EFFECTS OF INSECTICIDE APPLICATIONS ON *BEMISIA ARGENTIFOLII* (HOMOPTERA: ALEYRODIDAE) DENSITIES, HONEYDEW PRODUCTION, AND COTTON YIELDS

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Abstract

Honeydew contamination of cotton, *Gossypium hirsutum* L., lint by whiteflies, *Bemisia argentifolii* Bellows & Perring, is a major concern at textile mills and is well documented. Results of studies designed to determine adult whitefly densities at which cotton should be treated to reduce honeydew contamination have been variable. In this study, we determined the relationship between frequency of insecticide applications triggered by thresholds of 5, 10, 15, and 25 adult whiteflies per leaf and honeydew production by *B. argentifolii* feeding on cotton. Honeydew production was monitored on 15 dates from 21 May to 27 August 1996 in Brawley, CA, using water-sensitive papers placed on upper and lower leaves and bolls. On 4 dates lint was collected and analyzed for sugars using high performance liquid chromatography (HPLC). Whitefly densities and honeydew production were both affected by frequency of insecticide applications. Densities of adults per 5th mainstem leaf, adults per 10-s vacuum sample, 1st and 2nd instars, and 3rd and 4th instars per square centimeter of leaf were generally higher in control plots (1 insecticide application), plots treated at 25 adults (4 applications), and untreated plots than in plots treated at 5, 10, and 15 adults (11, 6, and 5 applications, respectively). In general, numbers of honeydew drops per square centimeter were higher in control, 25 adult, and untreated plots than in 5, 10, and 15 adult plots. Papers placed on uppermost bolls received more drops later in the season than did papers placed on the lowest bolls. Honeydew production was generally lowest throughout the season in the 5 adult treatment. However, it was not significantly different than the 10 or 15 adult treatments on 13, 20, and 27 August. There was no difference in honeydew drop diameters among treatments. Amounts of trehalulose did not differ among treatments on 23 July. However, amounts of trehalulose on top and bottom bolls were generally highest in control treatments and lowest in the 5 adult treatments on 6 and 20 August. There were generally no significant differences in the amounts from 5, 10, and 15 adult treatments. Honeydew drops per square centimeter were unexpectedly low in control and untreated plots on some later dates, especially on papers on bottom bolls. Coincidentally, control and untreated plants had fewer leaves than other plants during these times, with most of the lower, older leaves dropping off by August. This suggests leaf loss and plant level may account for some variability in honeydew production during late season. Seedcotton yields differed only between 10 and 25 adult threshold plots. At Brawley, CA, insecticide treatments at 5 and 10 adults per leaf seemed equally sufficient for reducing whitefly honeydew production. However, fewer applications were needed to maintain the 10 threshold, which would reduce the immediate costs to growers and also would reduce longer term problems associated with insecticide resistance.

Introduction

Honeydew contamination of cotton lint by whiteflies, *Bemisia argentifolii* Bellows & Perring, has been studied extensively in the past few years in California and Arizona. Both adult and immature whiteflies secrete copious amounts of honeydew that fall onto lint in open bolls, producing sticky cotton. Sticky cotton is a major concern at textile mills and is well documented (e.g., Rimon 1982; Perkins 1986; Hector and Hodkinson 1989; Henneberry et al. 1996). However, variable results have been obtained in studies attempting to relate whitefly densities to honeydew excretion or sticky cotton. A 2-year regional project covering 5 sites in Arizona, California, and Texas was initiated in 1994 to determine the best adult action threshold at which to treat cotton to prevent losses in lint yield and quality (Naranjo et al. 1996). Action thresholds were established whitefly densities at which insecticide applications were initiated. Higher whitefly densities (whiteflies per leaf) should result in higher honeydew contamination of cotton. However, no general relationship between thermodetector rating, a spot-count method designed to assess lint stickiness (Perkins 1993, Brushwood and Perkins 1993), and threshold levels of 2.5, 5, 10, and 20 adults per leaf emerged from these sites in 1994 and 1995. Lack of differences in stickiness among treatments was especially evident in Weslaco, TX, Bakersfield, CA, and Yuma, AZ, sites of relatively low whitefly densities, but this was also seen in Brawley, CA, a site of high whitefly populations, in 1995 (Naranjo et al. 1996). Field studies in 1990 in the Palo Verde Valley, CA, had also failed to demonstrate a correlation between whitefly density and lint stickiness, although rainfall may have been partly responsible (Toscano et al. 1992). Other studies have indicated whitefly densities and lint stickiness or sugar content are significantly related. In one study in Brawley, CA, 51.6 to 66.7% of the variation in minicard lint stickiness rating, a method using a system to detect sticky points on textile mill carding machines (Perkins 1993), were explained by numbers of nymphs and pupae per square centimeter of leaf area (Chu et al. 1994). Studies using high liquid performance chromatography (HPLC) indicated there was a good correlation between whitefly populations and trehalulose and other sugars from whiteflies on lint (Hendrix 1995, Henneberry et al. 1995). Cotton treated for

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whiteflies 6 times usually had significantly less trehalulose content than cotton treated 3 times during the season (Henneberry et al. 1995), and accumulated sugars and sticky cotton ratings were reduced in insecticide-treated versus untreated fields (Henneberry et al. 1996).

Water-sensitive papers designed to evaluate insecticide spray distribution have been used to detect honeydew production by whiteflies in the laboratory (Melamed-Madjar et al. 1984; Navon and Melamed-Madjar 1984; Butler et al. 1991; Blua and Toscano 1994) and field (Yee et al. 1996). Using honeydew drops to estimate survival of the tobacco whitefly, *B. tabaci* (Gennadius), on cotton after insecticide applications has been suggested (Melamed-Madjar et al. 1983; Melamed-Madjar et al. 1984; Navon and Melamed-Madjar 1984), but this method has never been reported in the literature. Although water-sensitive papers cannot be used to evaluate lint stickiness, they can be used for quick and accurate assessment of honeydew production.

Because of the variable results of previous research, the primary objective of this study was to more precisely determine the relationship between frequency of insecticide applications triggered by action thresholds and changes in whitefly honeydew production over a season. We determined the effects of insecticides on densities of adult and immature whiteflies and measured honeydew production by counting honeydew drops on water-sensitive paper. In addition, we measured quantities of different honeydew sugars on cotton lint. Seed cotton yields were also determined.

