SILVERLEAF WHITEFLY LINT STICKINESS, AND COTTON YIELDS IN LOW AND HIGH PLANT POPULATIONS OF UNTREATED AND INSECTICIDE-TREATED LONG AND SHORT STAPLE COTTONS

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Abstract

Cotton plant densities of 10 or 40 thousand plants/acre had no effect on numbers of silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring, adults, eggs, nymphs, extracted sugars from lint samples or thermodetector sticky cotton counts. Higher numbers of whiteflies occurred in early-season in Pima S-7 cotton than in DPL 50 or DPL 5415 cotton. Seasonal averages for sugars, percentages of total reducing sugars and thermodetector counts were higher for DPL 50 compared with Pima S-7 but not DPL 5415. The first open cotton bolls subject to honeydew contamination occurred between 17 and 22 August. Most of the sugar analyzed from lint samples occurred during a 24 day period from 22 August to 15 September for all cultivars harvested 25 September. DPL 50 and DPL 5415 had 99 and 91% of the bolls open during 22 August to 25 September as compared to 76% for Pima S-7 resulting in lower sticky cotton counts for Pima S-7 compared with DPL 50 but not DPL 5415. Insecticide treatments reduced thermodetector counts and associated sugars extracted from lint. Sticky cotton results for 20 boll randomly picked samples were comparable with results from total open cotton/plant harvests but both sample methods gave significantly lower individual sugar, percentage of total reducing sugars and thermodetector counts compared with machine-picked total cotton plot harvests. DPL 50 and DPL 5415 produced significantly more cotton than Pima S-7. Higher lint yields occurred in plots planted at 40,000 plants per acre compared with 10,000 plants per acre. Highest cotton harvests were obtained by hand picking all open bolls from all plants in 13.1 foot of row weekly as compared to a single 13.1 foot of row pick on 13 September and machine picking (spindle) on 25 September.

Introduction

Bemisia spp. infestations in cotton often result in honeydew deposits on lint of open cotton, *Gossypium* spp., bolls. The honeydew remains localized causing sticky cotton that adheres to machinery surfaces during harvest, ginning, and lint processing (Bourley et al. 1984, Khalifa and Gameel 1982, Miller et al. 1994, Carlson and Mohamed 1986). This is in contrast to plant physiological sugars that rarely cause stickiness problems because they occur evenly distributed and within the fiber lumen in cotton lint (Elsner et al. 1983, Bruno 1984). The cotton lint stickiness problem has increased with increasing *Bemisia* population development and spread and is of most concern at the textile mill (Hector and Hodkinson 1989). Increasing *Bemisia* spp. populations have been of concern worldwide (Debarro 1995) and numbers approaching epidemic proportions have occurred in cotton in some years in CA, AZ, and TX since 1986 (USDA 1995, 1996). Perring et al. (1993) suggested that the introduction of a new whitefly species *B. argentifolii* Bellows and Perring (formerly *B. tabaci* [Gennadius] Strain B) has contributed to the increasing problem in the United States.

The major sugars found in *B. tabaci* honeydew were reported by Byrne and Miller (1990), Tarczynszki et al. (1992), and Hendrix et al. (1992). Under laboratory conditions Miller et al. (1994) sprayed single sugars or mixtures of identified honeydew sugars on cotton lint, and found that different sugars and mixtures of sugars induced different levels of stickiness. In the field, Henneberry et al. (1995, 1996) found that trehalulose and melezitose produced by *Bemisia* spp., and certain other honeydew sugars (fructose and glucose) not specific to *Bemisia*, but found in cotton plants, were significantly correlated to increasing cotton stickiness. Cotton lint stickiness was reduced in insecticide-treated cotton compared with untreated cotton as were the above mentioned sugars. In contrast, Chu et al. (1994) reported that although insecticide applications reduced *B. argentifolii* numbers, control was not adequate to prevent high levels of cotton stickiness from occurring. The difference in results appear related to differences in whitefly population densities. Henneberry et al. (1996) also reported that trehalulose and melezitose accumulated in cotton lint in open bolls with increasing exposure in *B. argentifolii* infested cotton fields. Rainfall reduced amounts of all sugars found in lint and cotton stickiness. Although, the possibility of developing enzymes that hydrolyze honeydew sugars on cotton lint appears promising (Hendrix et al. 1993, Henneberry et al. In Press), the sticky cotton problem remains a serious issue in the textile industry.

In 1995, we conducted studies to further define *B. argentifolii* population development on long- and short-staple cotton cultivars and determine the influence of plant density and insecticides on whitefly populations, sticky cotton and cotton yields. We also compared cotton lint stickiness and lint yields for different methods of seed cotton sampling.

Materials and Methods

General. Deltapine (DPL) 5415 and DPL 50, *G. hirsutum* L., and Pima S-7, *G. barbadense* L., cotton seeds were

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planted 11 April 1995 in a four replicate split-split plot experimental design. Cultivars were main plots, plant densities of 10 or 40 thousand per acre were split plots and insecticide-treated and untreated units were split-split plots. Individual plots were 6 rows wide, rows 40" apart and 70' long. Insecticide applications were made with a high clearance ground sprayer when the need was determined by the University of Arizona's Maricopa Agricultural Center pest control advisor. This generally occurred when adult whitefly levels were ≅ 5 to 10 per leaf using the method of Naranjo and Flint (1995). For insecticide-treated plots, imidacloprid (Pravado®, Miles Inc., Kansas City, MO) at the rate of 3.75 oz. per acre was applied on 25 July, 2 August, and 6 September, Bifenthrin (Capture®, FMC Corp., Philadelphia, PA) plus acephate (Orthene® 755, Valent Corporation, Walnut Creek, CA) at 4 oz. (AI/Ac) and 3/4 lb. (AI/Ac), respectively on 8 and 22 August. Additionally, all plots were oversprayed with Lorsban (LOCKON®, Dow Elanco, Indianapolis, IN) at 1.5 pints AI/A plus acephate (3/4 lb. AI/A) on 31 July, 22 and 29 August for lepidopterous pests. Cotton defoliant was applied to all plots on 13 September.

