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Antennal Sensory Plaque Organs of the Delphacidae (Homoptera: Fulgoroidea)【Research report】

稻蝨科之觸角瓦楞感覺器（同翅目：蠟蟬總科）【研究報告】

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Abstract

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摘要

本文藉由掃描式電子顯微鏡共檢查稻蝨科81屬104種之觸角瓦楞感覺器，得知稻蝨科觸角瓦楞感覺器的瓦楞突起外形一致，透過錐狀突起的形態可發現瓦楞感覺器共有四型，它們的進化趨勢推論為第一→二→三型和第一→二→四型。

Key words: Homoptera, Fulgoroidea, Delphacidae, antennae, sensory plaque organs.
關鍵詞: 同翅目、蠟蟬總科、稻蝨科、觸角、瓦楞感覺器。

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Antennal Sensory Plaque Organs of the Delphacidae (Homoptera: Fulgoroidea)

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ABSTRACT

Scanning electron microscopy was used to examine the antennal sensory plaque organs of 104 species in 81 genera of Delphacidae. The plaques have the same external morphology in all examined Delphacidae. Four types of sensory plaque organs are recognized based on the morphology of the denticle, and the evolutionary trends are proposed as Type 1→Type 2 →Type 3 and Type 1→Type 2→ Type 4.

Key words: Homoptera, Fulgoroidea, Delphacidae, antennae, sensory plaque organs.

Introduction

Past investigations have suggested that the sensory plaque organs on fulgoroid antennae have strong variations occurring among or even within different families (Marshall and Lewis, 1971; Bourgoin and Deiss, 1994; Cheng and Yang, 1996). Therefore, these researchers believed that the sensory plaque organ characteristics (e.g. morphology of the denticle or plaque) have potential value for classification, and determining the phylogeny among the 20 Fulgoroidea families. Generic or fragmentary information on this topic has been furnished by Marshall and Lewis (1971), Aljunid and Anderson (1983), and Bourgoin and Deiss (1994). Bourgoin and Deiss (1994) described that each denticle of the sensory plaque organs in *Sogatodes cubanus* (Crawford) was pyamidal. Up to now, there has not been enough data to indicate that the sensory plaque organs have structural variations in Delphacidae.

The objectives of this paper are to describe the different types of antennal sensory plaque organs in the Delphacidae, and to discuss their diversity and value for hypothesizing relationships among different types.

Materials and Methods

The investigations were carried out on 104 species in 81 genera of Delphacidae by scanning electron microscopy (see Table 1 for a list of taxa examined). All the examined specimens, including males or females were placed in small vials containing 70% ethanol where they remained for at least 1 h. Whole adults became translucent in 10% KOH after 15 min at 60 ℃, after which their antennae were removed in 70% ethanol and cleaned by sonification for about 15-20 sec.

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Table 1. Sensory plaque organs of Delphacidae.

