EVALUATION OF *SERANGIUM PARCESETOSUM* (COLEOPTERA: COCCINELLIDAE) FOR BIOLOGICAL CONTROL OF SILVERLEAF WHITEFLY, *BEMISIA ARGENTIFOLII* (HOMOPTERA: ALEYRODIDAE), ON POINSETTIA

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ABSTRACT

Control of silverleaf whitefly (*Bemisia argentifolii* Bellows & Perring) on greenhouse poinsettia with biological agents has been unreliable. *Serangium parcesetosum* Sicard, a coccinellid predator, appears to have great potential for silverleaf whitefly control. In our study, dynamic changes in *B. argentifolii* populations on caged poinsettia in response to *S. parcesetosum* were monitored. Silverleaf whiteflies were introduced to caged poinsettias at 1 or 10 adults per plant and 6 weeks later *S. parcesetosum* were introduced at 0, 2 or 4 adults per plant. Within 2 weeks of *Serangium* release whitefly mortality increased dramatically, and for the ensuing 10 weeks whitefly levels remained at or near those observed at time of predator release. Beetle larvae were observed 2 to 10 weeks after *Serangium* release when prey was initially high but not when prey was initially low. Thus, whitefly control was primarily due to prolonged survival and continuous feeding of individual beetles. Our data suggest that *Serangium* may work well in a multiple species biological control program for whiteflies on poinsettia. However, further study is needed on multiple species interactions within the host (pest/plant) species, and on release management strategies.

Key Words: Population dynamics, caged study, predator, prey

RESUMEN

El control de la mosca blanca (*Bemisia argentifolii* Bellows & Perring) en poinsetias de invernadero con agentes biológicos ha sito errático. *Serangium parcesetosum* Sicard, un predador coccinélido, parece tener gran potencial para el control de *B. argentifolii*. En nuestro estudio, cambios dinámicos en poblaciones de *B. argentifolii* en poinsetias enjauladas en respuesta a *S. parcesetosum* fueron observados. Las moscas blancas fueron liberadas en poinsetias enjauladas de 1 a 10 adultos por planta y 6 semanas después *S. parcesetosum* fueron liberados de 0,2, o 4 adultos por planta. Dentro de 2 semanas desde la introducción de *Serangium* la mortalidad de la mosca blanca incremento dramáticamente, y por las próximas 10 semanas los niveles de moscas permanecieron en o cerca de aquellos observados al momento de introducción del predador. Larvas de escarabajos fueron observadas de 2 a 10 semanas después de la liberación de *Serangium* cuando el numero de presa estaba inicialmente alto pero no cuando el numero de presa estaba inicialmente bajo. Por lo tanto, el control de la mosca blanca fue debido principalmente a supervivencia prolongada y alimentación continua de escarabajos individuales. Nuestros datos sugieren que *Serangium* pudiera servir bien en un programa de control de especies múltiples de moscas blancas en poinsettia. Sin embargo, mas investigación es necesaria sobre las interacciones de especies múltiples dentro la especie (plaga / planta), y en estrategias de control de liberación.

Silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring (Homoptera: Aleyrodidae, also known as the sweetpotato whitefly, *B. tabaci* (Gennadius) Biotype B), is the most important arthropod pest on greenhouse grown poinsettias (Ecke et al. 1990). Poinsettia cuttings often arrive infested with whitefly nymphs at levels well below economic thresholds (Helgesen & Tauber 1977; Hoddle et al. 1999) but whitefly populations rapidly increase to exceed economic thresholds in the absence of effective controls.

Poinsettia is the single largest potted flowering greenhouse crop grown in the U.S. in terms of both number of pots produced (>59 million) and annual wholesale value (>$220 million dollars) (USDA 1997). It appears to be a good candidate-crop for biological control because it is produced as a monoculture and has few serious pest problems other than *Bemisia argentifolii* (Parrella et al. 1991). In practice however, economic biological control systems capable of suppressing *B. argentifolii* to the low thresholds required for ornamental crops have been elusive (Parrella et al. 1991). For example, Hoddle et al. (1997a) reported that when *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae) was used as the control agent, 23 to 70% of poinsettia plants were infested with immature whitefly at the end of the season. By com-

