External Morphology of Adult Leafhoppers of the Genus Scaphoideus

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ABSTRACT

The external morphology of leafhoppers in the genus *Scaphoideus* is treated. Morphology of the external sclerites and their terminology is discussed and illustrated. The literature pertaining to the origin, morphology, and terminology of the head sclerites and genital structures is treated in detail.

INTRODUCTION

Few general works treat the external morphology and terminology of members of the Cicadellidae (DeLong 1926; Evans 1946a, 1947b, 1957; Oman 1949), but complete and intensive studies of the external morphology are few. Further, some confusion exists in the terminology applied to various structures. Earlier, considerable weight was placed on information drawn from morphological studies on related families, especially the Cicadidae. Unfortunately, the transfer of information from related families was not always reliable as Orian (1964) noted after completing work on the morphology of Abricta ferruginosa. (Homoptera: Cicadidae). Also. there is considerable variation or modification of structures within the family Cicadellidae.

Most authors, in trying to find a common morphological basis among the orders of insects and an explanation of the extremely diversified structures present, have suggested a change in the morphological nomenclature. Hence a diverse set of terminology exists. The terminology in this paper follows that of the majority of workers currently treating species of cicadellids or favors terminology in use by morphologists. Alternate terms for many structures are also included.

MATERIALS AND METHODS

Material for study was collected in Kentucky. Various combinations of water, ethyl alcohol, and ethyl ether were tested

as the clearing solution. The following solution was best and consisted of 5 ml of ethyl ether, 50 ml of 70 percent ethyl alcohol, and 50 g of potassium hydroxide. The specimens were placed in the clearing solution until clear and the viscera and muscle were soft, about 20-40 min. Then the head and abdomen were disjointed from the thorax. Seventy percent alcohol was jetted into the head, thorax, and abdomen with a hypodermic syringe to remove the softened contents. The clearing solution was withdrawn, and the cleared material washed twice with distilled water. Then the prepared insect material was transferred to glycerine for study. The various structures were illustrated using a projecting microscope.

Musculature was studied by dissecting fresh material and examining stained serial sections.

RESULTS AND DISCUSSION

The head in dorsal aspect exhibits the triangular crown and posterolateral compound eyes (Fig. 1). The crown may be pointed or rather bluntly pointed, and the anterior crown margin in lateral aspect usually is rather sharply angled, but in certain species in the oriental region the anterior margin may be rounded, approaching the condition in the genus *Osbornellus*. In lateral view, the dorsal margin of the head is not completely flat (Fig. 2). A single ocellus is situated on the crown margin near each compound eye. The ocelli may be large (0.16 mm) or small (0.04 mm). A coronal suture originates at the



FIGS. 1–9. General morphology of Scaphoideus (Scaphoideus) titanus. 1. Head and thorax, dorsal aspect. 2. Head and thorax, lateral aspect. 3. Antenna, dorsal aspect. 4. Head, anterior aspect. 5. Labium, ventrolateral aspect. 6. Left mandible, lateral aspect. 7. Apex of mandible, lateral aspect. 8. Maxilla, lateral aspect. 9. Apex of maxilla.

posterior center of the crown and extends about half the distance to the anterior margin where it divides and each arm turns laterally. The antennae are setaceous and long (Fig. 3). The scape is cup shaped and frequently ornamented with scale-like sculpturing (Fig. 3). A single seta is present on the first, second, and third flagellar segments. Sensory structures as noted by Hansen (1890) were not found. The face is composed of a median frontal area, clypeal regions, and lateral to the clypeal regions, the "lorea" and genae (Fig. 4). The postclypeus is separated from the anteclypeus by a "transclypeal suture," a segment of the epistomal suture. The epistomal suture originates at the anterior tentorial pits and delineates the lorae, joins the anteclypeal sutures laterally near the ventral portion of the anteclypeus, and proceeds dorsally to the "transclypeal suture." In contrast, Kramer (1950) illustrated Aulacizes irrorata and showed the epistomal suture as originating at the frontal sutures. However, the lorae have been variously interpreted. Evans (1946a, 1946b) and Kramer (1950) interpreted the lorae as parts of the clypeus; later Evans (1957) called them paraclypeal lobes. Snodgrass (1938, 1944) and Butt (1943) interpreted the lorae as a part of the hypopharynx. But Pesson (1951), using nerve innervation and embryological evidence, refuted that association. Arora and Singh (1962) stated that the lorae were composite plates formed by the fusion of clypeal, tritocerebral, and mandibular parts. In the genus Scaphoideus, the lorae are continuous with the genae. The frontal sutures extend dorsally from the lateral margins of the transclypeal suture to near the antennal sockets where they become somewhat indistinct. They appear to pass the antennae medially and continue to the ocelli where they divide and pass on either side of each ocellus becoming indistinct after passing over the anterior crown margin. Hence, the crown appears to be composed of portions of the frons and vertex. The most lateral areas of the face are the genae. Cogan (1916) indicated that the area was

