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ORIGINAL PAPER

Structure and sensilla of the mouthparts of *Alobaldia tobae*, *Maiestas dorsalis* and *Stirellus indrus* (Hemiptera: Cicadellidae: Deltocephalinae)

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Abstract

The morphology of adult mouthparts of the leafhoppers *Alobaldia tobae*, *Maiestas dorsalis* and *Stirellus indrus* was studied using a scanning electron microscope. The mouthparts are of the typical piercing–sucking type, similar to mouthparts found in other hemipteran insects, and comprise a three-segmented labium with a deep groove in the anterior side, a stylet fascicle consisting of two mandibular and two maxillary stylets, and a small cone-shaped labrum. The mandibular stylets, located laterad of the maxillary stylets, have sculpturing on their tips. The maxillary stylets are interlocked to form a larger food canal and a smaller salivary canal. Sensilla detected on the three leafhopper species were at different locations on the labium. Three kinds of sensilla were found on the *Alobaldia tobae* and *Maiestas dorsalis* labium, including two types of sensilla trichodea (I and II), two types of sensilla basiconica (I and II), and one type of sensilla coeloconica (Sco I). Three kinds of sensilla were found on the *Stirellus indrus* labium, including three types of sensilla trichodea (I, II and III), two types of sensilla basiconica (I and II), and one type of sensilla coeloconica (Sco I). Among them, sensilla trichodea I are the most abundant on all of three species. This is the first report of sensilla coeloconica (Sco I) and sensilla trichodea III on the mouthparts of Deltocephalinae. Sensilla trichodea I (St I) were also found on the surface of the *Stirellus indrus* labrum, which is also a first report in the Deltocephalinae. These sensilla may be involved in host recognition and are likely chemo- or mechanosensory, or both. The potential functions of the sensilla are discussed. The morphology of mouthparts and the distribution of sensilla on the labium in *Alobaldia tobae*, *Maiestas dorsalis* and *Stirellus indrus* are discussed with respect to their possible functional significance.

Keywords Deltocephalinae · Leafhopper · Mouthparts · Scanning electron microscopy

Introduction

The mouthparts are important feeding organs for insects. Long-term evolutionary processes have given rise to diverse structural forms adapted to different hosts and tissues (Smith and Capinera 2005). Among insect herbivores, differences in the structures of mouthparts are related to variation in the surface characteristics of host plants. These differences are often useful for taxonomic classification and identification, and comparative study of mouthpart structure is also important for understanding the biology of these insects (Gullan and Cranston 2005). Hemipteran sucking mouthparts play important roles in host plant selection, feeding, and plant pathogen transmission (Backus and McLean 1982; Weintraub and Beanland 2006). Previous studies have shown that the segmental, interlocking mechanisms and sensory organs of the mouthparts of hemipteran insects are different across different groups, and such differences are important in the analysis of feeding mechanisms and for assessing phylogenetic relationships (Forbes 1969; Emeljanov 1987; Walker and Gordh 1989; Rani and Madhavendra 1995, 2005; Brożek and Chłond 2010, 2013a, b; Liang et al. 2013; Brożek and Zettel 2014). The study of the mouthparts of hemipteran insects was first applied to the study of their diets and to explain variation in mouthpart morphology. Using ultramicromorphological techniques, Cobben (1978) studied the structure and function of the beak, mouthpart sensilla and oral structures, applied these observations to systematic studies and related structural variation with feeding

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strategies. Brozek et al. (2006) also used scanning electron microscopy (SEM) techniques to elucidate structures of the oral apparatus of adults of Cephalorhyncha and Sternorrhyncha, and compare the interlocking mechanisms of the maxillary and mandibular stylets.

Many researchers now use optical and scanning electron microscopy to observe the structure of Hemiptera mouthparts (Anderson et al. 2006). Tavella and Arzone (1993) found that *Zyginidia pullula* feeds on leaf cell contents, *Empoasca vitis* feeds on phloem, and *Grapbocepbala fennahi* feeds on xylem but all have similar oral morphology. However, the maxillary stylet length ratio is greater in the xylem feeders than in other groups. Brozek and Herczek (2001) observed that in leafhoppers, the salivary tract is usually located on the right mandibular oral stylet. Leopold et al. (2003) discussed *Homalodisca vitripennis* (as *H. coagulata*), using the ultrastructural characteristics of the oral apparatus to explain the probing in plant tissues. It was speculated that the denticles at the end of the dendritic tract of the stylets might function as sensory organs and be used to locate the xylem during probing. Previous study of the oral apparatus of members of the largest leafhopper subfamily, Deltocephalinae, is limited to the structure of the oral apparatus of a few species with very little application to subsequent systematic or physiological study. Forbes and Raine (1973) described the structure of the maxillary and mandibular stylets of *Macrosteles fascifrons* in detail. Backus and McLean (1982) also studied the sensory system and feeding behavior of *Macrosteles fascifrons*. They found 20 chemoreceptors and an undescribed valve in the anterior sinus and 12 mechanoreceptors inside the stylet fascicle. Based on these observations, it was speculated that in the Cicadellidae, and perhaps even in the whole order Hemiptera, insect taste discrimination is carried out through chemoreceptors in the anteromedial sinus, while oral probing is used for proprioception and the antral sinus valve is used to regulate fluid intake. Zhao et al. (2010) described in detail the morphological characteristics, including types and distributions of sensilla in *Psammotettix striatus*, and the interlocking mechanism of the stylets, reporting that the sense organs on the mouthparts have the functions of taste and smell.

