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Constraints on Developing an Integrated Pest Management Program for Citrus Leafminer (Lepidoptera: Gracillariidae) in Florida Nurseries

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ADDITIONAL INDEX WORDS. *Phyllocnistis citrella*, *Ageniaspis citricola*, citrus pests, pesticide use, production systems, survey

SUMMARY. Florida citrus nursery growers were surveyed to learn about their citrus leafminer (*Phyllocnistis citrella* Stainton) (CLM) management practices as a preliminary step in developing an integrated pest management (IPM) program. All responses were kept anonymous. Survey responses from growers producing ≈4.2 million trees annually were obtained, which represents most of the estimated 5.2 million trees required to annually replant Florida groves. Large nurseries (20%) each produced ≥100,000 trees per year and jointly provided 88% of the trees produced annually. Small nurseries (80%) each produced <100,000 trees per year. The citrus leafminer was ranked the most important pest in nurseries during 1995.

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Pesticides used for CLM control included avermectin, azadirachtin, imidacloprid, fenoxycarb, diflubenzuron, and sulfur, in order of importance. Oil and soap also were used. Growers were concerned about the possibility that the CLM will develop resistance to pesticides. Producers potentially were willing to monitor CLM populations, switch pesticide types to improve survival of parasitoids of the CLM, and leave untreated trees inside the nursery to serve as refuges for CLM parasitoids. In order of importance, pest management advice was provided by private chemical companies, the Florida Citrus Pest Management Guide produced by the University of Florida/Institute of Food and Agricultural Sciences (UF/IFAS), UF/IFAS personnel, grower magazines, private consultants, the Florida Citrus Nurserymen's Association, and other growers.

Efforts have been made since 1993 to protect Florida citrus production from losses caused by the citrus leafminer (CLM) (*Phyllocnistis citrella* Stainton). Most of the work has been directed to protecting groves (Knapp et al., 1995) and little effort has been extended to citrus nurseries, where damage can be even more dramatic than that caused in mature trees (Stansly et al., 1996). A special set of integrated pest management (IPM) tactics may be needed to delay the development of resistance by the citrus leafminer to pesticides used in citrus nurseries. A strong biological control component should be included in any citrus nursery IPM program developed because an effective natural enemy of the citrus leafminer, *Ageniaspis citricola* Logvinovskaya, has been established in a classical biological control program (Hoy et al., 1995). Cultural control tactics and a judicious use of pesticides should be included as well. Unfortunately, plant resistance, physical and mechanical controls, genetic or autocidal control, and behavioral and legal controls are not well developed or can not be implemented to manage CLM populations in Florida nurseries and groves (Villanueva-Jiménez and Hoy, 1996).

When developing an effective IPM program it is important for researchers to understand the problems faced by the end users and to get feedback from potential users regarding tactics that are feasible and potentially implementable. Ideally, this discussion occurs before

beginning a research program. Studies on successful IPM implementation (Wearing, 1988) suggest that the allocation of resources and efforts (i.e., surveys, interviews, literature reviews) to understand the objectives of Florida citrus nurserymen are good investments.

Our goal in conducting a survey was to understand the state of the art of CLM pest management in citrus nursery production, to obtain an idea of what is possible to implement in managing the CLM, and to learn the needs, constraints, perceptions, and objectives of citrus nurserymen. In addition, we hoped to learn whether growers had independently developed ideas or techniques that could be evaluated as part of an IPM program for the CLM.

Materials and methods

Two sources of addresses were obtained for a mail survey. The Florida Citrus Nurserymen's Association (FCNA) mailing list contained 53 addresses. The list of Florida citrus nurserymen maintained by the Florida Dept. of Agriculture Division of Plant Industry contained 308 addresses. Both lists were compiled to generate a master list of 322 addresses by removing duplicate and inappropriate entries. Questionnaires were mailed in March 1996.

Thirteen questions were asked to determine the types of nursery production systems used, insect and mite problems encountered, pesticides used, CLM management practices currently used, and the sources of information used by nurserymen for their pest management advice (Appendix I). All replies were kept anonymous. For those growers who wanted to share their comments and experiences in CLM management, an extra data sheet was provided in which we asked for experiments or observations they have conducted and their willingness to be interviewed personally. This sheet was to be returned separately so anonymity of the questionnaire could be preserved. Because we focused on the importance of biological control as a basis for any IPM program, we also enclosed a citrus industry article about the recently established parasitoid *Ageniaspis citricola* (Hoy et al., 1995).

The responses were analyzed according to frequency (the number of times an option was chosen), percentage (the number of times an option was chosen divided by the total number of usable responses and multiplied by 100), and ranking (assigning the highest value

to the most important issues by multiplying the option's frequency times its ordinal or estimated nominal values to provide a weighted value).

The estimated number of trees per grower was calculated by taking the midpoint from the range of trees each grower circled on the questionnaire (i.e., 500 trees for the range 1 to 1,000). When >1,000,000 trees were chosen (one response), we considered 1,200,000 as the estimated total number of trees produced, given that the two biggest nurseries in Florida produce 1,000,000 to 1,400,000 trees (Phil Rucks, personal communication, Winter Haven, Fla.).

The estimated number of each type of rootstock and scion was calculated by taking the midpoint percentage value from the percentage range chosen in the questionnaire (Appendix I) by each grower (i.e., for 21% to 50%, the midpoint was 35.5%). All midpoint values were added among rootstocks and scions for each grower. Because the sum of midpoint percentage values of rootstocks or scions per grower yielded values greater than or less than 100% for that grower, a proportional adjustment of each midpoint percentage value was required (i.e., 35.5% 'Carrizo' + 13% 'Cleopatra' + 35.5% 'Swingle' = 84% for grower X. After proportional adjustment, values of 42.2% 'Carrizo', 15.6% 'Cleopatra', and 42.2% 'Swingle' were obtained). Then, the adjusted percentage of each rootstock or scion type was multiplied by the estimated number of trees per grower and was divided by 100 to obtain an estimated number of trees by cultivar or tree type per grower [i.e., $(42.2\% \times 50,000 \text{ trees})/100 = 21,100$ estimated 'Carrizo' trees of grower X.] Numbers presented in Table 1 were rounded to the nearest hundred.

