Seasonal Abundance and Insecticidal Control of Citrus Leafminer in a Citrus Orchard

Charles A. Powell¹, Michael S. Burton, Robert Pelosi, Mark A. Ritenour, and Robert C. Bullock

Indian River Research and Education Center, Institute of Food and Agricultural Sciences, University of Florida, 2199 S. Rock Road, Fort Pierce, FL 34945-3138

Additional index words. *Phyllocnistis citrella*, citrus canker, Admire, imidacloprid, Temik

Abstract. Population density of citrus leafminer, *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae), was monitored in a Florida citrus grove for 5 years by scouting weekly for larval-induced mines (leafminer-created tunnels in the leaves) in a replicated citrus plot treated with seven insect control regimes: Admire (imidacloprid) applied at 12, 6, 3, or 2-month intervals; Temik (aldicarb) applied annually; Metasystox-R (oxydemeton-methyl) applied annually; or no insect control. Leafminer populations were highest during the warmer months (April to September) and lowest during the cooler months (November to March). Populations peaked during June in all 5 years monitored. Trees treated with Temik or Metasystox-R had the same number of mines as the untreated controls. A biannual treatment with Admire reduced leafminer damage (number of mines) all 5 years compared with the controls. Additional Admire applications further reduced damage during some, but not all, years. A single application of Admire significantly reduced mines in 3 of the 5 years.

The citrus leafminer (CLM), *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae), was first described in Calcutta, India, in 1856 (Stainton, 1856). It has been a widely distributed pest in citrus-growing regions of Asia for many years (Clausen, 1931, 1933), including China (Sasscer, 1915), the Philippines (Sasscer, 1915), and Japan (Clausen, 1927). The pest has since moved into Eastern Africa (Badawy, 1967) and Australia (Beattie, 1989). In the last 15 years, leafminers have invaded most of the citrus-producing regions of the world, including the Mediterranean Basin (Garcia-Mari et al., 1997) and North, Central, and South America (Ware, 1994). It is widespread in the citrus-producing regions of Florida (Heppner, 1993).

Adult leafminers oviposit on young, tender leaves (new flush). The eggs mature within 1 d. The young larvae enter the leaf and burrow between the upper and lower cuticle. As the larvae move and feed on the epidermis, they leave a twisted, irregular tunnel (mine) (Achor et al., 1997; Sohi and Verma, 1965). The leaves frequently become distorted and curled with early abscission (Pandey and Pandey, 1964). The adult leafminer can deposit ≈ 50 eggs during her life. There are three larval stages plus a prepupal and pupal stage, which occur within the mine. The prepupa produces silk to form a pupal

chamber, usually located along the rolled edge of a leaf, where metamorphosis to the adult stage occurs. Adults emerge after ≈ 6 d or longer, depending on temperature. There can be 15 generations per year depending on the weather (Badawy, 1967; Beattie, 1989). In Florida, the life cycle is completed in ≈ 3 weeks.

CLM affects all citrus varieties (Pandey and Pandey, 1964) and a few closely related Rutaceae (Heppner, 1993), including *Aegle marmelos* (L.) Corr. Srv. (Fletcher, 1920), *Poncirus trifoliata* (L.) Raf. (Clausen, 1933), *Atalantia* sp. (Sasscer, 1915), *Murraya paniculata* (L.) Jack. (Pruthi and Mani, 1945), *Jasminum sambac* (L.) Aiton (Fletcher, 1920), *Pongamia pinnata* Pierre (Margo-bandhu, 1933), and *Alseodaphne semecarpifolia* Nees (Latif and Yunus, 1951). Damage to host plants, and particularly citrus, is incited by direct feeding and by providing an infection site for *Xanthomonas axonopodis* pv. *citri*, a bacterium that causes citrus canker. Feeding damage is related to availability of young leaves and flushing pattern.

Several studies have been conducted to correlate CLM damage with economic loss. Knapp et al. (1995) reported that a 10% leaf area loss did not affect citrus yield. In Florida, control of CLM increased yield of 3- to 5-year-old grapefruit or orange trees by 13.1% to 16.9% (Stansly et al., 1996). In another Florida study, a 16% to 23% leaf area loss caused significant yield reduction of 15-year-old Tahiti lime trees, and 18% to 85% leaf area loss caused significant yield reduction of 5-year-old lime trees (Peña et al., 2000).

The CLM may also help spread *Xanthomonas axonopodis* pv. *citri* and the citrus

canker disease it causes (Ando et al., 1985; Hill, 1918). This bacterium causes one of the most severe diseases of citrus worldwide and its attempted eradication has been a major source of tree loss in Florida. The bacterium is dispersed in windblown water, and leaf wounding increases the likelihood of establishment. Leafminer activity may provide leaf wounds by which the bacteria can gain access.

