SILVERLEAF WHITEFLY INFESTATION LEVELS AND PERCENT PARASITISM IN RELATION TO COTTON VARIETY AND INSECTICIDE TREATMENTS

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Abstract

Insecticide applications using Danitol 2.4 EC tank mixed with Orthene 90S reduced the numbers of silverleaf whitefly adults, eggs, and nymphs to levels significantly ($P \leq 0.05$) below the levels found in non-treated cotton among all varieties. There were no significant variety by insecticide treatment interactions for silverleaf whitefly infestation levels, levels of parasitism, or for seed cotton yield. Several of the Australian varieties had silverleaf whitefly infestation levels for adults, eggs and nymphs that were lower than any of the US varieties. The Australian varieties Siokra L23 and 87031-126 consistently had lower whitefly infestation levels than other variety entries and also had higher percent parasitism levels than the other varieties.

Introduction

Biological control and plant resistance to insects (PRI) offer economically and environmentally desirable pest control that can be incorporated into integrated pest management for cotton. PRI may result from intentional breeding goals or as a byproduct of selection for yield, quality, or other agronomic factors (Painter, 1951). While Berlinger (1986) discussed the loss of PRI through intentional selective breeding for other desirable factors, he and Painter conclude that a team approach is necessary for successful implementation of PRI.

Whitefly have long been sporadic pests of cotton in southern California and Arizona (Gerling 1967), until 1981 when the sweetpotato whitefly, *Bemisia tabaci* (Gennadius)caused severe economic losses (Johnson et al. 1982). Economic damage to cotton caused by whitefly infestations may result from their feeding(Hussain and Trehan 1983), including contamination of lint by honeydew and sooty molds (Gerling et al. 1980), reduced yield (Mound 1965), and transmission of cotton leaf crumple virus (Dickson et al. 1954, Duffus and Flock 1982). In 1981, high *B. tabaci* populations resulted in an estimated loss of $4 million to the cotton crop in the Imperial Valley of California, primarily due to sooty mold and reduced yields (Natwick 1983). Some foreign countries, notably Sudan, have difficulty selling their cotton on the world market due to honeydew contamination (Perkins 1983).

Host plant resistance in cotton cultivars as an initial step in sweetpotato whitefly, *Bemisia tabaci* Genn., management in cotton was studied in California during the 1980's (Natwick et al. 1991). The recent and severe outbreak of silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring, in Arizona, California, and Texas prompted study of resistance in cotton cultivars as an initial step in whitefly management in cotton. Upland and Pima cotton were evaluated in two trials from 1989 through 1993 (Natwick et al 1995).

During the 1991 growing season conservative estimates suggested direct dollar losses exceeding $200 million nationwide to crops damaged by *B. argentifolii*. The direct dollar loss to cotton producers in the Rio Grande Valley of Texas in 1991 was more than $80 million (Henneberry 1993). Direct dollar losses to all crops, including cotton, in the Imperial Valley of California in 1991 were estimated to be in excess of $120 million (Perring et al. 1991).

Insecticides applied to the foliage occasionally provide temporary suppression (due to insecticide resistance) of whitefly populations by killing adults (Gerling 1967). Whitefly populations quickly recover from insecticide applications because eggs and nymphs are distributed on the underside of leaves on the lower and middle crop canopy (Ohnesorge et al. 1980), and are typically not contacted by aerial applications of such materials. Whitefly adults from other crops also continually migrate to cotton to reinfect the crop. Insecticides can also allow whitefly populations to increase by reducing natural enemies (Gerling 1967). Insecticide resistance in *B. tabaci* was documented by Prabhaker et al. (1985) to several foliar applied compounds. Prabhaker et al. (1994) recently documented the early stages of resistance of *B. argentifolii* to endosulfan which is used to control both *B. tabaci* and *B. argentifolii*. Systemic granular insecticides have not provided an economically efficacious alternative to foliar insecticides for *B. argentifolii* control. Therefore, cotton cultivar selection could become an important component of an integrated pest management program to control *B. argentifolii*.

Certain cotton types, strains and varieties have been found to have differential susceptibility to whiteflies (Khalifa and Gameel 1983, Butler and Henneberry 1984). Cotton stickiness can be controlled through breeding cultivars resistant to whiteflies (Khalifa and Gameel 1983). Increased whitefly population levels have been reported in cotton varieties with pubescent leaves as compared to

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smooth-leaved cotton (Mound 1965). Cotton lines with okra leaf-shape, glabrous plant body and high gossypol content generate fewer *B. tabaci* as compared to other lines, while hairy-leaf cotton lines produce the highest *B. tabaci* population levels and therefore, the most honeydew (Khalifa and Gameel 1983, Berlinger 1986).