Subfamily Species (number examined)	Type (Subtype)	SPO No.	SPO Duam. (μm)	Denticle No.	Plaque No.
Asiracinae					
Ugyops pelorus Fennah (1)	1(1)	30−33	32.5−51.0	9−15	21−51
Ugyops caelatus (White) (1)	1(1)	39−43	34.5−50.0	10−15	18−52
Ugyops tripunctatus Kato (4)	1(1)	56−61	41.0−53.2	12−19	20−46
Delphacinae					
Delphax pulchellas (Curtis) (2)	1(1)	33−40	37.0−55.4	8−14	52−70
Specinervures liguida Yang and Yang (2)	1(2)	7−10	10.8−20.0	3−6	6−12
Bambusiphaga taiwanensis (Muir) (10)	1(2)	11−14	14.5−25.3	4−7	6−16
Eoeurysa flavocapitata Muir (3)	1(2)	12−15	18.9−29.9	4−6	13−27
Muellerianella brevipennis (Boheman) (3)	1(2)	13−15	20.8−34.8	5−10	8−36
Neometopina penghuensis Yang (2)	1(2)	14−16	28.9−34.6	6−7	18−30
Sogata hakonensis (Matsumura) (2)	1(2)	13−15	19.2−27.2	4−6	13−27
Stenocraninae					
Anypanconium auranitiacum Dlab. (2)	1(2)	13−15	24.6−30.6	6−7	11−20
Asiracinae					
Idiosystatus acutiusculus (Spinola) (3)	2	36−40	24.0−29.9	5−9	10−21
Asiracinae					
Asiraca clavicornis (Fabricius) (3)	3	18−23	32.4−54.4	10−15	18−35
Kelisiinae					
Anakelisia perspicillata (Boheman) (2)	4	13−16	26.4−31.2	6−10	14−23
Kelisia brucki Fieber (1)	4	16−19	23.5−30.5	7−8	16−24
Kelisia perrieri Ribaut (2)	4	16−19	30.3−33.8	6−9	15−19
Stenocraninae					
Stenocranus matsumurai Metcalf (2)	4	28−35	23.5−42.7	8−11	22−36
Stenocranus apamopsyche Kirkaldy (1)	4	27−30	25.6−36.7	6−9	17−28
Stenocranus longipennis (Cortis) (2)	4	19−23	23.8−31.7	6−9	15−32
Delphacinae					
Tsaurus dentatus Yang (1)	4	15	28.4−37.2	6−8	20−33
Vizcaya sp. (1)	4	68−70	29.6−65.2	9−13	16−31
Tropidocephala maculosa Mats. (3)	4	7−9	24.5−30.2	6−11	6−18
Chlorionidea bromi Emeljanov (2)	4	8−9	24.0−28.0	7−8	22−36
Formodelphax confusus Yang (2)	4	9	20.6−32.4	3−7	8−20
Epeurysa ramanei Asche (2)	4	9−10	17.5−28.2	5−6	9−14
Saccharosydne ornitapennis Muir (2)	4	9−12	20.0−37.5	4−10	13−22
Malaxa herioca Yang (2)	4	10−11	22.7−28.0	5−9	12−24
Coronacella sinhalana (Kirk.) (2)	4	10−14	21.6−28.4	5−8	10−18
Formodelphax formodus Yang (1)	4	11−12	20.5−28.0	3−6	10−18
Proscopus tricoloratus (Dlab.) (3)	4	10−12	16.8−30.2	5−9	22−33
Saccharosydne procerus (Mats.) (2)	4	11−12	27.5−44.0	4−9	8−20
Thymalops anderida (Kirk.) (2)	4	11−13	17.5−19.2	5−8	12−22
Unkanodes sapporona (Mats.) (3)	4	11−13	25.7−33.6	8−10	16−27
Garaga nagaragawana Mats. (1)	4	11−12	21.6−30.5	6−9	25−30
Garaga orchidensis Yang (3)	4	11−13	23.8−32.8	6−8	23−32
Hagamiodes limosugs Yang (3)	4	12−14	17.2−20.7	5−7	10−20
Laodelphax straitellus (Fallen) (3)	4	12−15	20.0−26.7	5−8	22−32

Table 1 (Continued)

