Infestation of Germplasm Lines and Cultivars of Cotton in Arizona by Whitefly Nymphs (Homoptera: Aleyrodidae)[1]

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ABSTRACT Seasonal abundance of whitefly nymphs, primarily sweetpotato whitefly, *Bemisia tabaci* (Gennadius), and bandedwinged whitefly, *Trialeurodes abutilonea* (Haldeman), on leaves of germplasm lines and cultivars of cotton, *Gossypium hirsutum* L., were determined in field plots at Maricopa, AZ, in 1987. In general, the germplasm lines with the greatest numbers of leaf trichomes (range 2 to 98 per cm^2) had the greatest numbers of nymphs (range 0.4 to 11.3 nymphs per leaf on 23 September). The okra-leaf characteristic did not have a consistent effect on the numbers of nymphs. Deltapine 20, Centennial, and Stoneville 506 cultivars planted on 30 April had significantly greater infestations (range 20.3 to 121.3 nymphs per leaf) on 16 October than did the same cultivars planted 21 May (range 4.5 to 53.0) or 11 June (range 7.0 to 31.5). The nectariless okra-leaf line WC-12NL and cultivar Deltapine 61 had 1.1 and 1.5 nymphs per leaf on 22 September, respectively, not significantly different.

KEY WORDS Insecta, Whitefly, *Bemisia,* Cotton, *Gossypium,* Host Plant Resistance.

The sweetpotato whitefly, *Bemisia tabaci* (Gennadius) and the banded winged whitefly, *Trialeurodes abutilonea* (Haldeman), infest cotton, *Gossypium* spp., in Arizona. They exude honeydew which causes lint to stick and serves as a growth medium for molds. Additionally they vector the cotton leaf crumple virus (Butler et al. 1985) and other viruses (Duffus and Flock 1982). Control is difficult because pesticides do not reach their feeding sites on the lower leaf surface and is further confounded by the development of insecticide resistance (Prabhaker et al. 1985, Sharaf 1986). Another approach to control this pest may be through the use of short-season and/or resistant cultivars. Mound (1965) first noted resistance in smoothleaf or semi-smoothleaf cotton plants from his work in the Sudan.

Berlinger (1986) found that the okra-leaf and glabrous (smoothleaf) characters in cotton usually confer resistance to whiteflies. Butler et al. (1986) had variable results with the okra-leaf character but showed that Stoneville 825, a pubescent cultivar, had significantly more adults and eggs than either the semi-smooth or smoothleaf isolines in greenhouse tests. Previous work by Butler and Henneberry (1984) showed that whiteflies preferred pubescent strains of cotton.

We investigated factors that might reduce whitefly damage in commercial cotton culture by evaluating (a) germplasm lines and cultivars with combinations of the okra-leaf and semi-smoothleaf characters; (b) planting date manipulation

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and (c) the potential of WC-12NL, a short season nectariless germplasm line with resistance to the pink bollworm, *Pectinophora gossypiella* (Saunders), to withstand whitefly infestation in comparison to Deltapine 61, a cultivar grown in Arizona.

Materials and Methods

General Methods. The tests were conducted at the University of Arizona, Maricopa Agricultural Center, Maricopa, AZ. Soil types at Maricopa belong to the Trix series and the growing season is about 245 days. All test plants were planted on 1.01 m row centers and were treated with phorate at planting.

Nymphs (including 'crawler' and 'pupal' stages) were counted on the underside of each leaf using microscopes of 10X magnification. No distinction was made between nymphs of the sweetpotato whitefly or the bandedwinged whitefly. One leaf per plant, from 10 plants at the center of each plot, was removed at the sixth node of the main stem (node number one being the top of the plant) because that node is the site of the highest infestation (Ohnesorge and Rapp 1986).

Leaf trichomes per cm^2 were measured by imprinting a 0.57 cm diameter circle with a grommet punch on the underside of a leaf on either side of the mid-vein and counting the trichomes (not individual hairs) under a microscope. Counts were made from 10 leaves per cotton collected during September.

The data for the 23 September infestations in the germplasm lines and cultivars were analyzed by ANOVA followed by an LSD test (20 treatments with four replicates in a randomized block design). A regression analysis was done on the numbers of nymphs per leaf using the number of trichomes per cm^2 as the independent variable. The data for infestations in cotton varieties by planting date were tested using ANOVA of a split plot design (Gomez and Gomez 1984) with planting dates as whole plots and varieties as split plots. The $P < 0.05$ level of significance was used for all tests, except where noted.

