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INFLUENCE OF LATE-SEASON INSECTS ON THE DEVELOPMENT OF STICKY COTTON IN PIMA AND ACALA COTTON IN CALIFORNIA

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Abstract

Cotton aphid, *Aphis gossypii*, and silverleaf whitefly, *Bemisia argentifolii*, populations are significant annual threats to cotton production in the San Joaquin Valley (SJV). Both pests can reduce cotton yields; however, the potential to contaminate cotton lint, creating a condition called sticky cotton, has been the primary concern in recent years. Aphid populations have been a challenge to cotton IPM in the SJV for ~15 years. Ten years of successful research and timely delivery for these results to clientele created a sound management program in late 1990's. However, the high level of scrutiny placed on sticky cotton by the cotton industry after the 2001 season and magnified importance of late-season insect infestations have hampered this program. The recent regulatory concerns over the levels of volatile organic compounds in the SJV and the role of cotton in this phenomenon have the potential to further strain the management of cotton aphids. Studies were conducted from 2002 to 2004 in Acala cotton and were designed to better understand sampling and control of late-season insect pests. In 2005, studies were expanded to also include Pima cotton.

Introduction

Cotton aphid (*Aphis gossypii*) and silverleaf whitefly (*Bemisia argentifolii*) are important pests of cotton and other crops in the San Joaquin Valley (SJV). Both these species damage cotton by direct feeding (removal of plant photosynthates) and by contaminating commodities with excrement (honeydew). These pests are fairly new challenges for cotton IPM. There are reports of cotton aphids in the SJV as early as the 1920's and it is perhaps an endemic species. However, it was rarely, if ever, a pest in cotton until the late 1980's. At this time, high populations were commonly seen on seedling stage cotton in April and May; these infestations were short-lived and the effects on cotton production were minimal. Beginning in the mid-1990's, cotton aphid populations developed on mid-season cotton (mid-June to late July), competing directly with the developing bolls for energy. This infestation timing was particularly damaging in 1995 and 1997 and SJV cotton yield losses from aphids were estimated at 3.5% in spite of management actions. Late-season cotton aphid infestations were spotty during the 1990's. However, in the 2000's, late-season aphid infestations increased and are now the primary concern of the industry. Silverleaf whiteflies (SLWF) have also increased in importance in recent years. This species (or strain) was first found in the SJV in 1992 and during the 1990's populations were generally greatest on the southern and eastern perimeter of the SJV. However, SLWF continued to adapt to the SJV and to spread its range and particularly in the 2000's, infestations have occurred earlier in the year, farther northward, and within the interior of the SJV. Infestations of these sucking insects during August to October can potentially reduce cotton quality as the excreted honeydew accumulates on the exposed cotton lint.

Late-season aphid and SLWF populations were particularly damaging in 2001 and the cotton industry has responded to this threat. The impacts of sticky cotton are difficult to quantify, but price deductions for contaminated lint and reduced demand due to an impaired reputation are possibilities. Since 2001 when mills complained about the quality of SJV lint, there has been an increased concern over quality cotton lint and cotton producers and PCAs have developed a near zero-tolerance for cotton aphid as well as SLWF. This is particularly true for pima cotton. Both Acala and Pima varieties are at risk but the latter tends to be most vulnerable to late-season infestations. Pima cotton requires a longer growing season and fields are often the last harvested providing the last attractive cotton habitat in an area.

The industry responded to the threat from late-season insects primarily through increased sampling and through more aggressive treatment regimes. From 2002 to 2003, insecticide use in cotton increased by 39% and use of acetamiprid (for aphid and SLWF management) increased by 400% as well as the use of thiamethoxam, endosulfan, and pyriproxyfen increasing. The sustainability of this management scheme is a concern from the standpoints of economics, resistance management, and environmental/regulatory aspects.

One of these regulatory concerns is air quality. The San Joaquin Valley air basin is out of compliance for ozone production between May and October. Volatile organic compounds (VOCs) are a principal component in the creation of ozone. The Clean Air Act requires California to reduce the emissions of VOCs in geographic areas (non-attainment areas) that do not meet ozone standard, such as the SJV. A primary culprit for VOC emission within agriculture are pesticides formulated as emulsifiable concentrates (EC); this accounts for 37% of the VOCs from pesticides (fumigants [49%] and other pesticide formulations account for the remainder). Of the insecticides, chlorpyrifos usage in cotton is a major contributor. This occurs due to the high emissions potential of Lorsban 4E, the high usage in cotton, and the high concentration of cotton acreage in the southern SJV.

