Areawide Population Dynamics of Silverleaf Whitefly (Homoptera: Aleyrodidae) and its Parasitoids in the Lower Rio Grande Valley of Texas[1]

B. C. Legaspi, Jr., J. C. Legaspi[2] R. I. Carruthers[3], J. Goolsby[4], J. Hadman[4], W. Jones, D. Murden[5], and L. Wendel[4]

Biological Control of Pests Research Unit, USDA-ARS-SARL
2413 East Highway 83
Weslaco, Texas 78596 U.S.A.

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ABSTRACT The population dynamics of the silverleaf whitefly (SLWF), *Bemisia argentifolii* Bellows and Perring (=sweetpotato whitefly, *B. tabaci* Biotype "B", [Gennadius]), and its endemic parasitoids (mostly *Encarsia* spp. [Aphelinidae]) were monitored in a heterogeneous cropping area, consisting of cotton, cantaloupe and kenaf (tall fiber crop). To assess the suitability of the whitefly for areawide pest management, we compared estimates of population densities using different sampling methods and determined the effects of agronomic practices on the whitefly and parasitoid populations. There was no correlation between adult SLWF estimates using sticky traps and those counted directly on the leaves. However, counts of immatures using disk subsamples were found to be good predictors of whole leaf counts. SLWF counts were low in cotton, until the harvest period of cantaloupes, which may have triggered migration from cantaloupe to cotton. The determinants of emigration from cotton were less clear. High numbers of adults were migrating well before harvest or the application of a defoliant. One likely contributing factor in triggering whitefly migration was leaf senescence. Despite rather high adult densities sampled in kenaf, populations of immature SLWF were low, suggesting that it is not a preferred host. Parasitoid populations were high in the kenaf fields, causing 20 to 80% parasitism and suggesting that kenaf could serve as a reservoir of natural enemies within a larger cropping system. Parasitism in cotton was less than that in kenaf, usually at ~10 to 15%. *Encarsia* spp. sampled on sticky traps indicated significant activity of the adults in the cotton and kenaf fields, and much lower numbers in the cantaloupe. Because it is a dispersive and polyphagous pest, areawide suppression of SLWF must include the consequences of farming practices and cropping patterns in heterogeneous fields, especially when they are under different management.

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[2] Current address: Texas Agricultural Experiment Station, 2415 East Highway 83, Weslaco, TX, 78596.

[3] USDA-ARS-NPS, BARC-WEST, Beltsville, MD 20705.

[4] Mission Biological Control Center, USDA-APHIS-PPQ, Mission, TX 78573.

[5] Rio Farms, Inc., Monte Alto, TX 78538.

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The future of United States agriculture is in the implementation of integrated pest management (IPM) over several contiguous agricultural areas. "Areawide pest management" is the extension of the principles of IPM on a large-scale. In 1994, the USDA announced the first areawide management pilot program to be funded in commercial apple and pear orchards in the western US against the codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae) (Senft 1995). Plans by the USDA to implement areawide IPM against other pests (including weeds and pathogens) suggest the advent of a new era in US agriculture.

Critical to successful areawide management is an understanding of the role of insect movement as affected by IPM practices, especially with regards to reinvasion of areas where the target pest has been suppressed (Schneider 1989). Managing insect pests over a large scale becomes especially challenging in heterogeneous cropping systems where the cropping pattern and agronomic practices may have profound effects on pest migration. In California, for example, the silverleaf whitefly (SLWF), *Bemisia argentifolii* Bellows and Perring (Homoptera: Aleyrodidae) (=sweetpotato whitefly, *B. tabaci* Biotype "B", [Gennadius]), was found to migrate from cotton to melons following cotton defoliation (Blua et al. 1994). In the Lower Rio Grande Valley (LRGV) of Texas, Riley and Wolfenbarger (1993) reported peaks in whitefly migration coinciding with cabbage and melon harvest and immediately following cotton defoliation.

Monitoring insect population dynamics over large areas requires the use of sampling methodology which minimizes cost and labor requirements while maintaining sufficient levels of reliability. Natwick et al. (1992) compared 7 methods for sampling *B. argentifolii* in cotton and found that the most reliable methods were also positively correlated to the standard 7.6 × 12.7 cm (3" × 5") sticky traps used by pest control advisors. Furthermore, comparisons between whole leaf counts of whitefly immatures and 3.88 cm^2 disk samples revealed variations based on cotton cultivar or nodal position (Naranjo and Flint 1994).

In this paper, we report the findings of an interagency research project conducted by the USDA-ARS Biological Control of Pests Research Unit (Weslaco, TX), in collaboration with USDA-ARS Remote Sensing Unit (Weslaco, TX), the Texas Agricultural Experiment Station (Weslaco, TX), Rio Farms, Inc. (non-profit farming enterprise, Monte Alto, TX), USDA-APHIS Mission Biological Control Center (Mission, TX), and units of USDA-APHIS in Brownsville and Harlingen, TX. The project was performed in 1993-1994 as a pilot study for the areawide pest management of the silverleaf whitefly with the objective of monitoring the population dynamics of *B. argentifolii* and its natural enemies using different sampling methods in a heterogeneous cropping area. We monitored especially short-range (<5.0 km; Byrne and Blackmer 1996) migration patterns resulting from agronomic practices. Data for 1993 are discussed in Legaspi and Carruthers (1995); here we report the findings for 1994.

