SYSTEMATICS

Description of a Species of *Bemisia* (Homoptera: Aleyrodidae)

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ABSTRACT *Bemisia argentifolii* Bellows & Perring, n. sp., is described from material collected in California and Florida. This species has been referred to elsewhere as *B. tabaci* strain B or *B. tabaci* poinsettia strain. The species has been demonstrated to be distinct from *B. tabaci* (Gennadius) by crossing experiments, studies on intraspecific and interspecific mating behavior, analysis of allozymic frequencies, PCR analysis of genomic DNA, and morphological evaluation. The description of the new species is based on morphological and allozymic characters. The species is distinguished from *B. tabaci* in the fourth nymphal instar by the absence of a dorsal seta, the width of the thoracic tracheal folds, the width of the wax extrusions from the tracheal folds, and, in the adult, by migration distances of allozymes for three enzyme systems.

KEY WORDS *Bemisia argentifolii, Bemisia tabaci,* whitefly

THE GENUS *Bemisia* contains 37 recognized species (Mound & Halsey 1978). *Bemisia tabaci* (Gennadius), the type species of the genus, has been interpreted as a widely distributed, morphologically variable species (e.g., Corbett 1935, Russell 1957, Danzig 1966); Mound & Halsey (1978) listed 22 synonyms for the species. Descriptions or type specimens of additional species of *Bemisia* are similar morphologically to *B. tabaci,* so it is conceivable that additional hitherto unrecognized synonyms exist. There is also evidence that the species referred to as *B. tabaci* comprises a species complex. Reports of populations of *B. tabaci* that reproduce successfully on some hosts (e.g., cassava) whereas other populations do not (Byrne et al. 1990, Burban et al. 1992) suggest the possibility of separate species.

For several years two whitefly populations in the United States have been referred to *B. tabaci* and distinguished as "strains" of this species (Bharathan et al. 1990, Byrne & Miller 1990, Bethke et al. 1991). The two populations have been variously referred to as *B. tabaci* strain A or cotton strain (which we refer to here as *B. tabaci*) and *B. tabaci* strain B or poinsettia strain. *Bemisia tabaci* has been in the United States since 1897 (Russell 1957, Mound & Halsey 1978), but "strain B" was recognized first in the United States in 1986 (Price et al. 1987). The widespread impact of the latter whitefly on North American agriculture in 1991 resulted in damages totaling a half billion dollars (Perring et al. 1993). The whitefly was found in several cropping systems and on native plants in several states.

Central to research on this whitefly is the identity of the organism. Several workers have identified differences between the whiteflies, including size (*B. tabaci* is larger [Bethke et al. 1991]), fertility (*B. tabaci* is less fecund [Bethke et al. 1991]), host plant range (Byrne & Miller 1990), feeding rate (*B. tabaci* produces honeydew at a lower rate [Byrne & Miller 1990]), and the ability to cause a plant disorder referred to as squash silverleaf (*B. tabaci* does not cause this disorder [Bharathan et al. 1990, Costa & Brown 1991, Perring et al. 1991, Cohen et al. 1992]). Gill (1992) suggested that the two whiteflies may represent distinct species, and Perring et al. (1993) concurred, proposing the common name silverleaf whitefly. The conclusions of Perring et al. (1993) were based on the absence of interspecific copulation and on genotypic and phenotypic differences. No female offspring resulted from eggs laid by females in interspecific crossing studies, indicating that there was no fertilization of eggs. Studies on copulation behavior demonstrated that copulation did not occur between the species. Phenotypic analyses using isoelectric focusing demonstrated fixed differences in allelic frequencies between the taxa (Perring et al. 1992, 1993). Further studies quantified substantial differences in single-primer PCR-amplified DNA sequences (Perring et al. 1993), with as little as 10% similarity between the two taxa, whereas similarity among different populations within each of the two taxa was 90%. Gawel & Bartlett (1993) also reported differences in PCR-amplified DNA products; in their studies they found that the two *Bemisia* species were as dif-

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ferent from each other as they were from two other whiteflies, *Parabemisia myricae* (Kuwana) and *Trialeurodes abutilonea* (Haldeman).

We report results from the examination of mounted series of nymphal and adult whiteflies from reared populations of *Bemisia tabaci*, mounted series of the new species, and the syntypes and previously identified material of *B. tabaci*. We provide a description of the new species, including a discussion of the morphological similarities to and differences from *B. tabaci*. We describe both morphological and allozymic diagnoses that can be applied to individual whiteflies, permitting the distinction of the new species from *B. tabaci*. We discuss the implications of these findings on the need for revision of the genus *Bemisia*.

Materials and Methods

Fourth-instar nymphs were prepared for examination by light microscopy by initially soaking them in 10% sodium hydroxide for 24–48 hours, followed by rinsing in alcohol. Specimens were then transferred to Essig's aphid solution (20 parts lactic acid, 2 parts saturated aqueous solution of phenol, 4 parts glacial acetic acid, 1 part water). A few drops of 5% aqueous solution of lignin pink were added, and specimens were heated in this fluid at 40°C for 1–2 h until the body contents had been macerated and the specimens were mostly transparent. Specimens were rinsed in Essig's aphid solution, and then dehydrated either by placing them directly into cellosolve, or by passing them through a series of alcohols starting with 50%, proceeding through 100% and finishing in cedar oil. Dehydrated specimens were mounted dorsum up in Canadian balsam on glass slides. Adult specimens were treated similarly. Some adult specimens were mounted, for temporary study, in Hoyer's mountant. Figs. 1–3 show the morphology of the fourth nymphal instar (pupal case) of *B. argentifolii* and of *B. tabaci*. Each of these illustrations was produced using a camera lucida at 400× magnification for tracing the outlines and placement of the structures. Completed illustrations were produced with computer software, with subsequent image reduction to page size; therefore the illustrations are not necessarily presented in the same scale. Each of these illustrations indicates the left dorsal side only. Certain ventral structures such as the legs, antennae, and thoracic tracheal folds are indicated as dashed lines. All the dorsal setae on the syntypes of *B. tabaci* are either broken near the base or missing entirely; the missing setae are drawn as approximations based on other material.

Specimens for scanning electron microscopy (n = 8) were removed from host plants and fixed in aqueous osmium tetroxide for 24 h, washed in distilled water twice for 5 min, then dehydrated in a graded series of acidulated ethanol, finishing with 100% ethanol, as described by Headrick & Goeden (1991). Specimens were then critical-point dried using CO_2 as a transfer fluid, mounted on stubs, sputter-coated with a gold-palladium alloy, and examined with a scanning electron microscope (JEOL JSM C-35) in the Department of Nematology, University of California, Riverside. All micrographs were prepared with Polaroid P/N film, at 15kV.

