1848 Influence of late-season insect populations on the development of sticky cotton in Pima and Acala cotton in California

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Abstract

Cotton aphid, *Aphis gossypii*, and sweet potato whitefly – strain B, *Bemisia tabaci*, populations are significant annual threats to cotton production in the San Joaquin Valley (SJV) of California. 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, after the 2001 season, an increased level of scrutiny and importance was placed on lint quality and this magnified the importance of late-season insect infestations. 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 2006 in Acala cotton and were designed to better understand sampling and control of late-season insect pests. In 2005 and 2006, studies were expanded to also include Pima cotton.

Introduction

Cotton aphid, *Aphis gossypii,* and sweet potato whitefly – strain B, *Bemisia tabaci*, are important pests of cotton and other crops in the San Joaquin Valley (SJV). Both these species damage crops, including 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 (Rosenheim et al. 1997). 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 (Godfrey and Wood 1998). 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 (Williams 1997). 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. Sweet potato whitefly strain B (also known as silverleaf whitefly, *B. argentifolii*) has also increased in importance in recent years. This strain (or species) 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 (Godfrey et al. 1996). However, this whitefly has 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 whitefly populations were particularly damaging in 2001 and the cotton industry has responded to this threat. The impacts of sticky cotton, including price deductions for contaminated lint and reduced demand due to an impaired reputation, can be devastating to an industry. Since 2001, there has been an increased concern over quality cotton lint and cotton producers and crop consultants have developed a near zero-tolerance for late-season honeydew-producing insects. This is particularly true for Pima cotton, *Gossypium barbadense*. 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 SJV cotton increased by 39% and use of acetamiprid (for aphid and whitefly management) increased by 400% as well as the use of thiamethoxam, endosulfan, and pyriproxyfen increasing (CDFA, 2003). 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 whitefly 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 a similar mode of action, resistance management is an issue. These same active ingredients are widely used for whitefly and to a lesser degree, western tarnished plant bug, *Lygus hesperus*, management. Without restrictions on the existing suite of products, resistance management for the neonicotinoids is still an issue. Carbine® (flonicamid) has recently been registered and is effective on cotton aphids and western tarnished plant bugs thereby aiding in resistance management.

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 whitefly populations and lint yield but relationships with honeydew deposition were lacking. The objective of this project was to investigate the relationship between population levels of late-season honey-dew-producing insects and lint stickiness in the San Joaquin Valley of California. The goal of the 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 were analyzed 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' (CPCSD, Shafter, CA) cotton in 2002-2004 and irrigated Acala, 'Phytogen 72' (Dow Agrosciences, Indianapolis, IN) cotton in 2005-2006. Studies were expanded to irrigated Pima, 'Phytogen 800' (Dow Agrosciences, Indianapolis, IN) cotton in 2005 and 2006. A similar approach was used during all years of the study. Insecticides were used to manipulate naturally-occurring populations of cotton aphids and whiteflies in field plots; during years where both cotton species were investigated the blocks of Acala and Pima cotton were neighboring. Treatments were applied with ground equipment to plots measuring 3.9 x 27.4 m with 4 replicates. Treatments were started at the initiation of boll opening and continued to a different set of plots at approximately weekly intervals until (and including) the time of defoliation (generally 4 to 6 weeks later). Cotton defoliation was scheduled using the nodes above cracked boll criterion (Roberts et al. 1996, Hutmacher et al. 2001). The treatments applied during all years included acetamiprid (Assail® 70WP; Cerexagri-Nisso LLC, King of Prussia, PA) at 0.12 kg/ha to control aphids and to reduce whitefly levels, lambda-cyhalothrin (Warrior®; Syngenta Crop Protection, Inc., Greensboro, NC) at 0.28 l/ha to flare aphid populations, and chlorpyrifos (Lorsban® 4E; Dow Agrosciences, Indianapolis, IN) at 1.75 l/ha to control aphids only. In 2006, spiromesifen (Oberon® 2SC; Bayer CropScience LP, Research Triangle Park, NC) at 1.2 l/ha and dinotefuron (Venom® 70%; Valent USA Corp., Walnut Creek, CA) at 0.2 kg/ha were included so as to control whiteflies without significantly effecting aphid populations and to better separate the influence of these two insect species. Untreated plots were also included. Treatments were re-applied if there was evidence of pest build-up, generally aphid populations, once a treatment regime was initiated. Insect populations were quantified every 5 to 7 days; leaf samples (ten fifth main stem node leaves [counting from the terminal of the plant] per plot) were collected and aphids and whitefly nymphs were counted in the laboratory.

