EVALUATION OF *ENCARSIA FORMOSA* (HYMENOPTERA: APHELINIDAE) TO CONTROL *BEMISIA ARGENTIFOLII* (HOMOPTERA: ALEYRODIDAE) ON POINSETTIA (*EUPHORBIA PULCHERRIMA*): A LIFETABLE ANALYSIS

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ABSTRACT

Weekly releases of the parasitoid *Encarsia formosa* Gahan failed to control a low density population (initially, 0.51 nymphs and pupae per plant) of the whitefly *Bemisia argentifolii* Bellows & Perring on greenhouse grown poinsettia plants in Massachusetts when released at the rate of 4-7 adult females per plant. A lifetable constructed for uncaged *B. argentifolii* in the presence of *E. formosa* indicated that survivorship from the first/second instar to adult emergence was 14%. In contrast, in a lifetable constructed for *B. argentifolii* on caged poinsettia from which *E. formosa* was excluded, survivorship was 67%. Release of *E. formosa* reduced the number of insecticide applications on poinsettia by 75%, but the cost of using *E. formosa* (on a per m^2 basis) was 9.5 times that of insecticides alone.

Key Words: Augmentation, biological control, integrated pest management, greenhouse, whitefly, parasitoid.

RESUMEN

Las liberaciones semanales de 4-7 hembras adultas del parasitoide *Encarsia formosa* Gahan por planta no pudieron controlar una baja densidad poblacional (inicialente, 0.51 ninfas y pupas por planta) de la mosca blanca *Bemisia argentifolii* Bellows & Perring en plantas de flor de pascua en Massachusetts. Una tabla de vida construida para *B. argentifolii* no mantenida en jaulas y en presencia de *E. fomosa* indicó que la sobrevivencia desde el primero/segundo instar hasta la emergencia del adulto fue del 14%. En contraste, en una tabla de vida construida para *B. argentifolii* sobre plantas de flor de pascua mantenidas en jaulas de las cuales *E. formosa* fue excluida, la supervivencia fue del 67%. La liberación de *E. formosa* redujo el número de aplicaciones de insecticida en las plantas de flor de pascua en un 75%, pero el costo del uso de *E. formosa* (por metro cuadrado) fue 9.5 veces el del insecticida solo.

The primary phytophagous pest affecting poinsettia (*Euphorbia pulcherrima* Willd. ex Klotzsch) is the silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring [= the 'B' strain of *Bemisia tabaci* (Gennadius)] (Homoptera: Aleyrodidae) (Perring *et al*. 1993, Bellows *et al*. 1994). In Massachusetts, 200 greenhouses produce approximately one million individually potted poinsettias annually, which have a wholesale value of $5 million. Poinsettia is the highest ranked ornamental sold in the last quarter of the year in this state [unpublished University of Massachusetts Integrated Pest Management Program Annual Report (1994)]. Because poinsettia is grown for its aesthetic qualities, growers have an extremely low tolerance for the presence of whitefly nymphs, adults, or honeydew. Insecticides are often applied on a calendar schedule, with applications being made every 3-5 days to reduce *B. argentifolii* populations to

acceptably low levels. Adverse effects of such intensive pesticide use against this pest have been documented (Parrella *et al*. 1992; Heinz & Parrella 1994 a,b).

The University of Massachusetts Cooperative Extension System for floricultural crops has initiated an integrated pest management program (IPM) to design a more effective management program for *B. argentifolii* on poinsettia. In the first phase of this program, scouts were employed to recommend pesticide application when susceptible whitefly stages exceeded tolerable densities. Targeted spraying in this manner has reduced insecticide use by 18-50% with most poinsettia growers in the program [unpublished University of Massachusetts Integrated Pest Management Program Annual Report (1994)]. The second objective of the IPM program is to reduce insecticide use even further with biological control agents (in particular parasitic wasps) for suppression of *B. argentifolii*.