Whitefly sampling. Adult whiteflies were sampled weekly from 27 June to 11 September using the binomial sampling method of Naranjo et al. (1994b) and Naranjo and Flint (1995). Single mainstem leaves from fifth plant nodes below the plant terminal were carefully turned and counted as infested if 3 or more whitefly adults were found and uninfested if fewer than 3 whiteflies were found. Moving diagonally across several rows in plots, samplers picked second leaves and so on until 15 leaves were counted. The procedure was repeated at a second site in each plot on each date. Data are presented as the proportion of leaves sampled with 3 or more adult whiteflies per leaf. Eggs and immatures were counted on 3.88 cm^2 leaf disks from 30 leaves taken on the same dates from the fifth node from the terminal of sampled plants (Naranjo and Flint 1994a). Immature life stages are presented as numbers per cm^2 of leaf area.

Cotton lint stickiness and yield. To determine cotton lint stickiness development during 7 day periods during the season, we hand-picked all open seed cotton from the same 13.1 feet of row each week beginning 22 August and ending 25 September. These samples were used to determine accumulation of honeydew during 7 day exposure periods and seasonal accumulated cotton yields, sugars and thermodetector counts. Additional cotton lint stickiness data was obtained from (1) 20 boll weekly (29 August to 20 September) samples of seed cotton hand-picked from all plots, (2) from samples of hand-picked cotton from all plants in 13.1 feet of row in each plot on 20 September, and (3) from samples from all plots for all cotton picked with a spindle-mechanical picker on 27 September. All cotton samples were ginned and lint and seed weighed. Lint samples were analyzed for percentages of total reducing sugars by the method of Perkins (1993) and lint stickiness by the thermodetector method of Brushwood and Perkins (1993). All determinations were done at the USDA-ARS Cotton Quality Research Station, Clemson, SC. Thermodetector analysis is accomplished by spreading 2.5 g lint samples between aluminum foil sheets followed by heating under pressure. Aluminum foil sheets are separated and the number of sticky spots counted. Less than 5 sticky spots indicates nonsticky cotton, 5 to 14, light stickiness, 15-24, moderate stickiness and above 24, heavy stickiness (Perkins and Brushwood 1995). The individual sugars and amounts of trehalulose, melezitose, fructose and glucose were determined by the High Performance Liquid Chromatography methods of Hendrix and Wei (1992).

Statistical analysis. All data were analyzed using ANOVA methodology (MSTAT-C 1988). Means were separated, following a significant F test, using the method of least significant differences ($P \leq 0.05$). Percentages were transformed to arcsins before analysis. Correlation and regression analysis were conducted with some data to determine relationships between selected variables measured in the study.

Results

General - plant density. Densities of 10 or 40 thousand plants per acre had no statistically significant effects on silverleaf whitefly adults, eggs, or nymphs. Similarly, there were no effects of plant density on percentages of total reducing sugars, trehalulose, melezitose, fructose, glucose, or thermodetector counts. There also were no significant interactions for plant density and cultivars or insecticide-treated and untreated cottons. Thus for these tabulated data, plant densities were averaged with cultivar and insecticide-treated and untreated plot data.

Whitefly sampling - adults. For 27 June and 3 July sampling dates, none and 1 leaf, respectively for all plots and replications, had 3 or more adults per leaf (results not tabulated). Mean percentages of cotton leaves with three or more adults per leaf ranged from 10 to 88 and 11 to 87 for 10 and 40 thousand plants per acre, respectively, for the 10 subsequent sampling dates. During early to mid season there were significant differences for whitefly adults between cultivars (Table 1, % leaves infested). Mean percentages of cotton leaves with 3 or more adults per leaf were significantly greater for Pima S-7 cotton than for DPL 50 or DPL 5415 on 10, 17, 24, 31 July and 7 August and for Pima S-7 and DPL 50 cotton on 14 and 21 August. Mean percentages of cotton leaves with 3 or more adults per leaf were also significantly greater in untreated plots compared with insecticide-treated plots on all sampling dates following the first insecticide applications on 25 July.

Whitefly sampling - Eggs and Nymphs. Numbers of eggs per cm^2 of leaf disk were significantly higher on Pima S-7 cotton leaf disks on 27 June, 3 and 10 July and 21 August compared with numbers on DPL 50 or on DPL 5415 leaf disks (Table 1, eggs/cm^2). Also, numbers of eggs per cm^2 of leaf disk were significantly reduced on leaf disks from insecticide-treated cotton compared with untreated cotton on each sampling date from 31 July through 11 September. Nymph populations were highly variable (Table 1, nymphs/cm^2). Higher numbers occurred on Pima S-7 leaf disks on samples of 27 June, 3 July and 21 August compared with DPL 50 and DPL 5415, but lower than on the two DPL cottons on 17, 24, and 31 July. There were no significant differences between cultivars on other sampling dates. Insecticide treatments significantly reduced numbers of nymphs on leaf disks compared to numbers on leaf disks from untreated cotton on all sampling dates from 31 July to 11 September.

