Despite all these impediments, one has to balance them against the strong, positive forces driving IPM forward. Pest management in ornamentals can never return to its state of 20 years ago, or even 10. It is extremely unlikely that individual components of IPM programs, such as the use of pest-resistant ornamentals, or biological control, will by themselves bring solution to a major number of ornamentals pest problems. The only reasonable course into the future seems to be IPM, and I am completely confident that this concept will continue to capture an increasing portion of the ornamentals pest market.

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ADVANCES IN SAMPLING IN ORNAMENTALS

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ABSTRACT
The traditional viewpoint that there is a zero tolerance level for pests or their damage on ornamental plants has hindered the development of statistically accurate sampling plans. Monitoring procedures determining initial presence, peak flight times, etc. have been developed, but actual methods to estimate pest populations on plants are lacking. This is changing coincidently with grower perceptions that some pests or damage can be tolerated. This attitude change is most common in crops where a considerable portion of early growth is not marketed, where pesticide resistance renders even weekly insecticide applications less than satisfactory, or where restrictions on pesticide use has forced growers to be more judicious about pesticide applications. Recent developments in sampling for adults and larvae of the leafminer, Liriomyza trifolii (Burgess) (Diptera: Agromyzidae) using yellow traps and/or leaf samples in chrysanthemums,
marigolds and gypsophila are reviewed. In addition, the utility of using yellow traps to monitor adult whiteflies, *Trialeurodes vaporariorum* (Westwood) and *Bemisia tabaci* (Gennadius) (Homoptera; Aleyrodidae) on poinsettias, is discussed.

**Resumen**

El punto de vista tradicional de que hay un nivel de cero tolerancia hacia plagas o a su daño a plantas ornamentales, ha sido un obstáculo en el desarrollo de muestreos estadísticamente precisos. Se ha desarrollado el procedimiento para determinar el chequeo de la presencia inicial, el ancho del vuelo, etc., pero actualmente faltan métodos para estimar la población de la plaga. Esto está cambiando al mismo tiempo con la percepción del productor de que algunas plagas o su daño se pueden tolerar. Este cambio de actitud es más común en cultivos donde una porción considerable del primer crecimiento es comercial, cuando la resistencia a pesticidas rinden aún aplicaciones semanales de insecticidas menos que satisfactorias, o cuando restricciones en el uso de pesticidas ha obligado a agricultores a ser más juicioso en la aplicación de insecticidas. Se revisan recientes avances en el muestreo de adultos y de larvas del minador, *Liriomyza trifoli* (Burgess) (Diptera: Agromyzidae), usando trampas amarillas y/o muestras de hojas de crisantemos, claveles y “gypsophila”. Adicionalmente, se discute la utilidad de usar trampas amarillas para chequear los adultos de la mosca blanca, *Trialeurodes vaporariorum* (Westwood) y de *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodida) en poinsettias.

In California in 1986, the production environmental horticulture industry was valued at greater than 1.3 billion dollars (Anon. 1988). Despite the size of this industry in California and in the United States, limited information is available on IPM or sampling.

This is gradually changing with considerable research focusing on spider mites attacking roses and foliage plants, whiteflies on poinsettia and leafminers attacking various cut flowers and seed crops. One reason for greater concentration by researchers on the development of sampling strategies is the realization (by both growers and researchers) that pest damage on an ornamental crop can be tolerated without loss of aesthetic (i.e., market) value. Prior to acceptance of this general concept, sampling plans were not necessary; it was pointless to estimate pest densities when the only acceptable level was zero or near to zero. Not all production ornamental crops can tolerate pest populations; however, there are specific situations when pests or their damage can be tolerated by growers. These include situations where a considerable portion of early growth is not marketed (e.g., many cut flower and seed crops). Furthermore, the decreasing availability of efficacious insecticides together with legislative restrictions governing their application will force growers to be more judicious about pesticide application. Estimates of pest populations would permit growers to time their sprays with increasing pest populations. This strategy may lead to an increase in the effectiveness of an insecticide as well as a decrease in the probability of the development of insecticide resistance. The alarming rate at which serious pests have spread worldwide throughout the ornamentals industry [e.g., *Liriomyza trifoli* (Burgess), Spodoptera exigua Hübner, Frankliniella occidentalis (Pergande), and *Bemisia tabaci* (Gennadius)] emphasizes the point that current prophylactic applications of pesticides are unsuccessful for controlling pests.

