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KEYS TO THE FAMILIES OF FULGOROMORPHA WITH EMPHASIS ON PLANTHOPPERS OF POTENTIAL ECONOMIC IMPORTANCE IN THE SOUTHEASTERN UNITED STATES (HEMIPTERA: AUCHENORRHYNCHA)

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ABSTRACT

Planthoppers (Hemiptera: Fulgoromorpha) are of concern to agriculture in the southeastern United States because of their potential to cause significant damage to economically important plants. These keys are intended to aid diagnosticians attempting to identify planthopper crop pests. This work includes lists of pathogen vectors and those species considered pests of economically important plants grown in the region, brief descriptions of planthopper collecting and curating techniques, a summary of morphological features used for identification, a revised key for identification of planthoppers to family, a key to the economically important delphacids, and a list of literature useful for planthopper identification.

Key Words: Insecta, Homoptera, Delphacidae, Cixiidae, pests

RESUMEN

Las cigarritas (Hemiptera: Fulgoromorpha) son de mucho interés a la agricultura en el sureste de los Estados Unidos por su potencial para causar daño significativo a plantas de importancia económica. Estas claves tiene la intención de ayudar a las personas que hacen el diagnóstico para identificar las cigarritas que son plagas en los cultivos. Este trabajo incluye una lista de los vectores patógenos y las especies consideradas como plagas de plantas de importancia económica sembradas en la region, una descripción breve de la técnicas para recolectar y montar las cigarritas, una clave de los delfácidos de importancia económica, y finalmente una lista de la literatura útil para la identificación de las cigarritas.

The planthoppers are a cosmopolitan group of insects placed in the infraorder Fulgoromorpha (=superfamily Fulgoroidea) which includes approximately 9,000 described species in 20 families. The vast majority of planthoppers feed on the phloem tissues of woody or herbaceous plants; however, some planthoppers feed on fungi, mosses, horsetails, or ferns (Wilson et al. 1994; Wheeler 2003). Their life histories range from highly polyphagous species that feed on numerous taxa of unrelated plants to strictly monophagous species that feed on only a single host plant species. Many planthoppers are univoltine and overwinter in the temperate zones in the egg stage; others are multivoltine where the number of generations per year depends on temperature and, perhaps, photoperiod, and many overwinter as nymphs or adults.

In this paper, I provide a brief survey of planthoppers of concern to agriculture in the southeastern United States. This survey includes lists of pathogen vectors and those species considered pests of economically important plants grown in the region, brief descriptions of planthopper collecting and curating techniques, a summary of morphological features used for identification, a revised key for identification of planthoppers to family, a key to the economically important delphacids, and a list of literature useful for planthopper identification.

THE ECONOMICALLY IMPORTANT PLANTHOPPERS

Planthoppers are of concern to agriculture because several species are significant pests of a number of important crop plants. A list of economically important species and their host plants was provided by Wilson & O'Brien (1987); many of the species included in their list are of relatively minor economic importance in that they have been reported as pests on only one or a few occasions and/or attack plants of minor economic importance. Several planthopper species are of major importance because they reach high population densities thereby damaging crops and/or they are vectors of bacterial, phytoplasma, or viral pathogens. Planthoppers found to serve as pathogen vectors include 36 species in 4 families (Table 1). As well, 8 species in 7 families are not known to be pathogen vectors but are considered pests due to population eruptions on economically important plants; 5 other species have been introduced to the United States and could ultimately prove to be of economic significance (Table 2). The planthopper species considered pests of crops of importance in the southeastern United States—corn, rice, sugarcane, and palms—and selected studies on their biology are listed in Table 3.

TABLE 1. PLANTHOPPER VECTORS AND PATHOGENS OF ECONOMICALLY IMPORTANT PLANTS.[1]

Planthopper Taxon	Pathogen[2]	Host plants	Region[3]
CIXIIDAE			
Hyalesthes obsoletus Signoret	StP, GBNP	polyphagous	PA-W
Myndus crudus Van Duzee	LYP, CFDV (?)	coconut palm	NA, NT
Myndus taffini Bonfils	CFDV	coconut palm	AP
Oliarus atkinsoni Myers	PYP	flax lily	AP
Pentastiridius beieri (Wagner)	StP	sugar beet	PA-W
DELPHACIDAE			
Caenodelphax teapae (Fowler)	UHBV	plantain signalgrass	NT
Chilodelphax albifascia (Mats.)	RBSDV, RSV	grasses (rice, etc.)	PA-E
Dicranotropis hamata (Boheman)	MRDV, OSDV, PGSV	grasses (oats, etc.)	PA-W
Javesella discolor (Boheman)	OSDV	grasses (oats, etc.)	HO
Javesella dubia (Kirschbaum)	EWSMV, OSDV	grasses (wheat, etc.)	HO
Javesella obscurella (Boheman)	EWSMV, OSDV	grasses (wheat, etc.)	HO
Javesella pellucida (Fabricius)	EWSMV, MRDV, OSDV	grasses (wheat, etc.)	HO
Laodelphax striatellus (Fallen)	BYSMV, MRDV, NCMV, RSV, RBSDV, WCSV, WSTV	grasses (wheat, etc.)	OR, PA
Megadelphax sordidulus (Stål)	PGSV	grasses (timothy, etc.)	PA-W
Muellerianella fairmairei (Perris)	NCMV	grasses (oats, etc.)	PA-W
Nilaparvata bakeri (Muir)	RGSV, RRSV	rice	OR
Nilaparvata lugens (Stål)	RGSV, RRSV	rice	AP, OR
Nilaparvata muiri China	RGSV	rice	OR
Peregrinus maidis (Ashmead)	FMMV, IMMV, MSSV, MSV	maize, sorghum	AP, ET, OR, NA, NT
Perkinsiella saccharicida Kirkaldy	FDV	sugarcane	AP, ET
Perkinsiella vastatrix (Breddin)	FDV	sugarcane	AP, ET
Perkinsiella vitiensis Kirkaldy	FDV	sugarcane	AP
Ribautodelphax notabilis (Logv.)	IMMV, MRDV, RBSDV	grasses (maize, etc.)	PA-W
Sogatella furcifera (Horvath)	PSV	grasses	AP, OR
Sogatella kolophon (Kirkaldy)	BWSV, DSV, MSSV	grasses (maize, barley, etc.)	AP, ET, OR, NA, NT
Sogatella vibix (Haupt)	FMMV, MRDV, MSSV	grasses (maize, etc.)	AP, OR, PA
Tagosodes cubanus (Crawford)	EHBV, RHBV	maize, coconut	ET, NA,
Tagosodes orizicolus (Muir)	RHBV	grasses (rice, barnyard grass)	NA, NT
Tarophagus prosperina (Kirkaldy)	CBV	taro	AP, OR
Terthron albovittatum (Matsumura)	RSV, RBSDV	rice, barnyard grass	OR, PA-E

[1]Sources: Cumber 1952, 1953; Wilson & O'Brien 1987; Maixner 1994; Nault 1994; Liefting et al. 1998; Sforza et al. 1999; Ponnamma & Babjan 2000; Gatineau et al. 2001; Mpunami et al. 2002; Rajan et al. 2002; International Committee on Taxonomy of Viruses, Universal Virus Database 2004; Randles et al. 2004.

[2]Pathogen Abbreviations:

Bacteria: *Bacillus amylovorus* (Burr.) DeToni (apple tree canker)

Phytoplasmas:	ANYLP	Areca nut yellow leaf phytoplasma	LYP	Lethal yellowing phytoplasma
	CP	Coconut phytoplasma (unidentified)	PYP	Phormium yellow leaf phytoplasma
	CRWP	Coconut root wilt phytoplasma	StP	Stolbur phytoplasma
	GBNP	Grapevine bois noir phytoplasma		
Viruses:	BWSV	Brazilian wheat spike disease	MSV	Maize stripe virus
	BYSMV	Barley yellow striate mosaic virus	NCMV	Northern cereal mosaic virus
	CBV	Colocasia babone virus	OSDV	Oat sterile dwarf virus
	CCSV	Cynodon chlorotic streak virus	PGSV	Phleum green stripe virus
	CFDV	Coconut foliar decay virus	PSV	Pangola stunt virus
	DSV	Digitaria striate virus	RBSDV	Rice black-streaked dwarf virus
	EHBV	Echinochloa hoja blanca virus	RGSV	Rice grassy stunt virus
	EWSMV	European wheat striate mosaic virus	RHBV	Rice hoja blanca virus
	FDV	Fiji disease virus	RRSV	Rice ragged stunt virus
	FMMV	Finger millet mosaic virus	RSV	Rice stripe virus
	IMMV	Iranian maize mosaic virus	UHBV	Urochloa hoja blanca virus
	MRDV	Maize rough dwarf virus	WCSV	Wheat chlorotic streak virus
	MSSV	Maize sterile stunt virus	WRSV	Wheat rosette stunt virus

[3]Biogeographic Regions Abbreviations: AP—Australo-Pacific, ET—Ethiopian, HO—Holarctic, NA—Nearctic, NT—Neotropical, OR—Oriental, PA—Palaearctic, PA-E—Eastern Palaearctic, PA-W—Western Palaearctic.

