Table 8. Efficacy of Imidacloprid soil drench treatment vs. several scale pests infesting 'Ray Ruby' grapefruit trees in the field-1992.

		Amt. per tree[z]	% trees infested with green soft scale, black scale, lesser snow scale, and CRW larvae at weeks after treatment 27 May[y]					
			+23		+33			
			GSS	BS	GSS	BS	LSS	CRW
Y	Imidacloprid 240 FS	0.53 ml	4b	0b	4b	6b	18b	33a
B	Imidacloprid 240 FS	1.10 ml	2b	0b	4b	12b	6b	17b
W	Control	0	65a	13a	52a	29a	46a	17b

[z]Y = 0.125 gm AI per tree delivered in 1 qt. water. B = 0.250 gm AI per tree delivered in 1 qt. water.
[y]Mean separation within columns by Duncan's Multiple Range Test, 5% level.
Note: GSS = green soft scale; BS = black scale; LSS = lesser snow scale; CRW = citrus root weevil complex.

Table 9. Efficacy of Imidacloprid soil drench and trunk treatment vs. citrus leafminer, *Phyllocnistis citrella* Stainton, on grapefruit trees in the field-1993.

Treatment	Method	Amt. product per inch trunk diam.	Mean number mines per terminal at wks after treatment 21 July[z]			
			+4	+6	+8	+10
Imidacloprid 5% RTU	Drench	2.1 ml	4.6b	5.5b	14.2b	7.2b
Imidacloprid 5% RTU	Drench	4.2 ml	2.6b	3.5b	2.5c	4.3b
Control	Drench	0	18.1a	44.0a	28.6a	19.3a
Imidacloprid 240 FS	Trunk paint	2.5 ml	2.3b			6.3b
Imidacloprid 240 FS	Trunk paint	5.0 ml	0.2b			0.7b
Control	Trunk paint	0	23.8a			96.0a

[z]Mean separation within columns by Duncan's Multiple Range Test, 5% level.

are still being produced on the same flush. Effective chemical control may be more easily achieved with a persistent systemic which effect extends through the complete cycle of flush development to maturity.

While Imidacloprid may be more efficacious as a foliar spray against pests other than adult root weevils, it may influence beneficial insects in the grove. Mizell & Sconyers (1993) found that surface residues showed little toxicity to 3 species of predatory mites but were toxic to most of the insect predators tested. The delivery of Imidacloprid to the trunk or roots may reduce interference with beneficial arthropod activity.

Imidacloprid exhibits some degree of activity against all ten arthropods evaluated in these experiments. South African results indicate that Imidacloprid is effective as stem and soil treatments for control of California red scale, psyllids, aphids, and citrus thrips (T. G. Grout, Outspan International, unpublished data). These additions expand the list of pests susceptible to this experimental compound.

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CONTROL OF THE CITRUS LEAFMINER IN SOUTH FLORIDA

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Abstract. **Field experiments were conducted to test efficacy of insecticides for control of citrus leaf miner (CLM), *Phyllocnistis citrella* on limes, *Citrus aurantifolia.* The performance of Agrimek + oil, NTN 33893, Fenoxycarb, Stalker and RH2485 provided satisfactory control of the leaf miner. Most of the chemicals used in these experiments reduced the number of larvae per leaf 1 week after spray, but their efficacy was reduced 14 days after spray. The number of mines per leaf provided a better evaluation assessment of CLM infestation than number of dead larvae or number of pupae per leaf.**

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Citrus leafminer (CLM), *Phyllocnistis citrella*, is an important pest of citrus in many citrus-growing regions throughout the world including Asia, Australia and Africa (Claussen, 1933; Stainton, 1856; Badawy, 1967; Kalshoven, 1981; Beattie, 1989; Heppner, 1993). The majority of the damage caused by the citrus leafminer is believed to result from mining on the adaxial and abaxial surfaces of the newly formed leaves. Young leaves curl-up, become chlorotic and eventually become necrotic. Consequently, affected leaves that host a heavy (more than 4 mines per leaf) CLM density are frequently distorted and may abscise. In countries where CLM is a pest, growth of nursery and newly planted trees is retarded by a reduction of the leaf photosynthetic area. As a result, fruit yields in older trees are often reduced (Hill, 1918; Ando et al., 1985). Additionally, CLM may help the spread of citrus canker. The severe damage caused by CLM made this species one of the most feared pests in citrus production areas.