Muellerianella extrusa (Scott) (2)	4	11−14	20.5−38.2	4−9	15−38
Neoconon incensa Yang (2)	4	11−14	20.5−30.4	6−7	20−28
Nycheuma coronata Asche (1)	4	12−13	33.0−42.3	5−10	5−48
Parametopina yushaniae Yang (3)	4	11−13	26.8−38.3	8−12	24−37
Sogatella furcifera (Horvath) (2)	4	12−13	23.6−32.8	8−10	22−33
Smicrotatodelphax marilimus Yang (3)	4	12−14	9.1−22.3	5−8	8−18
Belocera sinensis Muir (2)	4	12−14	30.6−40.2	7−16	25−55
Smicrotatodelphax paupaucus Yang (1)	4	13−14	12.5−23.1	6−9	11−22
Cemus punctatus Yang (2)	4	10−13	22.7−38.5	6−9	15−36
Nycheuma coctum Yang (2)	4	12−13	31.7−48.5	5−10	12−36
Eoeurysa ribauti Lbg. (3)	4	12−14	19.5−46.7	5−8	13−19
Falcotoya formosana Yang (2)	4	13−14	14.6−18.7	3−6	8−28
Falcotoya shaluensis Yang (2)	4	13−14	12.7−21.5	4−8	14−26
Hyledelphax elegantulus (Bohem) (2)	4	12−13	27.5−40.6	7−9	30−38
Latistria eupompe (Kirk.) (2)	4	11−13	27.5−31.2	7−8	17−23
Numata corporaalli (Muir) (2)	4	11−13	17.1−30.5	5−9	12−28
Sardia rostrata Melichar (2)	4	12−13	29.9−38.1	7−9	>10
Sinolacme sinuosa Yang (3)	4	11−15	25.9−30.1	5−7	15−27
Thymobares longispinus (Muir) (2)	4	11−13	23.4−42.3	7−8	14−30
Eoeurysa lineata Melichar (3)	4	12−14	22.8−39.1	7−10	13−19
Hadeodelphax pluto Kirk. (2)	4	12−14	28.2−36.6	6−9	18−36
Harmalia commelinage Yang (3)	4	14−16	16.3−32.6	5−8	15−23
Muirodelphax anberi (Perr.) (3)	4	12−15	24.6−38.7	7−11	21−37
Syndelphax disonymos (Kirk.) (1)	4	14−15	32.8−49.0	5−8	24−32
Tagosodes incanus (Distant) (2)	4	13−16	20.4−28.8	5−7	12−24
Terthron africanus Asche (1)	4	12−14	21.4−29.5	6−9	24−36
Terthron triandulum Asche (1)	4	11−14	26.5−36.1	5−7	12−30
Toya lazulis (Kirk.) (2)	4	13−14	19.2−35.2	7−11	16−32
Triambus taiensis Asche (1)	4	13−14	14.1−26.5	6−9	21−38
Dicranotropis hamata Bohem. (1)	4	15	20.0−36.0	6−11	22−36
Toya fulva (Yang) (1)	4	15	28.4−38.5	7−12	21−32
Arcofaciella verrucosa Fennah (2)	4	12−16	23.1−28.8	7−10	13−22
Neoterthrona spinosa Yang (2)	4	13−15	20.0−28.7	5−8	13−25
Onidodelphax serratus Yang (2)	4	14−15	15.6−32.4	7−9	23−38
Opiconsiva albicollis (Motschulsky) (2)	4	14−15	18.9−34.4	5−8	20−27
Spinidelphacella hargreavesi (Fabricius) (2)	4	13−16	23.7−36.0	6−9	20−33
Malaxa semifursca Yang and Yang (3)	4	14−16	25.4−30.6	7−11	16−24
Taidelphax chishanensis Yang (3)	4	13−16	16.3−32.6	7−9	16−23
Toya lima Yang (4)	4	13−16	31.3−40.6	8−11	20−34
Yanunka incerta Yang (1)	4	16	20.0−30.5	4−8	17−25
Diodelphax obstipus Yang (3)	4	16−19	16.5−28.7	5−8	20−25
Harmalia heitensis (Mats. & Ishihata) (2)	4	13−16	24.0−33.5	5−9	16−28
Javesella pellucida (F.) (2)	4	16−17	21.6−33.6	6−9	18−32
Megadelphax sordidulus Stal (2)	4	15−18	22.8−39.1	4−9	13−21
Peregrinus maidis (Ashmead) (2)	4	14−17	25.0−39.7	5−11	16−40
Perkinsiella thompsoni Muir (1)	4	16−17	28.2−35.2	6−10	22−32
Sogatodes neomphalus Asche (2)	4	14−17	26.8−36.7	5−8	25−45

Table 1 (Continued)

Ribautodelphax albostriatus (Firber) (1)	4	17−18	20.5−32.3	5−8	8−18
Neodicranotropis trungyaanesis Yang (2)	4	13−18	21.5−37.4	6−11	22−36
Nilaparvata lugens Stal (10)	4	16−17	26.5−35.3	6−9	20−30
Afrocoronacella tuneri (Muir) (2)	4	17−20	28.8−37.5	7−9	15−25
Matutinus yanchinus Khoh (2)	4	16−19	24.0−43.2	7−12	15−35
Purohita sinica Haung and Ding (3)	4	17−22	22.0−30.5	7−17	13−42
Kakuna albipennis (Mats.) (2)	4	16−19	23.8−37.5	6−10	18−25
Florodelphax paryphasma (Flor.) (2)	4	20−23	19.5−34.6	6−9	9−22
Megamelus notula (German) (2)	4	20−24	25.9−37.5	5−9	8−19
Ditropis pteridis (Spinola) (2)	4	23−25	28.0−40.2	4−9	6−32
Ditropis ptericis (Bohem) (2)	4	21−24	21.8−33.9	4−8	8−32
Perkinsiella saccharicida Kirk. (2)	4	22−24	30.8−46.7	6−11	16−34
Caenodelphax teapae Fowler (1)	4	>12	20.4−30.0	5−7	12−25
Epeurysa nenqkaoensis Yang and Yang (2)	4	7−8	10.8−20.4	5−7	9−17
Kormus artimisiae Fieber (1)	4	>10	17.9−33.4	4−8	9−21
Terachiana sagitta Kusnezov (1)	4	>13	22.5−33.4	5−8	12−27
Purohita picea Yang and Yang (5)	4	30−33	24.1−36.8	6−15	16−28
Purohita maculata Muir (3)	4	42−48	12.9−32.5	7−15	17−24
Preterkelisia magnispinosa (Kouh) (1)	4	17−20	20.8−33.8	6−9	20−25
Pseudaraeopus bolivari (Mel.) (2)	4	30−33	14.9−32.8	5−8	8−21