TABLE 1. (CONTINUED) PLANTHOPPER VECTORS AND PATHOGENS OF ECONOMICALLY IMPORTANT PLANTS.[1]

Planthopper Taxon	Pathogen[2]	Host plants	Region[3]
Toya propinqua (Fieber)	CCSV, MRDV	grasses (Bermuda grass, maize, etc.)	ET, NA
Unkanodes sapporonus (Mats.)	NCMV, RSV, RBSDV	rice	OR, PA-E
Unkanodes tanasijevici (Dlabola)	IMMV	grasses (maize, etc.)	PA-W
DERBIDAE			
Diostrombus mkusangai	CP (?)	coconut	ET
Proutista moesta (Westwood)	CRWP, ANYLP	coconut, areca nut	ET
FLATIDAE			
Anzora unicolor (Walker)	*B. amylovorus*	polyphagous	AP

[1]Sources: Cumber 1952, 1953; Wilson & O'Brien 1987; Maixner 1994; Nault 1994; Liefting et al. 1998; Sforza et al. 1999; Ponnamma & Babjan 2000; Gatineau et al. 2001; Mpunami et al. 2002; Rajan et al. 2002; International Committee on Taxonomy of Viruses, Universal Virus Database 2004; Randles et al. 2004.

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	CRWP	Coconut root wilt phytoplasma	StP	Stolbur phytoplasma
	GBNP	Grapevine bois noir phytoplasma		
Viruses:	BWSV	Brazilian wheat spike disease	MSV	Maize stripe virus
	BYSMV	Barley yellow striate mosaic virus	NCMV	Northern cereal mosaic virus
	CBV	Colocasia babone virus	OSDV	Oat sterile dwarf virus
	CCSV	Cynodon chlorotic streak virus	PGSV	Phleum green stripe virus
	CFDV	Coconut foliar decay virus	PSV	Pangola stunt virus
	DSV	Digitaria striate virus	RBSDV	Rice black-streaked dwarf virus
	EHBV	Echinochloa hoja blanca virus	RGSV	Rice grassy stunt virus
	EWSMV	European wheat striate mosaic virus	RHBV	Rice hoja blanca virus
	FDV	Fiji disease virus	RRSV	Rice ragged stunt virus
	FMMV	Finger millet mosaic virus	RSV	Rice stripe virus
	IMMV	Iranian maize mosaic virus	UHBV	Urochloa hoja blanca virus
	MRDV	Maize rough dwarf virus	WCSV	Wheat chlorotic streak virus
	MSSV	Maize sterile stunt virus	WRSV	Wheat rosette stunt virus

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PLANTHOPPER COLLECTING AND CURATING TECHNIQUES

Collecting Techniques. The method employed for most efficiently collecting planthoppers largely depends upon the structure of the host plant. Those on woody plants can be collected individually by knocking specimens into a vial, by use of an aspirator with a relatively large opening, or by putting a sheet or large net under the foliage and striking the branches above. Planthoppers on herbaceous plants can be collected with a sweep net with a very deep net bag which is slowly opened and the planthoppers collected with an aspirator as they crawl toward the opening. Another type of sweep net is constructed of a fine woven translucent plastic netting that retains its open shape; after sweeping, this type of net is held up toward the sun, the planthoppers tend to congregate at the back of the net and can be collected with an aspirator. As many planthoppers tend to live within the thatch near the ground, collecting them requires sitting on the ground, pushing the plants aside, then waiting for the insects to crawl up the plants where they can be sucked up in an aspirator (Beamer, L. 1946). A more efficient means of collecting in this type of habitat is to employ a vacuum, either a "D-vac" which is very heavy and has a somewhat unreliable engine or a modified leaf blower/vacuum which is much lighter and more reliable (Wilson et al. 1993). The net bag at the end of the vacuum can be placed in a plastic jar containing cotton balls soaked in ethyl acetate and the specimens sorted out later, or the bag can be emptied into a sweep net and the specimens collected with an aspirator. Planthoppers also can be collected with Malaise traps, Sante canopy traps, window traps (Weber & Wilson 1981), and blacklights. Blacklights are useful for collecting achilids, cixiids, and some dictyopharids but are of limited value in collecting certain delphacids and caliscelids as the vast majority of their populations are composed of brachypters.

Curating and Specimen Preparation. Collected planthoppers may be killed by placing them directly into 70% ethyl or isopropyl alcohol, or putting specimens in killing jars containing a cotton ball or plaster bottom soaked in ethyl acetate, or by freezing specimens. Nymphal specimens must

TABLE 2. NON-VECTOR PLANTHOPPERS OF ECONOMICALLY IMPORTANT PLANTS OF CONCERN IN THE SOUTHEASTERN UNITED STATES.

Planthopper Taxon	Host plants	Native region[1]	Introduced to
CALISCELIDAE			
Asarcopus palmarum Horvath	date palm	PA-W	California[2]
Caliscelis bonellii (Latreille)	grasses (?)	PA-W	California[3]
DELPHACIDAE			
Eoeurysa flavocapitata Muir	sugarcane	OR	—
Harmalia anacharsis Fennah	rice (?)	OR	Florida[4]
*Saccharosydne saccharivor*a (West.)	sugarcane	NA, NT	
FLATIDAE			
Melormenis basalis (Walker)	polyphagous (?)	NT	Florida[5]
Metcalfa pruinosa (Say)	polyphagous	NA	Europe
Ormenaria rufifascia (Walker)[6]	palms	NA	—
Siphanta acuta (Walker)	polyphagous	AP	California[5]
LOPHOPIDAE			
Pyrilla perpusilla (Walker)	sugarcane, rice	OR	—
MEENOPLIDAE			
Nisia nervosa (Motschulsky)	rice	OR	—
TETTIGOMETRIDAE			
Hilda patruelis (Stål)[7]	peanuts	ET	—
TROPIDUCHIDAE			
Numicia viridis Muir[8]	sugarcane	ET	—
Ommatissus lybicus DeBerg	date palm	PA-W	—

[1]See Table 1 for abbreviations; [2]Stickney et al. 1950; [3]O'Brien 1967; [4]Wooten et al. 1993; [5]Wilson, S. W. pers. obs.; [6]Mead 1965, Wilson & Tsai 1984; [7]Weaving 1980; [8]Carnegie 1980.

be stored in vials, preferably with caps with plastic cone inserts, filled with 70% ethyl or isopropyl alcohol; adults may be stored this way but colors will usually bleach out. Adult specimens are usually pinned or glued to a point on the right side of the specimen. Label data accompanying the specimen should include locality (country, state or province, county or district, nearest town, specific location, and if available, GPS coordinates), date, collector, and, if possible, host plant.

Accurate species identification in most planthopper taxa requires examination of the structures of the male genitalia; unfortunately, for many taxa, it is not possible to identify females to species, and in some cases, to genus level. Idenfication of males to species usually requires removing the abdomen with a pair of fine forceps or the point of an insect pin, then placing the abdomen in a 10% potassium hydroxide (KOH) solution for 12-24 h at room temperature (small, lightly sclerotized specimens may require as little as 4-8 h or less in the KOH solution). An efficient means of processing a relatively large number of specimens is to fill wells of a 96-well tissue culture plate with water, place a KOH pellet in each well containing water, then place an abdomen in a well. The pinned specimen is then placed in a Schmidt box or foam bottom insect drawer that has been marked with grid locations corresponding to those on the 96-well tissue culture plate (A1-H12). To examine the genitalia, remove the abdomen from the KOH solution and place it in a deep depression slide filled with water; let it soak in the water for a few minutes then place it in a depression slide filled with glycerine. If the genitalic structures are not clearly visible, hold the pygofer with a pair of fine forceps or the point of an insect pin then gently move the anal tube caudoventrally, or push the connective attached to the anterior base of the aedeagus caudally. This will usually force the aedeagus, anal tube, and styles out of the pygofer. After examination of the genitalia, fill a genital vial with glycerine, place the abdomen into the vial, cap the vial, then pin the vial through the cap under the specimen.