Materials and Methods

Field information. The research site (~2400 × 1600 m) was located near Monte Alto (26° 23' 00" N, 97° 57' 30" W) in the Lower Rio Grande Valley of Texas. The climate is subtropical with mean daily temperature usually constant at ~30° C from March to September. Hard winter freezes are rare, providing insect pests with a benign temperature environment throughout the year. Insects such as *B. argentifolii* are best able to exploit these climatic circumstances, because the whitefly has no dormant overwintering stage. The experimental site consisted of 5 cotton (*Gossypium hirsutum* var. "Stoneville 132") and 3 cantaloupe (*Cucumis melo cantalupensis* var. "Northrup King Explorer") fields, interspersed with *Citrus* sp., sorghum (*Sorghum bicolor*) and lima beans (*Phaseolus limensis*) (Fig. 1). A kenaf (*Hibiscus cannabinus)* field (85 m × 373 m) outside the experimental site was monitored for SLWF because kenaf is the only crop grown commercially in the LRGV that is not sprayed with insecticides. The cantaloupe fields were planted on 15 January 1994 and harvested 19 times (16, 17, 18, 19, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31 May and 2, 4, 10, 11, and 14 June). The cantaloupe fields were disked on 29 June 1994. The cotton crop was planted on 22 February; a defoliant was applied on 29 July, and the crop was harvested on 3 August, and disked on 15 August 1994.

Sampling methods. The cotton, cantaloupe and kenaf fields were monitored for SLWF and its parasitoids using sticky traps and visual leaf sampling. Sticky trap sampling continued into the fall and early winter, even though the crops were destroyed much earlier in the year, because of the presence of alternate hosts, such as kenaf, peas, soybean, pinto beans and even weeds. Twenty-five yellow sticky cards 7.6 × 12.7 cm per field were placed randomly around each of the 5 cotton and the 3 cantaloupe fields beginning in April 1994. The cards were placed on the edges of the fields, ~15 m apart, to minimize loss due to management practices. Every week, new cards were placed in the field for durations of 24 h. Field size was not considered critical to the number of traps used. The number of adult SLWF was counted on a 7.6 × 7.6 cm (3" × 3") sampling area on 1 side of each card. (The size of the sampling area was chosen to conform with that used in a separate study conducted concurrently by Texas A&M University and USDA-APHIS.) Twenty-five leaf samples were collected twice weekly across a diagonal transect of each field. Leaves were selected from the upper third of the plants in cotton ~0.6 m from the base of the plant in cantaloupe, and from the middle section of the kenaf plant. Before removal from the plant, each leaf was inspected for the presence of adult whiteflies which was recorded. All leaves were examined under a stereomicroscope for parasitoids, and SLWF eggs and nymphs, which were counted and the numbers recorded. Samples were taken from leaf disks (No. 14 cork borer, 3.88-cm^2 area, 2.22-cm diameter; Naranjo and Flint 1994) when whitefly numbers were so high that whole leaf samples took excessive time to count. This was determined when counts reached ~400 to 500 whiteflies, or took >15 min per leaf.

To compare leaf disks and whole leaf counts, a set of 25 cotton leaves was sampled using leaf disks cut by the No. 14 cork borer. Counts of immature SLWF on leaf disks were compared against whole leaf counts using the same leaves. Leaf areas of the cotton, cantaloupe and kenaf were measured using a