One of the parasitoids that has been considered for use in the IPM program is *Encarsia formosa* Gahan. *Encarsia formosa* is a commercially available parasitoid that is used to control the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), a serious pest of greenhouse vegetable crops. *Encarsia formosa* is used worldwide to control *T. vaporariorum* on vegetable crops in greenhouses (van Lenteren & Woets 1988). *Encarsia formosa* tested under laboratory conditions with *B. tabaci* (strain B) on poinsettia developed more slowly, exhibited higher mortality with reduced longevity, and was less fecund than parasitoids that developed on *T. vaporariorum* (Boisclair *et al*. 1990, Szabo *et al*. 1993).

Several studies on the use of *E. formosa* to control *B. tabaci* on poinsettia in greenhouses suggest this parasitoid is effective, contrary to the laboratory findings [the strain was not identified in these studies and others, but is assumed to be strain B which became problematic on poinsettia in Europe after 1987 (see Boisclair *et al*. 1990, Szabo *et al*. 1993)]. Investigations by Benuzzi *et al*. (1990) in Italy, Albert & Schneller (1989) and Albert & Sautter (1989) in Germany, and Stenseth (1993) in Norway concluded that *E. formosa* successfully suppresses *B. tabaci* (unidentified strain) on poinsettia grown for the Christmas market when *T. vaporariorum* is present. Work by Parrella *et al*. (1991) in California, USA, reports that *E. formosa* is an ineffective control agent for populations of *B. argentifolii* on poinsettia plants grown for cutting production in the spring. Because poinsettia growing conditions in the northeastern USA in the fall are more similar to those in Europe in the fall than to spring growing conditions in California, there was a need to evaluate the ability of *E. formosa* to control *B. argentifolii* populations on poinsettia in Massachusetts. To measure the efficacy of *E. formosa*, we constructed lifetables for *B. argentifolii* in both the presence and absence of the parasitoid.

Materials and Methods

Greenhouses and Cultivars

Two greenhouses at one commercial poinsettia producer in Massachusetts were monitored to determine whether insecticides or *E. formosa* provided better control of *B. argentifolii*. One greenhouse received *E. formosa* as a control measure and is designated here as the biological control greenhouse. The second greenhouse was managed using synthetic pesticides and is designated as the insecticide greenhouse. Each was a 170 m^2 'A' frame greenhouse (glass construction) with three benches in Cambridge, Massachusetts. The two side benches (1 m × 27 m) each held 156 pots (18 cm diam) with 5 single-stem unpinched plants per pot. The middle bench (2 m × 26 m) held 264 pots (19 cm diam) with 6 single-stem unpinched plants per pot for a total of

576 pots and 3144 plants per greenhouse. The poinsettia cultivars were white and marble 'Angelika'; red, pink and white 'Celebrate 2'; and pink 'Gutbier V-14'. The study started immediately after both greenhouses were filled with potted cuttings in August, 1994. Some plants were removed during the test from both houses to satisfy spacing requirements.

Population Density Estimation and Lifetable Construction

To estimate whitefly population densities, six leaves (2 from the bottom of the plant, 2 middle, and 2 top) of 30 plants in each greenhouse were inspected weekly for *B. argentifolii*. The number of eggs, first and second instars, third instars, fourth instars, red eyed pupae, and adults were recorded. *T. vaporariorum* was not observed in either greenhouse.

Three treatments were established in the biological control greenhouse: uncaged plants (Treatment 1), cages without *E. formosa* (Treatment 2), and cages with *E. formosa* (Treatment 3). Treatment 2 acted as the control, and Treatment 3 was a check for a cage effect on whitefly development in the presence of the parasitoid. In addition to estimating whitefly densities on randomly selected leaves in Treatment 1, the fate of marked cohorts of nymphs was determined. Cohorts were established by tagging and numbering naturally-infested plants bearing first or second instar *B. argentifolii*. Numbers were written on tagged leaves with an indelible marker beside young nymphs. Numbered nymphs were examined weekly, and their developmental stage recorded. Young nymphs (approximately 1-30 nymphs per leaf) found on 1-3 leaves of each of 3-5 plants were recruited every week for the lifetable study. Observations were continued until the nymphs had either died of unknown causes, disappeared, been parasitized, or emerged as adult whiteflies. Parasitism was noted when the whitefly pupa turned brown or a parasite had emerged. The recorded fates of all nymphs (204) in Treatment 1 were used to create a partial lifetable for *B. argentifolii*.