Materials and Methods

Study Site and Research Plots. The study was conducted at the USDA Irrigated Desert Research Station in Brawley in the Imperial Valley of California in 1996. Cotton seeds ('Deltapine 5415') were planted 19 March in raised clay-type soil beds and thinned to ≈ 1 plant every 20-30 cm on 8 May. Fields were furrow irrigated every 2 weeks until June, after which fields were irrigated every week until 21 August, which was the last irrigation date. Plots were arranged in a 5 × 5 Latin square design, with 5 replications of 4 treatments and a control. Action thresholds were 5, 10, 15 and 25 adults per leaf. Each treatment plot was 14.7 m long × 7.5 m wide (110 m^2) with 8 rows (beds) (≈ 600 plants), each row separated 1 m from others. In text descriptions, row number designations begin consecutively from the west side of plots. Plots were separated from one another by 4 skip rows and 3.6 m alleys of bare soil. Plots were arranged inside a field measuring 144.5 m long × 57.5 m wide. The field included untreated plants that occupied buffer plots 30.3 m long × 57.5 m wide (1,742 m^2) at one end (≈ 7,600 plants) and 18.0 m long × 57.5 m wide (1,035 m^2) at the opposite end (≈ 5,000 plants), both separated from adjacent regular plots by 3.6 m of bare soil. The cotton plants in these buffer plots were used as reference untreated plants after 25 June because control plots were inadvertently sprayed once on 26 June.

Whitefly Sampling Methods. Beginning 8 May, adults were counted on the undersides of 20 mainstem node leaves from randomly chosen plants across all rows within each plot between 0800 and 1100 hours (Pacific Standard Time). For the first 2 wk, when plants were at the 8 to 12 true leaf stage, the 2nd mainstem leaves from the top of the plants were sampled, but the 5th mainstem leaves (those at least the size of a quarter, including those that had not reached full size) were sampled thereafter on a weekly basis until 27 August. In this study, designations of leaf positions begin from the top of the plant, with the top leaf being at position 1. Forty to 60 leaves from each of the 2 untreated buffer plots were sampled after 25 June. As an additional measure of adult densities, adults were collected using hand vacuum (modified from a Black & Decker Dustbuster Cordless VAC, Shelton, CT). A 10-s sample was taken by moving the vacuum up and down 10 plants in row 4 of each plot between 1530-1700 hours throughout the season. The collection vial on the vacuum was 8.5 cm in height × 5.2 cm in diameter. Two and 3 vacuum samples from each of the 2 untreated buffer plots were taken after 25 June. From 6 August until the end of the season, 5 vacuum samples were taken from each of these latter plots.

To sample for immature insects, small pieces of leaves (≈ 8-10 cm^2) from the lower corners (near the petioles) of five 5th mainstem leaves and five 8th to 10th mainstem leaves were collected from randomly chosen plants across rows within plots (generally one sample per row). First and 2nd instars (mean length ± SE, 0.27 ± 0.01 mm, range, 0.21 to 0.36 mm, $n = 20$), and 3rd and 4th instars (0.65 ± 0.03 mm, 0.39 to 0.78 mm, $n = 20$) were counted on the undersides of 3.80 cm^2 disc samples from the pieces of leaves. After 25 June ten to fifteen 5th and 10th mainstem node leaves were also collected from the from the 2 untreated buffer plots.

Insecticide Applications. When the mean numbers of whiteflies reached or exceeded 5, 10, 15, or 25 adults per leaf, a mixture of 2.4 emulsifiable concentrate Danitol (Fenpropathrin) at 0.098 kg ai/ha and Orthene 90 solid (Acephate) (both Valent USA Corp., Walnut Creek, CA) at 0.565 kg ai /ha was applied 20 h after counts at a rate of 49 gallons/ha. The insecticide mixture was applied at 80 psi using a ground sprayer mounted on a John Deere Hi-Cycle 700 tractor driven at 10.46 km/h, and using 3 disc cone type nozzles (Spraying Systems Co., Wheaton, IL) per row, 1 overhead (135 cm above ground) and 2 at the sides (66 cm above ground) directed toward the center of each row. The mean insecticide spray volume output from all 12 nozzles (3 per row × 4 rows) was 231 ml/s (19 ml/s/nozzle). The last application was on 21 August.

Honeydew Collections. Pieces of 5.2 x 7.6 cm (39.5 cm^2) water-sensitive paper (Ciba-Geigy Limited, Basle, Switzerland) were used to collect whitefly honeydew the day before plots were sprayed throughout the season. Honeydew drops that fell onto the yellow-coated paper appeared as distinct shiny, slightly convex or globular blue, bluish, or sometimes clear spots that were easily seen. On 28 May to 11 June, when plants were $\leq$ 15 cm high, the paper was placed on the ground below leaves. Afterward, pieces of water-sensitive paper were secured onto a stem or leaf with a 2.75 × 0.55 cm paper clip on the 2 top and 2 bottom parts of 4 separate plants within each plot. Placement of papers and locations of bolls changed during the study because of plant growth during the season. From 18 June to 9 July, the top papers were placed directly on the 6th to 8th mainstem node leaves. From 18 June until 16 July, the bottom papers were placed on the 10th leaf. Bolls opened and lint first appeared 16 July, but there were only 1 or 2 open bolls per row on this date, and high numbers of bolls were first seen on 23 July. From 23 July until 27 August, the papers were placed directly on top of the uppermost and lowest opened bolls closest to the mainstem. The uppermost bolls were on the 6th to 10th to 15th node branches. From 23 July to 27 August the lowest bolls were on the 8th to 30th branch. Papers on bolls were held in place with the flat surface kept as parallel as possible to the ground using paper clips secured onto the stem of the boll, its branch, or adjacent stems or leaves. The papers were always placed on plants in rows 5 and 6 within plots. Honeydew drops from the 2 untreated buffer plots were collected the same way, using 5 top and 5 bottom papers per plot. Papers were placed on the plants beginning at 1200 to 1230 hours and were all collected by 1515 hours (mean exposure time 2 h) on each sampling date throughout the season. Counts of all honeydew drops were made in the laboratory under a dissecting microscope at 10× to 20×. All honeydew drops were counted on the entire 39.5 cm^2 of paper on the first 5 dates, but drop numbers reached > 11,000 per paper for some treatments later in the season, and drops on only half of each paper, on 19.8 cm^2 , were counted on the last 10 dates.

