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Research Article

The sensilla on head, antenna and mouth parts in *Aelia rostrata* Boh. (Hemiptera, Pentatomidae): A scanning electron microscopical study

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ABSTRACT: The sensilla who act as thermohygroreceptor, chemoreceptor, or mechanoreceptor are the main sensory structures of insects. Insects carry different types, numbers and distributions of sensilla in body parts such as head, antenna, mouth parts, and leg segments. In this study, the sensilla types on the head, antenna and mouth parts of *Aelia rostrata* Boh. (Hemiptera, Pentatomidae) were invastigated with using scanning electron microscope. According to the results of the study, 4 major types of sensilla with different diameters and cone-shaped protrusions have been identified: sensilla basiconica, sensilla trichodea, sensilla peg, and sensilla campaniformia. These sensilla show different distributions in the examined structures of the insect. The results obtained from the study were also compared with other species in the literature, and similarities and differences were revealed.

KEYWORDS: Chemoreceptor, Heteroptera, insect, mechanoreceptor, morphology.

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INTRODUCTION

Order Hemiptera is an extensive group that includes plant pests. The species belong to order Hemiptera have piercing-sucking mouth parts which gives insects an advantage in feeding on plant sap (Hao et al., 2016; Kanturski et al., 2017). *Aelia rostrata* Boh. (Hemiptera, Pentatomidae) which is known as wheat stink bug is a significant pest in Turkey.

The reason why it is called a wheat stink bug is mainly because it is a wheat pest. In addition, rye, barley, oats and some other graminaceous plants are also infested by this insect.

A. rostrata is a widely distributed and migratory species is located in Adıyaman, Batman, Diyarbakır, Gaziantep, Mardin, Şanlıurfa, and Şırnak provinces in Turkey. This species has also been found in Iran and Iraq (Brown, 1965; Lodos, 1981; Lodos et al., 1984; Önder et al., 1995; Özgen et al., 2005; Gözüaçık et al., 2011; Khaghaninia et al., 2013; Tarla, 2017; Bolu, 2020).

Insects have some structures called sensilla on their mouth parts and antenna which enter into crucial role in some functions such as feeding or mating [(e.g the sensilla on the mouth parts scan the surfaces of food (Chapman, 1998; Brozek & Zettel, 2014; Parveen et al., 2015) and antenna which is the main sensory organs of insects, detecting volatile chemicals in the air (Carey & Carlson, 2011; Rani et al., 2021)] (Isidoro et al., 2001; Fu et al., 2012; Cao & Huang, 2016; Seada & Hamza, 2018; Faucheux et al., 2020).

So, the insect recognizes plants at a distance (Brozek, 2013). Together with the different types of sensilla on the antenna, they function as chemoreceptors, thermohygrorecertors, and mechanoreceptors (Akent'eva, 2008; Fu et al., 2012; Brozek & Bourgoin, 2013; Freitas et al, 2020; Giglio et al., 2021; Zhang et al., 2021).

Many different types of classification can be made in sensilla in insects according to different criteria. For example, according to their perception ways, they are divided into 2 main groups as mechanoreceptors and chemoreceptors which are more common (Brozek & Chlond, 2010; Li et al., 2016). Sensilla can also be classified according to their morphological features, such as basiconic, placoid, trichoid, long hair-like, plate-like or coeloconic, etc. (Slifer 1970; Altner & Prillinger, 1980; Hallberg & Hansson, 1999; Shields 2010; Nowinska & Brozek, 2017).

Besides, insect sensilla can be classified according to their sensory modality, such as olfactory, gustatory, mechanosensory, and thermohygrosensory (Fernandes et al., 2008; Nowinska & Brozek, 2017; Li et al., 2018). Another classification is based on whether sensilla carry pores or not. According to this, they are collected in 3 groups as aporous, uniporous and multiporous (Nowinska & Brozek, 2017).

The morphological structure of the sensilla on the mouth parts and antenna varies among Hemiptera species (Brozek & Bourgoin, 2013; Nowinska & Brozek, 2017; Taszakowski et al., 2019; Amutkan Mutlu et al., 2021).

The main goal of this study is to disclose the morphological features of the cuticular structures of sensilla on the antenna and the mouth parts in wheat stink bug *A. rostrata*.

MATERIALS AND METHODS

The male and female individuals of *Aelia rostrata* (Figures 1A-B) were collected in Sinanlı and Oltan (Ayaş) and Çağa Village (Güdül) in Ankara province in July, 2018. All male and female individuals were adults.

First, the external surface of the integument of insects was cleaned. Then, the specimens were dried in the air and adhesive o the stubs.

Subsequently, the stubs were coated with gold with Polaron SC502 sputter coater, observed in JEOL JSM 6060 LV SEM, and photographed (at 10-15 kV accelerating voltage).

All studies were performed at Gazi University, Faculty of Science, Prof. Dr. Zekiye Suludere Electron Microscope Center.

RESULTS AND DISCUSSION

Insects have sensory organs called sensilla, which enable the detection of chemical substances in their environment in various parts of their bodies (Cao & Huang, 2016; Amutkan Mutlu et al., 2021). In this study, sensilla types found on the head, antennae and mouth parts of male and

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female *A. rostrata* individuals were investigated with SEM. The diagrams of different types of sensilla on mouth parts, antenna, and head of *A. rostrata* are shown in Figure 2. As a result of the study, it was observed that the sensilla trichodea (St) and the sensilla basiconica (Sb) were more common than other sensilla types. In this context, the mean values of the sensilla trichodea and the sensilla basiconica lengths are given in Table 1 and Table 2. In addition to these types of sensilla, sensilla peg (Sp) and sensilla campaniformia (Sca) were also detected as a result of our study.

Table 1. Mean values of St lengths in both males and females (µm)

	Mouth parts				
	Labium 1	**Labium 2**	**Labium 3**	**Labium 4**	**Labrum**
Male	45,1 ± 19,6	55,0 ± 15,6	41,3 ± 21,8	-	46,8 ± 5,4
Female	61,0 ± 23,2	40,3 ± 10,4	53,4 ± 21,1	-	-
	Antenna				
	Scape	**Pedicel 1**	**Pedicel 2**	**Flagellum 1**	**Flagellum 2**
Male	-	33,0 ± 5,6	39,3 ± 13,8	21,1 ± 9,5	24,5 ± 8,4
Female	-	29,9 ± 6,6	-	28,3 ± 6,0	33,7 ± 3,0
	Head				
	1	**2**	**3**	**4**	
Male	78,9 ± 20,4	82,7 ± 26,6	71,0 ± 22,7	-	
Female	37,8 ± 24,6	83,9 ± 22,1	52,5 ± 20,6	-	

Table 2. Mean values of Sb lengths in both males and females (µm)

	Mouth parts				
	Labium 1	**Labium 2**	**Labium 3**	**Labium 4**	**Labrum**
Male	-	42,1 ± 6,2	-	2,9 ± 0,6 (short) 12,3 ± 2,9 (tall)	-
Female	-	-	-	3,8 ± 0,8 (short) 14,3 ± 1,6 (tall)	-
	Antenna				
	Scape	**Pedicel 1**	**Pedicel 2**	**Flagellum 1**	**Flagellum 2**
Male	-	-	-	50,4 ± 7,8	37,7 ± 12,4
Female	-	-	51 ± 11,1	11,2 ± 2,3	10,3 ± 1,9
	Head				
	1	**2**	**3**	**4**	
Male	-	-	-	-	
Female	-	-	-	-	

Sensilla types on the mouth parts

The mouth parts are generally consisted of the labrum (Lm), the labium (Lb), and a labial groove in hemipteran insects (Figures 3A-B). Although the general structure of these parts is very similar, differences can be observed in their detailed structure, number of segments, sensilla types and distributions among different species.

The mouth parts of *A. rostrata* males and females have a labrum with proximal and distal sides, four segmented labium, labial groove, and stylet fascicle which is the defining characteristic of hemipterans species (Wang et al., 2020a; Amutkan Mutlu et al., 2021).

In *Piezodorus hybneri* (Gmelin, 1790) (Hemiptera, Pentatomidae), *Perillus bioculatus* (F.)(Hemiptera,Pentatomidae), *Eocanthecona furcellata* (Wolff) (Hemiptera, Pentatomidae), *Dolycoris indicus* Stål, 1876 (Hemiptera, Pentatomidae), *Macrocheraia grandis* (Gray, 1832) (Hemiptera, Largidae), *Physopelta quadriguttata* Bergroth, 1894 (Hemiptera, Largidae), *Physopelta gutta* (Burmeister, 1834) (Hemiptera, Largidae), *Physopelta cincticollis* Stål, 1863 (Hemiptera, Largidae), and *Cheilocapsus nigrescens* (Liu and Wang) (Hemiptera, Miridae), the labium have four segmented as in *A. rostrata*, but *Eurygaster testudinaria* has three-segmented labium in its mouth parts (Parveen et al., 2015; Wang et al., 2019, 2020a; Amutkan Mutlu et al., 2021).

