ISSN 2687 - 3249 (online edition)

J.Het.Turk.
Journal of the Heteroptera of Turkey

May, 2021
Volume 3, Issue 1

Research Article

A scanning electron microscope study of the sensilla on antenna and mouthparts in *Eurygaster testudinaria* (Geoffroy, 1785) (Hemiptera, Heteroptera, Scutelleridae)

Damla Amutkan Mutlu[1], Irmak Polat[2], Hanife Gözüpek, Suat Kıyak[1], Zekiye Suludere[1]

[1]Gazi University, Science Faculty, Department of Biology, Ankara, 06500, TURKEY
[2]Çankırı Karatekin University, Science Faculty, Dep. of Biology, Çankırı, 18100, TURKEY

E-mails: damlamutkan@gazi.edu.tr, irmakyilmaz@gazi.edu.tr, skiyak@gazi.edu.tr, zekiyes@gazi.edu.tr

ORCID IDs: 0000-0002-4780-8520 (DAM), 0000-0001-7230-4589 (IP), 0000-0001-8167-8283 (SK), 0000-0002-1207-5814 (ZS)

ABSTRACT: In insects, there are many sensilla showing different structural features on the mouthparts and antennae. These sensilla act as the sensory organs of insects. Main functions of the sensilla in insects are chemoreception, mechanoreception, and thermohygrosensory properties. *Eurygaster testudinaria* (Geoffroy) (Hemiptera, Heteroptera, Scutelleridae) is a widespread species that is a perilous pest for agricultural areas. In this study, the sensilla on the mouth parts and antennae of *E. testudinaria* were investigated by using scanning electron microscope technique. In our results we obtained, we identifed four types of sensilla such as sensilla basiconica, peg-like sensilla, sensilla trichodea, sensilla campaniformia. Each sensilla type were divided into subtypes and numbered. We hope to contribute to similar studies in the future with this morphological study.

KEYWORDS: Insect, Heteroptera, chemoreceptor, mechanoreceptor, morphology, systematic, taxonomy

To cite this article: Amutkan Mutlu, D., Polat, I., Gözüpek, H.,Kıyak, S., Suludere, Z., 2021, A scanning electron microscope study of the sensilla on antenna and mouthparts in *Eurygaster testudinaria* (Geoffroy, 1785) (Hemiptera, Heteroptera, Scutelleridae), *J..Het.Turk.,* 3 (1):14-30
DOI:10.5281/zenodo.4823578
To link to this article: https://www.j-ht.org/wp-content/uploads/2021/05/V31-A3.pdf
Received: Apr 22, 2021; **Revised:** May 17, 2021; **Accepted:** May 20, 2021; **Published online:** May 31, 2021

INTRODUCTION

Sensilla, which is found in the mouth and antennae parts of insects, plays an important role in vital functions such as mating by identification of sex pheromones, feeding and finding a host alive (Isidoro et al., 2001; Fu et al., 2012; Cao and Huang, 2016; Faucheux et al., 2020). The mouthparts and antenna in insects host many different types of sensilla that act as chemoreceptors and mechanoreceptors (Li et al., 2016). Most of these receptors are chemoreceptors (Brozek and Chlond, 2010). The researchers have classified the sensilla in insects into four major groups according to the sensory modality: gustatory, olfactory, mechanosensory and thermohygrosensory (Fernandes et al., 2008; Nowinskal and Brozek, 2017; Li et al., 2018). Some researchers classify olfactory sensilla and gustatory sensilla under the name of chemoreceptors (Brozek and Chlond, 2010). In addition, there are also varieties of sensilla such as trichoid, basiconic, plate-like, placoid, long hair-like and coeloconic when looking at external morphology (Slifer 1970; Altner and Prillinger 1980; Hallberg and Hansson 1999; Shields 2010; Nowinskal and Brozek, 2017). Besides, sensilla are divided into 3 major groups according to the presence of pores each with different functions: aporous, uniporous (terminal pores) and multiparous (wall pores) (Nowinskal and Brozek, 2017).

In the species belonging to the ordo Heteroptera (Hemiptera), the labial sensilla tracks the surfaces of the food sources such as plant and animals (Chapman, 1998; Brozek and Zettel, 2014; Parveen et al., 2015). The outer structure of the sensilla of insects shows variation among Hemiptera species (Brozek and Bourgoin, 2013; Nowinskal and Brozek, 2017; Taszakowski et al., 2019).

Insects perceive volatile chemicals in the air with their antennae (Carey and Carlson, 2011). Antennas are the primary sensory organs of insects and there are many different types of sensillas on them. These sensillas act as thermohygrorecertors, chemoreceptors and mechanoreceptors (Akent'eva, 2008; Fu et al., 2012; Brozek and Bourgoin, 2013; Freitas et al, 2020; Zhang et al., 2021). In species belonging to the order Hemiptera, antenna sensilla are used by the insect to recognize plants at a distance by olfactory ability (Brozek, 2013).

Hemiptera is a very large order that includes a wide variety of species. The piercing-sucking mouthparts of these Hemiptera species are a feature that allows them to feed on plant sap (Kanturski et al., 2017). Therefore, insects belonging to this ordo are generally known as plant pests (Hao et al., 2016).

Eurygaster is a holarctic genus of ordo Heteroptera (Hemiptera) which has 15 species (Kaplin and Burlaka, 2019). *Eurygaster testudinaria* (Geoffroy) (Heteroptera, Scutelleridae) is a species that belongs to this genus and has a wide distribution area. They have trans-Palaearctic distribution and have been recorded in Norway, Ireland, Finland, Great Britain, and Turkey in Europe, Tunisia and Morocco in Africa, Tajikistan, Kyrgyzstan, Kazakhstan, Uzbekistan, Japan, and Korea in Asia (Syromyatnikov et al., 2017; Kaplin and Burlaka, 2019). *E. testudinaria* has been recorded in meadows and on the species belonging the Cyperaceae family. Besides, it is also known to be a very dangerous pest for cereals (Linnavuori, 2008; Syromyatnikov et al., 2017).

The aim of this study is to divulge the morphological features of the sensilla of the mouth and the antenna parts according to their cuticular structures and to make the classification of them in *E. testudinaria*, an agricultural pest.

MATERIAL AND METHODS

The adult individuals of *Eurygaster testudinaria* were taken from field survey in Ayaş and Haymana in Ankara province in July, 2018 and carried to the laboratory in 2,5 L plastic bottles. The external structures of specimens were cleaned. The cleaned specimens were attached to SEM stubs after they were dried in air. Subsequently, the SEM stubs with specimens were coated with gold and observed in SEM (JEOL JSM 6060 LV). The micrographs were taken at

J.Het.Turk., 3(1), May 2021 (eISSN 2687-3249)

10kV accelerating voltage in different magnifications. All studies were carried out at Gazi University, Faculty of Science, Prof. Dr. Zekiye Suludere Electron Microscope Center.

RESULTS AND DISCUSSION

There are many sensory organs that determine different chemical substances and mechanical actions on the outer surface of the insects. Most of them are found on the mouthparts surface and can find food to feed on these various sensory organs. The others are found on the antenna surface and they can serve the functions of both smelling and touching (Blaney & Chapman, 1969; Cao & Huang, 2016). In this study, we revealed the sensilla morphology of the head including mouthparts, antenna and surface of the head in adult male and female *E. testudinaria* with scanning electron microscope (SEM). Different types of sensilla were observed on the surface of the mouthparts, the antenna, and the head. Each region of the mouth-parts and antenna was separately described and compared with those in previous studies. No obvious differences were noted between the mouthpart, antenna and head structure of female and male individuals.

The mouthparts in hemipteran species are composed of the labrum which is short and conical in shape, the labium which is long and segmented, and a labial groove in which mandibular and maxillary stylets are located, respectively (Wang et al., 2020). In the insect being studied (*E. testudinaria*), dorsal view of the species has shown that there is a three-segmented labium, labial groove, labrum, and stylet fascicle in mouth-parts. The defining feature of hemipterans is that it is a "stylet" which is sheathed within a modified labium (Figure 1A, 1B). In some species belong-ing to Hemiptera order, in Heteroptera suborder such as *Dolycoris indicus*, *Plautia crossota*, *Piezodorus hybneri*, *Eocanthecona furcellata*, *Perillus bioculatus* (Parveen et al., 2015), *Cheilocapsus nigrescens* (Wang et al., 2019), *Macrocheraia grandis*, *Physopelta quadriguttata*, *Physopelta cincticollis*, and *Physopelta gutta* (Wang et al., 2020) the mouthparts have a four-segmented labium.

In different Heteroptera species, while mouth parts are specified, the sensilla types on them are also shown. Various types of sensilla are determined unsymmetrically in each part, positioned on either sides of the labial groove or on the distal end of the labium in *E. testudinaria* (Figure 2).

