PHOTOSYNTHESIS AND STOMATAL CONDUCTANCE OF COTTON INFESTED BY DIFFERENT WHITEFLY THRESHOLD LEVELS

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Abstract

Photosynthetic rates and stomatal conductances of cotton, *Gossypium hirsutum* L., treated at different action thresholds for whiteflies, *Bemisia argentifolii* Bellows and Perring, were measured on 12 d from July to August 1995 in the Imperial Valley, California, using a LI-6200 portable photosynthesis system. Action thresholds were 2.5, 5, 10, and 20 adults per leaf. Untreated plots were also used for comparison in a 5 x 5 Latin Square Design. Photosynthetic rates of untreated cotton leaves were significantly lower than those of 2.5, 5, and 10 threshold treatment leaves on at least 9 of the 12 d. Rate differences between 2.5, 5, and 10 threshold treatments were generally nonsignificant. Photosynthetic rates of leaves treated at 20 adults per leaf were lower than those of other treated leaves on 2 or 3 d and were significantly higher than those on untreated leaves on 3 d. In general, no significant differences were detected between stomatal conductances from the 2.5, 5, and 10 threshold treatment leaves, and results were similar to the pattern seen with photosynthesis. Adult, egg, and nymphal densities on untreated cotton were usually significantly higher than those on all other treatments, but in general no differences in densities of any stage were seen in 2.5, 5, and 10 threshold treatments. Densities from the 20 threshold treatment were generally not significantly different from untreated nor from 2.5, 5, and 10 threshold treatments. Based on photosynthetic rates, stomatal conductances, and immature whitefly densities, the best action threshold on cotton in the Imperial Valley seems to be between 10 and 20 adult whiteflies per leaf.

Introduction

In 1993, the whitefly *Bemisia argentifolii* Bellows and Perring (formerly known as the sweetpotato whitefly *B. tabaci* (Gennadius) strain B) infested 70,000 acres of cotton *Gossypium hirsutum* L. in California, resulting in a loss of 5,426 bales of lint (Williams, 1994). Insecticide applications provide control, but are expensive and misuse often results in resistance development. As a result, attempts have been made to develop adult action thresholds on cotton in California (Chu et al., 1994, 1995, Henneberry et al., 1995a) and Arizona (Ellsworth and Meade, 1994, Naranjo et al., 1994) to prevent cotton lint yield losses, reduce costs of control, and to delay or prevent insecticide resistance development (Henneberry et al., 1995b). Adult and immature whitefly honeydew contaminates cotton lint, leading to sticky cotton (Cheung and Roberts 1980), and sooty mold can develop on the lint, further reducing its value.

The combined effects of treating cotton with insecticides at different action thresholds on cotton photosynthesis, stomatal conductance, and whitefly densities have not been investigated. Various insecticides seem to have negative or no effects on cotton photosynthesis and stomatal conductance (e.g., Jones et al., 1986, Youngman et al., 1990). However, it seems logical that feeding by high numbers of whiteflies would reduce stomatal con-ductance and possibly photosynthesis. Reduction of cotton photosynthesis and stomatal conductance may be directly related to adult and immature whitefly densities (i.e., by disruption of the photosynthetic apparatus through feeding or by coverage of stomata by the sessile nymphs) or indirectly (i.e., secretion of honeydew onto leaf surfaces), or both.

A positive relationship between photosynthetic rates and cotton lint yield has been found in artificially CO_2-enriched environments. Cotton in CO_2-enriched environments (630 ppm) compared to cotton in non CO_2-enriched environments (330 ppm) showed a 15% increased carbon exchange rate (CER) and also a 130% increase in lint yields (Mauney et al. 1978). Assessing lint yields is the most important factor in establishing action thresholds on cotton, but determining the adult levels at which photosynthetic rates and stomatal conductances are reduced also may be helpful in developing thresholds.

The main objective of this study therefore was to determine the effects of action thresholds for chemical control of whiteflies on photosynthetic rates and stomatal conductances of irrigated cotton. A second objective was to determine whether these action thresholds have effects on immature whitefly densities, and whether these densities are affected the same way as photosynthetic rates and stomatal conductances. Lint yield results from threshold plots used in this study will be reported elsewhere.