Control of CLM has focused on biological control using a variety of parasitic wasps (parasitoids); 39 parasitoid species have been identified (Heppner, 1993). In Florida, *Ageniaspis citricola* Logvinovskaya and *Cirrospilus ingenuus* Gahan have been released (Hoy and Nguyen, 1994, 1997; Hoy et al., 1995, 1997; Pomerinke and Stansly, 1998; Smith and Hoy, 1995). Control with specific parasitoids has been complicated by low leafminer populations during the winter months. Chemical control strategies for CLM have been used in Australia (Beattie, 1989) and Florida (Browning et al., 2007; Stansly and Knapp, 1994), but extensive insecticide evaluation in Florida is not yet complete.

Materials and Methods

The experimental area consisted of 294 'Valencia' sweet orange (*Citrus sinensis* L. Osbeck) trees grafted onto sour orange rootstock (*C. aurantium* L.). The trees were in single beds (rows) with 9.15 m between rows. The in-row spacing was 4.5 m.

The experiment was a randomized complete block design with each of six rows serving as a replication. There were seven treatments in each of the six replications with seven trees per experimental unit (plot). The treatments were an annual application of aldicarb (Temik; Bayer CropScience, Research Triangle Park, NC) (8.5 g/tree a.i. incorporated into the soil); an annual application of oxydemeton-methyl (Metasystox-R; Gowan Co. Yuma, AZ) (trunk drenched, 0.62 mL·L⁻¹); soil drenches with imidacloprid (1-[(6-chloro-3-pyridinyl) methyl]-N-nitro-2-imidazolidinimine) (Admire; Bayer CropScience) at 1920 mg·a.i./plant applied at 12-, 6-, 3-, or 2-month intervals; and no insecticide application. Temik was applied the last week of April, and the trunk drenches were applied in the spring between 19 Apr. and 22 May. Insecticide rates were based on manufacturers' recommendations.

The experimental area was scouted for leafminers every week over a 5-year period. Each tree was examined and the total number of mines (interepidermal tunnels that are easily visible and incited by burrowing of single leafminer larvae) was recorded. Weekly data were combined into monthly totals recorded within each replication for each treatment.

Mine numbers (square root transformed to normalize the variance) were subjected to an analysis of variance using the SAS software program (SAS Institute, Cary, NC). Main treatment effects means that had a significant

Received for publication 14 Mar. 2007. Accepted for publication 24 June 2007.

Indian River Research and Education Center Journal Series No. R-010701.

¹To whom reprint requests should be addressed; e-mail CAPowell@ufl.edu.

F test were separated by Fisher's protected least significant difference test at the 5% level of significance. When yearly data were totaled, each year was a block.

Results

Seasonal abundance. Because there was no difference among trees tested with Metasystox-R, Temik, or no insecticide treatment, these data were combined to analyze seasonal abundance. The mean numbers of mines per tree per month (averaged over 21 trees from non-Admire-treated trees in each of six replications) were very low during the cooler months (November through March) all 5 years (Table 1). Leafminer activity began in April or May (depending on the year) and subsided in October. Fewer than one mine per tree was detected over the 5-year period in January, February, March, and December. Large numbers of mines were detected in May through July, resulting in considerable damage to the young leaves in which the mines occurred. The numbers of mines were significantly higher in June than any other month in all 5 years. Leafminer activity also varied from year to year. The lower counts observed in 2004 were likely influenced by three hurricanes that impacted the area that year.

Insecticidal control. Annual applications of Temik or Metasystox-R were ineffective

in leafminer control (Table 2). An annual application of Admire reduced leafminers in 3 of 5 years, whereas biannual or more frequent applications of Admire significantly reduced mines all 5 years. Overall, the more frequent the Admire application, the better the control.

Discussion

The seasonal pattern of leafminer activity was fairly consistent over the 5-year study with populations peaking in the late spring and declining during the winter. The number of mines followed the flushing pattern of the trees to a great extent, as expected, because predominantly young leaves were mined.

The efficacy of the insecticides for leafminers was similar to that previously reported for aphids (Powell et al., 2006) and psyllids (Powell, unpubl. data), in that Admire, but not Temik nor Metasystox-R, reduced populations. The major difference was that one annual application of Admire performed better with aphids and psyllids than with leafminers.

Leafminers may not normally cause sufficient feeding damage to warrant control with insecticides because of the cost and environmental concerns. However, reducing leaf miners may reduce citrus canker. Admire will also reduce populations of aphids and psyllids and possibly the diseases they trans-

mit, citrus tristeza and citrus greening, respectively. One annual application of Admire may be considered as part of an integrated strategy to control these three insects and their associated diseases.

