IMPACT OF METHAMIDOPHOS AND METHOMYL ON POPULATIONS OF *LIRIOMYZA* SPECIES (DIPTERA: AGROMYZIDAE) AND ASSOCIATED PARASITES IN CELERY

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Abstract

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Methamidophos proved more suitable than methomyl for incorporation in an integrated pest management program for celery. Methomyl applications resulted in increased leaf mining and greater emergence of *Liriomyza* species leafminers. Methomyl use also increased adult parasite mortality, and significantly reduced the rate of parasitism by approximately 50% as compared to methamidophos or control treatments. Species composition of parasites was influenced by pesticide treatments; the *Diglyphus* species, *Chrysocharis* species and *Halticoptera circulus* (Walk.) demonstrated tolerance, but *Chrysonotomyia punctiventris* (Crawford) was intolerant.

Résumé

Le metamidophos est apparu plus convenable que le methomyl pour utilisation dans un programme de lutte intégrée en culture de céleri. Des traitements au methomyl ont augmenté le minage par les mineuses du genre *Liriomyza*, ainsi que leur émergence. Le methomyl a aussi augmenté la mortalité des parasites adultes et significativement réduit l'incidence de parasitismė d'environ 50 pourcent comparativement au traitement témoin et au metamidophos. La composition spécifique des parasites a été affectée par les traitements pesticides: des espèces des genres *Diglyphus* et *Chrysocharis* ainsi que *Halicoptera circulus* (Walk.) se sont montrés tolérantes, mais *Chrysonotomyia punctiventris* (Crawford) était intolérante.

Introduction

Many of the polyphagous agromyzids in the genus *Liriomyza* Mik have become serious pests of commercially grown vegetables and ornamentals in North America (Spencer 1973; Spencer and Stegmaier 1973). The potential for development of resistance by *L. trifolii* (Burgess) (Keil and Parrella 1983; Leibee 1981), and the capability for rapid population growth and host destruction shown by *L. sativae* Blanchard and *L. trifolii*, have led to numerous studies reporting observations on the biology and control of these and related species (Parrella, in press).

Much of the recent interest in *Liriomyza* species infesting vegetables has focused on use of integrated pest management (IPM) techniques which utilize biological control agents. The impact of permethrin (Poe *et al.* 1978), methomyl (Johnson *et al.* 1980*a*), oxamyl (Schuster *et al.* 1979), and several other pesticides (Pohronezny *et al.* 1978; Shorey and Hall 1963) on the population ecology of parasites of *L. sativae* infesting tomatoes has been investigated. With the exception of oxamyl, use of these pesticides caused reductions in parasite density. Unfortunately, oxamyl was not proven effective against *L. trifolii* in California. Insecticides suitable for incorporation into IPM programs for leafminer suppression on lettuce (Hills and Taylor 1951), peppers, peas and cantaloupe (Getzin 1960; Wene 1955) and artichokes (Lange *et al.* 1980) have also been reported, but the effects of methomyl and methamidophos on parasites of *L. trifolii* infesting celery have not been documented.

The introduction of *L. trifolii* into California has resulted in serious economic losses for the celery producing industry (Trumble and Nakakihara, in press). Therefore, the study reported here was conducted to determine the impact of pesticides used commercially in California for insect control in celery on the population growth of leafminers and their associated parasites.

Materials and Methods

Leafminer experiments were conducted in two fall plantings of celery (variety 52-70R) during 1981 and 1982 at the University of California's South Coast Field Station in Orange County, California. This field station is located within one of the major celery producing areas in California. Both crops were transplanted 18 cm apart on double-row beds with 100-cm centers, sprinkle irrigated for 2 to 3 weeks, then drip or furrow irrigated thereafter. The 1981 planting was transplanted by hand on 4 August and harvested the second and third weeks of November. In 1982, the celery planting was transplanted by machine on 5 August and harvested on 16 November.

A randomized block design incorporated 4 replicates of each treatment. Each replicate was 3 beds wide by 15 m long and separated from other treatments by 2 m of untreated celery. Weekly samples of two trifoliolates (uppermost and lowermost mined leaves) per plant from each of four randomly selected plants per replicate were sealed in plastic containers and transported to the laboratory. Each leaf was examined under a dissecting microscope equipped with substage lighting for numbers of live larvae, dead larvae, parasitized larvae, and empty mines. Following examination, leaf samples were replaced in plastic containers and stored at room temperature (22°–26°C). After 4 weeks, all emergent insects were identified and recorded.