Honeydew Drop Diameters. In order to determine if mean sizes of honeydew drops among treatments differed, the diameters of 20 randomly chosen drops from each piece of paper were measured under a dissecting microscope at 50× with a 10× eyepiece for samples from 5 dates (25 June, 9 and 23 July, and 6 and 20 August). Drops were randomly chosen by blindly moving the paper and measuring the drops closest to one end of the ocular ruler. Drops from all 4 quadrants of the paper were measured.

Honeydew Sugars on Cotton Lint. To examine lint for sugar contaminants, bolls with lint were collected from plants in rows 2, 3, and 7 within each plot, and from corresponding rows from the 2 untreated buffer plts on 23 July and 6 and 20 August. On each date except 23 July (when only lower bolls were open) 3 to 5 opened uppermost and lowest bolls or the 2nd bolls from the bottom closest to the mainstem were collected from every 2 to 5 plants in the middle of the 3 rows (10 to 14 total bolls). The same numbers of top and lower bolls were collected from each of the 2 untreated buffer plots in corresponding rows. Bolls were collected by clipping the petioles with pruning shears or scissors (avoiding as much as possible direct hand contact with the lint). Bolls were then placed inside paper bags and returned to the laboratory. Bracts, seeds and debris were removed by hand while wearing latex examination gloves. Cotton from each plot was mixed, parceled into 10-gram units (each boll yielded ≈ 1.5 g of lint), kept dry inside paper bags, and then analyzed for sugars using HPLC, as described by Hendrix and Wei (1994).

Numbers of Leaves per Plant. It appeared on 6 August that adult whitefly densities were correlated with the amount of living vegetation present and thus honeydew production among plots. Thus, the numbers of living leaves per plant were counted on 13, 21, and 27 August on 5 randomly chosen plants in the middle of rows 2 to 6 (1 per row) within each plot. Numbers of leaves on 5 or 10 randomly chosen plants in each of the 2 untreated buffer plots were also counted.

Seed Cotton Yields. On 6 August, 12 uppermost bolls and 12 lowest bolls closest to the mainstem from each plot were collected (4 each at each level in rows 2, 3, and 7). They were returned to the laboratory, their bracts removed, and the seed cotton weighed. On 4 September, all cotton bolls from 4-8 consecutive plants in the middle of rows 1, 4, and 6 were collected (12 or 24 total plants from previously unsampled rows). Similarly, all cotton bolls from 4 consecutive plants from 3 or 6 rows were collected from untreated buffer plots (12 or 24 total plants). Numbers of bolls were counted, bracts were removed, and the seed cotton weighed.

Statistics. Latin square analysis of variance (ANOVA) (Little and Hills 1972) was conducted after plots had received different numbers of insecticide applications (4 dates: 13, 20, and 27 August, and 3 September). Response variables analyzed were mean numbers of adult whiteflies per leaf and vacuum sample, immature whiteflies (1st and 2nd and 3rd and 4th instars) per square centimeter of leaf disc, honeydew drops per square centimeter of water sensitive paper, honeydew drop diameters, numbers of leaves per plant, μg of sugars per 10 g lint sample, g of seed cotton per plant, and numbers of bolls per plant. For count data (adult vacuum samples) and data derived from counts (i.e., density measures such as whiteflies per square centimeter of leaf disc) variates were transformed using the formulas $(y + 0.5)$ ½ and $\log (y + 1)$, respectively, before ANOVA in order to normalize their distributions and make the means independent of the variances. The Tukey honestly significant difference procedure (Sokal and Rohlf 1981) was used for pairwise comparisons at $P = 0.05$.

For all sampling dates during the experiment, simple and multiple regressions were performed to determine the relationship between honeydew drop densities (log $[y + 1]$) (mean from top and bottom papers, $n = 4$ per plot) and variables from 3 sources and collection methods. These were: (1) adults (log $[y + 1]$) from threshold counts; (2) adults ($[y + 0.5]^{1/2}$) from hand vacuum collections; (3) densities of 1st and 2nd and 3rd and 4th instars from leaf disc samples (taking the mean of upper and lower leaves). Honeydew drop densities from papers within a plot were matched with the different variables within the same plot. Analyses were conducted using the multivariate general linear hypothesis procedure in SYSTAT (Wilkinson 1990). Error bars associated with means are reported as ± SE.

Results

Rainfall occurred on 3 dates during the study, but not on any sampling dates. This affected sugar content on leaves and lint, but it probably had no effect on honeydew production on the sampling dates. On 27 July, rain fell for about 1 h; on 8 August, there was a brief 5 min shower; and on 29 August, an intense rain fell for ≈15 to 30 min.

Adult Whitefly Densities, Threshold Leaf Turn Counts. Table 1 shows the numbers of adults on the undersides of 5th mainstem node leaves throughout the 4 months of the experiment. As seen, the lower threshold treatments required fewer insecticide applications than higher ones, and the time of the 1st applications differed among plots. For example, the 15 and 25 adult plots remained unsprayed until 25 June, by which time the 5 and 10 adult plots had already received 2 and 1 applications, respectively. Peak densities of adults per leaf were seen 9 July and lasted until the last sampling date, 27 August. Numbers of adults per leaf differed among the different insecticide treatments (13 August: $F = 22.24$; df = 4, 12; $P < 0.001$; 20 August: $F = 30.61$; df = 4, 12; $P < 0.001$; 27 August: $F = 22.80$; df = 4, 12; $P < 0.001$). On 13 August, numbers of adults in control and 25 adult plots were significantly higher than those in 5, 10, and 15 adult plots (all $P \leq 0.001$). The mean number in untreated plots was slightly lower, but appeared comparable to those of control and 25 adult plots (Table 1). On 20 August, the number in control plots was significantly higher than those in 5, 10, 15, and 25 adult plots (all $P < 0.001$). The number in control plots was essentially the same as that in untreated plots (61.4 ± 5.8 versus 66.8 ± 4.6, respectively). On 27 August, numbers in control, 10, 15, and 25 adult plots were higher than in 5 adult plots (all $P < 0.001$). The number of adults in untreated plots was similar to those of treatments other than the 5 adult threshold treatment.

The numbers of adults on leaves at the 5th position declined noticeably in untreated plots from 30 July to 6 August (31.2 ± 7.2 to 13.7 ± 2.3, Table 1). This seemed associated with increasing age of the leaves at this position. Many of these leaves turned yellow and brown during this time. On 6 August, the numbers of adults in untreated plots on the newly formed young leaves at positions 1 and 2 at the plant tips were much higher, averaging 40.0 ± 1.0 ($n = 2$ plots, 12 leaves per plot), than on the older 5th mainstem node leaves.