Materials and Methods

Action Threshold Plots

Field plots were located at the USDA Irrigated Desert Research Station, Brawley, Imperial Valley, CA. Cotton

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(c.v. "DPL-5415") seeds were planted 10 March and emerged 27 March 1995. The soil was fertilized with 100 lb N (urea) and 100 lb P_2O_5/ac, and fields irrigated every 7 d. Plots were arranged in a 5 X 5 Latin Square design, with 5 replicate plots designated for untreated (control) plants and 4 action threshold treatments when numbers of adults per leaf turn were at or exceeded 2.5, 5, 10, or 20. Each treatment plot was 15.4 m long, and consisted of 8 planted rows spaced 1 m apart from one another. There were 2 skip rows between plots, with 3.01 m alleys. Adults were counted on the undersides of 5 to 30 5th mainstem node leaves per plot between 0500 and 0800 h (Pacific Standard Time) beginning 2 May, and at weekly intervals thereafter. When the mean number of adults reached the predetermined action thresholds, a mixture of fenpropathrin (Danitol[R] 2.4 EC, a-Cyano-3-phenoxybenzyl 2,2,3,3,-tetramethyl-cyclopropanecaboxylate) (0.1 ai/ac) and acephate (Orthene[R] 90S, O,S-Dimethyl acetylphoshoramidothioate) (0.5 lb/ac) was applied one day after counts. The insecticides were applied using a ground sprayer designed to improve underleaf coverage, as described by Akey et al. (1992).

Photosynthesis, Stomatal Conductances, and Leaf Temperatures of Cotton From Action Threshold Treatments

Photosynthetic rates (*u*mol $CO_2/m^2/s$), stomatal conductances (cm/s), and temperatures (ºC) of cotton leaves were measured on 12 d between 17 July and 28 August 1995 either 3 or 6 d post insecticide applications and 2 or 5 d post irrigation, respectively. Measurements were taken using a LI-6200 portable photosynthesis system (LI-COR, Lincoln, NE) near the terminal of 3rd mainstem node leaves. Third mainstem, fully expanded and fully sunlit leaves were chosen because they were less often shaded than the 5th mainstem node leaves, which normally are used for whitefly density estimates (Naranjo et al. 1994). Photosynthetic active radiation reaching the adaxial leaf surfaces during measurements ranged from 1400-1900 *u*mol of photons (*u*E)/m^2/s. A rectangular area of 5.625 or 7.500 cm^2 (one surface) was exposed inside a 1-liter leaf chamber (model 6000-12) and confined using sliding foam-padded inserts. These exposed areas allowed humidities inside the chamber to stabilize between 30 and 35%; larger areas caused excessive humidity increases. A drawdown of 5 ppm CO_2 (uptake by the leaf) was set as the criterion for the completion of a measurement. CO_2 concentration inside the chamber ranged from 330 to 380 ppm. Before measurements, leaves were gently turned over for about 10 to 15 s and the adults on the undersides counted. Adults were then gently brushed or shaken off before measurements. After measurements, the outline of the leaf area exposed inside the chamber and from which parameters were taken was traced with a pen. Entire leaves were then removed from plants and immediately sealed inside plastic bags and placed inside a cooler with frozen gel packs.

The sampling sequence in the Latin Square Design was the same each day. One leaf was selected from each treatment plot, yielding 5 measurements per treatment per sampling date, for a total of 25 observations (5 treatments x 5 replicate plots). All leaves were from plants about 2 m away from the plot edges and between rows 4 to 6 within the 8-row treatment plot. Measure-ments were taken between 0800 and 1045 h. On 2 d (7 and 14 August) additional measurements using the same sampling scheme were made in the afternoon between 1200 to 1430 h.

Whitefly Numbers and Densities From Action Threshold Treatments

To calculate adult whitefly densities, areas of entire leaves were measured using a LI-COR 3000 leaf area meter (LI-COR, Lincoln, NE), usually within 12 h of collections. The rectangular areas on leaves that were exposed inside the leaf chamber were then cut with scissors and the numbers of eggs, 1st and 2nd instar nymphs, 3rd and 4th instar nymphs, and exuviae and dead nymphs on both surfaces were counted under a dissecting microscope at 18X.

Photosynthesis and Stomatal Conductances of Untreated Cotton

To obtain additional information on seasonal trends of photosynthesis and stomatal conductances of whitefly-infested cotton, measurements also were taken on leaves from plants in an untreated field approximately 50 m from the action threshold plots. Measurements were taken on 6 d between 13 July and 18 August 2 d post-irrigation. Because fields were normally very wet, measurements were taken from plants located 2 to 4 rows inside from the plot edge (near drier areas). Measurements were taken between 1100 to 1300 h.