Bemisia argentifolii Bellows & Perring, n. sp.
(Figs. 1, 2, 4, 5, 6)

Fourth Nymphal Instar (Pupal Case). Colorless, with no evident adorning wax; dorsum with thin, inconspicuous, transparent wax layer; venter on ring of wax. Shape suboval, lateral margin smooth, not deflexed (Fig. 1); size dimorphic, 710–790 μm long by 480–570 μm wide, and 580–640 μm long by 380–430 μm wide. Tracheal pore area indented slightly from margin, without tracheal combs; derm of thoracic tracheal folds usually with numerous, minute spinules or hemispherical-appearing protuberances; spinules sometimes lacking on specimens with enlarged dorsal setae. Thoracic tracheal folds with average width 22.5 μm (range, 14.5–29.0, n = 9); smaller individuals with narrower folds. Dorsum of nymph generally smooth, without papillae or projections other than setae. Anterior marginal setae (AMS), posterior marginal setae (PMS), caudal setae (CS) present. Submarginal setae in anterior group (ASMS) and posterior group (PSMS) on dorsum, not present on intervening body segments; anterior submarginal setae (ASMS) 1–3 located anterior to first dorsal seta (Fig. 1); anterior submarginal seta 4 usually lacking; posterior submarginal setae 1–5 posterior to fourth abdominal segment. Usually five to six pairs of dorsal setae (DS), variable in size; setae not enlarged ≈12 μm long, enlarged setae 80–142 μm long (Fig. 2), arising from enlarged bases.

Small discoidal pores, with associated smaller porette, aligned in four, bilaterally symmetrical, serially arranged groups, with one pore-porette pair on each side on each body segment, with occasional duplication on some segments, particularly the thorax. Submarginal pore-porette series (SMaP) encircling pupal case; submedial series (SMeP) parallel and lateral of longitudinal midline from vasiform orifice to the head; subdorsal series (SDP) in arc from laterad of vasiform orifice to head; thoracic series (SThP) on thoracic segments between submedial and subdorsal series. Transverse molting sutures each with obtuse angle halfway to lateral margin. Transverse molting sutures not reaching lateral margin. Vasiform orifice triangular, not completely covered by operculum (Fig. 5a). Lingula spatulate, with two terminal setae; distal portion

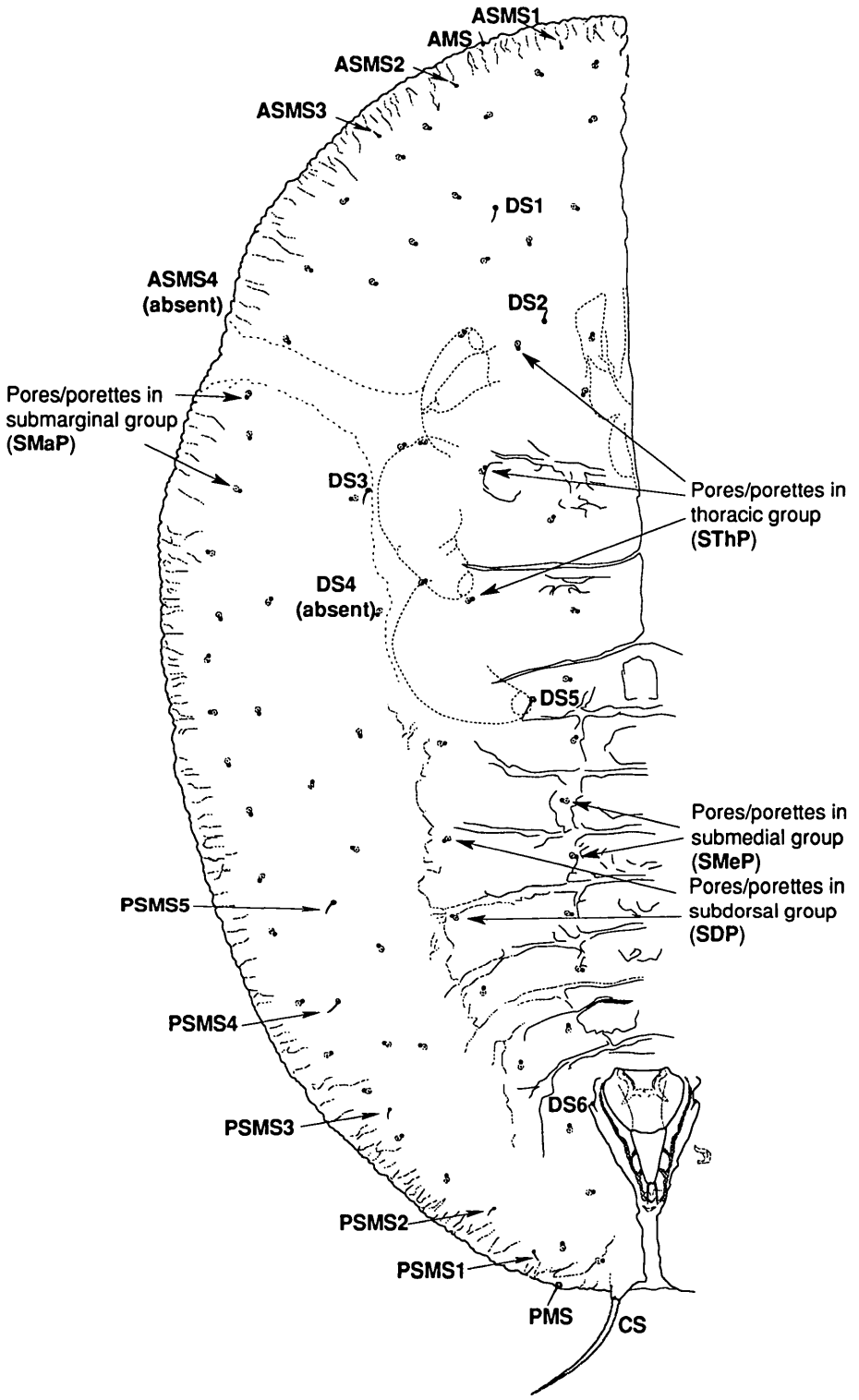

Fig. 1. *Bemisia argentifolii* Bellows & Perring, n. sp. Holotype. Dorsum of fourth nymphal instar (pupal case) of specimen without enlarged dorsal setae. AMS, anterior marginal setae; ASMS, anterior submarginal setae; CS, caudal setae; DS, dorsal setae; PMS, posterior marginal setae; PSMS, posterior submarginal setae; SDP, pores/porettes in subdorsal group; SMaP, pores/porettes in submarginal group; SMeP, pores/porettes in submedial group; SThP, pores/porettes in thoracic group.