parison they observed 30% of poinsettias in commercial retail outlets were infested with immature whitefly. With the *E. formosa* Beltsville strain, end-of-season whitefly infestation ranged from 77 to 100% of plants under various release rates compared to 28% of plants observed in commercial retail outlets (Hoddle et al. 1997b). Heinz & Parrella (1994) observed satisfactory whitefly control with a combination of *Encarsia luteola* Howard and *Delphastus pusillus* LeConte (Coleoptera: Coccinellidae) but at a cost 5-times higher than insecticide-based control. With weekly releases of *Eretmocerus eremicus* n. sp. Rose & Zolnerowich (Hymenoptera: Aphelinidae), Hoddle et al. (1998) reported that 73 and 83% of plants were infested with immature whitefly at the end of the season compared to only 28% of plants in commercial retail outlets. These studies underscore the need for continued evaluation of promising new biological control agents.

Serangium parcesetosum Sicard is a coccinellid predator that has demonstrated potential for the biological control of silverleaf whitefly (Legaspi et al. 1996). This species was originally collected from India in 1929 for release as a biological control agent of citrus whitefly, *Dialeurodes citri* Ashmead (Aleyrodidae), in the Union of Soviet Socialist Republics (Kapur 1954; Timofeyeva & Nhuan 1979). As a result of the success in that biological control program, and because of its rediscovery during foreign exploration in Podumbu, India, *S. parcesetosum* is currently being researched as a predator of silverleaf whitefly. *Serangium parcesetosum* (herein referred to as *Serangium*) has been known from the available literature to feed mainly on citrus whitefly, although in field trials in the U.S. it has also attacked silverleaf whitefly (M. C., unpublished). All of the known coccinellids belonging to the tribe Serangiini are obligate predators of whiteflies, or in a few cases, scale insects (Gordon 1985).

Laboratory studies to date show that both larvae and adults of *Serangium* are voracious feeders, capable of consuming large numbers of immature silverleaf whiteflies in short periods of time. Legaspi et al. (1996) showed adults consumed approximately 400 whitefly nymphs in a 24h period. *Serangium* larvae consumed 25 to 50 whitefly eggs or nymphs in 24 h, depending on the larval stage (M. C., unpublished). Furthermore, Legaspi et al. (1996) determined the cumulative lifetime predation rate to be approximately 5,000 whitefly nymphs per adult *Serangium*. These data suggest that *Serangium* may have the potential to control silverleaf whitefly at moderate to high levels. However, low whitefly infestation levels may not be adequate to sustain *Serangium* reproduction or even adult survival.

In this study we investigate the effects of *Serangium* release rates on the population dynamics of *B. argentifolii* on caged poinsettia.

Materials and Methods

Four rooted poinsettia (*Euphorbia pulcherrima* Willd. Ex. Klotzsch. cv. 'Freedom Red') cuttings were transplanted into individual 30 cm pots on 16 July 1997 in the University of Connecticut research greenhouse range. Each exclusion cage was constructed of a white organdy sleeve supported by 75 cm bamboo plant stakes and placed around each pot. Cages were sealed above the four poinsettia plants and below the lip of each pot. Velcro strips were used on two vertical seams, one on each side of the cage, to facilitate access to the plants.

After plants were established in the pots, silverleaf whiteflies were introduced on the caged poinsettia plants on 23 Aug. 1997 at a rate of either 1 or 10 adults per plant (equivalent to 4 or 40 adult whiteflies per cage). On 3 Oct., *Serangium parcesetosum* were introduced into cages at 0, 2 and 4 adults per plant (equivalent to 0, 8 and 16 *Serangium* per cage, respectively). The result was a 2×3 factorial design with initial levels of either 1 or 10 whiteflies per plant and 0, 2, or 4 *Serangium* per plant. Treatments were arranged in a randomized complete block with five replications. Poinsettias in separate cages, but without either prey or *Serangium*, were used to evaluate the effects of whitefly on plant growth. Prey and *Serangium* were shipped overnight from the USDA APHIS Mission Plant Protection Center (Mission, TX) in insulated containers with ice packs. A small Hibiscus plant infested with whitefly pupae was shipped just prior to emergence of the adults. Whiteflies were held in a controlled temperature chamber until adults emerged within 48 h. Newly emerged whitefly adults were aspirated and then transferred into the treatment cages. *Serangium* were shipped as adults in paper cartons with organza lids for ventilation. Each container held 25 adults. A Hibiscus leaf with whiteflies was included in each container for *Serangium* feeding in transit. Immediately upon arrival, *Serangium* beetles were introduced into treatment cages using a fine camelhair paintbrush.