For Treatments 2 and 3, nine pots (19 cm diam) with single-stem unpinched poinsettia plants (cultivars used; white 'Angelica,' red and pink 'Celebrate 2') were selected at random and enclosed by fine mesh bags (28 cm × 28 cm × 36 cm; mesh 6.2 × 6.2 threads per cm^2). Each bag was supported by four 50 cm stakes that were driven into the potting medium. A rubber band was used to seal the bottom of the bag against the exterior of the pot. One male and one female adult *B. argentifolii* were released into each bag. In Treatment 2, the resulting whitefly population was allowed to develop on poinsettia in the absence of *E. formosa*. In Treatment 3, three *E. formosa* were introduced into each of the nine cages weekly.

For Treatments 2 and 3, whitefly population density estimates were made, and cohorts of nymphs established in the same manner as Treatment 1. Numbered nymphs on tagged leaves were observed weekly for survivorship and parasitism. Mortality data for numbered nymphs in Treatments 2 and 3 were used to create partial lifetables for *B. argentifolii* populations on caged poinsettia plants in the presence and absence of *E. formosa*.

Calculating Marginal Probabilities of Mortality and k-Values

Marginal attack rates were calculated to separate mortality from each observed source (unknown death, disappearance, and parasitism). The marginal probability of attack is the number of pests that would be attacked by an agent in the absence of all other contemporaneous mortality agents. It is the net probability of dying (as opposed to the crude probability of dying, which is the apparent mortality calculated from

numbers observed to die from a cause) (Royama 1981, Elkinton *et al*. 1992). The marginal probability of attack was calculated for each factor (Table 1) as:

$$m_i = 1-(1-d)^{d_i/d}$$

where m_i= marginal probability of attack from the *i*th cause, d_i= death rate from the *i*th cause and d= death rate from all causes combined (Elkinton *et al*. 1992).

Killing powers or k-values (the negative logarithm of the proportion surviving in each stage) for each mortality factor were determined as:

$$k_i = -\log_{10}(1\text{-marginal probability of attack by the } i\text{th cause}),$$

where k_i= the k-value for the *i*th cause of mortality.

Wasp Releases, Percent Emergence and Emergence Pattern

Parasitoid releases in both the cages and open greenhouse began immediately after the biological control greenhouse was filled with poinsettias. Bunting Biological North America supplied release cards, each bearing 100 parasitized *T. vaporariorum* pupae. The number of cards put into the biological control greenhouse each week ranged from 140 to 268. Cards were hung on strings stretched between the pots and tied at the same height as the pot rims. In this position, wasps emerged below the foliage and were assumed to move upwards through the canopy searching for *B. argentifolii* nymphs.

Every week, all cards were removed from the biological control greenhouse before new cards were put out. Ten cards were randomly selected from those recovered and soaked in water and detergent for 30 min in the laboratory. Parasitized greenhouse whitefly and exuviae were rubbed off the card with a size 2 insect pin, and the mean number of parasitized greenhouse whitefly per card and the percent emergence of wasps were determined for each weekly release. These values were used to calculate the mean number of wasps released per plant per week. On two occasions, the emergence pattern of the parasitoid was determined by counting the number of wasps that emerged from the cards each day in the laboratory.

Cost Analysis

The cost of biological control vs. the cost of insecticides was determined by analyzing insecticide application records for both the insecticide and biological control greenhouses. The price of purchasing the required number of parasitoids was based on an averaged estimate from suppliers of beneficial insects. Labor costs associated with releasing parasitoids and applying insecticides were not included in the analysis.