The labium (Lb) is long, thin, and four segmented in both male and female *A. rostrata*. The first segment is concave and the labrum (Lm) runs parallel to the first segment of the labium (Figures 3A-B).

Therefore, looking at the insect from the ventral side, the labrum is in the middle and the first segment of the labium (Lb1) lie on either side of it. The first segment of labium has many sensilla in different sizes such as sensilla trichodea and sensilla campaniformia (Sca) in both male and female insects.

But, sensilla campaniformia is more common in females than males (Figures 3C-F).

The second and third segments of the labium (Lb2 and Lb3) are seen very similar to each other.

But the second segment is thinner and longer than the third segment. In both sexes of *A. rostrata,* the second segment of the labium has sensilla trichodea, sensilla basiconica and sensilla campaniformia (Figures 4A-F).

The sensilla trichodea and sensilla campaniformia can be also observed on the third segment of labium in both sexes.

However, there are differences in the morphological structures of the sensilla trichodea and sensilla campaniformia in males and females (Figures 5A-F).

In the fourth segment of the labium (Lb4), sensilla density is higher than in other segments.

There are sensilla trichodea and sensilla basiconica on the fourth segment of the labium of females and males (Figures 6A-F).

The labrum (Lm) is the part of the mouth which attaches to the anterior region of the head and extends to first segment of labium (Figures 3A-B).

The labrum has two regions according to the surface patterns: proximal and distal regions.

The proximal region is the part that is close to the region where the labrum attaches to the head and has smooth surface.

Very few sensilla trichodea are seen on this area in both sexes (Figures 7A-B).

The distal region is the part near the free end with transverse crests and has no sensilla in both males and females (Figures 7C-D).

Sensilla types on the antenna

In *A. rostrata*, the antenna is divided into 5 segments in both sexes and each segment has sensilla of different types, density and distribution (Figures 8A-B).

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On the surface of the scape, there are numerous one or two apex cone-shaped protrusions.

Also in this region there are only a few long sensilla peg (Sp) in males and females (Figures 8C-H).

Sensilla trichodea is found on pedicel 1, albeit rarely in males. There are also two different varieties of sensilla campaniformia in male individuals.

Although the sensilla in females are very similar to those in males, they have only 1 type of sensilla campaniformia (Figures 9A-F).

The density of sensilla on the pedicel 2 is much higher than the scape and pedicel 1.

Sensilla basiconica, sensilla trichodea, and two types of sensilla campaniformia were observed in both females and males, but sensilla basiconica is the predominant sensilla type in this segment (Figures 10A-B).

The highest number of sensilla is on the flagellum 1 and 2. In addition, sensilla variety is more in these segments. Different sizes of sensilla basiconica, sensilla peg and two types of sensilla trichodea were detected in the flagellum 1 in male and female individuals. In addition, in males there is also sensilla campaniformia (Figures 11A-D).

Flagellum 2 of male insects has sensilla basiconica, sensilla trichodea, sensilla peg, and sensilla campaniformia types.

In females, only sensilla basiconica, sensilla trichodea, and sensilla peg are found, and the bases of some sensilla basiconica appear swollen (Figures 12A-D).

Sensilla types on the head

As a result of the SEM analysis, it was determined that there are many different types of sensilla on the head regions of *A. rostrata* males and females.

The head can be divided into 4 regions, as in the figure, according to the sensilla on its surface (Figures 13A-B).

Sensilla campaniformia and different types of sensilla trichodea are found in the first and the second regions of the head in both males and females (Figures 13C-F).

In both sexes, only sensilla trichodea was seen on the third region of the head (Figures 14A-B).

In the fourth part, there are numerous one or two pointed cone-shaped protrusions on the surface (Figures 14C-F).

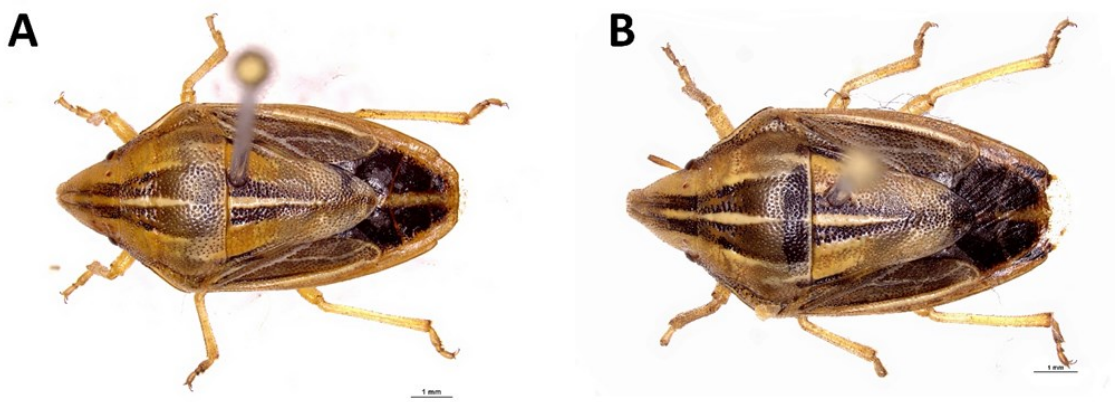

Figure 1. Stereomicroscope photograph of *A. rostrata*. A. Female individual, B. Male individual (Scale bar: 1 mm)

