Effects of Certain Insecticides on *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae) and its Parasitoids on Chrysanthemums in Hawaii[1]

ARNOLD H. HARA[2]

ABSTRACT

Cyromazine and abamectin were the most efficacious insecticides against *Liriomyza trifolii* (Burgess) on potted- and cut-chrysanthemums. Oxamyl, oxamyl plus methomyl (tank-mix), and permethrin plus microencapsulated methyl parathion (tank-mix) were also effective against *L. trifolii.* No adverse effects of tested insecticides to the leafminer parasitoids, *Diglyphus intermedius* (Girault) and *Ganaspidium hunteri* (Crawford) were observed. Results emphasized that permethrin and microencapsulated methyl parathion were effective in a tank-mix, but not when used separately. The ineffectiveness of permethrin or microencapsulated methyl parathion alone may be indicative of *L. trifolii* developing resistance to these insecticides.

The celery leafminer, *Liriomyza trifolii* (Burgess) was first observed in Hawaii in 1978 after chrysanthemum growers failed to achieve economic control of leafminers with common insecticides such as aldicarb and methomyl (Nakahara 1982). *L. trifolii* was probably introduced through infested chrysanthemum cuttings regularly shipped into Hawaii from propagating nurseries throughout Mainland U.S., including California and Florida. Parrella et al. (1981) speculated that *L. trifolii* was first introduced into California in ca. 1975–76 on chrysanthemum cuttings from Florida. Spencer (1981) stated that *L. trifolii* was introduced into numerous nurseries in England, France, and Netherlands in 1977 from a propagating nursery in Kenya that was regularly supplied with plants from Florida.

Oxamyl, permethrin, and microencapsulated methyl parathion have been used for *L. trifolii* control on chrysanthemums in Hawaii since 1978. However, some chrysanthemum growers have been dissatisfied with leafminer control with presently recommended insecticides.

The purpose of this study was to field evaluate presently registered and experimental insecticides for *L. trifolii* control and to quantify the nontarget effects of these treatments on the leafminer parasitoids, *Diglyphus intermedius* (Girault) and *Ganaspidium hunteri* (Crawford). *G. hunteri* is a new combination by Beardsley (1985).

MATERIALS AND METHODS

Experiments were conducted at a potted-chrysanthemum nursery in Hilo, Hawaii (122 m elev.) and a cut-chrysanthemum nursery in Mountain View, Hawaii (671 m elev.). The following insecticides were tested at the following rates (g of AI/100 liters of water): abamectin 0.15EC (avermectin B_1, MK–936, Avid®) at 0.6, 1.2, and 2.4 g, cyromazine 75WP (CGA 72662, Trigard®) at 15.0 and 30.0 g, methomyl 1.8L (Lannate® L) at 54.0 g, microencapsulated methyl parathion 2.0F (Penncap-M®) at 60.0 g, oxamyl 2.0L (Vydate® L) at 120.0 g, and permethrin 3.2 EC (Pounce®) at 24.0 g. Oxamyl 10G was tested at 0.9g/m^2. Abamectin, a fermentation product derived from a soil microorganism of the genus *Streptomyces*, is being developed by

[1]Jounal Series No. 2926, the Hawaii Institute of Tropical Agriculture and Human Resources.
[2]Beaumont Agricultural Research Center, University of Hawaii, 461 West Lanikaula St., Hilo, Hawaii 96720.

Merck Sharp and Dohme Research Laboratories. Cyromazine is an experimental insect growth regulator manufactured by Ciba-Geigy. A spreader-sticker, Triton B-1956 (Rohm and Haas, Philadelphia, PA) (23 ml/100 liters solution) was added to all spray treatments except for microencapsulated methyl parathion.

Identification of leafminers and their parasitoids were confirmed by Dr. John W. Beardsley, at the Department of Entomology, University of Hawaii.

Potted-Chrysanthemums: Rooted cuttings of the 'Luv' cultivar were obtained from Yoder Brothers, Inc. (Barberton, Ohio) and potted on May 13, 1983, in 12.7 cm diam. plastic pots containing 3 parts peat: 1 part vermiculite: 1 part perlite. Plants were kept in a lighted greenhouse (long day conditions) for 7 days and then placed in an unshaded fiberglass greenhouse under normal daylight conditions. Plants were fertilized according to the grower's standard practices. Plant terminals were soft-pinched 17 days after planting and lateral buds removed 5 weeks after planting. Seven weekly spray applications began on May 23, 10 days after planting, and continued to July 5. Three applications of the granular insecticide, Oxamyl 10G, were made at 2 week intervals. Insecticides were applied to runoff with a compressed CO_2 sprayer equipped with a No. 5500 adjustable ConeJet® nozzle (Spraying Systems Co., Wheaton, Ill.). Each insecticide was applied to 10 potted-plants arranged in a randomized complete block design with 2 blocks and 10 treatments (Table 1).

