Managing Macrosteles Near Severini (Auchenorrhyncha: Cicadellidae) and Myzus persicae (Hemiptera: Aphididae) in Florida Watercress

Authors: Smith, Hugh A., Nagle, Curtis A., Samuel-Foo, Michelle S., and Vallad, Gary E.

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Managing *Macrosteles* near *severini* (Auchenorrhyncha: Cicadellidae) and *Myzus persicae* (Hemiptera: Aphididae) in Florida watercress

Hugh A. Smith[1,*], *Curtis A. Nagle*[1], *Michelle S. Samuel-Foo*[2], *and Gary E. Vallad*[3]

Abstract

This is the first report of *Macrosteles* near *severini* Hamilton (Auchenorrhyncha: Cicadellidae), an invasive leafhopper, in Florida. The leafhopper was first detected in watercress in Florida in 2014. This leafhopper transmits the phytoplasma watercress aster yellows, which can cause significant yield losses. Insecticide trials were carried out in the spring of 2014 to compare the efficacy of buprofezin, flonicamid, flupyradifurone, sulfoxaflor, and tolfenpyrad, none of which were registered for use on watercress at the time of testing, with the grower standards of imidacloprid and spirotetramat, for management of *M.* nr. *severini*. All treatments except flonicamid resulted in statistically lower numbers of leafhopper nymphs than the untreated control after 3 or fewer applications. Efficacy data from this trial was provided in support of the registration of sulfoxaflor for watercress. Buprofezin and tolfenpyrad also demonstrated efficacy, and each possesses a mode of action that is distinct from imidacloprid and spirotetramat. In addition, flonicamid, sulfoxaflor, and tolfenpyrad demonstrated efficacy against *Myzus persicae* (Sulzer) (Hemiptera: Aphididae), an aphid pest of watercress.

Key Words: insecticide; *Myzus persicae;* sulfoxaflor; flonicamid; buprofezin; tolfenpyrad

