace treatments in the irrigation field were significantly higher than those in the untreated plots. On 13 July, only the thia1 treatment in the irrigation field had winged aphid levels significantly higher than those in the untreated plots in the dryland field. On 17 July, only the ace treatment in the dryland field had winged aphid levels higher than in all insecticide treatments in the irrigation field, except the thia1 treatment (Table 3).

Similar to data on winged aphid populations, the levels of fungal-infected winged aphids differed significantly among locations and among treatments (F= 1.56, DF=36, p<0.0292). Although infected winged aphids were observed as early as 6 July, differences in infection levels among treatments only occurred on 17, 20, and 24 July. On 17 July, infected winged aphids were found in all treatments, except the ace treatment in the irrigation field. On 20 July, levels of fungus-infected winged aphids were significantly lower in the thia1, thia2, and thia3 treatments than in the ace treatment in the dryland field (Table 4).

In this study, we examined a number of cultural and management practices used in cotton to determine their effects on cotton aphid populations, the cotton aphid pathogen, *Neozygites fresenii*. We also tested neonicotinoid insecticides to determine if an economic injury level could be determined for the cotton aphid. Treatments included early application, application after 30% of the plants were infested, and application after 90% infestation. Aphid numbers in all neonicotinoid treated plots were lower than in untreated plots and there was no difference in aphid numbers among any of the neonicotinoid treatments This indicates that if growers wait until 90% of the cotton plants are infested, they can still achieve adequate control of the cotton aphid. Fungus infection levels in all

Table 3. Effect of neonicotinoid insecticides and irrigation on percentage of winged aphids in cotton aphid populations (mean±SE) (treatments based on AIL) at Edisto REC, 2002

Date	Location	thia1	thia2	ace	thia3	untreated
		% of aphids that were winged in each of the insecticide treatments				
6/28	Irrigation	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	Dryland	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7/3	Irrigation	33.33±47.14 bc	2.27±4.55 c	16.67±33.34c	0.69±0.84c	1.48±1.88c
	Dryland	78.98±21.91 a	16.70±22.56c	63.33±42.69ab	2.40±1.08c	2.31±2.28c
7/6	Irrigation	73.11±43.39 a	5.90±6.84 b	78.69±34.78a	0.99±1.14b	1.02±2.04b
	Dryland	93.75±12.50 a	96.88±6.25a	97.50±5.00a	74.48±18.66a	3.92±2.81b
7/10	Irrigation	30.01±6.43a	21.74±17.05bc	36.15±22.23abc	14.47±18.96bc	3.24±1.92c
	Dryland	75.36±29.98 a	74.20±25.16a	45.59±9.55ab	51.38±21.23ab	4.62±5.62c
7/13	Irrigation	36.10±15.39	21.65±19.	16.69±6.8	32.10±14	6.57±5.87ab

		a	59ab	7ab	.99ab	
	Dryland	31.87±6.60ab	31.24±12.71ab	24.78±9.49ab	23.48±4.20ab	1.92±2.22b
7/17	Irrigation	10.88±8.92abc	3.50±4.73bc	1.79±3.57c	5.88±11.77bc	12.70±11.81abc
	Dryland	33.82±21.28ab	26.76±30.06abc	37.80±18.29a	2.76±2.25abc	4.20±7.18abc
7/20	Irrigation	0.00±0.00	1.73±3.45	1.61±2.07	0.83±1.67	2.09±2.61
	Dryland	11.81±13.68	8.42±11.40	27.15±33.37	2.83±3.79	18.41±18.12
7/24	Irrigation	2.27±4.55	0.00±0.00	0.00±0.00	0.00±0.00	5.40±3.79
	Dryland	2.63±5.27	8.57±10.17	9.37±16.09	6.95±13.89	0.00±0.00
7/27	Irrigation	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	Dryland	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7/31	Irrigation	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	Dryland	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

thia1= thiamethoxam 0.05 kg/ha for free-aphid treatment, thia2= thiamethoxam 0.05 kg/ha when 5 or more aphid per plant, ace= acetamiprid 0.05 kg/ha when 30% of plant infested, thia3= thiamethoxam 0.05 kg/ha when 90% of plant infested. Means within a row followed by the same letter are not significantly different p >0.05. Means without letters in the same row are not significantly different p > 0.05

Table 4. Effect of neonicotinoid insecticide treatments and irrigation on levels of fungus infection in winged cotton aphids (mean±SE) (treatments based on AIL) at Edisto REC, 2002

