TRI-TROPHIC INTERACTIONS AND PREDATION RATES IN CHRYSOPERLA SPP.[1] ATTACKING THE SILVERLEAF WHITEFLY[2,3]

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ABSTRACT

We investigated tri-trophic interactions among the host plant, the silverleaf whitefly (SLWF), *Bemisia argentifolii* Bellows and Perring, and the predatory lacewings *Chrysoperla rufilabris* (Burmeister) and *C. carnea* (Stephens). *B. argentifolii* females avoided ovipositing on leaves on which *C. rufilabris* larvae were previously located. This tendency appeared to increase with increasing exposure time of the predators to the leaves. We measured the effects of host plant on body weight, developmental duration and survival of the lacewing. SLWF reared on cantaloupes and cucumber appeared to be better quality prey than those reared on poinsettia or lima bean. Lacewings that fed on SLWF reared on cucumbers and cantaloupes developed more rapidly, showed increased survival, and weighed more as newly-emerged adults, compared to those reared on poinsettia and lima bean. Lacewings feeding on SLWF reared on poinsettia and lima bean did not survive to the pupal stage. We concluded that SLWF reared on poinsettia or lima bean may have been nutritionally inadequate for *C. rufilabris* development, or that SLWF may have accumulated plant compounds which were detrimental to the development of the lacewings. There was little difference in predation rates between larvae of *C. carnea* and *C. rufilabris*, although *C. carnea* may consume significantly more whiteflies during certain intervals. Both species consumed from 25 to 75 SLWF daily.

INTRODUCTION

The silverleaf whitefly (SLWF), *Bemisia argentifolii* Bellows and Perring (Homoptera: Aleyrodidae) [sweetpotato whitefly, *Bemisia tabaci* (Gennadius) Biotype "B"] caused crop losses estimated at over $500 million in 1991 (Perring et al. 1993). Crop losses due to this pest in the Imperial Valley of California alone from 1991 to 1994 were estimated at over $300 million (Birdsall et al. 1995). SLWF causes crop loss by direct feeding on phloem, vectoring viral plant pathogens, and by the production of honeydew exudate which is a medium for the growth of sooty mold fungi. SLWF also has a relatively high reproductive potential and a wide host range. Chemical control of SLWF is often insufficient because of insecticide resistance (Dittrich et al. 1990) and because the pest is often situated on the undersides of leaves where insecticides are difficult to apply.

Of the known predators, *Chrysoperla (= Chrysopa) rufilabris* (Burmeister) and *C. carnea* (Stephens) (Chrysopidae) are available commercially. Elkarmi et al. (1987) compared

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[1] Neuroptera: Chrysopidae

[2] Homoptera: Aleyrodidae

[3] This article presents the results of research only. Mention of a commercial or proprietary product does not constitute an endorsement or recommendation for its use by the USDA.

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life histories of the two predators to assess the possibility of mass rearing and also described much of the biology and life history of *C. rufilabris*. Breene et al. (1992) released first and second-instar *C. rufilabris* larvae against SLWF on *Hibiscus rosa-sinensis* L. in the greenhouse and found that releases of 25 or 50 larvae per plant at two-week intervals maintained the plants in marketable condition. Legaspi et al. (1994) studied prey preference and the effect of diet on development of *C. rufilabris* larvae provided SLWF, and a variety of diets, including lepidopteran eggs, aphids and an artificial diet. Lacewing larvae consumed an average of 532 SLWF (mostly eggs) daily, but showed increased survival and development when fed *Sitotroga cerealella* (Olivier) (Gelechiidae) or *Helicoverpa zea* (Boddie) (Noctuidae) eggs.

This is a report of our investigations of the possibility that *C. rufilabris* larvae release materials that reduce oviposition by SLWF. We also investigated the effect of host plant on development, survival and body weight of *C. rufilabris*, and we compared predation rates of *C. rufilabris* and *C. carnea*.

MATERIALS AND METHODS

C. rufilabris larvae were obtained from the USDA-ARS Biological Control of Pests Research Unit rearing facility at Weslaco, TX, and from the Rincon-Vitova Insectary (Oak View, California). Larvae were maintained following the methods described by Nordlund and Morrison (1992). *S. cerealella* eggs used for feeding *C. rufilabris* were also obtained from Rincon-Vitova. The experiments were conducted in an environmental growth chamber at 27°C, 50-60% RH and 14:10 L:D photoperiod, except where noted.