Chlorpyrifos in cotton is used primarily against cotton aphids. Late-season SLWF infestations are most optimally controlled with synergized pyrethroid applications with an organophosphate insecticide being the synergist. This combination flares aphid populations thus aphid controls like chlorpyrifos must also be applied. Alternatives to chlorpyrifos are available such as the neonicotinoids (acetamiprid, thiamethoxam, imidacloprid) but since they share similar mode of action, resistance management is an issue. These same active ingredients are widely used for SLWF and to a lesser degree, Lygus bug management. Without restrictions on the existing suite of products, resistance management for the neonicotinoids is still an issue.

Sampling and decision thresholds are key components of an effective IPM program. One of the keys to effectively managing late-season honeydew-producing insects is knowledge of the relationship between population levels and the amount of lint stickiness. This threshold value is critical for scheduling appropriate management actions, including insecticide applications. Rosenheim et al. (1995) suggested a threshold of 10-15 aphids per leaf following boll opening in California and Slosser et al. (2002) found the threshold ranged from 11 to 50 aphids per leaf in west Texas cotton. Naranjo et al. (1998) found significant relationships between silverleaf whitefly populations and lint yield but relationships with honeydew deposition were lacking. Godfrey et al. (2003, 2004, 2005) reported on studies conducted in 2002, 2003, and 2004 examining the relationship between late-season sucking insects and honeydew deposition on exposed Acala cotton lint. In summary, in 2002 results showed that the threshold for preventation of sticky cotton was 5 to 10 aphids per 5^{th} main stem node leaf. In 2003, aphid levels of 5 per leaf resulted in sticky cotton; however, this population of aphids was confounded with a low population of silverleaf whiteflies which also contributed to the stickiness. In 2004, mixed populations of aphids and whiteflies were studies and levels were manipulated with insecticides such that, in the absence of whitefly populations, plots treated for cotton aphids with Assail on 25 August or on 31 August produced the cleanest cotton (cotton was defoliated on 15 September). Whitefly infestation increased the number of sticky spots by 34 to 70%. The goal of the 2005 research was to investigate the influence of mixed whitefly and aphid infestations on honeydew contamination of Acala and Pima cotton lint. In addition, sugars on lint samples from 2004 were analyzed in greater detail to provide additional insights about the effects of late-season insects on lint quality. Finally, a greenhouse study was conducted to determine the effects of cotton species, irrigation level, and nitrogen level on honeydew production by cotton aphids.

Materials and Methods

Field Studies: All field studies were conducted at the Univ. of California Shafter Research and Extension Center in Kern County in irrigated Acala (‘Maxxa’) cotton in 2004 and irrigated Acala (‘Phytogen 72’) and irrigated Pima ('Phytogen 800') cotton in 2005. Details of the 2004 experiment are reported in Godfrey et al. (2005) as well as the overall results on cotton stickiness. Additional analyses were conducted on lint samples so as to detail the quantities of specific sugars present on the cotton lint. The field study in 2005 followed a similar approach as that used in 2004. Insecticides were used to manipulate naturally-occurring populations of cotton aphids and silverleaf whiteflies in neighboring field plots of Acala and Pima cotton. Treatments were applied with ground equipment to plots measuring 13 x 90 feet with 4 replicates. Treatments were started at the initiation of boll opening (12 Sept.) and continued at approximately weekly intervals until (and including) the time of defoliation (7 Oct. in Acala plot and 25 Oct. in Pima plot). The treatments applied were Assail 70WP (1.7 oz./A) to control aphids and to reduce SLWF levels, Warrior (3.8 fl. oz./A) to flare aphid populations, and Lorsban 4E at 24 oz./A to control aphids only. Untreated plots were also included. Insect populations were quantified every 5 to 7 days; leaf samples (10 fifth main stem node leaves per plot) were collected and aphids and whitefly nymphs counted in the laboratory. Aphid control treatments were re-applied if there was evidence of aphid build-up once a treatment regime was initiated.

