Biological control of leafminers in greenhouse chrysanthemums

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A parasitic wasp controlled L. trifolii, *reducing need for insecticides*

The leafminer, *Liriomyza trifolii* (Burgess), has become the most serious pest in commercial chrysanthemum and gerbera greenhouses throughout the world because of its short generation time, high reproductive rate, conspicuous damage, and ability to develop resistance to currently registered insecticides. As a result, researchers at the University of California, Riverside, have been working to develop an integrated pest management program (see *California Agriculture,* September-October 1981, November-December 1982, January-February 1984, September 1984, and July-August 1985), as have researchers in other states.

Biological control of ornamental plant pests in commercial situations is generally considered impractical because of the extremely low tolerance to insect damage when plants are reared exclusively for their aesthetic value. Chrysanthemums grown for cut flowers, however, lend themselves to biological control, because only about the top 32 inches of the plant are marketed. Also, the bottom 5 inches of each stem are stripped of all leaves. Damage on the lower part of the plant (approximately the first four to six weeks of plant growth) thus usually does not affect the marketable portion. Biological control of *L. trifolii* during this period can markedly reduce the number of insecticide sprays needed and still permit the production of a high-quality chrysanthemum crop. Reduction of pesticide applications has several advantages, such as less hazard to workers, less environmental contamination, lower cost to the grower, and reduced selection pressure for insecticide resistance.

After previous work had revealed some potentially useful natural enemies of *L. trifolii,* we conducted a biological control study in a commercial chrysanthemum greenhouse with promising results.

Greenhouse study

The study area comprised two separate greenhouses in the Duarte area of Los Angeles County. The first greenhouse (GH1) was about 10,000 square feet and served as a comparative chemical control greenhouse, where treatments were based on population trends of leafminers and other pests. The second greenhouse was about 50,000 square feet and was separated from GH1 by approximately 15 feet. It was divided into a biological control section (the first five sections, or 10,000 square feet) (GH2) and a section under chemical management similar to the first greenhouse. The grower allowed us to determine when a particular control strategy would be applied throughout the study area.

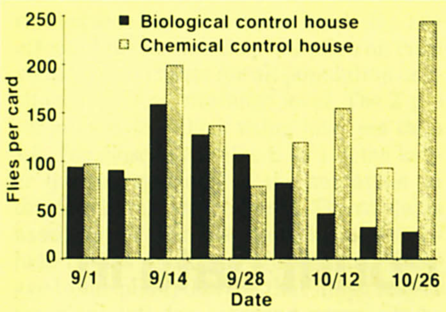
We observed population fluctuations in both treatments, monitoring adult flies by using yellow sticky cards, and larvae by randomly selecting 99 leaves from the area to be sampled (GH1, GH2), taking three leaves from either the bottom or middle of each plant (see *California Agriculture,* September 1984). We determined the percent parasitism by separately sampling five different areas in GH2, choosing each area on the basis of finding at least one leaf with a live larva. All leaves with mines in a 1-square-foot radius of where the live larva was found were taken to the laboratory. Each leaf was examined separately under a microscope, and mines present were scored as containing live or dead larvae, no larvae (completed development), or parasitized larvae.

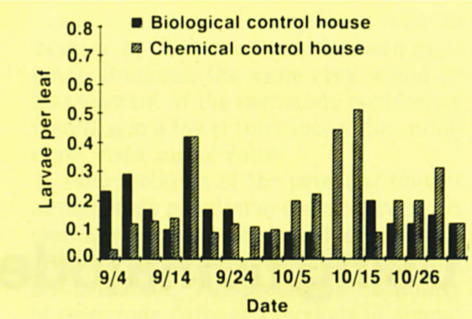
The main biological control agent used in this trial was the parasitic wasp, *Diglyphus intermedius* (Girault) (Hymenoptera: Eulophidae). We also released the parasitic wasp *Chrysocharis parksi* Crawford (Eulophidae) when it was available, but recovered none in the samples. The parasites were mass-reared in the laboratory at UC Riverside on chrysanthemum leaves infested with *L. trifolii.* An "inundative" release or "biotic insecticide" approach was used to control the leafminer with about 1,000 parasites released per week into GH2.