SPO=sensory plaque organs.

The bold type represents the type species.

The antennae were finally dried in an acetone solution on a hotplate at 70℃.

The antennae of specimens were mounted on aluminum stubs by double-sided tape, coated with gold for 3 min in an Eiko EB-2 ion coater and examined under a scanning electron microscope (Hitachi S-570) at an accelerating voltage of 15 kV.

Terminology (Figs. 1-6)

Sensory plaque organ: A kind of sensilla covers the surface of the pedicles of Fulgoroidea. It is composed of the cuticular ring, the denticles, the plate, and the plaques. The term "sensory plaque organs" was first used by Lewis and Marshall (1970). The sensory plaque organ is not plate-form except in Tettigometridae in Fulgoroidea. Therefore, in this paper, we use "sensory plaque organ" instead of the term "sensory plate organs"(Bourgoin and Deiss, 1994).

Cuticular ring: A sclerotized circular area which surrounds the plate for protection.

Denticle: The projectina part of the cuticular ring that it is believed to strengthen the protection.

Plate: The surface of the sensilla which is surrounded by a protective cuticular ring and denticles. In Tettigometridae, the plate is a true flat plate (Bourgoin, 1985; Cheng and Yang, 1996).

Plaque: The projection part of the plate which is innervated by many neurons arranged in groups (Marshall, 1973; Aljunid and Anderson, 1983).

Circular pore: The circular pore in the inner surface of the sensory plaque organ formed by the surface projection of the plate.

Results

There are 3 joint characters of the antennal sensory plaque organs found in all examined Delphacidae (Figs. 1, 4): (1)

Plaques are distributed all over the plate; (2) The external morphology of each plaque is uniform, which is filiform throughout, circular in transverse section, and bluntly pointed at the apex; (3) The inner surface of each sensory plaque organ is composed of a cuticular ring and many circular pores. Hence the sensory plaque organs of the Delphacidae are examined through (1) the lateral view of the denticle, (2) the transverse section of the denticle, and (3) the width of the denticle in outer view. The transverse section of the denticle is drawn through a broken denticle. Based on the observation data, 4 types of antennal sensory plaque organs are recognized as follows. All examined species and their observational data are listed in Table 1.

Type 1 (Figs. 1, 7-1)

Denticle erect throughout, acute and not incurved at apex, its surface nearly smooth; cone-shaped in lateral and outer views, but circular in transverse section.

In the present study, 2 subtypes can be separated based on the number of sensory plaque organs.

Subtype 1: Each pedicel has over 30 sensory plaque organs.

Subtype 2: Each pedicel has less than 16 sensory plaque organs.

Type 2 (Figs. 2, 7-2)

Denticle is erect, bluntly pointed at apex; thin plate-shaped, and having several slight ridges in lateral view; triangular in outer view, very blunt at apex, and having biforked ridges at basal part; asymmetrically notched, not sinuate in transverse section.

Type 3 (Figs. 3, 4,7-3)

Apex of denticle turns to central area of plate; thin fin-shaped plate, bluntly pointed at apex in lateral view, and having several asymmetrically distinct ridges, so appeared slightly skewed; triangular in outer view, sinuate and thin; like a gear notched in transverse section.