The estimated number of trees by cultivar or tree type was added among all growers to calculate a total estimated number of each rootstock or scion produced (Table 1).

Growers were asked to identify and rank the most important pests requiring chemical control in their nursery during 1995 as severe (3), moderate (2) or light (1). If a grower failed to respond to this question, we scored it 0. Ranked values by pest were added among large and small nurseries (i.e., broad mite among the six large nurseries = $3 + 1 + 1 + 1 + 2 + 1 = 9$). The sum of all ranked values by pest among each group of nurseries was considered as 100% (i.e., pests

among large nurseries = $9 + 9 + \dots + 4 + 5 = 97$, and 97 was considered as 100%.) Proportional adjustment of each pest rank was performed (i.e., broad mite adjusted rank among large nurseries = 9.28.) The relative importance of mites was compared with sucking insects in large and small nurseries using the average adjusted ranking of the three mite species minus the average adjusted ranking of the seven sucking insect species per grower (aveM-aveS). Data were analyzed by a *t* test using a StatView routine (Abacus Concepts, 1992) for large and small nurseries.

Mean cost of CLM control was calculated by taking each response as the midpoint value of the range of costs provided in the questionnaire (Appendix I), also including zero values by two growers.

Ranking of sources of advice was calculated giving a value of 7 to the most important source indicated (grower answering with a number 1), and decreasing one unit down to 1 in the case of the response ranked seventh. Spaces left blank were considered as 0.

Results and discussion

Our goal was to reach the 80 to 90 nurseries that Rucks estimated were producing trees for the citrus industry. Forty-three responses were received. After eliminating 13 unusable responses (11 of which were from nurseries that were only retailers or had gone out of business), 30 questionnaires remained, representing 33% to 38% of the 80 to 90 estimated production nurseries in Florida.

CITRUS TREE PRODUCTION. About 5.2 million new trees are needed each year in Florida. This estimate is based on the assumption that the mean number of trees per acre in Florida is 120, and $\approx 5\%$ of 860,000 acres planted with citrus are replanted every year (Ferguson and Taylor, 1993; Florida Agriculture Statistics Service, 1992; Hardy, 1996; Knapp et al., 1992).

Respondents produced an estimated total of 4.2 million trees (estimated range ≈ 3 to 5 million), indicating that we surveyed a large proportion of growers who produced trees for the citrus industry in the state.

Of 30 responses, 30% (9 respondents) were by growers who produced 1 to 1,000 trees in 1995; 20% (6 respondents) produced 1,001 to 10,000 trees; and 30% (9 respondents) produced 10,001 to 100,000 trees. These group

of 24 growers (80%) produced a total of $\approx 11.6\%$ (420,000 trees) of the citrus nursery trees produced by respondents.

Of the growers 17% (5 respondents) said they produced 100,001 to 1,000,000 trees. One grower (3%) produced more than one million trees. This group of six growers accounted for $\approx 88\%$ (3,700,000) of the citrus trees produced in 1995 by our respondents.

We separated the responses as "small nurseries" (24 responses) and "large nurseries" (6 responses) for analyses of pest problems and impact of the CLM in citrus nurseries.

Rootstocks. Respondents were asked to circle the names of all citrus rootstocks they produced during 1995, and to approximate the percentages of each cultivar or type produced. The estimated number of each type of tree produced during 1995 by sampled nurseries is presented in Table 1.

Eighteen rootstocks were listed (Table 1). The 10 most popular were 'Swingle' citrumelo (45.8% of estimated trees) produced in 16 nurseries, 'Carrizo' citrange (23.3%) in 17 nurseries, 'Cleopatra' mandarin (7.0%) in 12 nurseries, 'Smooth Flat Seville' sour orange

(7.0%) in 8 nurseries, rough lemon (6.3%) in 3 nurseries, 'Volkamer' lemon (3.8%) in 7 nurseries, 'Milam' lemon (3.3%) in 2 nurseries, sour orange (1.3%) in 5 nurseries, and 'Flying Dragon' orange (0.6%) and 'Trifoliate' orange (0.3%) produced by 2 growers each. Percentages of rootstocks used for registered scion propagation in Florida during 1995–96 are considered a reliable source of information about what is being produced in the citrus nursery industry (Neff, 1997a). Neff's rating of the top four rootstocks was similar to our results, being 'Swingle' first with

Table 1. Estimated number and percentage of rootstocks and scions produced in sampled Florida citrus nurseries during 1995.

Rootstock	Estimated		Respondents		Scions	Estimated		Respondents	
	trees (no.)	%	(no.)			trees (no.)	%	(no.)	
Swingle citrumelo	1,891,400	45.8	16		Valencia	1,755,500	42.0	21	
Carrizo orange	964,000	23.3	17		Hamlin	609,100	14.6	19	
Cleopatra mandarin	288,100	7.0	12		Pineapple	312,200	7.5	9	
Seville sour orange	287,700	7.0	8		Navel's	166,800	4.0	19	
Rough lemon	261,200	6.3	3		Sunburst	131,400	3.1	12	
Volkamer lemon	156,800	3.8	7		Marsh	129,600	3.1	13	
Milam lemon	136,000	3.3	2		Tahiti (Persian) lime	123,300	3.0	9	
Sour orange	52,000	1.3	5		Ruby Red	121,500	2.9	18	
Flying Dragon	24,900	0.6	2		Orlando	99,600	2.4	11	
Trifoliate orange	12,200	0.3	2		Honey (Murcott)	97,200	2.3	10	
Rusk citrange	12,000	0.3	1		Rio Red	77,600	1.9	9	
Benton citrange	10,000	0.2	1		Midsweet	68,000	1.6	4	
Sun Chu Sha	10,000	0.2	1		Minneola	61,600	1.5	16	
Grapefruit	7,400	0.2	3		Flame	58,400	1.4	6	
Sweet orange	7,200	0.2	1		Fallglo	50,500	1.2	10	
C-35	4,800	0.1	1		Robinson	50,000	1.2	8	
Citrus macrophylla	3,300	0.1	3		Ray Ruby	47,800	1.1	5	
Shekwasha	---	0.002	1		Dancy	41,700	1.0	8	
					Temple	37,100	0.9	7	
					Duncan	29,800	0.7	5	
					Lemon	24,800	0.6	7	
					Satsuma	20,200	0.5	6	
					Star Ruby	16,000	0.4	3	
					Henderson	15,800	0.4	2	
					Red Blush	12,300	0.3	2	
					Thompson (Pink Marsh)	10,900	0.3	4	
					Ponkan	3,700	0.1	1	
					Key lime	2,000	0.05	3	
					Ambersweet	1,500	0.04	3	
					Sunstar	1,400	0.03	1	
					Nova	900	0.02	3	
					K-early	800	0.02	1	
					Calamondin	600	0.01	2	
					Meyer lemon	500	0.01	1	
					Kumquat	500	0.01	1	
					Orange-grapefruit blend	500	0.01	1	
					Navel grapefruit	500	0.01	1	
					Orangequat	100	0.003	1	
					Ugley	100	0.003	1	
					Pummelo	---	0.0003	1	
					Total estimated trees	4.18 million			

Table 2. Months required to produce a marketable product by production systems used in Florida nurseries during 1995.