Statistical Analyses

For each date, analysis of variance (ANOVA) for Latin Square Designs (Little and Hills 1972) was conducted for each of the 5 treatments on photosynthetic rates, stomatal conductances, leaf temperatures, adult white-flies per leaf, and adult and immature whiteflies per cm^2 of leaf. Treatment means were separated using Tukey's honestly significant difference (HSD) method (Sokal and Rohlf 1981, Wilkinson 1990). Repeated measures ANOVA was used to determine if changes occurred in photosynthetic rates and stomatal conductances over the season within action threshold treatments. Plots were considered replicates, and weekly sampling of leaves from the same plots were considered repeated samples.

One-way ANOVA was used to detect between-day differences in photosyn-thetic rates and stomatal conductances of cotton from the separate untreated plot. Stepwise multiple regressions relating photosynthetic rates and stomatal conductances to densities of different immature whitefly stages (the independent variables) within days were also conducted.

Results and Discussion

Photosynthesis, Stomatal Conductances, and Leaf Temperatures of Cotton From Action Threshold Treatments

Fig. 1 shows that the photosynthetic rates (0800-1045 h) of cotton at whitefly thresholds of 2.5, 5, and 10 adults per leaf were similar throughout 12 sampling days in the 43-d experimental period. Cotton treated at 20 adults per leaf had intermediate photosynthetic rates, while untreated leaves had the lowest rates. Significant differences in photosynthesis occurred on each sampling day (F-value range = 3.63 to 21.26; df = 4, 12; P-value range = 0.037 to < 0.001), except for the first (17 July, $P > 0.05$). Multiple comparisons results showed that photosynthetic rates from 2.5, 5, and 10 adult threshold treatments did not differ signficantly (P > 0.05) from each other except on 25 August. However, rates for these 3 treatments differed from those of untreated leaves on 9 or 10 of the 12 d of sampling (P < 0.05). Photosynthetic rates of the 20 threshold treatment leaves were intermediate; they did not differ significantly (P > 0.05) from those of untreated or other treated leaves except on 2 or 3 of the 12 sampling days.

Fig. 2 shows that stomatal conductances of leaves from different threshold treatments followed trends similar to those seen with photosynthesis. Significant differences between treatments (F-value range = 4.76 to 16.44; df = 4, 12; P-value range = 0.016 to < 0.001) were detected on 9 of the 12 sampling days (P < 0.05). In general, leaves treated at 2.5, 5, and 10 adults per leaf had higher stomatal conductances than leaves from 20 adult treatments, while untreated plants had the lowest conductances (Fig. 2). Multiple comparisons results were similar to the photosynthesis rate comparisons. Significant differences between 2.5, 5, and 10 threshold treatments occurred only on 25 August (P < 0.05). Values from untreated leaves differed from the 2.5, 5, and 10 threshold treatments on 8 or 9 of the 12 sampling days (P < 0.05), but values from 20 threshold treatments differed from other threshold treatments on only 1 or 2 of the sampling days, and differed significantly (P < 0.05) from untreated leaves on only 2 d.

Fig. 3 shows that abaxial leaf temperatures (ºC) from 2.5, 5, 10, and 20 threshold treatments were lower than those of untreated leaves, and significant differences were detected on 10 of 12 sampling days (F-value range = 3.64 to 16.68; df = 4, 12; P-value range = 0.038 to < 0.001). Multiple comparisons results were generally similar to those associated with photosynthesis and stomatal conductances.

Whitefly Numbers and Densities From Action Threshold Treatments

Fig. 4 shows that mean numbers of adults per leaf at the time of photosyn-thetic, stomatal conductance, and leaf temperature measurements (0800-1045 h) fluctuated greatly during the season, e.g., ranging from a mean of fewer than 5 to more than 100 on the untreated cotton. Mean numbers of adults per leaf from 2.5, 5, and 10 threshold treatments were significantly lower than on untreated plants on 8 to 10 of the 12 sampling days (F-value range = 3.40 to 21.48; df = 4, 12; P-value range = 0.045 to < 0.001). Differences in adults per leaf between untreated and 20 threshold treatments occurred on 7 d. Significantly higher densities of adults (numbers per cm^2 of leaf) occurred on untreated plants compared with all other treatments on 4 to 8 of the 12 sampling days (F-value range = 3.66 to 40.82; df = 4, 12; P-value range = 0.036 to < 0.001). Differences in adult densities per cm^2 between untreated and 20 threshold treatments were seen on 5 d. Thus, more differences between untreated and 20 threshold treatments were seen with adult whiteflies per leaf and cm^2 than with photosynthesis and stomatal conductances.