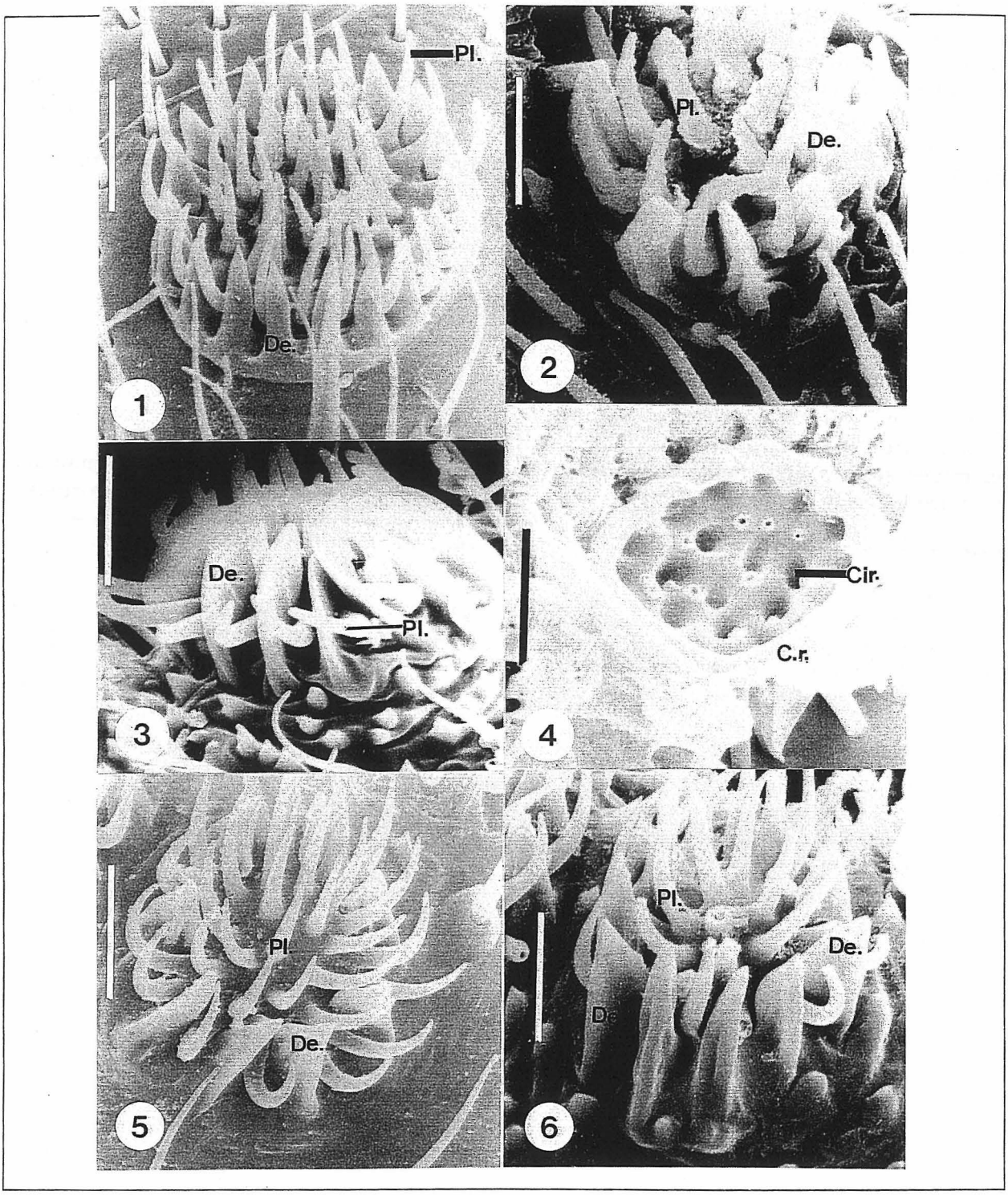
Type 4 (Figs. 5, 6,7-4)

Denticle erect, thin, and acute at apex; having several different thin plate-shaped projections in lateral view, including symmetrically or asymmetrically triangular, pentagonal, and acutely oval ones; each denticle having 0-5 obscurely or distinctly longitudinal ridges on each side, in general, ridges parallel or crossing each other; denticle nearly symmetrically triangular in outer view, symmetrically notched in transverse section.

Discussion

The conical denticle is commonly present in most families of Fulgoroidea (Cheng and Yang, pers. comm.). Yet, the thin, triangular, plate-shaped denticles are only present in Delphacidae and Cixiidae (Shih and Yang, unpublished data). Mayr and Ashlock (1991) pointed out "if one of two homologous characters that occur as variants within a single holophyletic or monophyletic group is also found in the sister group, it is the plesiomorphic character"; and in Wiely's (1981) intra-group repartition criterion, he stated "the ancestral condition is represented by the character that is most widely distributed among related taxa". From this view, the conical denticle which is circular in transverse section should be considered as the primitive character state in Fulgoroidea and the thin plate-shaped denticle which is notched in transverse section is relatively advanced character state.