Deltocephalinae is the largest subfamily in the Cicadellidae, including 39 tribes, 926 genera, and ~6700 valid species that are widely distributed around the world. Many species of Deltocephalinae are important agricultural pests. The grass-specialist leafhoppers *Alobaldia tobae* and *Maiestas dorsalis* belong to tribe Deltocephalini; while *Stirellus indrus* belongs to tribe Stenometopiini. They injure plants by sucking sap and transmitting plant pathogens. Adults and nymphs suck sap from plant leaves and sheaths, inhibiting growth and development of the plant and causing the leaves to turn yellow or, in heavy infestations, withering of the whole plant. Pathogens transmitted by these species cause even greater damage to agricultural production. Like other cicadellids, these three leafhopper species have highly specialized piercing–sucking mouthparts, adapted for tapping into and feeding on xylem or phloem.

Morphology and sensilla structure of the mouthparts of *Alobaldia tobae*, *Maiestas dorsalis* and *Stirellus indrus* have not been studied previously. The focus of this study is to use SEM to observe and compare the ultrastructural morphology of the oral apparatus of these three leafhopper species, including the labrum, labium, mandible and maxilla. Results of this research may provide an important basis for further research on leafhopper phylogeny and evolution as well as providing some additional understanding of feeding mechanisms and control strategies.

Materials and methods

The selected samples

Collections of *Alobaldia tobae* and *Maiestas dorsalis* adults were made in August 2018 at Dengjiahu Town, Changfeng County, Hefei City, Anhui Province. *Stirellus indrus* adults were captured in Taiping Lake, Huangshan City, Anhui Province during August 2018. Both male and female adults were collected, placed in 75% ethanol, and stored in a refrigerator at 4 °C for later use.

Sample preparation and SEM observation

The samples were placed under an anatomical mirror (Motic, K-700HS) for dissection. Heads of 10 specimens of each species were removed with forceps and insect pins, and were put in a 2.5% glutaraldehyde solution and fixed in the refrigerator at 4 °C for 12 h. After fixation, each was rinsed repeatedly with 75% ethanol, and then rinsed with 0.1 mol/L phosphate buffer (PBS, PH 7.2) 5 times every 5 min, then oscillated in an ultrasonic washer (JP-040S) twice, 40 s each time, and subsequently dehydrated in a graded series of ethanol solution (50%, 70%, 80%, 90%, 95% and 100%), 20 min per level. After dehydration, samples underwent isoamyl acetate replacement twice, 30 min each time, and dried for 6 h in a CO_2 critical point dryer (K850). The samples were then attached to scanning electron microscope studs with conductive adhesive and placed into a high-speed ion sputtering apparatus (Hitachi, E-1010) to coat with gold for 50 s. Finally, a (Hitachi, S-4800) cold field emission scanning electron microscope was used for observations and micrographs were taken with an acceleration voltage of 3.0 kV. The naming and classification of mouthpart sensory structures mainly follow Schneider (1964). Photographs were edited using Adobe Photoshop CS6.

Results

Gross morphology of mouthparts of three species leafhopper

The mouthparts of all of three leafhopper species, located at the back end of the head, are composed of a labrum (Lm), labium (Lb) and stylet fascicle (Sf). The stylet fascicle is the feeding organ of the leafhopper and includes two mandibular stylets (Md) and two maxillary stylets (Mx). The labrum is triangular and lies above the labium at the base. The labium is divided into three segments and has a longitudinal deep groove in the ventral view, called the labial groove (Lg), within which lies the stylet fascicle. The two mandibular stylets are closely attached to the two maxillary stylets. The mandibular stylets have serrations on the edges, and are slightly shorter than the maxillary stylets. The labium has different types of sensory organs distributed on the surface; some symmetrically arranged in the labium groove, some concentrated at the tip of the labium. There are almost no differences in the types, numbers and distribution of sensory organs between the male and female of the three leafhopper species.

Labrum

The labrum (Lm) of these three leafhopper species is conical, is connected to the anterior margin of the anteclypeus, and covers the labial groove (Lg) (Fig. 1a–f). The length of the labrum differs among the three species (Table 2). It is shortest in *Alobaldia tobae* and longest in *Stirellus indrus.* A sensillum trichodeum (St I) placed in the middle of the labrum of the latter species with length about 8.52 ± 0.30 µm (Fig. 1i). There are also a large number of brochosomes (Bs) on the labrum surface of these three species.