The labrum (Lm) attaches to the anterior margin of the head and extends to the junction of the head and thorax in both sexes (Figures 1A, 1B). The region (proximal region) where it attaches to the head is wide and the free distal end is thinner than the proximal region (Figures 3A, 3B). While the proximal surface of the labrum has short dome-shaped protrusions (Figures 3C, 3D), its other surface is almost smooth and also light and transverse pits were found (Figures 3E, 3F). Plate-shaped structures are noticeable at the end edges of the labrum (Figures 3G, 3H). Sensilla have not been found in this area. The similar structures related to the labrum are reported in *M. grandis* (Heteroptera), *P. quadriguttata* (Heteroptera), *P. cincticollis* (Heteroptera), and *P. gutta* (Heteroptera) (Wang et al., 2020).

The labium (Lb) is long, slender, and three segmented. Its anterior surface is deeply concave to form a longitudinal channel due to containing the mandibular and maxillary stylets. Each segment of three-segmented labium varies widely morphologically. The middle of the first segment is concave, and the labrum extends into this area (Figures 4A, 4B). Although the apex of the first segment is smooth and has no sensilla (Figures 4A, 4B), there are many different sized sensilla in the middle part, and a great number of small protrusions (Figures 4C, 4D). Sensilla are in the same form as sensilla basiconica (Sb) and

J.Het.Turk., 3(1), Mayıs 2021 (eISSN 2687-3249)

sensilla trichodea (St). Sensilla basiconica and sensilla trichodea are numbered according to the diagram in Figure 2. The last part of the first segment in labium is smooth in both sexes like in the apex. In the male individual, that area appears to be more swollen (Figures 4D, 4E).

The second and third segments of the labium have similar morphology along their length, but the second segment is narrower in contrast to the first and third segment. The surface of the junctions of the longitudinal channel in the second segment is differentiated as a plate (Figures 5A, 5B). The other surface is smooth and various sensilla are seen (Figures 5C-5F). There are four types of sensilla such as sensilla basiconica, sensilla trichodea, sensilla campaniformia, and peg-like sensilla in the second segment in both sexes (Figures 5C-5F).

A small canal structure was seen on the right and left edges of the junction of the second and third and the last segments in both sexes (Figures 6A, 6B). One sensilla campaniformia I (Sca1) and one sensilla basiconica V (Sb5) type sensilla were observed at the edges of both channels (Figures 6C, 6D).

In the third segment of the labium, a large number of sensilla basiconica I (Sb1), sensilla basiconica II (Sb2), sensilla basiconica III (Sb3), and basiconica V (Sb5) are interlaced on the surface (Figures 7A, 7B). They are quite straight with smooth surfaces. Apart from sensilla basiconica (Sb), sensilla trichodea III (St3) and sensilla campaniformia II (Sca2) type sensilla were also located in the third segment (Figures 7C-7F). The last part of the third segment is symmetrically divided into two lateral lobes (Figures 8A, 8B). There are many sensilla trichodea III (St3), sensilla trichodea IV (St4), and sensilla basiconica III (Sb3) type sensilla located on it (Figures 8C, 8D).

The antenna of *E. testudinaria* is composed of five segments in both sexes (Figure 9A, 9B). There were no significant differences in each segment between females and males. Four types of antennal sensilla, including four subtypes of sensilla basiconica (Sb), three subtypes of sensilla trichodea (ST), one type of peg-like sensilla (Ps), and one type of sensilla campaniformia (Sca) are observed along its surface (Figures 10-14).

The surface of the head in *E. testudinaria* has three types of sensilla such as St1, sensilla trichodea I; St2, sensilla trichodea II; Sca2, sensilla campaniformia II. These types of sensilla are shown in Figure 15. St1, sensilla trichodea I type sensilla is the most common type of sensilla on the surface of the head.

The labium of hemipterans plays an important role in recognizing foods using the sensory organs on its surface (Backus, 1988; Wang et al., 2019). Four types of sensilla on the tip and surface were observed on the labium of *E. testudinaria.* Each group of sensilla has different length and thickness; therefore, they were numbered in themselves. The most abundant sensilla on the labium are sensilla trichodea and sensilla basiconica. However, only sensilla trichodea on the labium was observed in *C. nigrescens* (Heteroptera, Miridae) (Wheeler, 2001; Wang et al., 2019). It has been stated that sensilla trichodea acts as mechanoreceptors to find nutrients, whereas sensilla basiconica type sensilla are involved in the movement of mouth parts (Liang et al., 2013; Gullan & Cranston, 2014; Wang et al., 2019). When we look at the sensors on the antenna, we observed four types of sensilla. These sensilla help insects to understand their environment. The feeding mechanism may be understood from the mouthpart morphology of insect species. The insect can choose the food

J.Het.Turk., 3(1), May 2021 (eISSN 2687-3249)

with the sensilla on the surface of the mouthparts. The diverse type, number and distribution of labial sensilla appear to be much more important because of being used as the morphological characteristics and presenting taxonomic and phylogenic data. In the light of the data we have obtained, we hope to contribute to future studies on insect mouthparts.

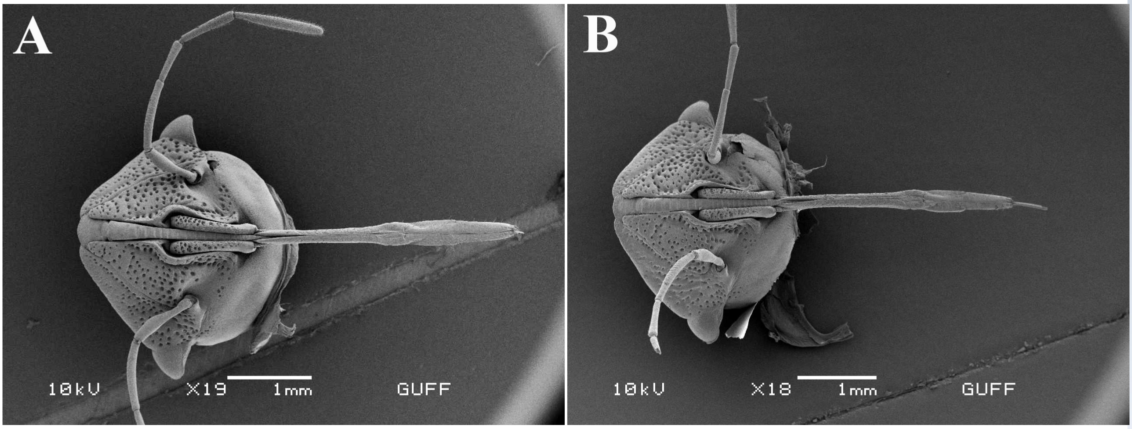

Figure 1. SEM micrographs of the head in *Eurygaster testudinaria.* A. Female individual; B. Male individual.

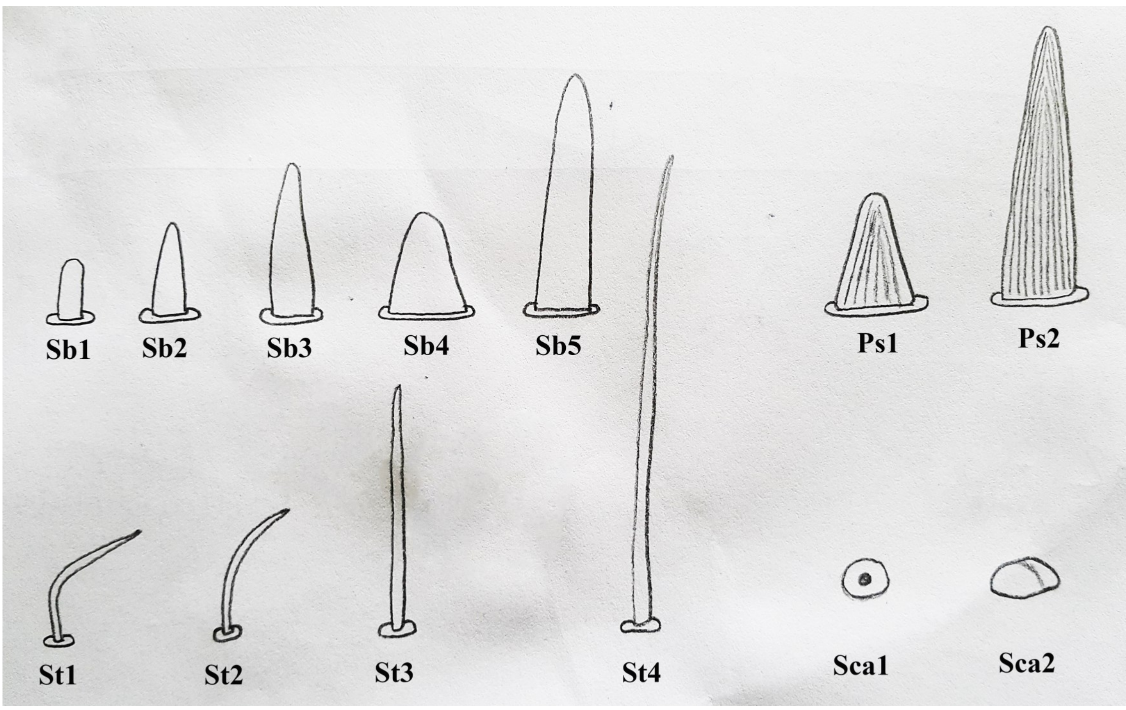

Figure 2. Diagrams of different types of sensilla on mouthparts, antenna, and head of *E. testudinaria.* Sb1, sensilla basiconica I; Sb2, sensilla basiconica II; Sb3, sensilla basiconica III; Sb4, sensilla basiconica IV; Sb5, sensilla basiconica V; Ps1, peg-like sensilla I; Ps2, peg-like sensilla II; St1, sensilla trichodea I; St2, sensilla trichodea II; St3, sensilla trichodea III; and St4, sensilla trichodea IV; Sca1, sensilla campaniformia I; Sca2, sensilla campaniformia II.