Cotton lint sugars and stickiness - weekly 20 boll cotton samples. Over all sampling dates percentages of total reducing sugars and thermodetector counts were higher for DPL 50 than for Pima S-7 and DPL 5415 cotton lint (Table 2). Amounts of trehalulose, melezitose, glucose and fructose from DPL 50 cotton lint were also significantly higher than from Pima S-7 cotton, but not DPL 5415 cotton except for fructose. Percentages of total reducing sugars, trehalulose, melezitose, and fructose but not glucose and thermodetector ratings were significantly higher for lint samples from untreated cotton plots compared with insecticide-treated plots. There was no significant interaction between cultivars and insecticide-treated-untreated cotton. Trehalulose increased with each sampling date from 29 August to 20 September. Results for 29 August compared to 5 September were not statistically different. For melezitose, there were no significant differences between 29 August, 5 or 13 September lint samples but, in each case, amounts were significantly lower compared with 20 September lint samples. The highest amount of glucose occurred on 5 September which was significantly different compared with 29 August and 13 September but not 20 September. The highest amount of fructose occurred on 29 August. Percentages of total reducing sugars increased from 29 August to 20 September. Amounts for 5 and 13 September samples were not significantly different. Thermodetector counts increased significantly from 29 August to 5 September, but were not significantly different thereafter.

Total cotton hand-picked weekly from 13.1 ft. of row. Open mature cotton bolls began to occur between 17 and 22 August (Figure 1). On 22 August <1, 6.7 and 6.4% of the total seasonal numbers of Pima S-7, DPL 50 and DPL 5415, respectively, bolls were open and exposed to honeydew deposition. Thereafter, percentages of open bolls increased for all cultivars and peaked for DPL 50 and DPL 5415 on 6 September. In contrast, peak numbers of open bolls for Pima S-7 did not occur until 15 September. On 22 August, mg/g of lint of trehalulose, melezitose, glucose and fructose overall treatments averaged 0.16, 0.08, 0.07 and 0.05, respectively and percentage of total reducing sugars 0.17 (Table 3). Percentages of total reducing sugars increased to 6 September but were significantly reduced 11 and 15 September compared to 6 September. Thermodetector counts were variable but significantly higher for 15 September samples compared with all other dates and significantly reduced in insecticide-treated plots compared with untreated plots. DPL 50 had higher levels of trehalulose, melezitose, glucose, fructose and total percentages of reducing sugars than Pima S-7 and higher levels of trehalulose and glucose compared with DPL 5415. Trehalulose and melezitose (except 15 September), percentages of total reducing sugars (except 22 August), and thermodetector counts on all sampling dates were significantly reduced in insecticide-treated compared with untreated plots. Of the total trehalulose, melezitose, fructose and glucose, 93, 85, 78, and 84%, respectively, was recovered from the lint from seed cotton picked 22 August to 15 September (24 days of whitefly exposure) (Figure 2). Insecticide treatments did not affect the percentage distributions of the amounts of sugars extracted from lint during the season. Percentages of total reducing sugars (81% between 22 August and 15 September) were similarly distributed for sampling dates for insecticide-treated and untreated cottons. The seasonal distribution of trehalulose, melezitose, fructose, glucose, and percentages of total reducing sugars on cotton lint were similar for all cultivars (Figure 3). Percentages of total seasonal thermodetector counts increased throughout the season, except for 11 September for treated and untreated plots and 25 September for insecticide-treated plots where significant decreases occurred.

Comparison of sugars and lint stickiness for hand picked 20 boll samples, (13 Sept), hand-picked total cotton per 13.1 feet of row (20 Sept) and machine harvested cotton (25 Sept). Mean percentages of total reducing sugars and mg/g of lint of trehalulose, melezitose, glucose and fructose and thermodetector counts over all treatments were significantly higher for machine-picked cotton lint compared with hand-picked 20 boll samples and from all cotton hand-picked from 13.1 feet of row (Table 4). In each case values were significantly higher for untreated cotton compared with insecticide-treated cotton. Results varied for the effects of cotton cultivars. DPL 50 had higher levels of sugars, except for glucose, and percentage of total reducing sugars compared with Pima S-7. There were no significant differences between DPL 50 and DPL 5415 except for fructose and percentage of total reducing sugars which were higher for DPL 50 compared with DPL 5415. The means for thermodetector counts for cultivars were not significantly different. There were no significant interactions for picking methods and cultivars, cultivars and insecticide treatment, or picking methods, cultivars and insecticide treatment. However, for machine-picked samples, there were significantly higher levels of trehalulose and melezitose in untreated cotton compared with untreated 20 boll hand-picked samples at harvest, or hand-picked 13.1 feet of row samples. Also, for melezitose significantly higher amounts occurred in insecticide-treated machine-picked cotton compared with insecticide-treated 20 boll hand-picked or hand-picked 13.1 feet of row samples.

Comparison of sugars and lint stickiness for weekly hand-picked 20 boll samples and weekly hand-picked total cotton from all plants in 13.1 feet of row. Significantly higher amounts of trehalulose and melezitose and thermodetector counts were found on lint on all but the 6 September sampling data from weekly 20 boll samples compared to amounts found on lint from cotton picked weekly from all open cotton in all plants from 13.1 feet of row (Table 5). Results were variable with fructose, glucose and percentages of total reducing sugars. However, averages over all treatments showed higher amounts of all sugars, percentages of total reducing sugars and thermodetector counts for the weekly 20 boll lint samples as compared to lint for total cotton picked from all plants weekly. Insecticide applications reduced thermodetector counts and all associated sugars. Generally, sugars, percentages of total reducing sugars and thermodetector counts increased during the season, but results were variable. DPL 50 had higher amounts of all sugars, total percentages of reducing sugars, and thermodetector counts compared with Pima S-7 but not DPL 5415.