Adult Whitefly Densities, Vacuum Samples. Fig. 1 shows numbers of adults per 10-s vacuum sample. Numbers fluctuated and differences among insecticide treatments were unclear. Across all treatments, peak numbers were seen in late June to mid July, after which populations noticeably declined. Significant differences in adult densities were detected (13 August: $F = 8.54$; df = 4, 12; $P = 0.002$; 20 August: $F = 10.29$; df = 4, 12; $P = 0.001$; 27 August: $F = 8.97$; df = 4, 12; $P = 0.001$). On 13 August, there was a higher mean number in control versus 5 and 10 adult ($P = 0.035, 0.032$, respectively) plots; in addition, there was a higher number in 25 adult plots versus 5, 10, and 15 ($P = 0.007, 0.006, 0.020$) adult plots. The mean number in untreated plots was low, and did not appear to differ from those in 5, 10, or 15 adult plots (Fig. 1). On 20 August, the number in control plots was higher than those in 5, 10, 15, and 25 ($P = 0.001, 0.002, 0.005, 0.004$) adult plots. The number in untreated plots was most similar to that in control plots. On 27 August, the number of adults in control plots was higher than in 5 adult plots ($P = 0.015$); numbers in 15 and 25 ($P = 0.001, 0.004$) adult plots were also higher than in 5 adult plots. The number in untreated plots was most similar to that in control plots.

Immature Whitefly Densities on Upper Leaves. Figs. 2 A and 2 B show 1st and 2nd instar and 3rd and 4th instar densities, respectively, on 5th mainstem leaves from different plots during the season. Densities of 1st and 2nd instars were higher than those of 3rd and 4th instars; furthermore, densities of the former two increased in control and in untreated plots as the season progressed, whereas those of the latter two were lower and more stable. Differences in 1st and 2nd instar densities were detected (13 August: $F = 7.90$; df = 4, 11; $P = 0.003$; 20 August: $F = 12.34$; df = 4, 12; $P < 0.001$; 27 August: $F = 18.43$; df = 4, 12; $P < 0.001$). On 13 August, the mean density in control plots was higher than those in 10 and 15 ($P = 0.008, 0.034$) adult plots, and the density in 25 adult plots was higher than those in 10 and 15 ($P = 0.010, 0.051$) adult plots. The mean number in untreated plots was between that in control and in 25 adult plots (Fig. 2 A). On 20 August, the density of 1st and 2nd instars in control plots was higher than in 5, 10, and 15 ($P = 0.003, 0.017, 0.004$) adult plots, and that in 25 adult plots was also higher than in 5, 10, and 15 ($P = 0.003, 0.017, 0.004$) adult plots. The number in untreated plots was essentially the same as those in control and 25 adult plots (Fig. 2 A). On 27 August, the density of 1st and 2nd instars in control plots was higher than in 5, 10, 15, and 25 ($P < 0.001, < 0.001, 0.005, 0.002$) adult plots; that in 15 adult plots was also higher than in 5 adult plots ($P = 0.026$).

Differences in 3rd and 4th instar densities on 5th leaves were also detected (13 August: $F = 10.08$; df = 4, 11; $P = 0.001$; 20 August: $F = 5.15$; df = 4, 12; $P = 0.012$; 27

August: $F = 7.85$; df = 4, 12; $P = 0.002$). On 13 August, the mean density in control plots was higher than in 5, 10, and 15 (P = 0.002, 0.001, 0.013) adult plots. The density in untreated plots was similar to those in 5, 10, 15, and 25 adult plots (Fig. 2 B). On 20 August, the density in control plots was higher than in 15 adult plots ($P = 0.022$) and higher in 25 than in 15 adult plots ($P = 0.044$). The density in untreated plots was between those in 5 and 10 adult plots (Fig. 2 B). On 27 August, the density in control plots was higher than in 5, 10, and 15 (P = 0.003, 0.020, 0.013) adult plots. The density in untreated plots was most similar to that in 25 adult plots (Fig. 2 B).

Immature Whitefly Densities on Lower Leaves. Figs. 3 A and 3 B show densities of 1st and 2nd and 3rd and 4th instars, respectively, on 8th to 10th node leaves during the season. Densities of both 1st and 2nd and 3rd and 4th instars in control and untreated plots increased in late July through August, with some fluctuations. Densities of all instars in the 5 adult treatment were maintained at low levels throughout the season. Differences in 1st and 2nd instar densities were detected (13 August: $F = 8.00$; df = 4, 12; $P = 0.002$; 20 August: $F = 8.78$; df = 4, 12; $P = 0.001$; 27 August: $F = 8.14$; df = 4, 12; $P = 0.002$). On 13 August, the mean density in control plots was higher than in 5 and 10 (P = 0.017, 0.001) adult plots, and that in 15 adult plots was higher than in 10 adult plots ($P = 0.043$). That in untreated plots was similar to those in plots other than control plots (Fig. 3 A). On 20 August, the density in control plots was higher than in 5, 10, and 15 (P = 0.001, 0.042, 0.004) adult plots. The density in untreated plots was most similar to that in control plots (Fig. 3 A). On 27 August, the density in control plots was higher than in 5, 10, 15, and 25 (P = 0.001, 0.013, 0.050, 0.024) adult plots. The density in untreated plots was most similar to that in control plots (Fig. 3 A).

Densities of 3rd and 4th instars on 8th to 10th leaves were generally highest in control and untreated plots throughout the season, as seen in Fig. 3 B. Differences in densities of these late instars were detected (13 August: $F = 12.10$; df = 4, 12; $P < 0.001$; 20 August: $F = 9.16$; df = 4, 12; $P = 0.001$; 27 August: $F = 8.23$; df = 4, 12; $P = 0.002$). On 13 August, the mean density in control plots was higher than in 5 and 10 (P = 0.001, 0.002) adult plots, and that in 25 adult plots was also higher than in 5 and 10 (P = 0.006, 0.031) adult plots. That in untreated plots was similar to that in control plots (Fig. 3 B). On 20 August, the density in control plots was higher than in 5, 10, and 15 (P = 0.002, 0.008, 0.003) adult plots. That in untreated plots was similar to that in 25 adult plots (Fig. 3 B). On 27 August, the density in control plots was higher than in 5, 10, and 15 (P = 0.002, 0.013, 0.015) adult plots, and that in 25 higher than in 5 ($P = 0.042$) adult plots. The density in untreated plots was nearly identical to that in control plots (Fig. 3 B). In comparison with upper leaves (Fig. 2), lower leaves (Fig. 3) had fewer early instars, but had similar numbers of late instars, on the last 3 dates.