MORPHOLOGY

This brief review of planthopper external morphology should provide enough basic information to allow effective use of the keys for identification. More complete treatments are provided by O'Brien & Wilson (1985) for all families, Asche (1985) for delphacids, Freund & Wilson (1995) for acanaloniids, and McPherson & Wilson (1995) for dictyopharids. Overviews of the anatomy of the male

TABLE 3. SELECTED BIOLOGICAL STUDIES ON THE PRINCIPAL PLANTHOPPER PESTS OF THE MAJOR ECONOMICALLY IMPORTANT PLANTS IN THE SOUTHEASTERN UNITED STATES.

Host plant	Planthoppers	Biological studies
Corn[1]	*Peregrinus maidis* (Ashmead)	Tsai & Wilson 1986
	Sogatella vibix (Haupt)	Ammar 1977
Sugarcane[2]	*Eoeurysa flavocapitata* Muir	Chatterjee 1971, Wilson & Tsai 1992
	Numicia viridis Muir	Carnegie 1980
	Perkinsiella saccharicida Kirkaldy	Bull 1972, Chang & Ota 1978, Sosa 1985
	Pyrilla perpusilla (Walker)	Brar & Bains 1979, Rahman & Nath 1940
	Saccharosydne saccharivora (West.)	Metcalfe 1969
Rice[3]	*Laodelphax striatellus* (Fallen)	Ruan et al. 1981
	Nilaparvata lugens (Stål)	Bae & Pathak 1970, Mochida & Okada 1979, Wilson & Claridge 1991
	Nilaparvata meander Fennah	Wilson & Claridge 1991
	Sogatella furcifera (Horvath)	Ammar et al. 1980
	Tagosodes cubanus (Crawford)	Wilson & Claridge 1991
	Tagosodes orizicolus (Muir)	Atkins et al. 1958
Palms[4]	*Asarcopus palmarum* Horvath	Stickney et al. 1950
	Myndus crudus Van Duzee	Howard et al. 1983, Wilson & Tsai 1982
	Ommatissus lybicus DeBerg	Hussain 1963, Klein & Venezian 1985, Asche & Wilson 1989

[1]*Zea mays* L.; [2]*Saccharum officinarum* L.; [3]*Oryza sativa* L.; [4]*Cocos nucifera* L., *Phoenix dactylifera* L.

genitalia for selected taxa are given by Muir (1926a); Fennah (1945); Bourgoin (1990); and Yang & Chang (2000). Descriptions and illustrations of the anatomy of the female genitalia are provided by Heady & Wilson (1990) and Bourgoin (1993).

Planthoppers can be separated from members of the Cicadomorpha by the location of the antennae which are ventral to the compound eyes (except in one cixiid subfamily in which the compound eyes are positioned anteroventrally to the compound eyes but are partially surrounded by cup-like concavities); the enlarged antennal pedicel bearing wart-like sensilla; the presence, in most taxa, of pad-like tegulae at the base of the forewings; the presence, again, in most taxa, of a "Y-vein", that is, two anal veins coalescing on the clavus of the forewing to form a "Y-shaped" set of veins; the elongate, widely separated base of the mesothoracic coxae; and the lack of rows of setae along the shaft of each metathoracic tibia as in Cicadellidae.

Head. The head in planthoppers ranges from a broad, short head to those that are strongly laterally compressed or some that have an elongate straight or curved projection extending well beyond the compound eyes. The dorsal aspect of the head is termed the vertex which may be separated from the anterior or anteroventral frons by a transverse carina or, in those planthoppers with broadly rounded heads, not be demarcated from it. The frons, in all but one family, is separated from the gena on each side by a longitudinal external lateral carina; as well, the frons may bear a median longitudinal carina and/or internal longitudinal lateral carinae. Posteroventral to the frons is the clypeus from which the three-segmented beak extends. Some planthoppers have a median ocellus on the frons; most have a lateral ocellus between the frons and gena. The compound eyes are generally large and may be strongly notched ventrally; in some subterranean species the eyes may be reduced or absent. The three segmented antennae in almost all planthoppers are situated ventral to the compound eyes; in some cixiids the antennae are in a cup-like concavity located anterior to the eyes. The basal antennal antennal segment is termed the scape, the middle segment which may be elongate and/or foliose is the pedicel, the terminal segment consists of a bulbous base and elongate, seta-like flagellum.

Thorax. The pronotum is generally short and collar-like and may bear a median longitudinal carina and a pair of lateral carinae. The mesonotum is generally subtriangular and may bear a median longitudinal carina and a pair of lateral carinae; a transverse suture demarcates a small triangular piece at the apex of the mesonotum in tropiduchids and some lophopids. The fore wings may be very large with numerous veins or greatly reduced as in brachypters and may be opaque, concolorous with the body or brightly colored, or completely or partially translucent. The subtriangular anal region of the forewings, or clavus, is set off from the rest of the wing by the postcubital vein which may or may not reach the edge of the wing. The clavus typically bears a "Y-shaped" vein and, in flatids, has numerous pustules on its sur-

TABLE 4. KEYS FOR IDENTIFICATION OF PLANTHOPPERS IN ECONOMICALLY SIGNIFICANT TAXA.

Taxa	Region or Topic	Reference
Families	World	O'Brien & Wilson 1985
Families	World, immatures	O'Brien et al. 1998
Families, Genera, Species	Central Europe	Holzinger et al. 2003
Families, Genera, Species	Fennoscandia	Ossiannilsson 1978
Families, Genera, Species	Eastern Russia	Anufriev & Emeljanov 1988
Families, Genera, Species	Eastern U.S.	Metcalf 1923
Families, Genera, Species	Illinois	Wilson & McPherson 1980c
Families, Genera, Species	Puerto Rico	Caldwell & Martorell 1951
Families, Genera, Species	Rice pests	Wilson & Claridge 1991
Acanaloniidae		
Acanalonia	U.S.	Freund & Wilson 1995
Caliscelidae		
Genera	U.S.	Doering 1938
Aphelonema	U.S.	Doering 1941
Bruchomorpha	U.S.	Doering 1940
Fitchiella	U.S.	Doering 1941
Cixiidae		
Genera	U.S.	Kramer 1983
Cixius	U.S.	Kramer 1981
Hyalesthes	Europe	Hoch & Remane 1985
Myndus	New World	Kramer 1979
Oecleus	U.S.	Kramer 1977
Oliarus	U.S.	Mead & Kramer 1982
Delphacidae		
Genera	Mississippi	Coley 1970
Achorotile	U.S.	Beamer 1954
Bakerella	U.S.	Beamer 1950
Bostaera	U.S.	Penner 1952
Delphacodes	North Carolina	DuBose 1960
Eurysa	U.S.	Beamer 1952
Kelisia	U.S.	Beamer 1951
Laccocera	U.S.	Penner 1945
Megamelanus	U.S.	McDermott 1952
Megamelus	U.S.	Beamer 1955
Neomegamelanus	U.S.	McDermott 1952
Pentagramma	U.S.	Penner 1947
Phyllodinus	U.S.	Morgan & Beamer 1949
Pissonotus	U.S.	Bartlett & Deitz 2000
Prokelisia	U.S.	Wilson 1982, Heady& Wilson 1990
Sogatella	World	Asche & Wilson 1990
Stobaera	U.S.	Kramer 1973
Stenocranus	U.S.	Beamer 1946
Tagosodes	World	Asche & Wilson 1990
Tumidagena	U.S.	McDermott 1952
Flatidae		
Subfamilies, Tribes	Panama	Metcalf 1938
Species	U.S.	Shepard 1939
Siphanta	Australasia	Fletcher 1985
Issidae		
Subfamilies, Tribes	World	Fennah 1954
Genera	U.S.	Doering 1938
Hysteropterum	U.S.	Doering 1938
Thionia	U.S.	Doering 1938
Tropiduchidae		
Subfamilies, Tribes	World	Fennah 1982
Genera, Species	U.S.	O'Brien 1992
Ommatissus	Old World	Asche & Wilson 1989

face. In some taxa, some or all of the forewing veins may bear enlarged pustules. The hind wings may be almost as large as the forewings or greatly reduced or absent. The hindwings of fulgorids have a characteristic reticulate venation in the anal region. The metathoracic or hind legs have numerous features useful for identification. The tibia has a row of apical spines on the plantar surface and usually bears large lateral spines along the tibial shaft. Delphacids have a characteristic metatibial spur which may be spike-like or foliose and with or without teeth on its inner margin. The tarsus consists of three tarsomeres: the basal or first tarsomere bears a row of apical teeth, the second tarsomere may have a row of apical teeth, one tooth on each side or may be lacking teeth; the third tarsomere terminates in a pair of claws and a central arolium.