Sales Inspection

At week 16 of the growing period, the finished plants were shipped to retailers. To determine the final whitefly density, six leaves on 15 plants from both the biological control and the insecticide greenhouses were inspected. The number of live nymphs and pupae on each leaf was recorded.

TABLE 1. PARTIAL LIFETABLES FOR *B. ARGENTIFOLII* FOR EACH OF THE THREE TREATMENTS IN THE BIOLOGICAL CONTROL GREENHOUSE.

Stage	l_x[1]			d_x			f_{dx}	q_x			Marginal Probability of Attack			k-Value		
	T_1[2]	T_2	T_3	T_1	T_2	T_3		T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
I_1/I_2[3]	204	192	286	55	52	195	unknown death:	44	24	154	0.22	0.13	0.54	0.22	0.14	0.60	0.11	0.06	0.39
							disappeared:	11	28	41	0.05	0.15	0.14	0.06	0.16	0.21	0.03	0.07	0.10
I_3	149	140	91	20	1	23	unknown death:	20	1	21	0.13	0.01	0.23	0.13	0.01	0.23	0.06	0.003	0.12
							disappeared:	0	0	2	0.00	0.00	0.02	0.00	0.00	0.03	0.00	0.00	0.01
I_4	129	139	68	17	7	27	unknown death:	16	6	24	0.12	0.04	0.35	0.12	0.04	0.36	0.06	0.02	0.20
							disappeared:	1	1	3	0.01	0.01	0.04	0.01	0.01	0.05	0.06	0.02	0.02
P	112	132	41	83	4	35	unknown death:	3	4	1	0.03	0.03	0.02	0.05	0.03	0.05	0.02	0.01	0.02
							disappeared:	1	0	0	0.01	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00
							parasitized:	79	0	34	0.71	0.00	0.83	0.72	0.00	0.85	0.56	0.00	0.81
A	29	128	6																

[1] l_x= Number entering the stage. d_x= Number dying in the stage. f_{dx}= Factor responsible for observed mortality. q_x= Proportion dying in that stage (see Southwood 1978 for more information on parts of lifetables).

[2] T_1= Lifetable for *B. argentifolii* on naturally infested poinsettia plants in the biological control greenhouse (Treatment one). Mortality from 1st/2nd instar to adult was 85.78%.

T_2= Lifetable for *B. argentifolii* on poinsettia plants inside mesh bags which excluded *E. formosa* in the biological control house (Treatment 2). Mortality from 1st/2nd instar to adult was 33.33%.

T_3= Lifetable for *B. argentifolii* on poinsettia plants inside mesh bags into which three *E. formosa* were introduced each week in the biological control greenhouse (Treatment 3). Mortality from 1st/2nd instar to adult was 97.90%.

[3] I_1/I_2= *B. argentifolii* first and second instar, I_3= third instar, I_4= fourth instar, P= pupae, A= adults.

RESULTS

Population Density Estimates and Lifetable Construction

Whitefly densities on caged poinsettia plants onto which one female whitefly had been introduced at the start of the experiment (Treatment 2, Fig. 1A) increased steadily, reaching 246 nymphs and pupae per plant by week 10. In contrast, whitefly densities on caged plants inoculated with three adult *E. formosa* per week (Treatment 3) were substantially lower by week six (Fig. 1A) and averaged only 20 live nymphs and pupae per plant in week ten, 8% of the recorded density on the control plants (Treatment 2) (Fig. 1A).

Whitefly populations on uncaged plants in the biological control greenhouse remained below six nymphs and pupae per plant until week 7 of the experiment. The number of immature whiteflies on these plants increased to approximately 39 nymphs and pupae per plant by week 10 (Fig. 1B). At that time parasitoid releases were terminated, and two insecticide applications were made. In contrast, whitefly densities in the insecticide greenhouse increased to 32 nymphs and pupae per plant by week 4, but declined to low densities (< 5 nymphs and pupae per plant) by week six (Fig. 1B). This low level of infestation was maintained in the insecticide greenhouse through week 10 because of regular insecticide applications (see Fig. 1C).