Cotton lint was hand-harvested from the Acala plots on 20 Sept., 6 Oct., 18 Oct., 2 Nov., and 7 Nov. and from Pima plots on 4 Oct., 20 Oct., 1 Nov., 14 Nov., and 18 Nov. Cotton was machine-harvested on 7 Nov. (Acala) and 18 Nov. (Pima). Additional samples of lint were hand-harvested from selected treatments on 5 Dec. following ~0.5 inch precipitation. All lint samples were ginned and stickiness determined at CIRAD (French Agricultural Research Centre for International Development) by high speed stickiness detector.

Greenhouse Study: A greenhouse study was conducted in Dec. 2004 to determine the effects of several factors on honeydew production by cotton aphids. Plants of Acala cotton ('Phytogen 72') and Pima cotton ('S-7') were grown in 4 x 4 inch pots within a sandy loam soil. Two irrigation regimes maintaining plants at ~-10 bars and ~-15to -18 bars were imposed on the plants at about the 5 leaf stage. Two fertility regimes, ~200 lbs. N/A and 50 lbs. N/A, were also imposed. At the 7-8 leaf stage, cotton aphid adults from a laboratory colony were placed on the underside of a leaf in each pot within clip cage (0.9 inch diameter). One day later, the adult aphids were removed and three first instar aphids were left. Clip cages were situated such that the honeydew droplets would fall onto a piece of clear plastic sheeting which formed the bottom of the clip cage; this piece of plastic was replaced daily. Aphid populations were also checked daily and the study was continued until the aphids reached adulthood. The numbers of droplets were counted from the pieces of plastic.

Results

Field Studies: Results on insect populations and on lint stickiness for the 2004 study were reported in Godfrey et al. (2005). HPLC results and analyses of the sugar type are shown in Fig. 1 and 2. Trehalulose is a sugar that is characteristic of a whitefly infestation and melezitose is a sugar characteristic of a cotton aphid infestation. That is not to say that these sugars are exclusively produced by the indicated insect species but they will predominate when the indicated species is present. Fig. 1 shows the percentage of each sugar type that was present on the four samples dates (two dates during the period of boll opening, the normal harvest timing, and a harvest after precipitation). Sugar data from plots with cotton aphids controlled and silverleaf whiteflies controlled (-A,-W) and plots with both pests present at natural levels (+A,+W) are shown as well as data from plots with each pest present individually. Overall, the levels of melezitose were higher than the levels of trehalulose. Levels of these sugars were overall slightly lower where the pests were controlled versus where they were at natural levels. It is also apparent that the majority of these two sugars were deposited by the first sample date (18 Aug.). Boll opening averaged ~50% on this date and aphid levels peaked at 6 per leaf and whitefly levels peaked at 1.4 nymphs per leaf from the start of boll opening to 18 Aug. Populations from 18 Aug. to 14 Oct. peaked at 0.9 and 3.4 aphids and whitefly nymphs per leaf, respectively. Following the 0.76 inch precipitation event, levels of trehalulose were reduced by ~75% and levels of melezitose were reduced by only~25%. Results on sugar incidence reported as percentage of all sugars are shown in Fig. 2.

In 2005, populations of whiteflies were very low in the Acala and Pima cotton plots; levels of cotton aphids were moderate and persistent during the open boll period. The insecticide treatments generally altered the populations as desired. Treatment regimes with the highest and lowest accumulation of aphid-days are indicated in Fig. 3 and 4. Aphid populations in the Pima cotton plot were twice that of the Acala cotton plot. Data on sticky cotton incidence in these plots are forthcoming.

Greenhouse Study: Data on honeydew droplet production are shown in Fig. 5. Only the plants with the normal irrigation regime (-10 bars) are shown as the aphid survival (and in some cases the plant survival) was negatively impacted by the drought treatment. Aphid survival in the normal irrigation treatments was similar across the other treatments, i.e., cotton species and fertility, and averaged 2.6 aphids per plant. Droplet production was higher on the Pima cotton with low nitrogen fertility than in the Pima cotton with high fertility or in the two Acala cotton treatments.