The objectives of this study were to: 1. Evaluate the effects of cotton cultivar selection on silverleaf whitefly infestation development; 2. Evaluate the interaction of cultivar selection and insecticide treatments in relation to silverleaf whitefly control and lint stickiness via percent sugar and thermodetector ratings; 3. Determine possible mechanisms of host plant resistance to silverleaf whitefly; and 4. Evaluate the effects of cultivar selections and insecticidal control on whitefly parasitism. As not all of the data collection has been completed of determining the mechanisms of resistance and on the sugar and stickyness analyses only objestives 1 and 4 will be covered in this manuscript.

Material and Methods

Seventeen cotton varieties were sown at the UC Desert Research & Extension Center into plots of a randomized complete block design experiment with split plots, replicated four times, and irrigated 20 March, 1996. Varieties included in the trial included: DP 20, DP 50, DP 90, DP 5415, DP 5432, DP 5461, DP 9050, DPX 9057, NuCOTN 33b, CB 1135, and CB 1233 from the US; and CS 50, Siokra L23, Siokra V-15, Siokra 1-4/649, 87031-126, and 89013-114 from Australia. Individual plots measured 14 m in length with 8-beds on 1 m centers. Plots were split into sub-plots with insecticide treatments being assigned at random to four beds in each plot. Insecticide treatments, Danitol 2.4 EC at 0.02 lb ai/acre tank mixed with Orthene 90S at 0.5 lb ai/acre, were applied as a foliar spray a total of seven times at weekly intervals starting 11 June, 1996. Helena Buffer PS at 23.6 ml/5 gal. and Sylgard 309 at 5.9 ml/5 gal. were included in all insecticide spray treatments.

Silverleaf whitefly adults were sampled from five plants at random in each plot, via the leaf turn method (Naranjo & Flint 1995), using the 5th main stem leaf from the terminal on 17 & 24 June, and 1, 8, 16, & 29 July, 1996. Silverleaf whitefly eggs and nymphs were counted on two leaf disks of 1.25 cm^2 from five 5th position leaves from the terminal extracted from plants in each plot on 17 & 24 June, and 1, 8, 16, 22 & 29 July, 1996. Seed cotton was hand picked from 0.002 acre per plot and seed cotton yield data were recorded on August 28, 1996. Cotton samples were ginned and lint samples were sent to the USDA/ARS Cotton Quality Research Station in Clemson, SC for stickiness analysis via the thermodetector technique (Perkins 1994) and percent sugar analysis (Perkins 1993). Statistical analysis procedures for whitefly adults, eggs, and nymphs, and for yield data included Bartlett's test for homogeneity of variance and two-way analysis of variance for a randomized complete block design ,including a test of non-additivity, used to analyze data sets for normal distribution. Factorial analysis of variance for split plot design, using log or square root transformed data to obtain normal distribution, were then performed on the data sets. Where significance was found, means were separated using Tukey's HSD mean comparison procedure. Analyses were performed using Michigan State University software MSTAT-C (MSTAT-C 1990).

The cotton variety trial was sampled on 23 July and 8 August 1996 to determine if cotton varieties had any effect on levels of parasitism of silverleaf whitefly by naturally occurring *Eretmocerus* sp. On each of the sampling dates six leaves were extracted from plants at random from the 8th node position below the terminal from each sub-plot. The random samples were collected from the inner two rows of each sub-plot, three leaves per row. Samples were examined in the laboratory and all whitefly pupae, emerged whitefly, *Eretmocerus* pupae, and emerged *Eretmocerus* were counted within a 2.7 cm^2 disk placed at the base of leaf sector 1. Percentage of parasitism was calculated by dividing the total number of *Eretmocerus* by the total number of *Eretmocerus* plus emerged whitefly. For analysis, percentage of parasitism was transformed using the arc-sine transformation for percent data. A split-plot analysis of variance was performed using insecticide treatment as the split factor. Where significance was found, means were separated using Tukey's HSD mean comparison procedure. Analyses were performed using SAS/STAT software (SAS Institute 1988).

Results and Discussion

On 23 July, there was a significant effect of variety type on levels of parasitism ($F=4.51$ $df=3,16$, $P<0.001$). In the non-treated plots, parasitism levels ranged from 24 to 68%. The highest levels of parasitism were observed in varieties Siokra L23 and 87031-126 of 68% and 65%, respectively. These levels were significantly higher than several of the other varieties. There were no significant interaction terms (Table 1).