Monitoring Silverleaf Whitefly and *Serangium* Populations

Two leaves per plant (8 leaves per cage) were harvested weekly from 3 Oct. to 5 Dec. 1997. Leaves were selected from the strata of the plant canopy with the greatest number of late instar whitefly nymphs; the sample strata was determined each week just prior to leaf harvest. A 25 cm^2 section of each leaf was examined under a dissecting microscope and the number of whitefly eggs and the number of live and dead nymphs and pupae were recorded. Immature whitefly were judged dead when they appeared discolored or desiccated, or when the empty integument

showed evidence of *Serangium* feeding. As leaf samples were harvested they were visually checked for *Serangium*, and all larvae and adults were returned to their respective cages.

At the conclusion of the study, 8 Dec. 1997, a stratified leaf sample was collected from each cage and whitefly population and percent mortality were determined. The stratified sample consisted of two leaves per cage from each of four locations on the plant: bracts, upper canopy, middle canopy and lower canopy. The two leaves per stratum were collected randomly and examined for whitefly life stages with a dissecting microscope. The poinsettia plants were then destructively harvested and total laminar surface area (leaves plus bracts) was determined for all plants in each treatment using a LI-COR 1600 leaf area meter (LI-COR, Inc. Lincoln, NE). Plants were separated into bracts, leaves and stems and dried in a forced-air oven at 70°C for one week. Plant dry mass was then recorded.

Data Analysis

The mean density of whitefly eggs, nymphs, and pupae (per 25 cm^2) was calculated for each treatment. Percent whitefly mortality was calculated as follows [1]:

[(dead nymphs + dead pupae)/(live nymphs + live pupae + dead nymphs + dead pupae)]*100

Equation [1]

Bartlett's test for homogeneity of variance was conducted on all data (Bartlett, 1937). Non-normal data for whitefly and *Serangium* counts and for plant measurements were transformed using the formula: log10 (x + 1), with x representing dependent variables. Non-normal data for whitefly mortality were transformed using the formula: Arcsine $(x/100)^{1/2}$, with x representing percent whitefly mortality. Analysis of variance was performed using the Statistical Analysis System (SAS Institute 1995). Insect population data were analyzed as a factorial in a randomized complete block design with five replicates. Plant data (laminar surface area and shoot dry mass) were subjected to a two-way analysis of variance with seven treatments and five replicates. The treatments included the six whitefly-*Serangium* combinations and a control with no predators or prey.

The Greenhouse Environment

Plants were grown under standard cultural practices for poinsettias (Ecke et al. 1990). Environmental conditions were recorded on a Campbell Scientific 21× Datalogger (Campbell Scientific, Logan, UT) at 1-minute intervals. LI-COR 190-SA quantum sensors (LI-COR, Inc. Lincoln, NE) were used to monitor photosynthetic photon flux and copper-constantan thermocouples were used to monitor temperature. Light intensity was monitored in the greenhouse immediately above the exclusion cages, and also above the plant canopy within the cages. Air temperature was monitored within the cages in the plant canopy and above the canopy, and directly outside of the cages. For the duration of the study, daily photosynthetic photon flux (±SE) averaged 9.1 ± 0.5 $mol \cdot m^{-2} \cdot day^{-1}$ in the greenhouse above the cage and 8.0 ± 0.5 $mol \cdot m^{-2} \cdot day^{-1}$ above the plant canopy in the cage. Air temperature in the cage and in the plant canopy (in the cage) averaged 21.3 ± 0.1°C and 21.4 ± 0.2°C (respectively) and the ambient air temperature in the greenhouse (outside the cage) averaged 22.4 ± 0.2°C.