Honeydew Collections, Top Papers on Leaves or Bolls. Fig. 4 A shows the mean numbers of honeydew drops per square centimeter collected over 2-h periods on papers placed on top of upper leaves or bolls. Similar to trends of adult vacuum collections (Fig. 1), peak drop densities in control and untreated plots were seen in early July to early August, after which a noticeable decline was seen. Honeydew drop densities per leaf area were very low at the beginning of the season when there were very few whiteflies. Drop densities in 5 adult plots were consistently low (< 50 drops per square centimeter) throughout the season, and were most similar to those in 10 and 15 adult plots. Differences in honeydew drop densities were detected (13 August: $F = 4.68$; df = 4, 12; $P = 0.017$; 20 August: $F = 8.04$; df = 4, 12; $P = 0.002$; 27 August: $F = 8.56$; df = 4, 12; $P = 0.002$). On 13 August, the mean drop density in 25 adult plots was higher than in 5 adult plots ($P = 0.022$). The drop density in untreated plots was similar to that in 25 adult plots (Fig. 4 A). On 20 August, the density in control plots was higher than in 5, 10, and 15 (P = 0.003, 0.027, 0.014) adult plots, and that in 25 adult plots was higher than in 5 adult plots ($P = 0.030$). The density in untreated plots was similar to that in control plots (Fig. 4 A). On 27 August, the density in control plots was higher than in 5, 10, and 15 (P = 0.001, 0.022, 0.015) adult plots, and that in 25 adult plots was higher than in 5 adults plots ($P = 0.048$). The density in untreated plots was most similar to that in the control plots (Fig. 4 A).

Lint on uppermost bolls appeared on 23 July. To estimate honeydew accumulation on these upper bolls, the mean numbers of honeydew drops per square centimeter ± SE collected on top papers per 2 h from 23 July until 27 August ($n = 6$ days) were calculated. Densities were as follows: control: 103.8 ± 24.1; 5 adult: 9.6 ± 1.6; 10 adult: 25.2 ± 2.6; 15 adult: 37.4 ± 9.6; and 25 adult: 45.9 ± 6.6; and untreated: 85.5 ± 22.5 drops per square centimeter. Thus, higher threshold treatments were accompanied by higher honeydew drop densities on papers placed on top of uppermost bolls.

Honeydew Collections, Bottom Papers on Leaves or Bolls. Fig. 4 B shows mean numbers of honeydew drops per square centimeter collected on paper placed on the ground, lower leaves, or lowest bolls. Densities were highest in untreated (at that time) plots in late June through late July (peaking on 2 July); thereafter densities decreased. The honeydew production patterns among treatments were less clear and less consistent than on upper parts of plants. The 5 adult plots generally had the lowest densities, but later in the season the patterns among treatments merged and were somewhat obscured. Significant differences in honeydew drop densities were detected on 13 August ($F = 4.19$; df = 4, 12; $P = 0.024$), but pairwise comparisons between 5 adult and control ($P = 0.067$) and 25 adult plots ($P = 0.068$) were not significant. On 20 August, the mean drop densities did not differ among any treatments ($F = 2.30$; df = 4, 12; $P = 0.118$), whereas on 27 August differences were detected (F

= 6.21; df = 4, 12; *P* = 0.006). The density in control plots was higher than in 5, 10, and 15 (*P* = 0.026, 0.047, 0.034) adult plots; that in 25 adult plots was higher than in 5 adult plots (*P* = 0.052).

Lint appeared on the lowest bolls on 16 July. The mean densities of drops ± SE falling on bottom papers from 16 July until 27 August (*n* = 7 days) were as follows: control: 71.2 ± 19.2; 5 adult: 42.7 ± 10.3; 10 adult: 45.6 ± 8.8; 15 adult: 49.6 ± 12.7; 25 adult: 61.6 ± 13.3; and untreated: 64.8 ± 27.5 drops per square centimeter. The relationship between threshold treatments and honeydew drop densities on the lowest bolls was not as strong as on the uppermost bolls. Honeydew drop densities on bottom papers were lower than on top papers in control and untreated plots; the opposite was true in the 5, 10, 15, and 25 adult plots. In comparison with top papers, bottom papers received more drops early in the season, before lint appeared. Afterward, more drops were generally collected on top papers.

When overall honeydew drop densities (top and bottom papers, *n* = 4 total papers per plot) were analyzed, significant differences among treatments were detected (13 August: *F* = 6.65; df = 4, 12 ; *P* = 0.005; 20 August: *F* = 5.50; df = 4, 12; *P* = 0.009; 27 August: *F* = 12.15; df = 4, 12; *P* < 0.001). On 13 August, the mean density in control plots was higher than in 5 adult plots (*P* = 0.021), and that in 25 adult plots was higher than in 5 and 10 (*P* = 0.009, 0.051). On 20 August, the density in control plots was higher than in 5 and 15 (*P* = 0.022, 0.011) adult plots. On 27 August, the density in control plots was higher than in 5, 10, and 15 (*P* < 0.001, 0.005, 0.003) adult plots; that in 25 adult plots was higher than in 5 adult plots (*P* = 0.010).

Honeydew Drop Diameters. Table 2 shows honeydew drop diameters among treatments. As seen, drops were larger across all treatments on 25 June. However, drops on top and bottom papers among treatments were similar in size within dates. There were no significant differences in honeydew drop diameters among different treatments on 20 August from top (*F* = 0.67; df = 4, 12; *P* = 0.624) and bottom (*F* = 0.81; df = 4, 12; *P* = 0.547) papers, or the 2 combined (*F* = 0.61; df = 4, 12; *P* = 0.661).

Honeydew Sugars on Cotton Lint. Table 3 indicates that there were no differences in the amounts of different sugars on lint among treatments on 23 July, about one week after lower bolls opened. Rainfall on 27 July probably accounted for the reduction in sugars on 6 August compared with 23 July. Unlike 23 July, on 6 August, the amounts of trehalulose and melezitose on lint from top bolls in control plots were higher than in other treatments. The differences were less evident in lint from lower bolls, as shown in Table 4. Higher amounts of sugars were found on lower than top bolls. On 20 August, the amounts of trehalulose in control and 25 adult plots were greater than in 5 adult plots, from both top and lower bolls. Amounts in 10 and 15 adult plots were intermediate, and did not differ from those in 5 adult plots at either level. Although the differences in amonuts of trehalulose and melezitose between the 5 and 10 treatments were not statistically different, the absolute amounts in the 5 treatment were always lower on all dates and levels. Table 5 shows the amounts of fructose, sucrose, and glucose from lint on 6 and 20 August. In general, differences in the amounts of these sugars among treatments were not significant.