Literature Cited

- Achor, D.S., H.Y. Browning, and L.G. Albrigo. 1997. Anatomical and histochemical effects of feeding by citrus leafminer larvae (*Phyllocnistis citrella* Stainton) in citrus leaves. *J. Amer. Soc. Hort. Sci.* 122:829-836.
- Ando, T., K.Y. Taguchi, M. Uchiyama, T. Ujiye, and H. Kuroko. 1985. (7Z-11Z)-7, 11-hexadecadienal sex attractant of the citrus leafminer moth, *Phyllocnistis citrella* Stainton (Lepidoptera, Phyllocnistinae). *Agr. Biol. Chem. Tokyo* 49:3633-3653.
- Badawy, A. 1967. The morphology and biology of *Phyllocnistis citrella* Staint., a citrus leaf miner in the Sudan. *Bull. Soc. Ent. Egypte* 51:95-103.
- Beattie, G.A.C. 1989. Citrus leaf miner. *NSW Agric. & Fisheries, Agfact*, H2. AE:41-44.
- Browning, H.W., R.C. Bullock, L.L. Knapp, J. Peña, and P.A. Stansly. 2007. Citrus leafminer. In: Knapp, J.L. (ed.). *Florida citrus pest management guide*. Florida Cooperative Extension Service, University of Florida/IFAS, Gainesville. (In press).
- Clausen, C.P. 1927. The citrus insects of Japan. *USDA, Washington, DC, Technical Bulletin* 15:1-15.
- Clausen, C.P. 1931. Two citrus leaf miners of the Far East. *USDA, Washington, DC, Technical Bulletin* 252:1-13.
- Clausen, C.P. 1933. The citrus insects of Tropical Asia. *USDA, Washington, DC, Circular* 266: 1-35.
- Fletcher, T.B. 1920. Life histories of Indian insects. *Microlepidoptera. Mem. Dept. Agr. India* 6: 1-217.
- García-Mari, F., J. Costa-Comelles, R. Vercher, and C. Granda. 1997. El minador de hojas de cítricos: Presente y futuro de una plaga importada. *Phytoma Espana* 92:94-102.
- Heppner, J.B. 1993. Citrus leafminer (CLM), *Phyllocnistis citrella* Stainton in Florida, (Lepidoptera: Gracillariidae: Phyllocnistinae). *Trop. Lepid.* 4:49-64.
- Hill, G.F. 1918. History of citrus canker in the Northern Territory (with notes of its occurrence elsewhere). *Northern Territory Australia Bulletin* 18:1-8.
- Hoy, M.A. and R. Nguyen. 1994. Classical biological control of the citrus leafminer: Release of *Cirrospilus quadristriatus*. *Citrus Industry*, November. p. 14.
- Hoy, M.A. and R. Nguyen. 1997. Classical biological control of the citrus leafminer *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae): Theory, practice, art, and science. *Tropical Lepidoptera* 8(suppl 1):1-19.
- Hoy, M.A., R. Nguyen, D. Hall, M. Pomerinck, J. Peña, H. Browning, and P. Stansly. 1995. Establishment of citrus leafminer parasitoid *Ageniaspis citricola* in Florida. *Citrus Industry*, December. pp. 12-17.
- Hoy, M.A., R. Nguyen, M. Pomerinck, R. Bullock, D. Hall, J. Knapp, J. Peña, H. Browning, and P. Stansly. 1997. Distribution and abundance of *Ageniaspis citricola*, a parasitoid of the citrus leafminer in Florida. *Citrus Industry* 78:51-52.
- Knapp, J.L., L.G. Albrigo, H.W. Browning, R.C. Bullock, J.B. Heppner, D.G. Hall, M.A. Hoy, R. Nguyen, J.E. Peña, and P.A. Stansly. 1995. Citrus leafminer, *Phyllocnistis citrella* Stainton: Current status in Florida, 1995. *Florida*

Table 1. Seasonal variation of citrus leafminers in a Florida citrus grove.^z

Month	Year				
	2000	2001	2002	2003	2004
January	2 a	0 a	0 a	0 a	0 a
February	0 a	0 a	0 a	0 a	1 a
March	0 a	0 a	0 a	0 a	0 a
April	0 a	6 a	39 b	5 a	7 b
May	46 b	65 c	27 b	277 d	9 b
June	147 c	160 c	123 c	512 e	15 c
July	32 b	23 b	111 b	116 c	6 b
August	47 b	0 a	10 b	21 b	8 b
September	15 b	3 a	31 a	19 b	4 b
October	27 b	5 a	3 a	19 b	0 a
November	3 a	8 a	0 a	0 a	0 a
December	0 a	4 a	0 a	0 a	0 a
Total	319	274	344	969	50

^zNumbers are the mean number of larval leafminers per tree (averaged from 21 trees in each of six replications). Data are from nonimidacloprid-treated trees. Numbers in a column followed by different letters are significantly different (5% level) by Fisher's protected least significant difference.

