

with very severe disease also had other problems such as soil compaction, overwatering, and/or phytophthora root rot. Even in these instances, however, powdery mildew did not reduce yields.

In our field trials, Bayleton 50WP has been very effective in controlling powdery mildew epidemics. In all instances, one application at a rate of 4 ounces per acre approximately 45 days after transplanting reduced the final disease severity to less than 50 lesions per 100 leaflets (table 3). This level of disease did not cause significant defoliation. Frequently, conidia and conidiophores on existing lesions appeared shriveled and distorted seven to ten days after the fungicide application.

Twenty-one commercial tomato cultivars and five primitive tomato species were evaluated for their susceptibility to powdery mildew. We screened the plants in a commercial tomato field in the San Joaquin Valley (Stanislaus County). The surrounding tomato fields had a very high level of disease.

All of the commercial tomato cultivars tested were susceptible to powdery mildew, although some differed considerably in the degree of susceptibility (table 4). The tomato cultivars tested differed in many characteristics, however, including vegetative growth habit, yielding capacity, and rate of maturation; all of these factors may influence powdery mildew severity.

Conclusions

We were not able to demonstrate any significant reduction in yield of fresh market tomatoes due to powdery mildew in either commercial or experimental field plots when tomatoes were harvested at the mature green stage of development. However, the fact that powdery mildew can substantially increase defoliation may predispose fruit to damage such as sunburning, reduced solid content, and insect damage although this has not yet been observed. Processing tomatoes are harvested much later in their development than are fresh market tomatoes and a high level of powdery mildew could have a substantial effect on fruit quality. This, however, has not been demonstrated.

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Biological control of leafminers on greenhouse marigolds

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In greenhouse marigolds grown for seed, a parasitic wasp suppressed leafminers for two months after establishment

Marigolds grown for seed in the Lompoc area of California (northern Santa Barbara County) are attacked by many pests. Some damage to foliage can be tolerated in seed crops, as opposed to most of those grown for cut flowers, but injury that may reduce seed production must be prevented. Pesticide applications are usually avoided after hand-pollination because of the possibility of seed shatter from the force of the spray. For those reasons, and because plants grown for seed are usually maintained for five months to three years, the use of biological control agents would be appropriate.

One of the most serious pests is the leafminer, *Liriomyza trifolii* (Burgess). This leafminer has a short developmental time, has a high egg-laying capacity, and rapidly develops insecticide resistance. These traits, coupled with increased restrictions on insecticide use, have contributed to the difficulty in controlling *L. trifolii* in greenhouses.

Use of the parasitic wasp *Diglyphus* sp. has shown great promise as a means of suppressing *L. trifolii* populations on greenhouse chrysanthemums (*California Agriculture*, November-December 1982, January-February 1986). We therefore established a trial to evaluate the use of *D. begini* (Ashmead) for control of *L. trifolii* on greenhouse marigolds.

Greenhouse trial

The trial was conducted from July through October 1986 in a 10,000-square-foot greenhouse in Lompoc planted with about 8,000 African marigolds. Male and female parental lines were maintained on separate plants. Plant composition was 50 percent female (variety D154), 50 percent male (variety Diamond Jubilee), and pollen was physically collected from male flowers and applied to female flowers for pollination.

To monitor the leafminer population in the absence of any parasites, a 3- by 5- by 3-foot control cage was placed over a section of female plants at the time of planting, enclosing the resident leafminers and preventing insects from entering. A small

box fan inside the cage maintained temperatures similar to those of the surrounding greenhouse. Probes attached to a Data-pod continuously monitored temperature and relative humidity inside the greenhouse and the control cage.

Adult insect populations were monitored with six Zoëcon yellow sticky cards uniformly distributed to sample the adult leafminer and parasite populations within the entire greenhouse. One card was also placed in each of the four cardinal directions, 30 feet outside the greenhouse walls, to monitor any surrounding insect populations that might have been able to get into the greenhouse. One small card was placed in the center of the control cage. Since insects stuck to the cards are physically removed from the population, the smaller card was used in the control cage to minimize the effect of sampling on the leafminer population. Cards in the greenhouse and in the control cage were changed every three to four days; those on the outside were changed weekly. The number of insects per species was counted for each card.

To estimate the number of immature leafminers and degree of parasitism, we subdivided the greenhouse into 18 equal sections. In each section, one plant per sample period was randomly selected and an average of five leaves collected randomly at intervals along the length of the plant. In the control cage, leaves were selected in the same way from two randomly chosen plants per sampling. Leaves were examined microscopically within 48 hours of collection and scored for the number of live, dead, and parasitized leafminer larvae.

Adult parasites were uniformly released into the greenhouse twice weekly, no later than 7:30 a.m., between July 28 and September 11. A total of 66,000 parasites, 30 to 50 percent female, were released over the entire trial for an average of 3,700 per release. At the time of release, the parasitic wasps were two to three days old and had been held in glass test tubes with honey for 36 hours. No insecticide applications for leafminer control were made during the trial.



Mesh cages kept parasitic wasps away from marigolds used as control plots in a greenhouse test of the wasp's effectiveness against leafminers.

Leafminer control

After three weeks of parasite releases, the adult leafminer population began to decline rapidly and remained at a very low level during all of September and October (fig. 1). A similar trend occurred in the larval numbers (fig. 2). Within six weeks after the first parasite releases, the larval population in the greenhouse began a precipitous decline and became virtually nonexistent by September 19.