J.Het.Turk., 3(1), Mayv 2021 (eISSN 2687-3249)

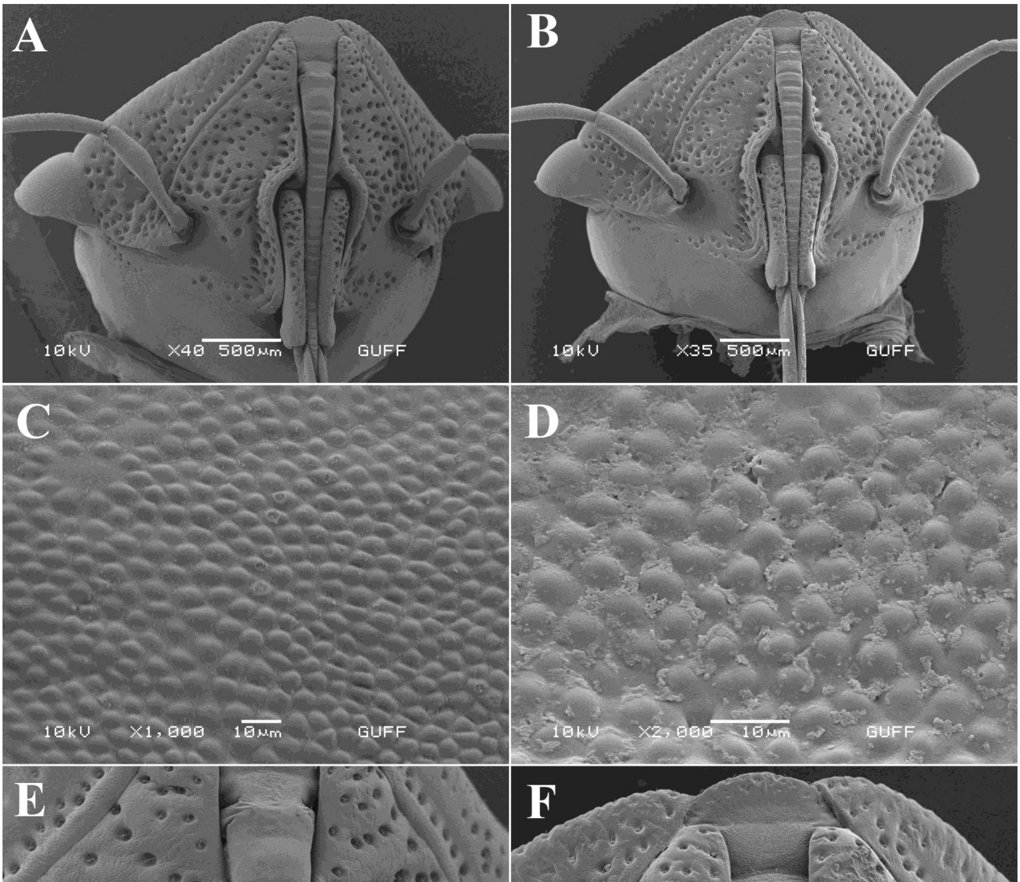

Figure 3. SEM micrographs of the head in *E. testudinaria;* A. Female individual; B. Male individual; C-D. Short dome-shaped protrusions on the surface of the proximal region; C. Female individual; D. Male individual; E-F. The surface of the other region of the labrum; E. Female individual; F. Male individual; G-H. Plate-shaped structures (*) at the end edges of the labrum; G. Female individual; H. Male individual.

J.Het.Turk., 3(1), May 2021 (eISSN 2687-3249)

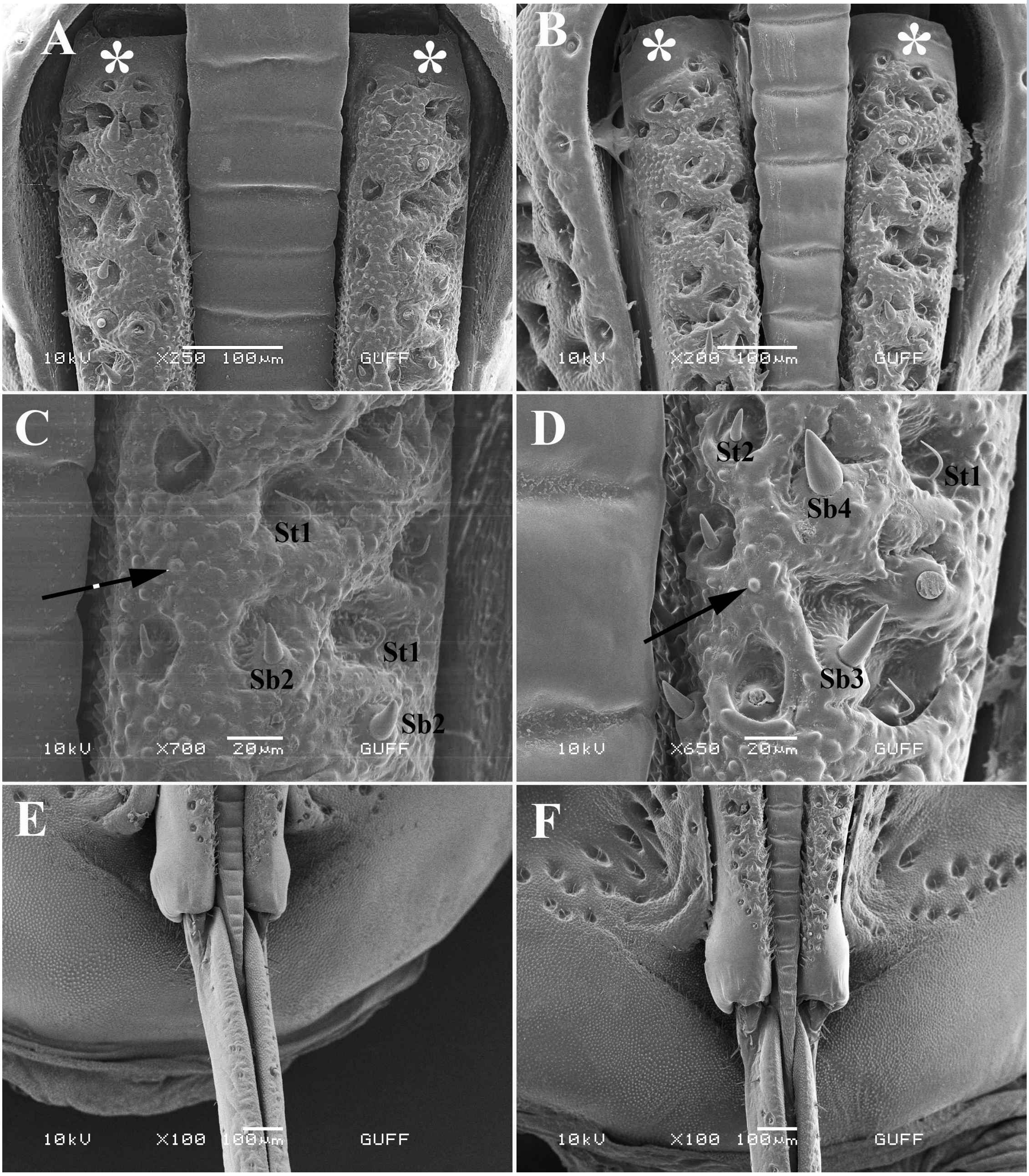

Figure 4. SEM micrographs of the first segment of labium in *E. testudinaria.* A. Female individual; B. Male individual; C. Different sized sensilla in the middle part of the labium in female; D. Different sized sensilla in the middle part of the labium in male; E. The last part of the first segment of the labium in female; F. The last part of the first segment of the labium in male. (*), the surface of the apex of the first segment; (→), small protrusions; St1, sensilla trichodea I; St2, sensilla trichodea II; Sb2, sensilla basiconica II; Sb3, sensilla basiconica III; Sb4, sensilla basiconica IV.