The first recorded invasion and establishment of CLM in Homestead, Florida was in spring 1993. Since then, infestations have been reported in almost all citrus producing areas in Florida. Citrus leafminer populations have increased in groves and nurseries, causing panic among growers, nurserymen and even homeowners with single trees in their yards.

Traditionally, limes, *Citrus aurantifolia* had the greatest market value of any tropical fruit crop in Florida. However, as a result of hurricane Andrew the lime acreage has been reduced by about one half (from about 7,000 to 3,500 acres). Efforts to establish new orchards have been dimmed by the damage caused by CLM. Despite the expense and heavy use of pesticides there is no published information on the effectiveness of pesticides to control this pest in Florida.

Early reports on efficacy of insecticides against CLM are conflictive. For instance, monocrotophos provided good control in India (Batra & Sandhu, 1981), but did not control CLM in Korea (Catling et al., 1977). Other pesticides recommended for CLM control in Asia are not recommended for control in Australia (Catling et al., 1977; Beattie, 1989; Wu and Tao, 1977).

The objectives of this paper are: (1) to describe the damage of CLM under southern Florida conditions, (2) to provide information on the damage levels to different species of the family Rutaceae and (3) to provide information on the efficacy of insecticides for control of the citrus leafminer in south Florida limes.

Materials and Methods

Damage Description. Damage to Tahiti lime, *C. aurantifolia* was evaluated by collecting leaves with different levels of damage and transported to the laboratory for examination, where the characteristics of the mine and CLM injury were assessed.

Evaluation of CLM Damage to TREC Citrus Collection. The 1.37 ha citrus germplasm collection at the Tropical Research and Education Center consists of approximately 38 cultivars of the family Rutaceae. To assess damage of the CLM to these cultivars, 5 15 cm long new leaf flushes and fruits were examined per tree (ca. 15/cultivar) and the presence or absence of CLM mines recorded.

Insecticide Tests. Certain insecticides were tested during 1993 for efficacy against CLM on limes. Four test plots were located at the University of Florida's Research Station in Homestead, Florida.

First Test. Insecticides were applied in a paired plot design with a control row of trees between each treated row, with a spray gun jet sprayer. Relative leafminer population density was estimated by number of mines, number of larvae and number of pupae per leaf in 5 10-15 leaf shoot sample, taken from each of 3 single tree replicates within each treatment and control plot. Each treatment was replicated 3 times. Sprays were applied on June 2, 1993 and pre-treatment and post-treatment samples were taken on 7, 11 and 18 June 1993.

Second Test. The insecticide Agrimek tank mixed with spray oil was compared to Cygon 4EC and Orthene and Asana treatments for efficacy against CLM. Treatments were randomly assigned to three tree plots and replicated 4 times in a lime orchard on 7 × 11 ft spacing. Foliar sprays were applied on 7 June to foliar runoff (ca. 1 gal/tree) using a high pressure handgun sprayer operating at 200 psi. At each count date, 1 leaf flush per replicate (ca. 40 leaves/treatment) was randomly selected and examined under the microscope.

Third Test. Insecticides for control of the citrus leafminer were evaluated June 1993. Pesticides were applied 16 June, 1993 with a spray gun jet sprayer, outside and inside coverage, approximately 100 gal/acre. The orchard was divided into 4 blocks with 1 replicate of each treatment allocated randomly within each block; each replicate consisted of 4 trees. Citrus leafminer larvae, number of mines, number of pupae per leaf and damage index per leaf evaluations were taken in June 15, and June 23, 1993.

