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LEAF SHAPE RELATIONSHIP TO WHITEFLY COLONIZATION IN COTTON

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Abstract

We compared okra- and normal-leaf upland cotton (*Gossypium hirsutum* L.) strains and cultivars and okra-leaf wild cotton (*Gossypium thurberi* L.) for susceptibility to colonization by silverleaf whitefly *Bemisia argentifolii* Bellows and Perring. Experiments were conducted at three locations at Holtville, CA during 2001 and 2002. Okra-leaf strains and cultivars, as a group, had lower numbers of adults, eggs and nymphs compared with normal-leaf cultivars indicating the potential of okra-leaf genetic traits for reducing colonization by *B. argentifolii*. The hairy-leaf cultivar 'Stoneville 474' had more adults, eggs and nymphs than smooth leaf strains and cultivars. Results suggest that okra-leaf and smooth leaf cotton may provide less favorable microclimate conditions for *B. argentifolii* habitation. The okra-leaf cultivar 'Siokra L23' appears to have genetic traits that should be examined further as a source of *B. argentifolii* resistance.

Introduction

Silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring, also referred to as *Bemisia tabaci* (Gennadius) biotype B, has been a serious pest of cotton in the southwestern United States. Despite extensive control efforts, 843,936 cotton acres were found infested with the pest in the United States in 2000 (Williams 2001). The B. argentifolii problem on cotton needs a long-term solution that is environmentally and economically acceptable. Differences in cotton plant susceptibility to colonization by *B. argentifolii* were reported between species (upland *Gossypium hirsutum* L., Pima *G. barbadense* L. and *G. thurberi* L; Natwick et al.1995, Percy et al. 1997, Natwick and Walker 2002), and among upland cultivars (Chu et al. 1998, 1999). Differences were attributed to variations in leaf pubescence and leaf shape. Genotypes with more trichomes were more susceptible to *Bemisia* colonization than genotypes with smooth leaf characteristics (Butler and Henneberry 1984, Flint and Parks 1990, Butler et al. 1991, Norman and Sparks 1997, Percy et al. 1997). Variation in cotton susceptibility to *Bemisia* infestation also are attributed to differences in leaf shape. Okra-leaf genotypes generally are less susceptible to infestation than normal-leaf genotypes (Berlinger 1986, Chu et al. 1999, Chu et al. 2002). Normal- and okra-leaf are defined as the cotton leaf shape with shallow and deep indentation between lobes, respectively (Chu et al. 2002).

Conventional plant breeding and selection warrant increased attention to develop insect resistant cultivars (Sippell et al. 1987). Where successful host plant resistance has been developed, reductions in insect pest populations have been dramatic (Wiseman 1999). The methodology is readily accepted and economically sound (Jenkins 1999). Numerous studies have been conducted to identify mechanisms of cotton plant resistance to *B. argentifolii* (Chu et al. 1998, 1999, 2000, 2001, 2002; Freeman et al. 2001). Our objective was to identify cotton leaf shape as a potential genetic trait for breeding of cottons resistant to *Bemisia*.

Materials and Methods

Three field experiments were conducted in 2001 and 2002 at the University of California Desert Research and Extension Center at Holtville, CA. The experimental design for all experiments was a randomized complete block design. Experiments I and II had six replicates and Experiment III had five replicates. Five okra- and three normal-leaf cottons were compared (Table 1). All okra-leaf cottons were smooth leaf genotypes, and included three strains and a cultivar of upland cotton *G. hirsutum* L. and one was a wild cotton species, *G. thurberi* L. Two of the normal-leaf cotton cultivars were smooth leaf genotypes and one was a hairy leaf genotype. Smooth leaf genotypes had few leaf trichomes, ≈20/cm^2 leaf disk or less branched stellate trichomes on the underleaf surface of fifth node main stem leaves as compared with 120/cm^2 disk for a hairy leaf cultivar 'Stoneville 474'. Not all strains and cultivars were tested in each experiment because of the availability of a seed source (e.g., 93020-88-753, E0223, E0798, and Texas 121). Standard agronomic practices were followed at each test site.