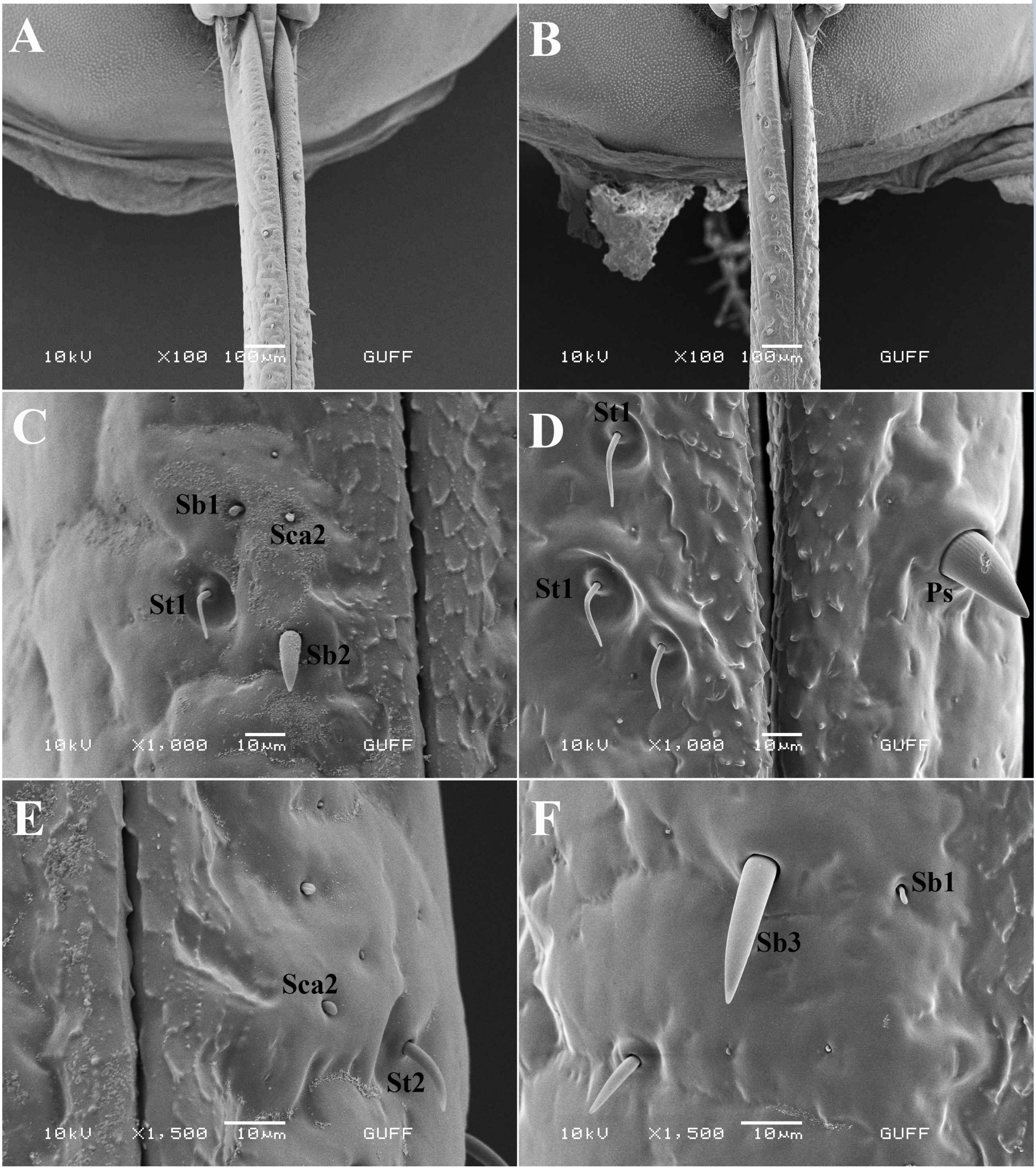

Figure 5. SEM micrographs of the second segment of labium in *E. testudinaria* A. Female individual; B. Male individual; C-F. SEM micrograph of four types of sensilla. C. and E. Female individual; D. and F. Male individual. Sb1, sensilla basiconica I; Sb2, sensilla basiconica II; Sb3, sensilla basiconica III; St1, sensilla trichodea I; St2, sensilla trichodea II; Sca2, sensilla campaniformia II; Ps1, peg-like sensilla I.

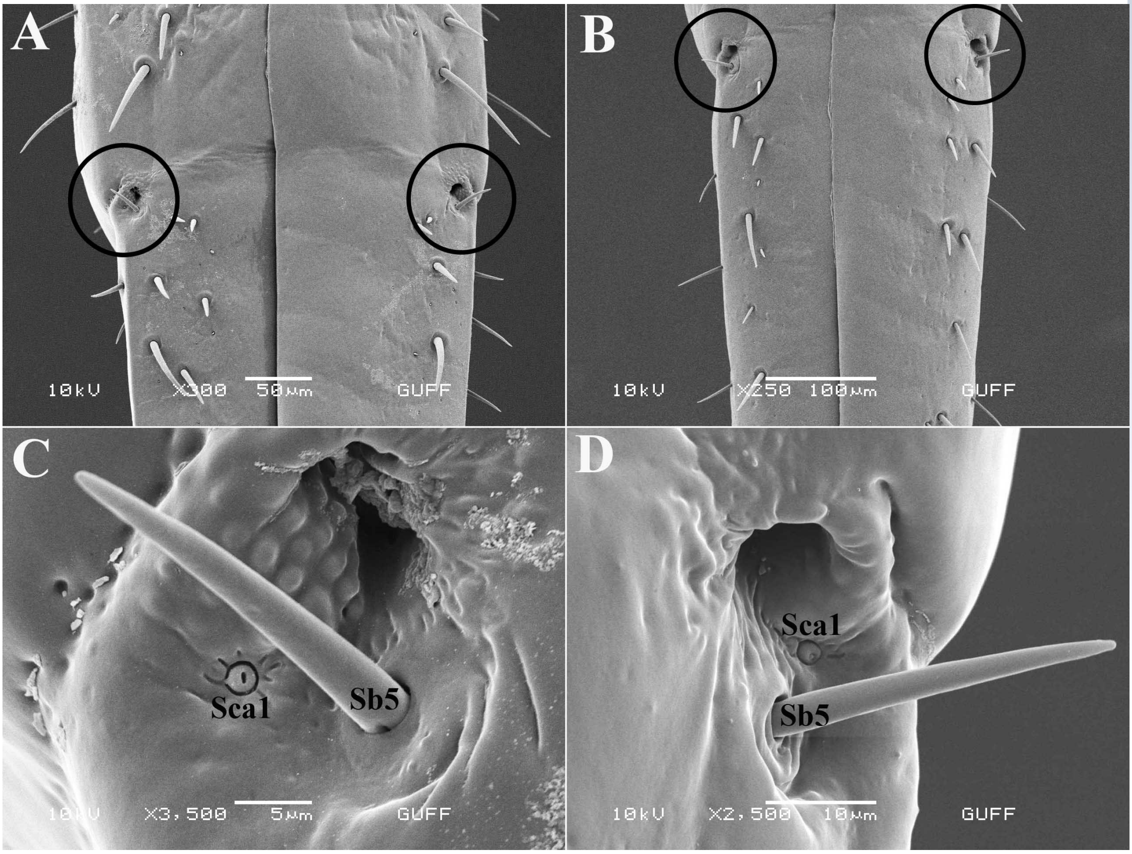

Figure 6. SEM micrographs of the junction of the second and third and the last segments in *E. testudinaria.* A. Female individual; B. Male individual; C-D. Sensilla campaniformia I (Sca1) and sensilla basiconica V (Sb5) type sensilla. C. Female individual; D. Male individual. (O), small canal structure.