Fourth Test. Insecticides for the control of CLM were evaluated Fall, 1993 on 15 year old Tahiti limes. Insecticides were sprayed with a hand gun sprayer 400 psi, complete coverage, approximately 200 gal per acre. The orchard was divided into 4 blocks with 1 replicate of each treatment allocated randomly within each block; each replicate consisted of 3 trees. CLM evaluations were taken 1 day before treatment and 3, 7, and 17 days after treatment.

Results and Discussion

Observations on CLM Damage to Limes. Eggs of CLM are laid singly on the underside or upperside of the leaf. After hatching, the neonate larvae bores into the epidermal cells making small serpentine mines which are regularly found parallel to the mid vein; as the silvery mine develops it becomes a labyrinthine mine filled with a central trail of excrement which is whitish first and later becomes darker. Depending on the larval behavior, larval density and leaf area, the mines can also be irregularly shaped. The neonate larvae is flat, very clear and becomes pale yellow to darker yellow during the later instars. The pupal chambers are regularly found at the edge of the leaf, but pupation can also occur on the middle of the leaf. Several symptoms were observed on leaves with more than 4 mines. The edges of the leaves curl upward, followed by chlorosis and later by necrotic spots that might become irregular holes. When the CLM cycle is completed, aphids, mealybugs or red mites invade the mine and continue feeding on the same damaged area.

Evaluation of TREC Citrus Collection. Most of the *Citrus* cultivars showed CLM damage (Table 1). The only *Citrus* cultivars without leaf mining were Schroeder lime, *Citrus*

Table 1. Infestation levels of *Phyllocnistis citrella* on the Rutaceae cultivar accessions at the Tropical Research and Education Center, Homestead, Florida.

Cultivar	Percent Shoots with CLM Mines
Citrus aurantifolia (Christm.) Swingle	
Key Lime	50
Bears Lime	100
Gifford Lime	100
Citrumelo	80
Schroeder	0
IChang	56
Thornless	60
Citrus depresa	26
Citrus sinensis	
Parson Brown	40
Valencia	33
C. maxima × *C. sinensis*	
Leonardi grapefruit	73
Citrus aurantium L.	40
Citrus lycopersico-formis	0
Citrus reticulata	
Dancy Shek	20
Cleopatra	60
Oneco	60
Citrus grandis	15
Green Shadock	60
Siamese	50
Citrus taiwanica	20
Citrus limon	
Meyer	40
Avon	80
Ponderosa	20
Citrus limonia	40
Citrus macrophylla	100
Citrus volkameriana	0
C. reticulata × *C. sinensis*	50
Aeglopsis chevalieri	40
Feromia limonia	60
Pamburus missionis	0
Atalantia monophyla	0
Poncirus trifoliata × *C. sinensis*	50

lycopersico-formis and *Citrus volkameriana*. The species *Pamburus missionis* and *Atalantia monophyla* had the lowest infestation (0%) level compared to *Aeglopsis chevalieri* (40%) and *Feromia limona*. This preliminary evaluation of the citrus cultivars does not indicate resistance levels to CLM but it may indicate that some cultivars escaped CLM infestation by production of leaf flushing earlier than the infested ones.

Insecticide Tests. First Test. The CLM density during this trial fluctuated between 1.57 to 3.37 mines per leaf (Table 2). Agrimek + Oil, Vydate, NTN 33893 and Asana gave good initial CLM control. Fourteen days after spray, Cygon 4EC, Asana and the untreated control had the lowest number of CLM larvae per leaf. Treatment efficacy as discussed in relation of CLM mines per leaf shows that Agrimek + oil and Vydate had less number of mines per leaf than other treatments. The treatments, Orthene + Asana, Orthene, Cygon and Dipel 2x had more pupae per leaf than Agrimek + oil and Vydate.

Second Test. The CLM populations were at low levels (1.60-2.11 mines per leaf) during the second trial (Table 3). Seven days after spray all treatments, including the untreated control had significantly less CLM larval infestation than Cygon. Fourteen days after treatment all treatments had similar larval infestation as the untreated control. Agrimek + oil had significantly lower CLM mines or pupae per leaf than did Cygon and Orthene + Asana 14 days following treatment application. At 14 days after application all treatments except Agrimek + oil had similar damage index per leaf compared with the untreated check.