Three weeks after planting when leaves extend over pots, leafminer infestation was monitored by a modified technique of Johnson et al. (1980). Circular plastic collars were installed above the water drainage holes of the pots to trap prepupal larvae emerging from the foliage. Collars were made from 23 cm diam. plastic dinner plates with a 10.2 cm diam. hole cut in the center. Leafminer pupae were collected from each plate at weekly intervals, placed in a plastic 10 dram vial, and held in the laboratory for leafminer emergence.

Leafminer parasitoids were monitored by sampling two leaves with mines from each potted-plant on May 31, June 13, June 28, and July 11. Leaf samples were held in the laboratory for one month in 3.8 liter glass jar with an organdy cover and observed for parasitoid emergence. Eight weeks after planting on July 11 (full bloom), completed leafmines on the youngest 4 leaves on each of 11 lateral stems were recorded on each potted-chrysanthemum. Completed leafmines were defined as those mines with exit larval holes.

Cut-Chrysanthemums: The experiment was conducted in one section of a polyethylene greenhouse (9.1 m × 30.5 m) with open sides. Rooted cuttings of the 'Blue Chip' cultivar were obtained from Yoder Brothers, Inc. and planted into 1.0 m × 3.1 m treatment plots with 70 plants per plot and 7 plots per row on June 17, 1983. A 1.0 m × 1.0 m buffer zone with no plantings was provided between treatment plots and a 0.6 m wide walkway between rows. The experiment was arranged in a randomized complete block design with 5 blocks (rows) and 7 treatments (Table 2). Ten days after planting, plants were soft-pinched and 18 days later pruned to 3 lateral stems per plant. Two weeks before harvest, the terminal bud of each stem was removed. Plants received the grower's standard fertilization and watering procedures. Insecticides were applied with a compressed CO_2 sprayer which delivered 757 liters water per acre and was equipped with a No. 8004 Teejet® nozzle. Eleven weekly spray applications began on July 1, 1983, 2 weeks after planting and ended on Sept. 9, 7 days before harvest (Sept. 16).

Two youngest leaves with developing mines from each of 10 plants were randomly sampled from each treatment plot (20 leaves per plot) on July 12, July 26, Aug. 9, Aug. 23, and Sept. 6. Leaf samples were held in the laboratory for one month in 3.8 liter glass jars with an organdy cover and observed for leafminer and parasitoid adult emergence. At harvest, the number of completed leafmines on all leaves of 50 single-stem chrysanthemums per treatment plot were counted to evaluate for leafminer damage.

Data Analysis: Data were transformed to log (x+1) prior to analysis of variance (P<0.05).

RESULTS

Potted-Chrysanthemums: Cyromazine and abamectin were the most efficacious insecticides for *L. trifolii* control based on the number of adults emerging from pupae collected in pupal plates (Table 1) and on number of completed leafmines (Table 1). Oxamyl, oxamyl plus methomyl (tank-mix) and permethrin plus microencapsulated methyl parathion (tank-mix) were also effective against *L. trifolii* with significantly less completed leafmines than on control plants. Permethrin and microencapsulated methyl parathion alone, and Oxamyl 10G were ineffective against *L. trifolii* at the tested rates.

Leafminer parasitoids were not recovered from any leaf samples taken periodically throughout the duration of the experiment.

Cut-Chrysanthemums: Cyromazine and abamectin treatments had the least number of completed leafmines followed by permethrin plus microencapsulated methyl parathion, and oxamyl treatments as in the potted-chrysanthemum trial (Table 2). No significant difference was observed in the number of completed leafmines between methomyl and control treatments, however, effective *L. trifolii* control was achieved when methomyl was tank-mixed with oxamyl.

TABLE 1. Effect of insecticide treatments on the number of *L. trifolii* adults emerging from pupae collected in pupal plates placed under each 'Luv' potted-chrysanthemum and on the number of leaves with completed leafmine at full bloom, 8 weeks after planting.