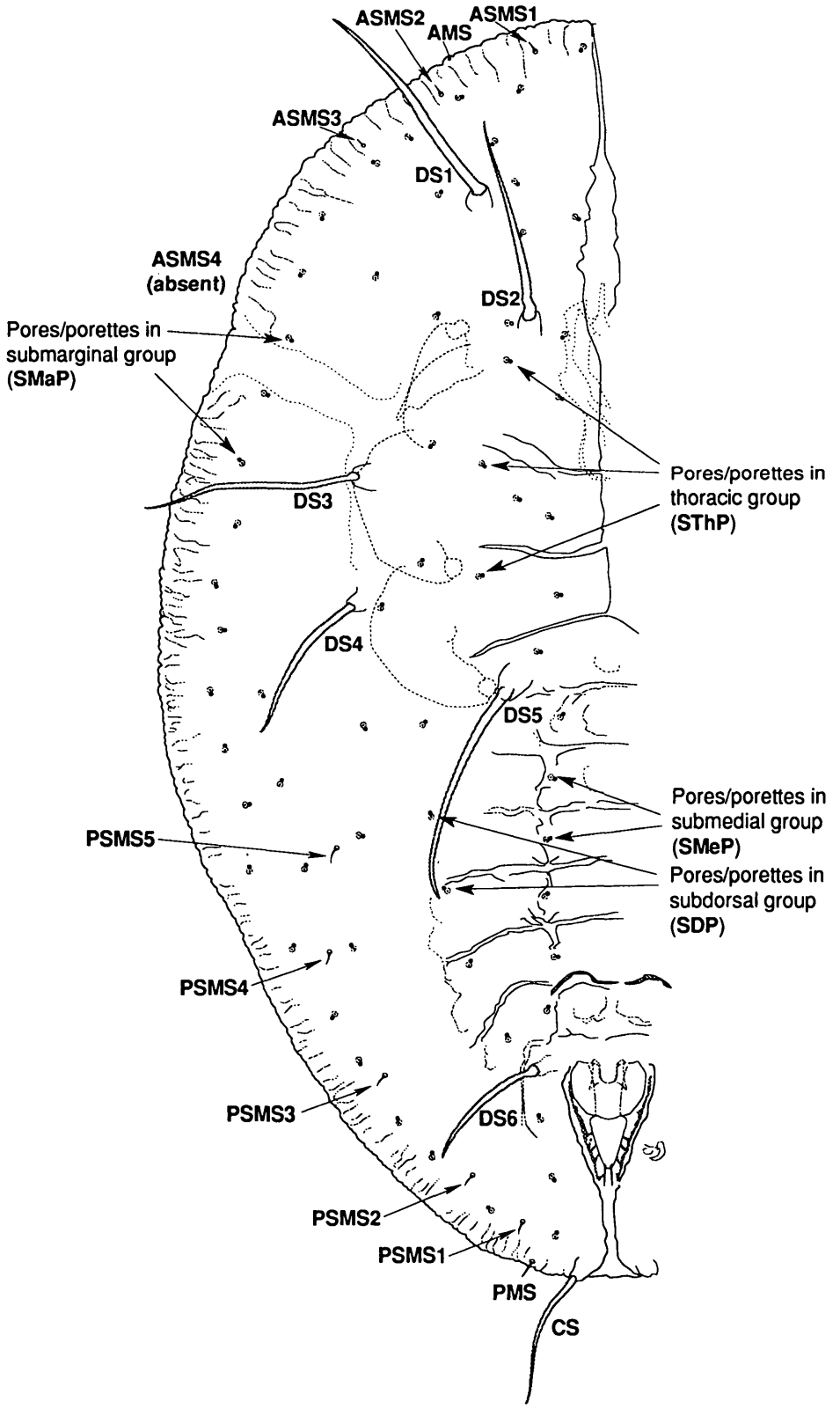

Fig. 2. *Bemisia argentifolii.* Data same as holotype. Dorsum of fourth nymphal instar (pupa) of specimen with enlarged dorsal setae. Abbreviations as in Fig. 1.