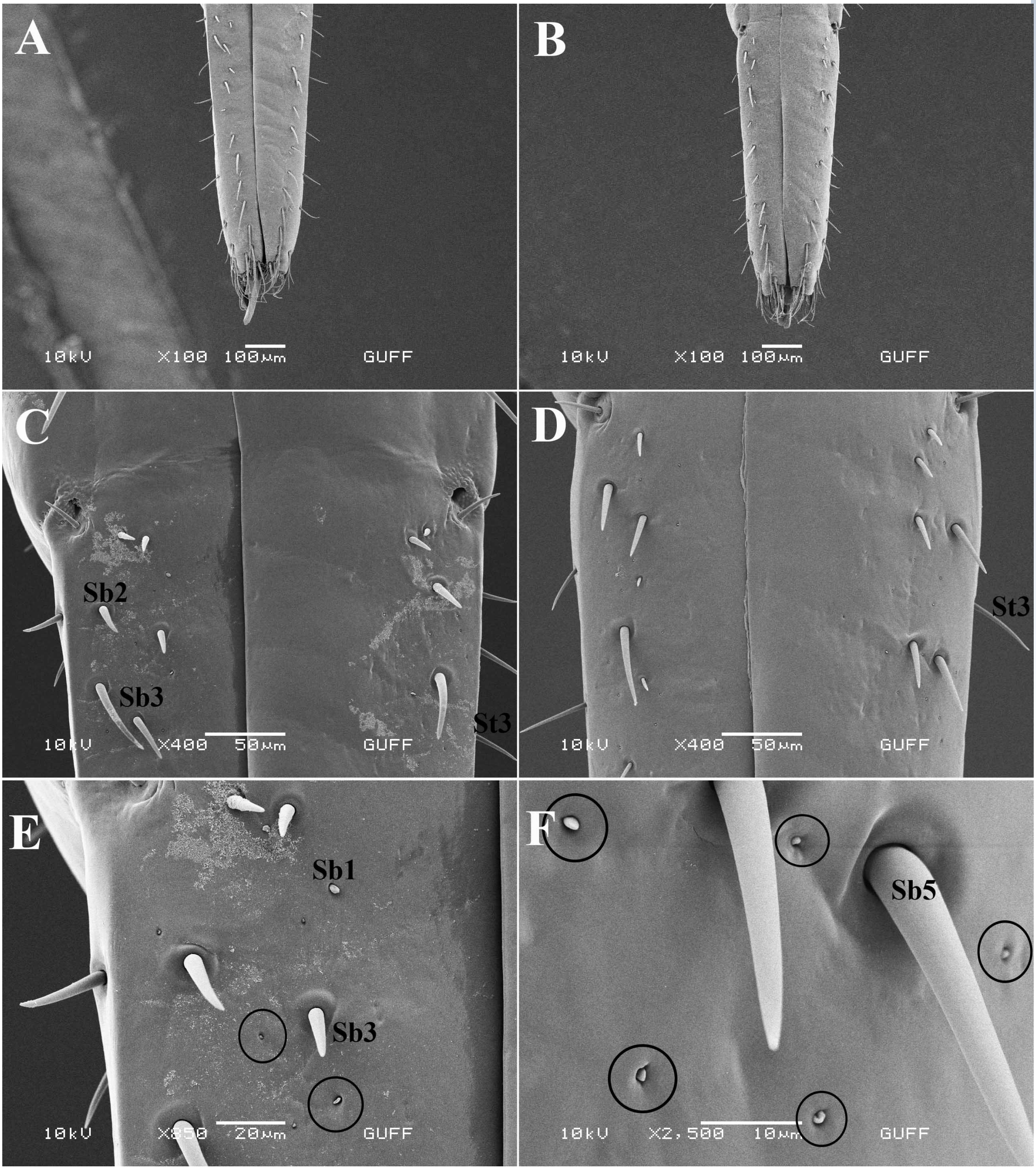

Figure 7. SEM micrographs of the third and the last segment in *E. testudinaria.* A. Female individual; B. Male individual; C-F. Sensilla basiconica (Sb), sensilla trichodea (St) and sensilla campaniformia (Sca) type sensila. C. and E. Female individual; D. and F. Male individual. Sb1, sensilla basiconica I; Sb2, sensilla basiconica II; Sb3, sensilla basiconica III; Sb5, sensilla basiconica V; St3, sensilla trichodea III; (O), Sca2, sensilla campaniformia II.

J.Het.Turk., 3(1), May 2021 (eISSN 2687-3249)

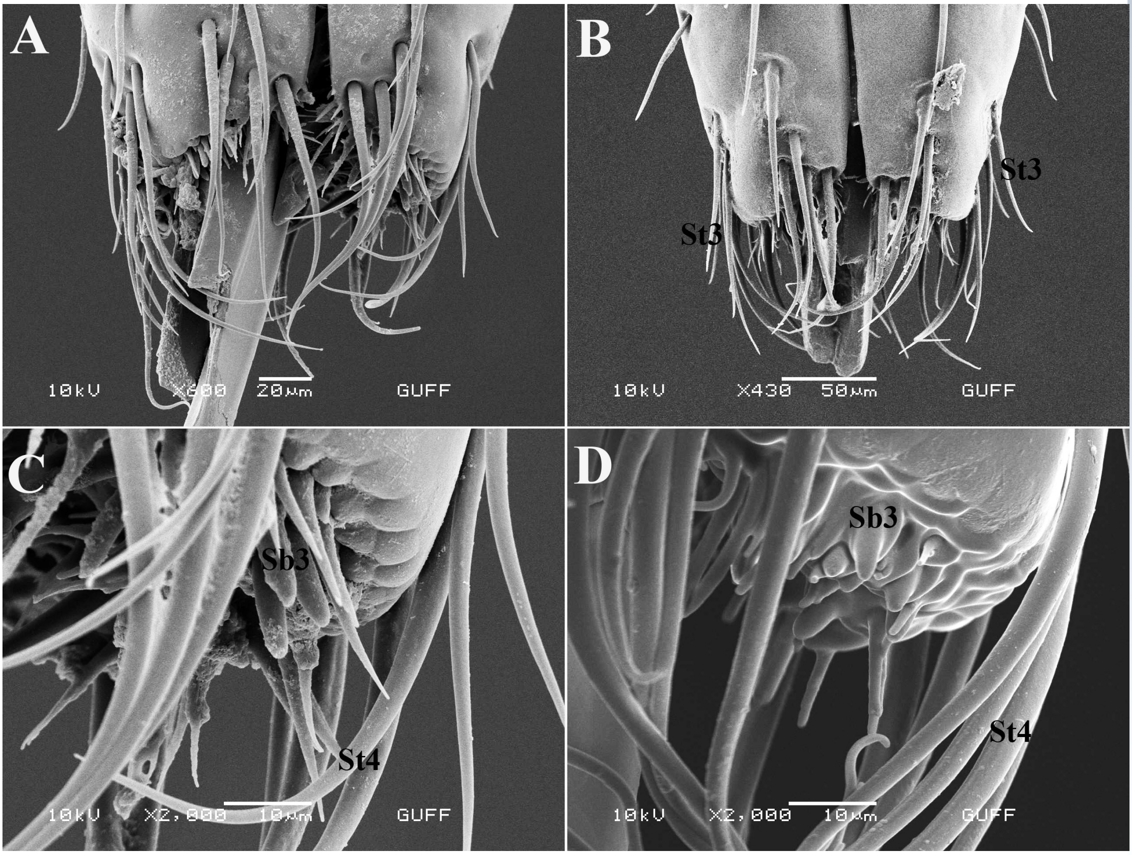

Figure 8. SEM micrographs of the last part of the third segment in *E. testudinaria*. A. Female individual; B. Male individual; C-D. Sensilla trichodea III (St3), sensilla trichodea IV (St4), and sensilla basiconica III (Sb3) type sensilla. C. Female individual; D. Male individual

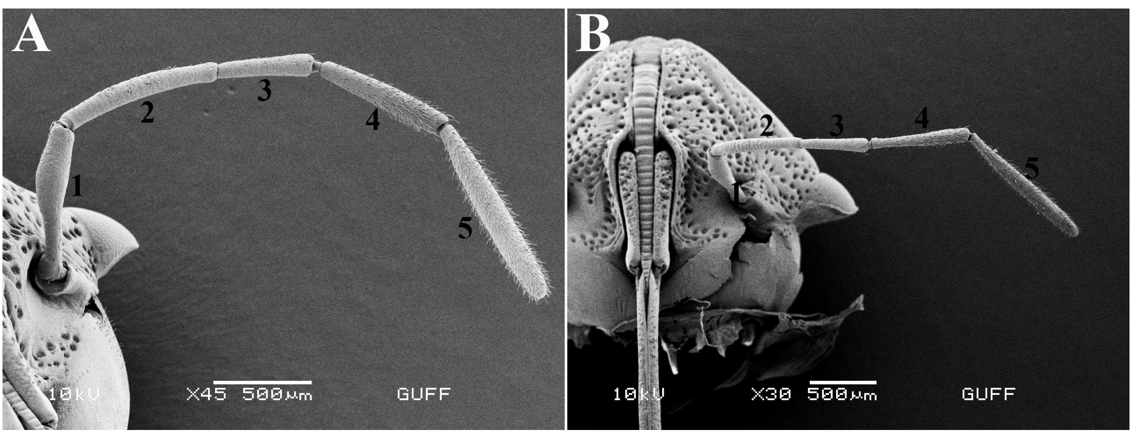

Figure 9. SEM micrographs of the antenna in *E. testudinaria.* A. Female individual; B. Male individual.