Results

Initial silverleaf whitefly release rates greatly affected final population densities of all whitefly life stages (Figs. 1 & 2; df = 1,16; eggs F = 12.3; P = 0.025, nymphs F = 32.8; P=0.005, pupae F = 10.7; P = 0.031). This effect was most evident when whitefly populations were left uncontrolled. For example, the final density of nymphs was approximately 10-times higher in cages with initial release rates of 10 whitefly adults per plant than in cages with initial release rates of 1 whitefly adult per plant (Fig. 1b). A similar pattern was observed

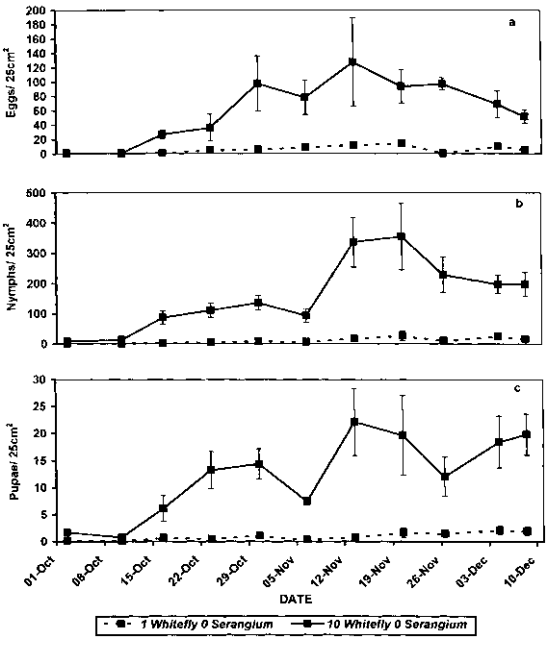

Fig. 1a-c. Changes in silverleaf whitefly life stages on poinsettia plants over time in the absence of a biological control agent. Plants were initially inoculated with either 1 or 10 whitefly adults per plant on 23 August. Stages include; a) eggs, b) nymphs, and c) pupae. Vertical bars denote standard error of the mean.

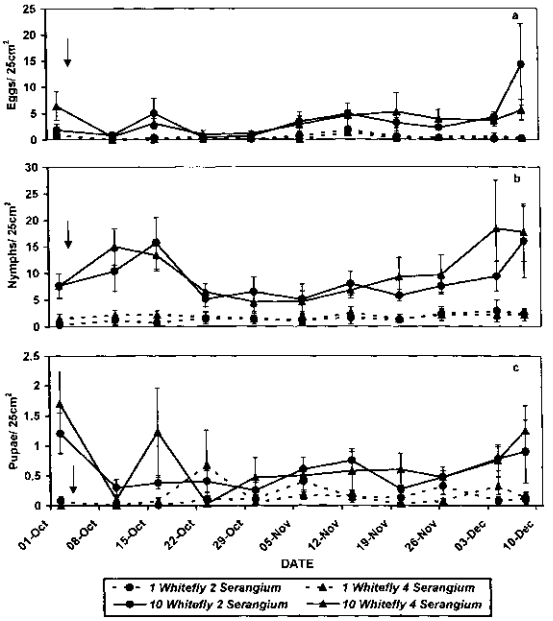

Fig. 2a-c. Changes in silverleaf whitefly life stages on poinsettia plants over time in response to different initial *Serangium parcesetosum* release rates. Poinsettia plants were initially inoculated with either 1 or 10 adult whiteflies per plant on 23 Aug., and 6 weeks later *S. parcesetosum* was introduced at 2 or 4 adults per plant. Whitefly stages include; a) eggs, b) nymphs, and c) pupae. Arrows denote *Serangium* introduction on 3 October. Vertical bars denote standard error of the mean.

with respect to both whitefly eggs (Fig. 1a) and pupae (Fig. 1c) at the 1 and 10 whitefly release rates.

A single release of adult *Serangium* beetles was extremely effective at stopping the growth of whitefly populations on poinsettias (Fig. 2). Six weeks after *Serangium* were introduced (13 Nov.), whitefly population densities were dramatically higher in cages without *Serangium* (Fig. 1) than in cages with *Serangium* (Fig. 2) [df = 2,16; eggs F = 13.9; P = 0.0003, nymphs F = 19.3; P = 0.0001, pupae F = 9.4; P = 0.002]. *Serangium* effectively maintained immature whitefly densities at or near those observed at the time of predator introduction (Fig. 2). For example, nymphal prey densities were 0.7 and 8.0 per 25 cm^2 of leaf surface in the 1 and 10 whitefly cages (respectively) when *Serangium* were introduced (Fig. 2b). These populations remained nearly constant when exposed to either the 2 or 4 beetles per plant release rates (Fig. 2b), while nymphal densities increased up to 70 fold in the ensuing 10 week period without *Serangium* (Fig. 1b). Within both the 1 and 10 whitefly treatments, similar final prey densities were observed for the high and low *Serangium* treatments (Fig. 2).