Abdomen. Some planthoppers have sound producing tymbals which consist of internal apodemes in the basal abdominal segments and a subrectangular piece of the first abdominal tergite. The sounds made by planthoppers are species specific courtship signals detected via substrate vibrations.

The structures of the male external genitalia are necessary for accurate species identification in most groups of planthoppers. The male genital capsule is a subcylindrical pygofer and represents the modified 9th abdominal segment. The pygofer may have lateral and/or ventral caudally-directed lobes or spines and, in delphacids, may have a partial dorsoventral wall or diaphragm. The diaphragm may bear lobes, spines or other forms of diaphragm armature on its median ventral margin. The anal tube, the 10th abdominal segment, is usually moveable and often bears spines or lobes on its caudal margin. The styles are a pair of clasper-like structures emanating from the ventrocaudal aspect of the pygofer. The styles may be elongate and can have spines or teeth or bear lobes or keels or, in some taxa, they can be relatively small and club-shaped. A "Y-shaped" connective attaches the base of the styles to the base of the aedeagus. The intrommitent organ, or aedeagus, ranges in shape from a simple tube-like structure to a complex elaborate entity bearing numerous spines and, in some taxa, inflatable translucent lobes.

Terminology used in describing female genitalia follows Heady & Wilson (1990). The external female genitalia, collectively referred to as the ovipositor, may be "orthopteroid" or "fulgoroid". In the "orthopteroid ovipositor" the fused median gonopophyses (=valvula) of the 9th abdominal segment often have a serrated dorsal aspect and serve as a saw-like structure for depositing eggs, usually into plant tissues. The lateral gonopophyses of the 9th abdominal segment and the gonopophyses of the 8th segment serve in egg deposition and may coat the eggs with wax. In some taxa, these structures are reduced and/or modified and very large wax plates are present. The "fulgoroid ovipositor" may be modified for raking particles prior to egg deposition in the soil or on the ground or for depositing eggs in plant tissue. In those that insert eggs into plant tissue the fused gonopophyses of the 8th abdominal segment serve as the saw-like deposition structure and the lateral gonopophyses of the 9th abdominal segment as protective covers and/or egg guide.

Identification of Planthoppers

There are 196 species in 11 families of planthoppers recorded from the southeastern United States (Wilson & McPherson 1980a; Wilson, unpubl. data). Most of these species are of no known economic significance; in fact, many are rare and little is known about their life cycles and hosts. A few species present in the region are of economic importance. As well, there are several species that could be imported by accident or on purpose into the region. To aid in identifying taxa of potential economic importance, keys to the 20 planthopper families and to the economically significant delphacids are included. The key to families has been adapted from O'Brien & Wilson (1985). Since publication of their key, the following family-level changes have been made: 18 genera of Issidae were transferred to Nogodinidae (Fennah 1984); the family Caliscelidae was established to include the former issid subfamilies Caliscelinae and Ommatidiotinae (Emeljanov 1999); the family Acanaloniidae was reestablished and includes the former issid subfamilies Acanaloniinae, Tonginae, and Trenopinae (Emeljanov 1999); and the family Achilixiidae was subsumed within Cixiidae (Liang 2001). Planthopper families with economically important species are designated with an asterisk (*).

The family Acanaloniidae is identified as one that includes species of potential economic importance because *Acanalonia conica* (Say), while not a significant pest in the United States, has been introduced to Sicily (D'Urso, personal communication). This species has a similar life history and feeding habits to *Metcalfa pruinosa* (Say), also not a significant pest in the United States, which was introduced to Italy from the United States in the late 1970s and has spread from Spain and southern France to Austria, Slovenia, and Greece (Wilson & Lucchi 2001). *Acanalonia conica* is often found in mixed nymphal feeding assemblages with *M. pruinosa* (Wilson & McPherson 1980b) and could become a pest in Europe. As such, it joins the native US species, *M. pruinosa* and *Prokelisia marginata* Van Duzee (Seljak 2004) that have recently been introduced to Europe and may be intercepted at United States ports of entry. The life histories and descriptions and illustrations of the immatures of *A. conica*, *M. pruinosa*, and similar associated species are provided by Wilson & McPherson (1981a, b).

There are no recent comprehensive keys to the genera and species of a number of families that include economically significant species (e.g., Flatidae). A list of keys that identify species in these taxa and those that survey taxa on selected economically significant crops is provided in Table 4. The following key to delphacids of potential economic importance includes species present in the United States, whether native or introduced, and known to be of economic significance, viral or phytoplasma vectors that could be introduced to the US, and those that are significant pests of crops grown in the United States. Several species recorded as transmitters of viral pathogens based only on laboratory or greenhouse studies with no apparent field evidence are not considered significant pests and, thus, are not included. As well, species that are vectors of pathogens of crop plants of little significance to agriculture in the southeastern United States are not included (e.g., *Javesella* spp. except for the ubiquitous *J. pellucida* (Fabricius)). A few common species that are likely to be frequently collected and those that can easily be confused with major pests are included in the key (e.g., *Caenodelphax teapae* (Fowler), *Nilaparvata wolcotti* Muir and Giffard). Finally, some taxa, such as *Sogatella* and *Tagosodes*, include numerous species, some of which could be introduced to the southeastern United States. If specimens fail to fit the key and illustrations given below, then the taxonomic literature on these taxa should be consulted (e.g., Asche & Wilson 1990; also, see Table 4). In order to ensure accurate identification of these and other delphacid taxa, species identifiers should always compare structures of the male genitalia with either the illustrations provided in this paper or with those in the works listed in Table 4. Figures accompanying the keys were redrawn from Muir & Giffard (1924); Muir (1926b); Doering (1940); Zimmerman (1948); Caldwell & Martorell (1951); Wilson & McPherson (1980c); Asche (1985); O'Brien & Wilson (1985); Tsai & Wilson (1986); Wilson & Claridge (1991); Wilson & Tsai (1992); Wooten et al. (1993); Freund & Wilson (1995); and Holzinger et al. (2003).

Key to the Families of Planthoppers

1. Hind tibia with a large movable spur at apex (Fig. 1) . . . . . Delphacidae*
   —Hind tibia without a movable spur at apex (Figs. 2-4) 2

2. Second tarsomere of hind legs with a row of apical spines (Fig. 2) 3
   —Second tarsomere of hind legs with one apical spine on each side (Fig. 3) or spines absent (Fig. 4) 9

3. Hindwings with numerous cross veins near apex and in anal area; head usually with a transverse suture separating vertex from frons (Fig. 5); aedeagus with inflatable lobes . . . . . Fulgoridae
   —Hindwings without cross veins near apex or in anal area; head without a transverse suture separating vertex from frons; aedeagus variable 4

4. Forewings overlapping posteriorly (Fig. 6); body usually flattened . . . . . Achilidae
   —Forewings not overlapping posteriorly; body variable 5