Acknowledgements

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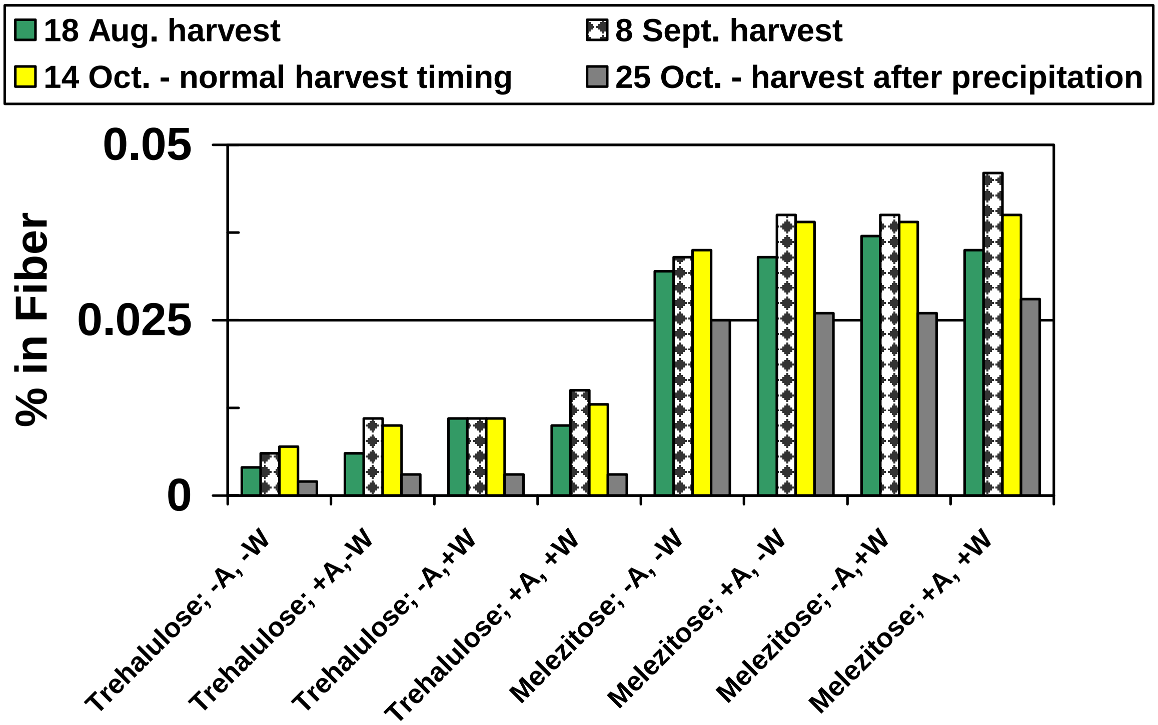

Figure 1. Influence of insecticide treatment and resulting aphid and whitefly populations (-A,-W=aphids and whiteflies controlled; +A,-W=aphids present at natural levels and whiteflies controlled; -A,+W=aphids controlled and whiteflies present at natural levels; +A,+W=aphids and whiteflies present at natural levels) on levels (% in fiber) of trehalulose and melezitose in four harvest dates, 2004.