A dramatic increase in prey mortality was observed within 14 days (16 Oct.) of *Serangium* release (Fig. 3; df = 2,16; F = 49.5; P = 0.0001). In cages with an initial release rate of 10 whitefly adults per plant, mortality reached 57 and 69% for the 2 and 4 *Serangium* treatments (respectively) on 16 Oct. (Fig. 3a). Whitefly mortality in these treatments peaked at about 85% during the 23 Oct. to 6 Nov. time period and was approximately 55% at final harvest. Over the 10 week experimental period, prey mortality averaged 60% (±4.4% SE) with *Serangium* present in cages with the 10 whitefly treatments.

In cages with an initial whitefly release rate of 1 adult per plant, the increase in prey mortality was less dramatic than in the 10 whitefly treatments (Fig. 3a). For example, mortality was only 10 and 38% for the 2 and 4 *Serangium* treatments (respectively) on 16 Oct. but reached approximately 50 and 80% on 30 Oct. At final harvest in the 1 whitefly treatment, prey mortality rates were about 20 and 60% with 2 and 4 *Serangium* (respectively). Over the 10 week experimental period, whitefly mortality averaged 24% (±3.9% SE) with an inoculation of 2 *Serangium* per plant and 52% (±3.9% SE) with 4 *Serangium* per plant. In contrast, mortality in cages without *Serangium*

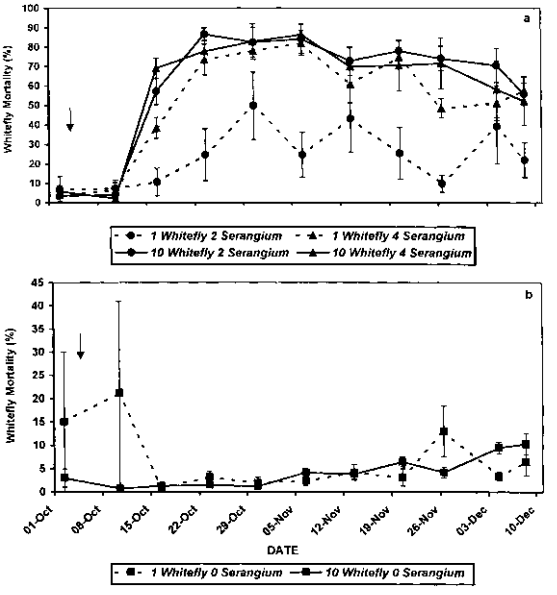

Fig. 3a-b. Changes in silverleaf whitefly mortality (%) on poinsettia plants over time in response to *Serangium parcesetosum* release rates of 2 or 4 adults per plant (a), or in the absence of biological control agents (b). Poinsettia plants were initially inoculated with either 1 or 10 adult whiteflies per plant on 23 Aug., and 6 weeks later *S. parcesetosum* was introduced at 0, 2, or 4 adults per plant. Percent whitefly mortality was calculated using the equation: [(dead nymphs + dead pupae)/(live nymphs + live pupae + dead nymphs + dead pupae)]*100. Arrows denote *Serangium* introduction on 3 October. Vertical bars denote standard error of the mean.

averaged 4.2% (±0.6% SE) in the 10 whitefly cages and 6.8% (±2.3% SE) in the 1 whitefly cages during the final 10 weeks of the study (Fig. 3b).

At final harvest, live immature whiteflies were observed throughout the plant canopy (Table 1). In cages without *Serangium*, approximately 70% of whiteflies were located in the upper leaf strata and on the red-colored poinsettia bracts. With *Serangium* present prey were more uniformly distributed in the leaf/bract strata in the 1 whitefly cages than in the 10 whitefly cages. This may indicate that *Serangium* needed to move more quickly to the upper canopy to find prey when prey populations were low but not when populations were high. In the 1 whitefly treatment cages with *Serangium*, the average live immature whitefly counts observed throughout the canopy were about 16% of those without predators (Table 1). In the 10 whitefly treatment cages with *Serangium*, the average live immature prey counts were about 10% of those without predators. Average live immature prey counts were similar for both the 2 and 4 *Serangium* treatments in all four strata of the plant canopy with an initial prey release of 1 per plant (Table 1). Only small differences in the number of live immature whiteflies in the middle and lower leaf strata were observed between the 2 and 4 *Serangium* treatments with an initial whitefly release of 10 per plant.

