Effect of Short-Term Releases of *Chrysoperla rufilabris* (Neuroptera: Chrysopidae) Against Silverleaf Whitefly (Homoptera: Aleyrodidae) in Field Cages[1,2]

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ABSTRACT We studied the effect of different lacewing (*Chrysoperla rufilabris* [Burmeister] release rates on control of the silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring, inside field cages in organically-grown watermelon and in *Lablab purpureus*, a leguminous forage crop. Second-instar *C. rufilabris* larvae were released at rates of 0 (control), 10, 25, and 50 per cage (0.37 m^2 area). Whitefly counts were made prior to release and compared with those taken 48 h after release of the lacewings. In the watermelon field, the control had approximately 35% more whiteflies over the entire season as compared to the predator treatment with the highest whitefly counts (25 lacewings per plant). The effects of predator releases were most evident during the second half of the season. However, higher rates of predator release did not result in increased pest suppression. No significant patterns of prey suppression were detected in the legume field, possibly because prey densities were already too high at the start of the experiment. Whitefly population dynamics in the lablab was apparently determined by environmental factors and crop phenology, rather than by predation. Possible reasons are presented for observed differences in degrees of pest suppression afforded by lacewing larvae in order to optimize control of the whitefly populations.

KEY WORDS *Chrysoperla rufilabris, Bemisia tabaci, Bemisia argentifolii,* biological control, predation.

The silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring (Homoptera: Aleyrodidae) [sweetpotato whitefly, *B. tabaci* (Gennadius) Biotype "B"], is an important pest of agricultural crops and dooryard gardens, especially in the tropics and subtropics. The extremely destructive nature of this pest arises from a combination of its explosive reproduction potential (e.g., high fecundity rate

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and short lifecycle) (Baumgartner and Yano 1990), wide host range (> 900 host plants) (Cock 1986, Byrne et al. 1990), ability to vector viral plant pathogens (Brown et al. 1992), and production of honeydew exudate which serves as a medium for the growth of sooty mold fungi. In Arizona, Florida, Texas and California alone, crop losses due to *B. argentifolii* in 1991 were estimated at over $500 million (Perring et al. 1993). Furthermore, crop value losses in the Imperial Valley of California alone were estimated at over $300 million from 1991 to 1994 (Birdsall et al. 1995).

Despite massive applications of broad-spectrum insecticides, the action of natural enemies plays an important role in reducing whitefly numbers, both through inundative releases (Parrella et al. 1992) or as natural control agents (Stansly et al. 1994). Nordlund and Legaspi (1995) discussed the potential of predators as biological control agents of *B. argentifolii,* listing 66 predatory species representing eight arthropod orders known to feed on the silverleaf whitefly. A further eight predator species were either undetermined or unreported. They include nine species of Neuroptera including the well studied and commercially available lacewings *Chrysoperla* (= *Chrysopa*) *rufilabris* (Burmeister) and *C. carnea* (Stephens). Much of the biology and life history of *C. rufilabris* was presented by Elkarmi et al. (1987) who compared the life histories of the two predators to assess the possibility of mass rearing. Another predator that has received much attention recently is the coccinellid *Delphastus pusillus* LeConte (Heinz and Parrella 1994a, 1994b, Hoelmer et al. 1993, 1994).

Breene et al. (1992) released first- and second-instar larvae of *C. rufilabris* against *B. argentifolii* on *Hibiscus rosa-sinensis* L. in the greenhouse. They found that releases of 25 or 50 larvae per plant at 2-wk intervals maintained the plants in marketable condition. Legaspi et al. (1994) studied prey preference and the effect of diet on larval development of *C. rufilabris* provided silverleaf whitefly and a variety of diets, including lepidopteran eggs, aphids and an artificial diet. The lacewing larvae consumed an average of 532 silverleaf whitefly daily, but showed increased survivorship and development when fed eggs of *Sitotroga cerealella* (Olivier) (Gelechiidae) and *Helicoverpa zea* (Boddie).

The potential of *C. rufilabris* as a commercially viable pest management tool was demonstrated in 1994, when 35 companies in North America were known to market this predator (Hunter 1994). Release rates recommended by the companies vary and depend on such factors as crop and degree of infestation. For example, Rincon-Vitova (Ventura, CA) suggests 5,000 to 50,000 eggs per acre (about 12,000 to 120,000 per ha) per season (Dietrick 1994) and Gardens Alive! (Lawrenceburg, IN) recommends 10 eggs per plant or 1,000 eggs per 200 sq. ft. (about 540,000 per ha) for moderate aphid infestations (Gardens Alive! 1992).