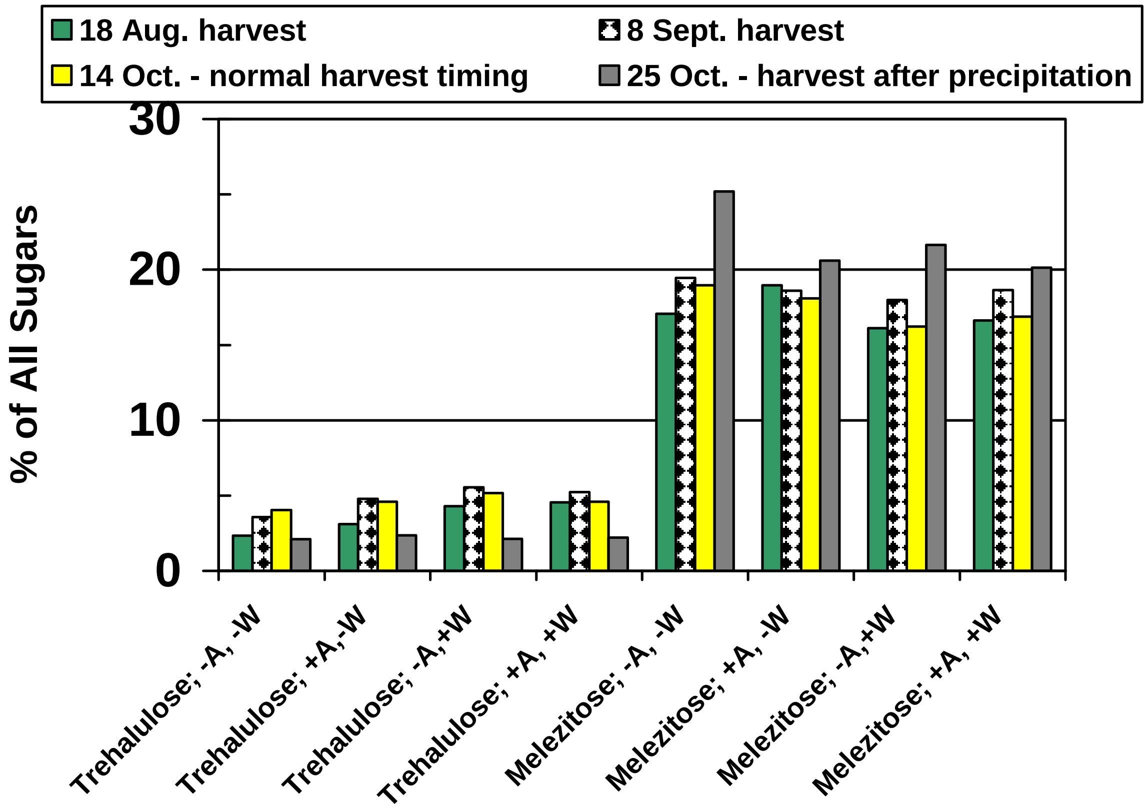

Figure 2. Influence of insecticide treatment and resulting aphid and whitefly populations (-A,-W=aphids and whiteflies controlled; +A,-W=aphids present at natural levels and whiteflies controlled; -A,+W=aphids controlled and whiteflies present at natural levels; +A,+W=aphids and whiteflies present at natural levels) on levels (% of all sugars) of trehalulose and melezitose in four harvest dates, 2004.

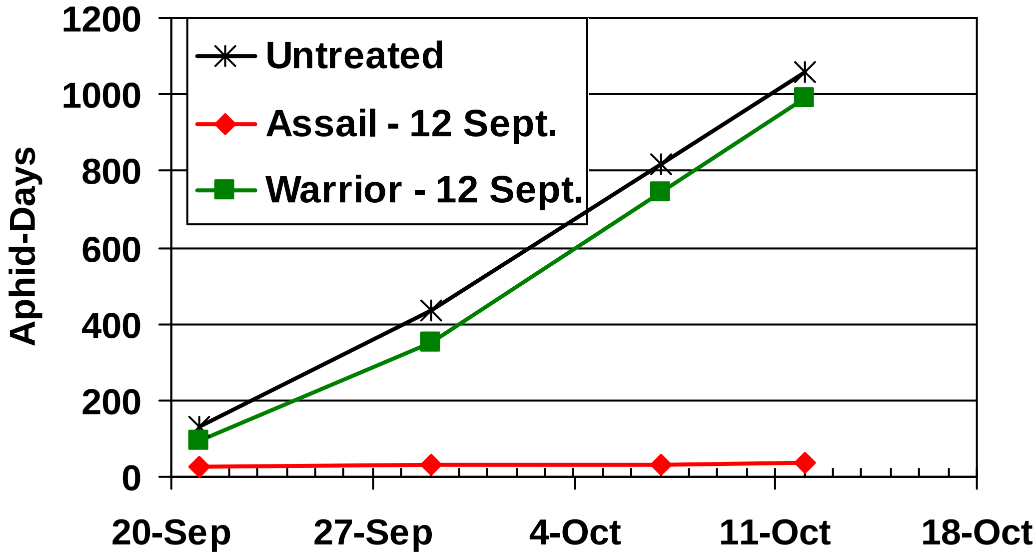

Figure 3. Aphid populations (accumulated aphid-days) as influenced by insecticide application made to late-season Acala cotton, 2005. Populations in the treatments and application dates with the highest and lowest aphid-day numbers are shown as well as the level in untreated plots.