In this study, all plaques of sensory plaque organs are filiform; the comprising 104 species in 81 genera of the Delphacidae can be separated into 4 types based on the morphology of the denticle from lateral view, transverse section. In type 1, the conical denticle, and circular, laterally unridged transverse section are the primitive character states. In Types 2



Figs. 1 to 6. The sensory plaque organs of Delphacidae. 1. Type 1, *Ugyops tripunctatus* (Kato) (Scale=20.0 mm); 2. Type 2, *Idiosystatus acutiusculus* (Spinola) (Scale=10.0 mm); 3 and 4. Type 3; 3. *Asiraca clavicornis* (Fabricius) (Scale=14.8 mm); 4. The inner surface of the sensory plaque organ of *Asiraca clavicornis* (Fabricius) (Scale=13.6 mm); 5 and 6. Type 4; 5. *Spinidelphacella hargreavesi* (Fabricius) (Scale=15.2 mm); 6. *Kelisia perrieri* Ribaut (Scale=15.2 mm). Cir.=Circular pore; C.r.=Cuticular ring; De.=Denticle; Pl.=Plaque.

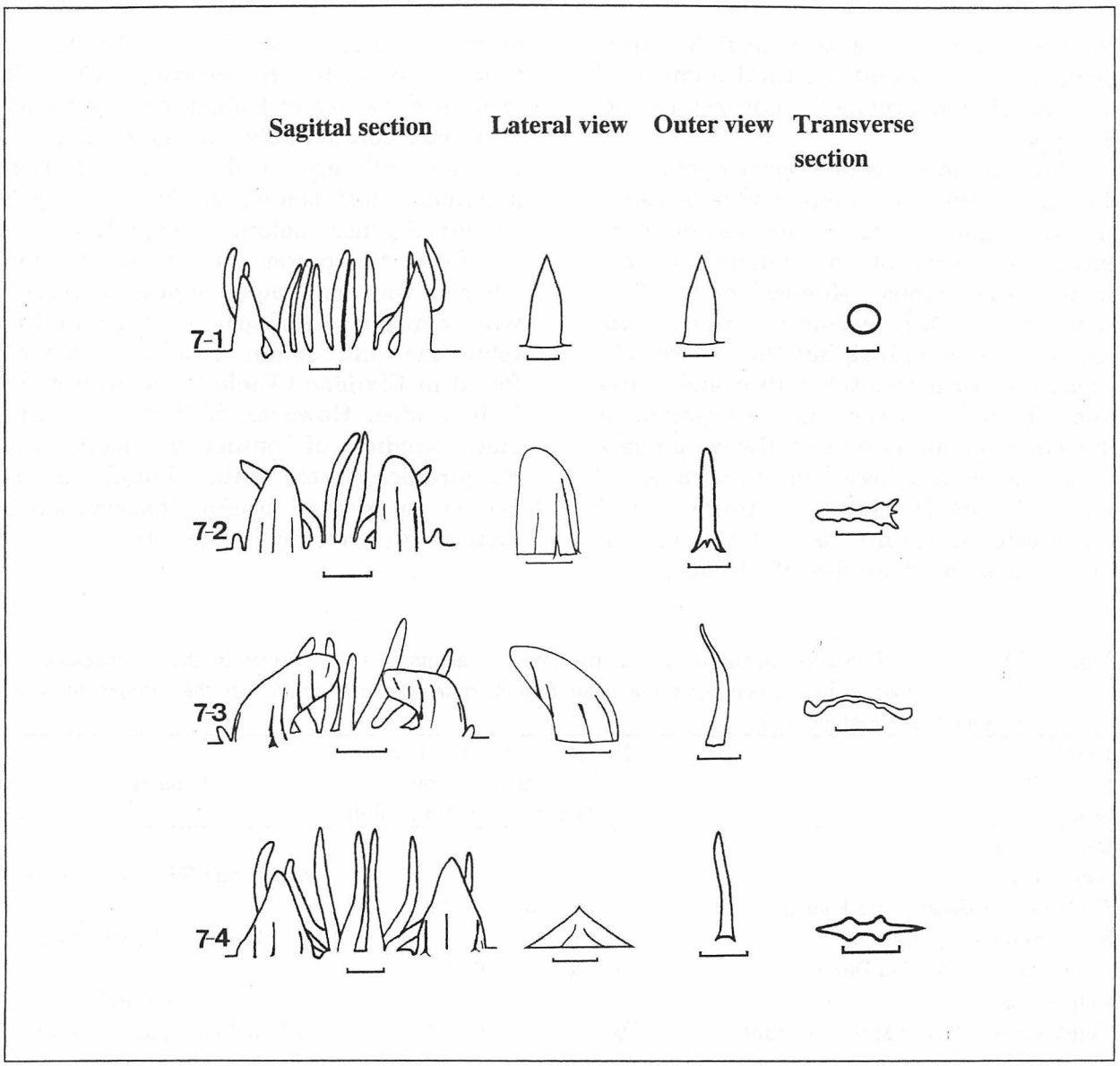


Fig. 7. The sensory plaque organs of Delphacidae. 7-1. Type 1; 7-2. Type 2; 7-3. Type 3; 7-4. Type 4. (Scale=5 mm).

to 4, the plate-shaped denticle, and thin laterally ridged transerverse section are the advanced character states. In Type 2, the denticle in transverse section based on outer portion which is still wider than the inner portion, but in Types 3-4, outer and inner portion is nearly same. In Type 3, the denticle at the apex turns to the central area of the plate; it is like a gear notched in transverse section and transformed from Type 2. In Type 4, the denticle is symmetrically notched in transverse section, which is transformed from Type 2. Base on the above data, the evolutionary trends among the 4 types are proposed to be Type 1→Type 2→Type 3 and Type 1→Type 2→Type 4.

The distribution pattern of sensory plaque organs is related to the total number. For example, in some species which have more than 40 sensory plaque organs, these organs are usually dis-

tributed over the entire pedicle. But, Table 1 indicates that the total number of sensory plaque organs is not related to the types.