At final harvest, the highest prey mortality was observed in the lower half of the plant canopy (middle and lower leaf strata v. upper leaf and bract strata) (Table 1). Throughout the plant canopy, the highest mortality consistently occurred in cages with *Serangium* and in cages with high initial whitefly release rates (Table 1).

Very few *Serangium* were recovered from cages at time of final harvest and the total number (larvae + adults) of *Serangium* recovered did not vary with treatment ($P \leq 0.05$). In cages with an initial inoculation rate of 1 prey, only adult *Serangium* were recovered and at an average density of 0.2 and 1.2 per cage for the 2 and 4 *Serangium* release rate treatments, respectively. In cages with an initial inoculation rate of 10 prey, 2 and 2.4 *Serangium* per cage were recovered from the 2 and 4 *Serangium* release rate treatments (respectively) and *Serangium* larva (1.2 per cage) were only observed in the 2 *Serangium* release rate treatment. During the final weeks of this study, whitefly mortality rates declined in all *Serangium* treatments (Fig. 3a) and simultaneously whitefly populations increased (Fig. 2). These data suggest that low *Serangium* counts at final harvest were not indicative of the predator levels that prevailed during the first eight weeks following *Serangium* release when maximum prey control was observed (Fig. 2).

Poinsettia growth was unaffected by whitefly populations in this study. Total laminar surface area (1.6 ± 0.03 m^2/cage, df = 6, 23; $F = 1.99$; $P = 0.11$) and shoot dry mass (84.7 ± 1.9 g/cage, df = 6, 23; $F = 0.86$; $P = 0.54$) were similar for plants in all treatments.

Discussion

Consumers have a low tolerance for insect pests on greenhouse ornamentals like poinsettia. Consequently, high standards must be set when evaluating the effectiveness of natural enemies and their management. Inundative releases of *Encarsia formosa* can produce satisfactory results if introduced in sufficient numbers before whitefly populations begin to build (Hoddle et al. 1997a,b). However, in instances where *Encarsia* fail to control whiteflies, alternative measures are required in order to maintain a salable plant (Parrella et al. 1991; Heinz & Parrella 1994).

In our study, silverleaf whitefly reached damaging populations 6-8 weeks after introduction when left uncontrolled even when initial populations were low (1 adult per plant). Heinz & Parrella (1994) observed a dramatic increase in whitefly populations on greenhouse grown plants (both inside and outside of exclusion cages) after nine weeks exposure to whiteflies even in the presence of weekly releases of *E. luteola*. However, a series of three weekly releases of the predatory beetle *Delphastus pusillus* (1 beetle per plant per week) effectively checked whitefly population growth until the study was ended 3 weeks after the final release. In our study, a single release of 2 *Serangium* per plant effectively checked further increases in prey population for up to 10 weeks.

Heinz & Parrella (1994) recovered several adult *D. pusillus* 3 weeks after the last release, but no evidence of successful predator reproduction was reported. Hoelmer et.al. (1993) reported that *D. pusillus* required 100-150 whitefly eggs per day to initiate and sustain oviposition. In our study, *Serangium* larvae were first observed 2 weeks after adults were released in cages with high initial whitefly levels (data not shown) but not in cages with low initial whitefly levels. In cages with high initial prey levels, *Serangium* larvae were recovered as late as 10 weeks after adults were introduced. Cohen & Brummett's (1997) data suggest that *Serangium* could consume a sufficient number of whitefly immatures during a daily 10 hour feeding to meet the minimum methionine requirement for normal growth and development. This calculation assumes an average handling time of 1 minute per prey item, and as with *D. pusillus* (Hoelmer et al. 1993), it appears from our study that *Serangium* can only reproduce (without nutritional augmentation) under high prey populations.

Legaspi et al. (1996) reported that the average life-span of *Serangium* ranged from 75 days at 20°C to 25 days at 30°C. In our study, typical commercial cropping practices were used, poinsettia

TABLE 1. DENSITY OF LIVE IMMATURE SILVERLEAF WHITEFLY AND INCIDENCE OF WHITEFLY MORTALITY AT FOUR LEVELS IN THE POINSETTIA CANOPY AT FINAL HARVEST.