Comparison of Susceptibility of Germplasm Lines and Cultivars to Whitefly. Whitefly nymphs on cotton leaves were sampled between 9 July and 23 September (eight samples, data pooled for 10 leaves/plot) in 17 germplasm lines (all nectariless, four with the okra-leaf characteristic, three with the semi-smoothleaf (Delta smoothleaf) characteristic, and three with combined okra and smoothleaf characteristics, Table 1) plus three cultivars, Deltapine 90 (DPL-90), Stoneville 825 (ST-825, a nectariless cultivar), and Gumbo 500, an okra-leaf cultivar. Each cotton was replicated in four plots, each 15 m by 8 rows, within a randomized complete block design planted 7 April. The final irrigation occurred on 14 August (approximately biweekly schedule during season) and no insecticides were applied to the cotton during the season.

Effect of Planting Date on Whitefly Nymphs in Three Cultivars. Whitefly nymphs on cotton leaves were sampled between 21 August and 16 October (five samples) in cultivars Deltapine 20 (DPL-20), Centennial, and Stoneville 506 (ST-506), arranged in blocks planted on either 30 April, 21 May, or 11 June. Each planting date block contained four replicate plots, 60 m by four rows wide, for each cultivar in a randomized complete block design. Cultural practices, except for insecticide applications, were similar for all blocks. Blocks of cotton by planting date were sprayed with insecticides to control the pink bollworm at the direction of the farm pest control advisor beginning 1 August. The 30 April planting received a total of eight applications while the 21 May and 11 June plantings each received

Table 1. Populations of whitefly nymphs on leaves of 17 germplasm lines and three cultivars of cotton at Maricopa, AZ.

Germplasm † line or cultivar	Trichomes/ cm^2	Whitefly nymphs/leaf* 9 July - 17 Aug.‡	1 Sept.	23 Sept.
DES-56 N cross §	72	2.4 ± 1.4	1.5	11.3 a
DPL-90 N cross¶	70	2.0 ± 1.8	1.3	4.2 b
7203-14-104 NL	58	1.6 ± 1.1	2.4	3.9 bc
ST-825 NL	81	1.3 ± 1.3	1.2	3.8 bc
ST-825 N	98	1.8 ± 1.1	1.5	3.7 bcd
DPL-733/712 N	38	0.9 ± 0.4	0.7	3.7 bcd
7203-14-104 N	60	1.5 ± 0.8	1.7	3.3 bcde
DES-56 N	48	2.1 ± 1.1	0.9	3.0 bcdef
ST-506 NL cross**	51	1.2 ± 1.4	0.8	2.2 bcdef
GUMBO 500L	32	1.8 ± 1.4	0.9	2.1 bcdef
7203-14-104 NSS	3	0.4 ± 0.3	1.1	2.0 bcdef
DPL-62 NSS	4	0.3 ± 0.2	0.9	1.8 bcdef
ST-825 NSS	7	0.4 ± 0.3	1.1	1.8 bcdef
DES 56 NL	27	1.0 ± 0.6	1.3	1.8 bcdef
ST-506 N cross**	90	2.7 ± 1.9	1.2	1.4 cdef
ST-825 NLSS	6	0.6 ± 0.3	1.3	1.4 cdef
7203-14-104 NLSS	5	0.2 ± 0.1	0.7	1.1 def
DPL-20 N	2	0.7 ± 0.6	0.9	0.8 ef
DPL-733/712 NLSS	9	0.3 ± 0.2	1.0	0.8 ef
DPL-90	10	0.4 ± 0.3	0.9	0.4 f

* Averages of 4 replicate plots, 10 leaves per plot, tested by ANOVA. Means followed by a common letter are not significantly different (P = 0.05, LSD).

† N = nectariless, SS = semi-smoothleaf, L = okra leaf.

‡ Average of 6 observations (not included 1 and 23 Sept.) ± standard deviation. Each observation is the avarage of 4 replicate plots, total nymphs for 10 leaves each plot.

§ [DES-56 × (DES-56N × AET-5)]BC_3F_3

¶ [DPL-90 × (DPL-90 × DES-56NL)]BC_1F_4

** [ST-506 × (ST-506 × DES-56NL)]BC_1F_4

three applications. These aerial applications were primarily synthetic pyrethroids for control of the pink bollworm.