Relationship Between Honeydew Drop Densities and Whitefly Densities. Table 6 shows the relationships between honeydew drop densities and adult threshold counts, adult numbers from vacuum samples, and immature whitefly densities. As seen, there were consistent significant relationships among the factors. However, the r^2 values were rarely much above 0.500, indicating that factors other than whitefly numbers or densities themselves are responsible for the explaining the variations seen in honeydew production among plots. R^2 values were higher later in the season because there were greater variations in whitefly densities among plots during this time. After bolls opened on 16 July, the most reliable predictor of honeydew production was adult counts from leaf turns (*n* = 20 per plot), which yielded values R^2 values of 0.354 to 0.708 (all significant, *P* < 0.05).

Numbers of Leaves per Plant. Table 7 shows that control and untreated plants generally had fewer leaves than other plants. Differences in the numbers of leaves per plant were detected on all 3 dates (13 August: *F* = 10.37; df = 4, 12; *P* = 0.001; 21 August: *F* = 28.78; df = 4, 12; *P* < 0.001; 27 August: *F* = 13.77; df = 4, 12; *P* < 0.001).

Seed Cotton Yields. On 6 August the mean weights of individual bolls with seeds from the top and lower parts of plants among plots were similar. The mean weights (g) per upper boll were: control: 3.48 ± 0.16; 5 adult: 3.66 ± 0.17; 10 adult: 3.84 ± 0.18; 15 adult: 3.65 ± 0.26; 25 adult: 3.75 ± 0.24; and untreated: 3.33 ± 0.25. The mean weights per lower boll were: control: 3.81 ± 0.17; 5 adult: 3.87 ± 0.22; 10 adult: 3.99 ± 0.13; 15 adult: 4.02 ± 0.22; 25 adult: 3.85 ± 0.20; and untreated: 4.08 ± 0.01. Analysis was not conducted because 15 and 25 adult treatments had not received different numbers of applications on this date.

Mean weight (g) of seedcotton per plant differed (*F* = 3.96; df = 4, 12; *P* = 0.028), but only between 5 and 25 adult plots (*P* = 0.040). The means (g) were: control: 33.0 ± 5.6; 5 adult: 46.0 ± 9.8; 10 adult: 50.5 ± 8.7; 15 adult: 34.9 ± 3.1; 25 adult: 28.8 ± 3.3; and untreated: 23.1 ± 1.1. Similarly, mean numbers of bolls per plant differed (*F* = 4.09; df = 4, 12; *P* = 0.026) only between 5 and 25 adult plots (*P* = 0.031). The mean numbers were: control: 10.9 ± 1.8; 5 adult: 14.2 ± 2.7; 10 adult: 15.4 ± 2.3; 15 adult: 11.0 ± 0.8; 25 adult: 9.7 ± 0.8; and untreated: 9.2 ± 0.04.

Discussion

This study clearly showed that whitefly densities and honeydew production were dependent on different numbers of insecticide applications that were triggered by prescribed adult whitefly thresholds. At thresholds of 5 and 10 adults, no significant differences in honeydew production were detected late in the season. However, the 10 adult threshold seemed more ideal than the 5 threshold because only 6 applications were needed to maintain the former, whereas 11 were needed to maintain the latter. Thus treatment at the 10 threshold results in reductions in time, effort, and cost. Ellsworth and Meade (1994) obtained similar results in Arizona and suggested the ideal threshold was between 1 and 10 adults per leaf. In their study, treatment at both 1 and 10 adults per 1st, 2nd, or 3rd leaf from the terminal resulted in cotton that was apparently clean and lacked sooty mold growth, although honeydew sugar production was not quantified. In our study, the 15 adult treatment, requiring only 5 applications, resulted in honeydew production that was also similar to those in the 5 and 10 adult plots at the end of the season. However, because honeydew production was higher at the time of lint appearance in this treatment, the 15 adult threshold may be above the ideal level. The 25 adult threshold, requiring only 4 applications, clearly was too high to prevent damage caused by high whitefly densities and honeydew production. This threshold resulted in densities of both variables similar to those in control and untreated plots. Ellsworth and Meade (1994) also observed unacceptable levels of stickiness in fields treated at 25 adults per leaf in Arizona.

In both control and untreated plots, whitefly infestations reduced the numbers of mid or lower leaves available for whitefly colonization. Many of these leaves died and dropped off by 6 August, leaving few whiteflies to deposit honeydew on the lowest bolls. This may explain why drop densities on the lowest papers decreased for a few weeks after cotton lint appeared in control and untreated plots, and why fewer adult whiteflies were collected in vacuum samples from these plots late in the season. New growth from the tip of plants, which were highly favored by the whiteflies, often occurred just above uppermost bolls. Papers on top of these bolls received more honeydew drops late in the season because these young leaves that had considerably higher 1st to 2nd instar densities than did leaves below them. In addition, many honeydew drops produced by whiteflies on the upper leaves were likely intercepted by the upper bolls or leaves before they could fall onto the lowest bolls.

In contrast to only 1 or no insecticide application, frequent applications reduced whitefly densities, resulting in less damage to leaves and less leaf loss, except in 25 adult plots. Because there were more leaves available for colonization on upper and lower parts of treated plants, the distribution of honeydew drops between levels in these plants would be expected to be more even. R^2 values of regressions of honeydew drops against whitefly densities, although significant, were generally below 0.500, suggesting factors such as leaf presence, boll level, or sample size played a large part in explaining variations in honeydew densities collected on the papers.