The plots for Experiment I were two rows wide, plots for Experiment II and III were four rows wide, and rows were12.2 m long 1 m apart with 3 m non-planted buffers between blocks for each experiment. Seeds were planted and watered for germination on 21 March, 2001 for Experiment I and on 22 April, 2002 for Experiments II and III. Plants in all three experiments did not receive insecticide seed treatments prior to planting and were not treated with insecticides during the growing seasons.

Whitefly adults were sampled from ten plants in each plot twice per month from 5 July through 18 September 2001 in Experiment I, and from June through mid-August in 2002 in Experiments II and III, using the leaf turn method (Naranjo & Flint 1995). In addition, ten 5th node leaves per plot were picked from plants at random on dates that adults were sampled. The nodes were in ascending numbers beginning with the first expanded leaf below the plant main terminal. Whitefly eggs and nymphs were counted on single leaf disks of 1.5 cm^2 taken from each of the ten leaves per plot.

Seasonal mean whitefly density for adults, eggs, and nymphs were analyzed using ANOVA (MSTAT-C 1989). Student-Neuman-Keul's Multiple Range Test (SNKMRT) was used for means separations. When the treatment effect was significant, an orthogonal comparison was conducted between okra- and normal-leaf cotton cultivars and strains and between hairy leaf and smooth leaf cotton cultivars and strains.

Results

Mean numbers of *B. argentifolii* adults on okra-leaf cotton strains and cultivars were significantly lower compared with normal-leaf cotton, including both smooth and hairy leaf cultivars, in Experiment I, II and III (Table 2: F = 38.3, 22.0, and 6.1 with df = 1, 22; 1, 22; 1, 33, respectively). Mean numbers of eggs on okra-leaf cotton strains and cultivars were significantly lower compared with normal-leaf in Experiments I, II and III (F = 22.6, 10.9, and 6.2 with df = 1, 22; 1, 22; and 1, 33, respectively). Mean numbers of nymphs on okra-leaf cotton strains and cultivars were significantly lower compared with normal-leaf cotton in Experiments I, II and III (F = 18.3, 12.6, and 4.5,with df = 1, 22; 1, 22; 1, 33, respectively). For overall means of the three experiments, numbers of adults, eggs, and nymphs for okra-leaf were significantly lower compared to normal-leaf strains and cultivars (F = 25.9, 22.0, and 28.4,with df = 1, 81, respectively).

When only smooth leaf cottons were included in the analysis (by deleting the hairy leaf Stoneville 474), mean numbers of *B. argentifolii* adults on okra-leaf cotton strains and cultivars were significantly lower compared with normal-leaf cultivars, in Experiment II (Table 3: F = 5.2 with df = 1, 16), but not in Experiments I and III (F = 1.6 and 2.7,with df = 1, 16 and 1, 28, respectively). Mean numbers of eggs on smooth okra-leaf cotton strains and cultivars were significantly lower compared with smooth normal-leaf cultivars in Experiment I (F = 6.6 with df = 1, 16), but not in Experiments II and III (F = 0.3 and 0.1,with df = 1, 16 and 1, 28, respectively). Mean numbers of nymphs on smooth okra-leaf cotton strains and cultivars were significantly lower compared smooth normal-leaf cultivars in Experiments I and III (F = 4.7 and 5.9,with df = 1, 16 and 1, 28, respectively). The exception was numbers of nymphs/ cm^2 of leaf disk in Experiment II, which did not show a significant difference between okra- and smooth normal-leaf cotton strains and cultivars (F = 0.8 with df = 1, 16). For overall means of the three experiments, numbers of adults, eggs, and nymphs for smooth okra-leaf were not significantly lower compared with smooth normal-leaf cotton strains and cultivars (F = 0.1, 1.8, and 0.1,with df = 1, 64, respectively).