The objective of this study was to determine the short term effect of releases of *C. rufilabris* larvae at different rates on *B. argentifolii* in the field.

Methods and Materials

Watermelon field. *Chrysoperla rufilabris* used in the study were obtained from Rincon-Vitova Insectaries, Inc., and from a colony maintained at USDA-ARS-SARL, Weslaco, TX. The fields used in this study were chosen because the crops were not routinely treated with conventional insecticides. During April-

May 1993, we released second-instar *C. rufilabris* on caged watermelon, *Citrullus vulgaris* cv. Regency and All Sweet, in a 4.9 ha (12 acre) commercial organic field (South Tex Organics) in Mission, TX. The field was planted in February 1993. Green lacewing larvae were released from April 23 to May 21 at 3 to 4-day intervals.

On each release date, 5 plants were selected randomly for each treatment and the control. Each plant was individually covered with a cage (61 cm × 61 cm, 0.37 m^2 area) made from PVC pipes (1.9 cm) and enclosed with an organdy fabric (mesh size ≈ 60) which was secured with an elastic belt. *Chrysoperla rufilabris* were released according to the following treatments: 1) 10 larvae per cage, 2) 25 larvae per cage, 3) 50 larvae per cage, and 4) no larvae (control). After 48 h, the cages were removed and 2 leaves per plant were selected randomly from within the confines of the cage for sampling whitefly numbers. The short exposure time was used to give the predators sufficient time to affect prey numbers without incurring significant changes in the densities and age structures of either predator or prey due to normal insect development. Numbers of whitefly immatures were recorded according to instar. The areas of the leaves selected were measured using a LiCor® leaf area meter (Li-Cor, Inc, Lincoln, NE). All counts of whitefly immatures were divided by the areas of the leaves on which they occurred and reported as counts per square cm. Air temperature also was recorded using an Omnidata® logger (Omnidata International, Inc., Logan, UT). The experiment was repeated 10 times during the season and new plants were chosen for each trial period.

Legume field. The experiment was repeated in a field planted to a leguminous forage crop, *Lablab purpureus* (L) Sweet (= *Dolichos lablab* or commonly called lablab), belonging to Rio Farms, Inc. in Monte Alto, TX. The lablab field (173 × 23.5 m) was sampled from 21 July to 28 September 1993. Because lablab leaves are smaller than the watermelon, four leaf samples rather than two were taken from each plant. This experiment was repeated 11 times during the cropping season and new plants were also selected for each replicate.

Statistical analysis. A log transformation [ln (x + 0.5)] was performed on the data prior to statistical analysis. The transformed data were then analyzed using a Nested Analysis of Variance using the Systat® (Systat, Inc., Evanston, IL) statistical package (Wilkinson et al. 1992). In the statistical model, the treatment effect was due to the number of predators released. The leaf samples were nested within the treatments. Both the treatments and leaf sample effects were analyzed as categorical data. Each sampling time was analyzed independently and all means were separated using Tukey's test with $\alpha = 0.05$ (Wilkinson et al. 1992). Statistical analyses are reported only for total numbers of whitefly immatures rather than for individual stages.

Results

Watermelon field. The population numbers of whitefly immatures show little effect of the 48-h feeding period in the first half of the crop season. However, the control plants had higher numbers of whiteflies per sq cm after the first week of May (Fig. 1). This pattern is repeated in the statistical analysis of total numbers of immatures in Fig. 2. The effect of the predators is evident from May 5 to 19. During this period, the control had the highest numbers of total immatures. However, the treatments with predators often did not differ statistically from each other, i.e. higher release rates of predators did not confer higher degrees of pest suppression during the 48-h exposure period. Mean weekly air temperature in this trial was 24.5°C ± 0.8 (n = 4).