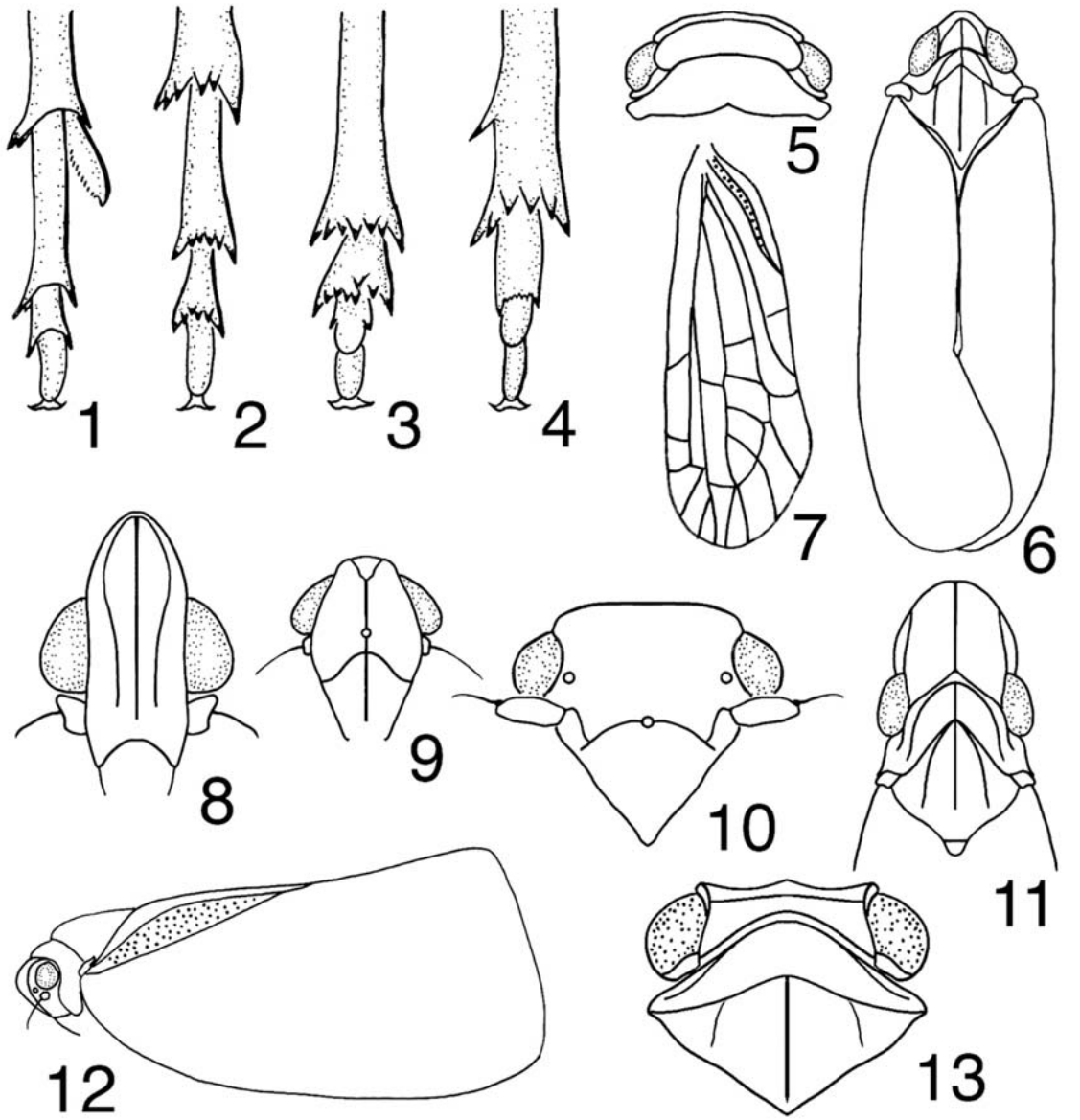
5. Forewings with tubercles on one or both claval veins (Fig. 7); beak with apical segment longer than wide . . . . . Meenoplidae*
   —Forewings usually without tubercles on claval veins; if so, then all veins with tubercles or beak with apical segment subequal in length and width 6

6. Forewings with tubercles on claval veins and beak with apical segment subequal in length and width; styles much longer than pygofer; anal tube not moveable, attached to pygofer . . . . . Derbidae (in part)
   —Forewings without tubercles on claval veins or with tubercles on all veins; beak with apical segment longer than wide; styles shorter than length of pygofer; anal tube moveable 7

7. Frons with two or three median carinae and/or head with elongate anterior projection (Fig. 8); if not, then tegulae absent . . . . . Dictyopharidae
   —Frons with one median carina (Fig. 9); head usually without elongate anterior projection; tegulae present 8

8. Forewings usually with tubercles on veins; abdominal tergites 6-8 subrectangular; females with caudally directed wax plates on tergite 9 and a spike-like ovipositor, or wax plates absent and ovipositor sword-shaped . . . . . Cixiidae*
   —Forewings without tubercles on veins; abdominal tergites 6-8 chevron shaped, females with wax plates on tergites 7-9; female genitalia greatly reduced . . . . . Kinnaridae

9. Second tarsomere of hind legs with one apical spine on either side (Fig. 3) 10
   —Second tarsomere of hind legs without apical spines on either side (Fig. 4) 17

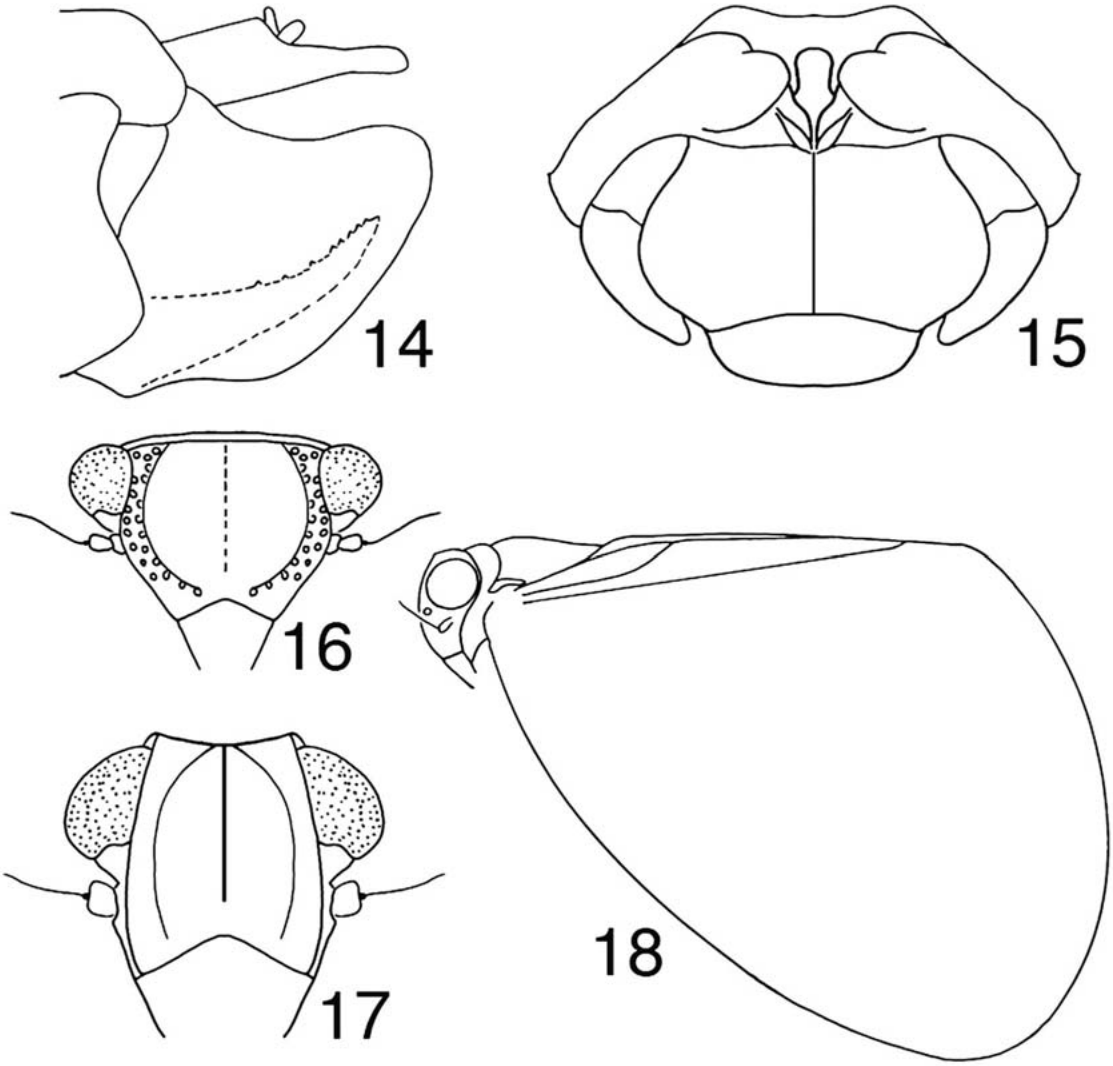


Figs. 1-13. Planthopper key structures. 1. Delphacid hind leg, dorsal view. 2. Cixiid hind leg, ventral view. 3. Flatid hind leg, ventral view. 4. Lophopid hind leg, ventral view. 5. Fulgorid head. 6 Achilid habitus. 7. Meenoplid forewing. 8. Dictyopharid head. 9. Cixiid head. 10. Tettigometrid head. 11. Tropiduchid head and thorax. 12. Flatid habitus. 13. Nogodinid head and pronotum.