The percentage of plants that were infested reached 100% in weeks 4 and 6 for the insecticide greenhouse and the biological control greenhouse respectively. The percentage of *B. argentifolii*-infested plants steadily declined in the insecticide greenhouse after week six. This trend was not observed in the biological control greenhouse (Fig. 1C).

In the biological control greenhouse, 86% of the whitefly nymphs that were followed individually died prior to adult emergence (see footnote Table 1); however, nymphal densities ultimately exceeded the grower's damage threshold for the crop. In Treatment 2, in which a *B. argentifolii* population developed on caged poinsettia plants in the absence of *E. formosa*, 33% of the nymphs died of natural causes (see footnote Table 1). In Treatment 3, where three *E. formosa* per week were released into identical cages, the level of nymphal mortality was 98% (see footnote Table 1).

Marginal Probabilities of Mortality and k-Values

Mortality from three factors (parasitism, unknown death, and disappearance) occurred contemporaneously. The marginal probability of attack and k-values for these factors in Treatments 1-3 are presented in Table 1. Treatment 3 consistently exhibited the highest levels of mortality for each of the immature lifestages (Table 1). The highest observed k-values were those for pupae which exhibited high levels of parasitism in Treatments 1 and 3 (Table 1).

Wasp Releases, Percent Emergence and Emergence Pattern

Number of parasitized pupae per card, percentage of wasps emerging, number of release cards put into the greenhouse each week, number of wasps released per plant, and number of wasps released per m^2 are shown in Table 2. Two shipments of *E. formosa* exhibited different emergence patterns in the laboratory. Group one exhibited a unimodal emergence pattern with wasp numbers peaking 5 days after receipt (mean daily maximum temperature= 24.7°C ± 0.7; mean daily minimum temperature= 23°C ±0.7) (Fig. 2A). Group two exhibited a bimodal emergence pattern, with wasp num-