J.Het.Turk., 3(1), May 2021 (eISSN 2687-3249)

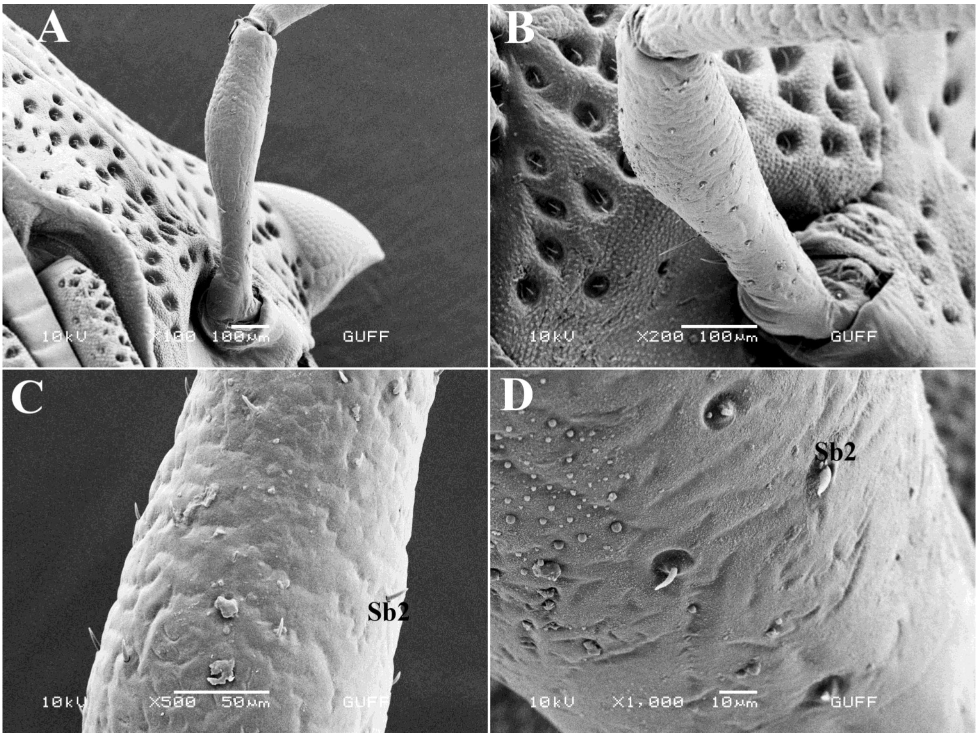

Figure 10. SEM micrographs of the first segment of the antenna. A. and C. Female individual; B. and D. Male individual. Sb2, sensilla basiconica II.

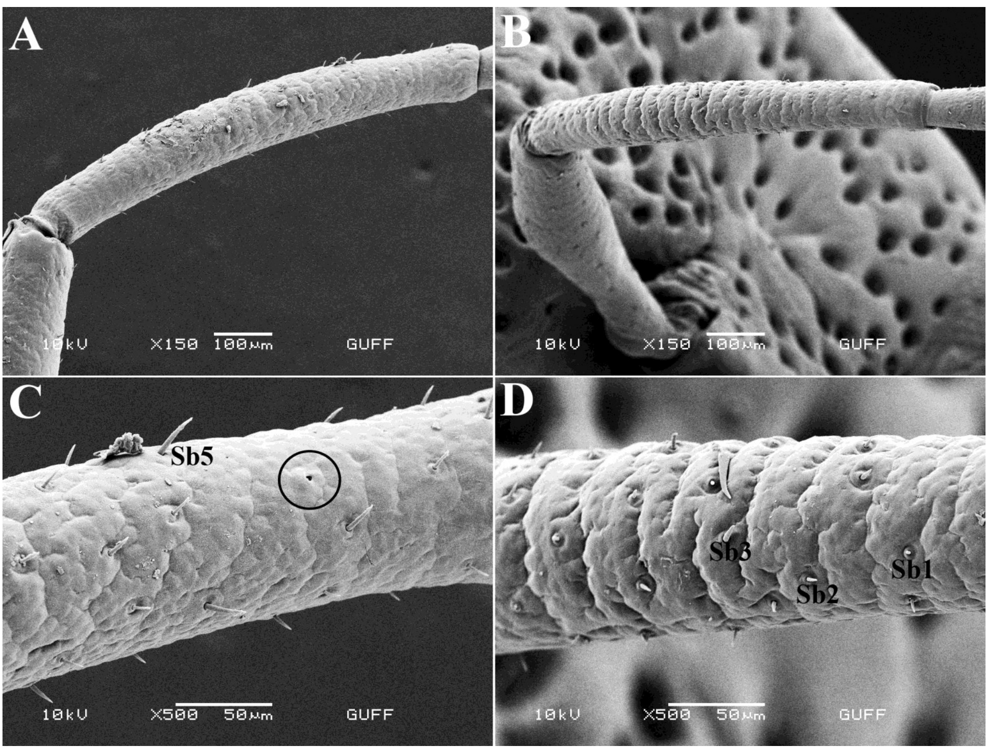

Figure 11. SEM micrographs of the second segment of the antenna. A. and C. Female individual; B. and D. Male individual. Sb1, sensilla basiconica I; Sb2, sensilla basiconica II; Sb3, sensilla basiconica III; Sb5, sensilla basiconica V; (O), Sca2, sensilla campaniformia II.

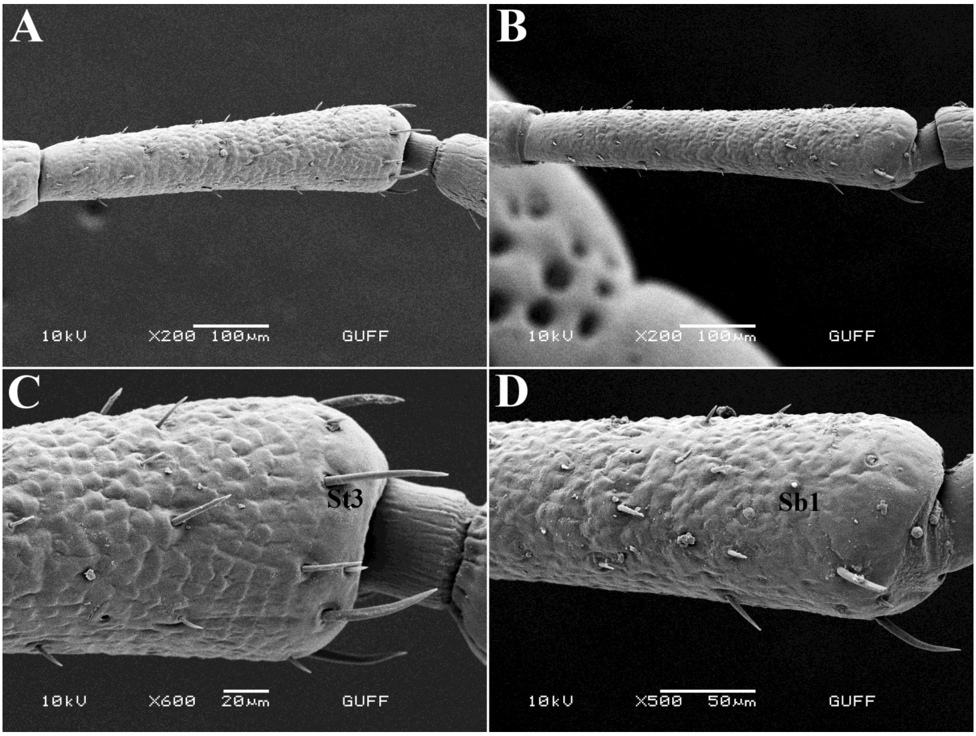

Figure 12. SEM micrographs of the third segment of the antenna. A. and C. Female individual; B. and D. Male individual. Sb1, sensilla basiconica I; St3, sensilla trichodea III.