Furthermore, among most species of the same genus in Delphacidae sensory plaque organs have stable morphology except for some of the genera, for example, the genus *Muellerianella*. The denticle of *Muellerianella brevipennis* (Boheman) is conical, but that of *Muellerianella extrusa* (Scott) is thin and plate-shaped. On the other hand, all genera in the same subfamily do not always possess a stable morphology. In the rank of subfamily in Delphacidae, there are 3 observational results as follows. (1) In Asiracinae, the denticles of *Ugyops, Idiosystatus* and *Asiraca* belong to 3 different types: Types 1-3 respectively. (2) All examined species of Kelisiinae and Stenocraninae, conformably belong to Type 4. (3) For all examined genera of Delphacinae, most belong to Type 4, only 8 examined genera belong to Type 1.

From the ontogenetic view, the number of sensory plaque organs increased with nymphal development stage in Delphacidae, and similar conditions can be found in Cixiidae (Table 2), as well as in Fulgoroidea. However, if there are sufficient studies of ontogeny among the Fulgoroidea, these data should be expected to provide useful characters for analyzing phylogeny in the future.

Table 2. The number of sensory plaque organs of nymphs and adults in some species of the Delphacidae and Cixiidae. Those values which have not been described by previous authors or the present study are presented by question marks.

Family Subfamily Species	No. of sensory plaque organs Nymphal instar 1st	2nd	3rd	4th	5th	Adult	Reference
Delphacidae							
Asiracinae							Wilson and Wheeler, Jr. (1986)
Pentagramma longistylata Penner	?	?	5	13	25	?	
Stenocraninae							Calvert and Wilson (1986)
Stenocranus lautus Van Duzee	0	0	4	9	14	?	
Delphacinae							Wilson (1985)
Delphacodes bellicosa Muir & Giffard	0	2	4	6	9	?	Aljunid and Anderson (1983)
Nilaparvata lugens Stal	0	1	?	5	10	17	
Cixiidae							
Cixiinae							Present study
Pentastiridius pachyceps (Mats.)	0	3	7	10	11	14−16	Present study
Oliarus polyphemus Fennah	?	?	?	?	15	16−18	

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稻蝨科之觸角瓦楞感覺器(同翅目：蠟蟬總科)

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摘　要

本文藉由掃描式電子顯微鏡共檢查稻蝨科81屬104種之觸角瓦楞感覺器，得知稻蝨科觸角瓦楞感覺器的瓦楞突起外形一致，透過錐狀突起的形態可發現瓦楞感覺器共有四型，它們的進化趨勢推論為第一→二→三型和第一→二→四型。

關鍵詞：同翅目，蠟蟬總科，稻蝨科，觸角，瓦楞感覺器。

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