Third Test. Again, in the third trial CLM population pressure was not severe (1.00-1.30 mines per leaf) at the begining of the trial (Table 4). Eight days after treatment,

Table 2. Impact of insecticides on infestation of CLM on *Citrus latifolia*, First Test.

Treatments	Dose/acre
1. Agrimek + FC 435 Oil (1%)	2 fluid ounces
2. Cygon 4EC	1 pint
3. Asana	1.7 fluid ounces
4. Orthene 75S	1.3 lbs.
5. Orthene 75S + Asana	1.3 lbs + 1.7 fluid ounces
6. NTN 33893	1.5 fluid ounces
7. Check	—
8. Dipel 2x	0.21 lbs.
9. Vydate	2 pints

Table 2. Continued.

	Mean CLM Larvae/leaf			
		Days After Spray		
Treatment	Pre Spray	3	7	14
1.	1.41abc	0.073c	0.00b	0.71abc
2.	0.71cde	0.705b	0.66a	0.35dc
3.	0.75cde	0.159c	0.24b	0.21d
4.	1.15bcd	1.270a	0.90a	0.54bdc
5.	0.21e	1.02 ab	0.88a	0.34dc
6.	2.06a	0.16 c	0.22b	0.91ab
7.	0.35ed	1.26 a	0.30b	0.45dc
8.	1.21bc	1.28 a	0.25b	1.04a
9.	1.81ab	0.11 c	0.78a	0.44dc

Table 2. Continued.

	Mean CLM Mines/leaf			
		Days After Spray		
Treatment	Pre Spray	3	7	14
1.	2.98ab	1.70c	1.77bc	1.05de
2.	1.96cd	2.00bc	2.31ab	1.47bcd
3.	2.14bcd	2.09abc	2.20abc	1.36bcd
4.	3.37a	1.85c	2.39a	1.61ab
5.	1.57d	2.68a	2.47a	1.55abc
6.	3.70a	1.97bc	0.41d	1.31bcd
7.	2.21bcd	2.57ab	2.47a	1.61bcd
8.	2.51bc	2.17abc	2.25abc	1.90a
9.	2.97ab	2.60a	1.71c	0.85e

Table 2. Continued.

	Mean CLM Pupae/leaf			
		Days After Spray		
Treatment	Pre Spray	3	7	14
1.	0.33bcd	0.00b	0.05c	0.03e
2.	0.57bc	0.15b	0.51a	0.50abc
3.	1.06a	0.45a	0.35ab	0.58bcd
4.	0.56bc	0.07b	0.58a	0.54ab
5.	0.41bcd	0.10b	0.33ab	0.79a
6.	0.06d	0.13b	0.00c	0.33bcde
7.	0.67b	0.13b	0.19bc	0.23cde
8.	0.24cd	0.00b	0.19bc	0.58ab
9.	0.18d	0.15b	0.00c	0.12de

Numbers followed by different letters within a column were significantly different as separated by Duncan's Multiple Range Test (P=0.05).

Table 3. Impact of insecticides on infestation of CLM on limes.

Treatment	Rate per Acre
1. Agrimek + FC 435 Oil	2 fl. oz. + 1%
2. Cygon 4EC	1 pt
3. Orthene 75S + Asana	1.3 lb + 1.7 fl oz
4. Check	

	Mean CLM Larvae/leaf		
		Days After Spray	
Treatment	Pre-spray	7	14
1.	0.19b	0.07b	0.24a
2.	0.33b	0.72a	0.12a
3.	0.78a	0.27b	0.20a
4.	0.83a	0.16b	0.27a

Table 3. Continued.