When plants reached a suitable height (ca. 25 cm), four pupal trays (10×20 cm) were inserted between the two rows of celery plants in the center bed of each replicate. Numbers of larvae, prepupae, pupae, and dead parasites collected in the trays were recorded weekly from 28 October to 18 November in 1981, and on 27 October and 3 November, 1982. Fewer samples were available during November 1982 as rain interfered with collection by washing some insects from the trays.

At harvest, five randomly selected plants per replicate were transported to the laboratory. Each plant was examined and the number of mined leaves per plant recorded.

Methomyl (1.0 kg ai/ha) and methamidophos (1.1 kg ai/ha), the two insecticides used most frequently for celery pest control in California, were applied using a tractor-mounted boom sprayer. As plant height and foliage density increased, nozzles varied from 1 to 3 per row and carrier (H_2O) increased from 467 to 935 L/ha. Hollow cone nozzles incorporated D_3 orifice disks, #25 cores, and 50-mesh screens. All treatments included 0.04% spreader-sticker (Leaf Act 40®). In 1981 and 1982, each planting received 13 and 11 weekly applications, respectively.

Results and Discussion

Leafminer populations (98% *L. trifolii*, 2% *L. sativae*) and host plant damage were significantly affected by pesticide applications (Table I). In 1981, more dead larvae and fewer empty mines per sample were found in the methamidophos treatments. However, this trend was not repeated in 1982, when leafminer density was lower. No significant differences were observed between methomyl and untreated control plots for these variables in 1981, but controls had fewer empty mines/leaf sample in 1982: more mines containing dead and parasitized larvae/sample may account for this difference. Host plant damage, as indexed by the number of mined leaves/plant at harvest, was lowest in the methamidophos treatment, intermediate in the control, and greatest in the methomyl plots. The significant increases in leaf damage apparent in the methomyl treatment was similar to that reported by Oatman and Kennedy (1976) for *L. sativae* infesting fresh market tomatoes.

Analogous results were found when pupal trays were utilized to document the emergence of *Liriomyza* species larvae from celery. On each sampling date in both years,

Table I. Impact of selected pesticides on populations of *Liriomyza* species in fall plantings of celery in Orange County, California

Treatment	Rate (kg/ha)	1981 $\bar{x}$ no. dead larvae per sample[a]	1981 $\bar{x}$ no. empty mines/sample	1981 $\bar{x}$ no. mined leaves/plant[b]	1982 $\bar{x}$ no. dead larvae per sample	1982 $\bar{x}$ no. empty mines/sample	1982 $\bar{x}$ no. mined leaves/plant
Control	–	2.4b	1.55a	85.7b	2.1b	0.16b	77.3b
Methomyl	1.0	2.5b	1.76a	127.7a	1.8b	0.34a	90.9a
Methamidophos	1.1	3.4a	0.52b	29.2c	2.1b	0.31a	20.9c

[a]Sample: 2 trifoliolates/plant, 16 plants/treatment/week for 11 weeks of sampling; means in columns followed by the same letter are not significantly different at the $P \leqslant 0.05$ level, DMRT.
[b]Mean of five randomly selected plants/replicate at harvest.

Table II. Impact of selected pesticides on parasitism of *Liriomyza* species infesting fall plantings of celery in Orange County, California

Treatment	1981 $\bar{x}$ no. live larvae per sample[a]	1981 $\bar{x}$ no. parasitized larvae/sample	1981 $\bar{x}$ percent parasitism[b]	1982 $\bar{x}$ no. live larvae per sample	1982 $\bar{x}$ no. parasitized larvae/sample	1982 $\bar{x}$ percent parasitism[b]
Control	1.5b	1.27a	45.2a	1.2b	0.21a	14.9b
Methomyl	2.8a	0.94b	25.0b	1.7a	0.15a	8.1c
Methamidophos	0.6c	0.46c	43.9a	0.8c	0.22a	21.6a

[a]See footnote *a*, Table I.
[b]Arcsine transformation prior to analysis.

significantly ($P \leq 0.05$, DMRT) more larvae or pupae/replicate were recorded from methomyl plots (ranges = 1981, 13.9–7.9; 1982, 5.5–1.9) than the other treatments. No significant differences were apparent between control (ranges = 1981, 0.4–0.1; 1982, 0.9–0.8) and methamidophos (ranges = 1981, 0.1–0.6; 1982, 0.2 only) treatments with the exception of 27 October 1982, when fewer larvae emerged from the methamidophos replicates.