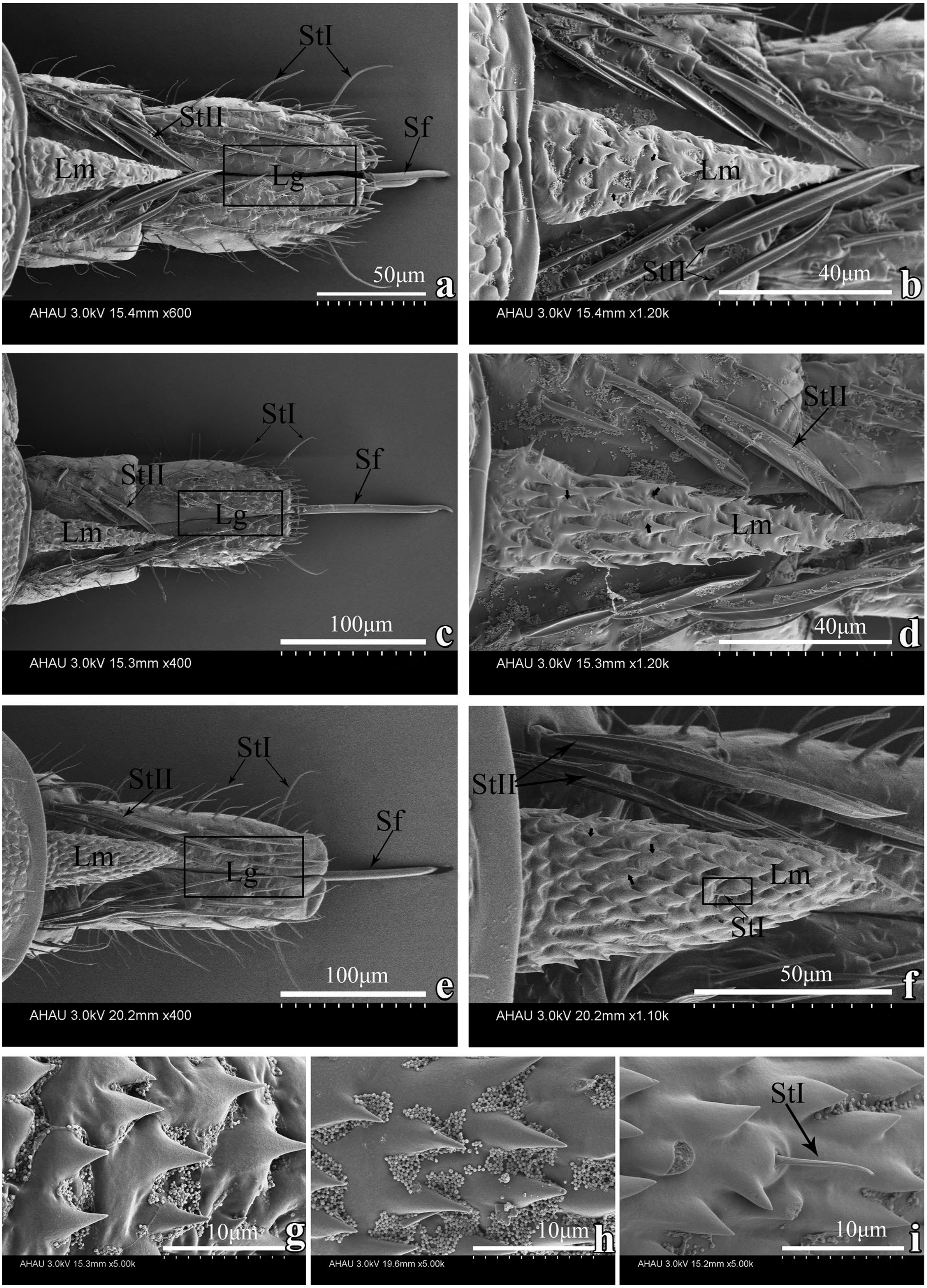
Labium

The labium (Lb) is long and cylindrical, divided into three sections of varying lengths. Its ventral surface is bisected by a deep labial groove (Lg) within which lies the stylet fascicle (Fig. 2a, c, e). The length of the labium differs among the three species (Table 2). The lengths of the three segments in *Alobaldia tobae* and *Maiestas dorsalis* are relatively similar. The distal segment of *Stirellus indrus* is significantly longer than the other two segments.

There are different types of sensilla on the labium surface, mainly concentrated on both sides of the labial groove. The first labial segment is shortest and partly covered by the anteclypeus. There are fewer sensilla on the first segment and the sculpture consists of several small denticles on the ventral surface. The second segment is narrower than the first segment; different sensilla are distributed on the ventral surface and the dorsal surface. The third labial segment is the most slender and longest of the three segments and covered with the most sensilla. The density of the labium sensilla of these three species is similar to their spatial distribution, but there are some differences in the shape and quantity of the sensilla among the different species.