Although the development of more sampling strategies in production ornamentals is currently underway, this segment of the environmental horticulture industry is far behind landscape trees and shrubs. In this division of the environmental horticulture industry, monitoring pest populations to establish optimum treatment times has been suggested for many years (Pritchard & Beer 1950, Koehler et al. 1965, Raupp, 1985
and references therein) and considerable work has been done relating pest population levels to acceptable plant injury (Raupp et al. 1988). Monitoring and sampling in landscape trees and shrubs will not be considered in this paper; rather, emphasis will be placed on recent developments in sampling in floriculture. In particular, studies with larvae and adults of the leafminer L. trifolii on gypsophila (Gypsophila paniculata), chrysanthemums (Dendranthema grandiflora) and marigolds (Tagetes popul) and adult whiteflies (Trialeurodes vaporariorum (Westwood) and B. tabaci on poinsettia (Euphorbia pulcherrima) will be discussed.

*Liriomyza trifolii* in Chrysanthemums

The first step in developing a sampling plan for larvae of this pest in chrysanthemums grown as cut flowers was to establish a relationship between mined leaves and aesthetic injury. This varied from grower to grower as well as during time of the year. Each grower has his/her own idea as to what level of damage is acceptable in a given situation. We found that this would vary with the historical quality of the crop and problems associated with insecticide resistance in *L. trifolii*. Growers known for producing perfect flowers, for example, rarely would settle for any damage. The resistance level of this leafminer has been shown to vary considerably from location to location (Haynes et al. 1986). The more difficult the leafminer is to control, the greater the crop damage at harvest. In addition, where the flowers are sold also influences the level of damage that is acceptable. Growers selling to a broker tolerate less damage than those selling at local flower markets. Finally, acceptable damage fluctuates with the time of year. During the holidays cut flowers are worth far more than at other times. Intuitively, it would seem that these holiday crops, which bring greater return to the grower, must have little damage; however, just the opposite is true. Because the demand for flowers is so great around these holidays, there is usually a flower shortage and growers can sell all of their production regardless of the amount of the damage. This would not be the situation if the flowers themselves were damaged in any way. During the summer months there is an overabundance of product and chrysanthemums with mined foliage will sell considerably below the market price.

Given the vagaries just described in establishing aesthetic injury levels, we felt that it would be best to develop a binomial sampling plan that permitted a very rapid assessment of the population with a minimum amount of work and did not require specifying a critical level of damage in advance. Each grower could therefore decide what damage level was acceptable and proceed to use population estimates as a guide to prevent additional damage (Parrella & Jones 1987).

*Liriomyza trifolii* Larvae in Chrysanthemum

Chrysanthemums can be harvested in as little as 12 weeks, but during this period the crop starts as small rooted cuttings approximately 10 cm in height and is greater than 100 cm tall at harvest. Studies on the distribution of oviposition and feeding by *L. trifolii* was conducted in the greenhouse as described by Parrella et al. (1987) Briefly, a greenhouse section (6 m wide x 30 m long) was planted with 3,000 chrysanthemum (cv 'Manatee Iceberg') plants arranged in 4 beds. Plants were grown as a pinched crop and normal grower practices were followed. A total of 50 plants were randomly selected within this area and upon planting, immediately caged to exclude flies. Cages were constructed from clear acetate (1 mm thick) which was rolled into a 20 cm diam cylinder. The edges of the cage were sealed with duct tape and the bottom of the cage was driven into the soil to prevent fly entry. The tops and two 12 cm diam air holes on the sides were covered with fine mesh cloth (200 holes/2.5 cm²) to allow air movement but to
exclude flies. No applications of pesticides were made in the study area until 11 weeks after planting. Population levels in the greenhouse during this time were high (>200 flies per yellow trap per week, Parrella et al. 1987).

Each week, three caged plants were randomly selected and their cages removed; one week later, plants were uprooted. Their roots were then placed in moist paper toweling and the plants were transported to the laboratory. The stems on each plant were ranked from tallest to shortest and, after 4 days, the plant, stem and leaf number (using the youngest leaf on each stem as leaf number 1) were recorded along with the number of feeding punctures and larvae or mines present on each leaf. The time between plant removal and counting permitted hatching of eggs laid just prior to removal. Only the 3 largest stems from each plant were used in the analysis because the other stems on the plant had markedly fewer leaves.

The mean number of mines per leaf was calculated for all 9 stems per week. These values were then used to calculate the percent of the total mines for that week found on each leaf. Oviposition pattern exhibited by L. trifolii through the growth of the crop

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**Fig. 1.** Percent or total mines caused by *Liriomyza trifolii* on different leaf nodes of chrysanthemum (leaf 1 is the youngest) during week 7-9. (N = 9 stems per week)
was consistent, they tended to avoid very old and very young leaves (Fig. 1). Consequently, leaf samples taken from the middle portion of the plant are most likely to contain larvae and provide the most reliable (and highest) estimate of leafminer population density.