Patterns were similar among the parasites. Their numbers and the level of parasitism steadily increased, peaking in the first week of September, followed by a steady decline over the rest of the trial. The population increase was due not only to the parasites released but also to the number of offspring they produced in the greenhouse. The parasite decline probably resulted from the decrease in leafminers. Without suitable hosts on which to feed and lay eggs, the parasite population falls rapidly.

Results from the control cage, from which parasites were excluded, indicate that the decline in the number of leafminers can be attributed to the presence of parasites in the greenhouse. Between August 26 and September 19, the adult leafminer population was substantially higher in the control cage than in the greenhouse (fig. 3). On September 2, there were over 60 times more leafminer flies in the control cage than in the greenhouse. Sampling of the control cage was discontinued after September 19, but if the pattern in the cage had continued, the adult leafminer population would probably have peaked again in early to mid-October.

Successful leafminer control in the greenhouse was due to the periodic releases of *D. begini* and not to parasites entering the greenhouse from the outside. The yellow sticky cards outside detected only a very small resident *Diglyphus* population. Furthermore, the greenhouse walls and roof were effective physical barriers to insects attempting to move in or out of the greenhouse.

Three other pest species—the beet armyworm, *Spodoptera exigua* Hübner, the greenhouse whitefly, *Trialeurodes vaporariorum* Westwood, and an unidentified aphid species—were periodic problems during the trial. Beet armyworm infestations were successfully controlled with spot applications of *Bacillus thuringiensis* Berliner (Dipel). In an attempt to control the whitefly population, 3,000 *Encarsia formosa* Gahan, a parasite of *T. vaporariorum*, were released on August 22. Although the whitefly population continued to increase after the release, its density was considered tolerable by the grower. Aphid populations were held in check with regular releases of green lacewing, *Chrysopa carnea* Stephens, together with spot applications of Safer's insecticidal soap.

In summary, within six weeks after the initial release of *D. begini*, effective control of *Liriomyza trifolii* was accomplished. After the leafminer population was significantly reduced, it was maintained at an extremely low level for eight weeks.

Feasibility

Use of natural enemies in an integrated pest management program for greenhouse-grown ornamental crops often is not considered feasible because of the de-

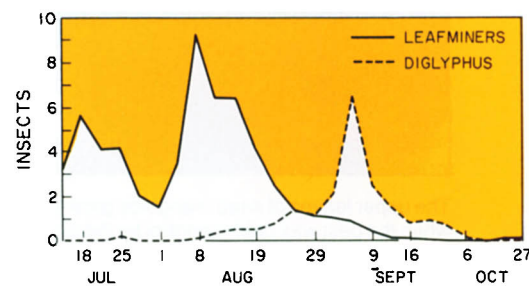


Fig. 1. Adult leafminer numbers declined rapidly after three weeks of parasite releases, then remained low. Parasite populations steadily increased until early September, then also declined.

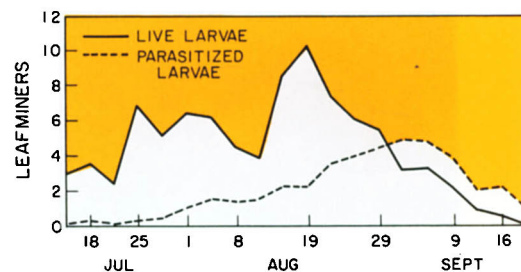


Fig. 2. Numbers of live leafminer larvae began to drop six weeks after parasite release. Larvae were virtually nonexistent by mid-September.

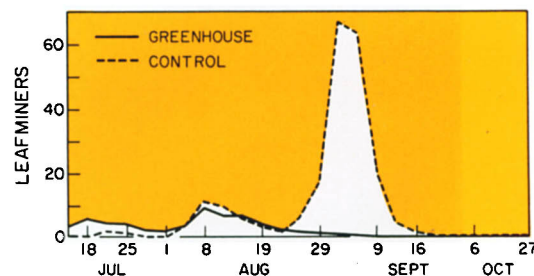


Fig. 3. By early September, there were 60 times more leafminer flies in the control cages than in the open greenhouse.



The upper leaves of seed marigolds grown in the greenhouse were almost free of leafminer injury when the pest was held in control by the parasitic wasp *Diglyphus begini*. Older, lower leaves showed damage from high leafminer populations before they were suppressed. Photo below shows the severe damage caused by uncontrolled leafminers.



lay that usually occurs between parasite introduction and reduction in pest populations. Most ornamentals are grown for their aesthetic value, and there is essentially no tolerance for damage. To be effective, control measures must reduce the pest population before it damages the marketable portion of the crop.

Early introduction of the leafminer parasite *D. begini* in relation to the growth of the pest population has the potential of bringing the leafminer population under control before it causes unacceptable damage. In the marigold study, the parasite suppressed the leafminer population to a very low level within two months and maintained control for another two months. At harvest, we found that the lower, older leaves had been damaged (when leafminer populations were high), but the upper portions were virtually free of leafminer injury (when the pest was held under control by the parasite).

Biological control might be feasible in some cut flowers, such as chrysanthemums, in which only the top portion of the plant is harvested. In a crop such as gerbera daisies grown for cut flowers, only the flower stalk that totally lacks foliage is harvested. As in a seed crop, the foliage is important for photosynthetic activity and flower production, but some damage is tolerable. If the leafminer population can be brought under control and maintained at a low level as in the marigold trial, the use of the parasitic wasp could be effective.

If *D. begini* is to provide reliable and repeatable biological control of *L. trifolii*, parasites must be readily available to the grower, and a parasite release program that causes a predictable response in the leafminer population needs to be developed. At this time there are no commercial insectaries in the United States that rear *D. begini* for sale to growers, although sufficient demand might change the situation. The second element, the release schedule, is currently under investigation.

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