In order to determine if pesticide impact on parasites was responsible for differences observed in our celery plantings, the seasonal percent parasitism was calculated by dividing the numbers of parasitized larvae/sample by the numbers of live larvae plus parasitized larvae per sample (Table II). Although the dead larvae present in leaf samples may have been killed as a result of feeding by adult parasites, these larvae would produce neither leafminers nor parasites, and were therefore excluded from the calculations of percent parasitism. In both plantings, celery treated with methomyl had a significantly lower rate of parasitism and more live larvae/sample. Thus, application of methomyl encouraged leafminer population growth through suppression of the natural control agents. These results were in agreement with those of previous studies which suggested that *L. sativae* density on tomatoes increased through a reduction in parasite populations (Johnson *et al.* 1980*a*,*b*; Oatman and Kennedy 1976). Low leafminer density found in the methamidophos treatment could be attributed to larval mortality (fewer live larvae/sample) and a rate of parasitism which was not significantly less than that of the untreated controls.

Methomyl applications resulted in significantly ($P \leq 0.05$, DMRT) more parasite mortality than the other treatments on every sampling date. Mortality was lowest in the control plots, and generally intermediate in the methamidophos treatment. Although celery treated with methamidophos only showed significantly more parasite mortality than the control on three of six sampling dates, low numbers of mines and living larvae may have reduced attractiveness of celery in the treated plots, and a greater proportion of the adult parasites in these areas may have been killed. However, results of this study corroborated the information documented in the rearing trial (Table II), and together these tests suggest that methamidophos application did not reduce the potential for biological control.

The species composition of parasites emerging from treated versus control plants indicated that some genera were tolerant of the pesticides tested (Table III). No significant differences in percent dominance were evident between treatments for the two *Diglyphus* species, *D. intermedius* (Girault) and *D. begini* (Ashmead). *Chrysocharis parksi* Crawford and *C. ainsliei* Crawford appeared tolerant, and increased in relative dominance in the

Table III. Species composition of leafminer parasites emerging from celery treated with selected pesticides[a]

Treatment	Percent of total parasites			
	Diglyphus species	*Chrysocharis* species	*Halticoptera circulus*	*Chrysonotomyia punctiventris*
		1981 planting[b]		
Control	75.3a	5.5b	3.0a	13.5a
Methomyl	64.2a	20.7a	2.2a	8.5b
Methamidophos	74.4a	17.0a	2.2a	5.4b
		1982 planting		
Control	63.4a	25.9a	2.0a	7.9a
Methomyl	65.0a	30.2a	2.4a	2.4b
Methamidophos	58.6a	32.2a	5.5a	3.7b

[a]Based on 2 trifoliolate samples/plant, 4 plants sampled/replicate/week for 13 weeks of sampling in 1981, 11 weeks of sampling in 1982; means in columns followed by the same letter are not significantly different at the $P \leq 0.05$ level, arcsine transformation, DMRT.

[b]Percentages in rows may not add up to 100 as unidentifiable parasites were not included in the analysis; *Diglyphus* species include *D. begini* and *D. intermedius*; *Chrysocharis* species include *C. ainsliei* and *C. parksi*.

chemical treatments during both years. *Halticoptera circulus* (Walk.) was similarly unaffected by methomyl or methamidophos, but remained below 6% in both plantings. *Chrysonotomyia punctiventris* (Crawford) proved intolerant of the pesticides. Significant decreases occurred in the chemical treatments during 1981 and 1982. Johnson *et al.* (1980*c*) reported similar results; *C. punctiventris* was more abundant on tomatoes in the absence of methomyl applications.

