CALIFORNIA CITRUS NURSERY BOARD

Grant Report December 2009

Project Leader: Beth Grafton-Cardwell, University of California
Lindcove Research & Extension Center
22963 Carson Ave., Exeter, CA 93221
Phone: 559-592-2408 extension 13, FAX: 559-592-5947 E-Mail: bethgc@uckac.edu

Cooperating Personnel:
David Haviland, UCCE Kern County, 1031 S. Mt. Vernon Ave. Bakersfield, CA 93307. off: (661) 868-6215. dhaviland@ucdavis.edu
David Headrick, Dept of Horticulture and Crop Science, Cal Poly, 1 Grand Ave., San Luis Obispo, CA, 93407. off: (805) 756-5382, dheadric@calpoly.edu
Kris Godfrey, Biological Control Program, California Department of Food and Agriculture, 3288 Meadowview Rd., Sacramento, CA 95832. off: (916) 262-1185, kgodfrey@cdfa.ca.gov

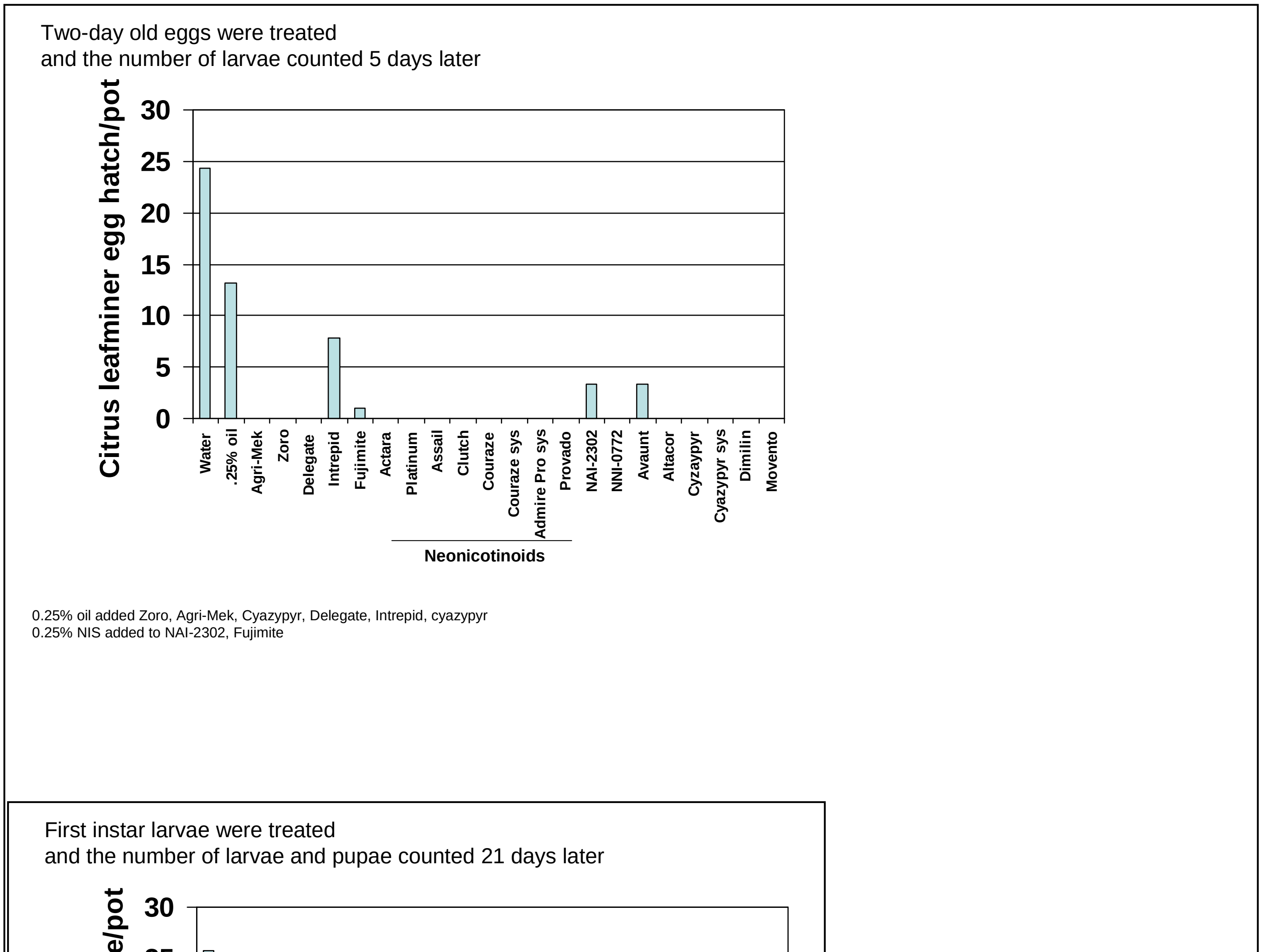
Project Title: Citrus Leafminer Management Program for Nursery Citrus

