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

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

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

**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

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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. nr. 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 & Constandinides 2004). Watercress aster yellows can also infect lettuce (*Lactuca sativa* L.; Asteraceae) and several weeds, including *Eclipta prostrata*...
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 nico-

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 cm³ collection 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 | Trade name & formulation | a.i. concentration | Dates of application |
|----------------------------------------|---------------|--------------------------|-------------------|---------------------|
| 1. Untreated                           | 0             |                          | 0                 | 26 Feb X X X        |
| 2. Imidacloprid                        | 52.6          | Advise 2FL               | 240.0 g/L         | X X X X            |
| + spirotetramat                       | 87.7          | Movento 2SC              | 240.0 g/L         | X X X X            |
| + nonionic surfactants                 | 420.8         | Induce 90%               | 900.0 g/L         | X X X X            |
| Imidacloprid                           | 52.6          | Advance 2FL              | 240.0 g/L         | X X X X            |
| + nonionic surfactants                 | 420.8         | Induce 90%               | 900.0 g/L         | X X X X            |
| 3. Flonicamid                          | 98.1          | Beleaf 50 SG             | 500.0 g/kg        | X X X X            |
| + nonionic surfactants                 | 420.8         | Induce 90%               | 900.0 g/L         | X X X X            |
| 4. Sulfoxaflor                         | 100.8         | Closer SC                | 240.0 g/L         | X X X X            |
| + nonionic surfactants                 | 420.8         | Induce 90%               | 900.0 g/L         | X X X X            |
| 5. Buprofezin                          | 428.6         | Courier 40SC             | 431.3 g/L         | X X X X            |
| + nonionic surfactants                 | 420.8         | Induce 90%               | 900.0 g/L         | X X X X            |
| 6. Flupyradifurone                     | 153.5         | Sivanto 200 SL           | 200.0 g/L         | X X X X            |
| + nonionic surfactants                 | 420.8         | Induce 90%               | 900.0 g/L         | X X X X            |
| 7. Tolfenpyrad                         | 237.1         | Torac 1.29 EC            | 154.5 g/L         | X X X X            |
| + nonionic surfactants                 | 420.8         | Induce 90%               | 900.0 g/L         | X X X X            |

*“<” means the products were combined; all treatments were applied in 187 L/ha.

A blend of alkyl aryl polyoxykane ether and free fatty acids.
Table 2. Mean (± SE) densities of Macrosteles severini adults associated with insecticide treatments; Indian River County, Florida, 2014.

| Treatmenta | 25 Febb | 28 Feb | 4 Mar | 7 Mar | 14 Mar | 18 Mar | 28 Feb to 18 March |
|------------|---------|--------|-------|-------|--------|--------|-------------------|
| 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 ± 9.3bcd | 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 |

Means within a column followed by the same letter are not significantly different by Fisher’s Protected LSD (P ≤ 0.05). Data were transformed by log_{10}(x+1) prior to ANOVA; non-transformed means are presented.

*All treatments were applied in 187 L/ha; see Table 1 for rates.

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

| Treatmenta | 25 Febb | 28 Feb | 4 Mar | 7 Mar | 14 Mar | 18 Mar | 28 Feb to 18 March |
|------------|---------|--------|-------|-------|--------|--------|-------------------|
| 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 ± 5.0bc | 111.7 ± 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 ± 0.3e | 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 ± 3.4bc | 9.0 ± 1.0b | 11.7 ± 4.8bc | 97.0 ± 21.6bc |

Means within a column followed by the same letter are not significantly different by Fisher’s Protected LSD (P ≤ 0.05). Data were transformed by log_{10}(x+1) prior to ANOVA; non-transformed means are presented.

*All treatments were applied in 187 L/ha; see Table 1 for rates.

*Pre-treatment sample.

*Data were pooled over post-treatment sample dates.