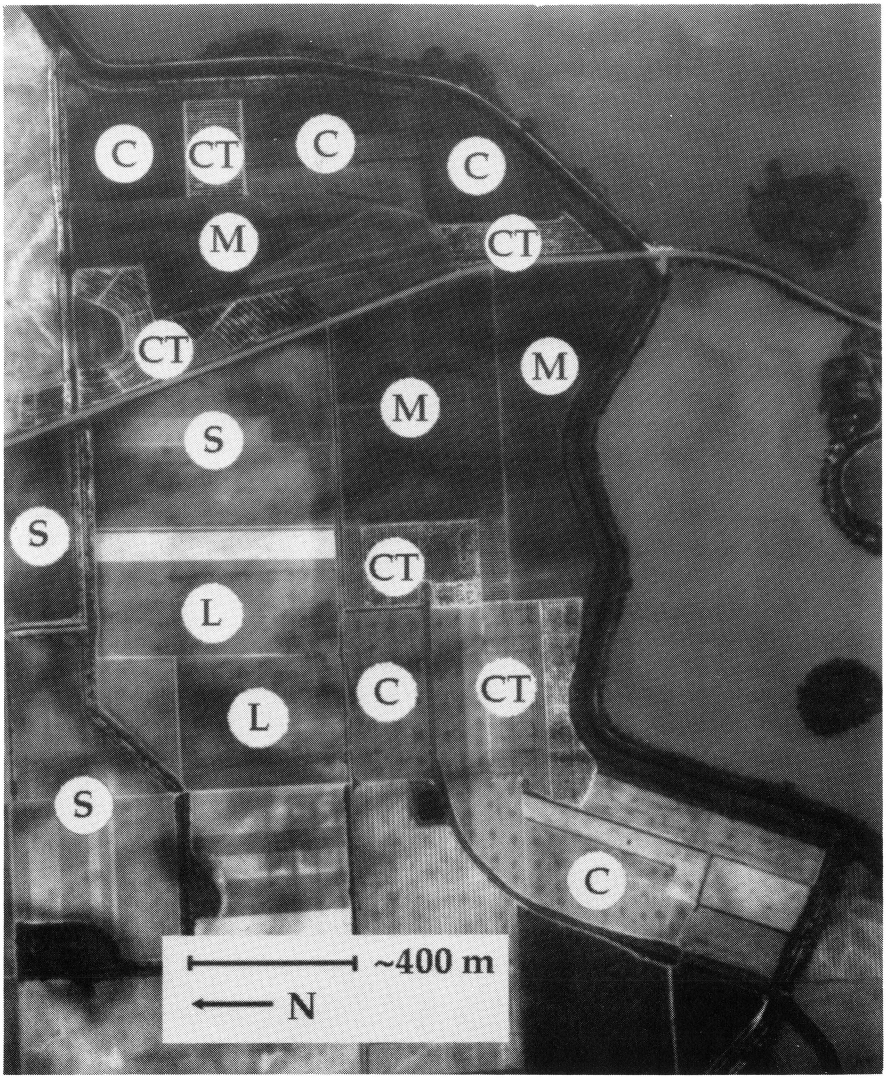

Fig. 1. Crop map, Rio Farms, Inc. (Monte Alto, TX) 1994. Crops are designated by the following letter codes: C = cotton, CT - citrus, M - cantaloupe, S - sorghum, L - lima bean.

Li-Cor® leaf area meter (Li-Cor, Inc., Lincoln, NE). To produce a per cm^2 count, counts for the disks were divided by the area of the disk. Counts for the whole leaves were divided by the leaf area.

After recording the whitefly immatures, 20 of the 50 leaves collected (biweekly samples of 25 leaves each combined) were placed in black plastic "emergence boxes" to determine the species of parasitoids that emerge and to estimate percentage parasitization of whiteflies. Stage-specific percentage parasitization was estimated by counting parasitized instars (3rd and 4th) on cotton and kenaf leaves, and then dividing by the sum of healthy and parasitized instars according to stage. Combined percentage parasitization of 3rd and 4th instars was calculated by dividing the sum of parasitized 3rd and 4th instars by the total number of 3rd and 4th instars present.

Results and Discussion

Similar data collected during 1993 are presented in Legaspi and Carruthers (1995). They monitored 9 cotton fields within a crop mix of citrus, cantaloupe and sorghum and found that populations of SLWF fluctuated among the cotton fields. However, populations increased steadily in July 1993, with peak whitefly densities occurring between the third week of July to mid-August, a period corresponding to cotton harvest. Peak whitefly adult populations exceeded 4,000 per 7.6 × 12.7 cm sticky card. The cards had been exposed to the whitefly populations for about 1 wk.

Comparison of sampling methods. A comparison between adult SLWF caught using sticky traps and those counted directly on cotton leaves suggests no correlation between the 2 sampling methods (Fig. 2). This is not surprising because yellow sticky traps catch insects both randomly and by providing a colored visual stimulus (Hutchins 1994). SLWF caught using sticky traps are, therefore, likely to be adults in the process of movement, either within or between fields sites. In contrast, adults sampled on leaves are presumably engaged in activities other than migration, such as oviposition. (Formal statistical analysis was not performed because the sampling dates for the 2 methods did not coincide.)

Counts of immatures using disk subsamples were found to be a good predictor of whole leaf counts. The numbers of eggs and nymphs are shown per cm^2 of leaf area for both the disks and whole leaves (Fig. 3). (The egg and nymph stages are combined for clarity of presentation and because they both represent relatively sessile life stages). In theory, the counts should be identical because they are obtained from the same leaf sample and expressed in identical units. This theoretical 1:1 relationship is depicted as the dashed line in Fig. 3. Although the disk counts were a good predictor of leaf counts ($Y = 0.143 + 0.491x$; $F = 192.5$; df = 1,23; $P < 0.01$; shown as solid line in Fig. 3), counts from the disk were ~2x higher than those for the corresponding whole leaves. Therefore, when SLWF densities required the use of disk subsamples, the regression equation was used to calculate whole leaf densities. This occurred on 3 sampling dates in late June (Julian dates 171-181). Similar variations between disk and whole leaf counts are reported by Naranjo and Flint (1994).