The last irrigation occurred on 22 August for the two earlier plantings and on 8 September for the later planting. This schedule allowed for completion of the first fruiting cycle for each cultivar but meant that the stages of plant growth could not be the same at each sample time.

Comparison of Whitefly nymphs in Deltapine 61 and WC-12NL. Deltapine 61 (DPL-61), a cultivar widely grown in Arizona, was compared to WC-12NL, an okra-leaf, nectariless, short-season germplasm line considered suitable for commercial production (Wilson 1987). Samples were taken between 17 July and 22 September (seven samples) from a randomized complete block design with five 0.8 ha plots of each cultivar planted 7 April. Insecticide sprays were applied when needed for control of the pink bollworm. DPL-61 was sprayed on 14 August, 5 and 12 September and WC-12NL was sprayed on 5 September.

Results

Comparison of Susceptibility of Germplasm Lines and Cultivars to Whitefly. In general, numbers of whitefly nymphs on leaves of the cotton lines did not increase between 9 July and 17 August (averages of 0.2 to 2.7 nymphs per leaf per sample, data for each line pooled and presented with its standard deviation, Table 1). There were no significant differences in whitefly infestations on 1 Sept. However, by 23 September the more pubescent lines tended to have greater average numbers of nymphs (regression equation without ST-506 nectariless cross: $Y = 1.0 + 0.05X$, correlation coefficient = 0.65, $P < 0.01$, 17df). The number of nymphs on the ST-506 nectariless cross did not fit the general trend as noted below. The number of nymphs per leaf between 1 and 23 September either did not increase (DPL-90 and two others) or increased up to 7-fold (DES-56 nectariless cross).

The DES-56 nectariless cross had significantly more whitefly nymphs on 23 September (11.3 per leaf) than all of the other cottons. The cultivar DPL-90 had the lowest average number of whitefly nymphs (0.4 per leaf) but was not significantly different from 12 other cottons. The ST-506 nectariless cross with 90 trichomes per cm^2, had an unexpectedly low average of 1.4 nymphs per leaf on 23 September, perhaps due to unnoted senescence of this particular line. However, samples of this line taken 17 August had the greatest numerical (2.7 nymphs per leaf) average infestation of any of the test lines.

The okra-leaf characteristic was not a consistent factor involved in whitefly infestation of the test lines. The DPL-90 nectariless cross had significantly greater numbers of nymphs than DPL-90 but also had pubescent leaves (70 compared to 10 trichomes per cm^2, respectively).

The two semi-smoothleaf lines of ST-825 with 6 and 7 trichomes per cm^2 had numerically but not significantly lower numbers of nymphs than the two pubescent lines with 81 and 98 trichomes per cm^2. The 7203-14-104 nectariless, okra-leaf line with the semi-smoothleaf trait had significantly fewer nymphs per leaf than the same line without that trait (5 compared to 58 trichomes, respectively). The 7203-14-104 nectariless line with the semi-smoothleaf trait had numerically but not significantly fewer nymphs than the same line without that trait (3 compared to 60 trichomes, respectively). Semi-smoothleaf was associated consistently with lower infestations of whitefly nymphs.

Effect of Planting Date on Whitefly Populations in Three Cultivars. DPL-20 had 0.2 trichomes per cm^2, the smoothest leaves found in any of the cultivars we studied (Table 2). Centennial and ST-506 are both pubescent cultivars but ST-506 has twice as many trichomes per cm^2 (85.0 compared to 41.9 for Centennial). The greatest numbers of nymphs per leaf during the 21 August to 25 September period (four samples) were recorded in the 25 September samples.

Centennial planted on 30 April had significantly greater numbers of whitefly nymphs on 16 October than when planted on 21 May or 11 June. There were no significant differences between numbers of nymphs for early and later plantings of DPL-20 or ST-506. However, the average numbers of nymphs per leaf for the three cultivars was significantly greater for the 30 April planting date (72.2) than for the 21 May or 11 June planting dates (25.1 and 20.3, respectively).

DPL-20 had significantly lower numbers of nymphs for the 30 April planting date than Centennial, and ST-506 was intermediate between the two. There were

Table 2. Numbers of whitefly nymphs in three cultivars of cotton by planting date at Maricopa, AZ.

