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Research Article

The morphological characterization of the sensilla on the antenna and mouth parts of *Notonecta viridis* Delcourt, 1909 (Hemiptera: Heteroptera: Notonectidae)

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ABSTRACT: The main sensory organs of the insects are sensilla who act as thermohygroreceptor, chemoreceptor, or mechanoreceptor and sensilla are found in various structures of insects such as the head, antenna, mouth, and legs. The number, distribution, position, and types of sensilla vary between insect groups and can be used as taxonomic characters. For this reason, since no study has been found on the sensilla of *Notonecta viridis* Delcourt, 1909 (Hemiptera: Heteroptera: Notonectidae) in the literature, it is aimed to study the morphology of the sensilla in the antennae and mouth parts of female and male individuals of this species. For this purpose, scanning electron microscope (SEM) techniques were used in this study. After cleaning and drying the female and male *N. viridis* individuals, the samples were coated with gold or gold-palladium and examined in SEM. According to the results that we got, 3 major types of sensilla with different diameters have been identified on the mouthparts: sensilla basiconica, sensilla trichodea, and sensilla coeloconica. But 2 major types of sensilla were found on the antenna: sensilla basiconica and sensilla trichodea. Of all these sensilla types, the most common is the sensilla trichodea. The results that we got from this research were also compared with other sensilla of different species in the literature, and similarities and differences were revealed.

KEYWORDS: Hemiptera, Heteroptera, Notonectidae, insect, morphology, sensilla, sensory organ

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INTRODUCTION

Predator insects effects the distribution and diversity of the several species and balance the population (Murdoch et al., 1984).

The genus *Notonecta* includes predator species that feed on other insects (Giller & McNeill, 1981). *Notonecta viridis* Delcourt, 1909 (Hemiptera: Notonectidae) is a predatory species that feeds on mosquito larvae of this genus (Figs. 1a-b). This species, which feeds on an average of 26 mosquito larvae daily, plays a role in preventing the excessive reproduction of flies.

Thus, it is ensured that the food chain in the aquatic environment is kept in balance.

Therefore, *N. viridis* is an ecologically important insect species (Suiçmez & Özmen, 2012).

Another important feature of this species is that it has a wide distribution area. Individuals of the *N. viridis* species have been reported by various researchers to be found in Turkey (Kıyak et al., 2004), Serbia, Slovenia, Bulgaria, Hungary, Croatia, Macedonia (Josivof, 1999; Protıć & Živıć, 2012), Romania (Berchi et al., 2011), Algeria (Annani et al., 2012), Ukraine (Grandova, 2013), Spain (Garcia-Aviles et al., 1996), Iran (Askari et al., 2009; Khaghaninia et al., 2010).

The distribution area of *N.viridis* in Turkey is in Afyon, Çorum and Amasya provinces (Kıyak et al., 2004; Salur & Mesci, 2011; Özmen, 2012).

Sensilla are structures found on many body parts of insects and play a vital role in processes important to their lives, such as finding food or mates (Isidoro et al., 2001; Fu et al., 2012; Cao & Huang, 2016; Seada & Hamza, 2018; Faucheux et al., 2020). For example, sensilla on the mouthparts are involved in finding food, while those on the antennae play a role in detecting volatile chemicals in the air (Chapman, 1998; Carey & Carlson, 2011; Brozek & Zettel, 2014; Parveen et al., 2015; Rani et al., 2021).

For all these processes, the sensilla act as chemo-receptors, mechanoreceptors, or thermohygroreceptors (Akent'eva, 2008; Fu et al., 2012; Brozek & Bourgoin, 2013; Freitas et al, 2020; Giglio et al., 2021; Polat et al., 2021; Zhang et al., 2021).

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

The main objective of this study is to determine the morphological structures of the sensilla in the antenna and mouth-parts of *N. viridis* and to establish its place in the literature.

MATERIALS AND METHODS

The adult male and female individuals of *Notonecta viridis* (Figures 1A-B) were collected in Isparta, Denizli and Antalya provinces in 2000-2001 and were preserved as museum material.

First of all, the outer surface of the integument of the samples stored in Gazi University was cleaned. Subsequently, the samples were air dried and mountened on the SEM stubs.

The samples on the stubs were coated with Au with Polaron SC502 or Au/Pd with Leica EM ACE200 sputter coater, observed in Hitachi SU5000 FESEM (Yıldırım Beyazıt University, MERLAB) and JEOL JSM 6060 LV SEM (Gazi University, Prof. Dr. Zekiye Suludere Electron Microscope Center) and photo-graphed (at 5-15 kV accelerating voltage).

RESULTS

In *N. viridis*, the mouth consists of a labrum and a 4-part labium, while the antenna is divided into 4 segments. But looking at these parts in general, 3 types of sensilla in different sizes were identified; sensilla basiconica (SB), sensilla trichodea (ST), and sensilla coeloconica (SCo) according to the results of this study, in which the sensilla, which are the main sensory organs on the mouth parts and antennae of *N. viridis*, were investigated. Compared to the mouthparts, there is a much denser sensilla appearance in the antenna region.