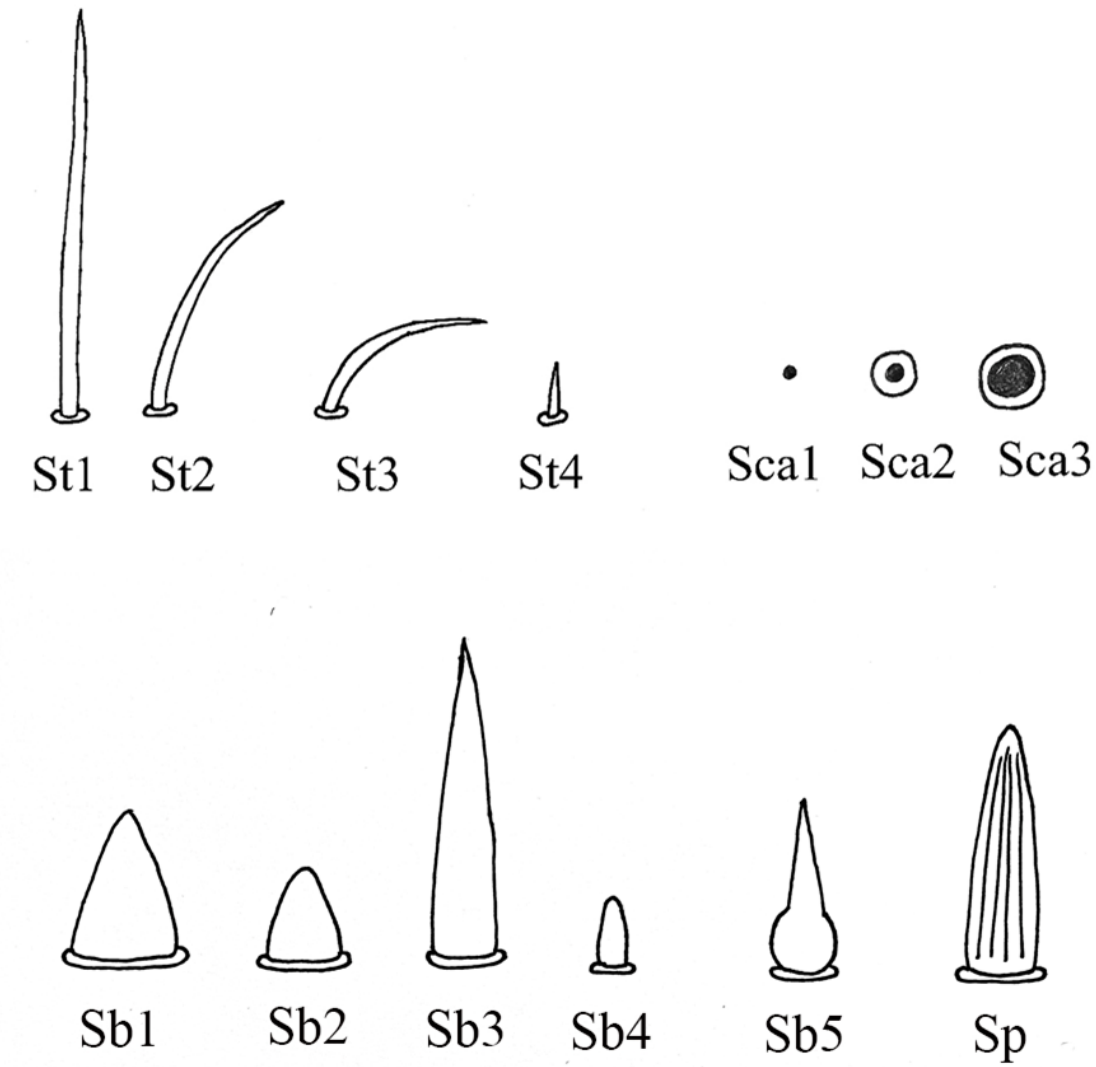

Figure 2. The schematic illustration of different types of sensilla on antenna, mouth parts and head of *A. rostrata*. St1: sensilla trichodea 1, St2: sensilla trichodea 2, St3: sensilla trichodea 3, St4: sensilla trichodea 4, Sb1: sensilla basiconica 1, Sb2: sensilla basiconica 2, Sb3: sensilla basiconica 3, Sb4: sensilla basiconica 4, Sb5: sensilla basiconica 5, Sp: sensilla peg, Sca1: sensilla campaniformia 1, Sca2: sensilla campaniformia 2, Sca3: sensilla campaniformia 3

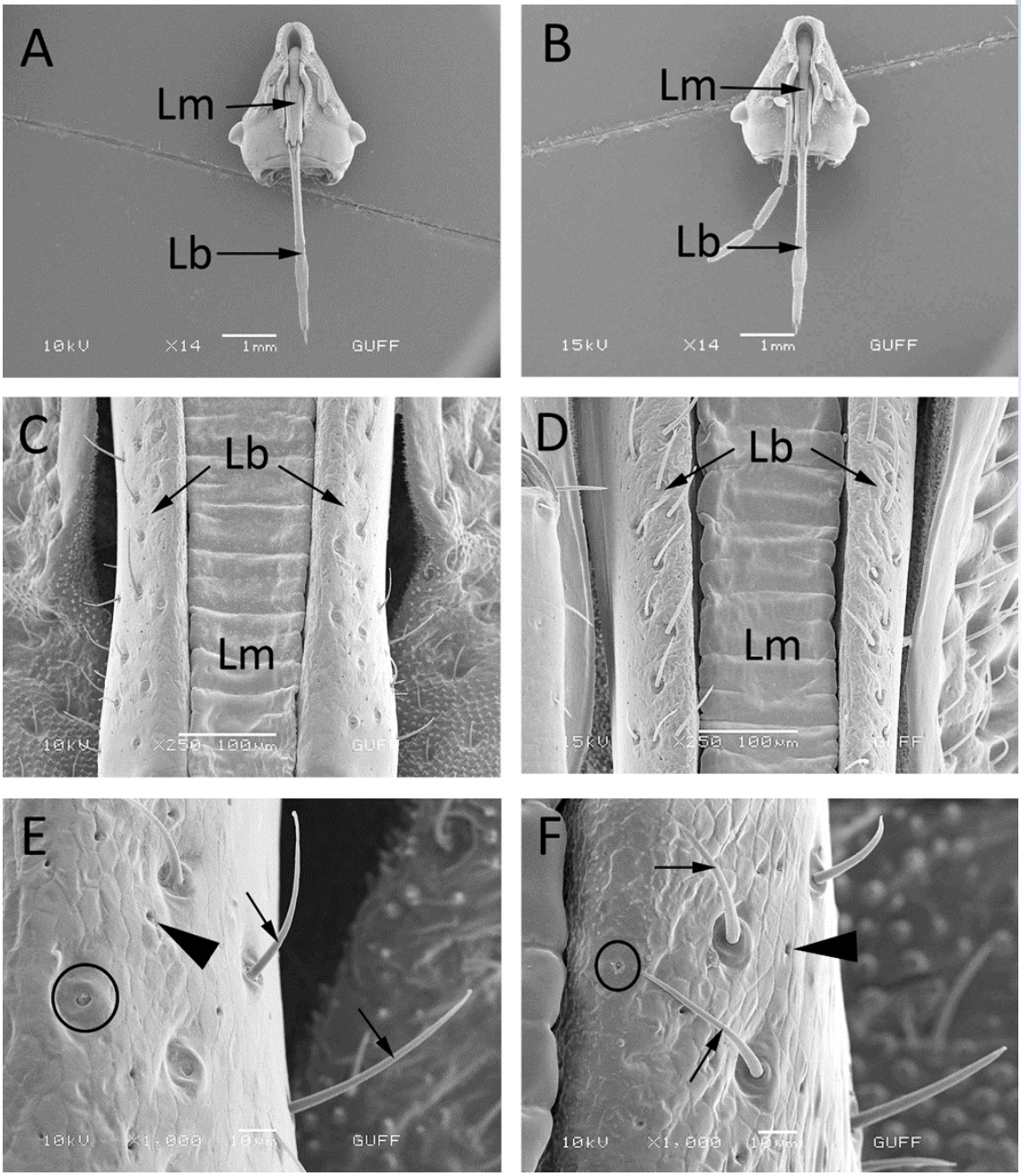

Figure 3. A-B. General view of the mouth parts, A: Female, B: Male. C-F. The first segment of the labium, C-E: Female, D-F: Male. Lb: labrum, Lm: labium, arrow: sensilla trichodea 2, arrowhead: sensilla campaniformia 1, encircled: sensilla campaniformia 2.