an amalgamation of genae and maxillary plate. However, no exact demarkation is visible anteriorly. The anterior tentorial pits are low on the face. The epistomal suture on leaving the anterior tentorial pit dips nearly to the ventral margin before joining the frontal suture, suggesting that most if not all lateral portions of the face are genae. DuPorte (1962) illustrated the genae as being shortened as the tentorial pit and genital suture of the Cicada rose. However, in Scaphoideus it seems to be lowered, considerably elongating the genae. The proximal portion of the maxillary stylets are associated with the maxillary lever, the anterior tentorial pits, and hypopharyngeal wings, and not with the lateral portions of the face. Hence, those areas are designated genae. The maxillary stylet has 2 protractor muscles (Arora and Singh 1962) inserted at the ventral margin of the face and immediately adjacent to the anteclypeus. There is no demarkation between genae and maxillary plate on the face, but certainly the maxillary plate is reduced and restricted to a small area ventrally, if present at all anteriorly. Posteriorly, a median suture divides the upper genal portion from what may be the maxillary plate ventrally. Pits on the genae are represented internally by tube- or saclike structures of unknown function. Those saclike structures are heavily sclerotized and appear to bridge the anterior and posterior surfaces. The labium consists of 4 segments, the most apical of which bears several distal setae (Fig. 5). The mandibles (bristles or stylets) are extremely long, thin, laterally flattened, and expanded proximally (Fig. 6). The distal tenth is dentate (Fig. 7). The maxillae are similar to the mandibles but are hooked distally (Figs. 8, 9). The labrum is triangular and reduced (Fig. 10). Cogan (1916) referred to that structure as the epipharynx. However, the epipharynx probably is very reduced and coalesced to the posterior region of the labrum.

The pronotum is sublunate in dorsal view (Fig. 11). Laterally, the episternum is undivided (Fig. 12). The prosternum is



LABRUM AND ANTECLYPEUS





VENTRAL ASPECT

VENTRAL ASPECT





RIGHT PLEURON, SECOND THORACIC SEGMENT, LATERAL ASPECT

FIGS. 10–16. External morphology of Scaphoideus (Scaphoideus) titanus. 10. Labrum and anteclypeus, dorsal aspect. 11. Notum, first thoracic segment, dorsal aspect. 12. Right pleuron, first thoracic segment, lateral aspect. 13. Sternum, first thoracic segment, ventral aspect. 14. Notum, second thoracic segment, dorsal aspect. 15. Right pleuron, second thoracic segment, lateral aspect. 16. Sternum, second thoracic segment, ventral aspect.



FIGS. 17-20. External morphology of Scaphoideus (Scaphoideus) titanus. 17. Second thoracic segment, posterior aspect. 18. Notum and pleuron, third thoracic segment, dorsoposterior aspect. 19. Front wing. 20. Hind wing.

deeply excavated anteriorly and much reduced (Fig. 13). The shape of the prosternum varies considerably in cicadellid genera and is triangular in *Idioscopus clypealis* (Srivastava 1958).

The mesonotum is dorsally rhomboid and incised anterolaterally by the parapsidal suture (Fig. 14). The prescutoscutal suture is anterior to the parapsidal suture and completely separated from it, a condition known to occur in the genus *Aulacizes* (Matsuda 1970). A central median scutal suture originates anteriorly and extends about one-third of the distance to the posterior apex. The transverse suture separates the scutum from the scutellum. A depressed lateral extension of the scutellum forms the tergal wing groove.

The mesothoracic segment in lateral view exhibits the dorsal outline as 2 convex areas (Fig. 15). The episternum is about as large as the epimeron and is more dorsal. The tegula is nearly the same size and form as the prealar sclerite and both are long thin sclerites that are oriented vertically. The mesosternum is 3 times the size of the prosternum and is somewhat rectangular with the lateral margins projected to points (Fig. 16). Internally, the mesothorax is incised dorsally by the phragma which occupies about half of the cavity (Fig. 17). The dorsal pleural apophysis nearly joins a lateral extension of the phragma. The ventral pleural apophysis joins the well-developed Y-shaped furca.