Seed cotton was collected, ginned, and lint stickiness determined by high speed stickiness detector at the International Textile Center at Texas Tech University in 2002-2004 and CIRAD (French Agricultural Research Centre for International Development) in 2005-2006. Additional analyses (HPLC) were conducted on lint samples so as to detail the quantities of specific sugars present on the cotton lint. Samples were hand harvested at the time of machine harvest during all years and hand harvests were done at 10 to 14 day intervals during the exposed lint period in 2004-2006, e.g., in 2005 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. Lint was also sub-sampled from machine picked cotton, hand-ginned, and stickiness determined. Finally, in 2004 and 2005, cotton was hand-harvested after a precipitation event (about 2 weeks after the normal time of machine picking) to determine the influence of precipitation of lint stickiness. Additional details and dates for the 2002, 2003, 2004, and 2005 studies can be found at Godfrey et al. (2003, 2004, 2005, 2006).

Greenhouse Study: A greenhouse study was conducted to determine the effects of several factors on honeydew production by cotton aphids. Plants of Acala cotton, 'Phytogen 72' (Dow Agrosciences, Indianapolis, IN) and Pima cotton, 'S-7' were grown in 10.2 x 10.2 cm pots within a sandy loam soil. Two irrigation regimes maintaining plants at ~-10 bars and ~-15 to -18 bars were imposed on the plants at about the 5 leaf stage. Two nitrogen regimes, ~225 kg/ha and 56 kg/ha, 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 (2.3 cm 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

Godfrey et al. (2003, 2004, 2005, 2006) detailed the results from the 2002-2005 studies 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 prevention of sticky cotton was 5 to 10 aphids per 5th main stem node leaf. In 2003, aphid levels of 5 per 5th main stem node leaf resulted in sticky cotton; however, this population of aphids was confounded with a low population of whitefly nymphs which also contributed to the stickiness. In 2004, mixed populations of aphids and whiteflies were studied and levels were manipulated with insecticides such that, in the absence of whitefly populations, plots treated for cotton aphids with acetamiprid 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%. 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 aphid populations as desired with the acetamiprid showing excellent (90-95%) control, populations were increased by the lambda-cyhalothrin, and moderate (70-80%) control was provided by the chlorpyrifos (Fig. 1 – Acala; Fig. 2 - Pima). Aphid populations were higher in the Pima cotton than the Acala cotton. Whitefly nymphal populations were low and never exceeded 1 nymph per leaf. Lint stickiness values for the acala cotton are shown in Fig. 3. Lint was hand-harvested four times as well as samples were collected from the picker. Slight precipitation (~0.4 cm) fell between the 18 October and 2 November harvests. Generally the lint stickiness values corresponded well with the aphid population data. Untreated plots had significant lint stickiness and acetamiprid-treated plots had reduced levels of stickiness with the earlier timings performing better than the later timings. Lambda-cyhalothrin treated plots also showed high levels of stickiness and in some cases greater than the untreated plots. Stickiness results from the Pima cotton, in spite of high levels of aphids, were not closely correlated with aphid levels. Data from only the first treatment timing are shown (Fig. 4).