10. Frons with lateral carinae 11
—Frons without lateral carinae (Fig. 10) . . . . . Tettigometridae*

11. Mesonotum with a posterior transverse suture (Fig. 11); forewings with few or no cross veins anterior to nodus, with numerous veins posterior to nodus . . . . . Tropiduchidae*
—Mesonotum usually without a posterior transverse suture; forewings with sparse venation or dense venation throughout 12

12. Beak with apical segment subequal in length and width; styles much longer than pygofer; anal tube not moveable, attached to pygofer . . . . . Derbidae (in part)
—Beak with apical segment longer than wide; styles shorter than length of pygofer; anal tube moveable 13

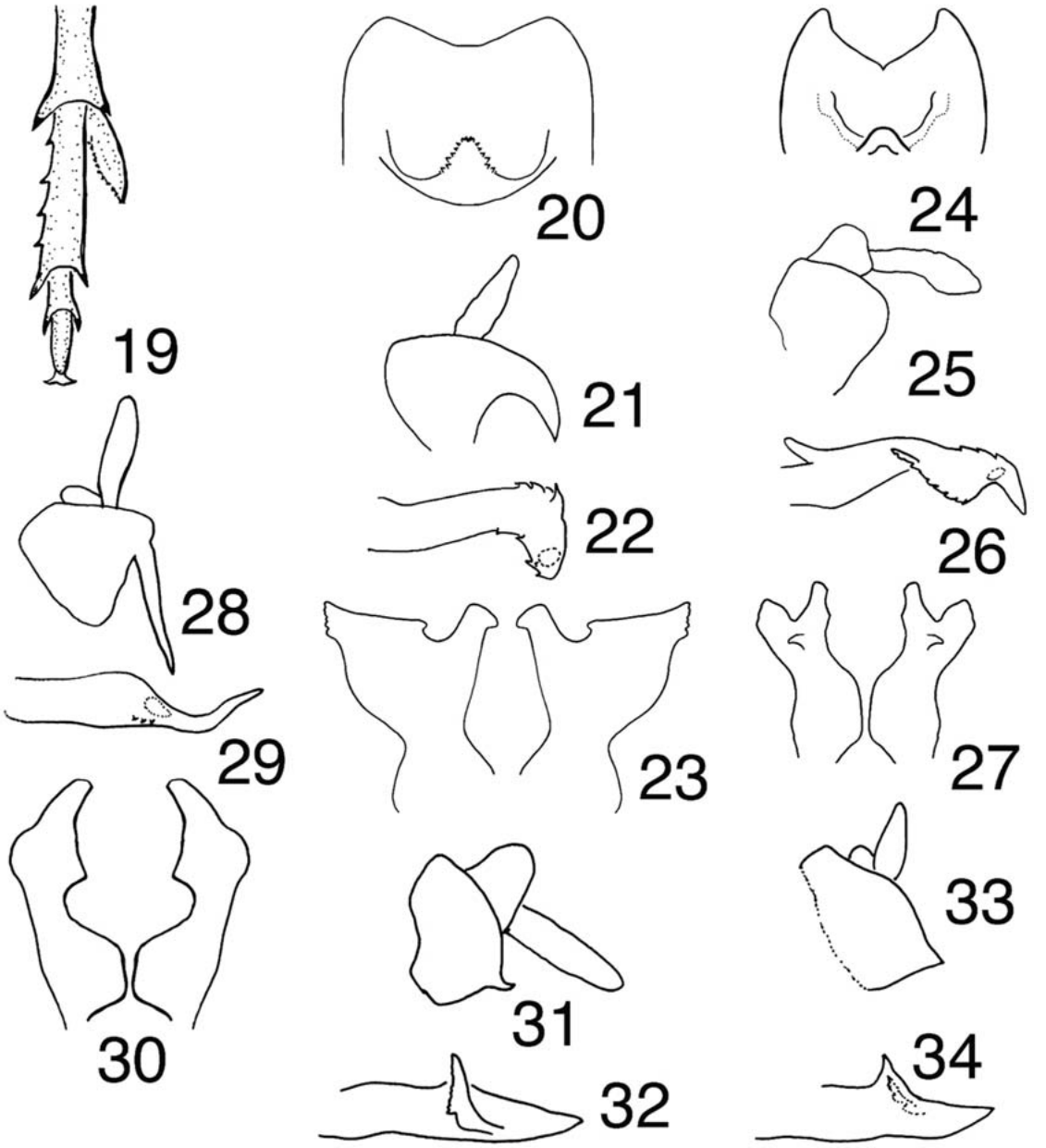


Figs. 14-18. Planthopper key structures. 14. Acanaloniid female genitalia, lateral view. 15. Issid female genitalia, ventral view. 16. Caliscelid head. 17. Issid head. 18. Ricaniid habitus.

13. Forewings with tubercles between veins on clavus (Fig. 12) and with numerous costal crossveins . . . . . Flatidae
—Forewings without tubercles on clavus; usually without numerous costal crossveins 14

14. Ovipositor laterally compressed, gonopophyses of the 8th abdominal segment bearing apical teeth (Fig. 14); pronotum extending anteriorly beyond middle of eyes (Fig. 13), or forewings usually with reticulate venation and hind tibiae without lateral spines 15
—Ovipositor not laterally compressed, gonopophyses of the 8th abdominal segment without apical teeth (Fig. 15); pronotum not extending anteriorly beyond middle of eyes; forewings of macropters with normal venation; hind tibiae with lateral spines 16

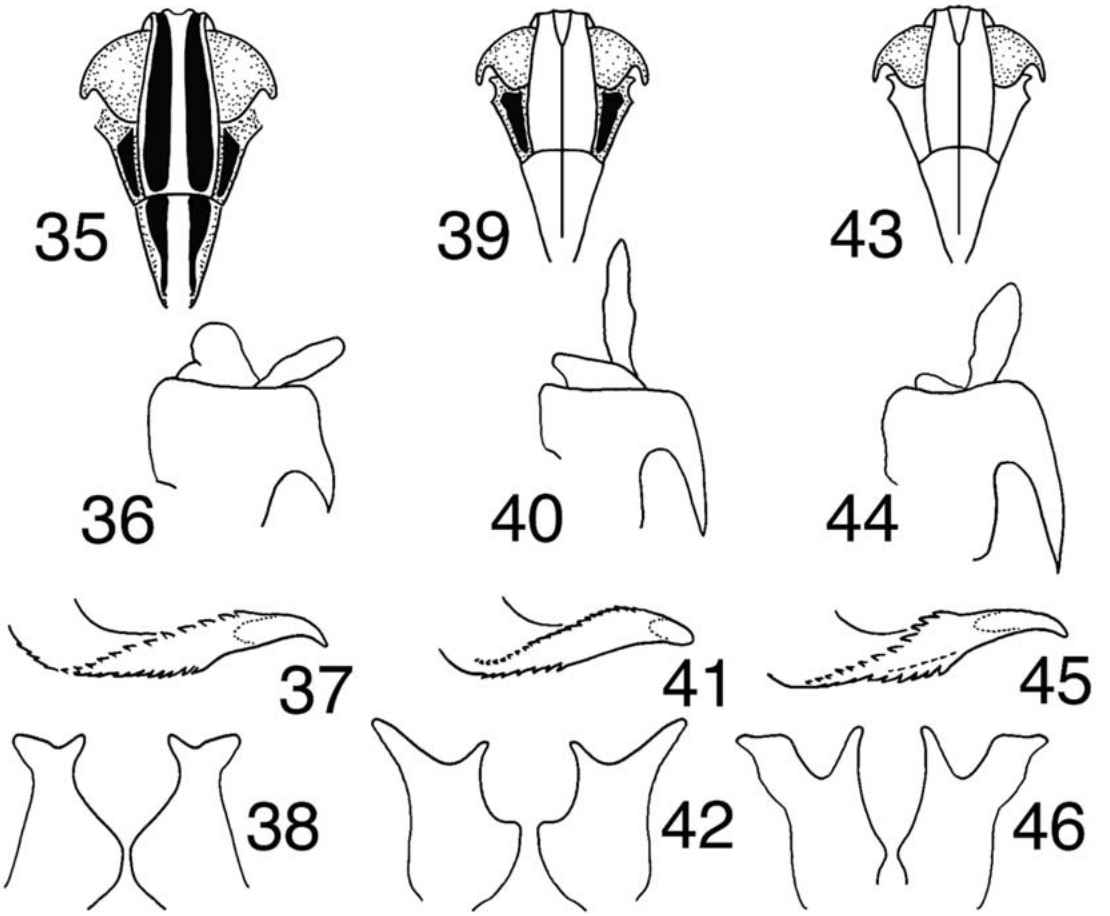
15. Pronotum extending anteriorly beyond middle of eyes (Fig. 13); clypeus with lateral carinae; macropterous or brachypterous; hind tibia with lateral spines . . . . . Nogodinidae
—Pronotum extending not much beyond posterior aspect of eyes; clypeus without lateral carinae; macropterous, often with reticulate venation; hind tibia usually without lateral spines . . . . . Acanaloniidae



Figs. 19-34. *Nilaparvata* spp. 19. Hind leg, ventral view. 20-34. Male genitalia. 20-23. *N. bakeri*. 24-27. *N. muiri*. 28-30. *N. lugens*. 31-32. *N. meander*. 33-34. *N. wolcotti*. 20, 24: Diaphragm armature of pygofer, caudal view. 21, 25, 28, 31, 33: Anal tube. 22, 26, 29, 32, 34: Aedeagus. 23, 27, 30: Styles.