In Arizona, Henneberry et al. (1996) found that plastic-wrapped styrofoam balls placed at middle and bottom of plants (nodes 6-14 from the bottom) collected higher amounts of honeydew trehalulose, melezitose, fructose, and glucose than did balls placed at the top of plants (nodes 15-20 from the bottom). These results are consistent with our cumulative sugar data. Honeydew production on cotton is dynamic, dependent on changing whitefly densities during the year. The final accumulations of sugars on lint among treatments were arrived at from differences in weekly honeydew production. The largest contribution to accumulated sugars in control and 25 adult threshold plots (assuming there had been no rainfall) probably occurred in mid July when bolls first open, suggesting this is the most critical time to have control over whitefly populations. The higher amount of honeydew that fell on top bolls late in the season was apparently not enough to offset the amount that fell on lower bolls earlier in the season. This occurred partly because top bolls present late in the year appeared weeks after the bottom bolls had already opened. However, amounts on top and bottom bolls were similar in control and untreated plots. One effect of frequent insecticide applications was to reduce the large week to week fluctuations in honeydew production seen in these plots. By applying insecticides at 5, 10, or 15 adults per leaf, large increases in honeydew production were prevented at the end of the season. When cotton was left untreated in Arizona, concentrations of honeydew sugars that accumulated on plastic-wrapped styrofoam balls were positively correlated with exposure time in whitefly-infested fields. Concentrations on balls exposed for 3-24 d did not differ, but concentrations on these balls did differ from those of balls exposed for 31-52 days (Henneberry et al. 1996). Concentrations of trehalulose and sucrose on lint is of utmost concern because trehalulose and sucrose are very sticky, whereas melezitose, fructose, and glucose are relatively nonsticky (Miller et al. 1994).

Honeydew drop diameters were similar, so it was valid to make comparisons among treatment plots. The larger drops seen on 25 June was probably related to the higher late to early instar ratio than was the case later in the year. This seemed independent of insecticide applications. The mean drop diameters excreted by mixed populations of *B. tabaci* (Gennadius) upwards onto water-sensitive paper ranged from 44.0 to 53.3 μm (Melamed-Madjar et al. 1983).

Adult population and honeydew population trends may have reflected changes in the quality of the cotton, as opposed to changes in general whitefly populations in the Imperial Valley. It is known that photosynthetic rates of older cotton leaves decline as the season progresses (Yee et al. 1996), reflecting reduced cotton leaf health, which may impact food quality. The possibility that reduced leaf quality affected honeydew production also exists. Another explanation for the higher honeydew drop densities on lower leaves during mid season is that plants were smaller and had fewer leaves at that time. Thus, drops falling from upper leaves were less likely to be intercepted by other leaves. Honeydew that occur on leaves just before lint appears may contaminate the lint, especially if leaves fall off and adhere to it.

We observed that plants were stickier before 27 July than the rest of the season (evidenced by stickiness on clothing during sampling), before the first rainfall. Rainfall had previously been associated with reductions in amounts of sugars and minicard sticky cotton ratings (Toscano et al. 1992, Henneberry et al. 1996). Heavier leaf cover probably also protects lower bolls from the washing effect of mild rainfall. Because control and untreated plants had fewer leaves than the other treated plants, bolls in the former plants were more exposed to the rain and thus more likely to be cleansed of honeydew than in the latter ones.

Differences in weight per boll, seedcotton yields, and numbers of bolls per plant were not as apparent as those in whitefly and honeydew drop densities among treatments. Large variability among soil quality in plots may have affected plant growth and contributed to the generally nonsignificant differences. Also, by the time the whitefly densities were very high in late June, the plants were probably vigorous enough to tolerate heavy whitefly feeding damage and had enough resources for healthy boll formation. With the exception of yields in 10 versus 25 adult plots, our results are inconsistent with those obtained by Naranjo et al. (1996) at Brawley. They found that there were no differences in lint yields (kg/ha) among plots treated at 2.5, 5, and 10 adults, but differences did seem to exist between these and untreated plots and those treated at 20 adults. Ellsworth and Meade (1994) found that yields were higher when cotton was treated at 1 and 10 versus 25 adults per leaf in Arizona. The results in our study underscore the importance of differentiating between treating insecticides to increase lint quality (i.e., decreasing stickiness) and treating to increase lint yields.

The determinants of honeydew production and honeydew contamination of cotton lint are complex and whitefly densities, leaf canopy, and boll level all are factors that affect how much honeydew produced actually reach the bolls. Despite problems with directly relating whitefly densities to honeydew production, different numbers of insecticide applications clearly affected whitefly densities enough to cause significant differences in honeydew production by whiteflies among plots. In Brawley, insecticide treatments between 5 and 10 adults per 5th mainstem node leaf seemed equally sufficient for reducing the numbers of honeydew drops falling onto bolls. The ideal threshold may be between the two. However, at the 10 threshold, many fewer insecticide applications were needed than at the 5 threshold, which would reduce immediate costs to growers, and also would reduce longer term problems associated with insecticide resistance.

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Table 1. Mean numbers of adult whiteflies per 5th mainstem node leaf used as a basis for treatment at different action thresholds at Brawley, CA, in 1996.

			Thresholds (adults)[a]			
Date	Untreat[b]	Control[b]	5	10	15	25
8 May	1.5	2.9	2.1	4.4	2.6	----
14	5.1	5.4(t)	7.8	5.2	6.3	----
21	1.2	1.6	1.4	1.2	1.1	----
28	1.4	1.2	1.4	1.2	1.0	----
4 June	10.1	8.6(t)	9.7	9.7	9.5	----
11	15.4	6.6(t)	14.1(t)	11.6	14.6	----
18	14.9	1.8	1.6	10.9	9.4	----
25	33.6(t)[b]	8.8[b]	19.3(t)	37.8(t)	34.0(t)	----
2 July	6.2	34.9(t)	3.2	6.7	8.9	49.4
9	35.4	7.7(t)	14.4(t)	27.4 (t)	28.4(t)	89.6
16	55.3	7.0(t)	6.4	10.8	14.7	64.4
23	53.5	5.6(t)	8.7	14.1	15.7	44.2
30	57.9	11.3(t)	27.3(t)	35.7(t)	39.6(t)	31.2
6 August	25.1	20.7(t)	17.9(t)	25.9(t)	24.1	13.7
13	103.4	23.5(t)	28.4(t)	22.1(t)	124.2(t)	81.2
20[c]	61.4	8.0(t)	7.5	9.0	13.7	66.8
27	46.5	3.8	35.2	45.6	41.1	44.4
Total no. applications	1	11	6	5	4	0

(t) Plots treated with insecticide 20 h after these counts.

[a] Dates of first application for 5, 10, 15, and 25 adults were: 14 May, 11 June, 25 June, and 25 June, respectively.

[b] Control plots instead of 5 adult plots inadvertently treated once on 26 June; means within untreated column are from 40 to 60 plants from each of 2 untreated buffer plots.

[c] Last insecticide application on 21 August.

Table 2. Mean diameters (µm) ± SE of whitefly honeydew drops collected on water-sensitive papers placed in different experimental plots on 5 dates[a] at Brawley, CA, in 1996.