HPLC results and analyses of the sugar type are shown in Fig. 5. Trehalulose is a sugar that is characteristic, i.e., sugar is not exclusively produced but it will predominate, of a whitefly infestation and melezitose is a sugar characteristic of a cotton aphid infestation. Fig. 5 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) in 2004 studies. 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 ~1.9 cm precipitation event, levels of trehalulose were reduced by ~75% and levels of melezitose were reduced by only~25%.

Greenhouse Study: Honeydew droplet production by *A. gossypii* was influenced by cotton species and conditions. Only the plants with the normal irrigation regime (-10 bars) were considered 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.

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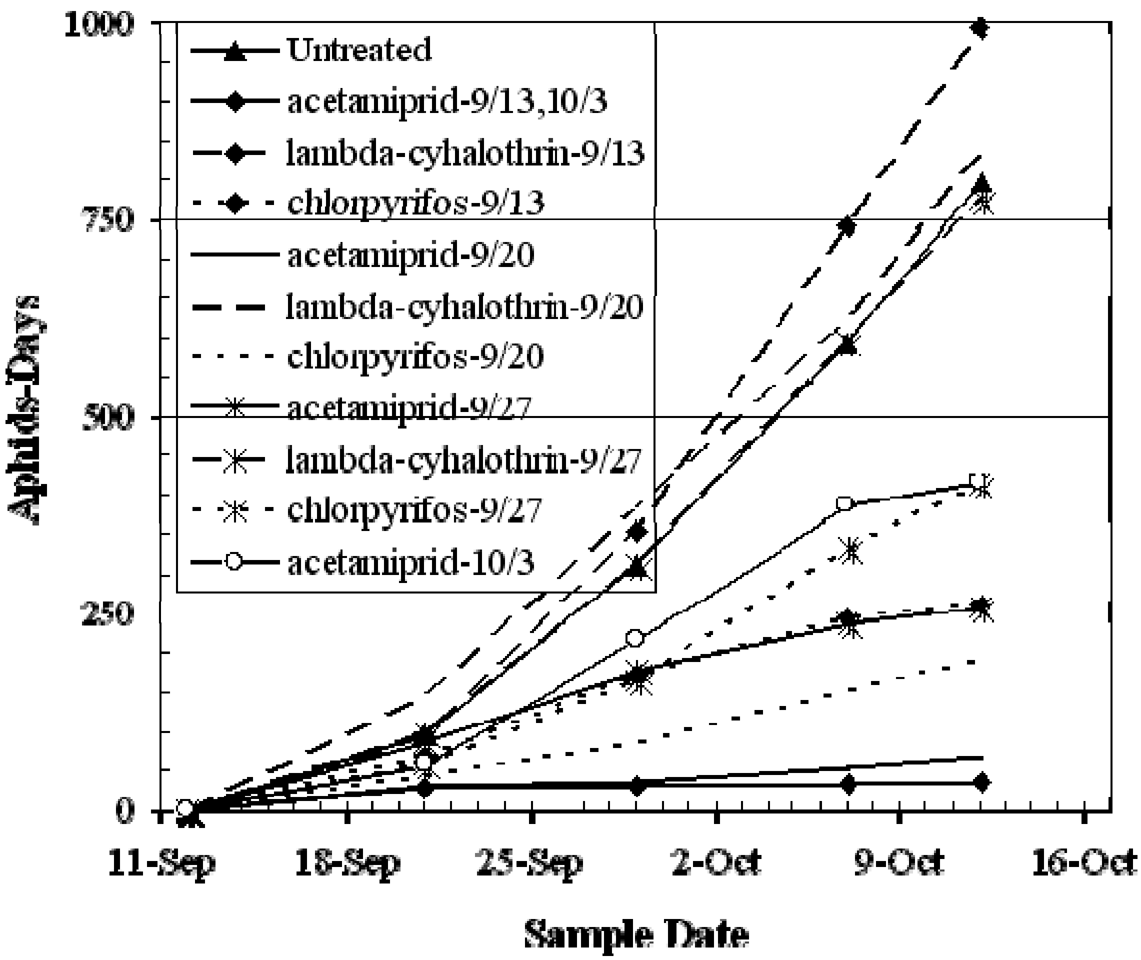

Figure 1. Accumulation of aphid-days on Acala cotton as influenced by insecticide treatments in 2005. Treatment initiation dates and aphid population sample date assessments are indicated.