Resumen

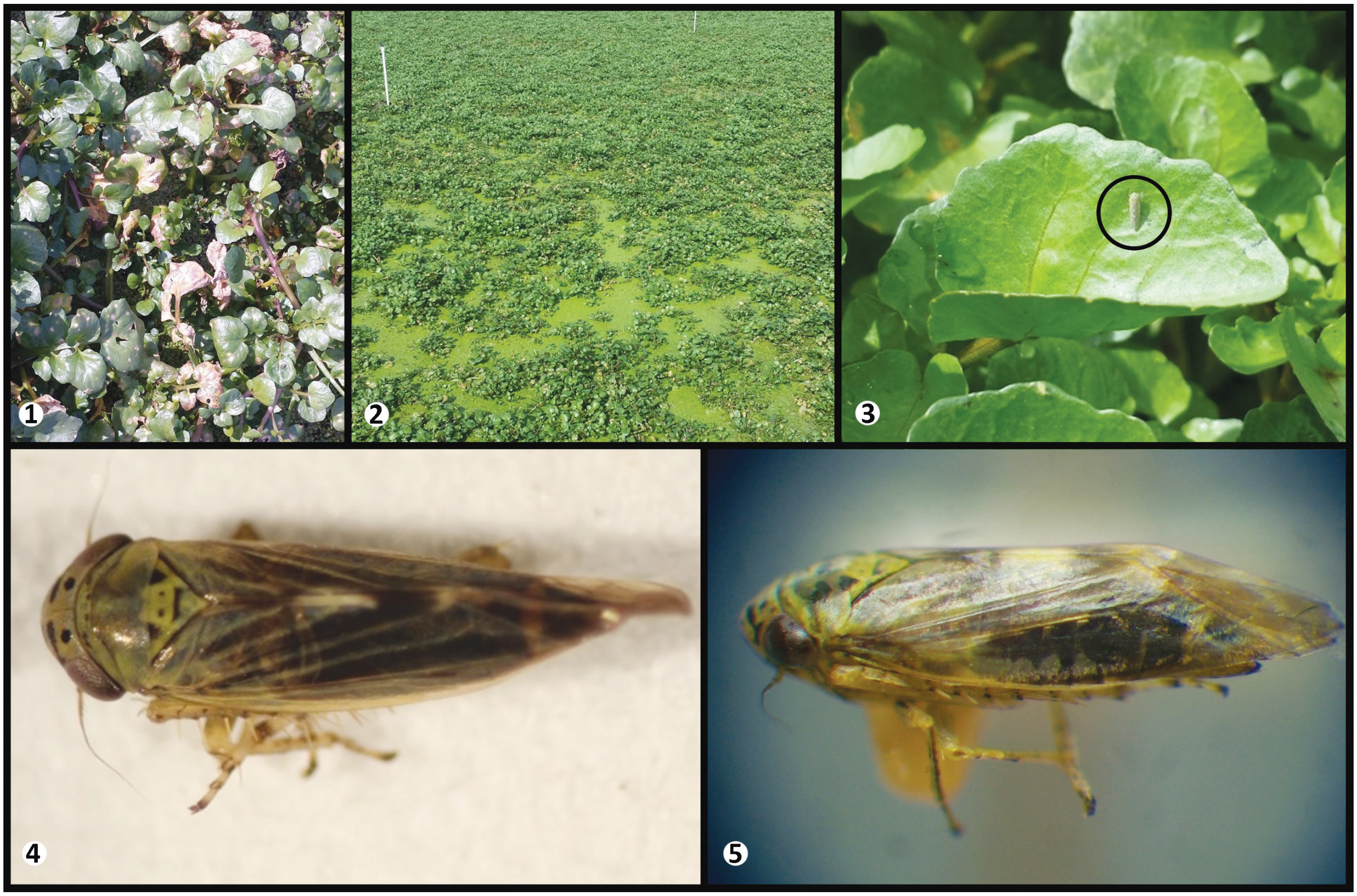
Este es el primer informe de *Macrosteles* cerca *severini* Hamilton (Auchenorrhyncha: Cicadellidae), una chicharrita (saltahoja) invasiva en la Florida. La chicharrita se detectó por primera vez en el berro de agua (*Nasturtium floridanum*) en Florida en el 2014. Esta chicharrita transmite el fitoplasma de amarillos del aster berro, que pueden causar pérdidas de rendimiento significativas. Se realizaron pruebas con insecticidas en la primavera del 2014 para comparar la eficacia de buprofezina, flonicamid, flupyradifurone, sulfoxaflor y tolfenpirad, ninguno de los cuales se ha registrado para su uso en berro en el momento de la prueba, con los estándares de cultivadores de imidacloprid y espirotretramat, para el manejo de *M*. nr. *severini*. Todos los tratamientos, menos flonicamid, resultaron en números estadísticamente menores de ninfas de las saltahojas que el testigo no tratado después de 3 o menos aplicaciones. Los datos de eficacia de este ensayo fue para apoyar el registro de sulfoxaflor de berros. Buprofezina y tolfenpirad también demostraron la eficacia, y cada uno posee un modo de acción que es distinto de imidacloprid y spirotetramat. Además, flonicamid, sulfoxaflor y tolfenpirad demostraron eficacia contra *Myzus persicae* (Sulzer) (Hemiptera: Aphididae), un pulgón plaga de los berros.

Palabras Clave: insecticidas; *Myzus persicae*; sulfoxaflor; flonicamid; buprofezina; tolfenpirad

This is the first report of the establishment in Florida of the invasive leafhopper *Macrosteles* near *severini* Hamilton (Auchenorrhyncha: Cicadellidae) and a phytoplasma it transmits, watercress aster yellows. Watercress (*Nasturtium officinale* W. T. Aiton; Brassicaceae) plants from a farm in Indian River County, Florida, began showing symptoms of watercress aster yellows in the fall of 2013. Watercress aster yellows symptoms include reduced leaf size, leaf yellowing and crinkling, and witches brooming (Borth et al. 2006) (Fig. 1). There was also significant die-back in the affected stands of watercress (Fig. 2). Plant tissue from the farm was analyzed using polymerase chain reaction (PCR) and tested positive for the phytoplasma in Jan 2014. Leafhoppers were first collected for identification from the watercress farm on 17 Jan 2014, and were sent to Andrew Hamilton, Agriculture and Agri-Food Canada, for identification. DNA barcoding from Florida specimens must be compared with specimens from California to confirm identification of the Florida populations as *M. severini* Hamilton. Until specimens are available from California to carry out barcoding, the new species in Florida will be referred to as *M*. near *severini* Hamilton.