There are a large number of sensilla trichodea (St I) on the ventral and dorsal surfaces of the third segment of all three species. There are some sensilla trichodea (St II) distributed on both sides of the labial groove at the junction of the second and third sections of the ventral surface. There are also some sensilla basiconica (Sb I) distributed at the end of the third segment, and 2 sensilla basiconica (Sb II) are placed on the dorsal surface end of the third segment, symmetrically on either side of the labial groove. There are 1–3 sensilla coeloconica (Sco I) distributed on the dorsal surface in *Maiestas dorsalis* and 4 in *Stirellus indrus*. The ventral surface of the second segment mainly has sensilla trichodea (St II), distributed on both sides of the labial groove. There are 2 sensilla coeloconica (Sco I) distributed on the ventral surface in *Alobaldia tobae* and *Maiestas dorsalis.* There are 1–2 sensilla coeloconica (Sco I) and only 1 sensillum trichodeum (St III) distributed on the dorsal surface of the second segment of *Stirellus indrus.* The fewest sensilla are distributed on the ventral and dorsal surfaces of the first segment, including only sensilla trichodea (St I) and sensilla coeloconica (Sco I). There are 1–4 sensilla coeloconica (Sco I) distributed on the ventral surface in *Alobaldia tobae* and 8 in *Stirellus indrus*; and 6 sensilla coeloconica (Sco I) are distributed on the dorsal surface.

Sensilla trichodea (St I) are slender and curved with the base inserted into a cylindrical sheath formed by epidermis protrusions, ranging in length from 18.93 ± 3.72 to 45.44 ± 6.70 µm (Fig. 2b). The longest sensilla trichodea (St I) are found on both sides of the labial groove end, having a length of about 44.11 ± 3.20–57.25 ± 5.25 µm (Fig. 2b). Sensilla trichodea (St II) are slightly flat and have longitudinal ridges, the base embedded in a socket formed by the protrusion of the epidermis, and the length is 32.71 ± 12.95–68.08 ± 12.30 µm (Fig. 2d). The sensillum trichodeum (St III) has fine lines on the surface, is thinner than the sensilla trichodea (St I and II), distinctly split at the end, and is about 54.33 µm long (Fig. 2f, f1). Sensilla basiconica (Sb I) are long, pointed at the end, and have a length of about 12.83 ± 3.78–13.92 ± 4.25 µm; they are inserted in a circular hole formed by a depression of the epidermis (Fig. 2g). There are only 2 sensilla basiconica (Sb II), which are small and have a length of about 4.46 ± 0.60–8.88 ± 0.23 µm; the base is spherical and these sensilla are placed symmetrically on both sides of the labial groove (Fig. 2h). Sensilla coeloconica (Sco I) consist of a


StI
StII
Sf
Lm
Lg
50μm
a
AHAU 3.0kV 15.4mm x600
Lm
StII
40μm
b
AHAU 3.0kV 15.4mm x1.20k
StI
Sf
StII
Lg
Lm
100μm
c
AHAU 3.0kV 15.3mm x400
StII
Lm
40μm
d
AHAU 3.0kV 15.3mm x1.20k
StI
StII
Sf
Lm
Lg
100μm
e
AHAU 3.0kV 20.2mm x400
StII
Lm
StI
50μm
f
AHAU 3.0kV 20.2mm x1.10k
10μm
g
AHAU 3.0kV 15.3mm x5.00k
10μm
h
AHAU 3.0kV 19.6mm x5.00k
StI
10μm
i
AHAU 3.0kV 15.2mm x5.00k

◂**Fig. 1** SEM of adult *Alobaldia tobae*, *Maiestas dorsalis* and *Stirellus indrus* mouthparts. **a** Anterior surface of *Alobaldia tobae* mouthparts. **b** Labrum (Lm) of *Alobaldia tobae*. **c** Anterior surface of *Maiestas dorsalis* mouthparts. **d** Labrum (Lm) of *Maiestas dorsalis*. **e** Anterior surface of *Stirellus indrus* mouthparts. **f** Labrum (Lm) of *Stirellus indrus*. **g** *Alobaldia tobae* labrum (Lm) showing triangular cuticular processes (black arrows). **h** *Maiestas dorsalis* labrum (Lm) showing triangular cuticular processes (black arrows). **i** *Stirellus indrus* labrum (Lm) showing triangular cuticular processes (black arrows)

cluster of fingerlike structures arranged in a round concavity; there are about 2–6 petal-like structures around the circular central cavity, each edge structure is short with smooth surface having a diameter of about 1.48 ± 0.20–2.01 ± 0.39 μm (Fig. 2i; Table 1).

Stylet fascicle

The stylet fascicle (Sf) is needle like, composed of two mandibular stylets (Md) and two maxillary stylets (Mx) (Fig. 3a, c, e). They originate from the head, passing beneath the labrum, through the labial groove for the full length of the labium and extend from the labial tip. The mandibular stylets are located on both sides of the maxillary stylets. The most obvious feature of the mandibular stylets is that the ends are sculptured; the inner edge has two rows of toothlike projections (Tp) and there are serrate ridges (Sr) on the outside. The ends of the mandibular stylets are gradually tapered, the serrate ridge of the outer side of the end gradually protrudes, and the maxillary stylets are fixed inside the mandibular stylets (Fig. 3b, d). The maxillary stylets are long and slender, with inner and outer surfaces smooth and unmarked. The ends protrude from the labium, and the tips are sharp and curved. The two maxillary stylets are tightly interlocked to form a hollow food canal (Fc) and a salivary canal (Sc) (Fig. 3f).