The development of sampling plans (utilizing leaf samples from the middle part of the plant) was conducted in two greenhouses during the summers of 1982 and 1983. Details are given in Jones & Parrella (1986a). An important aspect of the study was that covariance analysis revealed that the coefficients of Taylor's power law were not significantly different between plant strata or between crops with one or many cultivars. Thus, a common regression could be used to describe the relationship between variance and mean. A fixed sample size of 100 leaves provided a better estimate of mean population densities than a constant precision sample (i.e., a sequential sampling design in which sampling is terminated when a defined level of precision is achieved). A binomial (presence-absence) sampling plan was developed to estimate leafminer densities rapidly during crop growth as well as for total mining damage at harvest. The latter aspect was completed so growers (or researchers) could rapidly assess the final damage to the marketed portion of the chrysanthemum crop.

*Liriomyza trifolii* Larvae in *Gypsophila*

With the field grown flower crop, *Gypsophila paniculata* cv 'perfecta' (commonly called gypsophila or baby's breath), the most prevalent leafminer attacking this crop in California is the pea leafminer, *L. huidobrensis* Blanchard (Parrella & Bethke 1984). Baby's breath is planted as rooted cuttings and generally flowers in 60 to 120 days, depending on environmental conditions; peak flowering periods in California are from February-October. The crop is routinely cut back and will reflower. Some growers replant annually while others may keep plants as long as 5 to 6 years.

One coastal planting of gypsophila (70 x 160 m), consisting of ca. 6,000 plants, was sampled for leafminers immediately after it was cut back until flowering. Twenty plants were randomly chosen each week and 10 leaves were taken in a stratified design—10 from the bottom, vegetative part, 10 from the middle, bolting section, and 10 from the upper, flowering section. All leaves were returned to the laboratory and examined for feeding punctures and the presence of mines.

Data for punctures and mines plotted over the 14-week sample period clearly showed a preference by *L. huidobrensis* for the lower, vegetative section of the gypsophila plant (Figs. 2 and 3). A marketed bunch of baby's breath consists of the upper, flowering section where there are few mines or punctures. In addition, *L. huidobrensis* mines the lower leaf surface (Parrella et al. 1985) and the mines are usually not visible from the upper side of the leaf. Therefore, leafminer contol on gypsophila is usually not necessary, especially when considering the large parasite complex associated with leafminers in this crop (Price & Stanley 1982).

*Liriomyza trifolii* Adults in Chrysanthemum

Mark-release-recapture studies in a range of greenhouse chrysanthemums (Jones & Parrella 1986b) provided insight into the movement of *L. trifolii* within a greenhouse as well as information on proper yellow trap placement to obtain maximum data on leafminer population dynamics. This study demonstrated that traps should be spaced a minimum of 26 m apart for gathering information on population trends and 47 m apart (between plots) for evaluation of treatment effects within plots (e.g., pesticide evaluation).

Such information was used to develop constant precision sampling plans for yellow
traps (Parrella & Jones 1985). Trapping at several locations over a three-year period revealed that the variance/mean relationship of catches was consistent from year to year, location to location, and trap type to trap type. A requirement is that traps must
be positioned only over homogeneous blocks of chrysanthemums (i.e., chrysanthemums planted less than 30 days apart). Standard formulae (Taylor's power law and Iwao's patchiness regression) were fit to the data. Iwao's patchiness regression best described the variance/mean relationship and stop lines were generated with a fixed level of precision of 0.25. Validation of the sampling plant demonstrated that only 18% of the traps throughout the season needed to be counted to achieve the fixed level of precision.

Trapping and Damage

Although adult *L. trifolii* captured on yellow cards can provide the grower with important information regarding population fluctuations in the greenhouse, correlating these data to crop damage (i.e., mines) would increase the yellow card's utility in decision making. A consistent relationship is difficult to determine, probably because trap catches may vary with environmental conditions, normal greenhouse operations, cultivar location, type of greenhouse, and the delay between oviposition and when mines become visible. Some of these factors may affect the number of mines in the leaves differently than they affect trap catches. In addition, the number and type of cultivars (which differ in susceptibility to leafminers) in the greenhouse are of critical importance.