Initial release rate treatments		Sample strata in poinsettia canopy							
Whitefly	Serangium	Bracts		Upper leaves		Middle leaves		Lower leaves	
(No. per plant)		Whitefly[a] (No. ± SE)	Mortality (% ± SE)	Whitefly (No. ± SE)	Mortality (% ± SE)	Whitefly (No. ± SE)	Mortality (% ± SE)	Whitefly (No. ± SE)	Mortality (% ± SE)
1	0	8.2 ± 4.0	0	49.3 ± 18.5	6.7 ± 3.3	13.5 ± 5.2	8.3 ± 3.3	7.4 ± 4.8	0
1	2	1.5 ± 1.0	5.8 ± 4.9	3.5 ± 1.6	5.7 ± 3.5	2.9 ± 1.7	24.2 ± 10.9	1.9 ± 1.8	10.0 ± 10
1	4	1.8 ± 1.1	5.0 ± 5.0	2.8 ± 2.0	37.1 ± 11.4	3.5 ± 3.0	49.5 ± 17.9	1.3 ± 0.4	31.4 ± 9.8
10	0	104 ± 48	0	477 ± 100	14 ± 4.5	123 ± 30.6	17.1 ± 4.1	168 ± 24.7	4.0 ± 1.6
10	2	18.8 ± 10.2	16.2 ± 9.9	37.2 ± 25.5	52.8 ± 8.9	6.6 ± 0.9	79 ± 2.0	4.7 ± 1.5	69.7 ± 9.6
10	4	16.7 ± 4.5	6.4 ± 4.0	33.7 ± 18.5	38.2 ± 12.7	16.8 ± 6.3	66 ± 11.4	8.4 ± 1.0	64.8 ± 11.5
		Statistical effects							
Source of variation	df	F-value (P-value)	F-value (P-value)	F-value (P-value)	F-value (P-value)	F-value (P-value)	F-value (P-value)	F-value (P-value)	F-value (P-value)
Whitefly	1	17.2 (0.014)	1.2 (0.334)	32.4 (0.005)	7.1 (0.056)	29.4 (0.006)	11.3 (0.028)	47.9 (0.002)	34.7 (0.004)
Serangium	2	6.5 (0.009)	1.3 (0.308)	22.42 (<0.001)	4.7 (0.025)	7.0 (0.007)	7.1 (0.007)	16.0 (<0.001)	17.0 (<0.001)
Whitefly × Serangium interaction	2	0.9 (0.426)	0.4 (0.704)	14.6 (<0.001)	5.2 (0.02)	0.8 (0.456)	2.2 (0.145)	5.7 (0.014)	5.8 (0.014)

[a]Silverleaf whitefly counts are expressed per 25cm^2 of leaf surface.

canopy temperature averaged 21.6°C and the crop matured in a normal time period. Legaspi et.al. (1996) reported a mean life-time cumulative predation of 4909 whitefly (eggs and immature stages) for *Serangium* at a mean temperature of 20°C. Even without reproductive success, the single *Serangium* release in our study effectively prevented prey populations from increasing over a 10-week period (Fig. 1). It appears that this success was largely due to the prolonged survival and continuous feeding of individual adult beetles.

Due to the relatively high number of whiteflies needed to sustain *Serangium* reproduction and the extremely low pest levels tolerated on ornamental crops, it is unlikely that *Serangium* could function effectively as the sole biological control agent on a crop like poinsettia. However, *Serangium* would be especially useful for suppressing localized pest population increases or 'hot spots' in the greenhouse, or as the primary biological control agent on crops such as greenhouse tomato where pest population tolerance levels are higher than for ornamental crops. Based on our data it appears that *Serangium* might be best suited for inclusion in a multiple species biological control approach to silverleaf whitefly management on ornamental crops. As an obligate whitefly predator with a voracious feeding potential, *Serangium* is capable of checking rapid increases in whitefly populations (based on the caged studies herein), thus potentially enabling whitefly parasitoid species such as *Eretmocerus or Encarsia* to suppress whiteflies to acceptable thresholds. Heinz & Nelson (1996) found that *D. pusillus* provided the greatest suppression of silverleaf whitefly when used in conjunction with one or more species of *Encarsia*. In order to determine if *Serangium* would be effective in such a role, interspecific interactions between predator and parasite within the host species (pest/plant), as well as release management strategies, must be investigated.

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