Mean numbers of *B. argentifolii* adults on smooth leaf cotton strains and cultivars were significantly lower compared with the hairy leaf cultivar, in Experiments II and III (Table 4: F = 16.3 and 60.7 with df = 1, 22 and 1, 33, respectively), but not in Experiment I (F = 0.01 with df = 1, 22). Mean numbers of eggs on smooth leaf cotton strains and cultivars were significantly lower compared with hairy leaf in Experiment I, II and III (F = 19.9, 26.8, and 7.0 with, df = 1, 22; 1, 22; and 1, 33, respectively). Mean numbers of nymphs on smooth leaf cotton strains and cultivars were significantly lower compared with the hairy leaf cultivar in Experiment I, II and III (F = 15.4, 23.8, and 4.5,with df = 1, 22; 1, 22; 1, 33, respectively). For overall means of the three experiments, numbers of adults, eggs and nymphs for smooth leaf cultivars/strainswere significantly lower compared to hairy leaf strains and cultivars (F = 12.8, 7.7, and 14.4,with df = 1, 81, respectively).

Discussion

The results of our experiments corroborate results from Sudan that okra-leaf genotypes confer resistance to *Bemisia* (Sippell et al. 1987, Chu et al. 2002) and okra-leaf genetic traits may have potential for increasing cotton plant resistance to *Bemisia* infestation. *Bemisia* resistance in okra-leaf cotton is complex and may be influenced by factors other than leaf shape. When the confounding effect of hairiness in Stoneville 474 is eliminated, there is only weak evidence of an effect of okra leaf-shape on reduction of *Bemisia* numbers on cotton. Whitefly nymph (Flint and Parks 1990, Natwick et al. 1991) or adult (Butler and Wilson 1984) densities were not significantly different between okra-leaf WC12NL and normal-leaf DP61. In our study, the okra-leaf cottons compared with smooth normal-leaf cottons appeared to confer resistance to *B. argentifolii*, but the level of resistance was lower than the comparison of okra-leaf with a hairy normal-leaf cultivar included. The okra-leaf characteristic may provide higher ambient temperature and lower humidity in the cotton canopy (Chu et al. 2002).

The results of our experiments corroborate results that smooth leaf genotypes confer resistance to *Bemisia* (Butler and Henneberry 1984, Flint and Parks 1990, Butler et al. 1991, Norman and Sparks 1997, Percy et al. 1997). The smooth leaf characteristic appears to be a stronger and more consistent trait conferring resistance to *B. argentifolii* in these experiments than leaf shape. Leaf hairiness is associated with increased boundary layer humidity on leaf surfaces (Burrage 1971). Extremely high air temperatures, low relative humidity, and limited irrigation in the desert southwest United States may result in subtle changes in underleaf humidity influencing *Bemisia* egg and nymph survival (Chu et al. 2001).

Siokra L23 is an okra-leaf cultivar that appears to support lower *B. argentifolii* infestations compared with other cultivars in our study. The cultivar Siokra L23 and other okra-leaf strains and cultivars that appear to have genetic traits for resistance to colonization by *B. argentifolii* should be examined further.

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Table 1. Okra- and normal-leaf cotton strains and cultivars studied for susceptibility to colonization by *Bemisia argentifolii* at Holtville, CA.

	Leaf shape	**Leaf type**	**2001**	**2002**	
Strains/cultivars[a]	**O or N**[b]	**S or H**[c]	**Experiment I**	**Experiment II**	**Experiment III**
93020-88-753	O	S			X
E0223	O	S			X
E0798	O	S			X
Siokra L23	O	S	X[d]	X	X
G. thurberi	O	S	X	X	
DP 5415	N	S	X	X	X
Texas 121	N	S			X
Stoneville 474	N	H	X	X	X

[a] Cotton seeds were provided for Siokra L23 by Cotton Seed Distributors Ltd. Dalby, Queensland, Australia; 93020-88-753, E0223, and E0798 were provided by Australia's Commonwealth Scientific and Industrial Research Organization, Narrabri, Australia; DP 5415 was provided by Delta pine Land Co., Scott, MS; Texas 121 was provided by South Texas Planting Seed Association, Mercedes, TX; and *G. thurberi* was provided by University of California Riverside, Riverside, CA.
[b] O and N denote okra- and normal-leaf strains or cultivars, respectively.
[c] S and H denote smooth and hairy leaf strains or cultivars, respectively.
[d] X denotes the strains or cultivars tested in experiment.