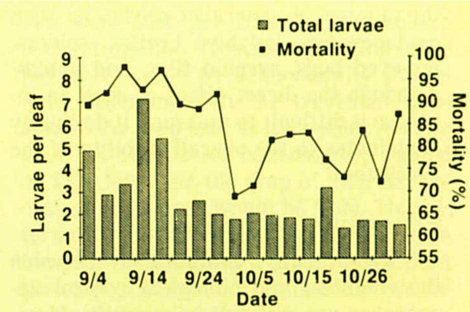
Results

Early in crop development, population trends of *L. trifolii* on the yellow sticky cards were similar in the biological and chemical control sections (fig. 1). Fly population levels on the yellow sticky cards are indicators of the egg-laying pressure in the greenhouse. Since levels are similar early in the season, any differences late in the season reflect the effectiveness of the control strategy. After September 14, estimates of adult flies were lower in the biological control house than in the chemical control house. This same trend was evident by October 1 in the estimates of live larvae (fig. 2). The population increase in the chemical control house, despite the increasing number of pesticide applications, may have been caused by poor spray coverage as the plant canopy density increased.

Parasitization of the leafminer (including mortality caused by both feeding and egg-laying on the host) remained high throughout the season (fig. 3). Initial larval parasitization was approximately 90







Numbers of adult leafminers were similar in biological and chemical control greenhouses early in season, but later dropped in the biological control house, indicating effective control (fig. 1, left).

The same trend was evident in population of live larvae (fig. 2, center). Parasitization of the leafminer remained high throughout the season (fig. 3, right).

percent but dropped to about 80 percent around October 1. Because of the high rate of parasitization, it was difficult to find a live larva by mid-September; we often spent 10 minutes or more before finding a single area to sample for parasite activity. Population fluctuations after October 1 were related to the percent parasitization observed (fig. 3).

On the last sampling date, we measured both the number of live larvae and all mining damage. About 42 percent of the leaves were infested with at least one mine (either empty or containing a live or dead larva) in the biological control house, and 72 percent in the other house. These estimates translate into about 0.8 and 2 mines per leaf, respectively. Although these estimates appear high, it should be remembered that we always sampled leaves from the portion of the plant where the most larvae are found (the leaves were randomly selected from this area, not chosen because they contained larva or mines). This method makes the population estimates higher (and hence more conservative), so that the grower has more time to react to increasing populations. In addition, mines found in the chemical control house were generally more noticeable, because more larvae lived to a later stage than in the biological control section.

Control of other pests

When biological control is first tried, other pests often increase noticeably, because the pesticide previously used to control the primary pest (in this case the leafminer) usually suppressed several secondary pests as well. In our plots, the beet armyworm, *Spodoptera exigua* (Hubner), was the secondary pest that required constant control when sprays for the leafminer ceased. Having lights on at night early in crop development to ensure vegetative growth further compounded the problem by attracting female moths to the greenhouse, where they laid eggs.

Since we were relying on parasites to control the leafminer, use of chemical pesticides for other pests would have disrupted the parasite life cycle. Accordingly, *Bacillus thuringiensis* (Dipel 2X), which is specific for lepidopterous larvae, was used to control beet armyworm in all plots. In the plots under chemical management, chlorpyrifos (Dursban) was also used, because it works well on most lepidopterous larvae and suppresses *L. trifolii* populations.

When leafminers reached critical levels in the chemical management plots, we used the insecticide abamectin (Avid) to control them. (Abamectin is not presently registered for this use in California.) We expected parasites released in GH2 to migrate into GH1, because the adjacent sides of the greenhouses were only partially covered; therefore, we used a low rate of abamectin early in the season in the hope that parasite survival would aid in leafminer control. Later in crop growth, a higher rate was used.

In the biological control house, aphids (primarily the melon aphid) and plant bugs (primarily *Lygus hesperus* and *L. elisus*) became problems after bud formation. Three applications of Safer's insecticidal soap were made for aphid control, and one application of abamectin for the bugs (table 1).

While the secondary pest species may initially increase under a biological control program, natural enemies also increase. We saw a noticeable increase in

TABLE 1. Insecticidal treatments applied to chrysanthemums in Duarte, California, summer 1984

	Chemical control house		Biological control house	
Date	Insecticide	Pest	Insecticide	Pest
13 August	Dipel	BAW*	Dipel	BAW
21 August	Dipel	BAW	Dipel	BAW
24 August	Dipel	BAW	Dipel	BAW
28 August	Avid†	*L. trifolii*	—	—
31 August	Dursban	*L. trifolii* BAW	—	—
4 September	Dipel	BAW	Dipel	BAW
7 September	Dipel	BAW	Dipel	BAW
10 September	Dursban	BAW *L. trifolii*	Dipel	BAW
14 September	Dipel	BAW	Dipel	BAW
18 September	Dipel	BAW	Dipel	BAW
22 September	Dursban Avid	BAW *L. trifolii*	—	—
25 September	—	—	Dipel	BAW
2 October	Avid	*L. trifolii*	Dipel	BAW
5 October	Avid	*L. trifolii*	Dipel	BAW
8 October	Avid	*L. trifolii*	—	—
12 October	Avid	*L. trifolii*	—	—
15 October	—	—	Safer's Soap	Aphids
18 October	Avid Pirimor‡	*L. trifolii* Aphids	—	—
22 October	Trigard§	*L. trifolii*	Safer's Soap**	Aphids
24 October	Avid	*L. trifolii*	—	—
26 October	Avid	*L. trifolii*	Dipel	BAW
29 October	—	—	Avid	Plant bugs *L. trifolii*
5 November	—	—	Safer's Soap**	Aphids
9 November	HARVEST		HARVEST	