Adults of *M.* near *severini* are about 4 mm in length (Heu et al. 2003). In the field, the insect appears uniformly pale green (Fig. 3). The vertex, pronotum, and mesoscutellum are pale green with black marks; the wings are transparent with a greenish hue (Figs. 4 and 5). Prior to the establishment of *M.* near *severini*, the only *Macrosteles* leafhoppers known to be established in Florida were *M. quadrilineatus* Forbes and *M. scripta* DeLong. *Macrosteles* near *severini* is probably native to California (Le Roux & Rubinoff 2009). It became established on the island of Oahu in Hawaii in 2000, where watercress aster yellows significantly affected the watercress industry (McHugh & Constantinides 2004). Watercress aster yellows can also infect lettuce (*Lactuca sativa* L.; Asteraceae) and several weeds, including *Eclipta prostrata*

[1]University of Florida, Department of Entomology & Nematology, Gulf Coast Research and Education Center, Wimauma, Florida 33598, USA; E-mail: hughasmith@ufl.edu (H. A. S.), cnagle@ufl.edu (C. A. N.)
[2]University of Florida, IR-4 Program, Food and Environmental Toxicology Lab, Gainesville, Florida 32611, USA; E-mail: mfoo@ufl.edu (M. S. S.-F.)
[3]University of Florida, Department of Plant Pathology, Gulf Coast Research and Education Center, Wimauma, Florida 33598, USA; E-mail: gvallad@ufl.edu (G. E. V.)
*Corresponding author; E-mail: hughasmith@ufl.edu (H. A. S.)



Figs. 1–5. The leafhopper *Macrosteles* near *severini* on watercress in Florida. **1.** Leaf necrosis in Florida watercress due to watercress aster yellows, which is transmitted by *M.* near *severini*. **2.** Die-back due to watercress aster yellows on a watercress farm in Indian River County, Florida, Jan 2014. **3.** Adult of *M.* near *severini* as it appears on watercress in the field. **4.** Adult of *M.* near *severini*, dorsal aspect. **5.** Adult of *M.* near *severini*, lateral aspect. All photographs by Hugh Smith.

L. (Asteraceae), *Emilia sonchifolia* (L.) (Asteraceae), *Sonchus oleraceus* L. (Asteraceae), *Myriophyllum aquatum* (Vell.) Verdc. (Haloragaceae), *Plantago major* L. (Plantaginaceae), and *Amaranthus* sp. (Amaranthaceae) (Borth et al. 2006).

Watercress is grown in Florida from Sep through Apr, and is harvested from cuttings over a 6 to 8 mo period. Multiple insecticide applications are required to suppress pests during the full crop season. Limited information on pests affecting Florida watercress was available prior to the present study; however, diamondback moth larvae, *Plutella xylostella* L. (Lepidoptera: Plutellidae), and an unidentified aphid species habitually infested the farm where *M*. near *severini* was detected. In 2014, only 2 insecticides with efficacy against sucking insects were labeled for use on watercress in Florida: imidacloprid (Admire Pro, Bayer Crop Science, Raleigh, North Carolina, and many generics, including Advise 2FL, Winfield Solutions, St. Paul, Minnesota), and spirotetramat (Movento, Bayer Crop Science, Raleigh, North Carolina).