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Sensilla on the mouth parts

The mouth parts of the *N. viridis* are composed of one-piece Lm and four segmented Lb both in male and females (Figs. 2a-b). The labrum is a triangular region located above the first segment of the labium. While SCo and ST were detected on the labrum of males, no sensilla was found in females (Figs. 3a-d).

The first segment of the labium (Lb-1) has ST on its surface in males. Some of them appear bent, while some are straight. Although females have the same sensilla, the bent ones are slightly more inclined than the males (Figs. 4a-b).

SEM images of the second segment of labium (Lb-2) show that SBs are the most common sensilla type in the image area on Lb-2.

There are 2 different types of SBs located towards both sides near the Lb-1 connection region of LB-2.

Although these two types of SB are close to each other in length, some are straight, while others are curved in a sickle shape. Apart from the SBs, there are also some STs. All the observations apply to both sexes (Figs. 5a-d).

According to the observations, there are STs in different sizes and shapes on the surface of the third segment (Lb-3) of the labium of both males and females. On the Lb-3, close to the other two parts of the labium, two pairs of STs are symmetrically located on either side of the midline.

In addition, STs were also found in the lateral regions of Lb-3. Some STs on the lateral sides of the Lb-3 have slightly bent ends. At the tip of Lb-3, close to the fourth segment of the labium (Lb-4), there are also long STs bent almost 90° from the bottom, and small and thin STs (Figs. 6a-f).

There are very small SBs in the portion of Lb-4 close to Lb-3. At the very tip of Lb-4, very long curled STs are the dominant sensilla types, and there are very small STs between them (Figs. 7a-b).

Sensilla on the antenna

The antenna of *N. viridis* males and females are composed of 4 segments (Figs. 8a-b). Each segment of antenna has a large number of sensilla of different types and lengths.

In the first segment of the antenna, which is close to the proximal part, there are thin and long STs with slightly curved arc-shaped ends (Fig. 9).

The second and third segments of the antenna are seen more densely in terms of sensilla ratio compared to other segments.

The second segment of the antenna is surrounded on all sides by long and curved STs. These sensilla are so densely arranged that the surface of the antenna is hardly visible.

At the posterior margin of the 2nd antennal segment there are a number of longer sensilla located side by side. These sensilla are flattened shaped sensilla that expand slightly from bottom to end (Figs. 10a-b).

The 3rd antennal segment, like the 2nd antennal segment, has a large number of slightly curved STs.

In addition, at the posterior margin of this segment, there are spatulate-type leaf-shaped sensilla with enlarged ends, which are arranged at a certain distance like sparse comb teeth (Figs. 11a-d).

The spatulate-type leaf-shaped STs with flattened and enlarged ends are also seen in the 4th segment, which is shorter than the 2nd and 3rd antennal segments (Fig. 12).

DISCUSSION

Although various organs in insects have some similar common features, when their detailed structures are examined, it is observed that there are some differences in these structures among insect taxa.

Although the mouth parts of Hemiptera insect species have some differences such

as number and sizes of segments or sensilla types and distribution, they contain similar parts, as the labrum (Lm), the labium (Lb), labial groove, and stylet fascicle (Wang et al., 2020; Amutkan Mutlu et al., 2021; Polat et al., 2021).

N.viridis also has a triangular one-piece labrum and a short labium. The labium divided four distinct parts in *N. viridis* such as in some other Hemipteran species like *Physopelta gutta* (Burmeister, 1834) (Hemiptera, Largidae), *Dolycoris indicus* Stål, 1876 (Pentatomidae), *Perillus bioculatus* (F.) (Pentatomidae), *Physopelta quadriguttata* Bergroth, 1894 (Largidae), *Piezodorus hybneri* (Gmelin, 1790) (Pentatomidae), *Eocanthecona furcellata* (Wolff) (Pentatomidae), *Macrocheraia grandis* (Gray, 1832) (Largidae), and *Aelia rostrata* Boh. (Pentatomidae).

On the contrary, some Hemipteran species have different segment number in their labium, such as *Eurygaster testudinaria* (Geoffroy, 1785) (Scutelleridae) (Parveen et al., 2015; Wang et al., 2019, 2020; Amutkan Mutlu et al., 2021; Polat et al., 2021).

In insects, sensilla are indispensable for the insect to maintain its vital activities. Each types of sensilla in insects has divergent sensory duties.

For instance, the ST on the mouthparts is reported as mechanoreceptors by various researchers.

The main role of them in nutrition is to find out of the nutrients. On the other hand, the BS provides the movement of the mouthparts (Wang et al., 2019; Amutkan Mutlu et al., 2021; Nowińska & Brożek, 2021; Polat et al., 2021).

Because, in the light of this information, it is thought that, on the mouthparts, sensilla types, distributions or numbers are related to the feeding habits of the insect (Polat et al., 2021).