In 1986, a correlation was run between adult *L. trifolii* caught on yellow cards and live larvae present in leaves. Data were collected from a 10,000 ft² greenhouse containing marigolds (*Tagetes erecta*) grown for seed. There were 6 cards (7.5 x 12.5 cm) in this greenhouse which were checked twice weekly. At the same time 18 plants were randomly selected and one leaf was removed every 2.5 7.5 cm of plant height. Live larvae were counted in these leaves immediately. Sampling was done over a 4-mo. time period, from crop inception to harvest. Methods were similar in 1987 except that the greenhouse was 6,700 ft² and there were 12 plants per sample. A strong correlation was found when leafminer populations were high (Fig. 4) \( r = 0.8556 \), P < 0.001. However, when populations were lower the following year in this same greenhouse (Fig. 5) there was no correlation. Unfortunately, it is more important from a decision-making standpoint to be able to use the yellow cards in a predictive sense when populations are

![Graph](image)

**Fig. 4.** Predictability of larval populations of *Liriomyza trifolii* in marigolds for adults caught on yellow cards. Correlation calculated with live larvae (abscissa) time lagged 7 days. This greenhouse represents high populations of adult leafminers.
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Fig. 5. Predictability of larval populations of *Liriomyza trifolii* in marigolds for adults caught on yellow cards. Correlation calculated with live larvae (abscissa) time lagged 7 days. This greenhouse represents low populations of adult leafminers.

low, before serious mining injury occurs. Based on our studies, yellow cards may not function effectively in predicting damage when populations are low.

Whiteflies and Poinsettia

During the fall of 1987, research was conducted in a Christmas crop of poinsettias, using yellow cards (hung 30 m over the crop) to trap both *T. vaporariorum* and *B. tabaci*. These cards were checked weekly through the crop although only 3 data sets (3 dates) are presented here. There were 275 yellow cards hung uniformly in an area encompassing ca. 0.4 ha.

A simple formula for calculating sample size which utilizes the standard error of the mean as a measure of precision (i.e., SE/\(\bar{x}\)) (Southwood 1982, Karandinos 1976) was applied to the trap catch data. We found the number of traps required to reach a precision level of 0.25 was well below the number currently in use (Table 1) particularly when the \(\bar{x}\) whiteflies per card exceeded 4.0. Therefore, the grower could reduce the number of traps and still be confident of population trends in the greenhouse. As the

<table>
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<th>Date</th>
<th>(\bar{x})</th>
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\(\bar{x}\) Estimated from 275 cards spaced uniformly over a 0.4 ha. poinsettia range. All cards checked weekly.

\(N = \frac{Z^2 \cdot S}{E^2}\) where \(N = \) samples required, \(Z = 1.96\) S = standard deviation, \(\bar{x} = \) mean, E = predetermined standard error as a decimal of the mean.
number of traps in use declines, however the potential to detect 'hot' spots in the greenhouse is also reduced. The grower must then make the decision as to the number of traps to employ and any known hot spots should be trapped separately.

As yellow traps become more and more popular, there are some who advocate their use in trapping out populations of whiteflies. This has been done in the Mediterranean area in tomato greenhouses where yellow cards were utilized together with parasite releases (van de Vrie & Vacante 1984). However, there have been no data published to date on the utility of mass-trapping whitefly populations in ornamental greenhouses.

**DISCUSSION**

Monitoring insect populations in the greenhouse can provide a grower with the following information:

1. Population trends in the greenhouse. Consequently, potential outbreaks can be anticipated.
2. Whether populations build up in the greenhouse or migrate in from outside. If migration is the main problem, screening can be considered.
3. The optimal time to apply pesticides. Sprays can be aimed at population peaks of the most susceptible stages.
4. An evaluation of spray efficacy. If populations targeted by the pesticide drop after application, then obviously the insecticide has been successful.
5. More intelligent, judicious use of pesticides based on population trends rather than on a calendar schedule. This will result in less residue, environmental contamination and worker exposure. This is becoming increasingly important as rules and regulations governing pesticides increase.
6. A reduction in the probability of insecticide resistance developing in the target pest through use of fewer pesticide sprays.
7. An overall monetary savings through reduction in pesticide use while maintaining plant quality.

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ECONOMIC AND AESTHETIC INJURY LEVELS 
AND THRESHOLDS FOR INSECT PESTS OF 
ORNAMENTAL PLANTS

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ABSTRACT

This article reviews decision-making considerations that apply to the management of insect pests of ornamental plants. In particular we estimate a modified Economic Injury Level (EIL) for the bagworm, Thyridopteryx ephemereformis (Haworth), attacking American arbor vitae, Thuja occidentalis under retail nursery conditions. Under these circumstances, the EIL was found to be only about four first instar larvae per 4 ft tree. This confirms earlier suppositions concerning the low tolerance for pests causing aesthetic injury. In addition, we briefly examine the concepts of Aesthetic Injury Levels