Fig. 5 shows that mean densities of eggs, 1st and 2nd instars, 3rd and 4th instars, and exuviae and dead whiteflies on 2.5, 5, 10, and 20 adult threshold treatment leaves were usually much lower than on untreated leaves. Significant differences in densities between different stages were detected on nearly every sampling day (e.g., 1st and 2nd instars: F-value range = 2.84 to 9.36; df = 4, 12 ; P-value range = 0.04 to 0.001). Multiple comparisons results showed that significant differences were usually seen only between untreated leaves and the other treatments. Densities within 2.5, 5, 10, and 20 threshold treatments did not differ significantly (P > 0.05), except for egg densities on 18 August. Immature whitefly densities between untreated and 20 threshold treatments differed significantly on more days than did photo-synthesis and stomatal conductances.

Despite some clear differences in photosynthesis, stomatal conductances, temperatures, and whitefly numbers and densities between treatments within days, values of the first 3 parameters from leaves within a treatment showed strong between-day fluctuations during the study (Figs. 1-3), and day effects were significant within all treatments (e.g., repeated measures ANOVA of photosynthesis: 2.5 adult treatment: $F = 4.18$; df = 6, 24; $P = 0.005$; untreated: $F = 5.28$; df = 6, 24; $P = 0.001$). Not unexpectedly, leaf temperature was the most variable parameter between days within treatments (e.g., 2.5 adults: $F = 23.77$; df = 6, 24; $P < 0.001$; untreated: $F = 21.28$; df = 6, 24; $P < 0.001$).

Afternoon Photosynthesis, Stomatal Conductances, and Leaf Temperatures From Action Threshold Treatments

Fig. 6 shows that 1200 to 1430 h photosynthetic rates, stomatal conductances, and leaf temperatures also differed between treatments (7 August: photosynthesis: $F = 5.28$; df = 6, 24; $P = 0.011$; stomatal conductance: $F = 7.76$; df = 6, 24; $P = 0.002$; temperature: $F = 4.58$; df = 6, 24; $P = 0.018$; 14 August: photosynthesis: $F = 8.69$; df = 6, 24; $P = 0.002$; stomatal conductance: $F = 5.58$; df = 6, 24; $P = 0.009$;

temperature: F = 6.30; df = 6, 24; P = 0.006) . Photosynthetic rates and stomatal conductances in general were lower during this period than from 0800-1045 h, but as with the morn-ing measurements, no significant differences were detected between 2.5, 5, and 10 threshold treatments ($P > 0.05$). Values from 20 threshold treatments were generally intermediate in magnitude, while values from untreated plants were the lowest ($P < 0.05$). Abaxial leaf temperatures of untreated cotton leaves were always higher than leaves from the 2.5 threshold treatment ($P < 0.05$), and in some cases from other treatments.

Photosynthesis and Stomatal Conductances of Untreated Cotton

Fig. 7 shows that photosynthetic rates and stomatal conductances of untreated cotton leaves (1100 to 1300 h) in a completely separate plot did not stay very constant during the summer, as was the case with cotton in the action threshold plots. One-way ANOVA indicated significant differences in photosynthetic rates (F = 38.83; df = 5, 81; $P < 0.001$) and stomatal conductances (F = 26.33; df = 5, 81; $P < 0.001$) between days, with significant decreases seen as the season progressed. At the same time, significant differences in densities between days of all stages of whiteflies were seen (P < 0.01) (Fig. 7). However, decreases in photosynthesis and stomatal conductances were not necessarily inversely related to increases in whitefly densities (Fig. 7). In addition, when densities of the 4 different immature and exuviae and dead stages were regressed stepwise against photosynthetic rates and stomatal conductances within 3 d (when $n \geq 18$: 17 July, 11 August, and 18 August), r^2 values were low (0.226-0.541), and no significant regressions were obtained ($P > 0.05$).