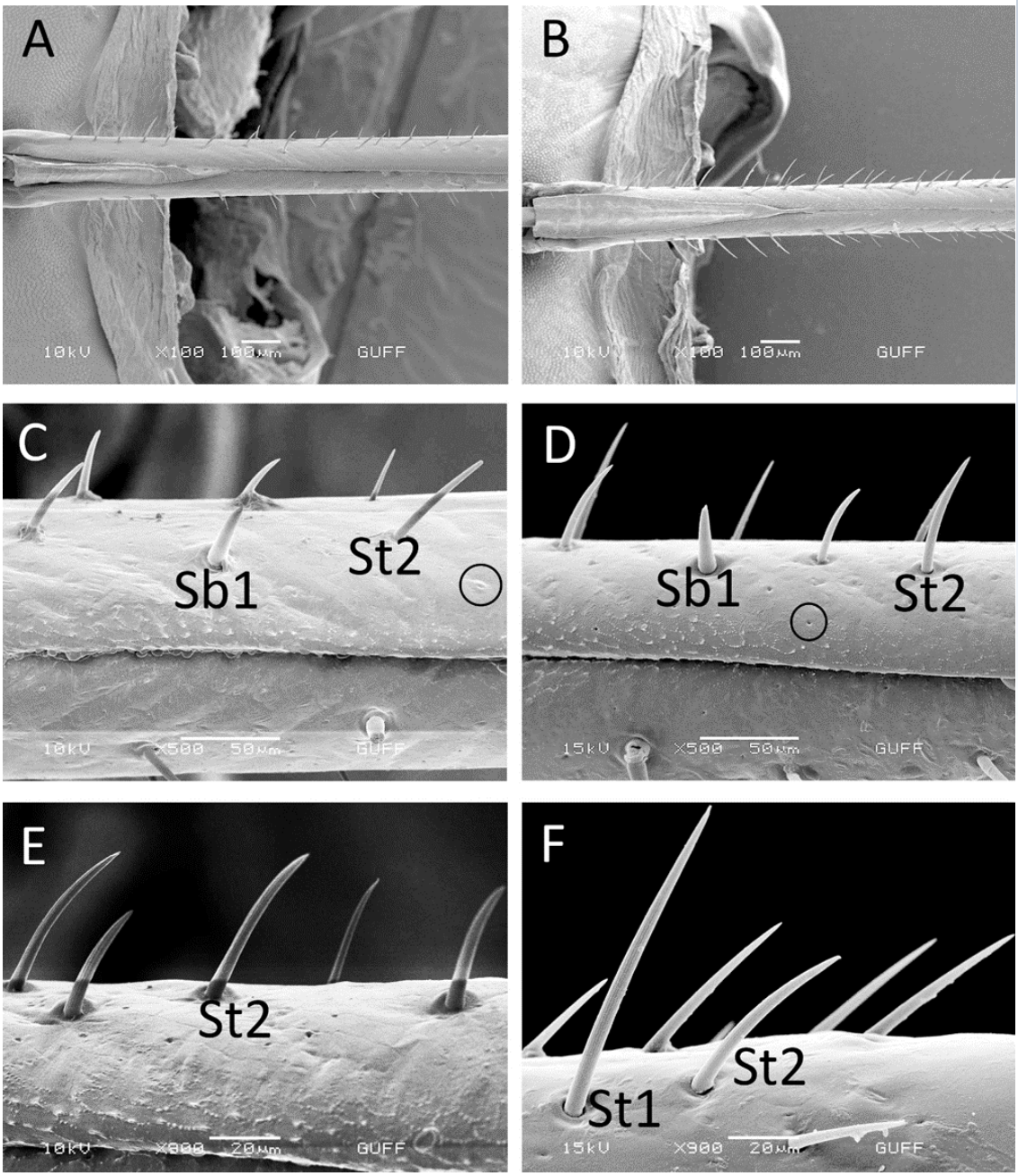

Figure 4. The second segment of the labium. A-C-E: Female, B-D-F: Male. Sb1: sensilla basiconica 1, St1: sensilla trichodea 1, St2: sensilla trichodea 2, encircled: sensilla campaniformia 1.

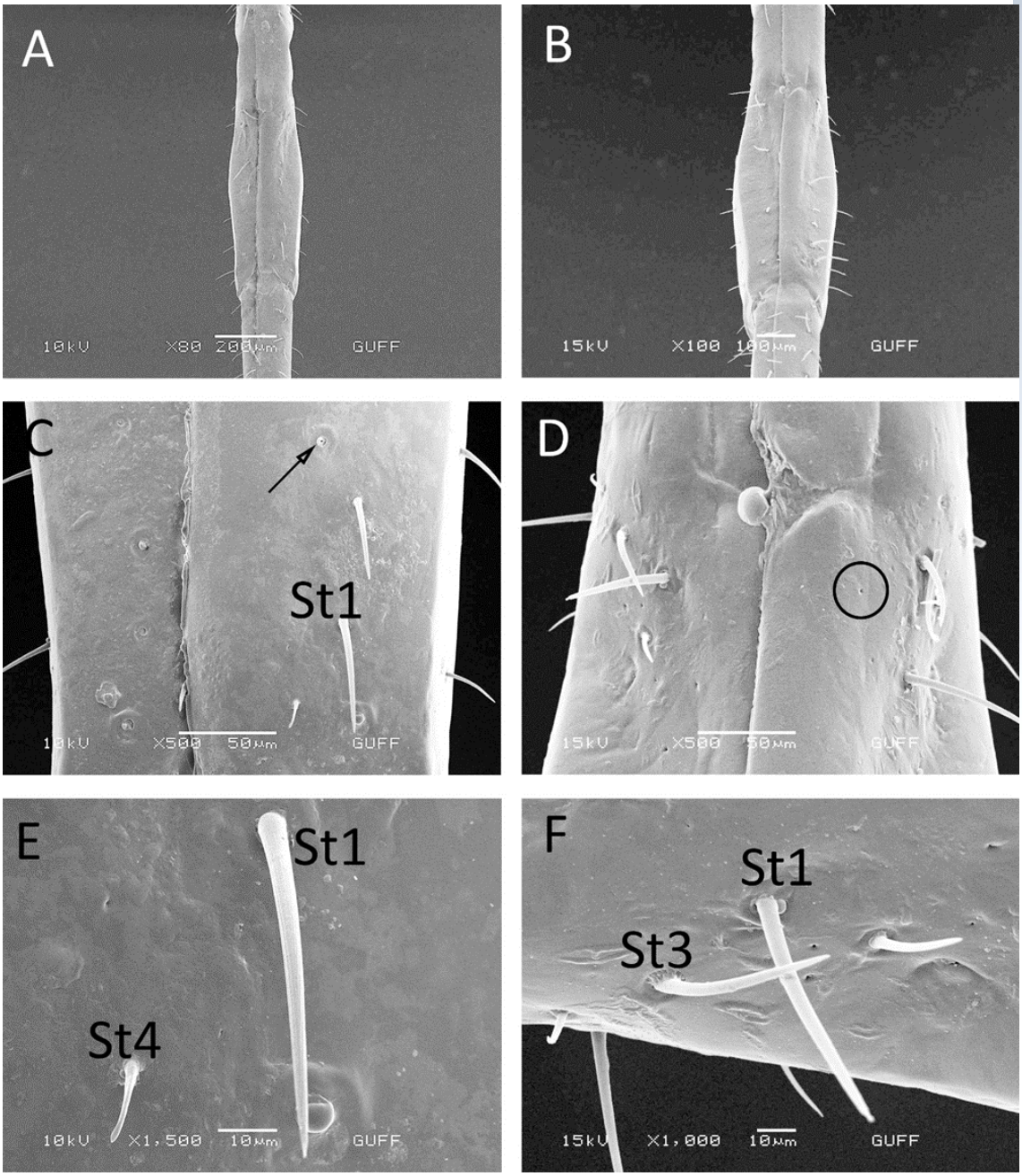

Figure 5. The third segment of the labium. A-C-E: Female, B-D-F: Male. St1: sensilla trichodea 1, St3: sensilla trichodea 3, St4: sensilla trichodea 4, encircled: sensilla campaniformia 1, arrow: sensilla campaniformia 2.

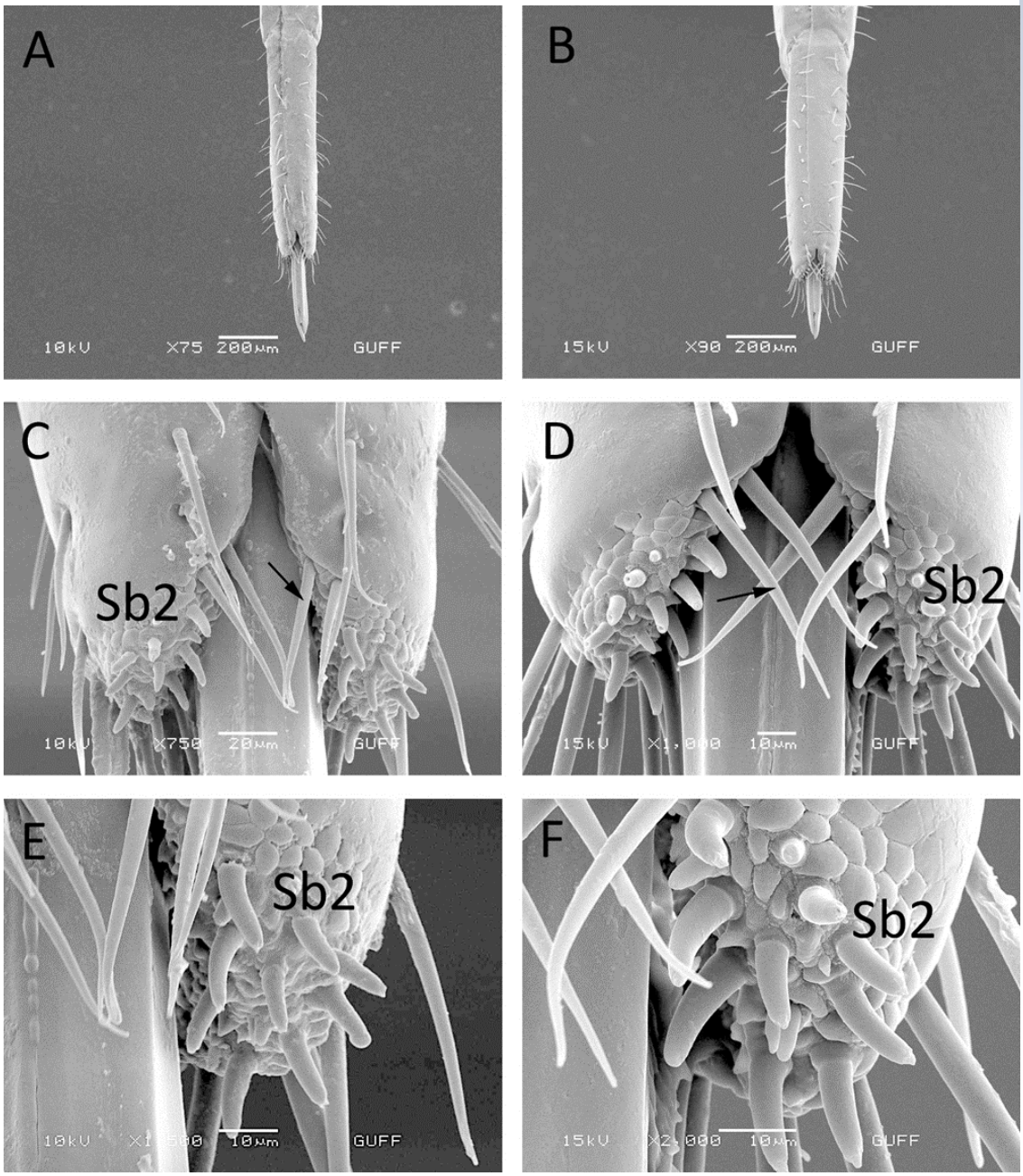

Figure 6. The fourth segment of the labium. A-C-E: Female, B-D-F: Male. Arrow: sensilla trichodea 1, Sb2: sensilla basiconica 2.

