Technology & Product Reports

Evaluation of Medium-applied Insect Growth Regulators Against Fungus Gnats and Western Flower Thrips Populations on African Violets

Scott W. Ludwig,[1]
Kelli Hoover,[2] and
Robert Berghage[3]

Additional index words. *Bradysia*, **diflubenzuron, fenoxycarb,** *Frankliniella occidentalis*, **greenhouse, pyriproxyfen**

Summary. In a previous study, three insect growth regulators, diflubenzuron, pyriproxyfen, and fenoxycarb, were shown to reduce the emergence of western flower thrips (*Frankliniella occidentalis*) from potting medium under experimental conditions. Our objective was to evaluate the impact of potting medium applications of fenoxycarb, diflubenzuron, and pyriproxyfen on western flower thrips and fungus gnats (*Bradysia* spp.) populations in conventionally grown african violets (*Saintpaulia ionantha*). In two trials conducted at a university greenhouse and one trial at a commercial flower grower's greenhouse, no reductions were observed in western flower thrips populations. In one university trial, all three insect growth regulators resulted in lower fungus gnat populations. In addition to medium treatment, results from the commercial greenhouse indicated that a pesticide application to the soil under the benches may also be needed to provide management of fungus gnats.

Department of Entomology, 501 Agricultural Sciences and Industries Building, The Pennsylvania State University, University Park, PA 16802

We thank Heather Reed, Bailey Klinestiver, and Christina Mullen for technical support and Judy Smith for scouting the commercial greenhouse site. We also thank Karl Lederer for use of greenhouse space, african violets, and technical support. We extend special thanks to Paul Heller and James Sellmer for reviewing earlier drafts of the manuscript. This research was funded by a grant from the Pennsylvania Department of Agriculture Green Industry Grower/Retailer IPM Program and the Bedding Plants Foundation, Inc.

[1]Extension program specialist–IPM; to whom correspondence should be addressed. Texas Cooperative Extension, P.O. Box 38, Overton, TX 75684.

[2]Assistant professor.

[3]Associate professor, Department of Horticulture, 314 Tyson Building, The Pennsylvania State University, University Park, PA 16802.

The impact of fungus gnat larvae on greenhouse crops has been difficult to assess since feeding damage occurs to the plant's root system within the potting medium. The larvae feed on fungi and organic matter in the media, in addition to feeding on healthy and diseased plant tissue. Feeding damage to the roots of healthy plants has been shown to predispose the plant to infection by plant pathogens (Leath and Newton, 1969). The ability of adult fungus gnats to transmit pathogens is also of concern. Fungus gnats in the genus *Bradysia* have been recorded to vector the pathogen responsible for verticillium wilt (*Verticillium albo-atrum*), root and stem rots, and damping off (*Pythium aphanidermatum*), black root rot (*Thielaviopsis basicola*), and fusarium wilt (*Fusarium oxysporum*) (Gardiner et al., 1990; Gillespie and Menzies, 1993; Harris et al., 1995; Jarvis et al., 1993; Kalb and Miller, 1986). This pest is also capable of rapid development under greenhouse conditions. At 20 °C (68.0 °F), fungus gnats (*B. impatiens*) can complete one generation in 16.3 d (Steffan 1974).

Western flower thrips are also difficult to manage in greenhouse production systems. At an average temperature of 20 °C, western flower thrips are capable of completing one generation in 21.4 d (Lublinkhof and Foster 1977). This pest not only causes significant damage to foliage and flowers of susceptible plants but also is capable of vectoring tospoviruses (Wetering et al., 1996). Western flower thrips management has become extremely difficult because thrips have developed resistance to many of the major classes of insecticides commonly used in conventional management programs (Brodsgaard, 1994; Immaraju et al., 1992; Zhao et al., 1995). Another challenge to the management of western flower thrips is that late second instar nymphs migrate off the plant into the potting media where the insect remains for two additional stages until adult emergence. This aspect of the lifecycle makes management difficult since these immature stages are not exposed to foliar insecticide applications. Adults emerging from the medium are capable of dispersing throughout the greenhouse. In addition, first instar nymphs that fed previously on virally infected foliage are capable of transmitting the virus to new susceptible plants as adults (Wetering et al., 1996).