Table 2. Mean ± SE numbers of *Bemisia argentifolii* on okra- and normal-leaf cotton strains and cultivars at Holtville, CA.

Experiment	Year	Treatment	n	No. adults/leaf	No./cm^2 leaf disc	
					Eggs	Nymphs
I	2001	Okra	2	1.9 ± 0.6 b	1.1 ± 0.3 b	0.6 ± 0.2 b
		Normal	2	7.6 ± 0.7 a	10.5 ± 2.0 a	6.0 ± 1.2 a
II	2002	Okra	2	0.3 ± 0.1 b	0.2 ± 0.6 b	0.2 ± 0.5 b
		Normal	2	2.8 ± 0.5 a	2.8 ± 0.6 a	2.9 ± 0.5 a
III	2002	Okra	4	1.8 ± 1.0 b	0.5 ± 0.4 b	1.2 ± 0.5 b
		Normal	3	7.1 ± 1.2 a	2.3 ± 0.4 a	3.6 ± 0.6 a
Pooled		Okra		1.4 ± 0.2 b	0.5 ± 0.1 b	0.8 ± 0.1 b
		Normal		5.9 ± 0.8 a	5.0 ± 0.9 a	4.1 ± 0.6 a

Within each experiment, means in column for paired comparison not followed by the same letter are significantly different by orthogonal comparison (*P = 0.05*).

Table 3. Mean ± SE numbers of *Bemisia argentifolii* on smooth okra- and smooth normal-leaf cotton strains and cultivars at Holtville, CA.

Experiment	Year	Treatment	n	No. adults/leaf	No./cm^2 leaf disc	
					Eggs	Nymphs
I	2001	Okra	2	1.9 ± 0.6 a	1.1 ± 0.3 b	0.6 ± 0.2 b
		Normal	1	5.6 ± 0.5 a	4.4 ± 0.3 a	2.3 ± 0.2 a
II	2002	Okra	2	0.3 ± 0.1 b	0.2 ± 0.1 a	0.2 ± 0.1 a
		Normal	1	1.2 ± 0.1 a	0.4 ± 0.1 a	0.7 ± 0.1 a
III	2002	Okra	4	1.8 ± 0.2 a	0.5 ± 0.1 a	1.2 ± 0.1 b
		Normal	2	2.7 ± 0.3 a	1.0 ± 0.1 a	1.4 ± 0.2 a
Pooled		Okra		1.4 ± 0.2 a	0.5 ± 0.1 a	0.8 ± 0.1 a
		Normal		3.1 ± 0.4 a	1.7 ± 0.4 a	1.5 ± 0.6 a

Within each experiment, means in column for paired comparison not followed by the same letter are significantly different by orthogonal comparison (*P = 0.05*).

Table 4. Mean ± SE numbers of *Bemisia argentifolii* on smooth and hairy leaf cotton strains and cultivars at Holtville, CA.

Experiment	Year	Treatment	n	No. adults/leaf	No./cm^2 leaf disc	
					Eggs	Nymphs
I	2001	Smooth	3	3.2 ± 0.6 a	2.2 ± 0.4 b	1.1 ± 0.2 b
		Hairy	1	9.7 ± 0.7 a	16.6 ± 1.3 a	9.6 ± 1.1 a
II	2002	Smooth	3	0.6 ± 0.1 b	0.3 ± 0.2 b	0.4 ± 0.2 b
		Hairy	1	4.3 ± 0.4 a	5.3 ± 0.4 a	5.1 ± 0.3 a
III	2002	Smooth	6	0.5^z ± 0.02 b	0.2^z ± 0.02 b	1.3 ± 0.2 b
		Hairy	1	1.2^z ± 0.06 a	0.8^z ± 0.05 a	7.9 ± 0.4 a
Pooled		Smooth		0.4^z ± 0.03 b	0.9 ± 0.2 b	1.0 ± 0.1 b
		Hairy		1.0^z ± 0.05 a	9.2 ± 1.5 a	7.5 ± 0.7 a

Within each experiment, means in column for paired comparison not followed by the same letter are significantly different by orthogonal comparison (*P = 0.05*).
^{z} Log transformed data used for analysis.