	Mean CLM Mines/leaf		
		Days After Spray	
Treatment	Pre-spray	7	14
1.	2.11a	0.27c	0.24c
2.	1.60a	2.07a	0.82a
3.	1.59a	1.15b	0.67ab
4.	1.70a	0.85b	0.48bc

	Mean CLM Pupae/leaf		
		Days After Spray	
Treatment	Pre-spray	7	14
1.	0.16a	0.00b	0.00b
2.	0.23a	0.38a	0.46a
3.	0.26a	0.48a	0.33a
4.	0.05a	0.11b	0.05b

	Mean CLM Damage Index/leaf		
		Days After Spray	
Treatment	Pre-spray	7	14
1.	1.32a	0.18c	0.22b
2.	1.07a	1.25a	0.63a
3.	1.14a	0.84a	0.50a
4.	1.20a	0.64b	0.45a

Treatment means within columns not showing a common letter are significantly different as separated by Duncan's Multiple Range Test (P=0.05). CLM Damage Index: 1 = No damage; 2 = leaf curled, no necrosis, less than 2 mines/leaf; 3 = leaf curled, no necrosis, more than 2 mines per leaf; 4 = leaf curled, chlorosis, more than 4 mines per leaf; 5 = leaf chlorotic and necrosed, holes, presence of pathogens on necrosed spots.

control of CLM larvae was successful with a single application of all treatments compared to the untreated control. Agrimek + oil and Supracide had less mines per leaf compared to the control.

Fourth Test. CLM population density in this test was higher than in the previous trials. Stalker, Agrimek + oil and Fenoxycarb had the lowest numbers of CLM larvae compared to other treatments and the untreated control 14 days after spray application (Table 5). All treatments were effective in reducing the number of CLM mines per leaf with the exception of Lannate which was considered ineffective.

In general, most of the chemicals used in these preliminary tests, reduce the number of larvae per leaf 1 week after spray, but their efficacy was reduced 14 days after spray. *The number* of mines per leaf provided a better evaluation assessment of CLM infestation than number of dead larvae or number of pupae per leaf. The 0.0125 lb AI/A of Agrimek suppresed CLM population longer than

Table 4. Impact of insecticides on survival of CLM on limes, Third Test.

Treatment	Rate lbs ai/A
1. RH2485	0.05
2. Lorsban 50W	1.5
3. Supracide 2E	0.37
4. Sevimol 4	1.0
5. FC 435 Oil	1.6%
6. Malathion 5E	0.62
7. Check	—

	Mean CLM Larvae/leaf	
Treatment	Pre-spray	8 Days After Treatment
1.	0.56ab	0.23b
2.	0.89a	0.32b
3.	0.33b	0.13b
4.	0.58ab	0.30b
5.	0.47ab	0.32b
6.	0.70ab	0.04b
7.	0.58ab	0.70a

Table 4. Continued.

	Mean CLM Mines/leaf	
Treatment	Pre-spray	8 Days After Treatment
1.	1.00a	0.69bc
2.	1.17a	0.92abc
3.	1.30a	0.60c
4.	1.27a	0.85abc
5.	1.00a	1.04ab
6.	1.15a	0.83abc
7.	1.00a	1.20a

Treatment means within columns not showing a common letter are significantly different as separated by Duncan's Multiple Range Test (P=0.05).

Table 5. Impact of insecticides on survival of CLM on limes, Fourth Test.

Treatment	Rate lb AI/A
1. Agrimek + FC 435 Oil	0.0125 + 1%
2. Agrimek + FC 435 Oil	0.0250 + 1%
3. Vydate 2L	1
4. Lannate	1
5. Stalker	0.31
6. Fenoxycarb	0.125
7. RH 2485	0.05
8. Check	—

Table 5. Continued.

	Mean CLM Alive Larvae/leaf				
		Days after Spray			
Treatment	Pre-spray	3	7	14	9 DASA
1.	1.39c	0.05e	0.00c	0.92c	0.27d
2.	1.60c	0.13de	0.00c	0.97c	0.69cd
3.	1.51c	0.38bc	0.30b	1.23bc	1.75b
4.	1.74bc	0.33bc	0.27b	1.54a	2.18a
5.	1.52c	0.33bc	0.30b	0.87c	1.52b
6.	1.89bc	0.48b	0.25b	0.92c	0.95c
7.	2.12b	0.26cd	0.17b	1.02bc	0.48d
8.	2.63a	0.82a	0.69a	1.40ab	2.25a

Table 5. Continued.