Production system	Mean months (no.)	SD	Responses (no.)
Greenhouse	16.2	(1.8)	5
Ground planting	27.8	(8.5)	8
Containers	11.2	(6.4)	7
Greenhouse and Ground planting	4.0 and 17.5	(0.0) and (3.5)	2
Greenhouse and Containers	3.9 and 12.1	(1.0) and (6.5)	7
Containers and Ground planting	8.0 and 19.0	(5.7) and (1.4)	2

41.3% of registered trees and 'Carrizo' second with 20.7%, 'Seville' third with 9.2%, and 'Cleopatra' fourth with 6.3%.

Scions. Forty-one scion cultivars were produced during 1995 by the sampled growers (Table 1). The top 10 scions produced were 'Valencia' orange (42.0% of estimated trees) produced by 21 growers, 'Hamlin' orange (14.6%) by 19, 'Pineapple' orange (7.5%) by 9, navel orange (4.0%) by 19, 'Sunburst' tangerine (3.1%) by 12, Marsh' grapefruit (3.1%) by 13, 'Tahiti' lime (3.0%) by 9, 'Ruby Red' grapefruit (2.9%) by 18, 'Orlando' tangelo (2.4%) by 11, and 'Honey' ('Murcott') tangerine (2.3%) by 10.

In agreement with our results, Neff (1997b) found that 'Valencia' orange was the most planted scion in Florida during 1993, 1994, and 1995 (39.5% of total trees planted). He also found that 'Hamlin', navels, and 'Pineapple'

oranges were planted in high percentages (33.3%). Tangerines represented 12.8% of the total trees planted during 1993-95, with 'Honey', 'Fallglo', 'Sunburst', 'Robinson', and 'Dancy' the most important. Colored grapefruit, 'Ruby Red', 'Rio Red', 'Flame', 'Ray Ruby', 'Star Ruby', 'Henderson', 'Red Blush', and 'Thompson Pink Marsh' represented 7.6% of the trees planted. White grapefruit 'Marsh' and 'Duncan' represented 4.1% of the trees planted during 1993-95 (Neff, 1997b).

Three growers responding to our survey indicated they produced trees by rooting cuttings, including an estimated 2,500 'Valencia' orange trees, 2,500 'Hamlin' orange trees, 500 'Meyer' lemon trees, and 500 'Calamondin' citrus trees. One grower produced an estimated 50,000 trees of 'Tahiti' lime by air layering. The estimated number of trees produced by rooted cuttings or air

layering were included in Table 1 as scions when calculating the total number of trees produced in 1995.

PRODUCTION SYSTEM. Of 29 producers sampled 41% indicated they started rootstocks and scions from seed, 34% from liners (seedlings ready to be grafted), 10% from rooted cuttings, and 3% from air layers. Two growers (7%) used seeds and liners, and one grower (3%) did not propagate citrus during 1995.

The time required to produce a finished (marketable) product averaged 16.2 months if trees were grown in a greenhouse (Table 2). On average, a finished product required 27.8 months if grown in the ground, or 11.2 months if grown in pots.

Production systems involving two steps were also reported (Table 2). Trees were grown in greenhouses for 4 months on average and then moved to the ground for an additional 17.5 months. When trees were planted in a greenhouse and then reported in containers, it took on average of 3.9 and 12.1 months, respectively. Some trees were planted in containers for an average of 8 months and then moved to the ground for an additional 19 months.

PEST PROBLEMS. Of the 30 grow-

Fig. 1. Ranking of arthropod pests by Florida growers with large and small nurseries in 1995. CLM = citrus leafminer, C. = citrus, Ct. cushion scale = cottony cushion scale.

Table 3. Ranking of diseases by importance, and fungicides used to control them in Florida citrus nurseries during 1995.

Diseases	Relative disease ranking (sum of respondents ranking disease as 1 or 2*)	Pesticides used (trade name)	Respondents using product
Foot rot or root rot	13	Metalaxyl (Ridomil)	10
		Fosetyl-al (Aliette)	5
		Ethazole (Banrot)	1
Citrus scab	9	Copper tri-basic	9
		Benomyl (Benlate)	5
		Ferbam (Carbamate)	1
		Neem extract (Triact)	1
Greasy spot	8	Copper tri-basic	12
		Oil (FC 435-66)	7
		Neem extract (Triact)	1
<i>Alternaria</i>	6	Copper tri-basic	7
		Iprodione (Rovral)	2
		Neem extract (Triact)	2
		Fosetyl-al (Aliette)	1
		Benomyl (Benlate)	1
Sooty blotch/sooty mold	4	Oil (FC 435-66)	6
		Neem extract (Triact)	1

*Scale rankings ranged from 1 to 5, with 1 as the most serious disease.

ers sampled, 53% considered the CLM as a major pest, 17% considered it a minor pest, and 30% did not respond to this question.

When compared with other citrus pests, CLM was ranked the most important in nursery citrus tree production in Florida in 1995, regardless of production system size (Fig. 1).