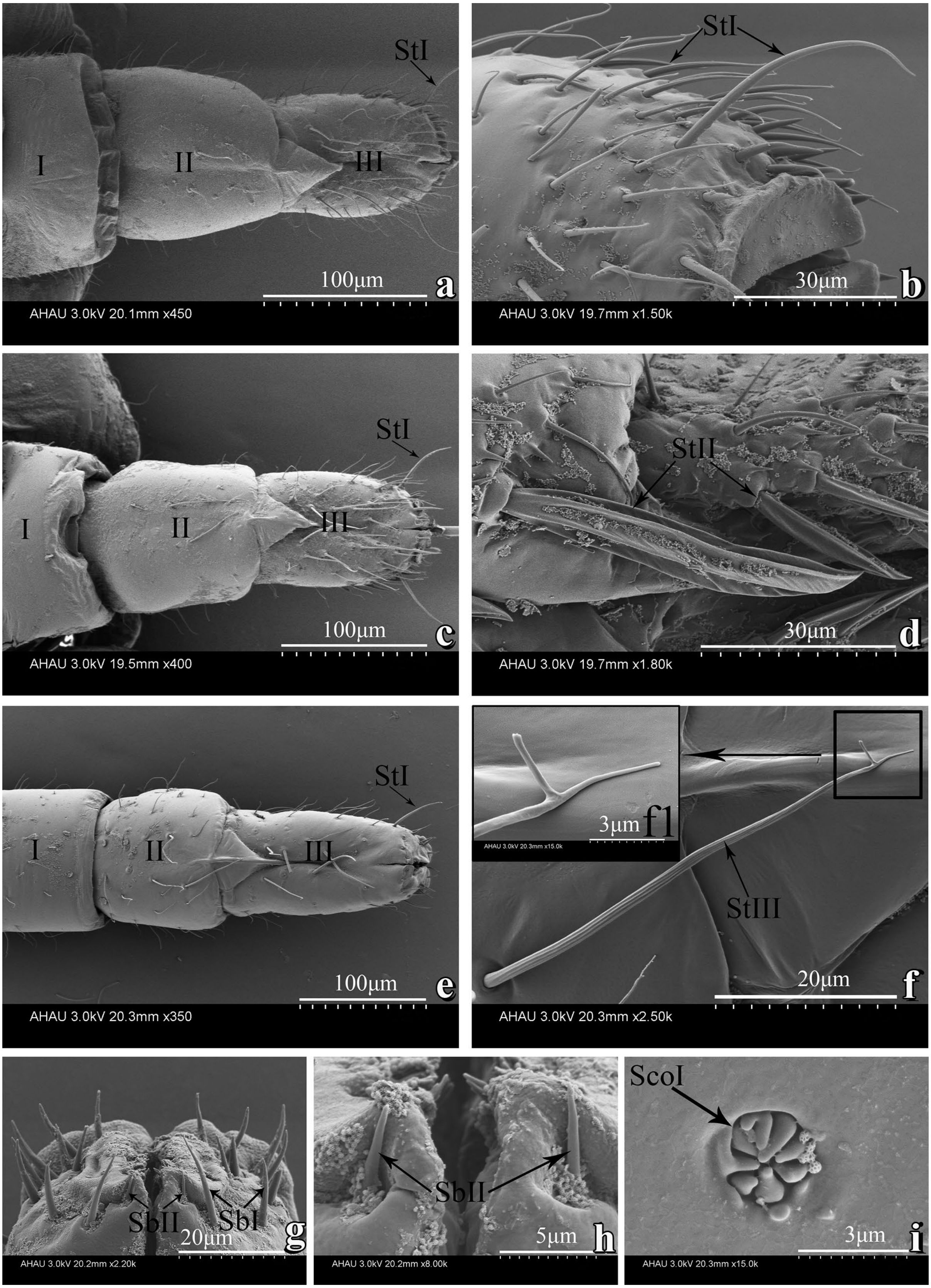
Although the stylet fascicles of all three species are similar in shape, they differ in length and in the length ratios of the mandibular and maxillary stylets. The mandibular stylets of *Alobaldia tobae* are only 3/4 as long as the maxillary stylets (Table 2). The mandibular stylets of the *Maiestas dorsalis* are only 3/5 as long as the maxillary stylets. The mandibular stylets of *Stirellus indrus* are only 2/3 as long as the maxillary stylets.

Discussion

Mouthparts of leafhoppers play important roles in host location, feeding, and transmitting plant pathogens. The structure of the three deltocephaline leafhoppers studied in this paper is generally similar to each other and to those described for other hemipterans (Pollard 1973; Tavella and Arzone 1993; Rosell et al. 1995; Freeman et al. 2001; Boyd et al. 2002; Boyd 2003; Wiesenborn 2004; Rani and Madhavendra 2005; Anderson et al. 2006) but there are still morphological differences between them.