We can generate an estimate of the effect of the predator releases by calculating the mean whitefly counts presented in Fig. 2 over the entire season. Mean whitefly counts per leaf (± SE) of the 10, 25, 50 predators per plant treatments and control were 5.13 (± 0.43), 6.35 (± 1.07), 4.78 (± 0.71) and 9.78 (± 2.1), respectively. The control had approximately 35% more whiteflies over the entire season as compared to the predator treatment with the highest whitefly counts (25 predators per plant). Whitefly counts were most significantly affected during the second half (May 7 to 21) of the crop season (Figs. 1 and 2). During the first half of the season (April 23 to May 5), mean whitefly counts averaged 4.2 (± 0.4), 5.96 (± 0.47), 2.94 (± 0.41) and 5.12 (± 0.63) per cm^2 leaf area for the respective treatments and control. The treatment using 25 predators per plant was slightly higher than that of the control. However, a marked difference between treatments and control is evident in the second half of the season, where treatment means were 6.06 (± 0.22), 6.74 (± 1.52), 6.62 (± 0.36), respectively and the control mean was 14.4 (± 2.02). In the second half of the season, the control had over 50% more whiteflies per leaf than the treatments, which accounts for much of the treatment effect measured over the season.

Legume field. The eggs to third instar counts in the lablab field are shown in Fig. 3. All life-stages appear to peak in early August and decline during the fall. Statistical analyses of total immature counts did not reveal significant patterns, unlike in the watermelon trial. The different predator treatments did not significantly affect whitefly densities when compared to the control. Mean weekly air temperatures in this trial was 29.2°C ± 1.4 (n = 10).

Discussion

In a similar study, Ridgway and Jones (1968) used *Chrysoperla carnea* to suppress populations of the bollworm, *H. zea* and tobacco budworm, *H. virescens* (F.) in cotton. The experiments were conducted in field cages, with lacewings released as either eggs or larvae. In one experiment, larvae were released at rates equivalent to 980,000 per ha, and the eggs at almost 2,000,000 per ha. They found that *Helicoverpa* populations were suppressed by 74 to 99% compared with the control. Differences in degrees of control were strongly affected by the abundance of alternate prey. In comparison, the release rates of 10, 25 and 50 larvae per cage that we used in this study are roughly equivalent to 270,000, 676,000 and 1,350,000 larvae per ha. The rates used in these experiments are higher than the 540,000 eggs per ha recommended by the commercial supplier.

Daane et al. (1993) compared the effectiveness of different lacewing release methods against the variegated grape leafhopper, *Erythroneura variabilis* Beamer (Homoptera: Cicadellidae) in experimental plots and commerical