Table 2. Population densities of citrus leafminer in a Florida citrus grove under seven different control strategies.^z

Treatment ^y	Year					Total
	2000	2001	2002	2003	2004	
Control	282 c	290 d	369 c	960 d	52 b	1953 e
Meta-Systox-R	312 c	307 d	309 c	924 d	48 b	1900 e
Temik	360 c	226 d	351 c	1024 d	51 b	2012 e
Admire 1x	94 b	264 d	11 b	44 c	63 b	476 d
Admire 2x	68 b	63 c	3 a	15 b	2 a	151 c
Admire 4x	4 a	28 b	0 a	2 a	0 a	34 b
Admire 6x	1 a	4 a	0 a	5 a	0 a	5 a

^zNumbers are the mean number of larval leafminers per tree (averaged from seven trees in each of six replications). Numbers in a column followed by different letters are significantly different (5% level) by Fisher's protected least significant difference.

^yAdmire 1x = imidacloprid applied annually; Admire 2x = imidacloprid applied every 6 months; Admire 4x = imidacloprid applied every 3 months; Admire 6x = imidacloprid applied every 2 months; Temik = applied annually; Metasystox-R = applied annually; Control = no insecticide applied.

- Cooperative Extension Service, Gainesville, FL.
- Latif, A. and C.M. Yunus. 1951. Food plants of citrus leaf miner in Punjab. *Bull. Entomol. Res.* 42:311–316.
- Margobandhu, V. 1933. Insect pest of oranges in the northern Circars. *Madras Agr. J.* 21:60–68.
- Pandey, N.D. and Y.D. Pandey. 1964. Bionomics of *Phyllocnistis citrella* St. (Lepidoptera: Gracillariidae). *Indian J. Entomol.* 26:417–423.
- Peña, J.E., A. Hunsberger, and B. Schaffer. 2000. Citrus leafminer (Lepidoptera: Gracillariidae) density: Effect on yield of 'Tahiti' lime. *J. Econ. Entomol.* 93:374–379.
- Pomerinke, M.A. and P.A. Stansly. 1998. Establishment of *Ageniaspis citricola* (Hymenoptera: Encyrtidae) for biological control of *Phyllocnistis citrella* (Lepidoptera: Gracillariidae) in Florida. *Fla. Entomol.* 81:361–372.
- Powell, C.A., M.S. Burton, R.R. Pelosi, P.A. Rundell, M.A. Ritenour, and R.C. Bullock. 2006. Six-year evaluation of brown citrus and spirea aphid populations in a citrus grove and the effects of insecticides on these populations. *HortScience* 41:688–690.
- Pruthi, H.S. and M.S. Mani. 1945. Our knowledge of the insect and mine pests of the citrus in India and their control. *Imp. Council Agr. Res. Sci. Monog.* 16:1–42.
- Sasscer, E.R. 1915. Important insect pests collected on imported nursery stock in 1914. *J. Econ. Entomol.* 8:268–270.
- Smith, J.M. and M.A. Hoy. 1995. Rearing methods for *Ageniaspis citricola* (Hymenoptera: Encyrtidae) and *Cirrospilus quadristriatus* (Hymenoptera: Eulophidae) released in a classical biological control program for citrus leafminer *Phyllocnistis citrella* (Lepidoptera: Gracillariidae). *Fla. Entomol.* 78:600–608.
- Sohi, G.S. and G.C. Verma. 1965. Feeding habits of *Phyllocnistis citrella* Stn. in relation to the anatomical structure of the leaf. *Indian J. Entomol.* 27:483–485.
- Stainton, H.T. 1856. Descriptions of three species of Indian Micro-Lepidoptera. *Transactions of the Entomological Society of London.* 3:301–304.
- Stansly, P.A., L.G. Albrigo, and R.E. Rouse. 1996. Impact of citrus leafminer on growth and yield of orange and grapefruit, pp. 47–48. In M. Hoy (ed.). *Managing the citrus leafminer. Proceedings of the International Conference*, 23–25 Apr. 1996, Orlando, FL. University of Florida, Gainesville.
- Stansly, P.A. and J.L. Knapp. 1994. Chemical control of citrus leafminer in Florida grapefruit, 1993. *Arthropod Management Test* 19:47–48.
- Ware, A.B. 1994. The biology and control of citrus leafminer. *Citrus J.* 4:26–28.