Treatment[a] (g AI/100 liters)	Adults after the following weeks[b]: 4	5	6	7	8	Lvs/plt w/mines[c]
Cyromazine 75WP (15.0)	0.0a	0.0a	0.0a	0.0a	0.0a	0.1a
Abamectin 0.15EC (0.6)	0.0a	0.6a	0.1a	0.0a	0.0a	0.0a
Abamectin 0.15EC (2.4)	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a
Oxamyl 2.0L (120.0)	0.0a	0.5a	0.6a	0.2a	0.1a	3.2b
Oxamyl 2.0L (120.0) + Methomyl 1.8L (54.0)	0.2a	0.7a	0.7a	0.2a	0.1a	4.2b
Methyl parathion 2.0F (60.0) + Permethrin 3.2EC (24.0)	0.9b	0.5a	0.7a	0.1a	0.0a	4.2b
Permethrin 3.2EC (24.0)	2.3c	2.6b	4.0b	0.4ab	1.3b	6.8bc
Methyl parathion[d] 2.0F (60.0)	2.1bc	4.0bc	3.3b	1.0b	0.9b	12.8d
Oxamyl 10G (8.0g/m^2)	1.9bc	2.8b	4.6b	1.6b	1.2b	10.5cd
Control	3.2c	6.1c	2.4b	3.2c	0.8b	7.7cd

[a]Total of 7 weekly spray applications, except for Oxamyl 10G with a total of 3 applications. Each treatment consisted of 10 potted-plants.
[b]Weeks after planting.
[c]Four youngest leaves on each of 11 lateral stems per potted-plant were observed for completed mines. Data transformed to log (x+1) before analysis. Means followed by different letters in a column are significantly different (P<0.05) by Duncan's Multiple Range Test.
[d]Microencapsulated.

TABLE 2. Effect of insecticide treatment on the number of completed leafmines of *L. trifolii* on 'Blue Chip' cut-chrysanthemum leaves at harvest.

Treatment[a]	Application rate (g AI/100 liters)	No. of completed leafmines/50 stems[b]
Cyromazine 75WP	30.0	0.9a
Abamectin 0.15 EC	1.2	0.4a
Methyl parathion[c] 2.0F + Permethrin 3.2EC	60.0 24.0	8.7b
Oxamyl 2.0L + Methomyl 1.8L	120.0 54.0	18.0c
Oxamyl 2.0L	120.0	22.2c
Methomyl 1.8L	54.0	137.7d
Control	-	192.2d

[a]Total of 11 weekly spray applications.
[b]Mean of 5 plots with 50 stems sampled per plot. Stems consisted of 10-12 leaves per stem. Data transformed to log (x+1) before analysis. Means followed by different letters are significantly different ($P<0.05$) by Duncan's Multiple Range Test.
[c]Microencapsulated.

Leaf samples taken on July 12, Aug. 23, and Sept. 6 showed significantly fewer leafminer adults emerging from the cyromazine, abamectin, microencapsulated methyl parathion plus permethrin, and oxamyl treatments as compared to the methomyl and control treatments (Table 3). The oxamyl plus methomyl treatment significantly reduced leafminer emergence on July 12 and Aug. 23 but did not differ from the methomyl and control treatments on Sept. 6. The highest number of leafminers and parasitoids were recovered on July 12 and declined thereafter. On July 12, *D. intermedius* emergence from the cyromazine, abamectin, oxamyl, methomyl, or control treatments were not significantly different. However, more *G. hunteri* were recovered from the methomyl and control treatments as compared to the other treatments (Table 3). On July 26 and thereafter, more *D. intermedius* and *G. hunteri* were recovered in the control and methomyl treatments than the other treatments. *D. intermedius* accounted for 75% of the recovered parasitoid species followed by *G. hunteri* with 24% of the recovered parasitoid species. *Diglyphus begini* (Ashmead) and *Diglyphus isaea* (Walker) accounted for the other 1% of the recovered parasitoid species.

Phytotoxic symptoms were observed with some of these tested insecticides. Methomyl 1.8L and oxamyl 2.0L caused slight marginal yellowing and necrosis on the 'Blue Chip' and 'Luv' cultivars. Cyromazine 75WP at 30.0 g of AI/100 liters of water caused moderate stunting and bronzing of the flower petioles on the 'Blue Chip' and 'Luv' cultivars.

