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AN EXTENSIVE SURVEY OF *BEMISIA TABACI* (HOMOPTERA: ALEYRODIDAE) IN AGRICULTURAL ECOSYSTEMS IN FLORIDA

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Bemisia tabaci (Gennadius) is a cryptic whitefly species, owing to lack of morphological characters that permit recognition of behavioral and/or genetic variants (Mound 1963; Mohanty & Basu 1986; Gill 1992; Gawel & Bartlett 1993; Bedford et al. 1994) and, consequently, has been considered a species complex (Brown et al. 1995; Rosell et al. 1997; Frohlich et al. 1999) or a complex species (Perring et al. 1993; Bellows et al. 1994). The *B. tabaci* complex is abundant in cultivated and uncultivated subtropical and tropical habitats worldwide and is unusual among whiteflies in that it is polyphagous on herbaceous plant species, whereas most whitefly species are monophagous on woody species (Mound 1963; Lopez-Avila 1986; Martin 1987). Among the few whitefly species that colonize herbaceous hosts, *B. tabaci* is unique in that its host range is highly variable across the species. Host range phenotypes vary from restricted to highly polyphagous, illustrating the key character that led to the recognition of 'host races' for *B. tabaci* (Bird 1957).

Host races are one variant of biotype (Diehl & Bush 1984) of *B. tabaci*, now referred to as 'biological types', that exhibit variation in geographical distribution, host range, fecundity, dispersal behavior, insecticide resistance, natural enemy complexes, and endosymbiont complement (Rowland et al. 1991; Costa et al. 1993a, b; Bedford et al. 1994; Costa et al. 1995; Kirk et al. 2000). Some of these factors may influence biotype evolution and possibly the formation of 'new' biotypes.

The first recorded whitefly outbreak occurred on tobacco in Greece in 1889 and led to the description of the whitefly as *B. tabaci* (Genn.) (Gennadius 1889). This insect was reported in Florida within the same decade (Mound 1963; Hamon & Salguero 1987), but was not considered a pest in the state until 1986 when large populations infested poinsettia (Price 1987). The appearance of a previously undescribed tomato irregular ripening disorder and a squash silverleaf disorder were associated with the introduction of this exotic biotype in Florida (Schuster et al. 1990, 1991). The spread of geminiviruses in beans and tomatoes (Blair et al. 1995; Polston & Anderson 1997) was also associated with the introduction of this new *B. tabaci* biotype. The new biotype (a.k.a. *B. argentifolii* Bellows & Perring, the silverleaf whitefly) was designated B to separate it from the original A biotype. The objective of this work was to conduct an extensive survey of *B. tabaci* populations in Florida agricultural ecosystems to determine if the B biotype had excluded non-B biotypes.

During the 2000-2001 growing seasons, an extensive survey was conducted in 13 locations, representing 8 different counties and corresponding principal vegetable producing areas in Florida (FDACS/FASS 1998), including 15 economically important agricultural crops and eight weed hosts found in proximity to the crop fields (Table 1). The same crops were surveyed across locations, when possible, and many counties were sampled multiple times. Adult whiteflies were collected at each location by vacuuming host plants with a Makita Cordless Cleaner (Model 4073D; Anjo, Aichi, Japan) outfitted with size 12-dram plastic collection vials (BioQuip Products, Gardena, CA). The plastic bottom of the collection vials was cut out, screened and placed directly into the hole made for vacuum attachments for easy sampling of host plants. At each location, leaves from crop and weed plants were collected to obtain whitefly nymphs. Adult whiteflies were counted and sexed, nymphs were removed from host leaves, and all whitefly samples were stored in 95% ethanol for molecular analysis. At the International Center for Tropical Agriculture (CIAT), in Cali, Colombia, whitefly species were verified as *B. tabaci* by classical morphological characteristics of the 4th nymphal instars and adult whiteflies were biotyped by RAPD/PCR analysis following methods adapted from De Barro and Driver (1997). CIAT has maintained whitefly colonies of the A biotype on multiple hosts since the mid-1980s. The B biotype of *B. tabaci* was detected and characterized in Colombia by Quintero et al. (1998), and colonies of this biotype have been maintained at CIAT since that time. Thus, CIAT provided the positive controls for this study. Whitefly data (mean number of nymphs, male, female and sex ratios (female: male) were analyzed by the General Linear Models (GLM) procedure where hosts were sampled more than once, and differences among hosts were determined by Ryan-Einot-Gabriel-Welsch multiple-range test (REGWQ) at $\alpha = 0.05$ (SAS Institute 2000).