The metathoracic segment is oriented in a nearly vertical plane and is best seen in caudal aspect (Fig. 18). The metascutum and postnotum are subrectangular. Many areas of the metathoracic segment become membranous and are difficult to distinguish. The metascutum usually has 2 caudoventral processes. The pleural sclerites are much narrowed and somewhat indistinguishably fused to each other and to the metanotal sclerites.

The venation of the mesothoracic wing (Fig. 19) and metathoracic wing (Fig. 20) are relatively similar for all species in the genus. In the mesothoracic wing, the costa and subcosta are fused and have trans-

verse ridges on the distal three-fourths. The radius divides in the distal third into R_2 , R_3 , R_4 , and R_5 , or R_5 may join M for a short distance before it separates from M. R_5 may or may not reach the wing margin. R_2 , R_3 , R_4 , and R_5 are often termed reflexed veins. The first and second r-m veins are present. The medius separates from Cu_1 in the proximal fourth of the wing and continues unbranched to the wing margin. Cu₁ parallels Cu₂ and divides into Cu_{1a} and Cu_{1b} in the distal fourth of the wing. Cu_{1a} turns anteriorly, closes the distal end of the Cu_1 cell, touches M, and turns sharply to the posterior. Cu_{1b} joins Cu_2 at a right angle. Cu_2 (claval vein or suture) is unbranched. There are 2 anal veins (claval veins of some homopterists); 1A may be branched, but usually neither branch reaches the wing margin. The appendix is well developed. The posterior wing margin is commonly called the commissural vein or line. An earlier terminology existed and is as follows: R before it branches was designated the first sector by some workers, and R was often called the outer branch of the first sector after the juncture of the r-m crossvein. M was called the inner branch first sector after the juncture of the r-m crossvein and the second sector before the juncture of the r-m crossvein. The first R₃ cell was known as the outer anteapical, the first R_5 as the central anteapical cell, and the second M as the inner anteapical cell. Cu_{1a} was known as the first apical cell. The third M cell was called the second anteapical cell. The second R₅ cell was termed the third anteapical cell and the second R_3 cell, the fourth anteapical cell. The Cu₁ cell was sometimes designated the brachial cell.

In the metathoracic wing, the costa and subcosta are fused. R branches in the distal third into R_{2+3} which zigzags to the anterior margin and R_{4+5} which proceeds to the wing apex. The medius divides in the midportion of the wing into M_{1+2} and M_{3+4} and both extend to the apex. Cu₁ and Cu₂ are undivided. Cu₂ is considerably enlarged apically. The anal vein is divided medially, and 1A is thickened; 3A is pos-



MALE ABDOMEN, VENTRAL ASPECT

FIGS. 21-25. External morphology of Scaphoideus (Scaphoideus) titanus. 21. Right leg of third thoracic segment, ventral aspect. 22. Right leg, first thoracic segment, posterior aspect. 23. Right leg and pleuron, second thoracic segment, lateral aspect. 24. Male abdomen, dorsal aspect. 25. Male abdomen, ventral aspect.

terior to the anal fold, undivided, and does not reach the wing margin.

The leg consists of the coxae, trochanter, femur, tibia, 3 tarsal subsegments, pretarsus, pulvillus, and 2 claws (Fig. 21). The procoxae are rather cylindrical, but the mesocoxae and metacoxae are quadrate, and flattened against the ventral body surface (Figs. 22, 23). The trochanter is subtriangular and ventral to the coxae and femur. The hind femur is long with the hind femoral setal formula 2-2-1. The tibia is about twice the length of the femur and has 4 rows of setae, most of which are sculptured. There are platellae at the apex of the tibia and at the apices of the 3 tarsal subsegments. The numbers of platellae are intraspecifically and bilaterally variable. The tarsi may or may not have setae. A short pretarsus is present from which originates apically 2 simple unornamental claws (ungues). A bilobed pulvillus without setae is present.