Oviposition deterrents of C. rufilabris. To prevent SLWF infestation, lima beans (*Phaseolus limensis* L.) (cv. 'Jackson Wonder') were enclosed in organdy nets in the greenhouse. Third-instar *C. rufilabris* larvae were isolated into 4-cm diameter petri dishes secured with rubber bands and lined with damp filter paper. Prior to the start of the experiment, larvae were fed *S. cerealella* eggs and an artificial diet, using the methods of Hassan and Hagen (1978) (see Legaspi et al. 1994). A single lima bean leaf was removed from the plant and placed in a plastic petri dish (15-cm diameter) lined with damp filter paper. Leaves were kept moist by surrounding the stem with damp cotton. To confine the predators, Tree Tanglefoot® (The Tanglefoot Company, Grand Rapids, MI) was applied on the leaf perimeter. Ten *C. rufilabris* larvae were placed on each leaf. To prevent cannibalism, *S. cerealella* eggs were placed on each leaf, after which the dishes were secured using rubber bands. The treatments consisted of placing the predators on the bean leaves for 2, 3 or 4-d durations. Each treatment had a corresponding control consisting of bean leaves with *S. cerealella* eggs and Tanglefoot and held for the same duration as the corresponding treatment. All treatments and controls were replicated ten times.

After each exposure treatment, the predators and the petri dish covers were removed. SLWF were collected from tomato (*Lycopersicon esculentum*) and cantaloupe (*Cucumis melo cantalupensis*) cv. 'Perlita', plants in a greenhouse using a modified hand vacuum. The treatment and control leaves were then placed randomly in a cage (≈ 75 x 45 x 45 cm) and exposed to SLWF. Length of exposure to the whiteflies was equal to the length of exposure to the predators, e.g. leaves exposed to the predators for 2 d were also exposed to the whiteflies for 2 d. Number of eggs laid on each leaf were then recorded.

Effect of host plant on development, survival and body weight of C. rufilabris. First to second-instar *C. rufilabris* were isolated individually in plastic petri dishes (4 cm diameter) lined with damp filter paper and secured with a rubber band. *B. argentifolii* were provided as prey by excising the plant tissue containing the immatures and placing this in the petri dishes with the predators. SLWF were reared from poinsettia (*Euphorbia pulcherrima*) cv. 'V-14 Glory' (Ecke Farms, Encinitas, CA), cucumber (*Cucumis sativus*), cantaloupe, and lima bean grown in the greenhouse. Each treatment was replicated ten times. Developmental time was recorded as days required for green lacewing larvae to molt from one instar to the next. Body weight of the larvae was recorded every 3-5 d using a Mettler® (Mettler Instrument Corp., Princeton, NJ) analytical balance AT200 (precision ± 0.01 mg) until the pupal stage was reached. Also, the body weight of the newly-emerging adult was recorded. Survival was calculated as the proportion of larvae alive at specific times.

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Comparison of predation and body weights between C. rufilabris and C. carnea.
This experiment was conducted in the laboratory at ambient temperatures (mean = 24.4°C, range = 23.3 - 26.7°C). Second to fourth-instar SLWF were used as prey. Second-instar *C. rufilabris* and *C. carnea* were separated individually in plastic petri dishes (4-cm diam) lined with damp cellulose support pads and secured with a rubber band. The predator larvae were provided SLWF prey ad libitum (about 50-100 prey per d) on leaf discs throughout their life. Each treatment had ten replicates. After each 24-hr feeding period, the number of prey attacked were recorded. Additional measurements included longevity (number of days the predator was alive), survival (number of predators alive at specific intervals), and developmental time from one larval stage to the next. The predator larvae were weighed twice a week.

Statistical analysis was performed using the Systat© package (version 5.2) (Wilkinson et al. 1992). All tests were judged at $P = 0.05$, and means were separated using Tukey's HSD test. The effect of host plant on body weights was analyzed using a General Linear Model analysis (see Wilkinson et al. 1992). A regression model was defined for body weight as a function of time and type of host plant, where host plant was specified as categorical data.