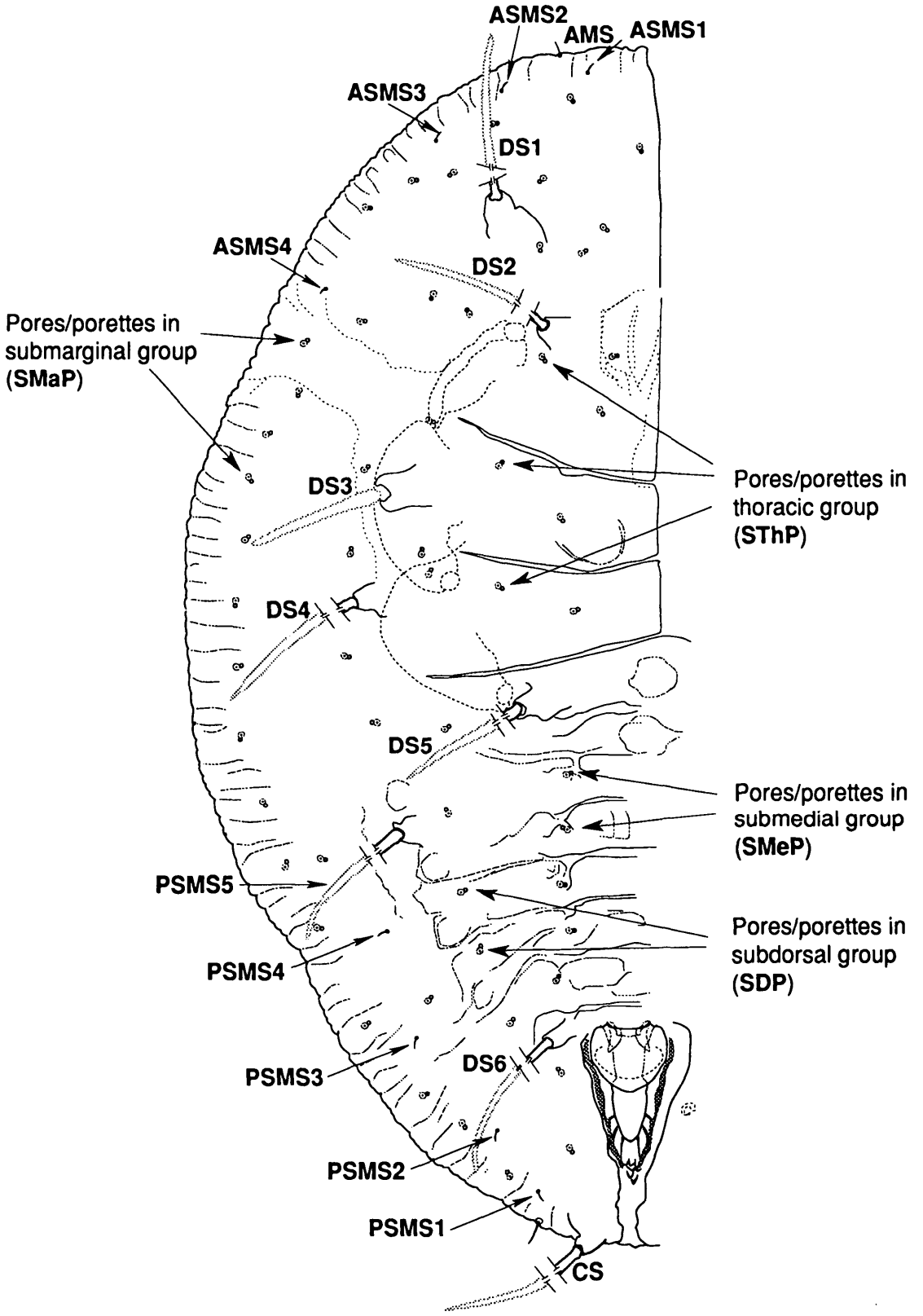

Fig. 3. *Bemisia tabaci*, syntype. Specimen from tobacco (*Nicotiana* sp.), Athens, Greece, 10 June 1899, P. Gennadius. Abbreviations as in Fig. 1.

of lingula covered with minute acanthae appearing as rugosities in mounted specimens.

Variation. The outline of the pupal case occasionally is indented, the result of development adjacent to stout leaf hairs. Size dimorphism is likely a result of sexual dimorphism, with the male nymph smaller than the female. The principal source of differences observed among individuals, even those from a single colony, is variability in numbers and location of enlarged dorsal setae. Enlarged dorsal setae can alter the curvature of the dorsum during slide-mounting, contributing to difficulty in locating and identifying minute characters, particularly the submarginal setae. The five to six dorsal setae are numbered from the anterior pair: DS1, associated with the head; DS2 with the prothorax; DS3 with the mesothorax; DS4 with the metathorax; DS5 with the first abdominal segment; and DS6 with the eighth abdominal segment (the vasiform orifice seta). The locations of DS1, DS2, DS3, and DS5 appear to be relatively constant. The positions of DS4 and DS6 can vary. If not enlarged, DS6 always occurs on the lateral margin of the vasiform orifice, pointing posteromedially toward the orifice; but if enlarged, this seta is found away from the orifice in an anterolaterad direction. Enlarged DS4 usually occur on the subdorsal area of the metathorax. If DS4 is not enlarged, it cannot be discerned; DS4 setae that are not enlarged have not been found in any *B. argentifolii* (or *B. tabaci*) material examined, but are known in other *Bemisia* species. Posterior submarginal setae PSMS5, if not enlarged, can occur in various places within the lateral area of abdominal segment 3 between the SMaP and SDP pore series and, in some specimens, are aligned with the setae in the posterior submarginal series. When enlarged, PSMS5 always is found in a more medial position directly associated with the subdorsal pore (SDP) series. Setal enlargement is variable in the species (as in other *Bemisia* spp. and other genera), and none, some, or all of the dorsal setal pairs may enlarge (see comments under **Remarks**).

Thoracic tracheal folds in this species are approximately half as wide as those of *B. tabaci*, ranging from 14 to 29 μm (mean, 22.5 ± 1.0 [SEM] μm) in nine specimens measuring 601–795 μm in length. In *B. tabaci*, tracheal fold width ranged from 38.7 to 67.8 μm (mean, 50.3 ± 2.2 [SEM] μm) in eight specimens measuring 727–920 μm in length.

Scanning electron microscopy revealed several morphological differences between populations of *B. tabaci* and *B. argentifolii*, particularly in the fourth nymphal instar. One character, which is visible with light microscopy in living specimens, involves the marginal wax projections from the thoracic and posterior tracheal folds (Fig. 4). In *B. argentifolii* these wax projections are narrow, with the wax filaments short and weak. In *B. tabaci* they are wider and more robust (Fig. 4). This character is consistent among specimens from a variety of host plant species examined to date and readily distinguishes the two species.

Adult. Body yellow, wings hyaline; both covered with sparse, powdery wax; antennal segment II about one-half as long as antennal segment III; antennal segment II with narrow, conical sensorium (Figs. 5b, c, 6a); length of antennal segment III about as long as antennal segments IV–VII combined (Fig. 5b, c); segment IV subequal to segments V, VI, or VII; one sensorium located on proximal portion of segment III; distal portion of segment III bearing three sensoria: a sensorial cone and two rhinarial-type sensoria in nonadjacent, more distal locations (Figs. 5b, c, 6b); segment V with an apical rhinarial-type sensoria, segment VI with a subapical sensorial cone, and segment VII with both a sensorial cone and an adjacent rhinarial sensorium, arising near middle of segment and terminating in narrow, conical sensorium (Figs. 5b, c, 6c); conical sensoria on segments III–VII fluted (Fig. 6d), rhinarial-type sensoria surrounded by minute, bifurcate acanthae (Fig. 6e); outline of antennal segments III–VII in slide-mounted specimens appearing rugose or scalloped, in SEM specimens antennal surface composed of irregular pleats or folds (Fig. 6c, e); antennae bearing minute acanthae, generally arising from ridges of folds in segments III–VII (Fig. 6c, d, e); in slide-mounted specimens acanthae apparently circumscribing antennae (Fig. 5b, c); upper eye composed of ≈45 ommatidia, each approximately 8.1 μm in diameter; lower compound eye composed of 31 ommatidia, each approximately 10.3 μm in diameter, arranged in interconnected groups of 6 pigmented ommatidia surrounding single relatively nonpigmented, slightly smaller ommatidium (Figs. 5g, 6f); upper and lower compound eye connected by a single ommatidium; metatibial combs consisting of 16–19 setae; all tibial brushes containing two adjacent setae; claspers paired, symmetrical, with ≈12 setae, medial hemispherical enlargement arising in distal third of each clasper (Fig. 5d), three long setae arising from hemispherical enlargement; aedeagus slightly curved (Fig. 5f).