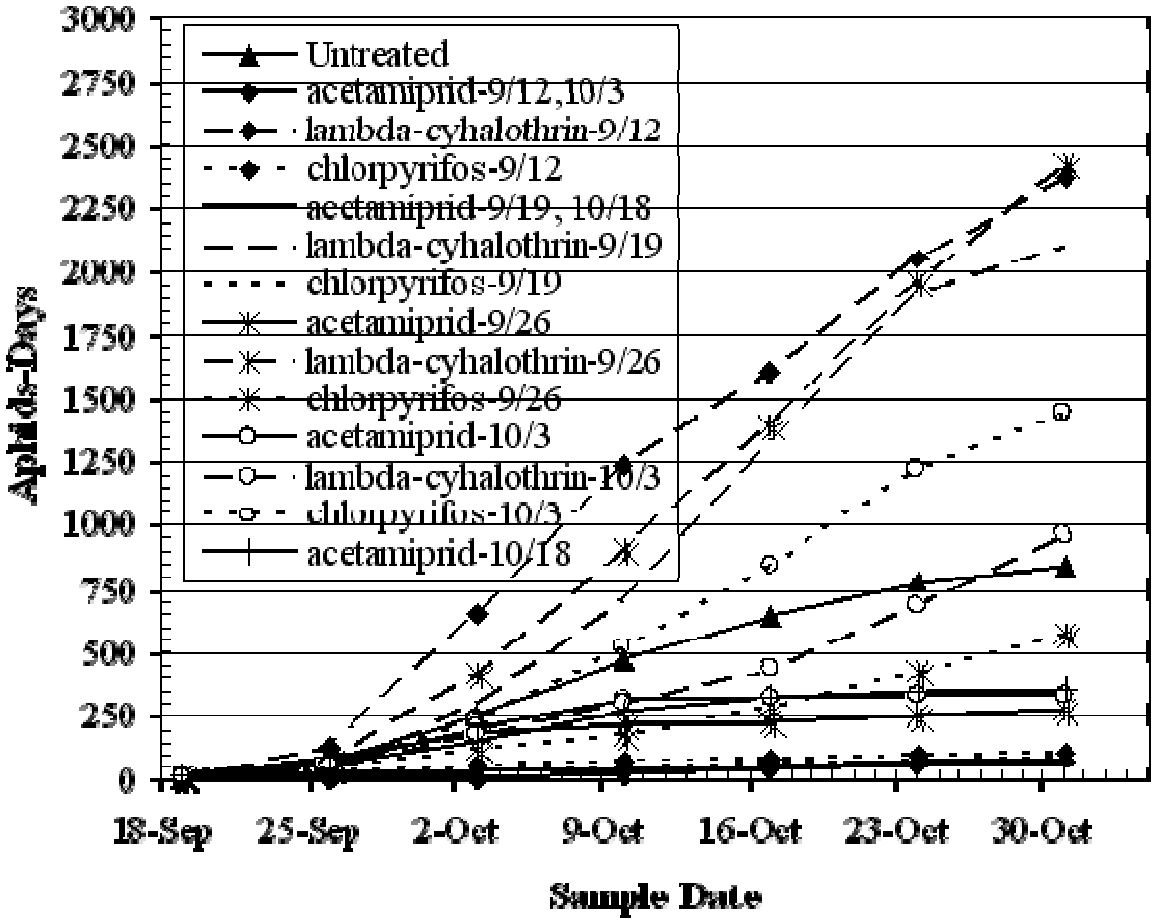

Figure 2. Accumulation of aphid-days on Pima cotton as influenced by insecticide treatments in 2005. Treatment initiation dates and aphid population sample date assessments are indicated.