In large nurseries, broad mite [*Hemitarsonemus latus* (Banks)] was ranked second in importance (Fig. 1). Citrus red mite [*Panonychus citri* (McGregor)] and root weevils [*Diaprepes abbreviatus* (L.), *Pantomorus cervinus* (Boheman), *Pachnaeus litus* (Germar), *P. opalus* (Olivier), and *Artipus floridanus* (Horn.)] were both ranked third, followed by fire ants [*Solenopsis invicta* (Buren)] in fourth place, and citrus rust mite [*Phyllocoptruta oleivora* (Ashmead)] in fifth place. Aphids [*Aphis spiraecola* Patch, *Toxoptera aurantii* (Boyer de Fonscolombe), and *A. gossypii* Glover] and citrus snow scale [*Unaspis citri* (Comstock)] both ranked sixth, whiteflies [*Dialeurodes citri* (Ashmead), *D. citrifolii* (Morgan), and *Aleurothrixus floccosus* (Maskell)] were seventh in importance, and orange dog [*Papilio cresphontes* Cramer] was eighth. A cluster formed by citrus blackfly [*Aleurocanthus woglumi* Ashby], citrus mealybug [*Planococcus citri* (Risso)], cottony cushion scale [*Icerya purchasi* Maskell], and purple scale [*Lepidosaphes beckii*

(Newman)] ranked ninth. No other pests were reported by large nursery managers.

Small nursery producers ranked aphids, white flies, citrus red mite, and fire ants as second, third, fourth, and fifth in importance, respectively (Fig. 1). Citrus broad mite and orange dog were both ranked sixth. Citrus rust mite was ranked seventh, citrus snow scale and citrus blackfly were both ranked eighth, root weevils were ninth, citrus mealybug and cottony cushion scale were both tenth, and purple scale ranked eleventh. One nurseryman also reported slugs [probably the marsh slug *Deroceras laeve* (Müller) or the Mexican slug *Leidyula moreleti* (Crosse & Fischer)] (Deisler and Stange, 1984; Stange, 1978) as an occasional pest problem.

Mites (broad, citrus red, and citrus rust mite) were more important in large nurseries than sucking insects (aphids, white flies, citrus snow scale, citrus blackfly, citrus mealybug, cottony cushion scale, and purple scale). [The mean of mite relevance average minus sucking insect relevance average (aveM - aveS) = 0.55, $P = 0.046$], whereas the importance of mites was not significantly different from the importance of sucking insects in small nurseries (mean aveM - aveS = 0.095, $P = 0.30$).] (Fig. 1).

DISEASES. Respondents were asked to rank five citrus diseases by importance on a scale of 1 to 5, 1 being the most important disease. Based on the frequency of the diseases receiving a

ranking of either a 1 or a 2, foot rot or root rot (*Phytophthora* spp.) was listed as the most important disease (Table 3), followed by citrus scab (*Elsinoe fawcettii* Bitanc. and Jenk.), greasy spot (*Mycosphaerella citri* Whiteside), alternaria brown spot (*A. citri* Ell. and Pierce), and sooty blotch and sooty mold [*Gloeodes pomigena* (Schw.) and *Capnodium citri* Berk. and Desm.].

Foot rot or root rot was treated with metalaxyl (Ridomil, Ciba, Greensboro, N.C.), fosetyl-al (Aliette, Rhône-Poulenc, Research Triangle Park, N.C.), and ethazole (Banrot, Scotts Co., Marysville, Ohio) (Table 3). Growers reported using copper products, benomyl (Benlate, Du Pont, Wilmington, Del.), ferbam (Carbamate, UCB Chemical Co., Smyrna, Ga.), and hydrophobic neem extract (Triact, Bioscape, Inc., San Francisco, Calif.) to control citrus scab. Greasy spot was treated with copper, petroleum oil, and hydrophobic neem extract. Copper also was used when *Alternaria* was present, as well as iprodione (Rovral, Rhône-Poulenc), hydrophobic neem extract, copper tri-basic, fosetylal (Aliette, Rhône-Poulenc), and benomyl. Sooty blotch or sooty mold was treated with oil and hydrophobic neem extract (Table 3).

NEGATIVE IMPACT OF THE CITRUS LEAF-MINER. When we asked "What is the most important effect of the CLM on your citrus production system?", four of six growers with large nurseries (production >10,000 trees) said that reduc-

Table 4. Relative importance of the citrus leafminer to citrus tree production in Florida during 1995.

Attribute	Responses (no.)			
	More important	Fairly important	Less important	No response
Large nurseries				
Growth reduction	4	0	2	0
Increased costs	2	2	2	0
Tree appearance	0	4	2	0
Small nurseries				
Tree appearance	15	6	2	1
Growth reduction	10	5	8	1
Increased costs	2	10	11	1

tion in growth was the most important effect, followed by increased production costs (Table 4). For four growers tree appearance was fairly important, and for two it was less important. No large nursery growers considered tree appearance as more important.

Of 24 growers with small nurseries, 15 considered appearance as the most important effect of the CLM, followed by reduction in plant growth indicated by ten (Table 4). For 10, increase in production costs was fairly important, and for 11 it was less important. Two small nursery growers considered increased costs as more important.

COST OF CLM CONTROL. Mean CLM control costs per tree were estimated as \$0.22 (SD = 0.26.) Two growers did not apply any pesticides, ten invested \$0.00 to \$0.10 per tree, six others invested \$0.11 to 0.20. Six growers estimated costs as \$0.21 to 0.50 per tree. Two nurseries had control costs ranging from \$0.51 to \$1.00 per tree. One nurseryman invested more than \$1.00 per tree

on CLM control. Three growers did not respond to this question.

PESTICIDE RESISTANCE CONCERNS. Of the 29 respondents, 72% were concerned about the possibility that the CLM will develop resistance to insecticides. One grower did not respond.

CONTROL METHODS FOR CLM. Of 29 respondents, 55% indicated that their CLM control methods were adequate.

Diverse pesticides were listed in response to the question "What pesticides or other methods did you use to manage the CLM in 1995?" (Table 5). In 14 nurseries, avermectin (Agri-Mek, Merck Co., Three Bridges, N.J.) was sprayed 2.1 times on average (a maximum of 8 times a year). In 11 nurseries, azadirachtin as Neemix (Thermo Trilogy Co., Columbia, MD) was used 3.9 times on average (1 to 13 times). Five growers used fenoxycarb (Eclipse, Ciba) 1 to 2 times. Diflubenzuron (Micromite, Uniroyal Chemical Co., Middlebury, Conn.) was used 6 times on average (a maximum of 15 times) by 3 growers.