Ludwig and Oetting (2001) found that three insect growth regulators, fenoxycarb, diflubenzuron, and pyriproxyfen, applied at label rates to the potting medium, reduced western flower thrips emergence from the potting medium. In a separate trial, pyriproxyfen applied to the potting medium of chrysanthemums at 3 mg a.i. and 6 mg a.i. per pot (28,350 mg = 1.0 oz) resulted in lower thrips emergence on two of three sample dates (C.P. Hesselein, unpublished data). If adult thrips emergence could be reduced by the use of medium treatments, fewer applications of foliar insecticides would be needed. The ability to use only one insecticide to manage both pests could decrease labor and insecticide costs for growers. In addition, the use of medium drenches for thrips control should reduce the number of foliar insecticide applications required. A reduction in foliar insecticide use would also decrease the likelihood that thrips would develop resistance to insecticides. The objective of this research was to evaluate under commercial growing conditions the im-

Table 1. Mean number ± SD of fungus gnats and western flower thrips per yellow and blue sticky cards in pesticide efficacy trials on african violets at a Pennsylvania State University research greenhouse (University Park) and Herman Lederer and Sons Greenhouse (Parker Ford, Pa.).

	Experiment location		
Insect	Parker Ford	University Park Trial 1	University Park Trial 2
Western flower thrips			
Yellow	0.5 ± 1.1 a[z]	3.7 ± 5.9 a	13.0 ± 14.0 a
Blue	0.09 ± 0.3 b	0.5 ± 0.8 b	0.2 ± 0.6 b
Fungus gnats			
Yellow	34.5 ± 23.1 a	6.2 ± 10.6 a	13.6 ± 13.4 a
Blue	4.9 ± 4.9 b	1.4 ± 2.7 b	0.1 ± 0.14 b

[z]Means within columns with the same letter for each pest species are not significantly different ($P > 0.05$, least significant difference test).

pact of fenoxycarb, diflubenzuron, and pyriproxyfen on western flower thrips and fungus gnat populations when the insecticides were applied to the potting medium of african violets at rates used for fungus gnat management.

Materials and methods

The following trials were conducted at a research greenhouse on The Pennsylvania State University campus (University Park) and at Herman Lederer and Sons Greenhouse (Parker Ford, Pa.). In all of the trials, rooted cuttings of african violets were planted in 4-inch (10.2-cm) pots and fertigated using drip tubes. The trials were conducted for 28 to 35 d to represent a typical african violet production cycle. The Pennsylvania State University greenhouse has a truss-frame covered with corrugated polycarbonate, a concrete floor, and insect screen between the cooling pads and the plants. The trials were replicated four times with 50 plants (trial one) or 33 plants (trial two) per block. Blocks were separated by 3 ft (0.9 m). The greenhouse at Herman Lederer and Sons Greenhouse is a quonset-style greenhouse with a soil floor and no insect screen. The Herman Lederer and Sons Greenhouse trial contained 144 plants per block and was replicated six times. In this trial, potato wedges were randomly placed in the potting medium 28 d after treatment application and checked for the presence of fungus gnat larvae 2 d later.

The treatments evaluated at label rates were 0.08 g·L^{-1} (0.011 oz/gal) a.i. fenoxycarb (Precision; Novartis, Greensboro, N.C.), 0.02 g·L^{-1} (0.003 oz/gal) a.i. diflubenzuron (Adept; Uniroyal, Middlebury, Conn.), 0.09 g·L^{-1} (0.012 oz/gal) a.i. pyriproxyfen (Distance; Valent U.S.A. Corp., Walnut Creek, Calif.), and an untreated control. For each treatment a 60-mL (2.1 fl oz) drench was applied to each pot at the initiation of the experiment and a second drench was made in the fenoxycarb and diflubenzuron treatments 14 d after the first drench.