Imidacloprid is a neonicotinoid insecticide and functions as a nicotinic acetylcholine receptor agonist. Spirotetramat is a lipid biosynthesis inhibitor. Some formulations of imidacloprid allowed for up to five 3 oz applications per acre per crop on watercress (five 219 mL applications per ha per crop). The spirotetramat label allows for six 4 oz applications per acre per crop (six 292 mL applications per ha per crop). The limited number of modes of action registered for use on watercress and the long crop season produced concerns that overuse of imidacloprid and spirotetramat could lead to resistance in the leafhopper populations. To determine if additional insecticides with distinct modes of action had efficacy against *M.* near *severini* in watercress, an on-farm trial was carried out in the spring of 2014. The materials evaluated were buprofezin (Courier 40SC, Nichino America, Wilmington, Delaware), flonicamid (Beleaf 50 SG, FMC Corporation, Philadelphia, Pennsylvania), flupyradifurone (Sivanto 200 SL, Bayer Crop Science, Raleigh, North Carolina), sulfoxaflor (Closer SC, Dow AgroSciences, Indianapolis, Indiana), and tolfenpyrad (Torac 1.29 EC, Nichino America, Wilmington, Delaware). Buprofezin is a growth regulator with efficacy against the nymphal stages of certain hemipteran insects. It also reduces the viability of eggs in adult females. Flonicamid is a modulator of chordotonal organs that causes feeding cessation in aphids and other sucking insects. Flupyradifurone and sulfoxaflor are nicotinic acetylcholine receptor agonists and tolfenpyrad is a mitochondrial complex inhibiter. Each has efficacy against a broad range of target pests. Flupyradifurone and sulfoxaflor have the same mode of action as imidacloprid; however, they were evaluated to determine comparative efficacy against *M.* near *severini*. During this trial, aphids were identified and treatment effects on aphids were also evaluated.

Materials and Methods

Six insecticide treatments and an untreated control were evaluated for control of *M.* near *severini* and aphids on a watercress farm in Indian River County, Florida. The insecticide treatments evaluated were imidacloprid/spirotetramat (grower standard), buprofezin, flonicamid, flupyradifurone, sulfoxaflor, and tolfenpyrad (Table 1). These treatments were applied once a week for 3 wk. Imidacloprid and spirotetramat were combined in the first 2 applications, and imidacloprid alone was applied for the 3rd application. Two 0.8 ha watercress fields were used as the study site. Watercress fields were divided by sprinkler irrigation ridges into twenty 9 × 46 m sections of approximately 0.04 ha each. Each treatment was replicated 3 times, in plots each equal to one such 0.04 ha section, in a randomized complete block design with an untreated buffer plot (0.04 ha) between each treated plot. Plots were sprayed with a hand-held, hand-pumped, backpack sprayer, pressurized by compressed air to 2.75×10^5 Pa (40 lb/inch^2), with a spray wand outfitted with a single spray nozzle (nozzle #11006, TeeJet® Technologies, Springfield, Illinois) fitted with a D2 disc and 110° core, calibrated to deliver 187 L/ha (20 gal/acre). Three applicators walking side by side applied the treatments. Treatments were applied on 26 Feb, 5 Mar, and 12 Mar 2014 (Table 1).

Plots were sampled using an "Insectazooka" field aspirator (product #2888A, Bioquip Products Inc., Rancho Dominguez, California), which delivers insects into a 30 cm^3 sampling cup. The sampling pattern was a transect line that ran diagonally from the left corner on the front 9 m side to the middle of the right 46 m side (marked by the central sprinkler) then diagonally back to the far left corner of the plot, a length of 49 m, forming the shape of a greater than (" >") sign. The front of the plot was considered the side bordering the access road. The person collecting the sample pressed the end of the aspirator lightly into the upper canopy of the watercress and moved the end of the aspirator from side to side while walking the transect. A pre-treatment sample was taken 1 d before the 1st application. Five additional samples were taken: 28 Feb, plus 4, 7, 14, and 18 Mar. Samples were taken to the University of Florida, Gulf Coast Research & Education Center (GCREC), Balm, Florida, where insects were frozen before being counted in 100 × 100 mm gridded Petri dishes (product # 08-757-11A, Fisher Scientific, Pittsburgh, Pennsylvania) under a stereomicroscope. Data recorded were numbers of adult and nymphal leafhoppers and alate and apterous aphids. Data were subjected to ANOVA ($P < 0.05$) by sample date and pooled over all post-treatment sample dates. Treatment means were separated by Fisher's Protected LSD ($P < 0.05$) using SAS software (SAS Institute 2008). All numerical data were transformed by $\log_{10}(x+1)$ prior to analyses; non-transformed means are reported in the tables.