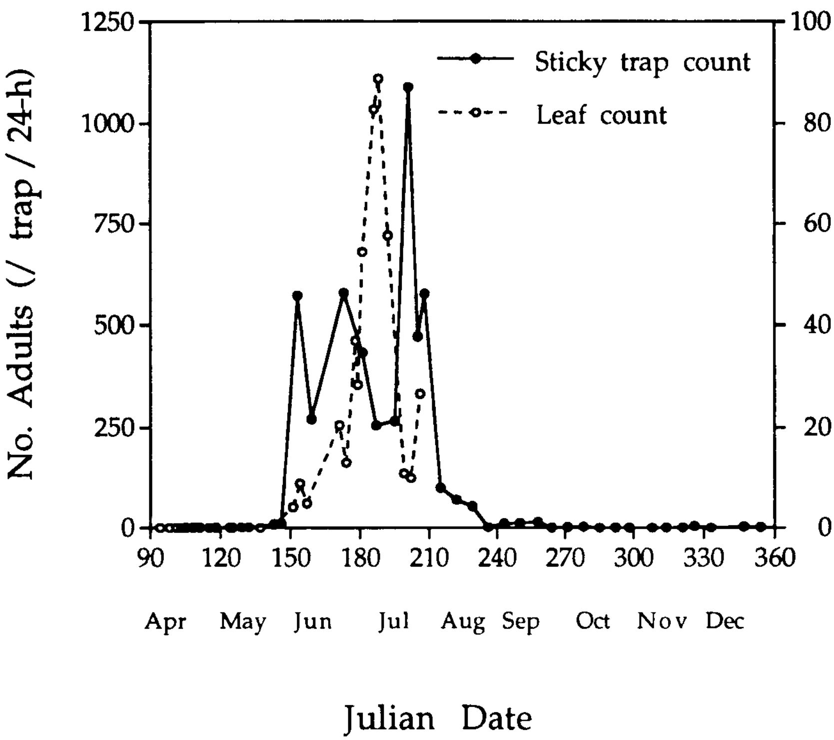

Fig. 2. Comparison of adult counts of *B. argentifolii* using sticky traps and leaf counts in cotton. Adult counts on sticky traps represent mean numbers (average of means for all fields) per 7.6 × 7.6 cm area on sticky traps per 24-h sampling period (axis on left), leaf counts represent mean numbers per cm^2 leaf area (axis on right). Leaf counts terminated on July 29 (Julian date 210) because of application of defoliants.

SLWF population dynamics. The population dynamics for both adult and immature whiteflies during the 1994 cropping season are summarized in Fig. 4 for cantaloupes (A) and cotton (B). Adults are shown as mean numbers per 7.6 × 7.6 cm sampling unit using the 7.6 × 12.7 cm sticky cards; units are shown on the left Y-axes of the figures. Numbers of eggs and nymphs are shown as counts per cm^2 of leaf area, with the axes on the right of each figure. Note that the scale of the cotton graph immatures is 10x that of the cantaloupe immatures. Beneath each graph is another graph showing mean leaf area (cm^2) measured after the leaf counts were taken. The scales for the numbers of adults per trap area and the leaf areas are identical in both graphs. The harvest period in cantaloupes is depicted by the horizontal bar (marked H), and the arrow (marked D) shows disking date (Fig. 4A). The harvest and disking dates in cotton are depicted by the arrows (marked H and D, respectively) (Fig. 4B).