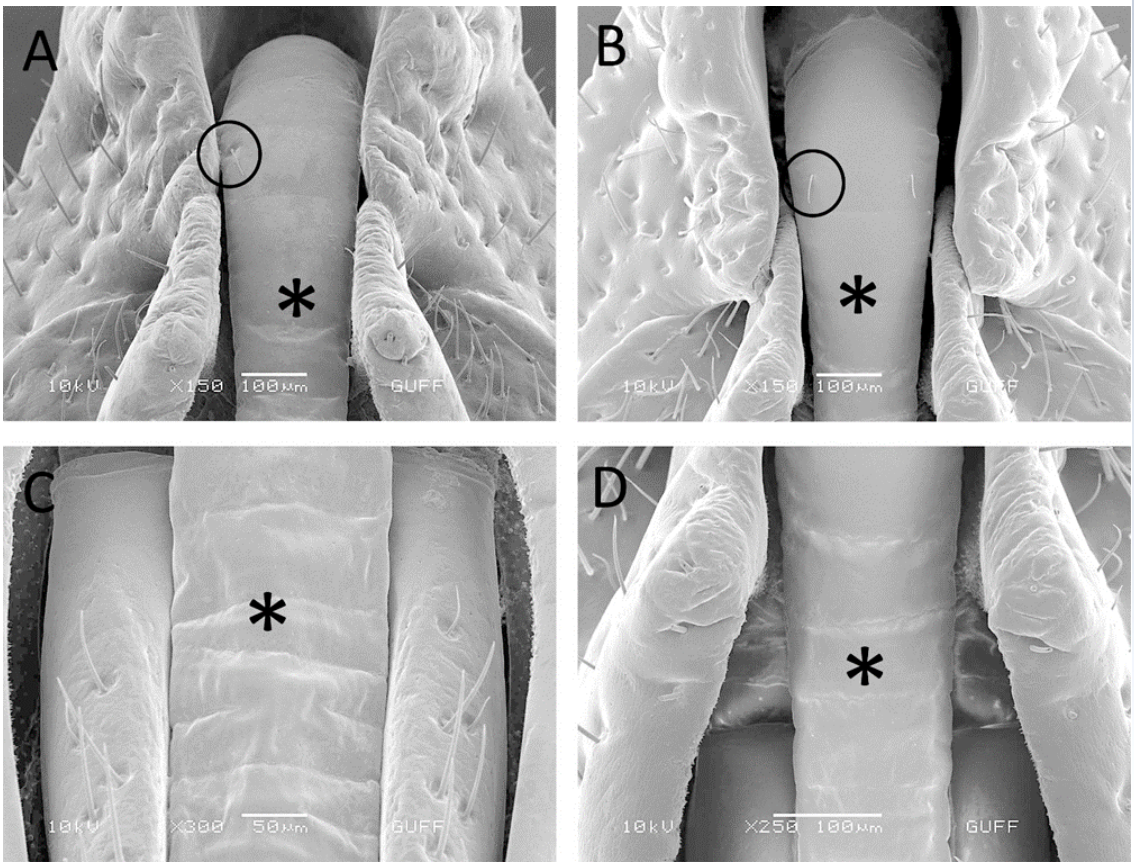

Figure 7. A-B. The proximal region of the labrum, C-D. The distal region of the labrum. A-C: Female, B-D: Male. Encircled: sensilla trichodea 3, asterisk: labrum.

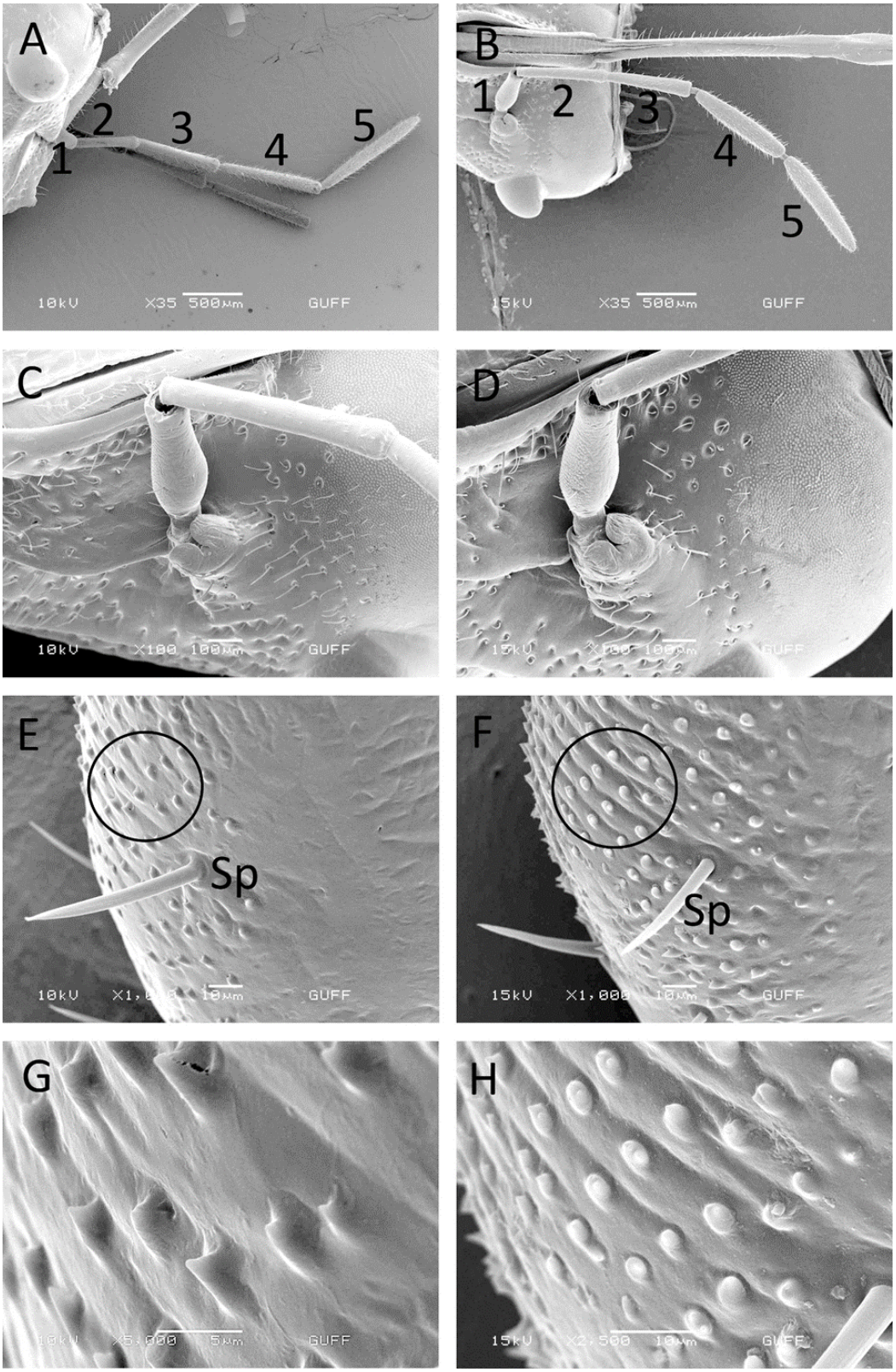

Figure 8. A-B. General view of the five segment of the antenna. C-H. The scape of the antenna. A-C -E-G: Female, B-D-F-H: Male. Sp: sensilla peg, encircled: cone-shaped protrusions.