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

| Treatment | 25 Feb | 28 Feb | 4 Mar | 7 Mar | 14 Mar | 18 Mar | 28 Feb to 18 Mar |
|-----------|-------|--------|-------|-------|-------|--------|------------------|
| 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 ± 1.0a | 1.0 ± 1.0c | 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*<sub>6,12</sub> | 2.62 | 0.59 | 8.53 | 13.87 | 21.85 | 52.13 | 45.25 |
| *P*-value | 0.0738 | 0.7328 | <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* ≤ 0.05). Data were transformed by log<sub>10</sub>(x+1) prior to ANOVA; non-transformed means are presented.

*All treatments were applied in 187 L/ha; see Table 1 for rates.

*Pre-treatment sample.

*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.

| Treatment | 25 Feb | 28 Feb | 4 Mar | 7 Mar | 14 Mar | 18 Mar | 28 Feb to 18 Mar |
|-----------|-------|--------|-------|-------|-------|--------|------------------|
| 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 ± 0.0b | 114.7 ± 38.9b |
| Flonicamid | 77.7 ± 30.6a | 27.3 ± 16.4a | 8.0 ± 0.8d | 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 ± 7.0a | 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 ± 0.3bc | 30.7 ± 7.6c |
| *F*<sub>6,12</sub> | 0.49 | 0.0855 | 0.4257 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| *P*-value | 1.08 | <0.0001 | <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* ≤ 0.05). Data were transformed by log<sub>10</sub>(x+1) prior to ANOVA; non-transformed means are presented.

*All treatments were applied in 187 L/ha; see Table 1 for rates.

*Pre-treatment sample.

*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.

Acknowledgments

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References Cited

Borth WB, Fukuda SK, Hamasaki RT, Hu JS, Almeida RPP. 2006. Detection, characterization, and transmission of *Macrolestes* leafhoppers of watercress yellows phytoplasma in Hawaii. Annals of Applied Biology 149: 357–363.

Heu RA, Kumashiro BR, Hamasaki RT, Fukuda SK. 2003. Watercress leafhopper *Macrolestes* sp. nr. *severini* Hamilton. New Pest Advisory No. 02-01. Division of Plant Industry, Hawaii Department of Agriculture, Honolulu, Hawaii, https://hdoa.hawaii.gov/pi/files/2013/01/npa02-01-wcleafhopper.pdf (last accessed 27 Aug 2016).

Le Roux JJ, Rubinoff D. 2009. Molecular data reveals California as the potential source of an invasive leafhopper species, *Macrolestes* sp. nr. *severini*, transmitting the aster yellows phytoplasma in Hawaii. Annals of Applied Biology 154: 429–439.

McHugh Jr JJ, Constantinides LN. 2004. Pest management strategic plan for watercress production in Hawaii. Workshop summary May 25, 2004. Pearl City Urban Garden Center, University of Hawaii at Manoa, Honolulu, Hawaii, http://www.ipmcenters.org/pmsp/pdf/HIwatercress.pdf (last accessed 23 May 2016).

SAS Institute. 2008. SAS Software, Version 9.2. SAS Institute, Cary, North Carolina.

Smith HA, McHugh Jr JJ, Constantinides LN, Le Roux JJ, Hamilton. New Pest Advisory No. 02-01. Division of Plant Industry, Hawaii Department of Agriculture, Honolulu, Hawaii, http://hdoa.hawaii.gov/pi/files/2013/01/npa02-01-wcleafhopper.pdf (last accessed 27 Aug 2016).

Tolfenpyrad 77.3 ± 11.3a | 19.3 ± 7.5a | 5.3 ± 1.2d | 5.3 ± 0.9c | 0.3 ± 0.3c | 0.3 ± 0.3bc | 30.7 ± 7.6c |

*F*<sub>6,12</sub> | 0.49 | 0.0855 | 0.4257 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| *P*-value | 1.08 | <0.0001 | <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* ≤ 0.05). Data were transformed by log<sub>10</sub>(x+1) prior to ANOVA; non-transformed means are presented.

*All treatments were applied in 187 L/ha; see Table 1 for rates.

*Pre-treatment sample.

*Data were pooled over post-treatment sample dates.