TABLE 1. *BEMISIA TABACI* SURVEY SITES AND HOST PLANTS IN FLORIDA AGRICULTURAL ECOSYSTEMS, MARCH 2000-MAY 2001.

Crop/weed host common name[1]	Scientific name[1]	County (# of collection sites)
Tomato	*Lycopersicon esculentum* Mill.	St. Lucie (2); Palm Beach (1); Collier (1); Seminole (1); Gadsden (1)
Cucumber	*Cucumis sativus* L.	Palm Beach (1); Seminole (1); Gadsden (1); Suwannee (1)
Cabbage	*Brassica oleracea* L. var.*capitata* L	Dade (1); Palm Beach (2)
Broccoli	*Brassica oleracea* L. *botrytis* L.	Palm Beach (1)
Kale	*Brassica oleracea* L. var. *acephala* DC	Palm Beach (1)
Eggplant	*Solanum melongena* L.	Dade (1); Palm Beach (2); Seminole (1)
Crook-neck squash (butternut squash)	*Cucurbita moschata* (Duchesne) Duchesne ex Poir.	Dade (1)
Summer squash (zucchini squash)	*Cucurbita pepo* L.	Dade (1); Palm Beach (4); Gadsden (2); Manatee (1)
Cantaloupe	*Cucumis melo* L. var. *cantalupensis* Naudin	Collier (1); Gadsden (1); Manatee (1)
Upland cotton	*Gossypium hirsutum* L.	Gadsden (1); Suwannee (1)
Peanut	*Arachis hypogaea* L.	Gadsden (1); Suwannee (1)
Bean	*Phaseolus vulgaris* L.	Dade (1); Palm Beach (1)
Black-eyed pea (southern pea)	*Vigna unguiculata* (L.) Walp	Palm Beach (2); Gadsden (1)
Soybean	*Glysine max* (L.) Merr.	Gadsden (1)
Watermelon	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	Gadsden (1)
Swiss-chard	*Beta vulgaris* L. subsp. *cicla* (L.) W. Koch	Palm Beach (1)
Sow-thistle	*Sonchus oleraceus* L.	St. Lucie (1)
American black nightshade	*Solanum americanum* Mill.	Gadsden (1)
Wild morning-glory	*Convolvulus arvensis* L.	Gadsden (1)
Lance-leaf ground-cherry	*Physalis angulata* L.	Gadsden (1)
Wild poinsettia	*Euphorbia heterophylla* L.	Gadsden (1)
Bristly star-bur	*Acanthospermum hispidum* DC.	Gadsden (1)
Wild radish	*Raphanus raphanistrum* L.	Gadsden (1)

[1]Common and scientific names according to Brako et al. 1995.

TABLE 2. MEAN NUMBER ± SE OF *BEMISIA TABACI* NYMPHS, FEMALES, AND MALES, AND SEX RATIO COLLECTED FROM SELECTED HOST PLANTS IN FLORIDA.

Host	n[1]	Nymph	Female	Male	Sex ratio (female: male)
Tomato	6	90.5 ± 19.3 a	138.3 ± 22.5 ab	50.7 ± 14.7 a	0.73 ± 0.05 a
Cucumber	4	72.8 ± 38.1 a	210.0 ± 69.9 a	71.0 ± 23.1 a	0.71 ± 0.11 a
Brassica[2]	5	136.2 ± 28.5 a	163.8 ± 35.3 ab	41.0 ± 9.0 a	0.80 ± 0.01 a
Eggplant	4	107.3 ± 44.4 a	47.5 ± 18.2 ab	11.3 ± 4.3 a	0.80 ± 0.05 a
Squash[3]	9	30.0 ± 28.5 a	86.3 ± 20.1 ab	9.7 ± 2.6 a	0.91 ± 0.01 a
Cantaloupe	3	70.0 ± 36.2 a	65.3 ± 40.7 ab	16.7 ± 13.7 a	0.84 ± 0.04 a
Cotton	2	101.5 ± 15.5 a	184.5 ± 27.5 ab	48.5 ± 13.5 a	0.80 ± 0.02 a
Peanut	2	54.0 ± 4.0 a	38.0 ± 14.0 ab	22.0 ± 15.0 a	0.68 ± 0.09 a
Bean	2	21.0 ± 9.0 a	29.0 ± 2.0 ab	12.0 ± 9.0 a	0.75 ± 0.15 a
Pea	3	35.3 ± 18.1 a	17.7 ± 2.3 b	11.3 ± 3.9 a	0.63 ± 0.06 a

Means within columns followed by the same lowercase letter are not different ($\alpha = 0.05$, REGWQ).