Results

LEAFHOPPER ADULTS

Flonicamid, sulfoxaflor, and tolfenpyrad reduced adult leafhopper numbers significantly compared with the untreated control within 2 d of the 1st application (Table 2). Each of the 6 chemical treatments reduced numbers of adult leafhoppers compared with the untreated control when data from post-treatment samples (collected 28 Feb to 18 Mar) were pooled. Moreover, when samples were pooled, densities of adult leafhoppers were significantly lower in the buprofezin treatment than in all other treatments except sulfoxaflor and tolfenpyrad. On some later sample dates, numbers of adult leafhoppers were not statistically different in the untreated control from plots receiving insecticide treatments.

LEAFHOPPER NYMPHS

Leafhopper nymphs were significantly fewer in the buprofezin treatment than in all other treatments within 6 d of the 1st application (Table 3). Within 2 d of the 2nd application, leafhopper nymphs were significantly fewer in the buprofezin, flupyradifurone, sulfoxaflor, and tolfenpyrad treatments than in the untreated control. Three days after the 3rd application, leafhopper nymphs were significantly fewer in the imidacloprid/spirotetramat, sulfoxaflor, buprofezin, and tolfenpyrad treatments than in the untreated control. Leafhopper nymph numbers in the flonicamid treatment did not separate statistically from the untreated control on any sample date, although there was a tendency for leafhopper nymph numbers to be lower in the flonicamid treatment than in the untreated control.

Table 1. Insecticide treatment rates and application timing; Indian River County, Florida, 2014.

Treatment program no. & chemical name(s)	Rate g a.i./ha[a]	Trade name & formulation	a.i. concentration	Dates of application		
				26 Feb	5 Mar	12 Mar
1. Untreated	—	—	—			
2. Imidacloprid	52.6	Advise 2FL	240.0 g/L	X	X	
+ spirotetramat	87.7	Movento 2SC	240.0 g/L	X	X	
+ nonionic surfactants[b]	420.8	Induce 90%	900.0 g/L	X	X	
Imidacloprid	52.6	Advise 2FL	240.0 g/L			X
+ nonionic surfactants	420.8	Induce 90%	900.0 g/L			X
3. Flonicamid	98.1	Beleaf 50 SG	500.0 g/kg	X	X	X
+ nonionic surfactants	420.8	Induce 90%	900.0 g/L	X	X	X
4. Sulfoxaflor	100.8	Closer SC	240.0 g/L	X	X	X
+ nonionic surfactants	420.8	Induce 90%	900.0 g/L	X	X	X
5. Buprofezin	428.6	Courier 40SC	431.3 g/L	X	X	X
+ nonionic surfactants	420.8	Induce 90%	900.0 g/L	X	X	X
6. Flupyradifurone	153.5	Sivanto 200 SL	200.0 g/L	X	X	X
+ nonionic surfactants	420.8	Induce 90%	900.0 g/L	X	X	X
7. Tolfenpyrad	237.1	Torac 1.29 EC	154.5 g/L	X	X	X
+ nonionic surfactants	420.8	Induce 90%	900.0 g/L	X	X	X

[a]A '+' means the products were combined; all treatments were applied in 187 L/ha.
[b]A blend of alkyl aryl polyoxylkane ether and free fatty acids.

Table 2. Mean (± SE) densities of *Macrosteles* near *severini* adults associated with insecticide treatments; Indian River County, Florida, 2014.