The stylet fascicle is the main feeding organ and is the means of pathogen acquisition and inoculation by the leafhopper vector species (Forbes and Raine 1973). Serrated edges along the mandibular stylets similar to those observed in the three studied species are also found in other hemipteran insects (Tavella and Arzone 1993; Crews et al. 1998; Freeman et al. 2001; Wiesenborn 2004; Anderson et al. 2006) and may function to cut channels into the plant tissues, anchor the stylets during feeding, and to immobilize the body during molting (Leopold et al. 2003). The tops of the mandibular stylets of the three studied species have obvious serrated edges and are very similar to those reported in *Psammotettix striatus* (Zhao et al. 2010). The overall depth of the serrated edges of the mandibular stylets may constrain choice of host in different species. In the three studied leafhoppers, the pair of maxillary stylets together forms a larger food canal and a smaller salivary canal; the former used for imbibing phloem, the latter for injecting saliva into the host plant (Forbes 1972).

Several different types of sensilla are distributed on different parts of the labium mainly on the sides and ends of the labial groove, while the posterior surface and sides of the labium have relatively few. The distribution density and morphology of the sensilla differ among the three studied leafhopper species. Sensilla trichodea (St I and II) occurring on both sides of the labial groove are probably mechanosensory, detecting changes in the position of the labium and stylet fascicle. Sensilla at the labial tip probably act as both chemo- and mechanoreceptors and aid in probing and locating feeding sites in most Hemiptera (Cobben 1978; Rani and Madhavendra 2005). The most abundant sensilla on the labium of the three leafhopper species are sensilla trichodea. This has also been reported for other Hemiptera, including *Homalodisca coagulata* (Leopold et al. 2003), *Psammotettix striatus* (Zhao et al. 2010), *Odontopus nigricornis* and *Nezara viridula* (Rani and Madhavendra 1995). Sensilla trichodea (St III), here observed on the second segment of the labium dorsal surface of *Stirellus indrus*, represent the first reported occurrence of such sensilla in Deltocephalinae. The sensillum trichodeum (St III) is thinner than the sensilla trichodea (St I and II), with longitudinal lines on the surface, obvious branches at the ends, and smooth surfaces on the branches. These sensilla may be modified from sensilla trichodea (St I) or sensilla trichodea (St II), but further research is needed. Although various types of sensilla trichodea (St I and II) have been reported to have different functions,


StI
I
II
III
100µm
a
AHAU 3.0kV 20.1mm x450
StI
30µm
b
AHAU 3.0kV 19.7mm x1.50k
StI
I
II
III
100µm
c
AHAU 3.0kV 19.5mm x400
StII
30µm
d
AHAU 3.0kV 19.7mm x1.80k
StI
I
II
III
100µm
e
AHAU 3.0kV 20.3mm x350
3µm
f1
AHAU 3.0kV 20.3mm x15.0k
StIII
20µm
f
AHAU 3.0kV 20.3mm x2.50k
SbII
SbI
20µm
g
AHAU 3.0kV 20.2mm x2.20k
SbII
5µm
h
AHAU 3.0kV 20.2mm x8.00k
ScoI
3µm
i
AHAU 3.0kV 20.3mm x15.0k

◂**Fig. 2** SEM of adult *Alobaldia tobae*, *Maiestas dorsalis* and *Stirellus indrus* labium (Lb). **a** Posterior surface of *Alobaldia tobae* labium. **b** Sensilla trichodea I (St I). **c** Posterior surface of *Maiestas dorsalis* labium. **d** Sensilla trichodea II (St II). **e** Posterior surface of *Stirellus indrus* labium. **f** Sensillum trichodeum III (St III). **f1** Tip of sensillum trichodeum III (St III) enlarged. **g** Sensilla basiconica I (Sb I). **h** Sensilla basiconica II (Sb II). **i** Sensilla coeloconica I (Sco I)

they seem to have similar functions and are considered to be chemoreceptors in *Odontopus nigricornis* (Pyrrhocoridae) and *Nezara viridula* (Pentatomidae) (Rani and Madhavendra 1995). On the other hand, Leopold et al. (2003) reported that in *Homalodisca coagulata*, these sensilla are mechanoreceptors important in probing the surface of the host plant. There are two types of sensilla basiconica [sensilla basiconica I (Sb I) and sensilla basiconica II (Sb II)] at the end of the third labial segment of the three studied leafhopper species. The placement of these sensilla suggests that they are not only olfactory and gustatory receptors that detect substances produced by host plants but also they may play a role in chemo- or mechanoreception (Backus and McLean 1982; Walker and Gordh 1989; Rani and Madhavendra 1995). Cobben (1978) proposed that such sensilla sense humidity because hemipterans feed on liquid food. Schoonhoven and Henstra reported (1972) that the sensilla at the lower labial tip of *Dysdercus* spp. are a chemoreceptor. Sensilla coeloconica (Sco I) differ in location and number among the three leafhopper species, and these sensilla were not found in the mouthparts of other species of the Deltocephalinae. Sweet (1979) reports that they are very sensitive to volatiles, and speculates that they are olfactory receptors based on ultrastructural and electrophysiological analysis.

The sensillum trichodeum I (St I) on the surface of the *Stirellus indrus* labrum represents the first report of such a sensillum in this position in Deltocephalinae. Further study is needed to determine the possible functional and phylogenetic significance of this sensillum. The triangular surface protrusions on the labrum surface also vary among species but the significance of this variation also remains unclear.