In this study insecticide treatments at action thresholds of 2.5, 5, and 10 adult whiteflies per leaf did not result in differences in photosynthetic rates nor in stomatal conductances of cotton leaves. Insecticide applications at these action thresholds also did not result in significant differences in adult and immature whitefly densities, which almost certainly influence stickiness of cotton. Thus, based on cotton photosynthesis, stomatal conductances, and whitefly densities, it appears that the earliest time necessary to insecticide-treat cotton occurs when 10 adult whiteflies per leaf are detected. Because the 20 adult threshold treatment leaves were intermediate in plant physiological responses and whitefly densities, and because these responses and densities were usually not significantly different from those of untreated cotton, the best action threshold may be somewhere between 10 and 20 adult whiteflies per leaf. In the southern California deserts in 1994, some insecticide treatments were initiated based on counts of 10 adult whiteflies per leaf (Hardee and Herzog 1995, Henneberry et al. 1995a). The results of the present study support the use of this threshold value, although they also suggest a slightly higher value (perhaps 15 adults per leaf) may be acceptable. In Arizona, the suggested threshold for initiation of treatments was between 1 and 10 adult whiteflies per leaf (Ellsworth and Meade 1994).

Differential feeding and associated damage by whiteflies from 2.5, 5, and 10 adult threshold treatments in the present study were too small to cause significant differences in photosynthesis and stomatal conductances. Perhaps these narrow threshold ranges were constantly in a state of flux because of migratory adults that may not necessarily stay to feed or lay eggs on the leaves. Thus, all 3 thresholds could be considered one treatment (grouped as 2.5 to 10 adults per leaf). However, high whitefly densities in 20 adult threshold treatments and in untreated cotton did seem to cause reduced photosynthetic rates and stomatal conductances. There were clear visible differences between untreated leaves and treated leaves. Untreated leaves were discolored, brown-splotched, and glistened with honeydew, whereas treated leaves were usually greener. Honeydew contamination probably was a major cause of reduced photosynthesis, with high whitefly densities accounting in large part for reduced stomatal conductance. Sooty mold on leaves appeared to play only a minor role, because it was not seen until later in August, and because 3rd mainstem node leaves were less contaminated with honeydew than lower leaves. Some of the leaves from the 20 adult threshold treatment displayed these characteristics as well.

Effects of different action threshold treatments on photosynthesis and stomatal conductances were discernible on 24 July, 1 week after the beginning of the study. This suggests insecticide applications are needed no later than mid July, when whitefly densities are usually very high. However, the results require further defining because measurements were not taken in June and earlier in July. It did not appear that decreased photosynthetic rates and stomatal conductances at the end of the season were linked directly to increased densities of whitefly immatures, based on data from untreated plots. Fluctuations in photosynthetic rates and stomatal conductances within action threshold treatments as shown by repeated measures analysis suggest that even keeping leaves relatively free of whiteflies does not prevent seemingly natural decreases in these parameters. Depressed values in action threshold and untreated plots may have been caused by earlier whitefly feeding (a possible cumulative effect), or related simply to increasing plant age and seasonal changes.

In addition, no relationship existed between whitefly densities and photosyn-thesis and stomatal conductances within the separate untreated plot, probably because the ranges of densities were not large enough (no leaf had zero whiteflies). In the only other study relating gas exchange and whitefly feeding, Buntin et al. (1993) found that feeding injury by larval and adult *B. tabaci* reduced photosynthetic rates and transpiration of tomato *Lycopersicon esculetum* Mill. leaflets. However, the relationship between photosynthesis and immatures per cm^2 was weak ($r^2 = 0.24$).

It is not clear from this study whether whiteflies and their honeydew were completely responsible for the reduced photosynthesis and stomatal conduct-ances or whether insecticide applications alone played a role in elevating the values of the parameters in treated cotton. A small effect due to insecticides may have been present, but evidence indicates insecticides have negative or no effects on cotton physiology. In California, 4 weekly applications of methyl parathion significantly reduced mesophyll conductance along with other plant growth parameters, but no insecticide tested, including chlordimeform, increased cotton growth parameters compared to controls (Youngman et al. 1990). Photosynthesis was also decreased by the defoliant ethephon (Pettigrew et al. 1993).

