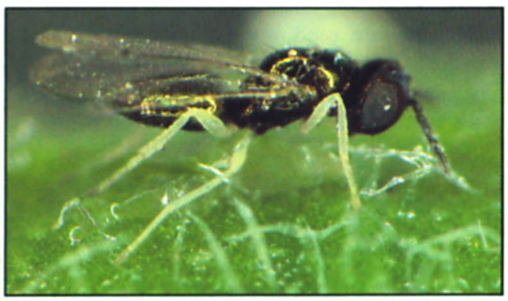
Adult female *L. trifolii.*

Young *Diglyphus* larva feeds on leafminer larva, effectively stopping mine development.



Chrysocharis parksi deposits eggs inside leafminer larva, where parasites will develop.

New parasites will emerge from leafminer pupa parasitized by *Chrysocharis* (left).

Tomato bug, *Cyrtopeltis modestus*, is a leafminer predator but also a secondary tomato pest.

Several natural enemies show promise against hard-to-control leafminer

Control of *Liriomyza trifolii* with biological agents and insect growth regulators

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A leafmining fly, the major pest of chrysanthemums grown for cut flowers and in pots, has proved impossible for growers to control with currently available insecticides, even with applications at three-day intervals. In a search for other methods of pest suppression, we have undertaken studies of potentially effective natural control agents of the serpentine leafminer, *Liriomyza trifolii* (Burgess), and have also evaluated insect growth regulators for their ability to control the larval and pupal stages. These materials are potentially compatible with natural control agents because of their low toxicity and host specificity.

Search for natural enemies

To determine the parasite fauna associated with chrysanthemum greenhouses, we placed mum plants infested with leafminer larvae (about 20 larvae per plant) alongside heavily infested chrysanthemum greenhouses in Orange and San Diego counties during periods of peak fly activity in July and August. After five to seven days of exposure, they were returned to the laboratory, where they were held for emergence of parasites. We found several species of parasites and are conducting biological studies of three of them.

Although our survey of the parasite fauna associated with chrysanthemum greenhouses is incomplete (approximately 17 species of parasites have been reared from *Liriomyza* in western North America), the parasites recovered are considered to be among the most important species parasitizing the leafminer in field-grown tomatoes and celery in California. Under reduced pesticide application programs, these parasites move into chrysanthemum greenhouses to parasitize *L. trifolii*. Following is a brief description of parasites being reared in our greenhouses.

Diglyphus intermedius (Girault) and *Diglyphus begini* (Ashmead). For the purpose of this article, we will discuss the biology of these species together under the format of a generalized life cycle for the genus, although we are studying them individually. *Diglyphus* spp. are characterized by a relatively short development time—egg to adult in about 11 days, compared with about 20 days for the leafminer at 78° F. Adult parasites lay their eggs near leafminer larvae; newly hatched parasite larvae feed externally on the leafminer larvae. This effectively stops larval and mine development and is important when considering that the mere presence of mines on a crop such as mums reduces their aesthetic and, thus, market value.

In addition, females of *Diglyphus* spp. sting and kill more leafminer larvae than their progeny need for development. After stinging a larva, the adult parasite feeds on exudate from the dying larva, a phenomenon known as host feeding and a positive aspect in reducing leafminer populations in the greenhouse. Females generally live three to four weeks and lay approximately 40 eggs.

Chrysocharis parksi (Crawford). This species is a larval-pupal parasite. It deposits its eggs inside the leafminer larva, and parasite development is internal. Parasitized leafminer larvae complete their development and drop to the ground, where pupation occurs. Then, instead of adult leafminers emerging from puparia, parasites emerge. *Chrysocharis* develops (egg to adult) in approximately the same amount of time as the leafminer. These negative aspects of

Chrysocharis (allowing complete mine formation and possessing relatively long development time) may be offset by the ease with which this parasite can be mass-produced for release. Parasitized pupae can be instantly separated from those unparasitized. Like *Diglyphus* spp., *Chrysocharis* females host-feed, killing more hosts than are needed for development of their progeny.

Feasibility of parasite release

Our research is directed toward finding the best parasites for use in an inundative release—that is, using them as a biological insecticide. The low level of mines per plant that are acceptable to growers precludes such releases for long-term suppression of *L. trifolii*. Instead, parasites would be released into mum greenhouses during the initial five to six weeks of crop development. The foliage on plants during this period is not present when the final flowers are cut.

Ideally, the parasites would keep the leafminer population at low levels without application of insecticides. After the sixth week, pesticides would be used, if needed, to protect marketable foliage—preferably, insecticides that are compatible with natural enemy releases.

Other natural agents

In conjunction with Harry Kaya, Associate Nematologist at U.C., Davis, and Carolyn Pickel, Cooperative Extension Area Specialist, we conducted preliminary efficacy trials with a predaceous nematode, *Neoaplectana carpocapsae* (Weiser), for leafminer control. This nematode is effective against several soil-inhabiting insects, and is being sold commercially in northern California as an alternative method of controlling leafminers in chrysanthemums. The nematode is applied as a soil drench and may attack leafminers in two ways: after mature larvae drop to the soil before pupation, and as adults emerge from the puparia. Preliminary screening trials with *N. carpocapsae* at 9 to 400 per square centimeter of soil surface did not provide consistent results. Further evaluations are planned.