The trials were set up as a randomized complete block design. Sampling for thrips and fungus gnats was conducted by the use of one yellow (Olympic Horticultural Products, Bradenton, Fla.) and one blue [Olympic Horticultural Products (grower trial), Olson Products, Medina, Ohio (university trial)] 3 × 5-inch (7.6 × 12.7 cm) sticky card placed in each block. The number of thrips and fungus gnats on each card was recorded at 7-d intervals.

A logarithmic transformation [log10 (x + 1)] of the data was used to make the variance independent of the means (Sokal and Rohlf, 1995). Data on the efficacy of the treatments, measured by the number of thrips or fungus gnats collected each sample period, were subjected to analysis of variance (GLM procedure). Means separation was accomplished by using the least significant difference test (LSD) at the $P < 0.05$ level (SAS Institute, 1985). All data are presented as untransformed means.

Results and discussion

In all three trials, yellow sticky cards trapped significantly more thrips and fungus gnats than the blue sticky cards (Table 1). Consequently, the results from the yellow sticky cards were used in evaluating thrips and fungus gnat populations.

UNIVERSITY TRIALS. There were no significant differences in either trial in thrips populations among the four treatments (Table 2). In the first trial, fungus gnat populations declined in all treatments immediately following the initiation of the study (Table 3). The diflubenzuron and pyriproxyfen treatments resulted in lower fungus gnat populations on three of the five sample periods after the treatments were initiated. In the second trial (Table 3) each of the three treatments resulted in significantly lower fungus gnat populations on three of the four sample periods after the treatments were initiated.

Because the medium was kept relatively dry during the first trial, fungus gnat populations decreased across all treatments due to unfavorable conditions for larval development. Keeping pots dry is a technique often used to reduce populations of fungus gnats. In addition, because the greenhouse used in this study had a concrete floor, there were no alternative breeding sites for fungus gnats within the greenhouse. Results from the second trial indicated that the use of diflubenzuron, pyriproxyfen, and fenoxycarb resulted in effective management of fungus gnat populations.

COMMERCIAL FLOWER GROWER TRIAL. In this trial, the mean thrips populations remained below one thrips per card for all treatments. In contrast to the thrips population, fungus gnats were high (Table 4). Fungus gnats did not appear to be affected by the medium treatments. The potato wedges yielded low fungus gnat larval populations, indicating that the adult fungus gnats being caught on the sticky cards were not emerging from the pots. Sticky cards placed under the benches on day 28 and counted on day 35 indicated a high fungus gnat population under the benches. We speculate that the fungus gnats sampled on the sticky cards were migrating from the floor. Although the greenhouse was kept clean and the soil floor was kept dry, fungus gnats were apparently completing development under the benches.

Conclusion

Diflubenzuron, pyriproxyfen, and fenoxycarb are effective tools for managing fungus gnats on greenhouse-produced ornamentals. While pesticide applications for fungus gnats are traditionally only made to the medium in which the plants are growing, there may be additional locations that need to be treated to provide adequate fungus gnat management. Results from the greenhouse trial at Herman Lederer and Sons Greenhouse indicated that a pesticide application to the soil under the benches was needed. While diflubenzuron, pyriproxyfen, and fenoxycarb have been shown to re-

Table 2. Mean number ± SD of western flower thrips per yellow sticky cards following applications of diflubenzuron, pyriproxyfen, and fenoxycarb to the medium of african violets at a Pennsylvania State University greenhouse (University Park).