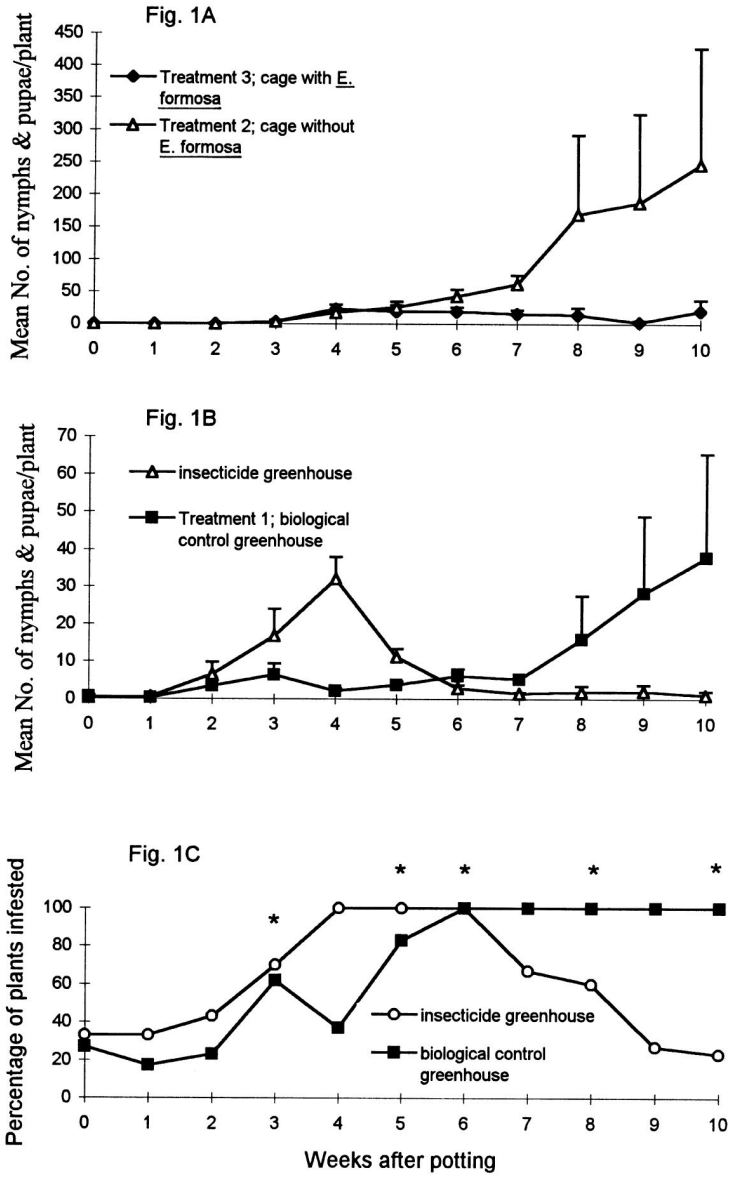
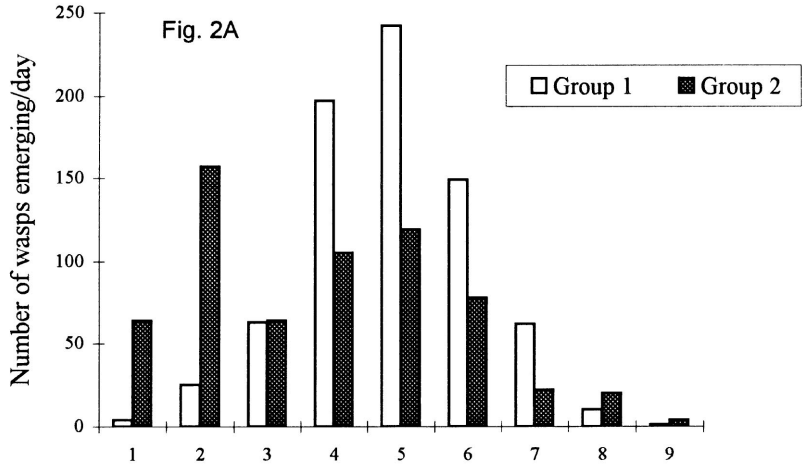


Figure 1. (A) The mean number of *Bemisia argentifolii* nymphs and pupae (± S.E.M.) on caged poinsettia plants in the absence (Treatment 2) and presence of *E. formosa* (Treatment 3). (B) The mean number of *Bemisia argentifolii* nymphs and pupae (± S.E.M.) per plant in the insecticide house and the biological control house (Treatment 1). (C) Percentage of plants infested with adult or immature stages of *Bemisia argentifolii* in the biological control and insecticide greenhouse; asterisk indicates dates of insecticide applications in the insecticide greenhouse.

TABLE 2. WEEKLY PERCENTAGE EMERGENCE OF *E. FORMOSA*, MEAN NUMBER OF PARASITIZED PUPAE PER CARD, TOTAL NUMBER OF CARDS WITH PARASITIZED *T. VAPORARIORUM* PUT INTO GREENHOUSE EACH WEEK, NUMBER OF ADULT PARASITOIDS EMERGING PER PLANT AND PER M^2, AND NUMBER OF PLANTS IN THE BIOLOGICAL CONTROL GREENHOUSE FOR EACH WEEK OF THE TRIAL.

Week#	Mean No. Parasitized Pupae/Card	% Wasp Emergence	No. Cards/ Week	Wasp No./ Plant/Week	No. Wasps/ M^2	No. Plants/ Greenhouse
1	104.5	84%	195	5.44	101	3144
2	101.1	81%	220	5.72	106	3144
3	105.8	82%	222	6.12	113	3144
4	103.9	79%	255	6.66	123	3144
5	99.2	69%	260	6.34	104	2800
6	99.6	71%	140	3.53	58	2800
7	99.2	76%	160	4.32	71	2800
8	104.6	76%	253	7.17	118	2800
9	97.1	70%	268	7.43	107	2455