Date	Location	% infection by *N. fresenii* in each irrigation and insecticide treatment				
		thia1	thia2	ace	thia3	untreated
6/28	Irrigation	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	Dryland	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7/3	Irrigation	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	Dryland	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7/6	Irrigation	30.00±47.61	0.00±0.00	11.91±15.79	0.00±0.00	0.00±0.00
	Dryland	12.08±14.18	21.31±17.10	18.75±21.92	16.75±19.71	41.67±50.0
7/10	Irrigation	18.33±21.34	17.50±23.63	36.91±17.00	25.00±50.00	0.00±0.00
	Dryland	27.19±3.29	30.69±19.93	15.41±16.66	20.13±17.51	48.22±40.9
7/13	Irrigation	44.61±25.43	43.34±41.63	33.33±23.57	25.84±21.15	33.33±23.5
	Dryland	46.81±22.31	34.40±31.09	32.58±17.65	43.89±16.06	0.00±0.00
7/17	Irrigation	12.50±25.00ab	25.00±50.00ab	0.00±0.00b	12.50±25.00ab	25.00±50.0

	Dryland	7.15±14.29ab	35.00±47.26ab	60.83±28.33ab	75.00±50.00a	28.57±48.09ab
0	Irrigation	0.00±0.00b	25.00±50.00b	50.00±57.74ab	25.00±50.00b	50.00±57.74ab
	Dryland	37.50±47.87ab	50.00±57.74ab	100.00±0.00a	50.00±57.74ab	62.50±47.87ab
4	Irrigation	25.00±50.00ab	0.00±b	0.00±0.00b	0.00±0.00b	75.00±50.00a
	Dryland	12.50±25.00ab	50.00±57.74ab	50.00±57.74ab	25.00±50.00ab	0.00±0.00b
7	Irrigation	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	Dryland	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1	Irrigation	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	Dryland	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

thia1= thiamethoxam 0.05 kg/ha for free-aphid treatment, thia2= thiamethoxam 0.05 kg/ha when 5 or more aphid per plant, ace= acetamiprid 0.05 kg/ha when 30% of plant infested, thia3= thiamethoxam 0.05 kg/ha when 90% of plant infested. Means within a row followed by the same letter are not significantly different p >0.05. Means without letters in the same row are not significantly different p > 0.05 neonicotinoid treated plots were lower than in untreated plots. This was probably due to lower aphid numbers in treated plots. These tests were run in both irrigated and dryland fields. Fungus infection levels in irrigated fields were not different from those in dryland fields.

Results of our study showed that the cotton aphid always disappeared from the field within approximately two weeks after *N. fresenii* was first observed in the field. Steinkraus *et al.* (1995) mentioned that even though predator populations were low, the cotton aphid could be controlled by this one natural enemy, *N. fresenii*. Conway *et al.* (2003) stated that when natural enemies such as predators and the fungus, *N. fresenii* are considered in the treatment decision process, the initial insecticide application can usually be delayed and the number of insecticide applications per season can be reduced. Peterson and Sprenkel (1999) also reported that beneficial arthropods can reduce numbers of heliothine eggs, as well as secondary pests such as fall armyworm, soybean looper, and cotton aphids

Population dynamics studies conducted in 2002 at the Edisto Research and Education Center showed that cotton aphid populations appeared in the field at the same time every year (late June) and epizootics of *N. fresenii* always developed several weeks later. Infection levels by this fungus peaked in mid-July and declines in aphid populations were always associated with these epizootics. At the end of the sampling period each year, there were always cotton aphids infected with resting spores. The same result was also reported by Steinkraus *et al.* (1995). This means that this fungus is well established in all cotton fields and survives from one year to the next in this resistant stage. It appears that most of the management practices used by cotton farmers do not interfere with the development of these fungal epizootics.

CONCLUSIONS

Aphid numbers in all nicotinoid treated plots were lower than in untreated plots and there was no difference in aphid numbers among any of the neonicotinoid treatments This indicates that if growers wait until 90% of the cotton plants are infested, they can still achieve adequate control of the cotton aphid. Fungus infection levels in all neonicotinoid treated plots were lower than in untreated plots. This was probably due to lower aphid numbers in treated plots. These tests were run in both irrigated and dryland fields. Fungus infection levels in irrigated fields were not different from those in dryland fields.

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