Azadirachtin as Proneem (Thermo Trilogy Co., Columbia, Md.) was sprayed 3 times by one grower. Several pesticides that were not listed in the survey, but were listed by growers were imidacloprid (Admire, Bayer Co., Kansas City, Mo.), applied 1.5 times on average (1 to 2 times) by 4 growers, avermectin as Avid (Merck) + oil used 12.5 times on average in 2 nurseries (10 and 15 times each), hydrophobic neem extract (Triact) sprayed 3 times by one grower, carbaryl (Carbaryl, Micro-Flo Co., Lakeland, Fla.) used once by one, sulfur applied 24 times by one, imidacloprid as Marathon (Olympic Horticultural Products Co., Mainland, Pa.) used 3 times by one, carbaryl as Sevin (Rhône-Poulenc) applied 3 times by one, and malathion (Malathion, United Agri Products, Greeley, Colo.) sprayed 3 times by one grower.

OTHER CONTROL TECHNIQUES TRIED OR USED. Seventeen growers relied on at least one oil spray for CLM control. Agricultural soaps were used at least

Table 5. Insecticides used to control the citrus leafminer (CLM) in Florida citrus nurseries during 1995.

Pesticide (trade name)	Applications (mean no.)	SD	Applications (median no.)	Range among respondents using product	Respondents using product
Chosen from questionnaire					
Avermectin (Agri-Mek)	2.1	2.1	1	1-8	14
Azadirachtin (Neemix)	3.9	3.7	2	1-13	11
Fenoxycarb (Eclipse)	1.2	0.5	1	1-2	5
Diflubenzuron (Micromite)	6	7.8	2	1-15	3
Azadirachtin (Proneem)	3	---	3	3	1
Provided by growers					
Imidacloprid (Admire)	1.5	0.6	1.5	1-2	4
Avermectin (Avid)+oil	12.5	3.5	12.5	10-15	2
Neem extract (Triact)	3	---	3	3	1
Carbaryl (Carbaryl)	1	---	1	1	1
Sulfur (Sulfur)	24	---	24	24	1
Imidacloprid (Marathon)	3	---	3	3	1
Carbaryl (Sevin)	3	---	3	3	1
Malathion (Malathion)	3	---	3	3	1

Table 6. Acaricides used in Florida citrus nurseries during 1995.

Acaricide (trade name)	Applications (mean no.)	SD	Applications (median no.)	Range among respondents using product	Respondents using product
Petroleum oil (FC 435-66)	6.5	(6.8)	4	1-24	17
Ethion (Ethion)	2.1	(0.9)	2	1-4	10
Hexakis distannoxane (Vendex)	1.4	(1.0)	1	1-4	9
Avermectin (Agri-Mek)	1.6	(1.1)	1	1-4	7
Dicofol (Kelthane)	2.3	(1.0)	2.5	1-3	4
Sulfur (Sulfur)	2.7	(1.5)	3	1-4	3
Formetanate hydrochloride (Carzol)	1	---	1	1	1
Propargite (Comite)	1	---	1	1	1
Dicofol (Dicofol)	1	---	1	1	1
Oxythioquinox (Morestan)	2	---	2	2	1
Micronized sulfur (Thiolux)	3	---	3	3	1
Hydrophobic neem extract (Triact)	3	---	3	3	1

once by four nursery managers. It is possible they were applied more than once, but we did not request information about the frequency of application in this question. Growers did not use traps, but one reported that they screened their nurseries to eliminate the adult CLM moth. No other control methods were mentioned.

GROWER INTEREST IN AN IPM PROGRAM. We asked growers if they were willing to consider new IPM practices to manage the CLM including monitoring CLM populations, switching to selective pesticides, leaving a few trees as parasitoid refuges, or screening nurseries to prevent infestation by the CLM (Appendix I, No. 12).

Of 25 usable responses, 23 (92%) indicated growers are willing to monitor CLM pest populations.

When we asked if they would consider switching pesticide types to improve survival of CLM parasitoids, 20 of 24 growers responded yes (83%).

Nurserymen were asked if they would leave a few midsize citrus trees untreated inside the nursery and manage those trees to serve as parasitoid refuges. Of 22 responses, 16 (73%) indicated grower willingness to consider this IPM tactic.

Screening nursery trees to prevent CLM attack was not a popular idea. Of 21 growers, 18 (86%) responded no to screening.

We asked nurserymen if they were willing to use other intensive management tactics if an IPM program for the CLM were developed for nurseries (Appendix I, No. 12). Of 20 growers, 14 (70%) were willing to consider the use of intensive management tactics.

Citrus nursery growers' interest in IPM options agree with the national trend in pest management in the greenhouse and nursery industry (Garber et al., 1996), when willingness to adopt nonchemical insect control measures increased between 1988 and 1993.

PESTICIDES USED FOR MITE CONTROL. Petroleum oil was the most commonly used miticide among all respondents (Table 6). Oil was sprayed up to 24

Table 7. Insecticides used to control insects other than the citrus leafminer in Florida nurseries during 1995.

Insecticide (trade name)	Applications (mean no.)	SD	Applications (median no.)	Range among respondents using product	Respondents using product
Chlorpyrifos (Lorsban)	2.8	(4.2)	1	1-16	13
Petroleum oil (FC 435-66)	5.0	(7.2)	2	1-24	10
Carbaryl (Sevin)	1.9	(1.7)	1	1-6	9
Ethion (Ethion)	1.5	(0.6)	1.5	1-2	4
Malathion (Malathion)	4	(2.4)	4.5	1-6	4
Methidathion (Supracide)	2	(1.4)	1.5	1-4	4
Dimethoate (Cygon)	1.3	(0.6)	1	1-2	3
Dimethoate (Dimethoate)	1.5	(0.7)	1.5	1-2	2
Azinphos-methyl (Azinphos-Methyl)	1.5	(0.7)	1.5	1-2	2
Methomyl (Lannate)	3.5	(3.5)	3.5	1-6	2
Oxamyl (Vydate)	1	(0.0)	1	1	2
Avermectin (Avid)+oil	10	---	10	10	1
Bt (<i>Bacillus thuringiensis</i>)	1	---	1	1	1
Oxydemeton-methyl (Metasystox-R)	1	---	1	1	1
Neem oil (Neemazad)	1	---	1	1	1
Azadirachtin (Neemix)	9	---	9	9	1
Propargite (Omite)	2	---	2	2	1
Endosulfan (Thiodan)	1	---	1	1	1