Cotton lint yields comparisons for hand-picked per 13.1 feet of row on 13 September, total cotton picked weekly/13.1 feet of row and machine harvest 25 September. Both upland cottons (DPL 50 and DPL 5415) matured more rapidly than Pima S-7 long-staple cotton (Figure 4). Most, 89 and 85%, respectively, of the total yield by DPL 50 and DPL 5415 was picked by 15 September as compared to 50% of the total Pima S-7 yield on the same date. There were significant differences for cotton lint yields depending on the method of cotton harvest (Table 6). Lint yield averaged over all treatments for cotton hand-picked weekly from all plants in 13.1 feet of row was significantly higher compared with cotton hand-picked from 13.1 feet of row on one harvest date at the end of the season (13 September). There was no significant difference between hand-picked weekly harvest lint yield and machine-picked yield nor between the single hand-picked harvest yield at the end of the season and machine-picked lint yield. DPL 50 and DPL 5415 yields were significantly higher than Pima S-7 yield. Averaged over all cultivars, harvest methods and insecticide-treated and untreated plots, cotton lint yield for 40,000 plants/acre (1318 ± 37 lbs./A) was significantly higher than for the 10,000 plants/acre (1240 ± 44 lbs./A). Also, the average yield for insecticide-treated plots (1342 ± 12 lbs./A) was significantly higher than for untreated plots (1216 ± 42 lbs./A). There was a significant plant density-harvest method interaction for all cultivars. For hand-picked single harvest, 40 thousand plants/acre yields were significantly greater than 10,000 plants/acre yields. There were no significant differences for 10,000 or 40,000 plants/acre machine-picked harvests or significantly greater yields for 10,000 plants/acre hand-picked weekly harvest compared to 40,000 plants/acre weekly hand-picked harvests. There were no other significant interactions for harvest method, cultivar, plant density or insecticide-untreated main effects.

Discussion

Adult silverleaf whitefly populations were higher on Pima S-7 cotton through 7 August compared with DPL 50 and DPL 5415. Results became variable thereafter and reversed in some instances. Results were similar for silverleaf whitefly eggs and nymphs up to 10 July. Natwick et al. (1995) also reported higher whitefly populations on Pima vs. upland cotton in three of four experiments. Although these results have generally suggested that higher whitefly populations occur on Pima vs. upland cottons, other investigations have reported higher populations on upland vs. *G. barbadense* cultivars (Khalifa and Gameel 1982). The differences in results remain unexplained but may be related to whitefly population densities, variations in susceptible or resistant characteristics within species, or different environmental or crop production methods. The variation in susceptibility within and between cottons does however suggest the possibility of plant breeding and/or molecular biology approaches to develop cotton cultivars less susceptible to whitefly attack.

The results of the present study agree with those previously reported (Henneberry et al. 1995) regarding the lack of effect of plant density on whitefly populations and lint stickiness associated with honeydew sugars. Also in these studies cotton lint stickiness was reduced following insecticide applications. Cotton stickiness levels were below those of concern for textile mill processing. These results are consistent with our previous report for Arizona (Henneberry et al. 1995) but in contrast to the results in Imperial Valley, Southern California (Chu et al. 1994) where insecticide applications failed to reduce cotton stickiness below threshold levels. The different results appear related to differences in whitefly population densities.

Cotton lint thermodetector counts and associated sugars extracted from lint were lower on all sampling dates when all open cotton was picked weekly from all plants in 13.1 feet of row compared with randomly picked 20 boll samples from the same plots. Open, mature cotton bolls began to occur (<1% for Pima S-7 and 6% for DPL 50 and DPL 5415), the week prior to 22 August and whitefly populations were relatively low compared with later sampling dates. Since open mature seed cotton was picked from all plants in each plot each week, lint in bolls for each sampling date was exposed for a maximum of 7 days in whitefly infested plots. These would be bolls that opened on the day of harvest but after all open bolls were picked. Boll opening on days 2 to 7 following harvest were exposed for lesser times. In contrast, 20 boll samples randomly picked each week in plots may represent an accumulation of honeydew from the day of opening until picked. This probably accounts for the higher amount of trehalulose, melezitose, and thermodetector counts compared with samples of total cotton picked weekly from all plants in 13.1 feet of row plots. Our weekly adult whitefly counts for untreated and insecticide-treated plots showed 92 ± 2 to 100 ± 0% and 54 $\pm$ 6 to 96 ± 1% of the leaves with 3 or more adults per leaf. Weekly nymph population counts for untreated plots ranged from 4.1 to 28.4/cm^2 of leaf and for treated plots from 0.6 to 3.2/cm^2. Within these adult and nymph population values, although some sugars and thermodetector counts increased during the 22 August to 15 September sampling dates, none of the cottons exposed in untreated or insecticide-treated plots for a maximum of 7 days to these numbers of adult and nymph populations were rated as more than lightly sticky.

Higher thermodetector counts and amounts of all sugars measured for machine-picked cotton vs. 20 boll samples randomly picked at harvest and all cotton picked from all plants in 13.1 feet of row at harvest also remains unexplained. The results may have occurred because of the greater amounts of cotton involved, that resulted in overall higher levels of sugar compared to the other sampling methods. A more probable explanation appears to be that large amounts of honeydew are present on leaves and other cotton plants that may be incorporated in machine picked seed cotton but not hand picked cotton. There may also be other factors we are at present unaware of regarding distribution of honeydew in a cotton field. This appears to be an important issue that needs defining since it suggests that small samples (e.g. 20 bolls) during the season may be adequate for relative comparisons of treatments for research but do not reflect the total amounts of honeydew that may occur in the harvested crop.