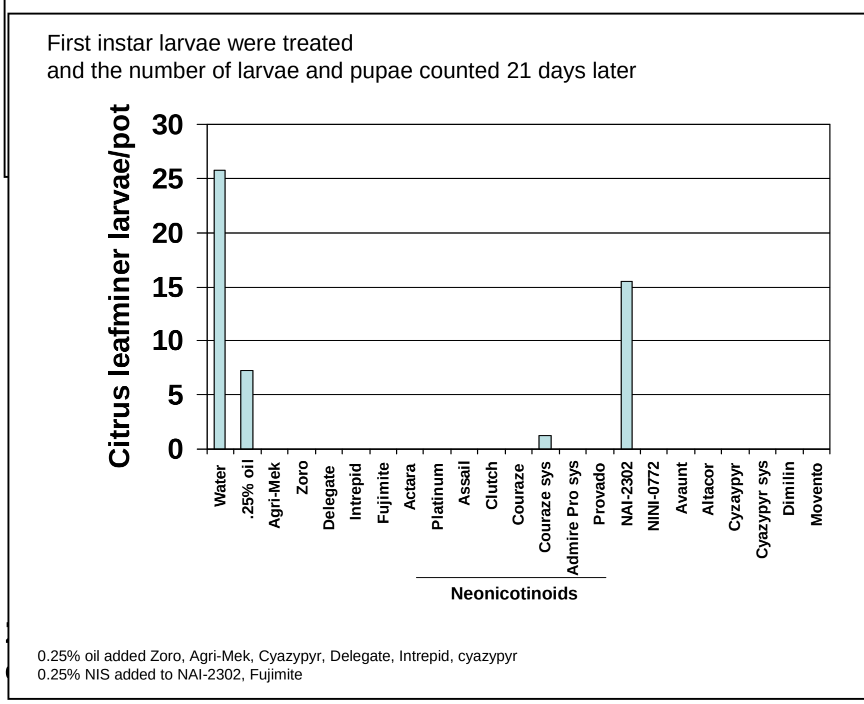
Objectives:
1) Determine the best insecticides and series and timing of rotations of insecticides for suppressing citrus leafminer infestations in nursery situations.
2) Determine if pheromones could be utilized as mating disruption or attract and kill technology to reduce overall leafminer infestations in greenhouse nursery situations.

Report
Citrus leafminer, *Phyllocnistis citrell*a, is a tiny moth that arrived in California, presumably from Mexico in 2000. It was first observed in southern California and has continued to spread northward, now infesting the southern and central coast regions and the San Joaquin Valley as far north as Stanislaus County. California is one of the last citrus growing regions in the world to be invaded by this pest. The moth lays its eggs on new flush growth of citrus and the larval stage feeds on the leaves creating serpentine mines. Mining damage causes retardation of plant growth of young trees and nursery stock and renders the leaves unsightly reducing sales to homeowners. Studies in Florida have shown that significant stunting can occur if trees are not protected from CLM from the time of budding until they are about 4 years of age. There are several insecticides that have been determined to be effective in control of citrus leafminer, including the neonicotinoids systemic imidacloprid (Admire) and acetamiprid (Assail) and to a lesser extent oils and azadirachtin (neem). Information is needed on the length of time between rotations of insecticides to minimize their use and so avoid resistance development. In addition, a highly effective pheromone has been developed for citrus leafminer. Since leafminer needs to mate to reproduce, there is potential for a pheromone-baited trap to be used to hinder male moths in their search for females, and so prevent mating, depress egg-laying and thereby suppress populations in greenhouse nursery situations.

Pesticide screening: A series of experiments were conducted during 2008 and 2009 using potted citrus seedlings to determine the impact of various pesticides on citrus leafminer survival. In the 2008 study, we purposefully infested potted citrus seedlings with eggs or larvae of citrus leafminer and then treated them with the insecticides. Figures 1 and 2 show that many insecticides were effective in killing the citrus leafminer for the 21 day period of the experiment. A single treatment of 0.25% 415 oil was only partially effective.

Fig 1. Impact of insecticides on the egg stage of citrus leafminer.





o treating the plants first, then
rs and indoors.