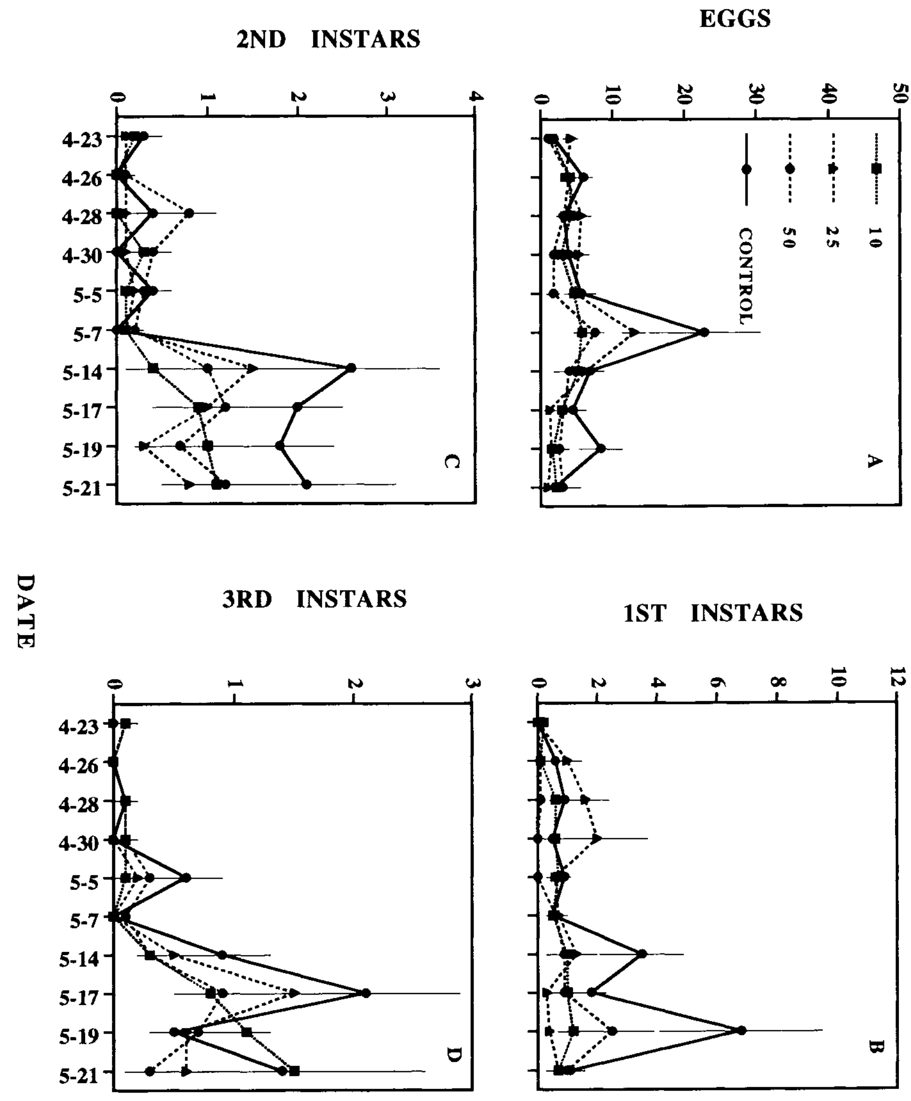

Fig. 1. Mean immature whiteflies in watermelon crop per cm^2 of leaf (± SE) are shown according to life-stage for whitefly eggs to third instars for all treatments: 10 larvae per cage (---■---), 25 per cage (---▲---), 50 per cage (---●---) and the untreated control (–●–). The life-stages are divided according to eggs (A), 1st (B), 2nd (C) and 3rd (D) instars. (4th instars are not shown due to low numbers sampled.)

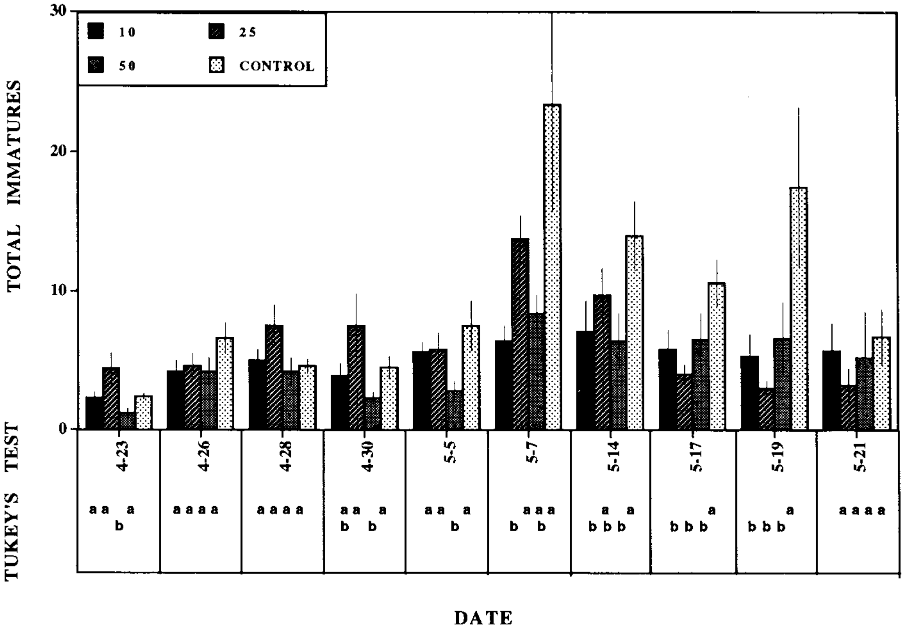

Fig. 2. Total mean immature whiteflies in watermelon crop per cm^2 of leaf (± SE) are calculated by adding together numbers of immatures of all stages for all treatments. Statistical analyses were performed on leaf counts following log transformation [ln (x + 0.5)]. The results of Tukey's tests are indicated by letters beneath the histograms where common letters indicate means not significantly different at $\alpha = 0.05$.

vineyards. They found the release rates of *Chrysoperla* spp. of between 7400 and 19700 per ha (costing $22 to $59 per ha, respectively) for each leafhopper brood reduced pest densities by 35%. Control was variable, with some release plots showing no differences compared to the controls. Daane et al. (1993) concluded that the effectiveness of *Chrysoperla* spp. against the leafhopper was highly dependent on method of release and synchronization with pest phenology.