Lint yield was reduced in untreated plots as compared to insecticide-treated plots. These results agree with those of Henneberry et al. (1995) and Chu et al. (1994). However, in 1995, we did not experience any differences in lint yield related to plant density whereas in the present studies, effects of plant density were highly variable with respect to cultivar and cotton harvest methods. The overall mean yield for all cultivars, harvest methods, and untreated-insecticide-treated plots for 40 thousand plants per acre was significantly higher than for 10 thousand plants per acre. The variability in our yield results may be partially explained by the confounding effects of high whitefly populations. For example, Norton et al. (1993) and Silvertooth et al. (1994) found significantly reduced lint yield for cotton plant densities of 16 to 18 thousand plants per acre compared to 30 to 40 thousand plants per acre which agrees with current Arizona recommendations for optimum cotton plant densities of 25 to 45 thousand plants per acre.

The results of our studies show that, at least in 1995, a high proportion (88 to 95%) of the sugars extracted from cotton lint samples occurred during the 24 day period from 22 August to 15 September that corresponds to the period when 96, 91, and 76%, respectively of DPL 50, DPL 5415 and Pima S-7 open cotton bolls occurred. The data strongly suggest that concentrated effort to reduce whitefly populations during this 24 day window of opportunity could dramatically reduce lint stickiness.

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Table 1. Mean percentages of Pima S-7, DPL 50 or DPL 5415 cotton leaves with three or more adult silverleaf whiteflies and eggs and nymphs/cm^2 of leaf in untreated and insecticide-treated plots.

	Main Effects of Cultivars[b]			Main Effects for Treatment[c,d]	
Sampling Date[a]	Pima S-7	DPL 50	DPL 5415	Untreated	Treated
	% Leaves Infested (3 or More Adults/Leaf)				
July					
10	19 a	1 b	1 b	7 a	7 a
17	69 a	45 b	47 b	52 a	55 a
24	78 a	66 b	61 b	72 a	65 b
31	96 a	86 b	79 b	93 a	81 b
August					
7	88 a	83 b	81 b	92 a	75 b
14	75 a	69 ab	59 b	97 a	35 b
21	92 a	87 ab	80 b	92 a	80 b
28	73 a	76 a	73 a	92 a	54 b
September					
5	92 a	93 a	89 a	99 a	84 b
13	99 a	98 a	97 a	100 a	96 b
	Eggs/cm^2				
June					
27	0.1 a	< 0.1 b	0.1 b	0.1 a	0.1 a
July					
3	0.1 a	0.5 b	<0.1 b	<0.1 a	0.1 a
10	0.7 a	0.3 b	0.3 b	0.4 a	0.5 a
17	1.6 a	1.0 a	0.9 a	0.9 b	1.4 a
24	4.4 a	3.7 a	3.5 a	3.9 a	3.9 a
31	3.6 a	4.3 a	3.0 a	5.8 a	1.4 b
August					
7	4.2 a	6.4 a	4.5 a	8.0 a	2.1 b
14	7.6 a	5.9 a	6.7 a	12.7 a	0.7 b
21	20.9 a	10.9 b	6.1 b	22.3 a	3.0 b
28	16.4 a	24.8 a	15.4 a	31.9 a	5.8 b
September					
5	18.3 a	31.4 a	23.3 a	42.1 a	6.6 b
11	80.4 a	111.8 a	80.2 a	170.6 a	10.9 b
	Nymphs/cm^2				
27	0.1 a	< 0.1 b	< 0.1 b	0.1 a	0.1 a
July					
3	0.2 a	< 0.1 b	< 0.1 b	0.1 a	0.1 a
10	0.2 a	< 0.1 a	< 0.1 a	0.1 a	0.2 a
17	0.2 b	0.4 a	0.6 a	0.3 a	0.5 a
24	1.0 b	1.9 a	1.8 a	1.5 a	1.7 a
31	0.6 b	2.7 a	2.8 a	2.7 a	2.0 b
August					
7	2.3 a	2.8 a	2.7 a	4.0 a	1.2 b
14	2.5 a	2.0 b	2.7 a	4.1 a	0.6 b
21	3.4 a	2.1 b	1.5 b	4.1 a	0.6 b
28	11.5 a	13.2 a	9.9 a	20.3 a	2.9 b
September					
5	11.9 a	10.9 a	10.3 a	19.3 a	2.9 b
11	12.7 a	16.2 a	18.5 a	28.4 a	3.2 b

[a] Means in a row not followed by the same letter are significantly different $P \leq 0.05$. Method of least significant differences.
[b] Means of 4 replications, 4 observations per replication.
[c] Means of 4 replications, 6 observations per replication.
[d] Pravado 3.75 oz./A on July 25, 2 August, and 6 September, Bifenthrin 4 oz. plus Orthene 0.75 lb./A on 8 and 22 August, Lorsban 1.5 pt./A plus Orthene 0.75 lb/A on 31 July, 22 and 29 August.

Table 2. Concentrations (mg/g of cotton lint) of sugars, percentages of total reducing sugars and thermodetector counts for 20 boll weekly cotton lint samples from insecticide-treated and untreated cotton plots.