Biological studies also are being conducted with the tomato bug, *Cyrtopeltis modestus* (Distant), a mirid predator of leafminer larvae and other insects. This insect is commonly found in tomato fields in southern California, where it is considered a secondary pest, primarily feeding on the stems. However, the tomato bug does not feed on chrysanthemum. Later stages and adults readily pierce leafminer larvae within the mesophyll of a chrysanthemum or tomato leaf. The bug quickly immobilizes the larva, sucking out its contents. In addition, the tomato bug attacks late third stage larvae that have emerged from the leaf before dropping to the ground to pupate.

There are still large data gaps, however, that need to be filled before the tomato bug could be considered for biological control of leafminer larvae. In addition, the possible movement of the bug from chrysanthemum to tomato may limit the areas where it can be used.

Insect growth regulators

Six insect growth regulators (IGRs) were evaluated for control of the larval and pupal stages of the leafminer—CGA 77622 (mode of action is unknown, but believed to be hormonal), methoprene, RO 13-5223E, RO 13-5223W (juvenile hormone mimics), Bay SIR 8514, and dimilin (chitin inhibitors). All these materials are characterized as nontoxic to mammals and relatively specific to the target pest; they show little or no effect on nontarget organisms.

Standard chrysanthemum plants (three-leaved, 30 days old) of the variety 'White Hurricane' were exposed to large colonies of leafminers for one hour, so that all oviposition, subsequent egg hatch, and larval development in all plants would be synchronous. IGRs were applied as foliar sprays to runoff with a 1-gallon sprayer at 60 psi. A sticker-spreader, B-1956, was added to each material at 1 milliliter per gallon. IGRs, except methoprene, were applied to plants containing newly hatched larvae. All IGRs, including methoprene, were also applied to plants containing third stage (mature) larvae. There were 10 plants for each larval age class for each treatment.

After IGR application to newly hatched larvae, plants were placed on greenhouse benches where larval development continued. When larvae were about ready to emerge, leaves were removed and placed on a thin layer of sand in small glass containers, which were held in an environmental chamber at 26.7° C, to 50 to 60 percent relative humidity, and 14.5-hour photophase. Pupating larvae were sifted out and placed in ventilated containers on moist sand under the same conditions. These were checked daily for emergence of adults. After IGRs were applied to plants that contained third stage larvae, leaves were removed and handled in the same way.

In addition, methoprene was evaluated as a soil drench in 5-inch pots filled with moist soil. The rate used was equivalent to 2.5 ounces of formulated material per 100 gallons per 1,000 square feet. Five pots were treated with methoprene, and five (controls) with

TABLE 1. Effect of selected insect growth regulators on newly hatched larvae of *Liriomyza trifolii* (Burgess)

			Posttreatment count‡			
Material	Rate*	Total larval pretreatment count†	Total emerging larvae /10 plants	Mean percent control	Total emerging adults /10 plants	Mean percent control
	lb			%		%
CGA 77622 5SC	0.5	181	0	100.0a	...	...
RO 13-5223 1E	0.8	174	141	19.5b	41	74.0a
RO 13-5223 50W	0.8	108	84	26.0b	68	40.8b
BAY SIR 8514 0.5E	0.5	178	115	29.7b	99	41.2b
Control	...	171	150	11.3b	120	22.3b
Dimilin 25W	0.5	217	187	20.9b	164	34.3b

*Pounds active ingredient per 100 gallons water.
†10 plants per test material with mean ± SE = 17.2 ± 1.4 larvae per plant.
‡Mean percent control was calculated with individual plants as replicates. Means followed by the same letter are not significantly different ($p>0.05$), Duncan's new multiple range test. No data transformation was necessary.

TABLE 2. Effect of selected insect growth regulators on late third-stage larvae of *Liriomyza trifolii* (Burgess)

			Posttreatment count‡			
Material	Rate*	Total larval pretreatment count†	Total emerging larvae /10 plants	Mean percent control	Total emerging adults /10 plants	Mean percent control
	lb			%		%
CGA 77622 5SC	0.5	192	0	100.0a	...	...
RO 13-5223 1E	0.8	222	216	3.5c	13	94.2a
Methoprene 5E	4.0	212	176	17.4b	17	92.1a
RO 13-5223 50W	0.8	171	156	11.9bc	68	63.7b
BAY SIR 8514 0.5E	0.5	218	208	3.7c	170	19.5c
Control		157	144	9.1c	129	18.6c
Dimilin 25W	0.5	247	231	9.6c	217	13.5c

*Pounds active ingredient per 100 gallons water.
†10 plants per test material with mean ± SE = 20.3 ± 1.2 larvae per plant.
‡Mean percent control was calculated with individual plants as replicates. Means followed by the same letter are not significantly different ($p>0.05$), Duncan's new multiple range test. No data transformation was necessary.

water. After treatment, 20 mature larvae, which had just emerged from chrysanthemum leaves to pupate, were added to the soil in each of the 10 pots. Each pot was capped with a ventilated cage and checked daily for adult emergence. Water was added to the soil whenever necessary to maintain a consistent level of moisture. All pots were kept in an environmental chamber as in other treatments.

CGA 77622 was the only IGR to provide 100 percent control of newly hatched and mature larvae; all larvae were killed while still within the leaf. However, some materials provided significant control of emerging adults. These IGRs generally provided better control when applied to leaves containing mature larvae rather than to those containing newly hatched larvae; RO 13-5223E and methoprene provided greater than 90 percent control of adult emergence. As a soil drench application, methoprene provided only 31 percent control of emerging adults, which was not significantly different ($p>0.05$, T test) from the control (19 percent).

Those IGRs that provided the best control (CGA-77622, RO 13-5223E, and methoprene) are currently being evaluated for phytotoxicity to chrysanthemums and for compatibility with selected natural enemies of the leafminer.

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