	Days after first insecticide application					
Trial 1	**0**	**7**	**14**	**21**	**28**	**35**
Diflubenzuron	0.5 ± 0.6 a[z]	4.0 ± 3.3 a	1.8 ± 1.7 a	3.0 ± 2.2 a	5.0 ± 2.9 a	6.8 ± 3.2 a
Pyriproxyfen	0.5 ± 0.6 a	2.8 ± 3.5 a	1.8 ± 2.9 a	0.5 ± 0.6 a	2.0 ± 2.0 a	5.5 ± 1.3 a
Fenoxycarb	0.3 ± 0.5 a	3.5 ± 3.8 a	0.8 ± 1.0 a	3.0 ± 1.8 a	4.3 ± 2.2 a	8.3 ± 3.3 a
Control	0.3 ± 0.5 a	2.5 ± 1.9 a	2.5 ± 3.7 a	3.8 ± 6.2 a	6.0 ± 8.8 a	20.3 ± 18.2 a
Trial 2	**0**	**7**	**14**	**20**	**28**	
Diflubenzuron	23.3 ± 17.5 a	19.0 ± 10.7 a	19.3 ± 16.5 a	10.5 ± 5.1 a	4.5 ± 1.7 a	
Pyriproxyfen	9.3 ± 4.6 a	5.0 ± 5.1 a	8.8 ± 3.3 a	4.8 ± 4.3 a	3.5 ± 1.3 a	
Fenoxycarb	28.0 ± 20.5 a	22.0 ± 12.5 a	25.3 ± 17.2 a	10.5 ± 4.4 a	3.0 ± 1.4 a	
Control	33.8 ± 39.7 a	15.3 ± 16.0 a	16.0 ± 6.7 a	6.0 ± 6.5 a	2.8 ± 3.2 a	

[z]Means within columns with the same letter are not significantly different ($P > 0.05$, least significant difference test).

Table 3. Mean number ± SD of fungus gnats per yellow sticky cards following applications of diflubenzuron, pyriproxyfen, and fenoxycarb to the medium of african violets at a Pennsylvania State University greenhouse (University Park).

	Days after first insecticide application					
Trial 1	**0**	**7**	**14**	**21**	**28**	**35**
Diflubenzuron	21.5 ± 12.5 a[z]	1.5 ± 1.3 b	1.5 ± 1.3 b	0.3 ± 0.5 a	1.0 ± 1.2 a	1.0 ± 1.4 b
Pyriproxyfen	5.25 ± 6.9 a	0.5 ± 1.0 ab	1.8 ± 1.0 b	0.3 ± 0.5 a	1.3 ± 1.5 a	0.3 ± 0.5 b
Fenoxycarb	7.3 ± 8.7 a	0.8 ± 2.1 b	2.5 ± 1.3 ab	1.0 ± 1.4 a	1.3 ± 1.3 a	0.3 ± 0.5 b
Control	27.8 ± 6.9 a	8.8 ± 6.9 a	5.8 ± 4.1 a	2.0 ± 2.7 a	0.3 ± 0.5 a	3.0 ± 1.8 a
Trial 2	**0**	**7**	**14**	**20**	**28**	
Diflubenzuron	11.5 ± 3.9 a	3.25 ± 2.1 b	18.0 ± 8.8 b	18.5 ± 9.1 ab	11.5 ± 1.8 b	
Pyriproxyfen	9.25 ± 8.8 a	4.0 ± 3. 5 ab	18.5 ± 6.7 b	8.3 ± 5.6 b	8.3 ± 6.6 b	
Fenoxycarb	5.0 ± 7.8 a	4.5 ± 2.4 ab	18.0 ± 2.2 b	16.3 ± 6.7 b	8.5 ± 5.1 b	
Control	19.0 ± 12.2 a	17.0 ± 16.6 a	53.8 ± 18.3 a	33.8 ± 15.2 a	22.5 ± 9.1 a	

[z]Means within columns with the same letter are not significantly different ($P > 0.05$, least significant difference test).

Table 4. Mean number ± SD of fungus gnats per yellow sticky cards following applications of diflubenzuron, pyriproxyfen, and fenoxycarb to the medium of african violets at Herman Lederer and Sons Greenhouse (Parker Ford, Pa.).