times, or an average of 6.5 times per year. Ethion (Ethion, FMC Co., Philadelphia, Pa.) was sprayed 2.1 times on average by 10 growers, hexakis distannoxane (Vendex, Du Pont) was used 1.4 times on average by 9 growers, avermectin (Agri-Mek) was sprayed 1.6 times per year in 7 nurseries. Dicofol (Kelthane, Rohm and Haas, Philadelphia) was sprayed 2.3 (1 to 3) times on average by 4 nurserymen, and sulfur was used up to 4 times (2.7 on average). The following products used for mite control were reported by only one respondent: formetanate hydrochloride (Carzol, AgrEvo USA Co., Wilmington, Del.), propargite (Comite, Uniroyal Chemical Co.), and dicofol (Dicofol, Rohm and Haas) applied once each; two applications of oxythioquinox (Morestan, Bayer), three applications of micronized sulfur (Thiolux, Sandoz Agro, Inc., Des Plaines, Ill.), and three of hydrophobic neem extract (Triact).

PESTICIDES USED TO CONTROL INSECTS OTHER THAN CLM. On average, chlorpyrifos (Lorsban, DowElanco, Indianapolis, Ind.) was sprayed 2.8 times in 13 nurseries against other insect pests, 5.0 applications of petroleum oil were made by 10 growers, and carbaryl (Sevin) was used 1.9 times in 9 nurseries (Table 7). Four nurseries used ethion (Ethion) 1.5 times a year, four nurseries used malathion (Malathion) 4.0 times, four growers used methidathion (Supracide, Ciba) 2.0 times, three growers used dimethoate (Cygon, Sureco, Inc., Tampa, FL) 1.3 times, and two growers used dimethoate (Dimethoate, Micro-Flo Co.), and azinphos-methyl (Azinphos-Methyl, Micro-Flo Co.) 1.5 times. Two growers sprayed methomyl (Lannate, Du Pont) 3.5 times on average, and two others reported 1 spray of oxamyl (Vydate, Du Pont). Single individuals used other products as follows: 10 applications per year of azadirachtin as Avid + oil, one spray of *Bt* (*Bacillus thuringiensis*, no brand name provided), one application of oxydemeton-methyl (Metasystox-R, Gowan Co., Yuma, Ariz.), one of neem oil (Necmazad, Bioscape, Inc.), nine of azadirachtin (Neemix), two of propargite (Omite, Uniroyal Chemical Co.), and one of endosulfan (Thiodan, FMC Co.). We did not ask growers whether they targeted more than one pest with the same product.

SOURCES OF ADVICE. Various information sources were used by citrus nursery producers (Fig. 2). Private chemical

companies were the most important sources of advice. The *Florida Citrus Pest Management Guide*, produced by the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS), was the second most important source, followed by UF/IFAS personnel. Growers' magazines were considered fourth in importance. Fifth place was taken by private consultants, followed by the growers' association. Three responses ranked 'other growers' as another very important source of advice. A single response by a large nursery manager indicated they used their own company research and development office for pest management advice. Various communication channels, and UF/IFAS ones in particular, seem to be appropriate to divulge research results about improved IPM practices for the CLM in Florida nurseries.

These results are similar to those obtained by Garber et al. (1996) in a national survey of national greenhouse and nursery industry producers. Garber et al. (1996) found producers relied heavily on other growers, trade journal articles, and the extension service for information on alternative pest management practices. Our survey results also agreed with those obtained by Garber et al. (1996) who concluded that more and better materials are needed to explain fully the details of the alternative IPM practices.

ADDITIONAL INFORMATION SHEET. Only six people returned the additional sheet (Appendix I, additional sheet). When we asked about new ideas for CLM management, three small growers responded by saying that they were using the parasitoid wasp *Ageniaspis citricola*. Two of them indicated that no pesticides were ever used, and the wasp

provided good control of the CLM (one respondent indicated obtaining 70% to 80% of control). The other three respondents expressed their satisfaction with a pesticide or a pesticide mixture [avermectin (Avid) + oil, permethrin (Ambush) + surfactant (Unifilm), and imidacloprid (Admire and/or Marathon)]. One grower pointed out that timing of application was the most significant factor for managing the CLM, and the same grower separated trees by varieties to obtain better control by spraying trees flushing at the same time.

Concluding remarks

The CLM was the most important pest in Florida citrus nurseries during 1995. Growers were primarily using the monotactic chemical control approach (no other control tactic) to deal with the CLM. However, they are concerned that the CLM will become resistant to pesticides and are willing to consider a multitactic IPM program (more than one control tactic) if one can be developed.

The survey results provided useful information about the constraints and the direction to take in developing a multitactic IPM approach that nursery producers will be willing to use. It was clear that chemical control has to be

Fig. 2. Sources of advice during 1995 for citrus nurseries in Florida. CC = chemical companies, IFAS = Univ. of Florida Institute of Food and Agricultural Sciences personnel, UFG = *Florida Citrus Pest Management Guide* (UF/IFAS), GM = grower's magazines, PC = private consultants, GA = grower's association, OG = other growers, R&D = own research and development department.

considered as a component of citrus tree production. The presence of several pests, the intensive production systems in use, and the diversity of cultivars being grown with various flushing patterns and susceptibility to pests and diseases require the use of pesticides more than once in citrus nurseries.

Nurserymen are concerned about the potential development of pesticide resistance by the CLM, which opens the possibility for the future use of integrated tactics that might delay resistance development (such as an effective natural enemy being present in the system). Assuming that natural enemies such as *A. citricola* can help to sustain growth and maintain a fair tree appearance, biological control could be enhanced in citrus nurseries if compatibility with pesticides is ensured. The selectivity of pesticides to *A. citricola* and other natural enemies needs to be investigated, as well as the effect of monitoring the pest and its natural enemies before applying any pesticide. Also, establishment of refugia for natural enemies in nursery production systems might be evaluated.