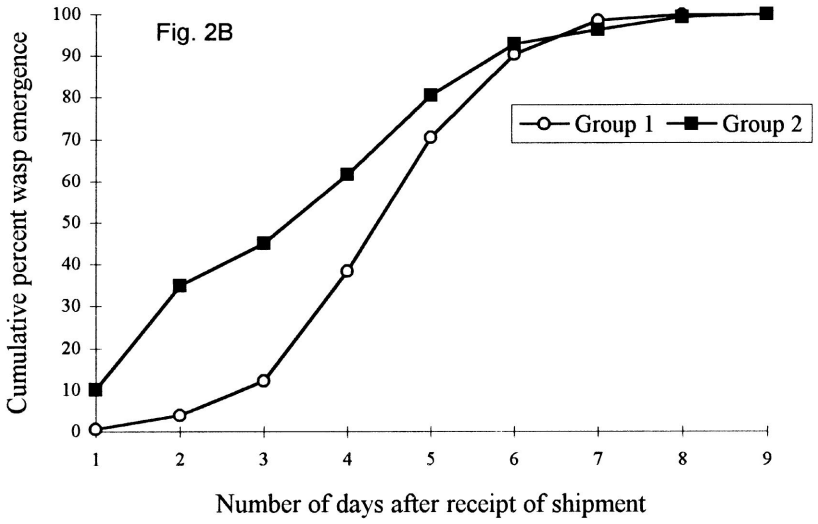


Figure 2. (A) Daily emergence of *Encarsia formosa* in the laboratory and cumulative percent (B) emergence of *Encarsia formosa* in the laboratory.

bers peaking on days 2 and 5 after receipt (mean daily maximum temperature= 24.4°C ± 0.7; mean daily minimum temperature= 23.3°C ± 0.3) (Fig. 2A). Over 97% of *E. formosa* had emerged after 7 days (Fig. 2B). In the biological control greenhouse,

the mean daily maximum temperature was 22.8°C ± 0.6; mean daily minimum temperature= 17°C ± 0.5.

Cost Analysis

The costs of controlling *B. argentifolii* with *E. formosa* or insecticides are presented in Table 3. Weekly releases of 4-7 *E. formosa* per plant for nine weeks, followed by two insecticide applications, were 9.5 times more expensive than using insecticides alone.

Sales Inspection

At week 16 of the growing period, the numbers of live nymphs on plants from both the biological control and insecticide greenhouse were low at the time of shipment. The mean numbers of nymphs per leaf were 0.01 ± 0.11 in the insecticide greenhouse and 0.02 ± 0.21 in the biological control greenhouse. There was no obvious difference in foliage quality between the biological control and the insecticide greenhouses.

DISCUSSION

Release of high numbers of *E. formosa* (4-7 wasps per plant per week) did not successfully control a population of *B. argentifolii* on poinsettia, even though parasitoid releases were initiated at the beginning of the growing period when the infestation of *B. argentifolii* nymphs was very low (0.09 per leaf or 0.51 per plant).

The high mortality (98%) observed in Treatment 3 (caged plants with wasps) (Table 1) may have occurred because cages prevented wasps from abandoning plants, thereby increasing residence and searching time. The differences between the observed k-values (Table 1) of Treatment 2 (caged plants with no wasps) and those of Treatment 1 (uncaged plants) and Treatment 3 (caged plants with wasps), with respect to unknown death for all nymphal stages, may be due to aborted parasitism (in older nymphs) or host feeding by *E. formosa*. In addition, some whitefly death observed in Treatment 3 may have resulted from superparasitism.

Another problem inherent with the use of cages to enclose single plants is the need to introduce adult whiteflies. An introduction rate of just 1 female and 1 male per

TABLE 3. COMPARISON OF THE COSTS OF WHITEFLY CONTROL IN THE INSECTICIDE GREENHOUSE AND THE BIOLOGICAL CONTROL GREENHOUSE[1].