Based on this research, pesticide selection is of considerable importance in the implementation of an IPM program for celery. Although methamidophos is suitable for an IPM program, use of methomyl for control of lepidopterous larvae in areas where *L. trifolii* is common, or during periods when leafminer density is increasing, can aggravate the leafminer problem and result in economic losses. Although weekly applications of methomyl were deleterious to adult parasites, judicious use may be feasible, since parasites consistently emerged from treated plants. Additional research is necessary to determine if occasional applications will reduce parasite populations to levels where economically important leafminer infestations develop.

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References

Getzin, L. W. 1960. Selective insecticides for vegetable leaf-miner control and parasite survival. *J. econ. Ent.* **53**: 872–875.

Hills, O. A. and E. A. Taylor. 1951. Parasitization of dipterous leaf miners in cantaloups and lettuce in Salt River Valley, Arizona. *J. econ. Ent.* **44**: 759–762.

Johnson, M. W., E. R. Oatman, and J. A. Wyman. 1980*a*. Effects of insecticides on populations of the vegetable leafminer and associated parasites on summer pole tomatoes. *J. econ. Ent.* **73**: 61–66.

——— 1980*b*. Effects of insecticides on populations of the vegetable leafminer and associated parasites on fall pole tomatoes. *J. econ. Ent.* **73**: 67–71.

——— 1980*c*. Natural control of *Liriomyza sativae* [Dip: Agromyzidae] in pole tomatoes in southern California. *Entomophaga* **25**: 193–198.

Keil, G. B. and M. P. Parrella. 1983. *Liriomyza trifolii* on chrysanthemums and celery: managing an insecticide resistant population. *Proc.* Ann. Industry Conf. on the Leafminer, Nov. 8–10, San Diego, Calif. **3**: 162–167.

Lange, W. H., G. G. Agosta, K. S. Goh, and J. S. Kishiyama. 1980. Field effect of insecticides on chrysanthemum leafminer and a primary parasitoid, *Chrysocharis ainsliei* (Crawford), on artichokes in California. *Environ. Ent.* **9**: 561–562.

Leibee, G. L. 1981. Insecticidal control of *Liriomyza* spp. on vegetables. *Proc.* IFAS - Industry Conf. on biology and control of *Liriomyza* leafminers **2**: 216–220.

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

Parrella, M. P. A review of the history and taxonomy of economically important serpentine leafminers in California. *Pan-Pacif. Ent.* (in press).

Poe, S. L., P. H. Everett, D. J. Schuster, and C. A. Musgrave. 1978. Insecticidal effects on *Liriomyza sativae* larvae and their parasites on tomato. *J. Ga ent. Soc.* **13**: 322–324.

Pohronezny, K., V. H. Waddill, W. M. Stall, and W. Dankers. 1978. Integrated control of the vegetable leafminer (*Liriomyza sativae* Blanchard) during the 1977-78 tomato season in Dade County, Florida. *Proc. Fla St. hort. Soc.* **91**: 264–267.

Schuster, D. J., C. A. Musgrave, and J. P. Jones. 1979. Vegetable leafminer and parasite emergence from tomato foliage sprayed with oxamyl. *J. econ. Ent.* **72**: 208–210.

Shorey, H. H. and I. M. Hall. 1963. Toxicity of chemical and microbial insecticides to pest and beneficial insects on poled tomatoes. *J. econ. Ent.* **56**: 813–814.

Spencer, K. A. 1973. Agromyzidae (Diptera) of economic importance. *Series Entomologica* 9. Dr. W. Junk, The Hague. 418 pp.

Spencer, K. A. and C. E. Stegmaier, Jr. 1973. Agromyzidae of Florida with a supplement from the Caribbean. Arthropods of Florida and neighboring land areas. *Fla Dep. Agric. Consumer Services* 7. Gainesville, Fla. 205 pp.

Trumble, J. T. and H. Nakakihara. Occurrence, parasitization and sampling of *Liriomyza* species (Diptera: Agromyzidae) infesting celery in California. *Environ. Ent.* (in press).

Wene, G. P. 1955. Effect of some organic insecticides on the population levels of the serpentine leaf miner and its parasites. *J. econ. Ent.* **48**: 596–597.

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