Commercial citrus tree production from our Florida sample was dominated by a relatively small number of large nursery growers (about six) who produced ≈88% of the trees needed for replanting diseased or dead trees. 'Swingle' citrumelo and 'Carrizo' citrange are the most important rootstocks, and are considered tolerant of citrus tristeza virus (CTV), as are 'Cleopatra' mandarin, rough lemon, 'Volkamer' lemon, 'Milam' lemon, trifoliolate orange, 'Rusk' citrange, 'Sun Chu Sha' mandarin, grapefruit, sweet orange, and 'C-35' rootstocks. It is unknown whether plant resistance or tolerance can play a role in an IPM program for the CLM. No CLM-resistant citrus cultivar has been found yet, and no difference in tolerance by cultivars has been documented.

About 1.3% of the plants being produced in 1995 by nurseries surveyed were from CTV-susceptible rootstocks, such as sour orange and Citrus macrophylla. 'Seville' (7.0% of the total citrus tree production surveyed) is planted by growers as a tolerant rootstock, although it has been reported as moderately susceptible to CTV (Castle et al., 1993; Davies and Albrigo, 1994). More information is needed to clarify its

status. With the recent detection and establishment of an efficient vector of CTV, the brown citrus aphid Toxoptera citricida (Kirkaldy), and a virulent strain of CTV (bark pitting strain) in Florida (CAPS and NAPIS, 1996; UF/IFAS, 1995), the trend to produce resistant or tolerant cultivars will continue. Trees in groves showing CTV symptoms will need to be replaced very soon. Management of CTV has to be compatible with any other IPM program in citrus, including managing the CLM. The arrival of other new pests into Florida, as well as agronomic modifications and economic changes, will also modify trends in rootstock and scion production in the years to come.

IPM programs ideally should be designed only after asking growers about their concerns and needs. Early knowledge of limiting factors should help to reduce the cost of extension, and promote the targeting of research to the user (Wearing, 1988). The primary constraint on the development of an IPM program should not be the lack of education of the IPM developers about the perceptions of growers.

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APPENDIX I

1996 Citrus Leafminer Management Survey

Please, answer the following questions. We will report a summary of the results of this survey in the CITRUS NURSERY NEWSLETTER. All replies will be kept **strictly confidential**.

I.- Please circle the number of trees you grew in 1995 in your nursery.

(a) 1-1,000	(d) 100,001-1,000,000
(b) 1,001-10,000	(e) more than 1,000,000
(c) 10,001-100,000	

2.- Please circle the names of the citrus rootstocks and varieties you produced during 1995. Please circle the approximate percentage of each relative to your total production.

ROOTSTOCKS	% of total		% of total
Carrizo orange	1-5, 6-20, 21-50, 51-75, 76-100	Grapefruit	1-5, 6-20, 21-50, 51-75, 76-100
Cleopatra mandarin	1-5, 6-20, 21-50, 51-75, 76-100	Rangpur lime	1-5, 6-20, 21-50, 51-75, 76-100
Palestine sweet lime	1-5, 6-20, 21-50, 51-75, 76-100	Rusk citrange	1-5, 6-20, 21-50, 51-75, 76-100
Rough lemon	1-5, 6-20, 21-50, 51-75, 76-100	Sweet orange	1-5, 6-20, 21-50, 51-75, 76-100
Sour orange	1-5, 6-20, 21-50, 51-75, 76-100	Trifoliate orange	1-5, 6-20, 21-50, 51-75, 76-100
Seville sour orange	1-5, 6-20, 21-50, 51-75, 76-100	Volkamer lemon	1-5, 6-20, 21-50, 51-75, 76-100
Swingle citrumelo	1-5, 6-20, 21-50, 51-75, 76-100	Others: _____	1-5, 6-20, 21-50, 51-75, 76-100
Troyer citrange	1-5, 6-20, 21-50, 51-75, 76-100	Others: _____	1-5, 6-20, 21-50, 51-75, 76-100
<i>Citrus macrophylla</i>	1-5, 6-20, 21-50, 51-75, 76-100	Others: _____	1-5, 6-20, 21-50, 51-75, 76-100

VARIETIES	% of total		% of total
Dancy	1-5, 6-20, 21-50, 51-75, 76-100	Honey/Murcott	1-5, 6-20, 21-50, 51-75, 76-100
Hamlin	1-5, 6-20, 21-50, 51-75, 76-100	Minneola	1-5, 6-20, 21-50, 51-75, 76-100
K-early	1-5, 6-20, 21-50, 51-75, 76-100	Nova	1-5, 6-20, 21-50, 51-75, 76-100
Navel's	1-5, 6-20, 21-50, 51-75, 76-100	Pineapple	1-5, 6-20, 21-50, 51-75, 76-100
Orlando	1-5, 6-20, 21-50, 51-75, 76-100	Satsuma	1-5, 6-20, 21-50, 51-75, 76-100
Robinson	1-5, 6-20, 21-50, 51-75, 76-100	Temple	1-5, 6-20, 21-50, 51-75, 76-100
Sunburst	1-5, 6-20, 21-50, 51-75, 76-100	Others: _____	1-5, 6-20, 21-50, 51-75, 76-100
Valencia	1-5, 6-20, 21-50, 51-75, 76-100	Others: _____	1-5, 6-20, 21-50, 51-75, 76-100
Fallglo	1-5, 6-20, 21-50, 51-75, 76-100	Others: _____	1-5, 6-20, 21-50, 51-75, 76-100

	% of total		% of total
Duncan	1-5, 6-20, 21-50, 51-75, 76-100	Flame	1-5, 6-20, 21-50, 51-75, 76-100
Henderson	1-5, 6-20, 21-50, 51-75, 76-100	Marsh	1-5, 6-20, 21-50, 51-75, 76-100
Ray Ruby	1-5, 6-20, 21-50, 51-75, 76-100	Red Blush	1-5, 6-20, 21-50, 51-75, 76-100
Rio Red	1-5, 6-20, 21-50, 51-75, 76-100	Ruby Red	1-5, 6-20, 21-50, 51-75, 76-100
Star Ruby	1-5, 6-20, 21-50, 51-75, 76-100	Thompson Pink Marsh	1-5, 6-20, 21-50, 51-75, 76-100
Lemons	1-5, 6-20, 21-50, 51-75, 76-100	Tahiti lime	1-5, 6-20, 21-50, 51-75, 76-100
Others _____	1-5, 6-20, 21-50, 51-75, 76-100	Others _____	1-5, 6-20, 21-50, 51-75, 76-100

3.- Do you start from seed (1) or from liners (2)? (Please circle.) How did you produce your trees? How long did it require to get them up to a marketable size? (Please, consider time from seed to finished product and circle the appropriate letter and insert the correct number.)