It is also unclear whether photosynthetic rates of whitefly-infested cotton in threshold plots have any relevance to lint yield. There is evidence that increased photosynthesis in several plant species results in increased crop yield (Zelitch 1982), and that in cotton it also results in increased lint yield (Mauney et al. 1978, Radin et al. 1987). In glasshouse CO_2-enriched environments, increased photosynthesis was associated with an increased harvested lint fraction (Mauney et al. 1978). The effects of CO_2-enriched environments on photosynthesis and lint yield and the effects of non CO_2-enriched environments interacting with insecticide treatments and whitefly feeding on photosynthesis may be quite different. In the Imperial Valley, photosynthetic rates probably would be closely related to lint yields if it is reduced by whitefly feeding and honeydew contamination in the very early growth phases of cotton, which might cause stunting of the plants. In the present study, most plant reserves for boll formation in cotton probably were present before high whitefly feeding intensity in July and August could effect them severely. This was evidenced by observations of bolls that apparently formed synchronously on plants in different treatment plots.

Numbers of adult whiteflies per leaf were highest on untreated leaves as expected, but they were usually not different between 2.5, 5, 10, and 20 threshold treatment leaves. This was also the case with immature whitefly densities. These results were similar to photosynthesis and stomatal conductance results. However, the results with adults on leaves did not agree exactly with those of photosynthesis and stomatal conductance, which were measured on the same leaves. Numbers of adults per leaf and adults per cm^2 in untreated and 20 threshold treatments were significantly different on 7 and 5 out of 12 d, respectively, whereas for photosynthesis they were different on 3 d and for stomatal conductance they were different on 2 d. Treating at 20 adults per leaf seemed to be beyond the best threshold, as nymphal densities increased by that point. Similar to the effects on adult densities, the differential effects of untreated and 20 adult threshold treatments on nymphal densities were slightly more pronounced than were their effects on photosynthesis and stomatal conductance. Thus, both adult and nymphal density estimates were more sensitive to 20 threshold treatments than were photosynthetic rates and stomatal conductances. Based on the latter 2 parameters, it appears that on some days 20 threshold treatments had a similar physiological effect on cotton leaves as leaving plants untreated.

The relationship between whitefly densities and lint yield appears clearer than the relationship between photosynthesis and lint yield. The seasonal average total numbers of whitefly adults, eggs, and nymphs were negatively correlated ($r = -0.84$) to lint yield (lbs/A), and untreated plots with higher nymphal densities had higher honeydew sugar (trehalulose) amounts (mg/g of cotton lint x 10) than treated plots (Henneberry et al. 1995b). Chu et al. (1994) also found that lint stickiness was related to the number of nymphs and pupae per cm^2 ($r^2 = 0.516$ to 0.667).

In conclusion, photosynthetic rates and stomatal conductances of cotton were clearly affected by whitefly action thresholds maintained by insecticide treatments. Differences in parameters between 2.5, 5, and 10 threshold treatments were generally nonsignificant. Differences in parameters between these and 20 threshold treatments were significant or nonsignificant, whereas differences between the 20 threshold treatment and untreated leaves were often nonsignificant. Photosynthetic rates and stomatal conductances of 20 threshold treatment leaves were more similar to untreated leaves than were adult and nymphal whitefly densities between these treatments. Nevertheless, photosynthesis, stomatal conductance, and whitefly density estimates all suggested that the best action threshold in the Imperial Valley is between 10 and 20 adults per leaf. Furthermore, the action threshold suggested by preliminary lint yield data (Henneberry et al. 1995a) is similar, indicating that perhaps a multitude of factors can be reliably used in developing action thresholds for *B. argentifolii*.

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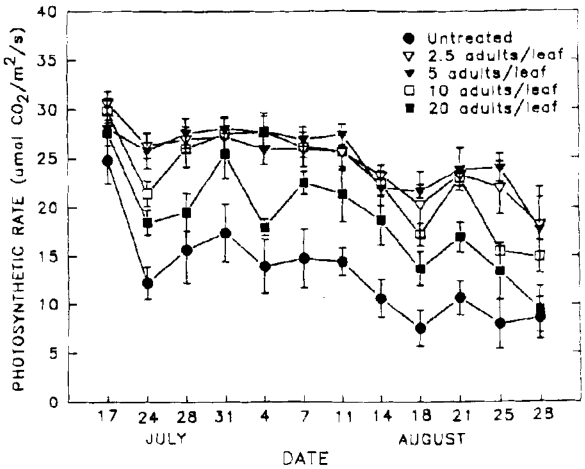

Fig. 1. Mean photosynthetic rates (± SEM) of cotton leaves (n = 5) treated at different *B. argentifolii* action thresholds from 0800 to 1045 h.