	Insecticide House	Biological Control House
Total cost of sprays	$268.47	$43.28
Total cost of *E. formosa*	NA	$2520.00
Total treatment cost	$268.47	$2563.28
Treatment cost per plant	$0.09	$1.02
Cost m^2	$1.58	$15.08

[1]Insecticide costs are based on 1993 catalogue prices. The *E. formosa* price was based on a rate of $12.00 per 1000 wasps.

Insecticide costs per m^2 in Massachusetts range from $0.32 - $2.26 in poinsettia crops [unpublished University of Massachusetts Integrated Pest Management Program Annual Report (1994)].

plant to establish an experimental population resulted in the caged plants having an initial adult whitefly density nine times that of the biological control greenhouse; before *E. formosa* was released, the mean number of adult whiteflies in the biological control house was 0.22 ± 0.45 adults per plant. Consequently, this may have exaggerated the observed densities in the control cages (Treatment 2). However, this would not affect comparisons between Treatments 2 and 3, as both were inoculated with equal numbers of whiteflies.

The limited control provided by *E. formosa* was 9.5 times more expensive than insecticides on a per m^2 basis (Table 3). Albert & Sautter (1989) achieved cheaper control of *B. tabaci* (the strain of whitefly was not identified) on poinsettia with *E. formosa* than with chemicals, but *T. vaporariorum*, a preferred host for *E. formosa*, was present in the crop. This may have affected parasitoid population levels in the greenhouse.

At sale of the crop, whitefly densities in the chemical greenhouse and biological control greenhouse were 0.01 ± 0.11 and 0.02 ± 0.21 nymphs per plant respectively. Plants from both houses were marketed successfully. In the biological control greenhouse, insecticide use was reduced by 75% by release of wasps (from eight to two insecticide applications), but pest control costs were increased from $0.09 to $1.02 per plant.

Several agronomic practices associated with poinsettia production should favor biological control of *B. argentifolii* in Massachusetts. First, poinsettias are grown from June (if cuttings are being produced) until December and entire greenhouses are devoted to poinsettia production. Monocultural production simplifies pest management because *B. argentifolii* is the only arthropod causing foliar damage, and this nullifies incompatible management programs for pest complexes (Heinz & Parrella 1994a, Parrella *et al*. 1991).

Second, the majority of growers in Massachusetts purchase poinsettia cuttings in July or August from suppliers who typically sell plants with very low densities of adult and immature *B. argentifolii*. Therefore, initial *B argentifolii* densities are sufficiently low that a favorable ratio of parasitoids to whiteflies could be established. Third, fungal diseases of poinsettia foliage can be controlled with fungicides that are compatible with biological control agents (Parrella *et al*. 1991). Fourth, winters in the northeastern USA prevent continual immigration of *B. argentifolii* into greenhouses from outdoor host plants, and growers need only manage the whitefly population that had established in the greenhouse before the onset of cold weather.

In view of these considerations, two major constraints to successful biological control of *B. argentifolii* on commercially grown poinsettia in Massachusetts are: (1) the commercial non-availability of an effective natural enemy for *B. argentifolii*, and (2) lack of information as to which release strategies would maximize the impact of a suitable control agent. A suitable release program should span the entire window of pest susceptibility to ensure maximum mortality by host feeding and parasitism. Variable release rates and timings may be necessary to achieve this objective as foliage density, pest density, and levels of parasitism change over the season. Variable release rates of a parasitoid may result in higher levels of parasitoid recycling through reproduction. Natural reproduction in the greenhouse could augment weekly releases and reduce the cost of parasitoid releases.

Complete reliance on biological control may not be feasible for this ornamental crop, but incorporation of natural enemies in the context of an IPM program for poinsettia should be an attainable goal. Colonies of aphelinid parasitoids that attack *B. argentifolii* exist at several research institutes in the United States. Further work in greenhouses is needed to evaluate the efficacy of these parasitoids for *B. argentifolii* control on poinsettia.

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