This study found that a large number of brochosomes are distributed on the labrum and labium surfaces of the three leafhopper species. Brochosomes, lipoproteinaceous particles secreted by the Malpighian tubules of leafhoppers, are a phenomenon peculiar to the Cicadellidae (Deitz and Dietrich 1993; Rakitov 2004). Rakitov (2004) showed that brochosomes provide leafhoppers with an extremely hydrophobic coating that enables them to avoid becoming trapped in water droplets, and may also have a role in resisting pathogens and avoiding predators and parasites.

Leafhopper feeding has previously been described to involve the following steps. The labium is first used to detect the surface condition of the host plant. This is followed by stylet penetration and the formation of a salivary sheath to seal the stylet fascicle (Miles 1968, 1972). In general, the mandibular stylets only penetrate into the host for a short distance, while the maxillary stylets are pushed forward. Once the phloem or xylem is found, the leafhopper feeds by withdrawing the plant sap until the stylet fascicle is retracted (Backus 1985; Freeman et al. 2001; Wiesenborn 2004).

Table 1 Distribution and morphometric data for various sensilla on different parts of the labium of *Alobaldia tobae*, *Maiestas dorsalis* and *Stirellus indrus*

	Alobaldia tobae			*Maiestas dorsalis*			*Stirellus indrus*		
	Distribution	Length (μm)	*N*	Distribution	Length (μm)	*N*	Distribution	Length (μm)	*N*
St I	Lb1–Lb3	18.93 ± 3.72–45.52 ± 5.36	5	Lb1–Lb3	28.30 ± 4.56–44.11 ± 3.20	5	Lm, Lb1–Lb3	8.52 ± 0.30 45.44 ± 6.70–57.25 ± 5.25	2, 5
St II	Lb2-V, Lb3-V	39.6 ± 16.96	5	Lb2-V, Lb3-V	32.71 ± 12.95	5	Lb2-V, Lb3-V	68.08 ± 12.30	5
St III	–	–	–	–	–	–	Lb2-D	54.33	1
Sb I	Lb3	13.38 ± 3.36	5	Lb3	13.92 ± 4.25	5	Lb3	12.83 ± 3.78	5
Sb II	Lb3-D	7.31 ± 0.41	5	Lb3-D	8.88 ± 0.23	5	Lb3-D	4.46 ± 0.60	5
Sco I	Lb1-V, Lb2-V	1.48 ± 0.20	5	Lb2-V, Lb3-D	1.51 ± 0.16	5	Lb1, Lb2-D, Lb3-D	2.01 ± 0.39	5

N number of leafhoppers, *St I* sensilla trichodea I, *St II* sensilla trichodea II, *St III* sensillum trichodeum III, *Sb I* sensilla basiconica I, *Sb II* sensilla basiconica II, *Sco I* sensilla coeloconica I, *Lm* labrum, *Lb1* part 1 of labium, *Lb2* part 2 of labium, *Lb3* part 3 of labium, *V* ventral, *D* dorsal