16. Frons with lateral carinae bordering a large disc-like or elongate areolet (Fig. 16); usually brachypterous . . . . . Caliscelidae*
—Frons with median carina, with or without lateral carina (Fig. 17); if lateral carinae present, not enclosing a central areolet; macropterous . . . . . Issidae

17. Brachypterous, or forewings barely exceeding beyond the apex of the abdomen and with apical venation strongly carinate (southern Africa) 18
—Macropterous, forewings almost always exceeding well beyond the apex of the abdomen, venation not carinate 19



Figs. 35-46. *Sogatella* spp. 35-38. *S. furcifera*. 39-42. *S. vibix*. 43-46. *S. kolophon*. 35, 39, 43: Head. 36, 40, 44: Anal tube. 37, 41, 45: Aedeagus. 38, 42, 46: Styles.

18. Eyes reduced, body white, brachypterous, adults subterranean . . . . . Hypochthonellidae
—Eyes not reduced, body pigmented, macropterous with strongly carinate apical veins, adults not subterranean . . . . . Gengidae

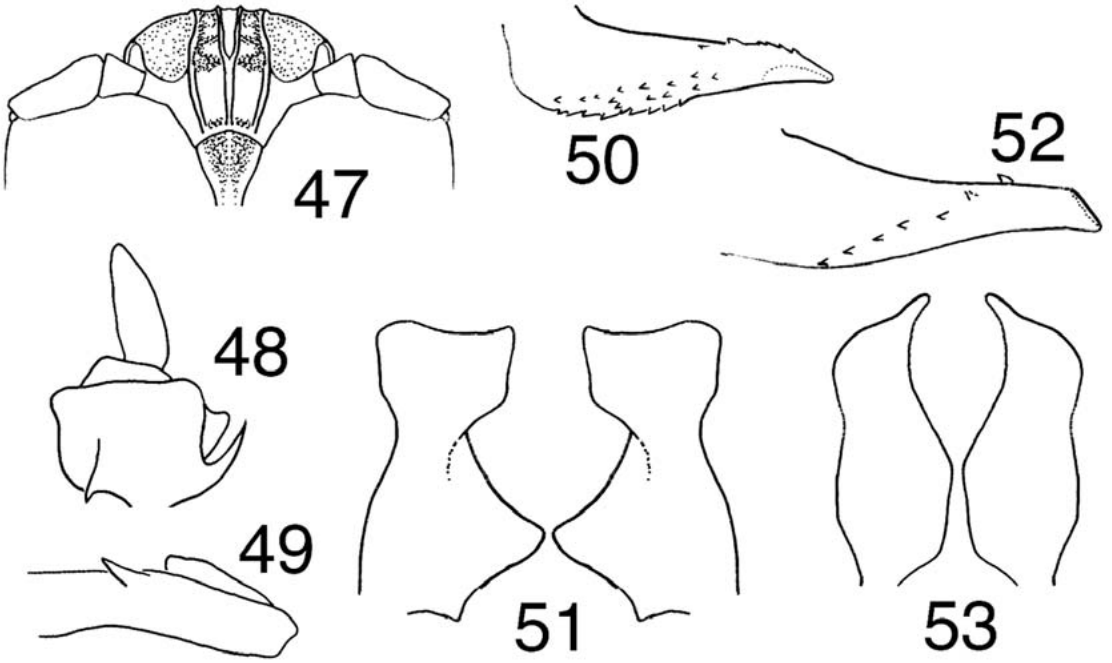
19. Forewings at least twice as long as wide; claval vein extending ca. 2/3 to 3/4 distance to caudal aspect of wing 20
—Forewings broadly triangular, almost as wide as long; claval vein extending almost to caudal aspect of wing (Fig. 18) . . . . . Ricaniidae*

20. Clypeus with lateral carinae; vertex with length more than 1/3 width, frons usually longer than wide and with 1-3 longitudinal carinae . . . . . Lophopidae*
—Clypeus without lateral carinae; vertex with length less than 1/3 width, frons wider than long with obscure median carina or carina absent . . . . . Eurybrachidae

Key to the Economically Important Delphacidae*

1. Hind legs with lateral spines on first (basal) tarsomere (Fig. 19) . . . . . *Nilaparvata*, 2
—Hind legs without lateral spines on first tarsomere (Fig. 1) 6

2. Pygofer with process on ventral margin (Figs. 20, 24) 3
—Pygofer without processes on ventral margin 4



Figs. 47-53. *Perkinsiella* and *Tagosodes* spp. 47-49. *P. saccharicida*. 50-51. *T. orizicolus*. 52-53. *T. cubanus*. 47: Head. 48: Anal tube. 49, 50, 52: Aedeagus. 51, 53: Styles.

3. Pygofer process with lateral spines (Fig. 20); genitalia as in Figs. 21-23 . . . . . *N. bakeri* (Muir)
—Pygofer with three small processes without lateral spines (Fig. 24);
genitalia as in Figs. 25-27 . . . . . *N. muiri* China

4. Anal tube with elongate spines; styles not bifurcate; genitalia as in Figs. 28-30 . . . . . *N. lugens* (Stål)
—Anal tube with very small upturned spines or lacking spines (Figs. 31, 33) 5

5. Anal tube with very small upturned spines (Fig. 31), aedeagus as in Fig. 32 . . . . . *N. meander* Fennah
—Anal tube lacking spines (Fig. 33), aedeagus as in Fig. 34 . . . . . *N. wolcotti* Muir & Giffard

6. Mesonotum light brown to black with median longitudinal pale stripe;
genitalia as in Figs. 36-46, 50-53 7
—Mesonotum without median longitudinal pale stripe;
genitalia as in Figs. 48-49, 54-75 13

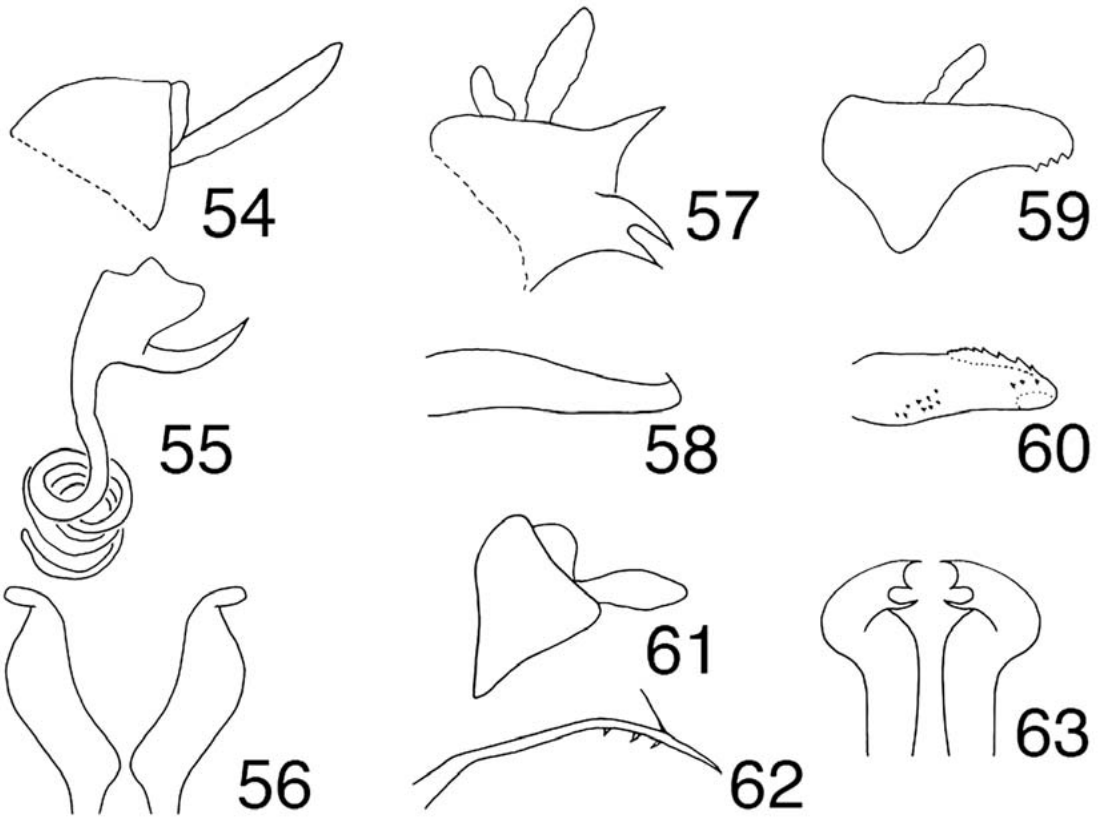
7. Pygofer with diaphragm margin thickened and U-shaped, aedeagus with dorsal
and ventral elongate rows of teeth (e.g., Fig. 37) . . . . . *Sogatella,* 8
—Pygofer with diaphragm margin not thickened and U-shaped, aedeagal teeth,
if present, not arranged as above (e.g., Fig. 50) 11