RESULTS AND DISCUSSION

Oviposition deterrents of C. rufilabris. The effect of exposure of leaves to *C. rufilabris* on SLWF oviposition is shown in Fig. 1. Exposure time of 2 d did not produce significant differences between treatment and control. Leaves treated with the predator were found to have a mean of 72.7 (SE 24.0) eggs compared to the control which had 40.4 (SE 11.9) ($t = 1.2$, $N = 10$, $P > 0.05$). However, exposure times >2d produced significant reductions in the mean numbers of eggs laid by SLWF females. Leaves exposed for 3 d were found to contain 42.9 (SE 16.2) eggs in the treatment, compared to 154.3 (SE 41.8) eggs in the control ($t = 2.48$, $N = 10$, $P < 0.05$).
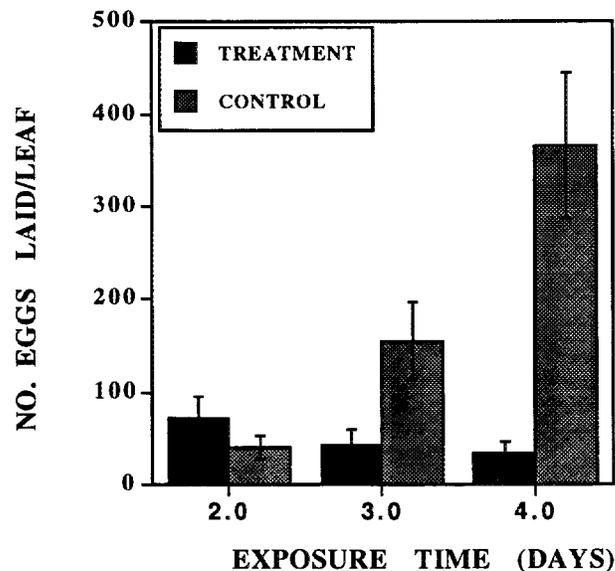

FIG. 1. Oviposition of *B. argentifolii* on control lima bean leaves and leaves on which *C. rufilabris* larvae were confined for 2, 3, or 4 d.

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The tendency of SLWF to avoid ovipositing in the treatment was even more pronounced in the 4-d treatment; mean number of eggs on treated leaves was 34.9 (SE 12.5) compared to 365.9 (SE 79.2) on control leaves ($t = 4.13$, $N = 10$, $P < 0.01$). These results indicate that *B. argentifolii* females tended to avoid ovipositing in leaves on which *C. rufilabris* larvae were previously located. Moreover, this tendency appears to increase with increasing exposure time of both predators and whiteflies to the leaves. These results are in agreement with those found by Butler and Henneberry (1988) and may indicate the presence of an oviposition deterrent (kairomone) produced by the *C. rufilabris* larvae.

Effects of host plant on development, survival and body weight of C. rufilabris. The effect of host plant on the mean body weight (mg ± SE) of *C. rufilabris* is shown in Fig. 2A; means excluded larvae that had either died or pupated. Fig. 2B indicates the size of each sample.
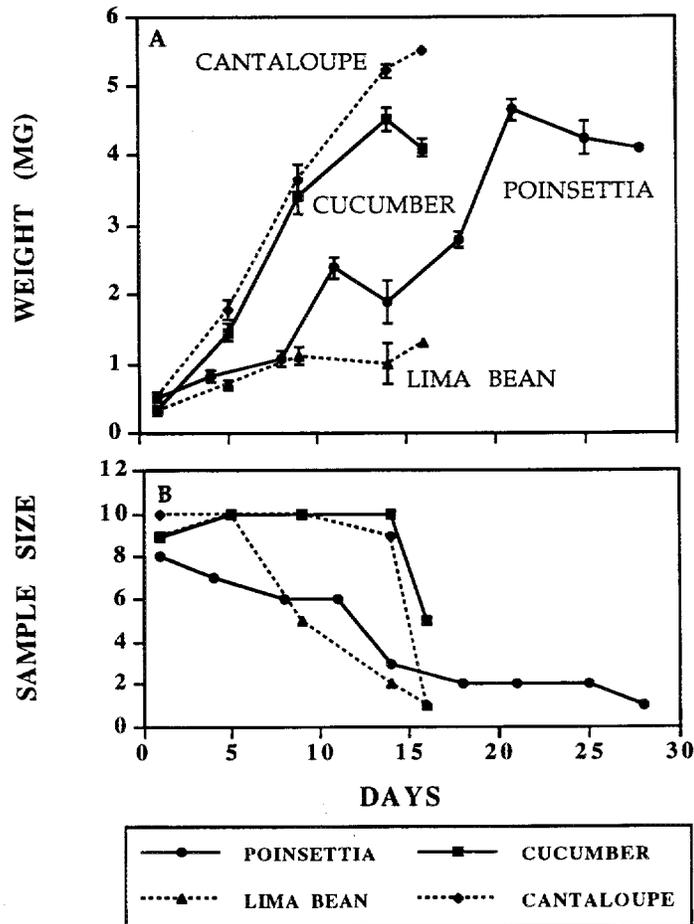