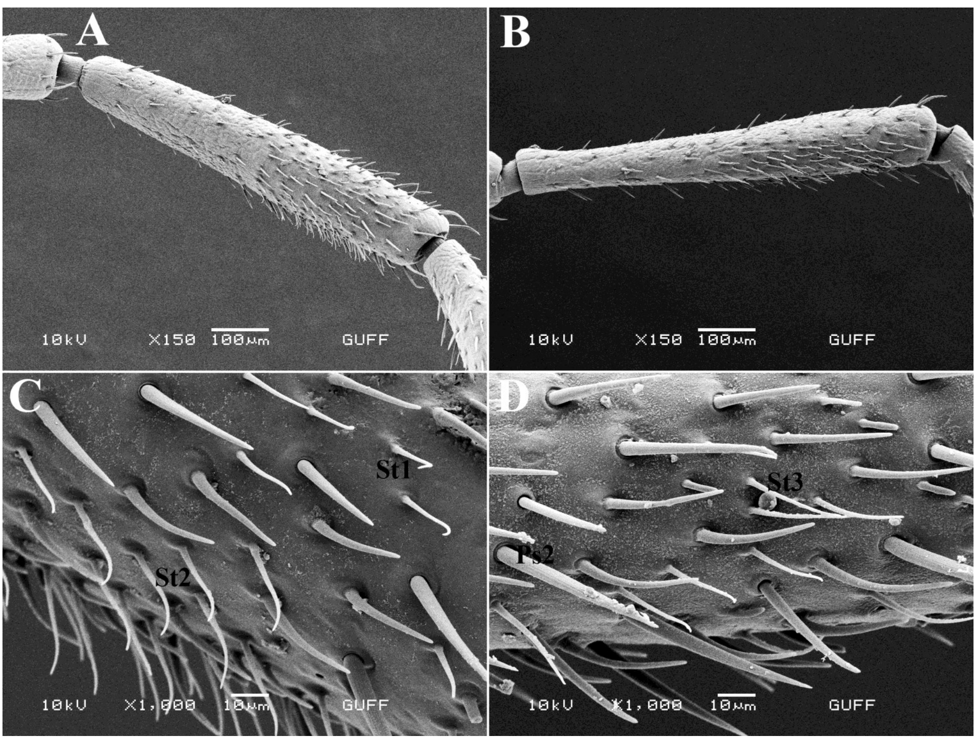

Figure 13. SEM micrographs of the fourth segment of the antenna. A. and C. Female individual; B. and D. Male individual. St1, sensilla trichodea I; St2, sensilla trichodea II; St3, sensilla trichodea III; Ps2, peg-like sensilla II.

J.Het.Turk., 3(1), Mayıs 2021 (eISSN 2687-3249)

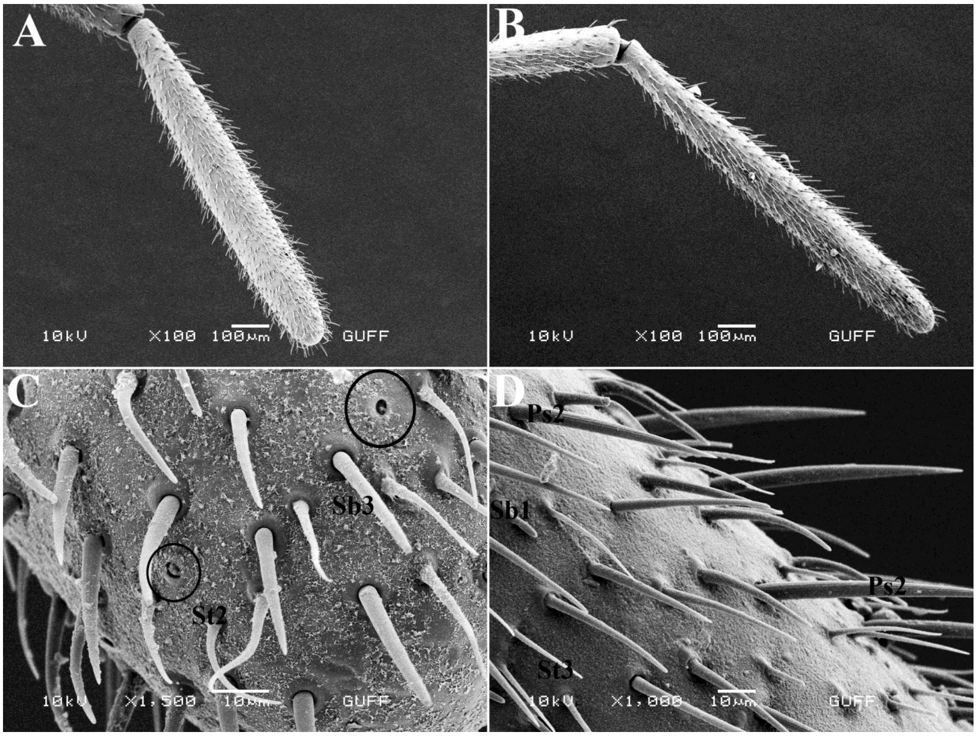

Figure 14. SEM micrographs of the fifth segment of the antenna. A. and C. Female individual; B. and D. Male individual. St2, sensilla trichodea II; St3, sensilla trichodea III; Sb1, sensilla basiconica I; Sb3, sensilla basiconica III; (O), Sca2, sensilla campaniformia II.

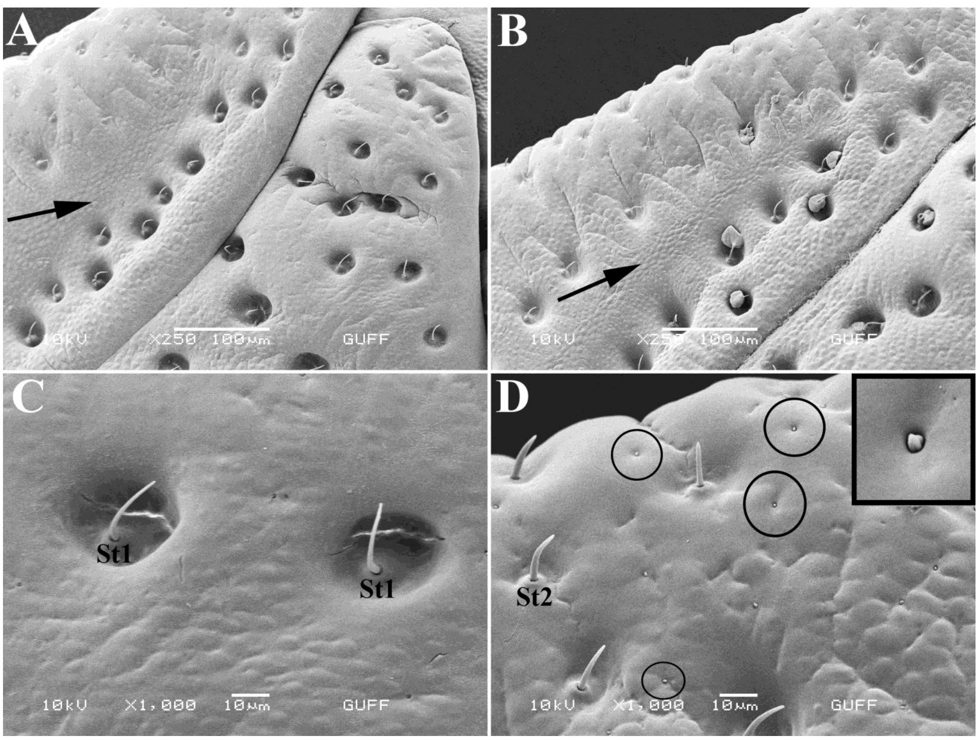

Figure 15. SEM micrographs of the surface of the head. A. and C. Female individual; B. and D. Male individual. (→), short dome-shaped protrusions on the surface; St1, sensilla trichodea I; St2, sensilla trichodea II; (O), Sca2, sensilla campaniformia II. The high magnification view of Sca2, sensilla campaniformia II (O) type sensilla is shown in the corner of Figure 5D. Its magnification is 5,000.

J.Het.Turk., 3(1), May 2021 (eISSN 2687-3249)

REFERENCES

Akent'eva, N. A., 2008, The formation of the antenna sensory apparatus in some bug (Heteroptera) species in the course of their postembryonic development. *Entomological Review*, 88(4): 381-390. https://doi.org/10.1134/S0013873808040015

Altner, H, Prillinger, L., 1980, Ultrastructure of invertebrate chemo- thermo- and hygroreceptors and its functional significance. *International Review of Cytology*, 67: 69-139. https://doi.org/10.1016/S0074-7696(08)62427-4

Ammar, E. D., Hall, D. G., 2012, New and simple methods for studying hemipteran stylets, bacteriomes, and salivary sheaths in host plants. *Annals of the Entomological Society of America*, 105(5), 731-739. https://doi.org/10.1603/AN12056

Backus, E. A., 1988, Sensory systems and behaviors which mediate hemipteran plant-feeding: A taxonomic overview. Journal of Insect Physiology, 34: 151-165. https://doi.org/10.1016/0022-1910(88)90045-5

Blaney, W. M., Chapman, R. F., 1969, The fine structure of the terminal sensilla on the maxillary palps of *Schistocerca gregaria* (Forskal) (Orthoptera, Acrididae). *Zeitschrift für Zellforschung und Mikroskopische Anatomie*, 99: 74-79. https://doi.org/10.1007/BF00338799

Brożek, J., Bourgoin, T., 2013, Morphology and distribution of the external labial sensilla in Fulgoromorpha (Insecta: Hemiptera). *Zoomorphology*, 132(1), 33-65. https://doi.org/10.1007/s00435-012-0174-z

Brozek, J., Chlond, D., 2010, Morphology, arrangement and classification of sensilla on the apical segment of labium in Peiratinae (Hemiptera: Heteroptera: Reduviidae). *Zootaxa*, 2476(1), 39-52.