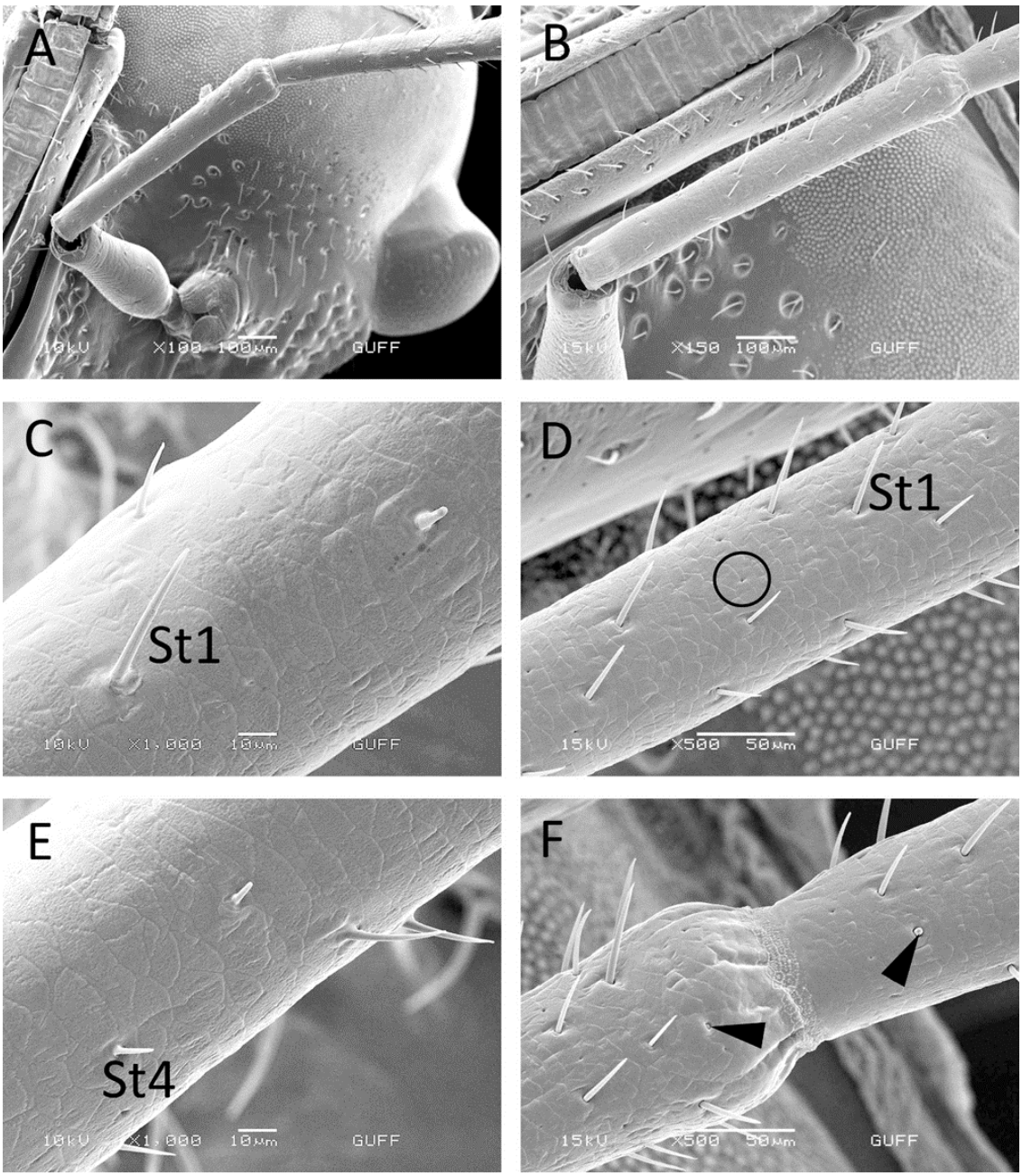

Figure 9. The pedicel 1 of the antenna. A-C-E: Female, B-D-F: Male. Encircled: sensilla campaniformia 1, arrowhead: sensilla campaniformia 2, St1: sensilla trichodea 1, St4: sensilla trichodea 4.

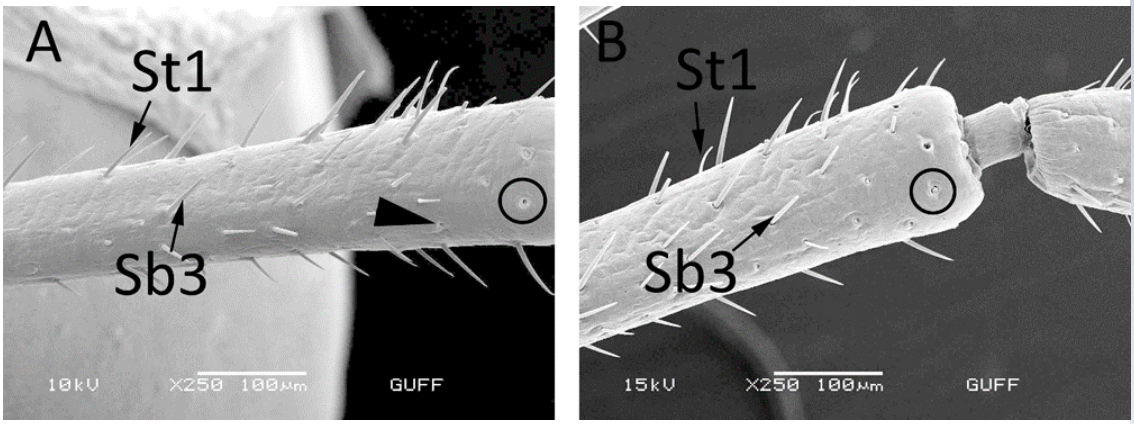

Figure 10. The pedicel 2 of the antenna. A: Female, B: Male. St1: sensilla trichodea 1, Sb3: sensilla basiconica 3, arrowhead: sensilla campaniformia 1, encircled: sensilla campaniformia 2.

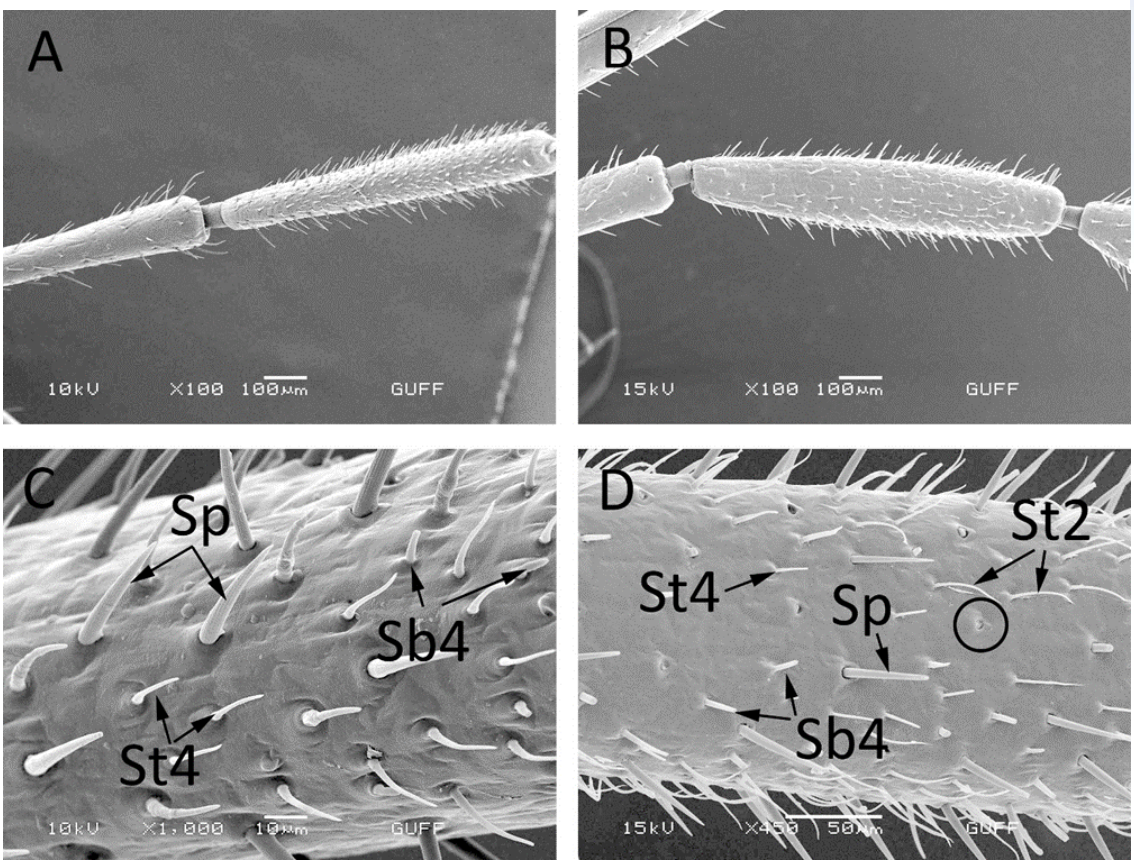

Figure 11. The flagellum 1 of the antenna. A-C: Female, B-D: Male. St2: sensilla trichodea 2, St4: sensilla trichodea 4, Sp: sensilla peg, Sb4: sensilla basiconica 4.