In the 2009 outdoor experiment (Table 1), the plants were treated and then placed in the field to be exposed to citrus leafminers that were emerging from nearby infested plants. The data show that 8 days after treatment, all treatments were effective except the 0.25% Omni 6E oil and the Silmatrix. At 24 days after treatment, the populations were beginning to increase in most treatments, likely due to the fact that new flush develops after 21 days it is usually unprotected by the foliar treatments. Three insecticides showed exceptional control of citrus leafminer through 65 days after treatment: 4 oz Altacor 35 WG (rynaxypyr), 13.5 oz DPX-HGW86 10 SE (cyazypyr), and 10 oz AgMectin 0.15 EC (abamectin) + 0.25% Omni 6E oil. We will pursue registration of cyazypyr registration for nursery citrus as it represents a new insecticide class.

In the 2009 greenhouse experiment (Table 2), the plants were treated and then placed in a greenhouse and leafminer moths were released every 2-3 weeks. The first data column shows that all insecticides allowed eggs to hatch except for Agri-Mek, AgMectin and Delegate. In the other treatments, once eggs hatched, Intrepid, Dimilin, Movento and Altacor completely killed the larvae. All treatments except the Omni 6E 415 oil reduced the leafminer at 17 days after treatment. The most effective treatments were Intrepid, Altacor, Agri-Mek, AgMectin and Delegate. Only Delegate control was completely effective through 45 days after treatment.

Conclusions: The data suggest that most registered insecticide treatments will last 2-4 weeks, depending on how fast the flush grows. Insecticides in the greenhouse experiment exerted longer control than the field experiment – this is likely due to the rate of flush growth and environmental factors (sunlight) affecting the residuality of the insecticides.

It is very important that nurserymen change insecticide class each time a spray is applied to reduce selection for resistance to insecticides in citrus leafminer, as resistance has developed in populations in other areas of the world. Available insecticide classes include: group 4 neonicotinoids (Actara, Platinum, Provado, Admire Pro, Couraze, Assail), group 5 spinosyns (Delegate), group 6 abamectin (Agri-Mek, Zoro, AgMectin), group 15 insect growth regulators (Dimilin), group 18 insect growth regulators (Intrepid), group 21 acaricides (Fujimite), group 23 (Movento) and oils.

Table 1. Effects of various insecticides when applied to potted seedlings and then the seedlings were exposed to citrus leafminer in the field. Treatments were applied in 200 gpa to 'Thong Dee' pummelos in block 63 at the Lindcove Research and Extension Center. Six trees per treatment were evaluated for live larvae and pupae on new flush. Treatments were applied on Sept 28 except Silmatrix that was applied on Sept 18, 2009.