Date/ Trtmt[a]	Treh.	Mele.	Gluc.	Fruc.	% TRS	TD
Aug 29						
U	0.90 d	0.36 cd	0.30 b	0.65 ab	0.35 c	8.7 b
T	0.23 e	0.21 ef	0.36 ab	0.76 a	0.27 d	3.1 c
Sept 5						
U	1.34 c	0.43 bc	0.40 ab	0.47 bc	0.52 b	12.7 a
T	0.22 e	0.13 f	0.42 a	0.24 d	0.28 d	2.8 c
Sept 13						
U	1.83 b	0.47 b	0.32 ab	0.56 a-c	0.49 b	13.0 a
T	0.23 e	0.16 ef	0.29 b	0.24 d	0.23 d	2.4 c
Sept 20						
U	2.28 a	0.59 a	0.37 ab	0.63 ab	0.59 a	13.2 a
T	0.46 e	0.26 de	0.41 a	0.36 cd	0.34 c	3.8 c
Mean - dates						
Aug 29	0.56 c	0.29 b	0.32 bc	0.70 a	0.31 c	5.9 b
Sept 5	0.78 c	0.28 b	0.41 a	0.35 b	0.40 b	7.8 a
13	1.03 b	0.32 b	0.31 c	0.39 b	0.36 b	7.7 a
20	1.37 a	0.43 a	0.39 ab	0.50 b	0.47 a	8.5 a
Mean - insecticides						
U	1.59 a	0.47 a	0.35 a	0.58 a	0.49 a	11.9 a
T	0.28 b	0.19 b	0.37 a	0.40 b	0.28 b	3.0 b
Mean - cultivars						
Pima S-7	0.74 b	0.24 b	0.28 b	0.21 c	0.34 b	7.4 b
DPL50	1.09 a	0.38 a	0.42 a	0.81 a	0.44 a	8.6 a
DPL5415	0.98 a	0.37 a	0.38 a	0.44 b	0.38 b	6.4 b

[a] U = untreated, T= insecticide treated, means of 4 replications, 6 observations/replication for individual treatment dates, 4/replications for mean dates, 12 observations, 4/replications, 12 observations for insecticides and cultivars. Means within a group not followed by the same letter are significantly different $P \le 0.05$. Method of least significant differences.

Treh. = Trehalulose; Mele. = Melezitose; Gluc. = Glucose; Fruc. = Fructose; TRS = Total Reducing Sugars; TD = Thermodetector Counts

Table 3. Concentrations (mg/g of cotton lint) of sugars, percentages of total reducing sugars and thermodetector counts for cotton picked weekly on all plants (13.1 foot of row) in insecticide-treated and untreated cotton plots.

Date/ Trtmt[a]	Treh.	Mele.	Gluc.	Fruc.	% TRS	TD
Aug 22						
U	0.23 d-f	0.09 cd	0.06 d	0.05 f	0.18 hi	–
T	0.10 f	0.06 d	0.07 d	0.04 f	0.15 i	–
Aug 29						
U	0.64 bc	0.30 a	0.26 bc	0.60 ab	0.28 ef	3.1 b
T	0.13 ef	0.11 cd	0.18 c	0.28 e	0.21 gh	0.8 c
Sept 6						
U	1.11 a	0.33 a	0.40 a	0.65 a	0.50 a	4.0 b
T	0.32 d	0.20 b	0.41 a	0.31 de	0.34 cd	1.3 c
Sept 11						
U	0.73 b	0.22 b	0.36 a	0.51 a-c	0.37 bc	3.2 b
T	0.14 ef	0.14 c	0.35 ab	0.29 de	0.25 fg	0.5 c
Sept 15						
U	0.55 c	0.21 b	0.38 a	0.50 bc	0.38 b	7.0 a
T	0.26 de	0.19 b	0.42 a	0.44 cd	0.31 de	4.0 b
Mean dates						
Aug 22	0.16 c	0.08 c	0.07 c	0.05 b	0.17 e	–
29	0.39 b	0.20 b	0.22 b	0.44 a	0.25 d	2.0 bc
Sept 6	0.71 a	0.27 a	0.41 a	0.48 a	0.42 a	2.7 b
11	0.43 b	0.18 b	0.35 a	0.40 a	0.31 c	1.9 c
15	0.40 b	0.20 b	0.40 a	0.47 a	0.35 b	5.5 a
Mean - insecticides						
U	0.65 a	0.23 a	0.29 a	0.46 a	0.34 a	4.4 a
T	0.19 b	0.14 b	0.29 a	0.27 b	0.25 b	1.7 b
Mean - cultivars						
Pima S-7	0.35 b	0.11 b	0.21 c	0.15 c	0.26 b	2.7 b
DPL50	0.52 a	0.23 a	0.36 a	0.64 a	0.31 a	2.9 ab
DPL5415	0.39 b	0.21 a	0.30 b	0.31 b	0.32 a	3.5 a

[a] U = untreated, T= insecticide treated, means of 4 replications, 6 observations/replications for individual treatment dates, 4/replications for mean dates, 12 observations, 4/replications, 12 observations for insecticides and cultivars. Means within a group not followed by the same letter are significantly different $P \le 0.05$. Method of least significant differences.

Treh. = Trehalulose; Mele. = Melezitose; Gluc. = Glucose; Fruc. = Fructose; TRS = Total Reducing Sugars; TD = Thermodetector Counts

Table 4. Mean amounts (mg/g of cotton lint) of sugars, percentages of total reducing sugars and thermodetector counts for machine and hand-picked Pima S-7, DPL50, and DPL5415 cottons.