Allozymic Distinction Between *B. argentifolii* and *B. tabaci*. Migration distances of several enzymes (Perring et al. 1993) were defined with the isoelectric focusing technique described by Perring et al. (1992), which can be conducted on individual whiteflies. *Bemisia argentifolii* is distinguished from *B. tabaci* by the migration distances of the two enzymes phosphoglucose isomerase and phosphoglucomutase (Table 1). These migration distances represent fixed allelic differences for the two species. Analyses of individuals from populations within each species were not polymorphic in *B. argentifolii* and only

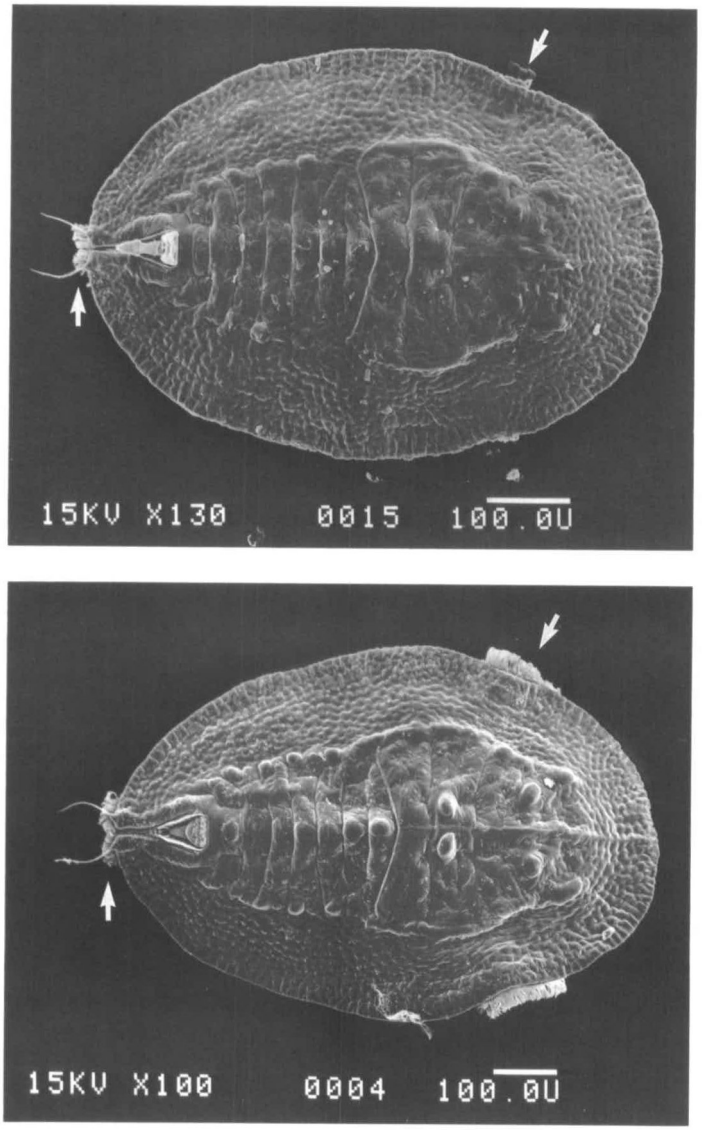

Fig. 4. Scanning electron micrographs of *Bemisia argentifolii* and *B. tabaci.* (Top) *Bemisia argentifolii* fourth nymphal instar (pupal case), dorsal view, anterior to right. (Bottom) *Bemisia tabaci,* fourth nymphal instar (pupal case), anterior to right. Arrows denote anterior and posterior wax at marginal opening of tracheal folds. In *B. argentifolii,* anterior wax fringes are narrower and less robust, and posterior wax fringe is as wide as separation of caudal setae. In *B. tabaci,* the posterior wax fringe extends laterad of caudal setae.

rarely polymorphic in *B. tabaci;* no fixed differences among populations within species were observed. In addition to these two enzymes, we noted differences in esterases, as have other authors (Costa & Brown 1991, Cohen et al. 1992, Liu et al. 1992, Perring et al. 1993). However, this enzyme is highly polymorphic in this species, and because differences in migrational distances for this enzyme are subtle (Table 1), we do not rely solely on esterase banding patterns to distinguish between *B. tabaci* and *B. argentifolii.* Also, differences in esterases have been reported among populations of *B. tabaci* in response to various host plants (Burban et al. 1992) or pesticide exposure (Wool & Greenberg 1990).

Type Material. HOLOTYPE pupal case on slide labeled USA, California, Riverside, December 1992, stock culture, reared ex *Phaseolus limensis* Macfady deposited in USNM. PARATYPES (additional pupal cases): 64 specimens from *P. limensis* on 19 slides, same location, collected XII-92; 24 specimens from cotton (*Gossypium hirsutum* L.) on 12 slides, same location, collected VII-93; 60 specimens from melon (*Cu-*