Treatment	Insecticide	Rate Form/acre	Mean number larvae + pupae/suitable leaf					
			8 Oct 8 DAT	20 Oct 24 DAT	29 Oct 33 DAT	6 Nov 41 DAT	17 Nov 52 DAT	30 Nov 65 DAT
Water control			0.53 ± 0.29a	0.50 ± 0.23abcd	1.33 ± 0.59ab	0.30 ± 0.30bc	2.29 ± 1.38ab	1.43 ± 0.53a
Omni 6E (NR 415) Oil	415 oil	0.25%	0.32 ± 0.16abc	0.11 ± 0.04bcdef	1.34 ± 0.47ab	1.04 ± 0.31a	2.52 ± 0.74a	1.57 ± 0.90a
Intrepid + NR 415 oil	methoxyfenozi de	10 fl oz 0.25%	0.07 ± 0.07cd	0.41 ± 0.20abcd	1.52 ± 0.71ab			
Dimilin 2L	diflubenzuron	20 fl oz	0.03 ± 0.03d	0.55 ± 0.19abcd	2.14 ± 0.33a			
Movento + NR 415 oil	spirotetramat	10 fl oz 0.25%	0.10 ± 0.06cd	0.34 ± 0.16abcde	1.87 ± 0.86ab			
Provado + NR 415 oil	imidacloprid	10 fl oz 0.25%	0.03 ± 0.02d	0.35 ± 0.12abcd	1.94 ± 0.52ab			
Altacor 35 WG	rynaxypyr	4 oz	0.00 ± 0.00d	0.12 ± 0.12f	0.26 ± 0.14cde	0.19 ± 0.12bc	0.75 ± 0.51cd	0.24 ± 0.19b
DPX-HGW86 10SE	cyazypyr	13.5 fl oz	0.01 ± 0.01d	0.00 ± 0.00f	0.08 ± 0.08e	0.00 ± 0.00c	0.00 ± 0.00d	0.00 ± 0.00b
Agri-Mek 0.7 SC + NR 415 oil	abamectin	2.25 fl oz 0.25%	0.01 ± 0.01d	0.04 ± 0.04ef	0.93 ± 0.43abc	0.68 ± 0.32ab	0.59 ± 0.21bc	0.36 ± 0.08a
Agri-Flex 1.55 SC + NR 415 oil	Abamectin + thiamethoxam	5.5 fl oz 0.25%	0.00 ± 0.00d	0.19 ± 0.07abcde	1.27 ± 0.34ab			
Actara 25 WG + NR 415 oil	thiamethoxam	4 fl oz 0.25%	0.01± 0.01d	0.84 ± 0.42abc	1.79 ± 0.77ab			
Actara 25 WG + NR 415 oil	thiamethoxam	5.5 oz 0.25%	0.04 ± 0.04d	1.09 ± 0.38a	3.11 ± 1.73a			
Clutch	clothianidin	6 oz	0.01 ± 0.01d	0.13 ± 0.10def	1.73 ± 0.71ab			
Warrior II 2.09 CS + NR 415 oil	Lambda-cyhalothrin	2.8 fl oz 0.25%	0.08 ± 0.06cd	0.33 ± 0.15abcd	2.49 ± 1.14abc			
Endigo 2.06 ZC + NR 415 oil	L-cyhalothrin + thiamethoxam	6.5 fl oz 0.25%	0.00 ± 0.00d	0.10 ± 0.08cdef	0.85 ± 0.37abc			
Purespray Green 435 oil	Organic 435 oil	0.25%	0.25 ± 0.14bcd	0.64 ± 0.40abcde	0.88 ± 0.68bcd			
AgMectin 0.15 EC + NR 415 oil	abamectin	10 fl oz 0.25%	0.00 ± 0.00d	0.17 ± 0.17def	0.19 ± 0.19de	0.09 ± 0.09c	0.06 ± 0.05cd	0.03 ± 0.03b
AgMectin 0.15 EC + Orocit	abamectin	10 fl oz 0.25%	0.01 ± 0.01d	0.26 ± 0.17bcdef	2.97 ± 0.88a			
AgMectin 0.15 EC	abamectin	10 oz	0.00 ± 0.00d	0.26 ± 0.14bcdef	1.41 ± 0.34ab			
Sil-Matrix	Potassium silicate	0.25%	0.47 ± 0.21ab	0.67 ± 0.21ab	3.52 ± 1.92a			

Means followed within a column by the same letter are not significantly different (LSD, P=0.05) after log10(x+1) transformation. Untransformed means listed.

Table 2. Effects of various insecticides on citrus leafminer infestation. Treatments were applied to 6 trees per treatment using 200 gallons per acre on ‘Thong Dee’ pummelos in the greenhouse at the Kearney Ag Center. CLM were released after treatment every two weeks and larval development was evaluated.

Treatment	Application date	Rate Form/acre	Mean number stages/plant				
			7 Dec (17 DAT)		21 Dec (31 DAT)	4 Jan (45 DAT)	
			No. egg hatch	# Live larvae	# live larvae + pupae	# live larvae + pupae	
Water control			7.12 + 1.40a	7.17 + 1.40a	9.67 + 1.98a	2.33 + 1.02c	
Omni 6E (415 oil)	20 Nov	0.25%	2.17 + 0.65bcd	2.17 + 0.65bc	3.50 + 1.12bcd	4.00 + 1.88bc	
Purespray 15 E oil	20 Nov	0.25%	4.12 + 1.45b	4.17 + 1.45b	4.00 + 1.06bc	9.50 + 1.95a	
Purespray 15 E oil x 3	20 Nov + 8 Dec + 21 Dec	0.25%	3.67 + 1.05b	3.67 + 1.05b	7.33 + 1.38ab	5.83 + 2.12abc	
SilMatrix systemic + foliar	12 Nov + 20 Nov	0.25% + 0.25%	2.50 + 0.43bc	2.50 + 0.43bc	8.67 + 1.02a	8.00 + 2.18ab	
Warrior II 2.09 CS + Omni 6E oil	20 Nov	2.8 fl oz 0.25%	2.33 + 0.80bcd	1.83 + 0.79c	4.50 + 1.67bcd	4.50 + 1.57abc	
Provado 1.6 F + Omni 6E oil	20 Nov	10 fl oz +0.25%	0.67 + 0.49ef	0.17 + 0.17d	1.33 + 1.14ef	2.17 + 0.98cd	
Actara 25 WG + Omni 6E oil	20 Nov	5.5 fl oz +0.25%	1.17 + 0.31cde	0.33 + 0.33d	0.83 + 0.40ef	3.00 + 1.59cd	
Assail 70 WP	20 Nov	2.5 oz	0.67 + 0.33ef	0.17 + 0.17d	2.50 + 0.81cde	3.33 + 1.31bc	
Intrepid 2F + Omni 6E oil	20 Nov	10 fl oz 0.25%	2.00 + 0.58bcd	0.0 ± 0.0d	0.0 + 0.0f	2.33 + 0.99cd	
Dimilin 2L + Omni 6E oil	20 Nov	20 fl oz + 0.25%	1.00 + 0.45de	0.0 ± 0.0d	4.00 + 2.29cde	2.50 + 1.18cd	
Movento 240 SC + Omni 6E oil	20 Nov	10 fl oz + 0.25%	3.00 + 0.73bc	0.0 ± 0.0d	1.33 + 0.49def	5.67 + 1.02abc	
Altacor 35 WG	20 Nov	4 oz	0.50 + 0.34ef	0.0 ± 0.0d	0.33 + 0.33f	3.17 + 1.78cd	
Agri-Mek 0.7 SC + Omni 6E oil	20 Nov	2.25 fl oz + 0.25%	0.0 ± 0.0f	0.0 ± 0.0d	0.0 + 0.0f	3.83 + 1.49abc	
Agri-Mek 0.15 EC + Omni 6E oil	20 Nov	10 fl oz + 0.25%	0.0 ± 0.0f	0.0 ± 0.0d	0.50 + 0.50f	3.17 + 0.94bc	
AgMectin 0.15 EC + Omni 6E oil	20 Nov	10 fl oz + 0.25%	0.0 ± 0.0f	0.0 ± 0.0d	1.00 + 0.52ef	5.33 + 1.58abc	
Delegate WG + Omni 6E oil	20 Nov	4.8 oz + 0.25%	0.0 + 0.0f	0.0 ± 0.0d	0.0 + 0.0f	0.0 + 0.0d	