Treatment	Mean CLM Dead Larvae/leaf				
	Pre-spray	Days after Spray			
		3	7	14	9 DASA
1.	0.01bc	0.24a	0.00b	0.05	0.02d
2.	0.13a	0.11bc	0.01b	0.08b	0.10dc
3.	0.02abc	0.14abc	0.01b	0.09b	0.32ab
4.	0.01bc	0.20ab	0.04ab	0.28a	0.38a
5.	0.12ab	0.15abc	0.01b	0.05b	0.22b
6.	0.11abc	0.09bc	0.02ab	0.11b	0.04d
7.	0.06abc	0.09bc	0.06a	0.05b	0.18c
8.	0.00c	0.08c	0.00b	0.03b	0.02d

Table 5. Continued.

Treatment	Mean CLM Mines/leaf				
	Pre-spray	Days after Spray			
		3	7	14	9 DASA
1.	3.12bc	1.03e	0.07d	1.68bc	0.80d
2.	2.98c	1.23de	0.18d	1.69bc	0.95d
3.	3.30bc	1.46bc	0.52c	2.11b	2.84b
4.	3.17bc	1.41c	1.03b	2.74a	3.43a
5.	3.28bc	1.36dc	0.64c	1.75bc	2.08c
6.	3.43bc	1.75ab	0.71c	1.74bc	1.94c
7.	3.51ab	1.10de	0.55c	1.62c	1.66c
8.	3.92a	1.90a	1.57a	2.57a	3.38a

Table 5. Continued.

Treatment	Mean CLM Pupae/leaf				
	Pre-spray	Days after Spray			
		3	7	14	9 DASA
1.	0.10b	0.00b	0.00b	0.04b	0.00d
2.	0.05b	0.05b	0.00b	0.01b	0.01cd
3.	0.11b	0.03b	0.02b	0.03b	0.31a
4.	0.17b	0.00b	0.17a	0.04b	0.28a
5.	0.45a	0.15a	0.14a	0.17a	0.13bc
6.	0.14b	0.03b	0.02b	0.02b	0.14b
7.	0.11b	0.02b	0.00b	0.04b	0.01cd
8.	0.11b	0.05b	0.05b	0.01b	0.15b

Treatment means within columns not showing a common letter are significantly different as separated by Duncan's Multiple Range Test (P=0.05).
DASA = Days after second application.

the 0.002 lb AI/A. The treatments, Agrimek + oil, NTN33893, RH2485, Stalker and Fenoxycarb showed good potential for CLM control. While some of these treatments are not registered for use in citrus trees in Florida, their performance during these preliminary tests suggest their potential value for use in a CLM management program in Florida.

Two strategies of chemical control of gracillarid leaf miners have been recommended: sprays targeted at adults and timed to their emergence, or insecticide timed to control the sap feeding larvae.

Control of CLM adults would be difficult because of their prolonged and overlapping emergence and may require multiple sprays. Using an insecticide that act both as an adulticide and an ovicide can cut the number of treatments, but its success will be based on the knowledge of the adult laying potential, the number of generations per year, etc. These data may be available for countries with a long history of CLM infestation, for Florida however, this knowledge is still in the preliminary phase. When these data are available, it might be feasible for growers or pest management specialists to monitor egg deposition with a magnifying hand lens, or by examining leaf samples microscopically, and to make spray decisions based on an expected number of mines per leaf.

Secondly, our preliminary work on indigenous enemies of CLM taken at various sites since the time of CLM appearance, allowed us to observe the potential of at least 2 species of Eulophid (*Pnigalio* spp.) and Braconid (*Oncophanes* spp.) parasitoids against the invader insect. Therefore, the insecticides to be used for management of CLM should be those less harmful to the adult parasitoids of CLM.

Thirdly, because of the history of insecticide resistance by populations of gracillarids (Pree et al., 1990), alternative strategies for management should be considered. These may include: (1) rotating the use of different pesticides; (2) selecting and targeting of the most selective life stages; (3) combining insecticides with synergistics and (4) defining and increasing economic thresholds for Florida citrus.

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