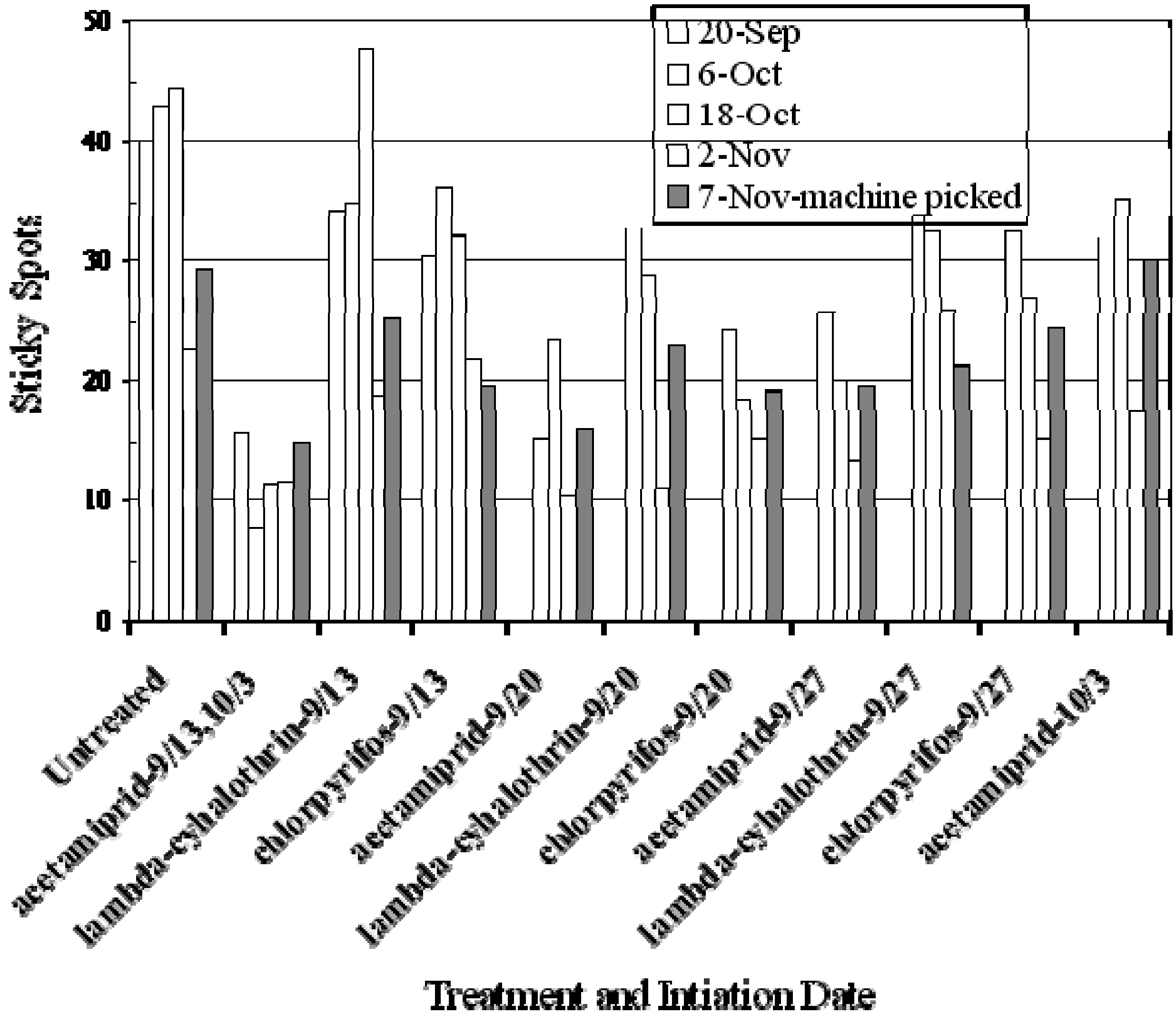

Figure 3. Lint stickiness (high speed thermal detection) on Acala cotton as influenced by insecticide treatments in 2005. Treatment initiation dates and lint sample dates are indicated.