On 8 August, parasitism in non-treated plots ranged from 36 to 66% and there was a significant effect of variety on levels of parasitism $F=1.85$ df 3, 16, $P<0.05$). However, no significant differences were found among means as the Tukey's mean separation test is more conservative than analysis of variance which does not control for experiment-wise error rate (Table 1).

There were no significant variety by insecticide treatment interactions on either date, though insecticide treatment had a significant effect on parasitism on 23 July ($F=11.14$ $df=3,1$, $P<0.002$). No significant effects of insecticide treatment on parasitism were found on 8 August ($F=0.56$ df 3,1, $P<0.46$). Parasitism levels in the insecticide treated plots ranged from 8 to 58% and 26 to 70% on 23 July and 8 August respectively.

On all sampling dates there were significant effects of variety on levels of infestation of whitefly adults, eggs and nymphs. However, on several sampling dates no significant differences were found among means for whitefly adults, eggs or nymphs as the Tukey's mean separation test is more conservative than analysis of variance which does not control for experiment-wise error rate. There were significant effects of variety on seasonal levels of infestation of whitefly adults ($F=14.2$ $df=3,16$, $P<0.001$), eggs ($F=11.71$ $df=3,16$ $P<0.001$) and nymphs($F=22.09$ $df=3,16$ $P<0.001$). The varieties Siokra L23 and 87031-126 had the lowest seasonal means for whitefly adults among all of the entries in the trial, significantly greater ($P\leq0.05$) than several varieties, Table 2. All but CS 50 among the Australian varieties had the lowest seasonal means for whitefly eggs and nymphs among all of the entries in the trial, Table 2. Varieties Siokra L23 and 87031-126 had the lowest seasonal means for whitefly eggs and nymphs among all of the entries in the trial, significantly greater than several varieties. The variety CB 1135 had the highest seasonal mean for eggs and nymphs, significantly greater ($P\leq0.05$) than varieties 87031-126 and Siokra L23. The high dgree of susceptibility of CB 1135 to whitefly infestation was consistant with 1991 research results (Natwick et al. 1995).

There were no significant variety by insecticide treatment interactions on any of the sample dates, though insecticide treatment had a significant effect on the levels of whitefly adults, eggs, and nymphs and on seed cotton yield. There were significant effects of insecticide treatment on levels of silverleaf whitefly infestation. On all sample dates insecticide treatments had significantly lower ($P\leq0.05$) numbers of whitefly adults, eggs, and nymphs as compared to non-treated across all varieties. There were significant effects of insecticide treatments on seasonal means of adults ($F=208.51$ $df=3, 1$, $P<0.0001$), eggs ($F=417.11$ $df=3, 1$, $P<0.0001$), and nymphs ($F=291.36$ $df=3, 1$, $P<0.0001$). Insecticide treatments had significantly lower seasonal mean values for whitefly adults, eggs, and nymphs as compared to non-treated across all varieties.

There were significant effects of variety on seed cotton yield ($F=29.51$ $df=3,16$, $P<0.001$). DP 5461 had a significantly lower seed cotton yield than DP 50, NuCOTN 33b, DP 5415, and DP 20 ($P\leq0.05$), Table 3. There were no other differences among the cotton varieties for seed cotton yield. There were no significant variety by insecticide treatment interactions on seed cotton yield ($F=1.26$ $df=3,16$, $P=0.256$). There were significant effects of insecticide treatments on seed cotton yield ($F=325.63$ $df=3, 1$, $P<0.0001$). Insecticide treatments had significantly greater seed cotton yields as compared to non-treated for all varieties.

In conclusion, there may be some effect on variety type on levels of parasitism as some varieties had consistently high levels of parasitism on both sampling dates (Table 1). There also may be some effect on variety type on levels of silverleaf whitefly infestation as some varieties had consistently lower levels of adults, eggs and nymphs on all sample dates and for seasonal mean values, Table 2. Varieties Siokra L23 and 87031-126 may have some useful traits that make them more attractive to parasites or perhaps renders silverleaf whitefly more susceptible to attack. Varieties Siokra L23 and 87031-126 may have some useful traits that make them less attractive to silverleaf whitefly adults or traits that make them more resistant to attack by the nymphs.