It must be emphasized that our study differs from the previously cited works in that the predators were allowed only 48 h in which to feed instead of allowing the *C. rufilabris* to feed until pupation. Second-instar lacewings will take about 14 days to develop to the pupal stage in cantaloupe in the laboratory (J. C. Legaspi, unpubl. data). Higher field temperatures and natural mortality factors will probably reduce this predaceous stage significantly. However, it is likely that the second instars placed in the cages would have continued to feed beyond 48 h, had they not been removed. Given the limited feeding time of only 48 h, the 50% reduction found in the second half of the watermelon season actually seems quite promising.

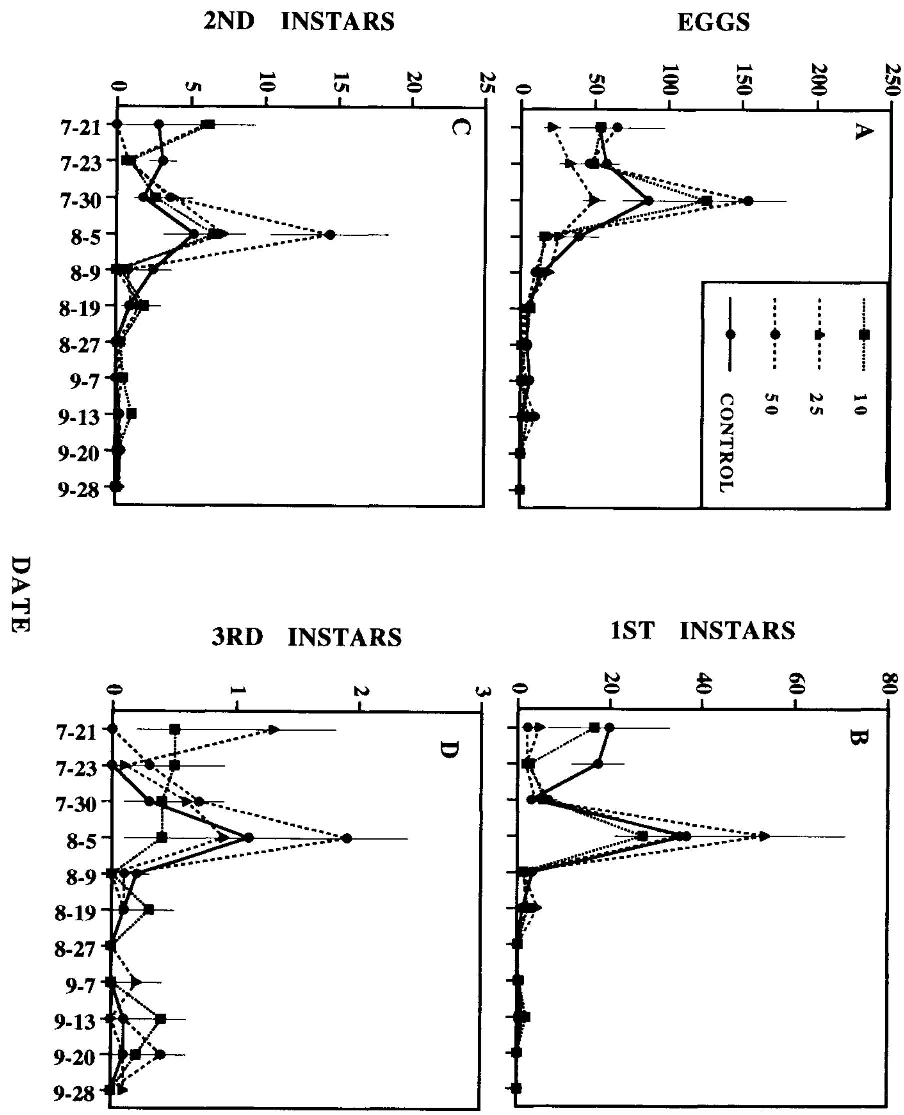

Fig. 3. Mean immature whiteflies in lablab crop per cm^2 of leaf (± SE) are shown according to life-stage for whitefly eggs to third instars for all treatments: 10 larvae per cage (---■---), 25 per cage (---▲---), 50 per cage (---●---) and the untreated control (–●–). The life-stages are divided according to eggs (A), 1st (B), 2nd (C) and 3rd (D) instars. (4th instars are not shown due to low numbers sampled.)