	Adults of *Macrosteles* near *severini* (no./49 m sample)						
Treatment[a]	25 Feb[b]	28 Feb	4 Mar	7 Mar	14 Mar	18 Mar	28 Feb to 18 Mar[c]
Untreated	32.0 ± 1.5a	22.0 ± 4.5a	59.3 ± 13.3a	87.7 ± 27.9a	65.7 ± 21.7a	89.0 ± 5.5a	323.7 ± 55.9a
Imidacloprid/spirotetramat	17.3 ± 4.6a	13.3 ± 0.9ab	38.7 ± 9.1abc	36.0 ± 4.2bc	43.0 ± 8.6a	68.0 ± 11.0a	199.0 ± 22.5b
Flonicamid	24.3 ± 2.3a	7.3 ± 3.3c	35.3 ± 8.2bc	50.0 ± 15.3ab	38.3 ± 17.0a	58.3 ± 10.4a	189.3 ± 48.5b
Sulfoxaflor	21.0 ± 1.7a	7.0 ± 1.0c	27.3 ± 6.7c	18.7 ± 7.7d	27.3 ± 6.1a	69.7 ± 20.0a	150.0 ± 38.2bc
Buprofezin	13.7 ± 3.4a	18.3 ± 2.9ab	31.3 ± 7.4bc	23.7 ± 10.7cd	22.7 ± 13.2a	21.3 ± 13.8b	117.3 ± 47.4c
Flupyradifurone	17.3 ± 3.7a	17.0 ± 3.5ab	48.0 ± 7.0ab	30.0 ± 9.3 bcd	30.7 ± 0.9a	70.0 ± 10.2a	195.7 ± 25.6b
Tolfenpyrad	20.7 ± 2.8a	13.3 ± 3.4b	33.7 ± 1.7bc	17.3 ± 4.9d	30.0 ± 6.6a	48.0 ± 11.4a	142.3 ± 26.4bc
$F_{6,12}$	2.28	8.74	3.20	7.68	1.88	7.21	7.87
P-value	0.1058	0.0008	0.0408	0.0015	0.1656	0.0019	0.0013

Means within a column followed by the same letter are not significantly different by Fisher's Protected LSD ($P \leq 0.05$). Data were transformed by $\log_{10}(x+1)$ prior to ANOVA; non-transformed means are presented.
[a]All treatments were applied in 187 L/ha; see Table 1 for rates.
[b]Pre-treatment sample.
[c]Data were pooled over post-treatment sample dates.

APHIDS

The aphids infesting watercress at the trial site were *Myzus persicae* (Sulzer) (Hemiptera: Aphididae). Alate aphid numbers were modest prior to treatment, and there were no differences among treatments 2 d after the initial applications had been made. By 6 d after the 1st application (4 Mar), only plots treated with flonicamid or tolfenpyrad possessed alate aphid densities lower than in the untreated plots (Table 4). Treatments of imidacloprid/spirotetramat, flonicamid, sulfoxaflor, and tolfenpyrad resulted in densities lower than in the untreated plots for the remainder of the trial. Apterous aphid densities were about 20 times greater than densities of alates prior to chemical applications. Their responses to the treatments followed a similar pattern to that of the winged forms (Table 5). Treatments of buprofezin and flupyradifurone did not result in aphid densities lower than in the untreated plots at any time during the trial. Buprofezin was not expected to have any effect on aphid numbers.

Discussion

These trials demonstrated that the growers' standard approach to managing *M. severini* with imidacloprid and spirotetramat was effective in reducing numbers of leafhopper nymphs after 3 weekly applications. Alternate materials, not registered for use on watercress in Florida at the time the trials were carried out, showed promise as additional rotational tools for management of leafhoppers that can offset the development of insecticide resistance. The fact that adult leafhopper numbers were not statistically different among treatments on some later sample dates may be due to dispersal of leafhopper adults from adjacent untreated buffer zones. Buprofezin possesses a mode of action distinct from that of the neonicotinoids and so would complement presently registered insecticides for management of leafhoppers. Although buprofezin does not directly affect adult leafhopper survival, it suppresses oviposition, reduces egg viability and prevents nymphs from reaching the adult stage. Tolfenpyrad produced promising results; however, because of its high toxicity to fish and aquatic invertebrates, it is unlikely to receive registration for use in a semi-aquatic crop. Results of this trial contributed to the registration of sulfoxaflor for management of leafhoppers in Florida watercress in 2014. However, sulfoxaflor is presently under review by the US Environmental Protection Agency. Flonicamid, sulfoxaflor, and tolfenpyrad also demonstrated efficacy against *M. persicae*.