The abdomen joins the thorax narrowly, then expands immediately and appears broadly joined. The abdomen continues to increase in width and height to a little before the middle, where it decreases in both height and width to the caudal apex. A cross section has a semicircular outline. The terga are arched and form the dorsal and lateral sides; the laterotergites and sterna are flat and form the ventral side of the semicircle. The lateral edges of the terga are bent slightly dorsad before joining the sterna or the laterotergites. The first and second abdominal terga are minute. In dorsal aspect, the first abdominal tergum is divided into 2 pieces, the first diamond shaped (Fig. 24), and the second transversely rectangular with 2 small anterior projections. The second abdominal tergum is a close reproduction of the second piece of the first abdominal tergum. The third abdominal tergum is broadly rectangular and each successive tergum to the eighth is progressively more quadrate except for the female eighth tergum which usually is triangular.

The laterotergites are absent from abdominal segments 1 and 2 (Fig. 25); however, a pair of spiracles is present in the membranous region where they would be situated. The third abdominal segment usually has an undivided laterotergite, but segments 4 through 8 have the laterotergite divided into 2 pieces. The most lateral piece of the laterotergites is the largest and contains the spiracle in the caudal portion. Spiracles are present in laterotergites 4 through 7.

Abdominal sterna 1 and 2 are transversely oriented and extremely long and thin. Sterna 3 through 8 in ventral aspect follow the same form as terga 3 through 8. A cluster of small setae usually is present on the third sternum. The female eighth sternum usually is triangular and fitted into a pocket dorsal to the seventh sternum.

The male genitalia were discovered to be of considerable taxonomic value in the Cicadellidae in the early 1900's. Until that time, little morphological work had been completed on the genitalia of the group and only a few structures had terms assigned to them. Taxonomists adopted the few terms available and/or proposed new terms. Generally, taxonomists did not complete extensive morphological, embryological, or comparative studies. Consequently, homologous terms did not always agree with homologous structures. The confusion was amplified by diverse terms applied to the same structure, or further compounded by designating 2 different structures by the same name. Newell (1918) attempted to clarify the situation for the various orders of insects, and Kershaw and Muir (1922) and Singh-Pruthi (1925) did the same for the auchenorrhynchous Homoptera. Tuxen (1970) listed the various terms applied to genital structures. Considerable controversy existed earlier as to the origin of the genital structures and, consequently, their terminology. Many workers argued that the genital structures were of appendicular origin, others that they were a combination of appendicular and adjacent segmental papillae. Still others believed that genital structures were outgrowths of the sterna. Excellent reviews of the proponents of each



FEMALE GENITALIA, VENTRAL ASPECT

FIGS. 26–36. Morphology of genital structures of several Scaphoideus species. 26. Male pygofer, lateral aspect. 27. Right plate, ventral aspect. 28. Right plate, ventral aspect. 29. Right style, ventral aspect. 30. Right style, ventral aspect. 31. Connective and paraphyses, ventral aspect. 32. Connective and paraphysis, lateral aspect. 33. Aedeagus, lateral aspect. 34. Aedeagus, lateral aspect. 35. Aedeagus, lateral aspect. 36. Female genitalia, ventral aspect.

theory and their individual terminologies were given by Nel (1929), Gustafson (1950), Matsuda (1958) and Scharov (1966). However, application of the proper terminology depends upon homology which probably can best be derived and interpreted from comparative morphology as observed during embryology and/ or preadult development. Until recently, most terminology inferences were drawn from the study of adult specimens. Smith (1969) suggested that the components of the external genitalia of both sexes of ectognathous insects are homologous in all orders and that the genitalia consist of presumed telopodites or for males perhaps exites of the genital coxopodite. But Helms (1968) determined that the genital structures of Empoasca fabae (Homoptera: Cicadellidae) were of sternal origin. He found that primary phallic rudiments in the center of the ninth sternum began to differentiate during the third and fourth stadia into 2 pairs of structures. The lateral structures became the style rudiments, and the median pair of structures became fused on their dorsal and ventral margins to form the aedeagal rudiment. The connective (first phallobase) was not discussed by Helms, but from the position of the rudimentary styles, aedeagus, accessory glands, and ejaculatory duct, it seems reasonable that the connective is of sternal origin, perhaps formed from the rudimentary median mesomeres. The same possibly is true of the paraphyses (= parameres of some)authors) which are paired distal structures associated with the connective and aedeagus. Other studies (Kershaw and Muir 1922, Singh-pruthi 1925, George 1928, Metcalf 1932, and Dupis 1949) showed the same kind of development in members of the auchenorrhynchous Homoptera. Studies in most other orders of insects have indicated that the genitalia are of sternal origin (see Matsuda 1958, Smith 1969, and Snodgrass 1963 for references concerning the other orders and the exceptions that exist).