For interpretation of parasite results, it should be noted that due to the large size of the experiment very few sample leaves were selected from each plot (n=6). This may have resulted in poor estimates of the true levels of parasitism. Also it should be noted that in three out of the four replicate blocks the plots with varieties Siokra L23 and 87031-126 were adjacent to each other. Though it seems unlikely, if there was some pattern of *Eretmocerus* distribution within the field based on plot location rather than variety type, this spatial arrangement of plots may have led to spurious results. It should also be noted that the Australian varieties may not be well adapted to the growing conditions in the Imperial Valley of California reducing their yield potential. However, if useful whitefly resistance characteristics can be identified, resistance characters may be introduced into cultivars adapted to various growing conditions.

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Table 1. Percentage of parasitism of silverleaf whitefly by *Eretmocerus* spp. on cotton varieties not treated with insecticides at Holtville, CA, 1996.

Variety	23 July	8 August
Siokra L23	68 a	62 a
87031-126	65 ab	64 a
CS 50	54 abc	64 a
89013-114	50 abc	66 a
Siokra V-15	49 abc	57 a
DP 20	42 abc	49 a
DP 50	39 bc	41 a
DP 90	39 bc	51 a
CB 1233	39 bc	60 a
DP 5432	39 bc	36 a
DPX 9057	36 bc	49 a
Siokra 1-4/649	34 bc	61 a
DP 5461	32 c	41 a
NuCOTN 33b	30 c	50 a
CB 1135	30 c	53 a
DP 9050	30 c	50 a
DP 5415	24 c	45 a

Mean separations within columns by Tukey's HSD, $P \leq 0.05$.

Table 2. Silverleaf whitefly seasonal means for adults per leaf and eggs and nymphs per cm^2 of leaf for cotton varieties at Holtville, CA, 1996.

Variety	Adults[a]	Eggs[a]	Nymphs[a]
DP 9050	45.70 a	27.65 a	20.76 ab
DP 5432	40.37 ab	29.02 a	21.72 ab
CB 1135	36.70 ab	29.27 a	26.98 a
DP 5415	26.55 abc	17.70 ab	17.41 abc
DPX 9057	25.69 abc	18.41 ab	14.74 abcd
DP 5461	25.17 abc	22.57 ab	17.80 abc
CB 1233	24.86 abc	20.92 ab	21.80 ab
NuCOTN 33b	23.30 abc	15.75 ab	13.80 abcd
Siokra 1-4/649	22.98 abc	13.11 ab	10.96 bcd
DP 90	20.19 abc	17.85 ab	16.22 abc
CS 50	20.17 abc	17.35 ab	17.27 abc
DP 20	19.14 abc	14.47 ab	13.57 abcd
Siokra V-15	18.44 abc	10.64 ab	7.97 cd
DP 50	18.06 bc	16.45 ab	14.97 abcd
89013-114	17.25 bc	12.66 ab	9.61 bcd
Siokra L23	10.69 c	6.43 b	6.70 cd
87031-126	8.00 c	5.93 b	4.76 c

[a] Square root transformed data used for analyses; reverse transformed means reported.
Mean separations within columns by Tukey's HSD, $P \leq 0.05$.

Table 3. Seed cotton as kilograms per hectare, pounds per acre, and lint as pounds per acre for varieties at the University of California Desert Research and Extension Center, Holtville, CA, 1996.

Variety	Kg seed cotton/ha[a]	Lb seed cotton/acre	Lb lint/acre	480 lb bales/acre
DP 50	3636.6 a	3244.6	1081.5	2.25
NuCOTN 33b	3500.0 a	3122.7	1040.9	2.17
DP 5415	3488.7 a	3112.6	1037.5	2.16
DP 20	3467.1	3093.3	1031.1	2.15
Siokra V-15	3376.6	3012.6	1004.2	2.09
DPX 9057	3372.1	3008.6	1002.9	2.09
CB 1135	3269.5	2917.0	972.3	2.03
DP 90	3209.7	2863.7	954.6	1.97
89013-114	3146.3	2807.1	935.7	1.95
Siokra 1-	3139.5	2801.1	933.7	1.95
Siokra L23	3044.9	2716.6	905.5	1.89
CB 1233	3019.1	2693.6	897.9	1.87
87031-126	2864.8	2556.0	852.0	1.77
CS 50	2745.4	2449.4	816.5	1.70
DP 9050	2741.8	2446.2	815.4	1.70
DP 5432	2731.8	2437.3	812.4	1.69
DP 5461	2503.3 b	2233.4	744.5	1.55

[a] Log transformed data used in analyses; reverse transformed means reported.
Mean separations within columns by Tukey's HSD, $P \leq 0.05$.