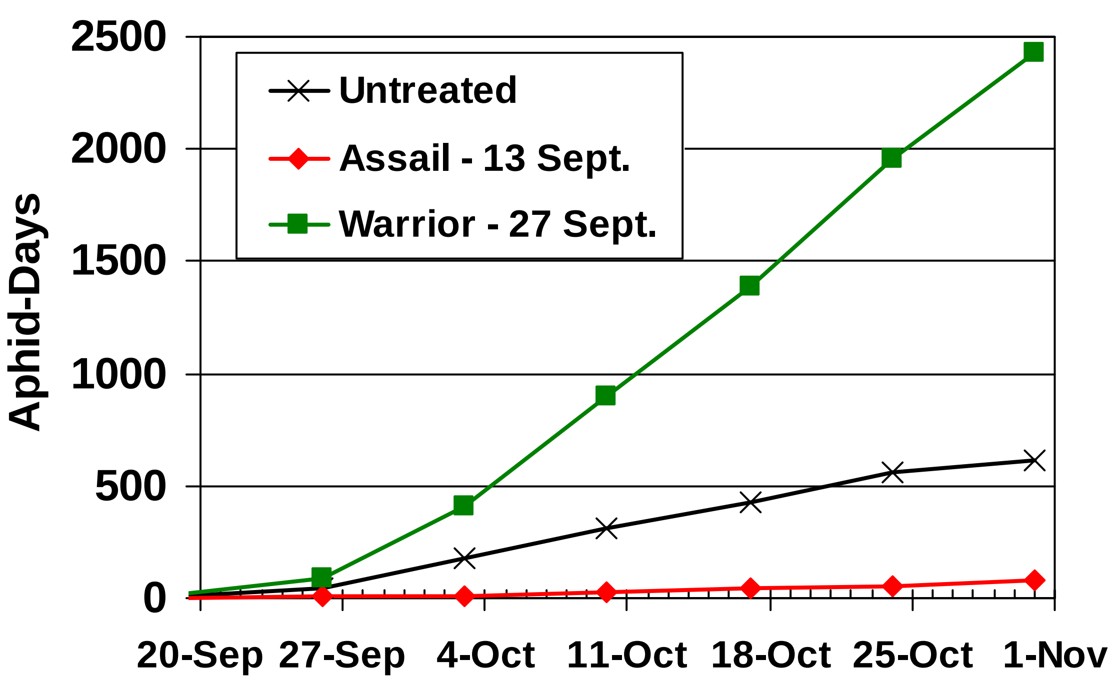

Figure 4. Aphid populations (accumulated aphid-days) as influenced by insecticide application made to late-season Pima cotton, 2005. Populations in the treatments and application dates with the highest and lowest aphid-day numbers are shown as well as the level in untreated plots.

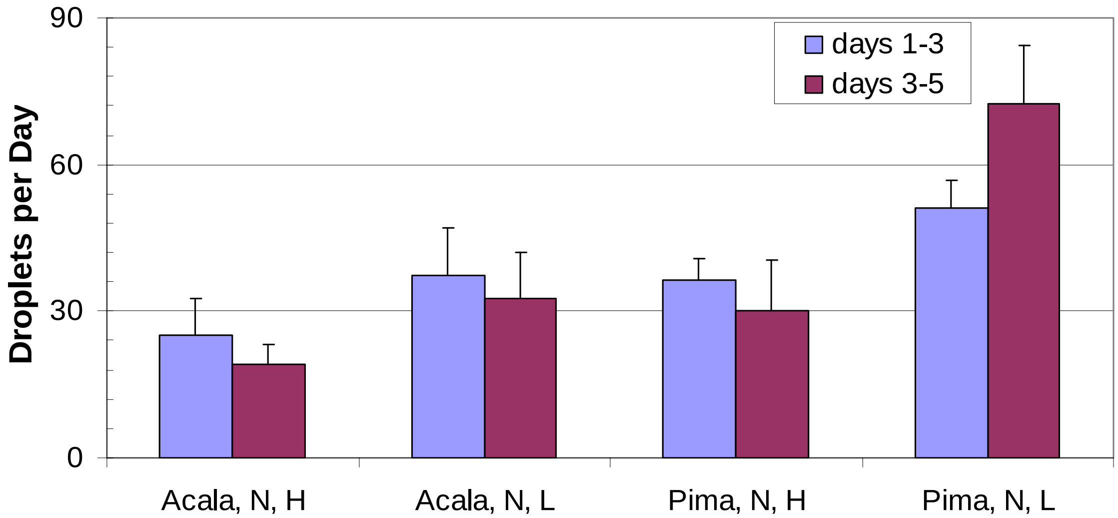

Figure 5. Honeydew droplet production per day from cotton aphids on Acala cotton and Pima cotton with normal irrigation (N), and high nitrogen (H) and low nitrogen fertility (L) in a greenhouse study. Production during days 1 to 3 and days 3 to 5 of the aphid development are shown.