FIG. 2. Effect of host plant on body weights of *C. rufilabris*. Predator larvae feeding on whiteflies on cucumbers and cantaloupes had significantly higher mean body weights (± SE) than those with poinsettias and lima beans as the host plant (Fig. 2A). Fig. 2B indicates the numbers of lacewings represented by the corresponding means.

Body weights of *C. rufilabris* on cantaloupe and cucumber were similar. Predators reared on lima beans were smallest among the different host plants. Predators reared on poinsettias were smaller than on cantaloupe or cucumber, but survived longer and pupated later than those on the other host plants. The General Linear Model analysis supported these conclusions. Both time ($F = 428.9$, df = 1, 143, $P < 0.01$) and host plant type ($F = 44.3$, df = 3, 143, $P < 0.01$) were highly significant factors affecting predator body weight. Mean body weight was highest on cantaloupe and cucumber, and lowest on poinsettias and lima beans (Tukey's test, $P < 0.05$) (Fig. 3).
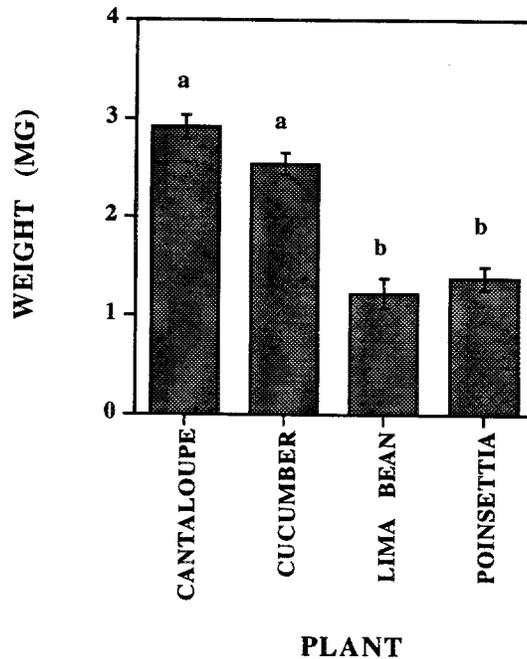

PLANT

FIG. 3. Effect of host plant on mean body weight (± SE) of *C. rufilabris*. Mean body weights are calculated over total time on the host plant prior to death or pupation. The effect of host plant on body weight is highly significant ($F = 44.3$, $P < 0.01$). Means with the same letters are not significantly different (Tukey's HSD, $P = 0.05$).

Development of first and second instars of *C. rufilabris* differed according to the host plants upon which their prey SLWF were reared (Fig. 4). Only *C. rufilabris* larvae provided SLWF from cucumbers and cantaloupes reached the adult stage, with an adult weight of 2.23 mg (SE 0.63, $N = 3$) for cucumber and 3.1 mg ($N = 1$) for cantaloupe. *C. rufilabris* provided larvae from poinsettia and lima bean lived only to the third instar and died before reaching the pupal stage. Survival of *C. rufilabris* provided SLWF from the different host plants is shown in Fig. 5. The survival curve for larvae that were provided SLWF reared on poinsettia and lima beans shifted to the left, indicating a much lower survival compared with larvae that were provided SLWF from cantaloupe and cucumber plants.