	Days after first insecticide application				
	7	**14**	**21**	**28**	**35**
Diflubenzuron	22 ± 11.06 a[z]	54.3 ± 17.6 a	35.8 ± 25.9 a	41.7 ± 31.9 a	54.0 ± 28.8 a
Pyriproxyfen	14.2 ± 10.2 a	49.7 ± 31.2 ab	32 ± 28.8 a	39.7 ± 29.2 a	44.5 ± 20.3 a
Fenoxycarb	18.7 ± 17.1 a	28.5 ± 24.5 a	28 ± 28.7 a	24.5 ± 12.3 a	41.8 ± 7.7 a
Control	17.2 ± 6.5 a	39.8 ± 15.6 ab	19.5 ± 6.7 a	31.2 ± 17.3 a	49.2 ± 14.1 a

[z]Means within columns with the same letter are not significantly different ($P > 0.05$, least significant difference test).

duce thrips emergence from potting medium in other studies, no definitive results could be obtained from these trials. Additional studies are warranted to further investigate medium drenches as a tool for thrips management.

Literature cited

Brodsgaard, H.F. 1994. Insecticide resistance in European and African strains of western flower thrips (Thysanoptera: Thripidae) tested in a new residue-on-glass test. J. Econ. Entomol. 87: 1141–1146.

Gardiner, R.B., W.R. Jarvis, and J.L. Shipp. 1990. Ingestion of *Pythium* spp. by larvae of the fungus gnat *Bradysia impatiens* (Dipters: Sciaridae). Ann. Appl. Biol. 116:205–212.

Gillespie, D.R. and J.G. Menzies. 1993. Fungus gnats vector *Fusarium oxysporum* f.sp. *radicis-lycopersici*. Ann. Appl. Biol. 123:539–544.

Harris, M.H., R.D. Oetting, and W.A. Gardner. 1995. Use of Entomopathogenic nematodes and a new monitoring technique for control of fungus gnats, *Bradysia coprophila* (Diptera: Sciaridae), in floriculture. Biol. Control 5:412–418.

Immaraju, J.A., T.D. Paine, J.A. Bethke, K.L. Robb, and J.P. Newman. 1992. Westen flower thrips (Thysanopters: Thripidae) resistance to insecticides in coastal California greenhouses. J. Econ. Entomol. 85:9–14.

Jarvis, W.R., J.L. Shipp, and R.B. Gardiner. 1993. Transmission of *Pythium aphanidermatum* to greenhouse cucumber by the fungus gnat *Bradysia impatiens* (Diptera: Sciaridae). Ann. Appl. Biol. 122:023–029.

Kalb, D.W. and R.L. Miller. 1986. Dispersal of *Verticillium albo-atrum* by the fungus gnat. Plant Dis. 70:752–753.

Leath, K.T. and R.C. Newton. 1969. Interaction of a fungus gnat, *Bradysia* sp. (Sciaridae), with *Fusarium* spp. on alfalfa and red clover. Phytopathol. Notes 59:257–258.

Lublinkhof, J. and D.E. Foster. 1977. Development and reproductive capacity of *Frankliniella occidentalis* (Thysanoptera: Thripidae) reared at three temperatures. J. Kan. Entomol. Soc. 50: 313–316.

Ludwig, S.W. and R.D. Oetting. 2001. Evaluation of medium treatments for management of *Frankliniella occidentalis* (Thripidae: Thysanoptera) and *Bradysia coprophila* (Diptera: Sciaridae). Pest Management Science 57:1114–1118.

SAS Institute. 1985. SAS User's guide: Statistics, version 5 ed. SAS Inst., Cary, N.C.

Sokal, R.A. and F.J. Rohlf. 1995. Biometry: the principles and practice of statistics in biological research. Freeman, New York,

Steffan, W.A. 1974. Laboratory studies and ecological notes on Hawaiian Sciaridae (Diptera). Pacific Insects 16:41–50.

Wetering, F.v.d., R. Goldbach, and D. Peters. 1996. Transmission of tomato spotted wilt virus by *Frankliniella occidentalis* after viral acquisition during the first larval stage. Acta Hort. 431: 355–358.

Zhao, G., W. Liu, J.M. Brown, and C.O. Knowles. 1995. Insecticide resistance in field and laboratory strains of western flower thrips (Thysanoptera: Thripidae). J. Econ. Entomol. 88:1164-1170.