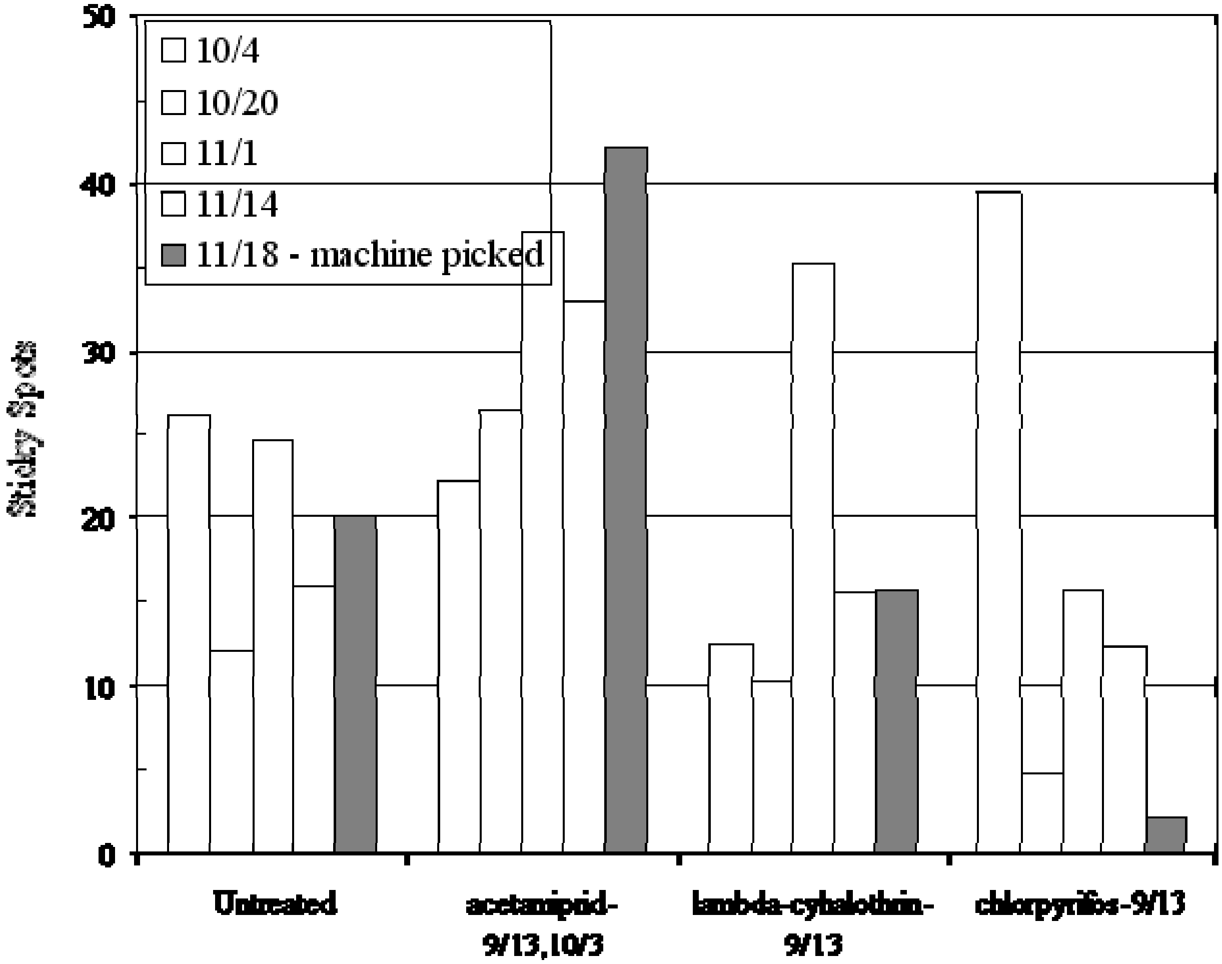

Figure 4. Lint stickiness (high speed thermal detection) on Pima cotton as influenced by insecticide treatments in 2005. Treatment initiation dates and lint sample dates are indicated (selected treatments shown).