Means followed within a column by the same letter are not significantly different (LSD, P=0.05) after $\log_{10}(x \pm 1)$ transformation. Untransformed means listed.

Citrus Leafminer Pheromone Experiments conducted in the Greenhouse at the Kearney Ag Center
All experiments: 72 schaub rough lemon seedlings, 1 ft tall were placed in each room of about 12 x 18 feet. Spacing of 1.5 ft between plants and 2 feet between rows. Citrus leafminer pupae in plants were placed in the room among the seedlings and the moths were allowed to emerge naturally. One room received pheromone caps (ISCA) hung on trees evenly spaced throughout the benches and the control room was left without pheromone caps. The number of larvae per plant was counted approximately 15 days after the pupae were placed in the greenhouse.

			CLM larvae/pot			
Exp #	No. pupae	No. pheromone caps	Control	Pheromone	% control	Month conducted
1	500	24	15.30	7.55	51%	March 09
2	50	24	0.92	0.42	54%	May 09
3	100	4	3.40	1.21	64%	July 09
4	100	4	.68	.36	47%	Aug 09
		Average % control in exp 1-4			54%	

Citrus Leafminer Experiments Conducted in the Greenhouse at Shafter Research and Ext. Center
All experiments: 12 potted grapefruit trees, 5 ft tall in each room. Four benches in an area of about 7 x 15 feet. Spacing of 1.5 ft between plants and 2 feet between benches. The same procedures were used as the Kearney experiments.

			CLM larvae/tree			
Exp #	No. pupae	No. pheromone caps	Control	Pheromone**	% control	Month conducted
1	500	12	17.58	10.70	39%	Aug 09
2	200	12	40.25	13.35	67%	Sep 09
3	200	12	79.58	43.22	46%	Oct 09
		Average % control in exp 1-3			51%	

*high temperature due to a cooler malfunction in the pheromone greenhouse caused high levels of CLM mortality.

Pheromone in combination with oil spray.
For this experiment, 200 pupae were released in each of two rooms. One room received 4 pheromone caps and the other room received no pheromone. Prior to treatment, ½ of the potted seedlings in each room were sprayed with 0.25% Omni 6E oil. Pheromone treatment reduced the number of leafminer per plant by 49% and the oil + pheromone treatment reduced citrus leafminer by 84%.

	Leafminer per pot	
	Pheromone	No pheromone
Oil	0.17	0.28
No oil	0.55	1.08

Overall Results: A total of 8 experiments in greenhouses cubicles comparing rooms with pheromone lures and rooms without, demonstrates that pheromone lures can reduce citrus leafminer infestations by about 50%. As few as 4 caps in 12 x 18 foot room were sufficient to cause this effect. This technique was successfully used in combination with an oil spray to reduce leafminer infestation by 84%.