Comparison of predation between C. rufilabris and C. carnea. Larval body weights of both species increased from about 0.25 mg per larvae to a maximum of about 2.0 mg (Fig. 6). Body weights did not differ between the two species ($F = 0.056$, $P = 0.81$). Numbers of whiteflies consumed by the two species of lacewings are shown in Fig. 7.
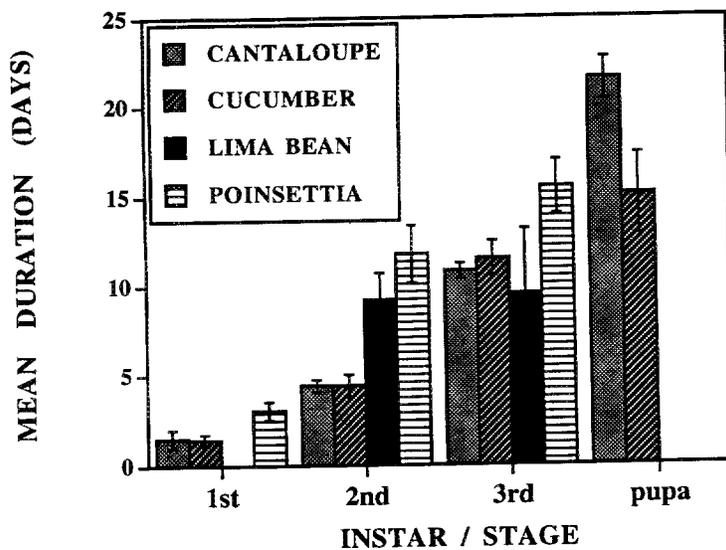
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FIG. 4. Developmental times of *C. rufilabris* as affected by host plant (±SE). The lima bean treatment was started using 2nd instar predataors. *C. rufilabris* in lima bean and poinsettia treatments did not survive to pupation.
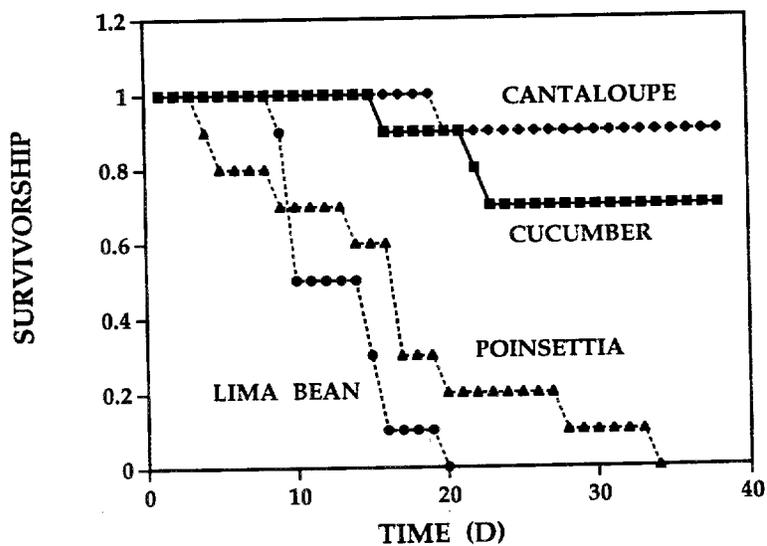