Although we found the release of *C. rufilabris* to suppress whitefly counts occasionally, the release rates did not appear to affect the degree of suppression. Release rates are not inversely correlated with pest densities as might be expected. Given the voracity and known cannibalistic nature of *Chrysoperla* spp., it is conceivable that application rates of up to 50 larvae per cage resulted in cannibalism rather than predation on pests.

The question exists as to why releases were more effective in the second half of the watermelon season. Numerous possible explanations exist, such as more favorable weather which enhanced predator activity. Another likely possibility is that the suppression of prey is effective or is measurable over a limited range of prey densities. Prey densities within the range of 10 to 25 per cm^2 appear to produce the greatest measurable effects (Figs. 2 and 4). The effect may be more difficult to measure at lower densities because of sampling error associated with counting few insects on a leaf. At higher densities (> 25 per cm^2), there were perhaps too many prey for the predators to reduce appreciably.

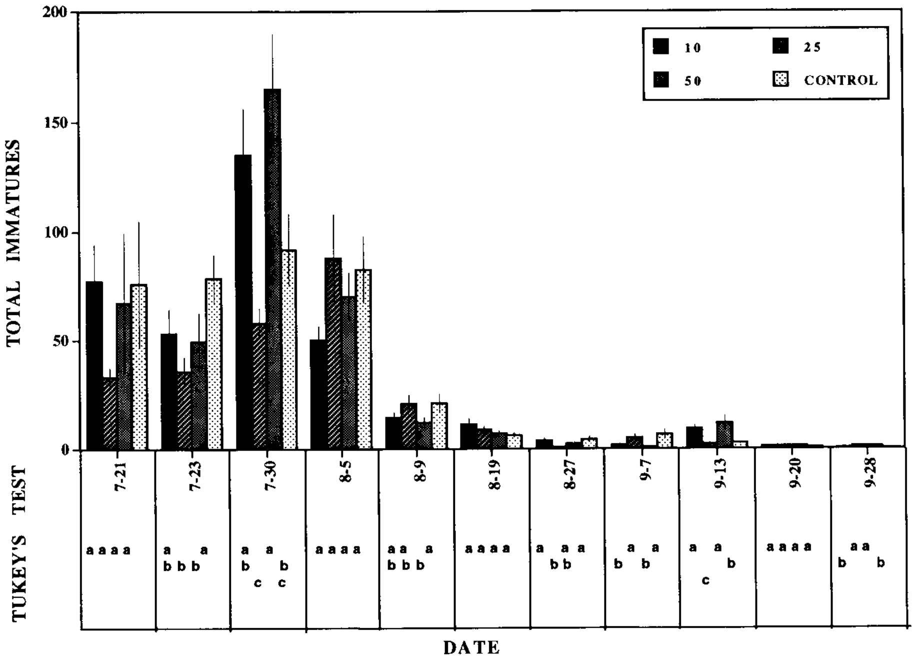

Fig. 4. Total mean immature whiteflies in lablab crop per cm^2 of leaf (± SE) are calculated by adding together numbers of immatures of all stages for all treatments. Statistical analyses were performed on leaf counts following log transformation [ln (x + 0.5)]. The results of Tukey's tests are indicated by letters beneath the histograms where common letters indicate means not significantly different at $\alpha = 0.05$.

Variability in degree of pest suppression was evident in this study, possibly due to less efficiency of predation on the lablab plant. A predator may be less efficient on a plant if the plant has a rather large surface area for it to search, or if the leaf surface is not conducive for search because of the presence of leaf trichomes, for example, which impede the rate of predator search. Leaf trichomes are unlikely to explain the differences in predator efficiency because lablab has relatively smooth leaves.

Another possible explanation for the lack of effect in the lablab field may be simply because whitefly numbers were already too high when the releases were started at the end of July. Counts of total immatures were generally in the range of 50 to 150 per cm^2 during the start of the experiment (Fig. 4). This period coincides with the harvesting of cotton in the area which produces high immigration into the few fields available, such as the lablab site. Predator releases may have had an effect on the whitefly population had they been initiated earlier in the crop season. Whitefly population dynamics in the lablab was apparently determined by environmental factors and crop phenology, rather than by the effects of the predators released. These results suggest that *C. rufilabris* may be used as a tool in the management of *B. argentifolii*, but that the predator alone may not be effective for control of the whitefly. Clearly, much more research is necessary before *Chrysoperla* spp. can be used effectively in integrated management systems for the silverleaf whitefly.

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