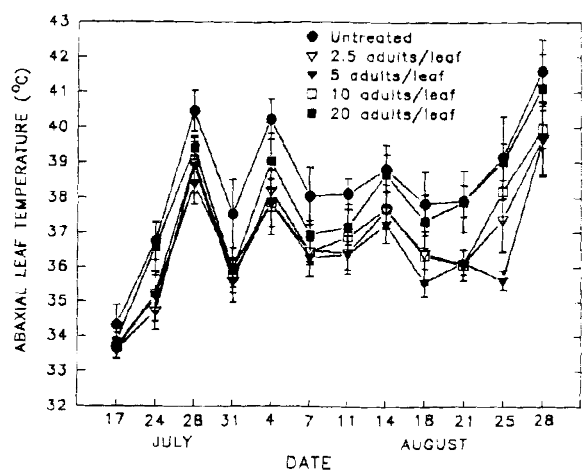

Fig. 3. Mean leaf temperatures (± SEM) of cotton leaves (n = 5) treated at different *B. argentifolii* action thresholds from 0800 to 1045 h.

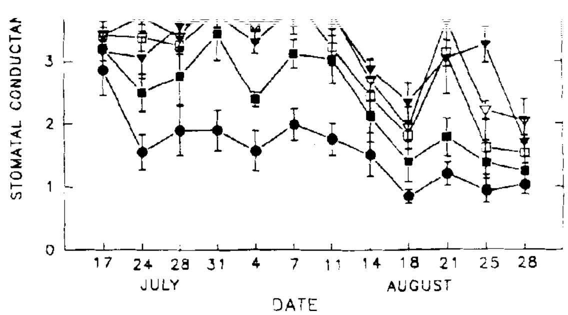

Fig. 2. Mean stomatal conductances (± SEM) of cotton leaves (n = 5) treated at different *B. argentifolii* action thresholds from 0800 to 1045 h.

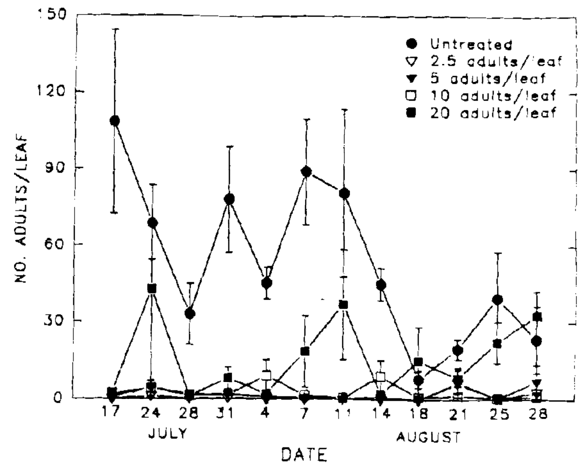

Fig. 4. Mean numbers of adult whiteflies (± SEM) per leaf of cotton (n = 5) treated at different *B. argentifolii* action thresholds from 0800 to 1045 h.

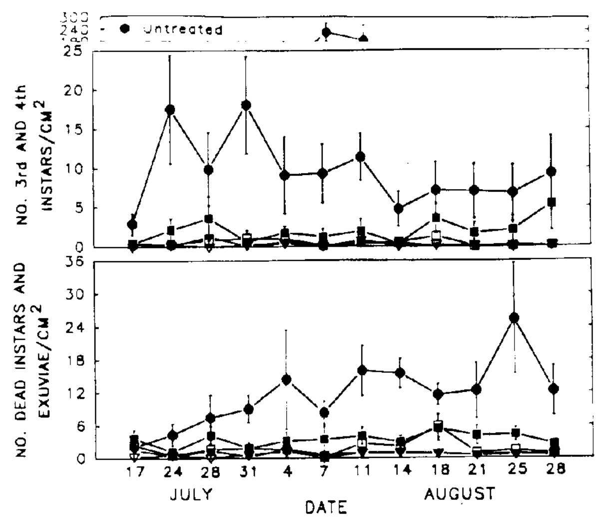

Fig. 5. Mean numbers of immature whitefly stages and exuviae and dead immatures per cm^2 (± SEM) of cotton (n = 5) treated at different *B. argentifolii* action thresholds.