In members of the genus *Scaphoideus*, segments 9 through 12 in the male and 8

through 12 in the female are modified into genital or anal structures. The male external terminalia, commonly called the genital capsule (Fig. 26), are composed of a pygofer formed of 2 large lateral pieces connected by a dorsal bridge, a ventral valve (hypandrium of Crampton 1922), and 2 apical ventral plates (hypovalves) that are mirror images. The lateral walls of the pygofer have a narrow membranous suture from the anterior ventral margin to the middle of the pygofer along an imaginary line from the anterior ventral corner to near the dorsal posterior margin. Setae on the pygofer and plates frequently are sculptured. Spines occur ventrocaudally on the pygofer in some species. The number of setae on structures on the right half of the individual may differ from the left. Frequently, the pygofer apex has 2 tufts of large long setae. The anterior margin of the male plate is membranously attached to the posterior margin of the valve, and the anterolateral apex of the plate is articulated to the lateral apex of the valve. The plates may be bluntly rounded (Fig. 27) or rather sharply pointed (Fig. 28). The valve also is articulated to the pygofer anterolaterally and is obtusely triangular. The male internal genitalia are partially enclosed by the pygofer, valves, and paired plates, and are composed of the paired styles, paraphyses, anal collar, a connective, and an aedeagus. The anal collar may be broad or narrow and is situated in the caudal membrane of the pygofer. The anal collar extends from near the dorsal margin to a little below the middle of the pygofer. The connective is almost entirely internal. The styles are anteriorly internal and caudally external. The aedeagus is external. The styles may be long and attenuated or short and bluntly pointed and broad or narrow at the base (Figs. 29, 30). Setae are present on the styles of some species. The connective is always bifid anteriorly and may be bifid posteriorly. In species that have the connective fused to the paraphyses, the bifid nature of the connective is often indistinguishable (Fig. 31). Dorsal apodemes usually are present on the

connective and sometimes are greatly extended (Fig. 32). The connective is a sclerotized shaft articulated with the styles anterolaterally and fused or articulated posteriorly with the paraphyses. The paraphyses may be small and membranous or large, well sclerotized, and heavily tanned (Fig. 31). They are almost entirely external. The paraphyses are the most specifically unique structures in the genus and take numerous forms distinct for each species. The aedeagus is free and attached only membranously to the connective. The caudal apex of the aedeagus usually is expanded laterally sometimes into spine-like processes. The aedeagal shaft may be long and narrow or short and enlarged (Figs. 33, 34). The dorsal apodeme (paired or double paired) and the preatrium may be pronounced or reduced. A few species have atrial rim processes (Fig. 35). The gonopore is apical on the aedeagus. There appears to be no endotheca or endophallus in species of this genus.

The female external genitalia include segments 8 and 9 (Fig. 36). Segment 8 consists only of a cone-shaped tergum commonly called the pygofer. The ovipositor is fitted into a small narrow ventrocaudal slit in the pygofer. The pygofer tapers to a caudal apex with only the ovipositor in its circular form. The ovipositor is approximately the same width over its entire length and narrows only at the apex.

The ovipositor consists of 3 pairs of valvulae numbered I, II, and III. Valvulae II are innermost and are fused to the valvifer attached to the anterior ventral pygofer. Valvulae I surround Valvulae II in lock-and-key fashion and form the cylindrical tubelike ovipositor sheaths. Valvulae I are membranously attached to the eighth sternum. No valvifer is distinguishable. Valvulae III are much broader than Valvulae I or II and usually bear a group of minute setae on the caudal fifth. Valvulae III are attached to the posterior of the triangular valvifer which is articulated medially to the pygofer and anterolaterally to Valvulae II. The apical two-fifths of Valvulae II are slightly enlarged and bear dorsally a number of teeth near the apex. A single isolated tooth is near the middle. In most species, internal ducts are visible in the caudal portion. The rami of Valvulae I and II are curled dorsally. The ovipositor usually extends beyond the pygofer.

The anal tube is composed of 3 segments, 10, 11, or 12 in both sexes near the dorsal apex of the pygofer. The tenth segment is tubular, and may or may not be divided dorsally. The eleventh segment usually is divided into an anterior and posterior section. The posterior section consists of 2 pairs of oval pieces laterally. The twelfth segment (the telson or anal papilla of Britton 1923 or anopapilla of Crampton 1922) is elongate and is called the flicker by some homopterists. It bears the anal opening or anolabii as a dorsal slit. Usually, the anal slit is flanked laterally by small setae and bears several long setae apically.

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