		Whitefly nymphs/leaf				
	Trichomes/	Cultivar range	On 16 Oct. by planting date*			Varietal†
Cultivar	cm^2	21 Aug. - 25 Sept.	30 April	21 May	11 June	mean
DPL-20	0.2	0.1 - 1.4	20.3 aB	4.5 aA	7.0 aA	10.6 B
Centennial	41.9	0.4 - 14.7	121.3 aA	53.0 bA	31.5 bA	68.6 A
ST-506	85.0	0.9 - 4.7	75.0 aAB	17.8 aA	22.5 aA	38.4 AB
		Planting date mean	72.2 a	25.1 b	20.3 b	

* Tested by ANOVA, split-plot design (Gomez and Gomez 1984). Planting date means with lower-case letter in common (within rows) are not significantly different (P = 0.05; LSD for planting date means over varieties = 35.3; LSD for mean within varieties = 61.2.

† Varietal means with capital letter in common (within columns) are not significantly different (P = 0.05; LSD for varietal mean over planting date = 53.4; LSD for varietal mean within planting date = 72.9).

no significant differences between the numbers of nymphs in the three cultivars planted 21 May or 11 June. The average numbers of nymphs per leaf for all planting dates of DPL-20 (10.6) was significantly lower than the average for Centennial (68.6) while ST-506 (38.4) was not significantly different from either.

Comparison of Whitefly Nymphs in DPL-61 and WC-12NL. There were no significant differences in the numbers of whitefly nymphs on DPL-61 and on WC-12NL on any of the seven sample dates. They had similar numbers of trichomes (DPL-61 = 16, WC-12NL = 10 per cm^2) and similar average numbers of whitefly nymphs (DPL-61 = 1.1, WC-12NL = 1.5 nymphs per leaf, LSD = 0.73 NS) on 22 September, the last sample date. The seasonal average whitefly infestations ($X \pm S.D.$) were 0.56 ± 0.50 and 0.35 ± 0.4 nymphs per leaf for WC-12NL and DPL-61, respectively. Thus, the orka-leaf and nectariless characteristics of WC-12NL did not significantly influence whitefly infestation.

Discussion

The okra-leaf characteristic did not have a consistent effect on infestations of whitefly nymphs in our tests. Other orka-leaf cotton lines have supported greater or fewer numbers of whiteflies than their normal-leaf isolines (Butler et al. 1986). However, Sippell et al. (1983) found that the okra and super-okra leaf types conferred resistance to the sweetpotato whitefly. They suggested that the drier microclimate associated with the more open canopy was less favorable for this whitefly. Considering the available data, it does not appear that the okra-leaf characteristic can be used to predict resistance to whiteflies in Arizona.

The density of leaf trichomes appears to be the most useful characteristic for predicting resitance to whiteflies. Omran and El Khidir (1978) found that *B. tabaci* prefer to lay their eggs at the base of leaf hairs (eggs are attached by one end perpendicular to the leaf surface). Butler et al. (1986) showed that halves of pubescent leaves shaved with an electric razor collected one-fourth as many whitefly eggs as unshaved halves. It is not known whether the survival of nymphs is increased on pubescent leaves.

The DPL-90 control in the test of germplasm lines had a relatively low infestation and is a commonly grown cultivar in Arizona. It appears that the lines tested do not offer any advantage over DPL-90 for whitefly control. Butler and Henneberry (1984) showed that DPL-61, another cultivar grown in Arizona, was among the most whitefly resistant of several Deltapine varieties. DPL-61 and WC-12NL had similar numbers of whitefly nymphs during the season. This is favorable for WC-12NL because it is currently being tested for short season production in areas of California and Arizona where pink bollworm and whiteflies are major pests (F. D. Wilson, personal communication).

The cotton cultivars planted early and sprayed more often in the planting date test had more whitefly nymphs late in the season. Meyerdirk and Coudriet (1986) suggest that the application of insecticides, particularly synthetic pyrethroids, destroys the natural enemy complex of whiteflies. Destruction of natural enemies combined with insecticide resistance leads to secondary outbreaks of whiteflies. It is important to note that DPL-20 with very smooth leaves maintained the lowest numbers of nymphs throughout the test and that all cotton cultivars had much lower numbers of nymphs on 25 September than on 16 October. In short season practice commercial cotton would be defoliated in September, avoiding the late season increase in whitefly nymphs.

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