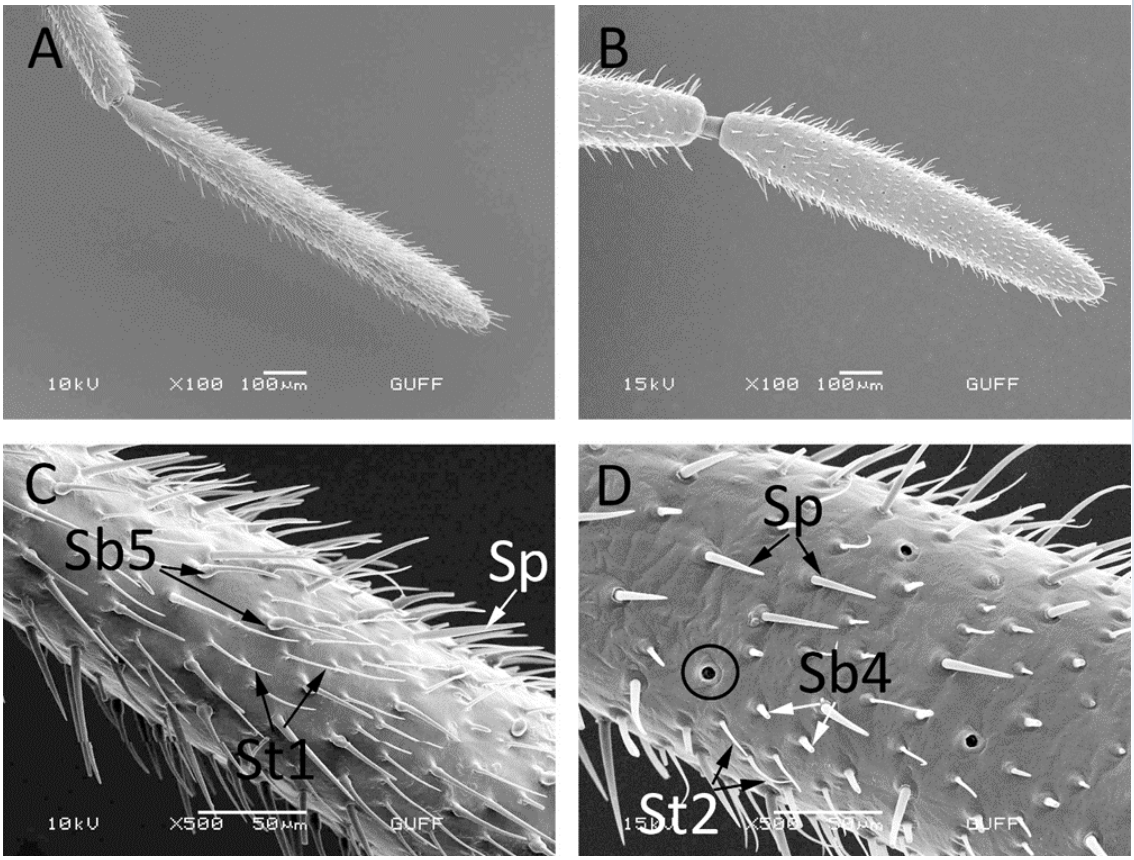

Figure 12. The flagellum 2 of the antenna. A-C: Female, B-D: Male. St1: sensilla trichodea 1, St2: sensilla trichodea 2, Sb4: sensilla basiconica 4, Sb5: sensilla basiconica 5, Sp: sensilla peg, encircled: sensilla campaniformia 3.

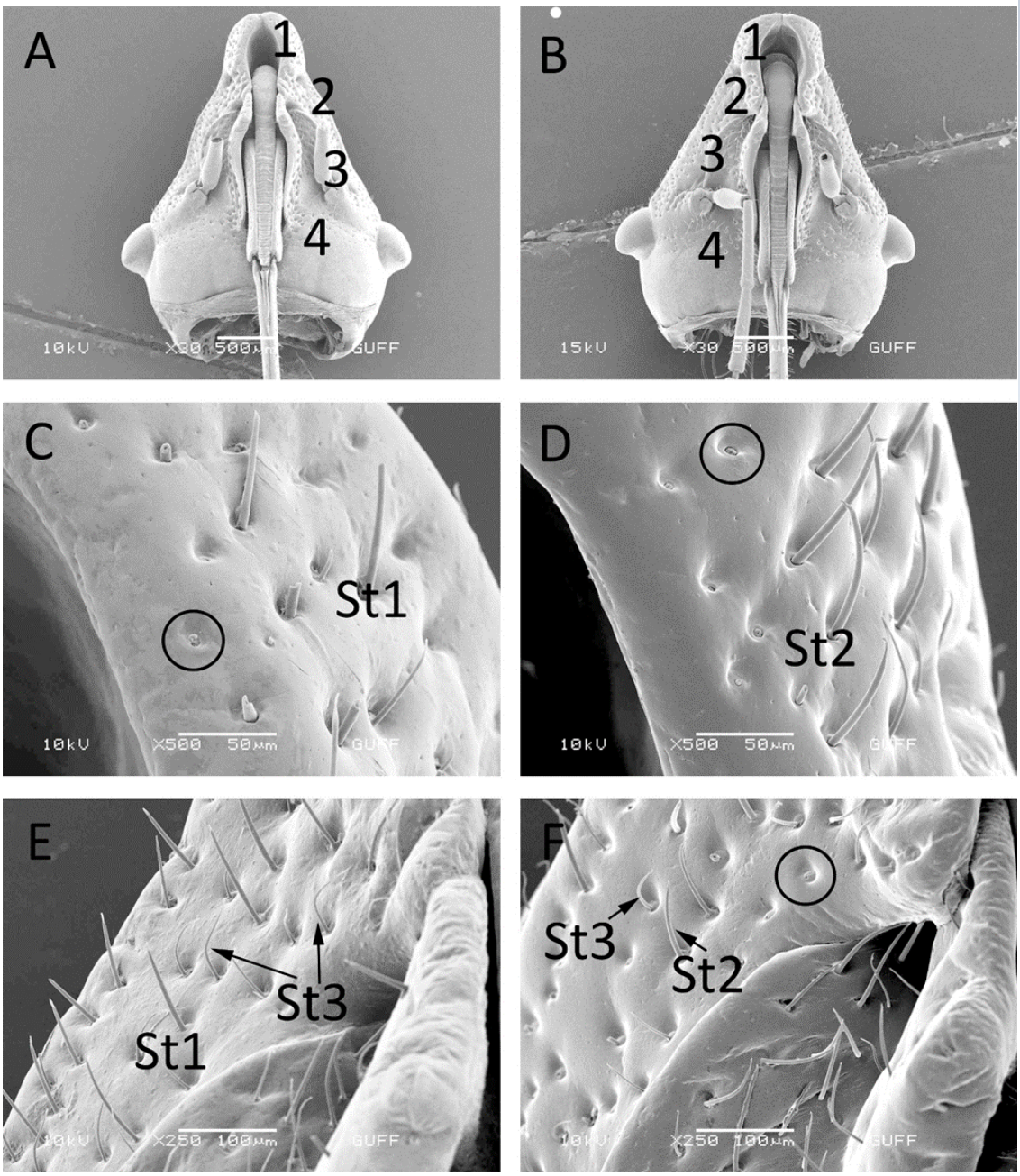

Figure 13. A-B. General view of 4 regions of the head. C-D. The first region of the head. E-F. The second region of the head. A-C-E: Female, B-D-F: Male. St1: sensilla trichodea 1, St2: sensilla trichodea 2, St3: sensilla trichodea 3, encircled: sensilla campaniformia 2.