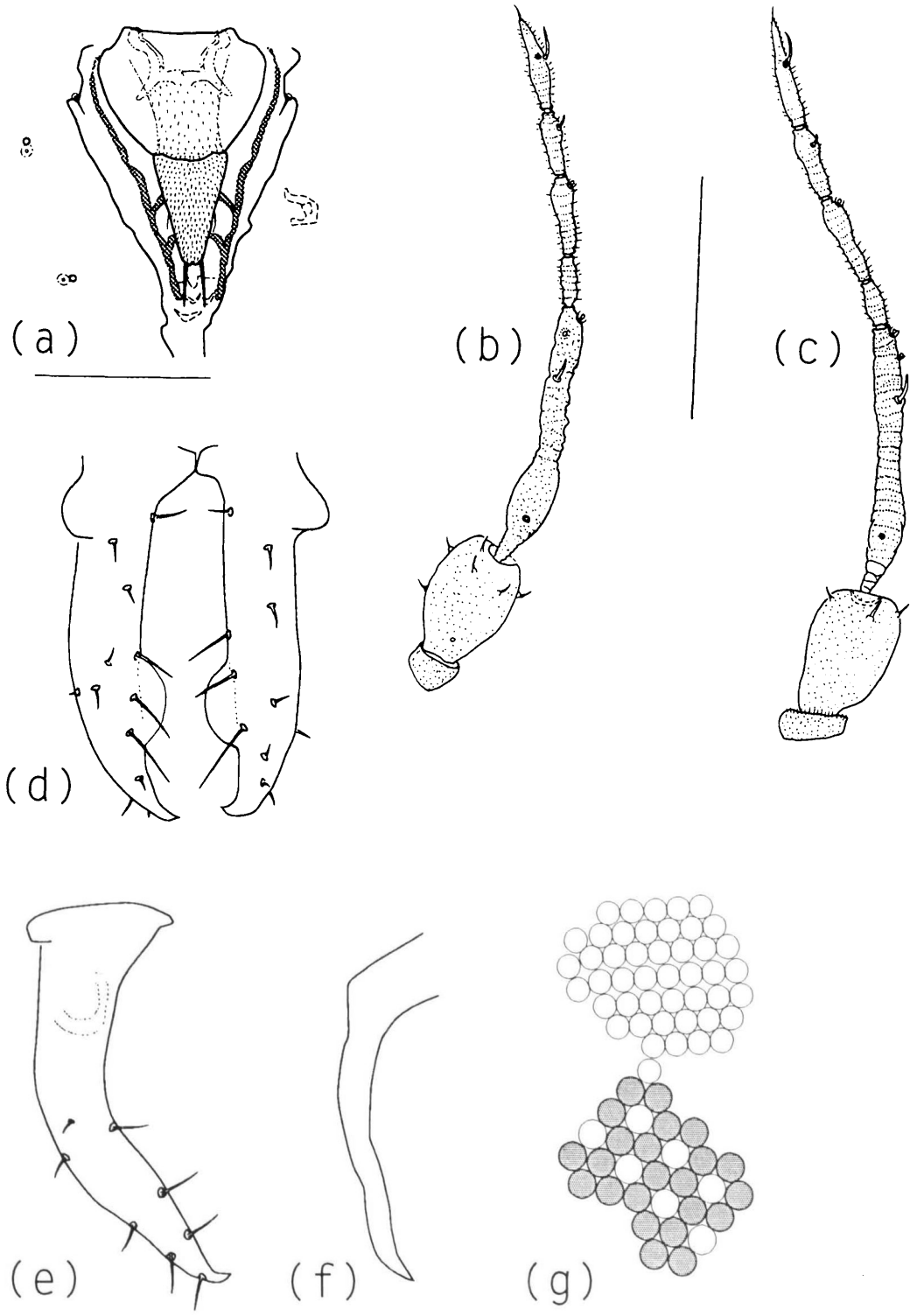

Fig. 5. *Bemisia argentifolii.* (a) Vasiform orifice of fourth nymphal instar. (b) Male adult antenna. (c) Female adult antenna. (d) Male claspers, dorsal aspect. (e) Male clasper, lateral aspect. (f) Aedeagus, lateral aspect. (g) Diagrammatic representation of left compound eye of adult female. a, d, e, and f drawn to same scale, with scale bar for a of 50 μm; scale bar for b and c of 100 μm.

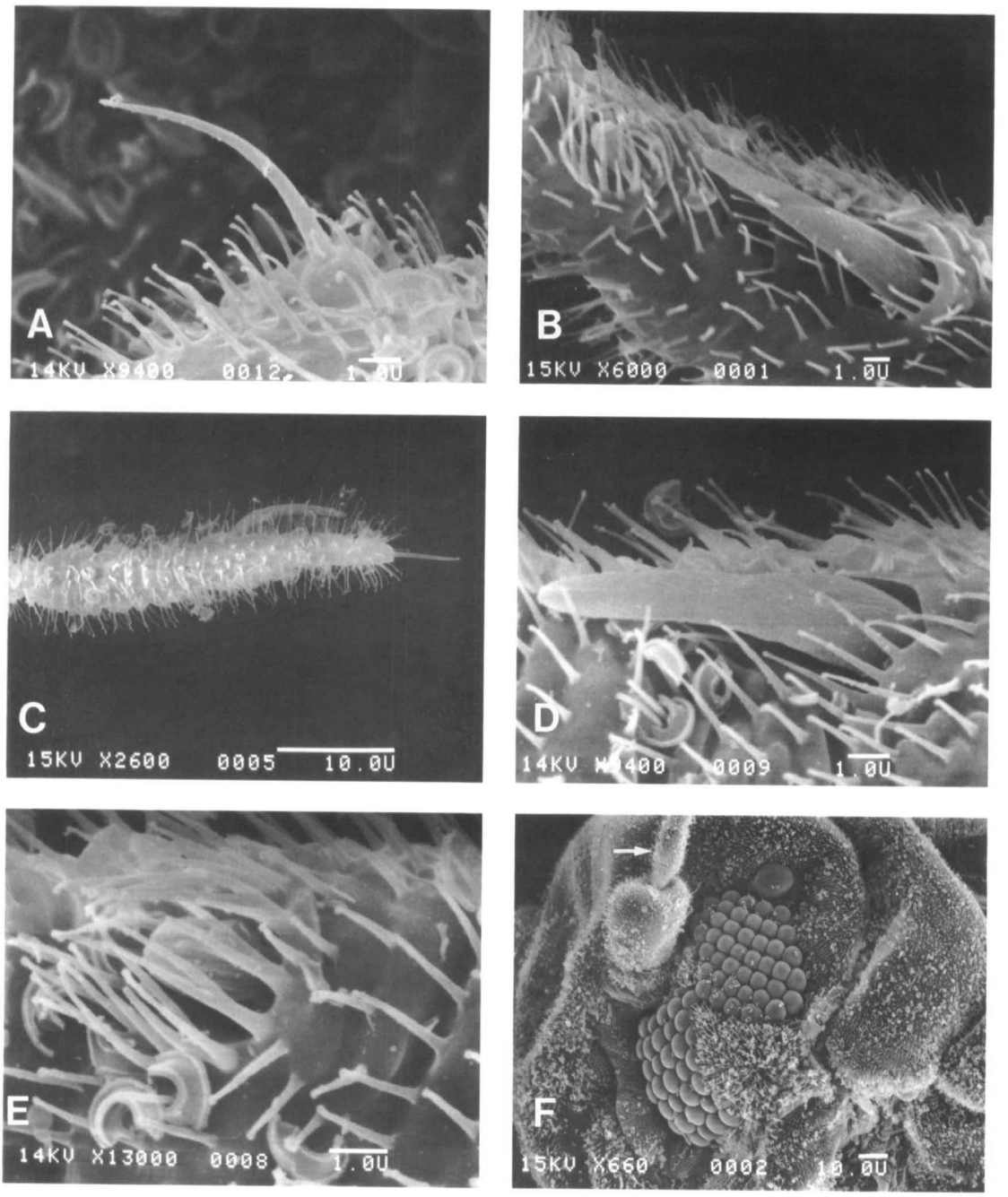

Fig. 6. Scanning electron micrographs of *Bemisia argentifolii* adults. (A) Conical sensorium on female antennal segment II. (B) Rhinarial and conical sensoria on female antennal segment III. (C) Female antennal segment VII. (D) Conical sensorium on female antennal segment III, showing fluting. (E) Rhinarial-type sensorium surrounded by bifurcate acanthae on female antenna. (F) Side view of female head, showing compound eye; arrow indicates crenulations on antennal segment III.