8. Frons dark brown, carinae often pale (Fig. 35); genitalia as in Figs. 36-38 . . . . . *S. furcifera* (Horvath)
—Frons pale yellow (Figs. 39, 43); if frons brown then styles as in Fig. 46 9

9. Sides of head beneath eyes dark brown (Fig. 39); genitalia as in Figs. 40-42 . . . . . *S. vibix* (Haupt)
—Sides of head beneath eyes pale yellow (Fig. 43) or dark brown;
genitalia as in Figs. 44-46 10

10. Sides of head beneath eyes pale yellow (Fig. 43); forewing without dark marking
at apex of clavus . . . . . *S. kolophon* (Kirkaldy)
—Sides of head beneath eyes dark brown; frons pale or light brown;
forewing with dark marking at apex of clavus . . . . . *S. molina* (Fennah)

11. Frons with median carina forked near ventral aspect of eyes, dorsal half
of frons dark with pale spots, ventral half pale (Fig. 47);
genitalia as in Figs. 48, 49 . . . . . *Perkinsiella saccharicida* Kirkaldy



Figs. 54-63. *Saccharosydne*, *Eoeurysa*, *Caenodelphax*, and *Peregrinus* spp. 54-56. *S. saccharivora*. 57-58. *E. flavocapitata*. 59-60. *C. teapae*. 61-63. *P. maidis*. 54, 57, 59, 62: Anal tube. 55, 58, 60, 63: Aedeagus. 56, 61: Styles.

—Frons with median carina forked near dorsal aspect of eyes, frons not darker dorsally and lighter ventrally . . . . . *Tagosodes*, 12

12. Styles broad at apex, aedeagus with numerous ventral teeth (Figs. 50-51) . . . . . *T. orizicolus* (Muir)
—Styles slender at apex, aedeagus with one row of ventro-lateral teeth on each side (Figs. 52-53). . . . . *T. cubanus* (Crawford)

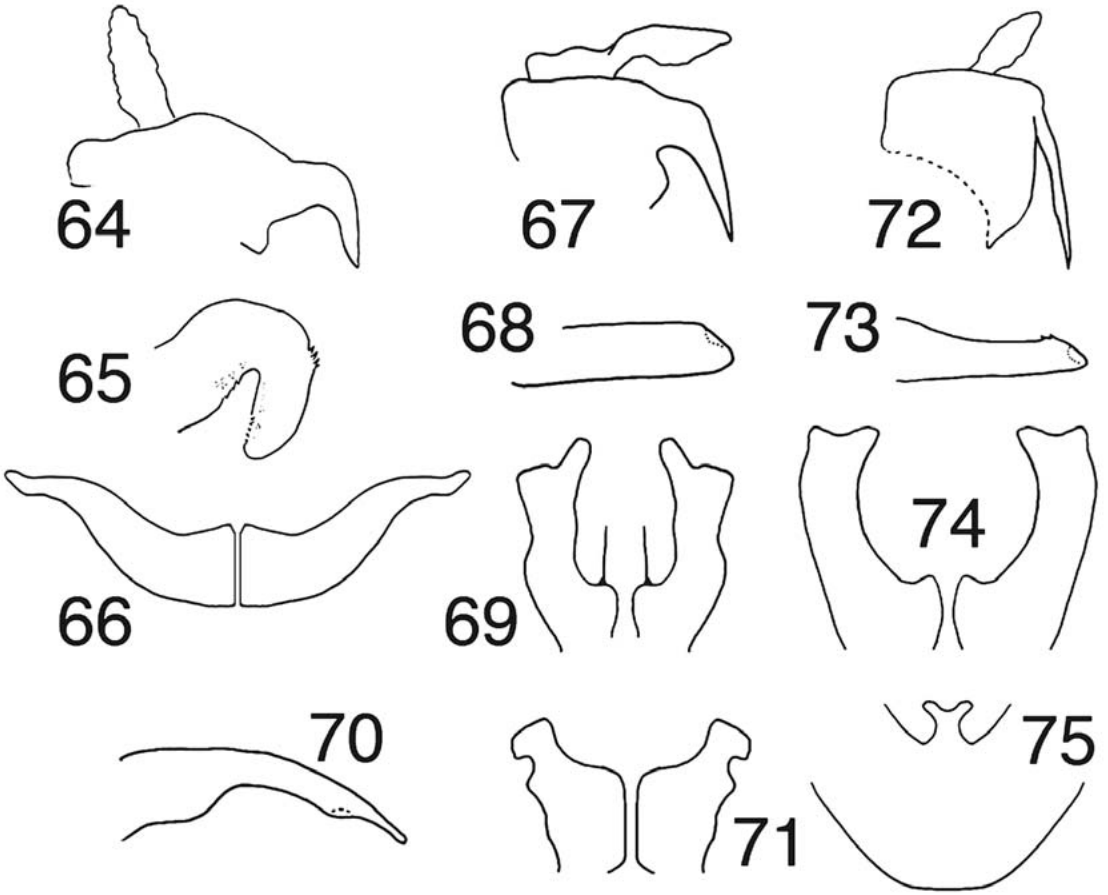
13. Head narrow, produced well beyond eyes; body green to yellow; anal tube without spines, styles with small, apical lobes, aedeagus elongate, ribbon-like (Figs. 54-56) . . . . . *Saccharosydne saccharivora* (Westwood)
—Head broad, not produced much beyond eyes; body not green 14

14. Forewings almost entirely dark black 15
—Forewings clear or with dark markings 16

15. Forewings dark with pale transverse stripe; anal tube with bifurcate posterocaudal spine on each side (Figs. 57-58) . . . . . *Eoeurysa flavocapitata* Muir
—Forewings dark without pale transverse stripe; anal tube with minute teeth on posterocaudal aspect (Figs. 59-60) . . . . . *Caenodelphax teapae* (Fowler)

16. Forewings with dark markings in apical half; aedeagus slender with spine-like dorsal projections (Figs. 61-63) . . . . . *Peregrinus maidis* (Ashmead)
—Forewings without dark markings in apical half; aedeagus not as above 17

17. Styles splayed laterally; aedeagus bent strongly ventrally (Figs. 64-66) . . . . . *Javesella pellucida* (Fabricius)
—Styles oriented dorsoventrally; aedeagus directed caudad 18



Figs. 64-75. *Javesella*, *Harmalia*, *Laodelphax*, and *Toya* spp. 64-66. *J. pellucida*. 67-69. *H. anacharsis*. 70-71. *L. striatellus*. 72-75. *T. propinqua*. 64, 67, 72: Anal tube. 65, 68, 70, 73: Aedeagus. 66, 69, 71, 74: Styles. 75: Diaphragm armature of pygofer, caudal view.

18. Styles each with elongate rounded process at apex; aedeagus without dorsal teeth (Figs. 67-69). . . . . *Harmalia anacharsis* Fennah
—Styles each without elongate rounded process at apex 19

19. Mesonotum black; aedeagus curved ventrally (Figs. 70-71) . . . . . *Laodelphax striatellus* (Fallen)
—Mesonotum light brown to straw yellow; aedeagus straight with minute dorsal teeth near apex; pygofer with "y-shaped" dorsal armature (Figs. 72-75) . . . . . *Toya propinqua* (Fieber)

Note—to ensure accurate species identification always compare the dissected male genitalia with illustrations in the appropriate publications.

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