[1]n = the number of sites (replication) whitefly collections were made for a given host; hosts sampled only once were not included in this analysis.

[2]All *Brassica oleracea* varieties were combined for analysis.

[3]All *Cucurbita* spp. were combined for analysis.

A total of 9,963 nymph and adult *B. tabaci* were collected in 13 locations across Florida (nymph = 3,364; female = 5,061; male = 1,538). Sex ratios (female: male) were not different among host plants (F = 2.23; df = 9,21; P = <0.0629) and ranged from 0.63 on pea to 0.91 on *Cucurbita* spp. (Table 2).

RADP/PCR analysis of statewide whitefly samples using Primer set H16 (Fig. 1) indicated that only the B biotype of *B. tabaci* was present. Gels for all locations and hosts were identical to Fig. 1 (data not shown). Primer set H9 was used (data not shown) to confirm the biotype B origin of each whitefly sample. Band pattern variation in lanes 14 (Fig. 1a) and 12 (Fig. 1b) represent natural within biotype variation related to the RAPD method used as described by De Barro and Driver (1997). Minor band variability within the 600 to 900 bp region demonstrates some polymorphism between different B biotype individuals. However, the real area of interest is the region between 300 and 600 bp which demonstrates a consistently reproducible pattern (520, 500, and 344 bp) that is unique to the B biotype (De Barro and Driver 1998). These bands are not present in the case of other biotypes studied.

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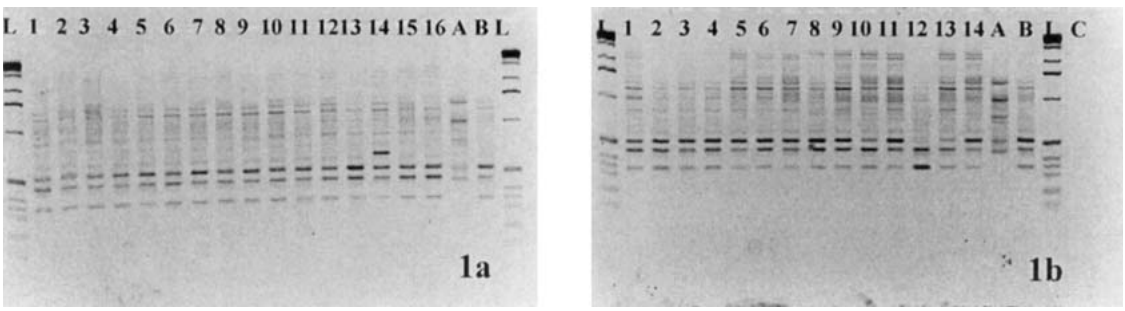

Fig. 1. Electrophoretic profiles of amplified DNA obtained for *Bemisia tabaci* samples collected from agricultural ecosystems in Florida with RAPD-PCR analysis. L, molecular weight marker Gibco-BRL 1-Kb; A, + control for *Bemisia tabaci* biotype A; B, + control for *Bemisia tabaci* biotype B; C, (-) water control with H16 primers. Gel 1a, lanes 1-10 sampled from common bean, *Phaseolus vulgaris*, Kendall Farms, Homestead, FL; Gel 1a Lanes 11-16 and gel 1b lanes 1-4, sampled from tomato, *Lycospersicon esculentum* Mill., U. S. Horticultural Research Laboratory, Fort Pierce, FL; Gel 1b, lanes 5-14 sampled from tomato, *L. esculentum* Mill., Neil's U-Pick Farm, Fort Pierce, FL.

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Summary

An extensive survey of *B. tabaci* populations in 15 economically important crops and 8 weed species in Florida was carried out from March 2000 through May 2001. Sex ratios did not significantly differ among host plants. Biotype analysis by RADP/PCR indicated the presence of only the B biotype of *B. tabaci* in all collections. These data suggest that in Florida the B biotype of *B. tabaci* has excluded the native non-B biotypes in agricultural ecosystems.

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