* Beet armyworm
† Avid (abamectin) is not presently registered for this use in California.
‡ Pirimor = pirimicarb.
§ Trigard = cyromazine.
** Only spot treatments with a backpack sprayer.

the number of generalist predators, such as lacewings, ladybird beetles, spiders, big-eyed bugs, syrphid flies, and nabids. Although the direct effect of such an increase is difficult to measure, it definitely contributes to the overall stability of the ecosystem.

Economic comparison

Economically, comparisons between the chemical and biological control approaches are difficult to quantify. Monitoring costs for both methods would be similar and so are not included in the following analysis.

The cost of pesticides in the chemical control house was $530. A total of 21 applications at about $30 per application brought the entire control cost to $1,160. In the biological control house, total pesticide cost was $405. A total of 16 applications at $30 each brought the control cost to $885, or $275 less than in the chemical control house. When the economic analysis is restricted to control of the leafminer alone, there is a difference of $295 in chemical costs and $330 in application costs, for a total difference of $625 (the cost of leafminer control includes the one spray of abamectin for plant bugs, because that insecticide also suppresses leafminer populations).

Production costs for the parasites are unavailable at present, but we released 13,295 *Diglyphus*. Based on the $275 difference in costs between the biological and the chemical control houses, prices up to $13 per thousand would be economically feasible. Once commercial mass production begins, prices would probably be at least in this range. Even at higher prices, the benefit of reduced selection pressure towards insecticide-resistant leafminers must be considered in the economic analysis.

Given the rapid development of leafminer resistance to microencapsulated methyl parathion (Penncap M) and permethrin (Pounce) in California, and to a large number of compounds in Florida, the use of biological control to augment and extend the life of present chemical control strategies becomes attractive. In addition, reduced pesticide use should benefit California ornamental growers faced with urban encroachment and increased concern by their neighbors about pesticide contamination.

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Using nematode count data in crop management decisions

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Nematode density and expected crop damage should be the basis for rational control decisions

A fundamental principle of crop and pest management is that management or control is unnecessary unless the pest is at a level expected to damage the crop. The more individuals there are of the pest population, the greater the expected damage (fig. 1). In some cases, any incidence of the pest or pathogen is intolerable, and preventive measures are required.

Knowledge of the relationship between the pest population density and the expected crop damage should form a basis for rational pest management decisions. Determination of these relationships (known as damage functions) may be difficult, however, and they vary with environmental and economic conditions. The relationships become more apparent as further information is gathered about the biology of the crop and pest systems. The basis for management decisions can be summarized as tables or graphs and can be put into a format for interactive access in computer-based models.

When decisions are based on the number of pest individuals present, the problem of population assessment arises. Use of a damage function relating the number of organisms to expected crop loss presupposes that the organism population is measured with the same efficiency, or at least is expressed in the same terms, as the population for which the damage function was developed. One can avoid potential errors by evaluating the efficiency of the population assessment technique and making appropriate corrections of data for this efficiency.

Since 1976, we have conducted studies on several annual crops in various California locations to determine the relationship between crop yield and density of the root-knot nematode, *Meloidogyne incognita*, in the soil before planting. Basing the prediction of yield or yield loss on a preplant sample of the nematode population is significant, because most management alternatives (soil fumigation, crop rotation, use of resistant varieties) require preplant decisions and commitments.

An equation predicting the timing or magnitude of crop yield and value based on a single observation of the pest population is known as a "critical point" model. Such models are appropriate for nematodes in annual crops, because they permit timely decisions and, further, because nematode generation times are relatively long and population assessment is not confounded by unpredictable immigration. The nematode population is relatively immobile and is already present in the soil at planting time.

In pest systems with greater volatility and uncertainty (unpredictable invasion times, rapid rates of population increase), a "multiple-point" approach to population assessment is necessary. This allows initial detection and determination of the rate of population change and damage with time. For nematodes, such approaches are necessary as a basis for management decisions on perennial crops.

To develop an equation for crop loss due to nematodes, we selected the model derived by J. W. Seinhorst (as published in *Nematologica* 11, in 1965). This model recognizes that, for some crop and nematode combinations, there may be a minimum yield (m) — some residual crop growth, even at high nematode population densities. Further, there may be a nematode density below which damage is not