cumis melo L.) on 30 slides, same location, collected VII-93; 50 specimens from grape (*Vitis* sp.) on 25 slides, same location, collected VII-93; 16 specimens from sweet potato (*Ipomea batatas* (L.) Lam) on eight slides, same location, collected VII-93. Paratype material deposited in the Department of Entomology, University of California, Riverside, and California Department of Food and Agriculture, Sacramento. Holotype without enlarged dorsal setae; paratypes with

Table 1. Allelic frequencies from three loci in *Bemisia argentifolii* and *Bemisia tabaci*

Enzyme system	Allele[a]	*Bemisia argentifolii*	*Bemisia tabaci*
Phosphoglucomutase	0.17	1.00	—
	0.30	—	0.97
	0.42	—	0.03
Phosphoglucose isomerase	0.16	—	0.97
	0.20	1.00	—
	0.29	—	0.03
Esterase IV	0.42	—	0.04
	0.43	0.005	—
	0.44	—	0.88
	0.48	0.995	—
	Null	—	0.08

[a] Numbers for each allele = distance between center of protein band and cathode/inter-electrode distance.

varying degrees of setal enlargement. Adult paratypes (5 specimens ex *P. limensis*) on slides, deposited in the Department of Entomology, University of California, Riverside, and an additional adult series of 100 adults is in cryogenic storage, University of California, Riverside.

Additional Material Examined. Adults. USA: Coachella, California, 9-IX-91, ex *Citrus paradisi* (grapefruit), *Vitis* sp.; Imperial County, California, 23-IX-91, ex *Medicago sativa* L. (alfalfa), *Cucumis melo* (cantaloupe), *Brassica oleracea* L. (broccoli), *Ficus* sp., *Lantana* sp., *Lactuca sativa* L. (lettuce), *Citrus* sp. (tangelo); Bakersfield, California, 23-IX-91, ex *Poinsettia* sp; Bradenton, Florida, 23-IX-91, ex *Lycopersicum esculentum* Mill (tomato); Riverside, California, 30-X-92, ex *Gossypium hirsutum* (cotton).

Distribution. USA: California, Florida. Probably widely distributed.

Biology. Species is multivoltine and polyphagous (see Type Material and Additional Material Examined). The species causes a phenomenon known as squash silverleaf, a plant disorder that leads to silvering of the foliage of certain susceptible squash (Cucurbitaceae) species. This whitefly is the only species known at this time to cause this disorder, and every population known of this species that has been tested causes the disorder (Bharathan et al. 1990, Yokomi et al. 1990, Costa & Brown 1991, Perring et al. 1991, Cohen et al. 1992).

Etymology. The species is named for the occurrence of the whitefly-induced phenomenon known as squash silverleaf. We have suggested silverleaf whitefly as the common name for the species (Perring et al. 1993).

Remarks. Two morphological differences are noted between *B. argentifolii* and *B. tabaci*. One of these is the difference in thoracic tracheal fold widths, which appears constant and distinct between the species. The second difference is the occurrence of submarginal seta ASMS4. Russell (1948) recognized the effects of hosts on the morphology of the pupal stages of whiteflies, specifically in the development and placement of wax-extruding papillae in the genus *Trialeurodes*. Mound (1963) studied in depth the connection between setal enlargement in the pupae of *Bemisia tabaci* in relation to the hairiness of the leaf surfaces of the host. Nymphs reared on relatively glabrous leaf surfaces showed little or no setal enlargement, whereas those reared on hirsute leaf surfaces showed setal enlargement. Setal enlargement in relation to plant host is not confined to *B. tabaci* and *B. argentifolii*, but is known in other *Bemisia* species and in other aleyrodid genera. In *B. tabaci* and *B. argentifolii*, the actual number of setae that enlarge on a specimen on any given leaf can vary. The pattern of enlargement usually begins with enlargement of DS1 only; other setae may enlarge in other specimens in pairs usually from front to back. Occasionally the setal enlargement may be asymmetrical. For instance, we have observed a specimen with DS6 on one side not enlarged and on the rim pointing into the vasiform orifice, but enlarged and removed from the margin of the vasiform orifice on the other side.

These enlargements of various setae on the pupae occur in both *B. argentifolii* and *B. tabaci*. One of the morphological differences noted between these two species is the presence or absence of the anterior submarginal seta ASMS4. It is present in the syntypes of *B. tabaci* (Fig. 3), in *B. tabaci* material collected in the United States before 1981, and in *B. tabaci* specimens collected from poinsettia before 1986. It is nearly always absent in *B. argentifolii*. Of the specimens slide-mounted as the type series of *B. argentifolii*, only two specimens appear to have a seta in this position, and then on one side only. The seta is missing from nearly all material collected from poinsettia since 1987, as well as from numerous specimens, from several different hosts, that either are believed or have been demonstrated by allozyme analyses to be *B. argentifolii*. Reasons why this seta is rarely present in *B. argentifolii* are not clearly understood, but do not seem to be related to factors that cause the enlargement or disappearance of the other body setae on the dorsum. In specimens with enlarged setae, the pupae tend to be more convex than otherwise, and in the slide-mounting procedure the area where the seta ASMS4 occurs often is rolled into a vertical position. In such specimens, the presence or absence and location of this seta on species that have it (such as *B. tabaci*) can be nearly impossible to ascertain.

Discussion

Bemisia argentifolii is the name now applied to material previously referred to *B. tabaci* "strain B" in the United States. Although there are similarities in gross morphology between *B. argentifolii* and *B. tabaci*, *B. argentifolii* is

genetically distinct (as demonstrated by both genotypic and phenotypic [allozymic] analyses), reproductively isolated, differs in several biological characteristics, and differs morphologically. Cryptic species and species complexes in the Insecta are not uncommon (e.g., Diehl & Bush 1984, Henry et al. 1993). The present analysis indicates the possibility of a complex of species related to *tabaci* in *Bemisia,* and literature records of host plant relationships among populations of *B. tabaci* (Burban et al. 1992) may refer to separate species in this group.