Harvest Method[a]	Treh.	Mele.	Gluc.	Fruc.	% TRS	TD
Hand picked (total/plant (20 Sept)						
U	1.46 c	0.40 b	0.40 b	0.61 ab	0.48 c	13.8 c
T	0.35 d	0.19 d	0.32 c	0.29 d	0.29 d	5.0 d
Machine picked						
U	2.55 a	0.65 a	0.51 a	0.67 a	1.15 a	26.7 a
T	0.57 d	0.29 c	0.46 ab	0.43 c	0.71 b	16.5 b
Hand picked 20 boll samples (13 Sept)						
U	1.82 b	0.47 b	0.32 c	0.56 b	0.49 c	13.0 c
T	0.23 d	0.16 d	0.30 c	0.24 d	0.23 d	2.4 d
Mean pick method						
Hand picked	0.90 b	0.30 b	0.36 b	0.45 b	0.39 b	9.44 b
Machine picked	1.56 a	0.47 a	0.49 a	0.55 a	0.93 a	21.63 a
20 boll samples	1.03 b	0.32 b	0.31 c	0.40 b	0.36 b	7.69 b
Mean insecticide						
U	1.95 a	0.51 a	0.41 a	0.61 a	0.71 a	17.9 a
T	0.38 b	0.21 b	0.36 b	0.32 b	0.41 b	7.9 b
Mean cultivars						
Pima S-7	0.89 b	0.26 b	0.37 a	0.32 c	0.54 b	12.5 a
DPL50	1.39 a	0.40 a	0.42 a	0.66 a	0.60 a	13.7 a
DPL5415	1.21 a	0.42 a	0.37 a	0.42 b	0.54 b	12.5 a

[a] Means of 4 replications, 2 observations per replication for untreated, treated comparisons, 4 replications for pick method comparisons, 6/replications for insecticide comparisons and 4/replications for cultivar comparisons. Means in a column not followed by the same letter are significantly different $P \leq 0.05$. Method of least significant differences.
Treh. = Trehalulose; Mele. = Melezitose; Gluc. = Glucose; Fruc. = Fructose; TRS = Total Reducing Sugars; TD = Thermodetector Counts

Table 5. Mean amounts (mg/g of cotton lint) of sugars, percentages of total reducing sugars and thermodetector counts for weekly 20 boll samples and weekly total open cotton picks on all plants in 13.1 feet of cotton row.

Sampling[a] Method/ Date	Treh.	Mele.	Gluc.	Fruc.	% TRS	TD
Hand-picked 20 boll samples weekly						
August						
29	0.56 de	0.29 b	0.33 bc	0.70 a	0.31 d	5.9 b
September						
6	0.78 c	0.28 b	0.41 a	0.35 c	0.40 b	7.8 a
11	1.03 b	0.32 b	0.31 c	0.40 bc	0.36 c	7.7 a
15	1.37 a	0.43 a	0.39 ab	0.50 b	0.47 a	8.5 a
Hand picked total cotton/plant weekly						
August						
29	0.38 f	0.20 cd	0.22 d	0.44 bc	0.25 e	2.0 c
September						
6	0.71 cd	0.27 bc	0.41 a	0.48 bc	0.42 b	2.7 c
11	0.43 ef	0.18 d	0.35 a-c	0.40 bc	0.31 d	1.9 c
15	0.40 ef	0.20 cd	0.40 ab	0.47 bc	0.35 c	5.5 c
Mean sampling methods						
20 bolls weekly	0.93 A	0.33 A	0.36 A	0.49 A	0.39 A	7.5 A
Total cotton/plant weekly	0.48 B	0.21 B	0.34 A	0.45 A	0.33 B	3.0 B
Mean dates						
Aug 29	0.47 C	0.24 B	0.27 C	0.57 A	0.28 C	3.9 C
Sept 6	0.75 B	0.27 AB	0.41 A	0.42 B	0.41 A	5.2 B
Sept 11	0.73 B	0.25 B	0.33 B	0.40 B	0.33 B	4.8 B
Sept 15	0.89 A	0.32 A	0.39 A	0.48 AB	0.41 A	7.0 A
Mean insecticides						
U[b]	1.18 A	0.37 A	0.35 A	0.57 A	0.44 A	8.1 A
T	0.25 B	0.18 B	0.36 A	0.36 B	0.28 B	2.3 B
Mean cultivars						
Pima S-7	0.57 C	0.19 B	0.26 C	0.20 C	0.31 C	5.0 B
DPL 50	0.84 A	0.32 A	0.43 A	0.80 A	0.39 A	5.7 A
DPL 5415	0.72 B	0.30 B	0.36 B	0.40 B	0.37 B	4.9 B

[a] Means of 4 replications, 2 observations per replication for hand picked 20 boll hand picked total cotton comparisons, 4 replications, 6 observations/replication for 20 bolls vs. total cotton weekly. Means in a column and group not followed by the same letter are significantly different $P \leq 0.05$). Method of least significant differences.
[b] U = untreated, T = insecticide-treated.
Treh. = Trehalulose; Mele. = Melezitose; Gluc. = Glucose; Fruc. = Fructose; TRS = Total Reducing Sugars; TD = Thermodetector Counts

Table 6. Machine-picked and hand-picked cotton lint yields for Pima S-7, DPL50 and DPL5415 planted at 10 or 40 thousand plants per acre.

Harvest method/ plant density	Cultivar: Pima S-7	DPL50	DPL 5415	Means: Density	Harvest Method
Machine picked					
10	1065 gh	1479 b-d	1298 d-f	1281 b	–
40	1047 gh	1433 c-e	1292 d-f	1257 b	–
					1269 ab
Hand picked at harvest					
10	748 i	1134 f-h	942 hi	941 c	–
40	1108 f-h	1644 ab	1771 a	1507 a	–
					1224 b
Total for hand picked weekly					
10	1190 fg	1718 a	1588 a-c	1499 a	–
40	1062 gh	1269 ef	1236 eg	1189 b	–
					1344 a
Mean cultivars	1037 c	1446 a	1354 ab	–	

Means of 4 replications, 2 observations per replication. Means not followed by the same letter are significantly different $P \leq 0.05$. Method of least significant differences.