Macrosteles near *severini* and the phytoplasma it transmits have not become established within the Hawaiian Islands outside of watercress on the island of Oahu (Smith et al. 2002). By implementing a clean culture program that involved planting of phytoplasma-free cuttings, judicious use of insecticides, and removal of all plant residue after harvest, watercress growers on Oahu reduced watercress aster yellows to negligi-

Table 3. Mean (± SE) densities of *Macrosteles* near *severini* nymphs associated with insecticide treatments; Indian River County, Florida, 2014.

	Nymphs of *Macrosteles* near *severini* (no./49 m sample)						
Treatment[a]	25 Feb[b]	28 Feb	4 Mar	7 Mar	14 Mar	18 Mar	28 Feb to 18 Mar[c]
Untreated	88.0 ± 11.8a	6.3 ± 1.5a	90.0 ± 48.0a	100.3 ± 32.3a	37.7 ± 10.9a	51.7 ± 13.0a	286.0 ± 88.0a
Imidacloprid/spirotetramat	79.0 ± 14.0a	7.3 ± 1.2a	56.0 ± 14.4a	31.0 ± 4.0abc	5.3 ± 0.9bc	14.0 ± 4.7bc	113.7 ± 16.1bc
Flonicamid	103.0 ± 31.8a	16.7 ± 10.7a	50.3 ± 19.2a	60.3 ± 16.2ab	34.0 ± 9.1a	34.3 ± 3.5ab	195.7 ± 44.2ab
Sulfoxaflor	58.7 ± 28.3a	2.3 ± 0.3a	50.7 ± 17.7a	11.0 ± 6.1de	0.3 ± 0.3de	8.7 ± 6.2c	73.0 ± 30.1cd
Buprofezin	62.0 ± 21.1a	24.7 ± 12.3a	14.0 ± 5.5b	2.0 ± 0.6e	0.0 ± 0.0e	0.3 ± 0.3d	41.0 ± 17.9d
Flupyradifurone	75.3 ± 21.9a	6.7 ± 2.3a	81.0 ± 25.6a	23.3 ± 16.6cd	4.3 ± 3.8cd	10.3 ± 6.4c	125.7 ± 46.0bc
Tolfenpyrad	60.0 ± 20.2a	11.7 ± 6.4a	46.3 ± 13.6a	18.3 ± 3.4bcd	9.0 ± 1.0b	11.7 ± 4.8bc	97.0 ± 21.6bc
$F_{6,12}$	0.74	1.92	4.44	8.58	16.95	9.52	8.33
P-value	0.6258	0.1588	0.0136	0.0009	<0.0001	0.0006	0.0010

Means within a column followed by the same letter are not significantly different by Fisher's Protected LSD ($P \leq 0.05$). Data were transformed by $\log_{10}(x+1)$ prior to ANOVA; non-transformed means are presented.
[a]All treatments were applied in 187 L/ha; see Table 1 for rates.
[b]Pre-treatment sample.
[c]Data were pooled over post-treatment sample dates.

Table 4. Mean (± SE) densities of *Myzus persicae* alates associated with insecticide treatments; Indian River County, Florida, 2014.