DISCUSSION

Cyromazine and abamectin were the most efficacious insecticides for *L. trifolii* control on potted- and cut-chrysanthemums. This was probably due to their toxic action on the immature stages (Brown and Dybas 1982; Parrella et al. 1982) and to the lack of resistance to these newly developed insecticides. Cyromazine and abamectin appear to be compatible with the leafminer parasitoid, *D. intermedius* as indicated by recovery of numerous adult parasitoids and minimal leafminer adults in treated

TABLE 3. Effect of insecticide treatments on the emergence of *L. trifolii* adults and the parasitoid adults, *D. intermedius*, and *G. hunteri* from 'Blue Chip' cut-chrysanthemum leaves.

Treatment[a]	Adults emerging on the following sampling dates[b]:				
	Jul. 12	Jul. 26	Aug. 9	Aug. 23	Sep. 6
			L. trifolii adults		
Cyromazine 75WP	0.0a	0.0a	0.0a	0.0a	0.0a
Abamectin 0.15 EC	0.4a	0.2a	0.0a	0.0a	0.0a
Methyl parathion[c] 2.0F + Permethrin 3.2 EC	4.4b	0.4a	0.0a	1.1b	0.0a
Oxamyl 2.0L + Methomyl 1.8L	6.2b	0.0a	0.4a	1.8b	2.2b
Oxamyl 2.0L	5.9b	0.3a	0.0a	0.3a	0.7a
Methomyl 1.8L	17.2c	1.6a	0.0a	3.6c	2.5b
Control	16.4c	2.0a	1.1b	5.6c	4.1b
			D. intermedius adults		
Cyromazine 75WP	14.8c	0.3a	0.0a	0.0a	0.0a
Abamectin 0.15EC	11.9bc	1.1ab	0.0a	0.0a	0.0a
Methyl parathion[c] 2.0F + Permethrin 3.2 EC	2.0a	0.7ab	0.0a	0.2a	0.0a
Oxamyl 2.0L + Methomyl 1.8L	3.9ab	0.4a	0.9a	1.1ab	0.2a
Oxamyl 2.0L	9.5bc	3.3bc	0.3a	0.7a	0.4a
Methomyl 1.8L	9.7bc	8.8c	2.7b	2.8bc	1.0a
Control	16.4c	6.1c	6.6c	3.9c	1.2a
			G. hunteri adults		
Cyromazine 75WP	0.0a	0.3a	0.0a	0.0a	0.0a
Abamectin 0.15EC	0.4a	0.2a	0.0a	0.0a	0.0a
Methyl parathion[c] 2.0F + Permethrin 3.2EC	0.4a	0.0a	0.0a	0.2a	0.0a
Oxamyl 2.0L + Methomyl 1.8L	1.8abc	0.7a	0.4ab	0.0a	0.2a
Oxamyl 2.0L	1.1ab	0.7a	0.0a	0.0a	0.4a
Methomyl 1.8L	7.3c	1.5a	1.1b	0.0a	0.8a
Control	3.8bc	1.1a	0.2a	0.2a	1.7a

[a]See Table 2 for application rates. Total of 11 spray applications.
[b]Mean number of adults emerging from 20 leaves per treatment plot per sampling date. Data transformed to log (x+1) before analysis. Means followed by different letters in a column are significantly different ($P<0.05$) by Duncan's Multiple Range Test.
[c]Microencapsulated.

plants in earlier sampling dates. Populations of *D. intermedius* and *G. hunteri* were significantly lower at later sampling dates due to the absence of leafminers in the cyromazine and abamectin treatments. Parrella et al. (1983) also demonstrated the compatibility of cyromazine and the parasitoid species, *Chrysocharis parski* (Crawford) in California.

Methomyl is able to induce leafminer outbreaks due in part to its adverse effects on leafminer parasitoids and its ineffectiveness against leafminers (Oatman and Kennedy 1976). In this study, the inability of methomyl to control *L. trifolii* was confirmed. However, the adverse effects of methomyl to *D. intermedius* and *G. hunteri* were not observed. Parasitoid and leafminer recoveries were similar in both methomyl and control treatments. Similar results were obtained by Johnson (1984) on onion in Hawaii. When methomyl was tank-mixed with oxamyl, effective control of *L. trifolii* was achieved indicating oxamyl may be able to prevent leafminer outbreaks associated with the use of methomyl.