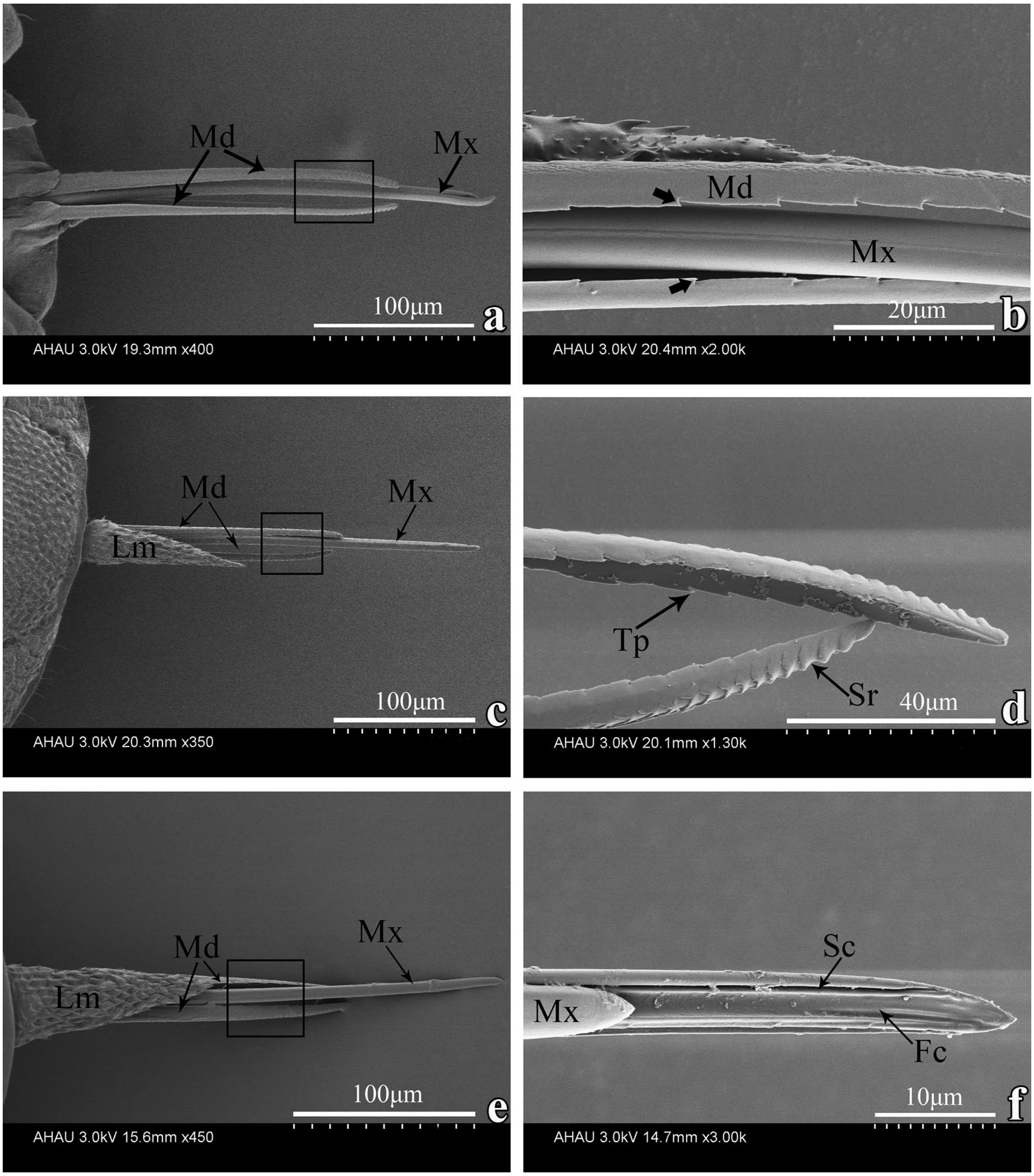


Fig. 3 SEM of the stylet fascicles of *Alobaldia tobae*, *Maiestas dorsalis* and *Stirellus indrus*. **a** *Alobaldia tobae* whole stylet fascicle (Sf). **b** Enlarged views of outlined boxes of **a**, **c**, **e** showing the mandibular stylets (Md) appressed to each side of the maxillary stylets (Mx), and the tooth-like projections (black arrows) on the inner edges of each mandibular stylet. **c** *Maiestas dorsalis* whole stylet fascicle (Sf). **d** Tip of mandibular stylet (Md), showing tooth-like projections (Tp) on the inner edges and serrate ridge (Sr) on the convex external surface. **e** *Stirellus indrus* whole stylet fascicle (Sf). **f** One of the maxillary stylets (Mx) showing inner surface, food canal (Fc) and salivary canal (Sc)

Table 2 Morphometric data for mouthparts of *Alobaldia tobae*, *Maiestas dorsalis* and *Stirellus indrus*

	Alobaldia tobae	*Maiestas dorsalis*	*Stirellus indrus*	*N*
Lm				
Length (μm)	96.07 ± 13.36	109.68 ± 10.94	116.25 ± 15.77	8
Width (μm)	29.13 ± 3.87	28.45 ± 3.21	44.2 ± 3.07	
Lb				
Length (μm)	295.62 ± 30.53	298.30 ± 27.27	352.99 ± 22.39	8
Lb1				
Length (μm)	103.99 ± 7.06	73.76 ± 3.60	113.21 ± 11.98	5
Width (μm)	130.93 ± 8.19	126.28 ± 15.13	116.04 ± 4.30	
Lb2				
Length (μm)	94.80 ± 6.13	109.41 ± 17.57	97.73 ± 3.35	5
Width (μm)	96.30 ± 7.02	91.07 ± 7.95	99.33 ± 2.53	
Lb3				
Length (μm)	107.03 ± 4.79	115.44 ± 18.09	154.0 ± 7.72	5
Width (μm)	70.17 ± 5.86	69.38 ± 7.26	85.0 ± 4.05	
Sf				
Width (μm)	26.18 ± 0.98	23.07 ± 1.13	26.80 ± 2.23	5
Md				
Length (μm)	206.30 ± 9.41	200.17 ± 11.86	283.14 ± 8.41	5
Mx				
Width (μm)	275.68 ± 17.20	299.51 ± 15.83	361.83 ± 22.17	5

N number of leafhoppers, *Lm* labrum, *Lb* labium, *Lb1* part 1 of labium, *Lb2* part 2 of labium, *Lb3* part 3 of labium, *Sf* stylet fascicle, *Md* mandibular stylets, *Mx* maxillary stylets

Conclusions

In this study, details of the mouthparts of three species of Deltocephalinae were observed and compared by scanning electron microscopy. Although the mouthparts of the three species were similar overall, they differed in the lengths of different components of the labrum, labium and stylet fascicle and, in some cases, presence or absence of sensillum trichodeum (St III). Further study is needed to determine the possible evolutionary and functional significance of the variation observed.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

Ethical approval All applicable international, national, and institutional guidelines for the care and use of animals were followed. No endangered species or animals from protected areas were used for this study. This article does not contain any studies with human participants performed by any of the authors.

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