	Aphid alates (no./49 m sample)						
Treatment[a]	25 Feb[b]	28 Feb	4 Mar	7 Mar	14 Mar	18 Mar	28 Feb to 18 Mar[c]
Untreated	2.0 ± 1.2a	1.3 ± 0.3a	13.0 ± 2.9ab	31.0 ± 4.0a	29.7 ± 0.7a	33.3 ± 6.3a	108.3 ± 11.9a
Imidacloprid/spirotetramat	4.3 ± 0.9a	4.3 ± 2.3a	10.7 ± 3.3ab	7.7 ± 2.2b	1.3 ± 0.3b	0.7 ± 0.3bc	24.7 ± 5.8b
Flonicamid	1.0 ± 0.6a	2.3 ± 0.7a	1.0 ± 1.0c	1.0 ± 1.0c	1.0 ± 0.6b	0.0 ± 0.0c	5.3 ± 1.8c
Sulfoxaflor	2.3 ± 0.9a	2.3 ± 0.9a	8.0 ± 3.0b	15.0 ± 1.2ab	2.0 ± 1.5b	1.7 ± 0.9b	29.0 ± 3.2b
Buprofezin	11.7 ± 8.2a	3.3 ± 2.0a	21.0 ± 7.0a	29.7 ± 8.0a	34.3 ± 5.5a	41.7 ± 6.6a	130.0 ± 6.0a
Flupyradifurone	0.3 ± 0.3a	1.7 ± 0.9a	9.7 ± 3.5ab	30.3 ± 10.4a	16.7 ± 4.1a	22.0 ± 5.1a	80.3 ± 6.8a
Tolfenpyrad	1.3 ± 1.3a	2.3 ± 2.3a	1.7 ± 0.7c	1.3 ± 0.9c	1.0 ± 1.0b	0.3 ± 0.3bc	6.7 ± 3.2c
$F_{6,12}$	2.62	0.59	8.53	13.87	21.85	52.13	45.25
P-value	0.0738	0.7328	0.0009	<0.0001	<0.0001	<0.0001	<0.0001

Means within a column followed by the same letter are not significantly different by Fisher's Protected LSD ($P \leq 0.05$). Data were transformed by $\log_{10}(x+1)$ prior to ANOVA; non-transformed means are presented.
[a]All treatments were applied in 187 L/ha; see Table 1 for rates.
[b]Pre-treatment sample.
[c]Data were pooled over post-treatment sample dates.

Table 5. Mean (± SE) densities of *Myzus persicae* apterous aphids associated with insecticide treatments; Indian River County, Florida, 2014.

	Apterous aphids (no./49 m sample)						
Treatment[a]	25 Feb[b]	28 Feb	4 Mar	7 Mar	14 Mar	18 Mar	28 Feb to 18 Mar[c]
Untreated	70.0 ± 5.3a	10.0 ± 1.2a	142.3 ± 47.0ab	151.7 ± 13.7a	66.7 ± 26.8a	38.7 ± 12.3a	409.3 ± 94.3a
Imidacloprid/spirotetramat	109.7 ± 32.3a	27.3 ± 11.0a	45.3 ± 19.9c	39.0 ± 13.1b	1.0 ± 0.0bc	2.0 ± 2.0b	114.7 ± 38.9b
Flonicamid	77.7 ± 30.6a	27.3 ± 16.4a	8.0 ± 0.6d	6.3 ± 2.8c	0.7 ± 0.7c	0.0 ± 0.0b	42.3 ± 19.9c
Sulfoxaflor	70.3 ± 17.4a	26.3 ± 4.7a	54.7 ± 10.7bc	48.3 ± 19.0b	5.0 ± 3.1b	5.7 ± 4.7b	140.0 ± 41.8b
Buprofezin	67.3 ± 15.1a	33.7 ± 15.1a	155.0 ± 15.0a	145.7 ± 55.9a	86.0 ± 18.0a	109.7 ± 27.8a	530.0 ± 111.3a
Flupyradifurone	70.0 ± 28.4a	19.0 ± 8.7a	158.7 ± 39.4a	153.7 ± 22.4a	65.0 ± 10.6a	53.7 ± 1.8a	450.0 ± 63.1a
Tolfenpyrad	77.3 ± 11.3a	19.3 ± 7.5a	5.3 ± 1.2d	5.3 ± 0.9c	0.3 ± 0.3c	0.3 ± 0.3b	30.7 ± 7.6c
$F_{6,12}$	0.49	1.08	20.34	32.19	34.12	19.30	31.75
P-value	0.8055	0.4257	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Means within a column followed by the same letter are not significantly different by Fisher's Protected LSD ($P \leq 0.05$). Data were transformed by $\log_{10}(x+1)$ prior to ANOVA; non-transformed means are presented.
[a]All treatments were applied in 187 L/ha; see Table 1 for rates.
[b]Pre-treatment sample.
[c]Data were pooled over post-treatment sample dates.

ble levels (John McHugh, personal communication). The leafhopper and phytoplasma have not been detected outside of localized watercress infestations in Florida, and efforts are ongoing to contain the problem.

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