				Thresholds (adults)			
Date	Level[b]	Untreated	Control	5	10	15	25
25 June	T	89±3	91±3	88±3	80±2	85±2	-------
	B	86±3	88±2	85±2	76±3	75±4	-------
9 July	T	74±6	80±6	89±3	84±2	83±3	91±7
	B	88±4	88±6	87±5	88±4	89±2	93±1
23 July	T	66±2	65±2	75±1	70±5	72±1	66±1
	B	60±2	64±2	73±2	69±3	69±3	72±3
6 August	T	71±4	78±3	79±3	76±1	78±2	75±4
	B	69±2	75±1	71±2	73±1	76±2	74±2
20 August	T	76±4	79±4	77±2	77±2	71±3	75±3
	B	74±2	72±3	77±2	77±4	71±1	69±3

[a] n = 5 plots, 40 drops measured per plot, except untreated, where n = 2 plots, 100 drops measured per plot.

[b] T, Papers placed on 6th to 8th leaves or uppermost bolls; B, papers placed on 10th node leaves or lowest bolls.

Table 3. Mean amounts (µg) of 5 sugars extracted from 10-g cotton lint samples of lower bolls collected on 23 July 1996 from different experimental plots in Brawley, CA.[a]

Treatment	Trehalulose	Melezitose	Sucrose	Fructose	Glucose
Control	5,068	3,855	3,116	4,688	1,420
5 adults	3,797	3,228	1,910	4,270	1,385
10 adults	4,561	3,665	3,396	4,347	1,639
15 adults	4,897	3,287	2,422	3,923	978
25 adults	3,937	4,132	3,031	3,593	954
Untreated	4,602	3,270	2,946	4,406	1,135

[a] There were no significant differences among treatments for any of the sugars (Tukey honestly significant difference test, $P > 0.05$); untreated not included in the statistical analysis.

Table 4. Mean amounts (µg) of trehalulose and melezitose extracted from 10-g lint samples of top and bottom bolls collected on 6 and 20 August 1996 from different experimental plots in Brawley, CA.

	6 August 1996			
	Trehalulose		Melezitose	
Treatment	Top Bolls	Lower Bolls	Top Bolls	Lower Bolls
Control	1,477a	3,284a	962a	1,487a
5 adults	306b	1,840b	450b	877a
10 adults	334b	2,794ab	515b	1,481a
15 adults	647b	2,773ab	584ab	1,402a
25 adults	467b	3,021ab	450b	1,415a
Untreated	962	3,360	570	1,564
	20 August 1996			
Control	4,808a	4,606a	3,246a	2,567a
5 adults	1,269b	3,229b	865b	1,857a
10 adults	2,440bc	3,887abc	1,648bc	2,336a
15 adults	2,320bc	4,079abc	1,395bc	2,326a
25 adults	3,496ac	4,706ac	1,884c	2,758a
Untreated	3,131	4,376	1,601	2,354

Means followed by the same letters within columns and dates are significantly different (Tukey honestly significant difference test, $P < 0.05$); untreated not included in the statistical analysis.

Table 5. Mean amounts (µg) of fructose, sucrose, and glucose extracted from 10-g lint samples of top and bottom bolls collected on 6 and 20 August 1996 from different experimental plots in Brawley, CA.

	Fructose		Sucrose		Glucose	
Treatment	Top	Lower	Top	Lower	Top	Lower
6 August 1996						
Control	2,205a	1,817a	1,432a	1,179a	889a	596a
5 adults	1,368a	1,581a	569b	746a	734a	661a
10 adults	1,399a	1,568a	497b	969a	774a	642a
15 adults	1,518a	1,970a	733ab	1,000a	763a	740a
25 adults	1,341a	1,855a	555b	896a	656a	671a
Untreated	2,137	2,237	919	1,318	998	785
20 August 1996						
Control	3,137a	2,376a	1,661a	1,343a	1,081a	926a
5 adults	1,276b	2,019a	517a	1,079a	584a	774a
10 adults	1,859b	2,061a	1,064a	1,459a	1,057a	903a
15 adults	1,605b	2,105a	1,074a	1,565a	875a	833a
25 adults	2,153ab	2,391a	1,495a	1,851a	996a	930a
Untreated	2,416	2,291	1,167	1,451	1,031	801

Means followed by the same letters within columns and dates are significantly different (Tukey honestly significant difference test, $P < 0.05$); untreated not included in the statistical analysis.

Table 6. R^2 values from regressions of mean numbers of honeydew drops per cm^2 against densities of different whitefly stages from experimental plots at Brawley, CA, in 1996.

Date	N[a]	Adults		1st, 2nd	3rd, 4th
		Leaf turns	Vacuum	instars	instars
21 May	24	0.033ns	0.082ns	0.080ns	-------------[c]
28	24	0.021ns	0.004ns	0.028ns	0.114ns
4 June	24	0.162ns	0.078ns	0.020ns	0.072ns
11	23	0.401***	0.042ns	0.071ns	0.068ns
18	25	0.455***	0.511***	0.456***	0.457***
25	25	0.470***	0.194*	0.058ns	0.427***
2 Jul[b]	27	0.024ns	0.001ns	0.233*	0.510***
9	26	0.287**	0.334**	0.343**	0.243**
16	27	0.481***	0.245**	0.311**	0.135ns
23	27	0.545***	0.286**	0.370**	0.218*
30	27	0.532***	0.338**	0.200*	0.055ns
6 Aug	27	0.354**	0.032ns	0.484***	0.261**
13	27	0.708***	0.576***	0.382**	0.480***
20	27	0.416***	0.305**	0.545***	0.600***
27	27	0.402***	0.216*	0.552***	0.481***

ns, nonsignificant regression, $P > 0.05$; * $P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

[a] Number of plots.

[b] All plots received treatments by 2 July.

[c] insufficient numbers of late instars to analyze.

Table 7. Mean numbers of leaves per cotton plant[a] among different experimental plots at Brawley, CA, in 1996.

	Action Thresholds (Adults)					
Date	Control	5	10	15	25	Untreated
13 August	36.2a	93.5b	83.4b	64.5b	59.4ab	39.6
21 August	41.9a	159.8b	124.6bc	89.5cd	79.0d	63.4
27 August	40.1a	136.0b	109.0bc	94.3bc	73.3c	59.1

[a] $n = 5$ plots, 5 plants per plot.

Means followed by different letters within a row significantly different (Tukey honestly significant test, $P < 0.05$); untreated not included in this analysis because only 2 replications available outside Latin square design.