FIG. 5. Survival of *C. rufilabris* as affected by host plant. The predator displayed higher survival on cantaloupe and cucumber than on poinsettia and lima beans.
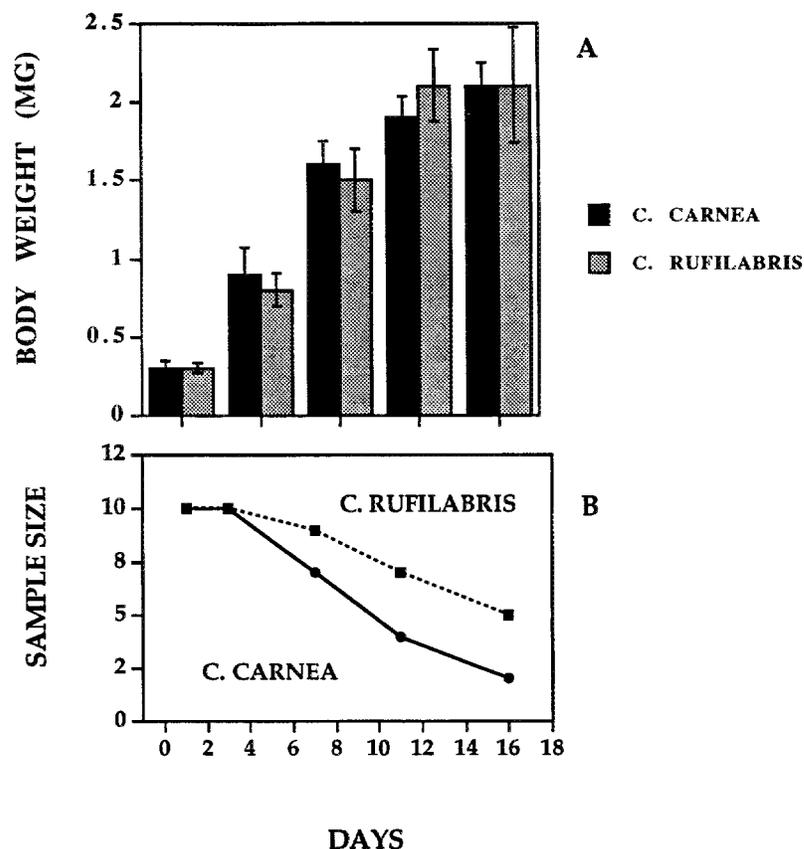
FIG. 6. Comparison of body weights of *C. rufilabris* and *C. carnea*. Body weights (± SE) of *C. rufilabris* and *C. carnea* were not significantly different using poinsettia as the host plant ($F = 0.056$, $P = 0.81$) (Fig. 6A). Fig. 6B indicates the numbers of lacewings represented by the corresponding means.