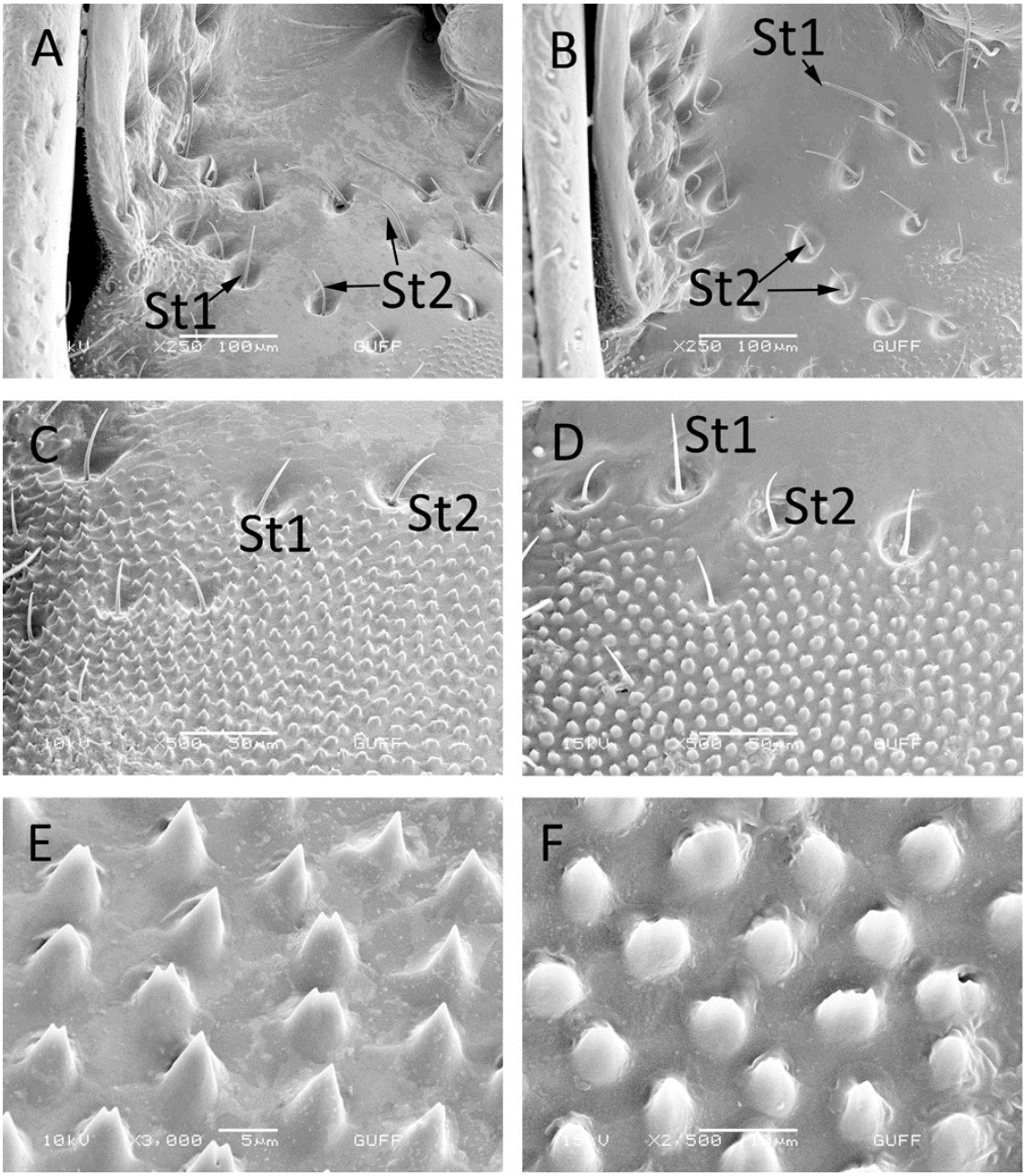

Figure 14. A-B. The third region of the head. C-F. The fourth region of the head. E and F shows the one or two pointed cone-shaped protrusions. A-C-E: Female, B-D-F: Male. St1: sensilla trichodea 1, St2: sensilla trichodea 2.

Sensilla types and distributions in insects are thought to be related to the insects' diet. Because, each sensilla has different sensory functions. For example, sensilla basiconica in the mouthparts is responsible for the movement of these parts, while sensilla trichodea acts as a mechanoreceptor and in this way ensures the discovery of nutrients (Liang et al., 2013; Gullan & Cranstone, 2014; Wang et al., 2019; Amutkan Mutlu et al., 2021). Comparison of sensilla types of some species in the literature is given in the Table 3. It is seen in the table that

sensilla types can vary in different species of insects. We can say that sensilla varieties, numbers and distributions give us taxonomic and phylogenetic data, especially thanks to their morphological contributions to the nutrition of insects and thus to the structure of their mouth-parts. The fact that it has so many different types of sensilla shows that it can receive various chemical stimuli in *A. rostrata*. We hope that this study on the sensilla of *A. rostrata* will contribute to other studies and literature on this subject.

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Table 3. Comparison of sensilla types of *A. rostrata* and some species belong to the order Hemiptera in the literature.

Species	Mouth parts					Antenna					Head	Reference
	Labium 1	Labium 2	Labium 3	Labium 4	Labrum	Scape	Pedicel1	Pedicel2	Flagellum1	Flagellum2		
Aelia rostrata	St, Sca	St, Sb, Sca	St, Sca	St, Sb	St	Sp, cone-shaped protrusions	St, Sca	St, Sb, Sca	St, Sb, Sp	St, Sb, Sca, Sp	Sca, St, cone-shaped protrusions	-
Dolycoris indicus	-	-	-	-	-	-	-	-	St, Sb, Sca, Sch**		-	Ahmad et al., 2016
Plautia crossota	-	-	-	-	-	-	-	-	St, Sb, Sca		-	Ahmad et al., 2016
Eucanthecona furcellata	-	-	-	-	-	-	-	-	St, Sb, Sca, Sco***, Spl****		-	Ahmad et al., 2016
Perillus bioculatus	Sp, Sstc*, St, Sb, Sca				-	-	-	-	St, Sb, Sca, Sco		-	Parveen et al., 2015; Ahmad et al., 2016
Trissolcus japonicus	-	-	-	-	-	St	Sb, St		St, Sch, Spap****, Sca, sickle-shaped, grooved-peg sensilla		-	Yang et al., 2016
Trissolcus plautiae	-	-	-	-	-	St	Sb, St		St, Sch, Spap, Sca, sickle-shaped, grooved-peg sensilla		-	Yang et al., 2016
Stephanitis nashi	-	-	-	-	-	St, Sco	St, Sb, Sca		St	St, grooved-peg sensilla, SCo	-	Wang et al., 2020b
Halyomorpha halys	-	-	-	-	-	Sb, Sco, Sch	Sb, Sco, Sch	Sb, Sco, Sch	Sb, St, Sco, Sch	Sb, St, Sco, Sch	-	Ibrahim et al., 2019
Euschistus heros	-	-	-	-	-	-	Sb	Sb	St, Sb	St, Sb	-	Silva et al., 2010
Edessa meditabunda	-	-	-	-	-	-	Sb, Sch	Sb, Sch	St, Sb	St, Sb	-	Silva et al., 2010
Piezodorus guildinii	-	-	-	-	-	-	Sb, Sch	Sb, Sch	St, Sb	St, Sb	-	Silva et al., 2010
Eocanthecona furcellata	Sp, St, Sstc, Sb, Sch				-	Sch, Sb	St, Sch, Sb	St, Sch, Sb, Sco	St, Sch, Sb, Sco	St, Sch, Sb, Sco	-	Parveen et al., 2015; Zhao et al., 2021
Dolycoris indicus	Sp, St, Sb, Sca, Sch				-	-	-	-	-	-	-	Parveen et al., 2015;

Table 3. Continued

Plautia crossota	Sp, St, Sb, Sca, Sch				-	-	-	-	-	-	-	Parveen et al., 2015;
Piezodorus hybernı	Sp, St, Sb, Sca, Sch				-	-	-	-	-	-	-	Parveen et al., 2015;
Eurygaster testudinaria	no sensilla	Sb, St, Sca, Sp	Sb, St, Sca		dome-shaped protruzions, plate-shaped structures	Sb, St, Sca, Sp	Sb, St, Sca, Sp	Sb, St, Sca, Sp	Sb, St, Sca, Sp	Sb, St, Sca, Sp	St, Sca,	Amutkan Mutlu et al., 2021
Arma chinensis	-	-	-	-	-	Sb	Sb	Sb, Sch	St, Sb, Sch	St, Sb, Sch, Sca, Sco	-	Zhang et al., 2014

*: sensilla styloconica, **: sensilla chaetica, ***: sensilla coeloconica, ****: sensilla placoidea, *****: sensilla papillary