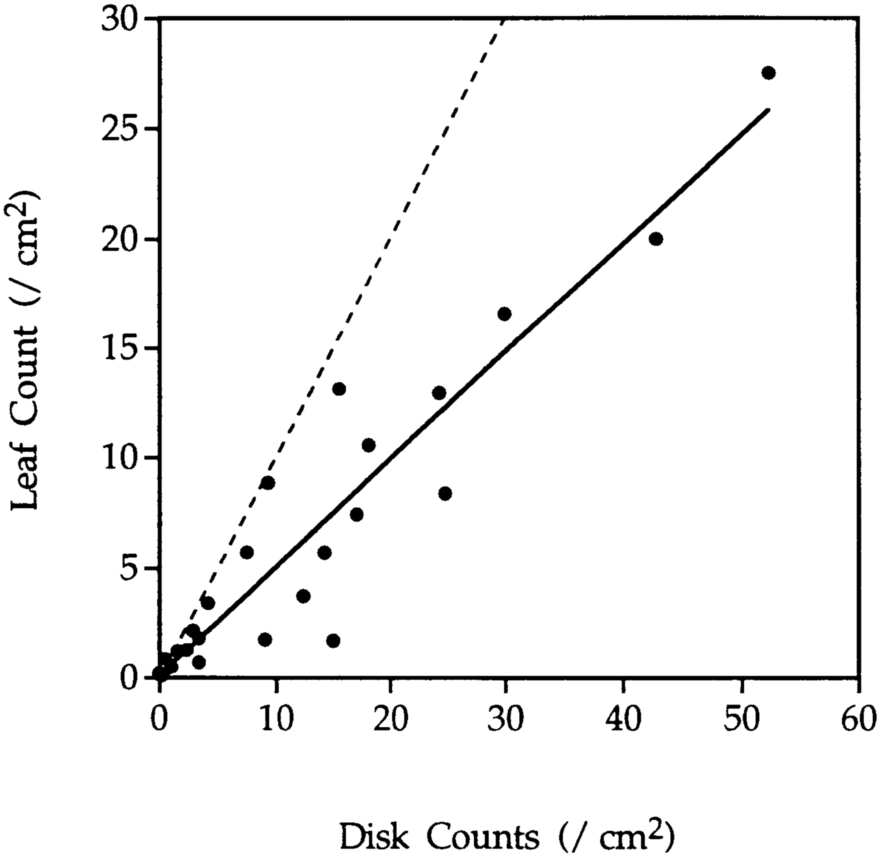

Fig. 3. Comparison of *B. argentifolii* eggs and nymph counts using disk subsamples (3.88 cm^2) vs. whole leaf counts. Both counts are expressed in units per cm^2 of leaf area. Solid line represents linear regression equation using disk counts as independent variable ($Y = 0.143 + 0.491x$; $F = 192.5$; $df = 1,23$; $P < 0.01$). Dashed line represents theoretical 1:1 prediction when disk counts equals leaf count.

Mean adult SLWF numbers were <1,200 per sticky trap in cotton (Fig. 4B), as compared with >4,000 reported by Legaspi and Carruthers (1995). The whitefly counts are not directly comparable because of the different exposure times and sampling areas used. However, independent sampling for SLWF adults performed in the LRGV also suggests that whitefly numbers were lower in 1994 than 1993 (Riley et al. 1996). Both adult and immature SLWF numbers were lower in the cantaloupe compared with cotton. The whitefly immatures increased on the cantaloupe leaves in May and June (Fig. 4A). Adult numbers in the cantaloupe were low until the harvest period. Continued sampling for SLWF adults indicated low whitefly adult movement within the cantaloupe field after disking, although the disking may have produced a peak in

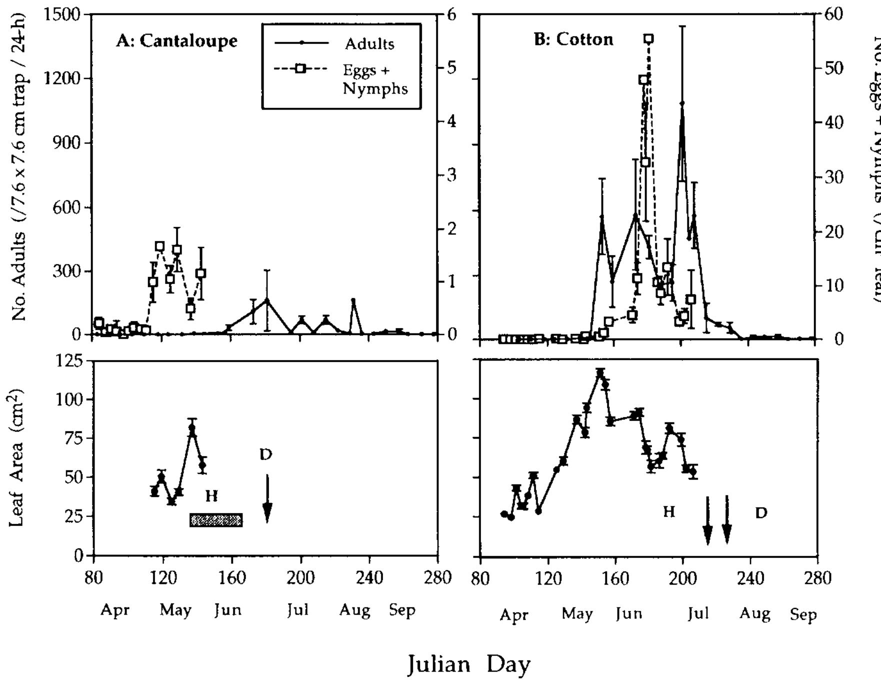

Fig. 4. Population censuses of silverleaf whitefly on cantaloupes (A) and cotton (B). Adults are presented as mean numbers (across all fields) per 7.6 × 7.6 cm area on sticky traps per 24-h sampling period (units on left axis), eggs and nymphs as mean numbers per cm^2 leaf area (units on right axis). Scale of immatures on cotton is 10x that for cantaloupes. Respective leaf areas (cm^2) are shown below using the corresponding time frame. In cantaloupe, the box represents the harvesting period (H); the arrow, disking date (D) (Fig. 4A). In cotton, the arrows are marked H and D for harvest and disking respectively (Fig. 4B).

whitefly activity. It is possible that whiteflies migrated to the nearby cotton crops when the cantaloupes were harvested. This finding is similar to the field-to-field migrations following harvest reported previously (Riley and Wolfenbarger 1993, Blua et al. 1994).

The determinants of whitefly activity in the cotton fields are less clear. High numbers of whitefly adults were caught in June and July, well before harvest or the application of the defoliant. This finding is in contrast to that of Legaspi and Carruthers (1995) who found peak adult whitefly sampled during the last week of July to mid-August, which corresponded to the period of cotton harvest. Several factors may trigger short-range migration in the whitefly (Byrne and Blackmer 1996). One likely contributing factor was deteriorating leaf quality caused by senescence.