Statistical analysis of the numbers of whiteflies consumed over the entire experiment indicates a significantly higher number of whiteflies consumed by *C. carnea* than by *C. rufilabris* ($F = 4.7$, $P < 0.05$). The significant difference in predation between the two species was due largely to the increased predation rate by *C. carnea* during the 5-d period from days 12 to 16. Analysis of the data from days 1 to 11 only produced no significant differences in numbers of whiteflies consumed between the two species ($F = 0.1$, $P = 0.75$). However, the differences in predation rates are highly significant for the subset of data collected from days 12 to 16 ($F = 6.7$, $P < 0.01$). Based on these results, the most prudent conclusion is that there is little difference between predation rates between larvae of *C. carnea* and *C. rufilabris*, although *C. carnea* may consume significantly more whiteflies during certain intervals. More tests are necessary to demonstrate conclusively if differences exist in predation rates between species. Both predators consumed an average of 25 - 75 whiteflies daily (Fig. 7).
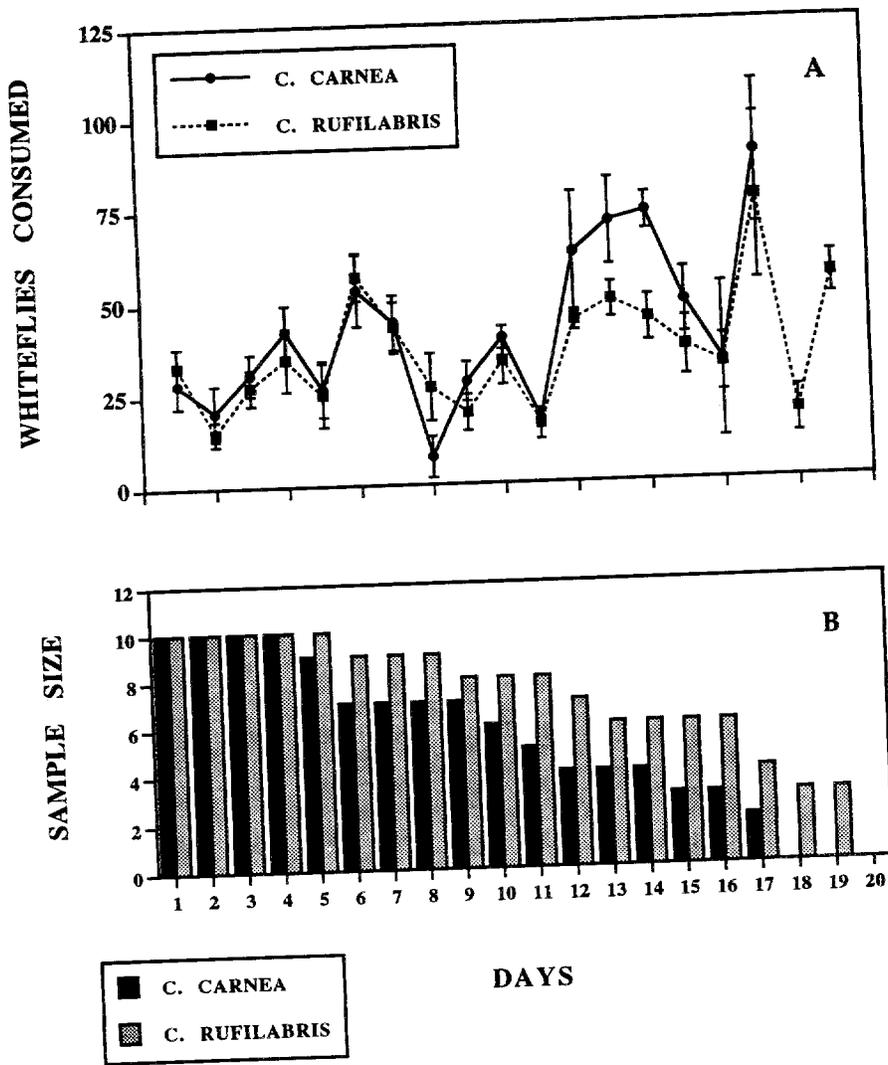
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FIG. 7. Comparison of predation between *C. carnea* and *C. rufilabris* on poinsettia. Daily numbers of whiteflies consumed are shown (± SE) as a function of time (Fig. 7A). A significantly higher number of whiteflies was consumed by *C. carnea* than by *C. rufilabris* ($F = 4.7$, $P < 0.05$). Fig. 7B indicates the numbers of lacewings represented by the corresponding means.

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Results of these experiments demonstrate the effect of tri-trophic interactions between the host plant, phytophagous pest and entomophagous insect. The presence of the predator on a host plant was shown to deter oviposition by the whitefly after the predators had been removed from the plant. The adaptive significance of this behavior may relate to improving the survival of the whitefly offspring by avoiding sites infested with predators. The precise chemical cues which cause this behavior and possible applications in biological control programs will require further study.

The host plant can affect body weight and survival of the predator, presumably through the sequestration of plant compounds into the phytophagous prey, or by influencing the nutritional quality of the prey. In these experiments, SLWF feeding on cantaloupes and cucumber appeared to be better quality prey than those feeding on poinsettia or lima bean. *B. argentifolii* and the plants that they were reared on apparently affect *C. rufilabris'* development, survival, and body weight. Lacewings that preyed on SLWF that were reared on cucurbits such as cucumbers and cantaloupes developed more rapidly, showed increased survival, and weighed more as newly-emerged adults, compared to those from poinsettia and lima bean. Lacewings feeding on the latter two plants did not reach the pupal stage. This phenomenon supports the findings of Legaspi et al. (1994) who speculated that the SLWF reared on poinsettia or lima bean were nutritionally inadequate (see also Hydorn and Whitcomb 1979) for *C. rufilabris* development, or *B. argentifolii* reared on these plant hosts may have an accumulative toxic effect on *C. rufilabris*. However, because the predators were in contact with the lima bean and poinsettia foliage, reduced survival could also be attributed to direct effects of the plant rather than nutritional or allelochemical effects via the host. Further nutritional studies on the quality of *B. argentifolii* and *C. rufilabris* as well as a biochemical analysis of the plants will increase our understanding of the tri-trophic interaction between predator, prey and plants.

ACKNOWLEDGMENT

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