Microencapsulated methyl parathion and permethrin alone, were not effective against *L. trifolii*. This was probably due to restricted toxicity of these insecticides to mainly adult leafminers and to insecticide resistance resulting from using these insecticides for several years in Hawaii. Keil and Parrella (1982) documented a 30-fold resistance to permethrin by *L. trifolii* in a commercial California chrysanthemum greenhouse. Parrella (1983) speculated that because most chrysanthemum growers apply permethrin at ca. 7-day intervals to this year-round crop, resistance to this insecticide may be more widespread. Similarly, within the next few years, Hawaii will probably experience more widespread resistance to registered insecticides against *L. trifolii*.

Based on past experiences in Florida and California, a 'crisis' resulting from *L. trifolii* developing resistance to all registered insecticides is a possibility in Hawaii. Insecticide resistance management should be implemented prior to this development. Populations of *L. trifolii* should be continuously monitored for insecticide susceptibility and a pest management program developed for *L. trifolii* and other arthropod pests on chrysanthemums.

ACKNOWLEDGMENTS

I gratefully acknowledge H. Eunice Nursery Inc. and Mauna Loa Farms Inc. for their cooperation; Shinsuke Matayoshi, Angel Magno, and Brian C. Bushe for assistance in collecting biological data; Marshall W. Johnson, Ronald F.L. Mau, and Mike A. Nagao for critically reviewing this manuscript; and the Governor's Agriculture Coordinating Committee of the State of Hawaii for financial support.

REFERENCES CITED

Beardsley, J.W. 1986. The taxonomy of eucoilid parasitoids of agromyzid leafminers in Hawaii (Hymenoptera: Cynipoidea). Proc. Hawaii. Entomol. Soc. 26:31, 35.

Brown, R.D. and R.A. Dybas. 1982. MK-936: A novel miticide/insecticide for control of *Liriomyza* leafminers. pp. 59–61. *In* S.L. Poe (ed.), Proc. 3rd Annu. Ind. Conf. Leafminer, San Diego, Ca., Soc. Am. Flor., 216 pp.

Johnson, M.W. 1984. *Liriomyza* species associated with onions on Maui, Hawaii. pp. 97–107. *In* S.L. Poe (ed.), Proc. 4th Annu. Ind. Conf. Leafminer, Sarasota, Fl., Soc. Am. Flor., 191 pp.

Johnson, M.W., E.R. Oatman, J.A. Wyman, and R.A. Van Steenwyk. 1980. A technique for monitoring *Liriomyza sativae* in fresh market tomatoes. J. Econ. Entomol. 73:553–555.

Keil, C.B. and M.P. Parrella. 1982. Managing insecticide resistant leafminers on chrysanthemum and celery. pp. 162–167. *In* S.L. Poe (ed), Proc. 3rd Annu. Ind. Conf. Leafminer, San Diego, Ca., Soc. Am. Flor., 216 pp.

Nakahara, L.M. 1982. Notes and Exhibitions. Proc. Hawaii. Entomol. Soc. 24:8.

Oatman, E.R. and G.G. Kennedy. 1976. Methomyl induced outbreak of *Liriomyza sativae* on tomato. J. Econ. Entomol. 69:667–668.

Parrella, M.P. 1983. Evaluations of selected insecticides for control of permethrin-resistant *Liriomyza trifolii* (Diptera: Agromyzidae) on chrysanthemum. J. Econ. Entomol. 76:1460–1464.

Parrella, M.P., W.W. Allen, and P. Morishita. 1981. Leafminer species causes California mum growers new problem. California Agriculture 35(9 and 10):28–30.

Parrella, M.P., K.L. Robb, G.D. Christie and J.A. Bethke. 1982. Control of *Liriomyza trifolii* with biological agents and insect growth regulators. California Agriculture 36(11 and 12):17–19.

Parrella, M.P. G.D. Christie, and K.L. Robb. 1983. Compatibility of insect growth regulators and *Chrysocharis parski* (Hymenoptera: Eulophidae) for control of *Liriomyza trifolii* (Diptera: Agromyzidae). J. Econ. Entomol. 76:949–951.

Spencer, K.A. 1981. A revisionary study of the leafmining flies (Agromyzidae) of California. Division of Agricultural Sciences, Univ. of Calif., Special Publication 3273, 489 pp.