Kenaf. SLWF nymphal density in kenaf was generally low, with the exception of the first sampling in field K3 which yielded > 70 nymphs/cm^2 of leaf (Fig. 5A). For the remainder of the samples, populations peaked at ~2/cm^2 in field K3 in July and August, and in late September in field K5 (Figs. 5A and 5B). Densities averaged <1/cm^2 leaf area throughout most of the sampling periods. Note that due to large inter-field differences in insect density, the 2 kenaf fields illustrated in Fig. 5 are presented in 2 different scales. The population trends of the SLWF immatures on the leaves and the *Encarsia* adults sampled by traps appear to be similar. There is no evidence that parasitoids are attracted to yellow, thus we assume that their density on traps is a relative indicator of parasitoid foraging activity. Kenaf might serve as a reservoir of natural enemies within a larger cropping system, as has been suggested in California (Roltsch et al. 1995).

SLWF adults (per 7.6 × 7.6 cm area of sticky trap) had much higher inter-field variations in insect densities and are presented using different axis scales (Fig. 5C). Adults in field K3 had an initial peak of > 1,300 per trap, which reflected initial high nymphal density found on the same date (Fig. 5A). Despite rather high adult densities sampled, populations of immature SLWF were low, suggesting that kenaf is not a preferred host plant for oviposition, or that natural enemies were suppressing the immatures. Field K5 had adult SLWF densities usually <10/trap, with a single peak of > 35 (Fig. 5C). The data reflect considerable inter-field variability in insect densities in the same plant host over an identical time frame.

Parasitoids. Parasitoid populations were relatively high in the kenaf fields, possibly because they were not treated with insecticides. The parasitoid emergence from leaves collected in field K3 produced peaks of ~30 females and ~10 male *Encarsia* spp. (Hymenoptera: Aphelinidae) (Fig. 6A). In contrast, the leaves collected from the cantaloupe and cotton fields resulted in very low numbers of parasitoids. *Eretmocerus* spp. were reared in low numbers for both sexes. Combined percentage parasitization generally was between 20 to 80% for both instars for K3 (Fig. 6B), although total numbers of parasitoids counted declined from >400 to 2 during the season. Parasitism in cotton was generally less than that in kenaf, increasing in late-May and peaking ~mid-June, usually at 10 to 15% (figure not shown). In kenaf, both the whitefly and *Encarsia* populations declined after 28 August (Julian day 240) and parasitism rates increased (Figs. 5 and 6). The decline in the host population cannot be attributed