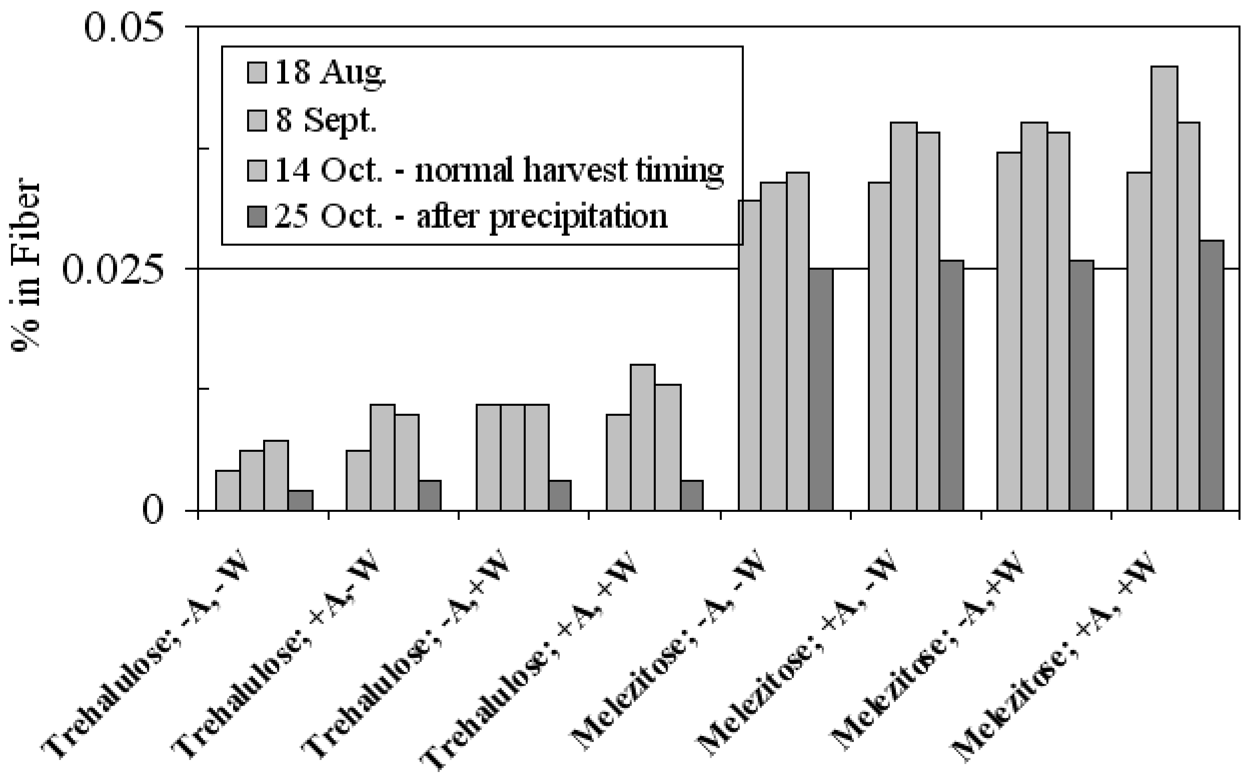

Figure 5. Influence of insecticide treatment and resulting aphid and whitefly populations (-A,-W=aphids and whiteflies controlled; +A,-W=aphids present at natural levels and whiteflies controlled; -A,+W=aphids controlled and whiteflies present at natural levels; +A,+W=aphids and whiteflies present at natural levels) on levels (% in fiber) of trehalulose and melezitose in four harvest dates, 2004.