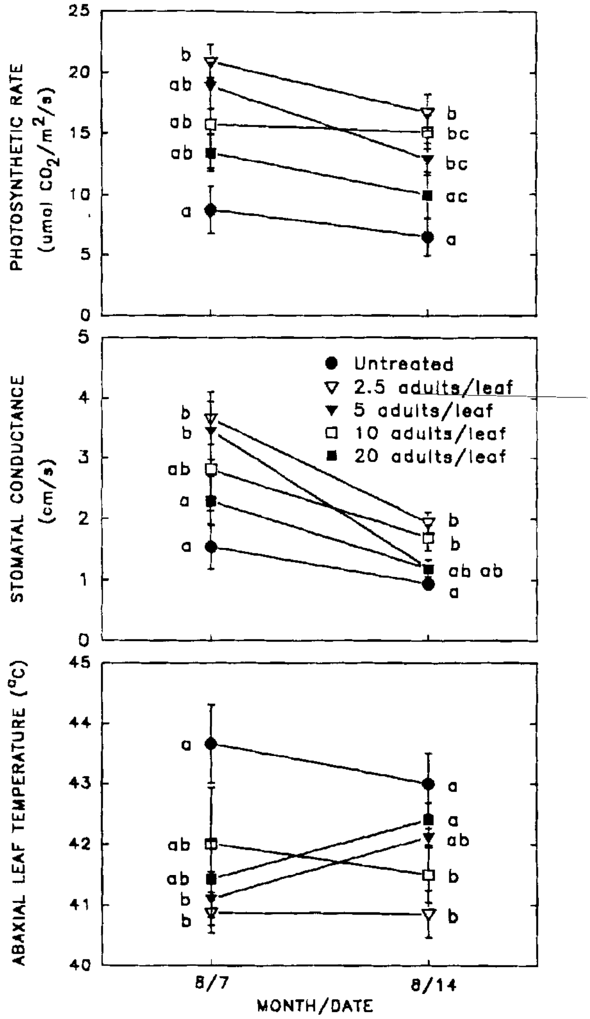

Fig. 6. Mean photosynthetic rates, stomatal conductances, and abaxial leaf temperatures (± SEM) of cotton leaves (n = 5) treated at different *B. argentifolii* action thresholds from 1200 to 1430 h. Means with different letters within each date are significantly different ($P < 0.05$, Tukey's HSD test).

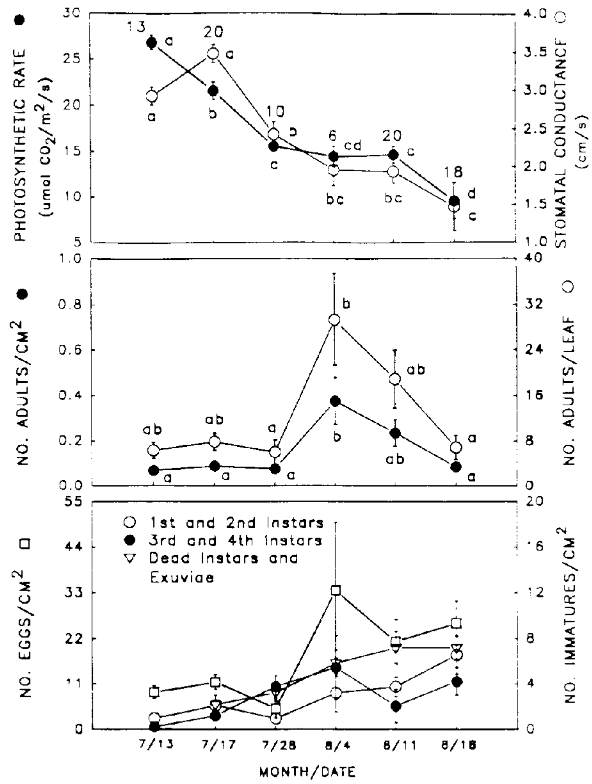

Fig. 7. Mean photosynthetic rates, stomatal conductances, and numbers of adult and immature *B. argentifolii* per cm^2 (± SEM) of untreated cotton (n = 6 to 20) from 1100 to 1300 h. Means with different letters within each measurement parameter are significantly different ($P < 0.05$, Tukey's HSD test).