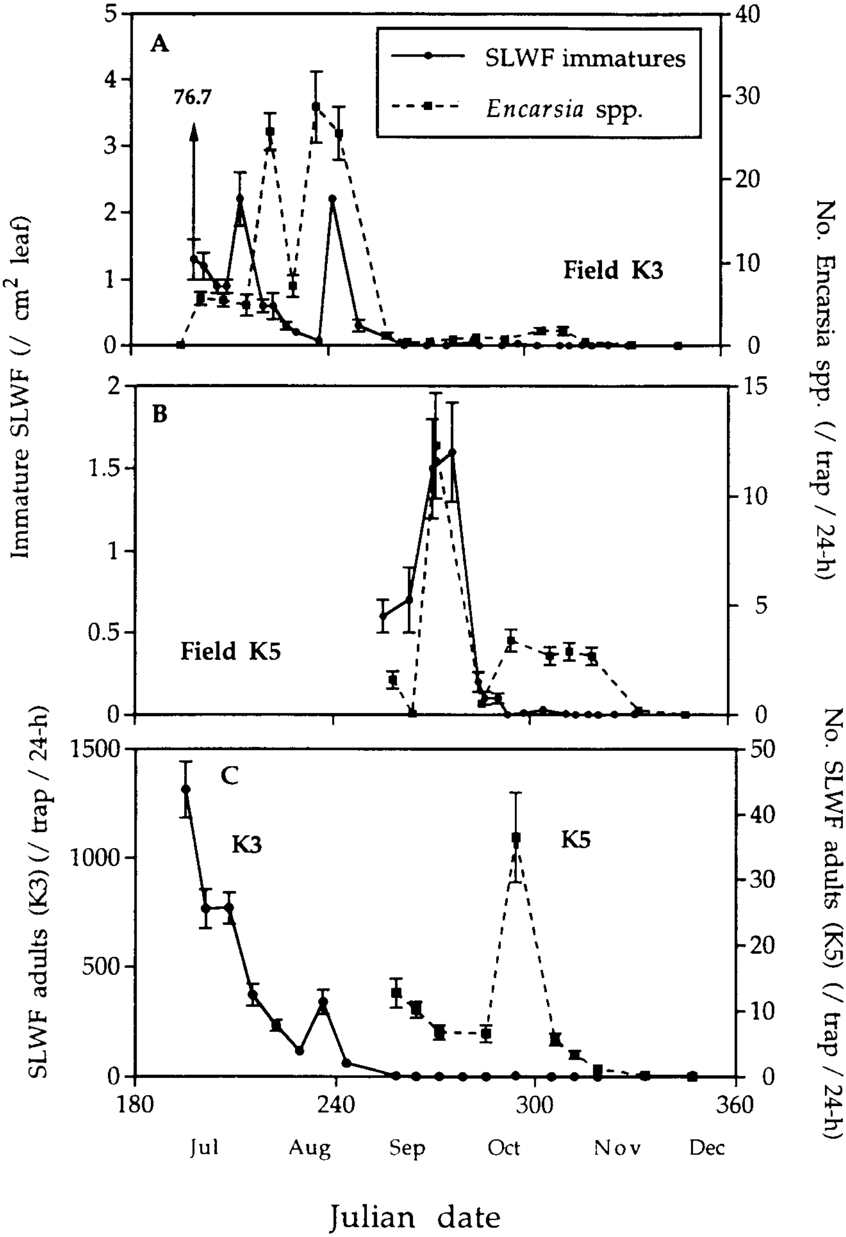

Fig. 5. Numbers of immature *B. argentifolii* (per cm^2 leaf, axis on left) and *Encarsia* spp. (per trap per 24-h, axis on right) in kenaf field K3 (A) and K5 (B). SLWF adults (per trap) for kenaf fields K3 (axis on left) and K5 (axis on right).

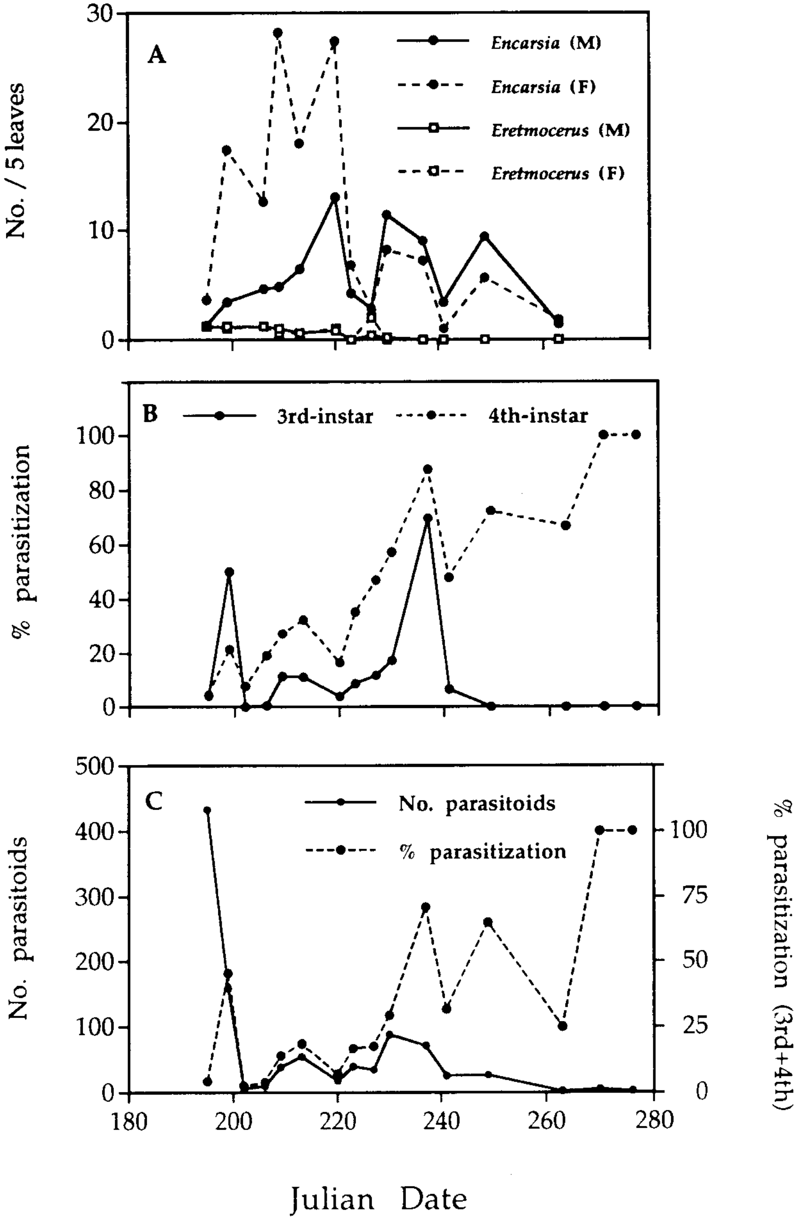

Fig. 6. Parasitism in kenaf field K3. Parasitoids reared from emergence boxes are designated by sex and genus. Data are numbers reared from a total of 5 leaves (A). Parasitoids are differentiated according to genus and sex (M: males; F: females). Percentage parasitism is shown for 3rd-instars, and 4th-instars (B). Total number of parasitoids per disk sample and percentage parasitization of 3rd- and 4th-instars (from B) are shown in Fig. 6C.

to parasitism by the *Encarsia* spp. Fig. 6C illustrates how reporting only percentage parasitization may give misleading impressions regarding the impact of parasitoids. In this case, increasing percentage parasitization was caused primarily by decreases in the numbers of hosts, rather than in increases in the population size or efficiency of the parasitoid community.