Brożek, J., 2013, Comparative analysis and systematic mapping of the labial sensilla in the Nepomorpha (Heteroptera: Insecta). *The Scientific World Journal*, 1-44. https://doi.org/10.1155/2013/518034

Brożek, J., Zettel, H., 2014, A comparison of the external morphology and functions of labial tip sensilla in semiaquatic bugs (Hemiptera: Heteroptera: Gerromorpha). *European Journal of Entomology*, 111(2): 275-297. http://hdl.handle.net/20.500.12128/9062

Cao, Y. K., Huang, M., 2016, A SEM study of the antenna and mouthparts of *Omosita colon* (Linnaeus) (Coleoptera: Nitidulidae). *Microscopy Research and Technique*, 79(12): 1152-1164. https://doi.org/10.1002/jemt.22770

Carey, A. F., Carlson, J. R., 2011, Insect olfaction from model systems to disease control. *Proceedings of the National Academy of Sciences*, 108(32): 12987-12995. https://doi.org/10.1073/pnas.1103472108

Chapman, R. F., 1998, *Mechanoreception. Chemoreception*, In: Chapman R. F. (Ed.). The Insects, Structure and Function. Cambridge University Press, UK, 610-652 pp.

Faucheux, M. J., Németh, T., Kundrata, R., 2020, Comparative antennal morphology of agriotes (Coleoptera: Elateridae), with special reference to the typology and possible functions of sensilla. *Insects*, 11(2): 137. https://doi.org/10.3390/insects11020137

Fernandes, F. D. F., Bahia-Nascimento, A. C., Pinto, L. C., Leal, C. D. S., Secundino, N. F. C., Pimenta, P. F. P., 2008, Fine structure and distribution pattern of antennal sensilla of *Lutzomyia longipalpis* (Diptera: Psychodidae) sand flies. *Journal of Medical Entomology*, 45 (6): 982-990. https://doi.org/10.1093/jmedent/45.6.982

Freitas, S. P. C., Santos, L. C., de Souza, A. C., Junqueira, A. C. V., 2020, Morphological aspects of antennal sensilla of the *Rhodnius brethesi* Matta, 1919 (Hemiptera: Reduviidae) from the Negro river, Amazon region of Brazil. *Journal of Parasitology Research*, 1-6. https://doi.org/10.1155/2020/7687041

Fu, B. X., Bellis, G. A., Hong, J., Wang, J. R., Wu, Q., Tang, Q. Y., Cheng, J. A., Zhu, Z. R., 2012, Morphology, distribution, and abundance of antennal sensilla of male and female macropterous and brachypterous small brown planthopper, *Laodelphax striatellus* (Fallén) (Hemiptera: Delphacidae). *Microscopy Research and Technique*, 75 (11): 1492-1512. https://doi.org/10.1002/jemt.22093

J.Het.Turk., 3(1), Mayv 2021 (eISSN 2687-3249)

Gullan, P. J., Cranston, P. S., 2014, The Insects: An Outline of Entomology, 5th ed., Wiley Blackwell: Oxford, UK, 95-124 pp.

Hallberg, E., Hansson, B. S., 1999, Arthropod sensilla: morphology and phylogenetic consideration. *Microscopy Research and Technique*, 47: 428-439. https://doi.org/10.1002/(SICI)1097-0029(19991215)47:6<428::AID-JEMT6>3.0.CO;2-P

Hao, Y., Dietrich, C. H., Dai, W., 2016, Structure and sensilla of the mouth-parts of the spotted lanternfly *Lycorma delicatula* (Hemiptera: Fulgoromorpha: Fulgoridae), a polyphagous invasive planthopper. *PloS one*, 11(6): e0156640. https://doi.org/10.1371/journal.pone.0156640

Isidoro, N., Romani, R., Bin, F., 2001, Antennal multiporous sensilla: their gustatory features for host recognition in female parasitic wasps (Insecta, Hymenoptera: Platygastroidea). *Microscopy Research and Technique*, 55 (5): 350-358. https://doi.org/10.1002/jemt.1183

Kanturski, M., Akbar, S. A., Favret, C., 2017, Morphology and sensilla of the enigmatic Bhutan pine aphid *Pseudessigella brachychaeta* Hille Ris Lambers (Hemiptera: Aphididae)-A SEM study. *Zoologischer Anzeiger*, 266: 1-13. https://doi.org/10.1016/j.jcz.2016.10.007

Kaplin, V. G., Burlaka, G. A., 2019, Phenotypic variability of body coloration in the populations of scutellerid bugs (*Eurygaster* Laporte; Heteroptera, Scutelleridae) in cereal crops and the ecological factors responsible for it. *Entomological Review*, 99(8): 1099-1112. https://doi.org/10.1134/S0013873819080049

Li, S., Zhang, W., Wang, X., Lei, C., Zhu, F., 2016, Ultrastructure of sensilla on larvae and adults of *Chrysomya megacephala* (Diptera: Calliphoridae). *Entomological News*, 126(1): 52-63. https://doi.org/10.3157/021.126.0107

Li, Y., Liu, F., Du, X., Li, Z., Wu, J., 2018, Ultrastructure of antennal sensilla of three fruit borers (Lepidoptera: Crambidae or Tortricidae). *PloS one*, 13 (10): 1-10. https://doi.org/10.1371/journal.pone.0205604

Liang, X. M., Zhang, C. N., Li, Z. L., Xu, L. F., Dai, W., 2013, Fine structure and sensory apparatus of the mouthparts of the pear psyllid, *Cacopsylla chinensis* (Hemiptera: Psyllidae). *Arthropod Structure & Development*, 42: 495-506. https://doi.org/10.1016/j.asd.2013.08.002

Linnavuori, R. E., 2008, Studies on the Acanthosomatidae, Scutelleridae and Pentatomidae (Heteroptera) of Gilan and the adjacent provinces in northern Iran. *Acta Entomologica Musei Nationalis Pragae*, 48(1): 1-21.

Nowińska, A., Brożek, J., 2017, Morphological study of the antennal sensilla in Gerromorpha (Insecta: Hemiptera: Heteroptera). *Zoomorphology*, 136: 327-347. https://doi.org/10.1007/s00435-017-0354-y

Parveen, S., Ahmad, A., Brożek, J., Ramamurthy, V. V., 2015, Morphological diversity of the labial sensilla of phytophagous and predatory Pentatomidae (Hemiptera: Heteroptera), with reference to their possible functions. *Zootaxa*, 4039(2): 359-372. http://dx.doi.org/10.11646/zootaxa.4039.2.9

Shields, V. D. C., 2010, High resolution ultra-structural investigation of insect sensory organs using field emission scanning electron microscopy. Microscopy: science, technology, applications and education. *Formatex Badajoz*, 321-328.

Slifer, E. H., 1970. The structure of arthropod chemoreceptors. *Annual Review of Entomology,* 15: 121-141.

Syromyatnikov, M. Y., Golub, V. B., Kokina, A. V., Soboleva, V. A., Popov, V. N., 2017, DNA barcoding and morphological analysis for rapid identification of most economically important crop-infesting Sunn pests belonging to *Eurygaster* Laporte, 1833 (Hemiptera, Scutelleridae). *ZooKeys*, 706: 51-71. doi: 10.3897/zookeys.706.13888

Taszakowski, A., Nowińska, A., Brożek, J., 2019, Morphological study of the labial sensilla in Nabidae (Hemiptera: Heteroptera: Cimicomorpha). *Zoomorphology*, 138(4): 483-492.

J.Het.Turk., 3(1), May 2021 (eISSN 2687-3249)

https://doi.org/10.1007/s00435-019-00455-3

Wang, Y., Brożek, J., Dai, W., 2020, Morphological disparity of the mouth-parts in polyphagous species of Largidae (Heteroptera: Pentatomomorpha: Pyrrhocoroidea) reveals feeding specialization. *Insects*, 11(3): 145. https://doi.org/10.3390/insects11030145

Wang, Y., Li, L., Dai, W., 2019, Fine morphology of the mouthparts in *Cheilocapsus nigrescens* (Hemiptera: Heteroptera: Miridae) reflects adaptation for phytophagous habits. *Insects*, 10 (5): 143. https://doi.org/10.3390/insects10050143

Wheeler, A. G., 2001, Biology of the Plant Bugs (Hemiptera: Miridae): Pests, Predators, Opportunists, Cornell University Press, Ithaca, NY, USA.

Zhang, Y. J., Chen, D. Y., Chao, X. T., Dong, Z. S., Huang, Z. Y., Zheng, X. L., Lu, W., 2021, Ultrastructure of antennal sensilla of *Copidosomopsis nacoleiae* (Eady) (Hymenoptera: Chalcidoidea: Encyrtidae), a parasitoid of *Diaphania angustalis* (Snellen) (Lepidoptera: Crambidae). *Microscopy Research and Technique*. DOI: 10.1002/jemt.23770