Clearly a revision of the genus *Bemisia* will prove fruitful in identifying and clarifying these issues. Such a revision probably will involve genetic as well as morphological analyses of different populations, because morphological similarity among some species is substantial, and morphological variability occurs within species. Analyses of genes for ribosomal RNA from *B. tabaci* and *B. argentifolii* (Campbell 1993) and from their symbiotic microorganisms (Clark et al. 1992) indicated a high degree of similarity in sequences between these species. Therefore, future genomic studies may include analyses of additional nuclear DNA; such analyses have previously demonstrated differences between these species (Gawel & Bartlett 1993, Perring et al. 1993). Electrophoretic characterization of enzymes also may contribute to future revisions. However, there may be variation in the reliability of some enzymes, such as esterases, and in general proteins (Richardson et al. 1986); thus, allozyme markers should be selected carefully.

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References Cited

Bethke, J. A., T. D. Paine & G. S. Nuessly. 1991. Comparative biology, morphometrics, and development of two populations of *Bemisia tabaci* (Homoptera: Aleyrodidae) on cotton and poinsettia. Ann. Entomol. Soc. Am. 84: 407–411.

Bharathan, N., W. R. Graves, K. R. Narayanan, D. J. Schuster, H. H. Bryan & R. T. McMillan, Jr. 1990. Association of double-stranded RNA with whitefly-mediated silvering in squash. Plant Pathol. (Lond.) 39: 530–538.

Burban, C., L.D.C. Fishpool, C. Fauquet, D. Fargette & J.-C. Thouvenel. 1992. Host-associated biotypes within west African populations of the whitefly *Bemisia tabaci* (Genn.), (Hom., Aleyrodidae). J. Appl. Entomol. 113: 416–423.

Byrne, D. N. & W. B. Miller. 1990. Carbohydrate and amino acid composition of phloem sap and honeydew produced by *Bemisia tabaci.* J. Insect Physiol. 36: 433–439.

Byrne, D. N., T. S. Bellows, Jr., & M. P. Parrella. 1990. Whiteflies in agricultural systems, pp. 227–261. *In* D. Gerling [ed.] Whiteflies: their bionomics, pest status and management. Intercept, Andover, U.K.

Campbell, B. C. 1993. Congruent evolution between whiteflies (Homoptera: Aleyrodidae) and their bacterial endosymbionts based on respective 18S and 16S rDNAs. Curr. Microbiol. 26: 129–132.

Clark, M. A., L. Bauman, M. A. Munson, P. Bauman, B. C. Campbell, J. E. Duffus, L. S. Osborne & N. A. Moran. 1992. The eubacterial endosymbionts of whiteflies (Homoptera: Aleyrodidae) constitute a lineage distinct from the endosymbionts of aphids and mealybugs. Curr. Microbiol. 25: 1583–1587.

Cohen, S., J. D. Duffus & H. Y. Liu. 1992. A new *Bemisia tabaci* biotype in the southwestern United States and its role in silverleaf of squash and transmission of lettuce infectious yellows virus. Phytophathology 82: 86–90.

Corbett, G. H. 1935. Malayan Aleyrodidae. J. Fed. Malay States Mus. 17: 722–852.

Costa, H. S. & J. K. Brown. 1991. Variation in biological characteristics and esterase patterns among populations of *Bemisia tabaci,* and the association of one population with silverleaf symptom induction. Entomol. Exp. Appl. 61: 211–219.

Danzig, E. M. 1966. The whiteflies (Homoptera, Aleyrodoidea) of the Southern Primor'ye (Soviet Far East). Entomol. Obozr. 45: 364–386 [in Russian]. [English translation in Entomol. Rev. 48(4): 552–559.]

Diehl, S. R. & G. L. Bush. 1984. An evolutionary and applied perspective of insect biotypes. Annu. Rev. Entomol. 29: 471–504.

Gawel, N. J. & A. C. Bartlett. 1994. Characterization of differences between whiteflies using rapid-PCR. Insect Mol. Biol. (in press).

Gill, R. J. 1992. A review of the sweetpotato whitefly in southern California. Pan-Pac. Entomol. 68: 144–152.

Headrick, D. H. & R. D. Goeden. 1991. Life history of *Trupanea californica* Malloch (Diptera: Tephritidae) on *Gnaphalium* spp. in southern California. Proc. Entomol. Soc. Wash. 93: 559–570.

Henry, C. S., M. Martinez Wells & R. J. Pupedis. 1993. Hidden taxonomic diversity within *Chrysoperla plorabunda* (Neuroptera: Chrysopidae): two new species based on courtship songs. Ann. Entomol. Soc. Am. 86: 1–13.

Liu, H. Y., S. Cohen & J. E. Duffus. 1992. The use of isozyme patterns to distinguish sweetpotato whitefly *(Bemisia tabaci)* biotypes. Phytoparasitica 20: 187–194.

Mound, L. A. 1963. Host-correlated variation in *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae). Proc. R. Entomol. Soc. Lond. Ser. A Gen. Entomol. 38: 171–180.

Mound, L. A. & S. H. Halsey. 1978. Whitefly of the world. Wiley, New York.

Perring, T. M., A. Cooper, D. J. Kazmer, C. Shields & J. Shields. 1991. New strain of sweetpotato whitefly invades California vegetables. Calif. Agric. 45(6): 10–12.

Perring, T. M., A. Cooper & D. J. Kazmer. 1992. Identification of the poinsettia strain of *Bemisia tabaci* (Homoptera: Aleyrodidae) on broccoli by electrophoresis. J. Econ. Entomol. 85: 1278–1284.

Perring, T. M., A. D. Cooper, R. J. Rodriguez, C. A. Farrar & T. S. Bellows. 1993. Identification of a whitefly species by genomic and behavioral studies. Science (Washington, DC) 259: 74–77.

Price, J. F., D. J. Schuster & D. E. Short. 1987. Managing sweetpotato whitefly. Greenhouse Grower (December): 55–57.

Richardson, B. J., P. R. Baverstock & M. Adam. 1986. Allozymic electrophoresis: a handbook for animal systematics. Academic Press, New York.

Russell, L. M. 1948. The North American species of whiteflies of the genus *Trialeurodes*. U.S. Dep. Agric. Misc. Publ. 635.

1957. Synonyms of *Bemisia tabaci* (Gennadius) (Homoptera, Aleyrodidae). Bull. Brooklyn Entomol. Soc. 52: 122–123.

Wool, D. & S. Greenberg. 1990. Esterase activity in whiteflies *(Bemisia tabaci)* in Israel in relation to insecticide resistance. Entomol. Exp. Appl. 57: 251–258.

Yokomi, R. K., K. A. Hoelmer & L. S. Osborne. 1990. Relationships between the sweetpotato whitefly and the squash silverleaf disorder. Phytopathology 80: 895–900.

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