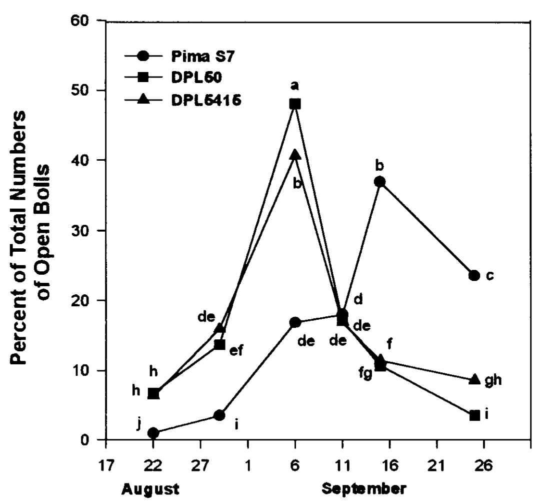

Figure 1. Percentages of the total numbers of open cotton bolls occurring during the season for two upland (DPL50 and DPL5415) and one long staple (Pima S-7) cotton cultivar. Means for points on a line not followed by the same letter are significantly different $P \leq 0.05$. Method of least significant differences.

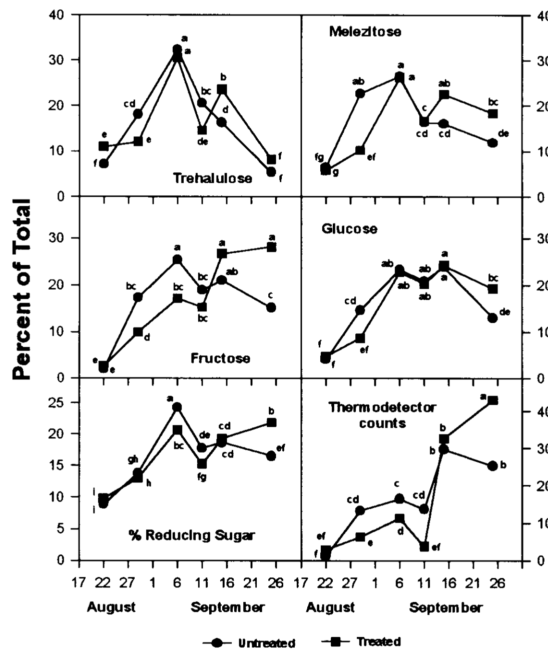

Figure 2. Percentages of the total amounts of sugars and thermodetector counts occuring during the season from samples from all open cotton bolls per plant picked weekly. Means for points on a line not followed by the same letter are significantly different $P \leq 0.05$. Method of least significant differences.

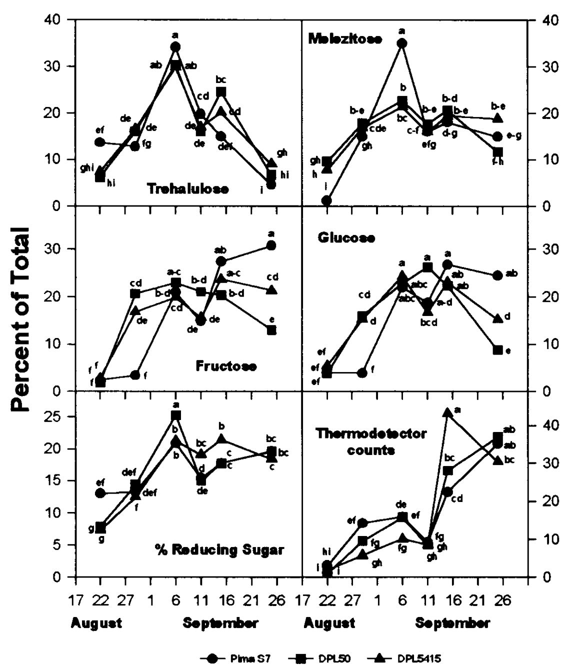

Figure 3. Percentages of the total amounts of sugars and thermodetector counts occuring during the season from samples from all cotton bolls per plant picked weekly. Means for points on a line not followed by the same letter are significantly different $P \leq 0.05$. Method of least significant differences.

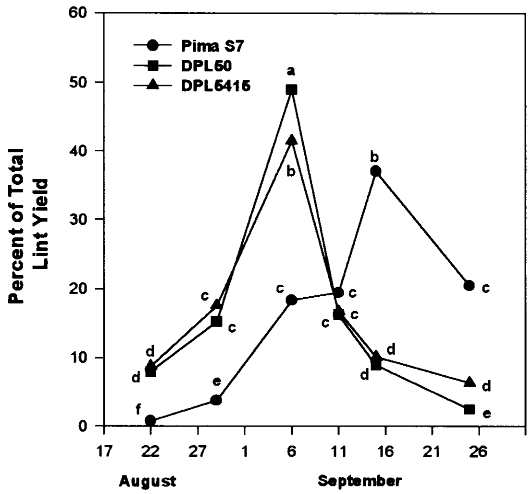

Figure 4. Mean percentages of total cotton lint yields for two upland (DPL50 and DPL5415) and one long-staple (Pima S-7) cotton occurring during the season. Means for points on a line not followed by the same letter are significantly different P≤ 0.05. Method of least significant differences.