In an unrelated study, exotic parasitoids were released in field K3, although they contributed negligible parasitism and can effectively be omitted from this analysis. A total of 3,045 parasitoids were reared from pupae collected in the LRGV during May to December 1994. From these collections, 2,579 (84.7%) were native *E. pergandiella* Howard it is consistently the most common species in this area (Carruthers et al. 1993). Native *Eretmocerus* spp. comprised 14.8% (n = 449), and other native *Encarsia* spp. 0.3% (n = 9). Only 8 (0.26%) parasitoids (5 *Encarsia* spp. from Spain, 3 *Eretmocerus* spp. from College Station, TX) were of introduced species. Parasitism by exotic species has increased since 1994 (J. Goolsby unpubl. data), but is likely irrelevant to this study. The degree of establishment of the exotics, as well as their effects on the whitefly communities can be determined only after several years.

Encarsia spp. sampled on sticky traps indicated significant activity of the adults in the cotton and kenaf fields, and much lower activity in the cantaloupe (Fig. 7A-C; representing means across all fields). The cantaloupe crop showed low levels of parasitoid activity except on Julian date 173 (22 June). This sample was taken between harvest and disking which was a period of considerable whitefly and possibly, parasitoid migration. Parasitoids were active in the cotton crop until 24 July (Julian day 205). After the application of the defoliant on Julian day 210, parasitoid activity was generally low until mid-November (Fig. 7B). The cantaloupe showed a similar increase in the numbers of parasitoids captured, although much less pronounced (Fig. 7A). Any increase in parasitoid activity so late in the season was caused by external factors because both crops had already been disked.

High numbers of parasitoids were captured in kenaf (Fig. 7C). It is not possible to determine activity patterns before Julian day 195, the 1st day of sampling in kenaf. The relatively high numbers of *Encarsia* adults caught supports the conclusion drawn previously (Fig. 6), that kenaf may serve as a refuge crop for these parasitoids in a heterogeneous crop. Furthermore, high numbers of *Chrysoperla* spp. also were found in kenaf using sweep net samples (J. C. Legaspi, unpubl. data). However, it is difficult to draw reliable conclusions in a comparison between kenaf and the other crops because kenaf was outside the experimental site.

Kogan (1996) asserted that areawide management of *Bemisia* spp., including the silverleaf whitefly, is complicated because they are highly dispersive, highly polyphagous, and apparently not amenable to economic control using soft technologies such as mating disruption or sterile male release. A dispersive and polyphagous pest can be expected to move from field to field, depending on the farming practices and cropping patterns implemented in an area. We found that harvesting in cantaloupe was most likely responsible for short-range migration of whiteflies to cotton. A combination of factors, especially leaf senescence, probably caused migration from cotton to other crops, including kenaf. However, related studies suggest that cotton harvest also may trigger

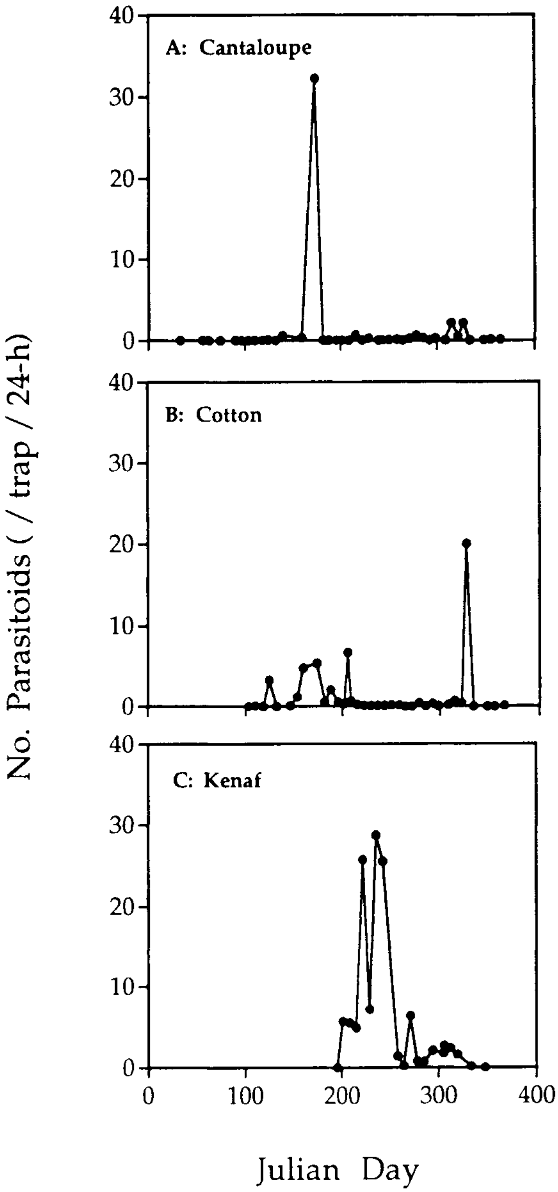

Fig. 7. Parasitoids caught in sticky traps for all crops. The points represent mean numbers per trap across fields for A: cantaloupe; B: cotton; and C: kenaf.

short-range silverleaf whitefly migration. Areawide IPM of this pest must, therefore, consider the consequences of farming practices and cropping patterns in heterogeneous fields, especially when they are under different managements. Further research is needed on the effects of agronomic practices on short-range whitefly migration before areawide management of *B. argentifolii* becomes effective.

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