- (1) I start from seed (2) I start from liners
- (a) in the greenhouse, _____ months
- (b) in the ground, _____ months
- (c) in containers, _____ months
- (d) in the greenhouse (_____ months), and then in the ground (_____ months)
- (e) in the greenhouse (_____ months), and then in containers (_____ months)
- (f) in containers (_____ months), and then in the ground (_____ months)

4.- Among this list of insects and mites, which were the **most important pests requiring chemical control** in your nursery during 1995? Rank them as **Severe (S)**, **Moderate (M)**, or **Light (L)**.

_____ Broad mite	_____ Citrus snow scale	_____ Purple scale
_____ Citrus red mite	_____ Cottony cushion scale	_____ Citrus mealybug
_____ Rust mite	_____ Whitefly	_____ Citrus blackfly
_____ Citrus leafminer	_____ Aphids	_____ Orangedog
_____ Fire ants	_____ Root weevils	_____ Other: _____

5.- What insecticides or acaricides did you apply to control mites or insects **other than the citrus leafminer (CLM)** during 1995? How many times?

For mites:

Agri-Mek (abamectin) _____	Microthiol (micronized sulfur) _____
Carzol (formetanate hydrochloride) _____	Morestan (oxythioquinox) _____
Comite (propargite) _____	Petroleum Oil (FC 435-66) _____
Dicofol (dicofol) _____	Sulfur (sulfur) _____
Ethion (ethion) _____	Thiolux (micronized sulfur) _____
Kelthane (dicofol) _____	Vendex (fenbutatin-oxide) _____

For insects other than CLM:

Biobit, Dipel, Javeline (<i>B. thuringiensis</i>) _____	Metasystox-R (oxydemeton-methyl) _____
Cygon (dimethoate) _____	Nemacur (fenamiphos) _____
Cythion (malathion) _____	Omite (propargite) _____
Dibrom (naled) _____	Petroleum Oil (FC 435-66) _____
Dimethoate (dimethoate) _____	Sevin (carbaryl) _____
Ethion (ethion) _____	Supracide (methidathion) _____
Guthion (azinphos-methyl) _____	Telone (dichloropropene) _____
Lannate (methomyl) _____	Temik (aldicarb) _____
Lorsban (chlorpyrifos) _____	Thiodan (endosulfan) _____
Malathion (malathion) _____	Vydate (oxamyl) _____

6.- Did you spray your nursery trees **for diseases** during 1995? Rank the most important diseases from 1st (most) to 5th (least important.) Circle or add the name of the products applied on the appropriate line.

_____ For Alternaria brown spot: Tri-basic (copper sulfate), _____

_____ Citrus scab: Benlate (benomyl), Copper, Carbamate WDG (ferbam), _____

_____ Greasy spot: Petroleum Oil (FC 435-66), Copper, _____

_____ Root rot/Foot rot: Aliette (fosetyl-al), Ridomil (metalaxyl), Copper _____

_____ Sooty blotch/Sooty mold: _____

7.- Do you consider the citrus leafminer as a **major** or **minor** pest in 1995? (circle one.)

Why? Rank following reasons from most important (**1st**) to least important (**3rd.**)

_____ Reduces growth rate

_____ Increases production costs

_____ Affects the appearance

8.- What pesticides or other methods did you use to manage the citrus leafminer in 1995? Indicate number of applications of each, please.

Non-traditional pesticides (circle those used, please.)

Align (azadirachtin) _____	Neemix (azadirachtin) _____	Azatin (azadirachtin) _____
Proneem (neem oil) _____	Eclipse (fenoxycarb) _____	Agri-Mek (abamectin) _____
Micromite (diflubenzuron) _____	Other: _____, _____	

Other techniques tried/used

Mass trapping	Exclusion by screening	Soaps	Oils
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Other non-traditional methods (please indicate) _____

9.- How much did you spend on citrus leafminer chemical control per tree during 1995?

- (a) \$0.00-0.10 (b) \$0.10-0.20 (c) \$0.21-0.50 (d) \$0.51-1.00 (e) more than \$1.00

10.- How effective do you consider your current CLM control methods? (circle.)

Adequate

Inadequate

11.- Are you concerned about the possibility of developing pesticide resistance in the CLM?

Yes

No

12. If an Integrated Pest Management program for the citrus leafminer were developed for nurseries, would you be willing to:

(a) monitor flush or sticky traps for citrus leafminer (CLM) to decrease the number of pesticide applications?	Yes	No
(b) alter pesticide types used to allow CLM parasites to persist?	Yes	No
(c) leave a few mid-size trees inside your nursery and manage those trees to maintain CLM parasite populations, perhaps by selective sprays or pruning?	Yes	No
(d) grow your seedlings under screening to reduce CLM infestation?	Yes	No
(e) or other intensive management tactics?	Yes	No

13.- Where did you get your advice for pest management during 1995? Please, rank them in order of importance, with 1 the most important. (This will help us deliver our research results to you.)

_____ Grower's Associations

_____ Growers magazines, such as *Citrus Industry*

_____ Private chemical companies

_____ Private Consultants (not affiliated with chemical companies)

_____ Florida Citrus Pest Management Guide (University of Florida/IFAS)

_____ University of Florida/IFAS personnel

_____ Others (please indicate) _____

OPTIONAL

Supplementary information

To guarantee the anonymity of the survey, this page is optional.

Please, send it in the separate envelope supplied. We will not match the survey with your name in any way.

Have you conducted experiments or made consistent observations about improved methods for managing the CLM? (circle)

Yes

No

Are you willing to share this information with us and the Citrus Nursery Association?

Yes

No

Please describe (write on the other side of the page if needed): _____

Are you willing to be interviewed personally? Yes No

Name: _____

Address _____

Phone _____ Fax _____

e-mail address _____

Thank you for your help. If you have questions or comments, please contact:

Dr. Marjorie A. Hoy

or

Juan A. Villanueva-Jiménez

Entomology and Nematology Department

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Please, return the Survey and the Supplementary Information by **March 31st, 1996.**