Sensilla are important not only for nutrition but also for activities such as finding a mate. All these processes are provided by detecting volatiles in the air such as pheromones or nutrients by sensilla chemically, mechanically or with thermo-hygro-receptor way (Chapman, 1998; Carey & Carlson, 2011; Brozek & Zettel, 2014; Parveen et al., 2015; Nowińska & Brożek, 2021; Rani et al., 2021). Although the sensilla in the mouthparts of *N. viridis* are not very dense, the most common types are ST and SB.

The density of sensilla in antenna in *N. viridis* is much higher than in mouthparts.

The most common type of sensilla is ST. Similarly, in the study of Nowińska & Brożek in 2021, they displayed a large number of sensilla, most of which were ST, in the antenna of the species they examined. These sensilla of antenna sensilla, on the other hand, have various functions.

Generally, STs are classified as sensilla that act as mechanoreceptors. In their research it is reported that thick ST sensilla of *Plea minutissima* were olfactory and thin ones were chemosensilla (Nowińska & Brożek, 2021). A sensilla type can be determined by its external structure (Nowińska & Brożek, 2021).

The number, distribution and structure of the sensilla in insects may be of taxonomical significance. In many studies with insect sensilla, it has been mentioned that these features can be used as distinguishing characters.

This is due to the variation in morphology, distribution, and densities of different sensilla among different insect families, genus, species, and even between the both sexes of the same species (Ågren, 1978; van Baaren et al., 1999; Brożek, 2008; Nowińska & Brożek, 2021; Polat et al., 2021).In conclusion, there are 3 kinds of sensilla with different subtypes on the mouthparts and antennae of *N. viridis*.

The presence of different types of sensilla in *N. viridis*, especially on the antenna, is an indication that they can perceive various stimuli. It is hoped that, this study based on the sensilla on the mouthparts and antenna of *N. viridis* will contribute to literature shed light on the work to be done on this subject.

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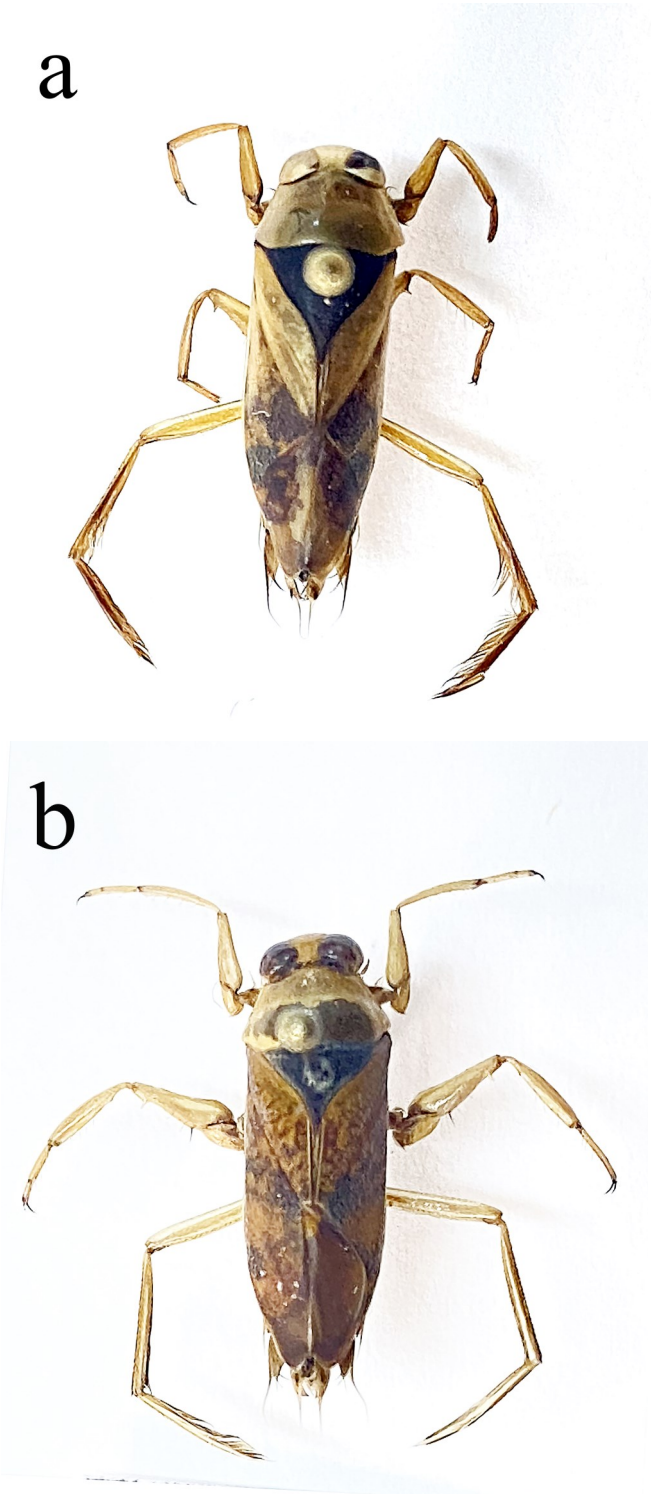

Figure. 1. The female (a) and the male (b) individual of *N. viridis*

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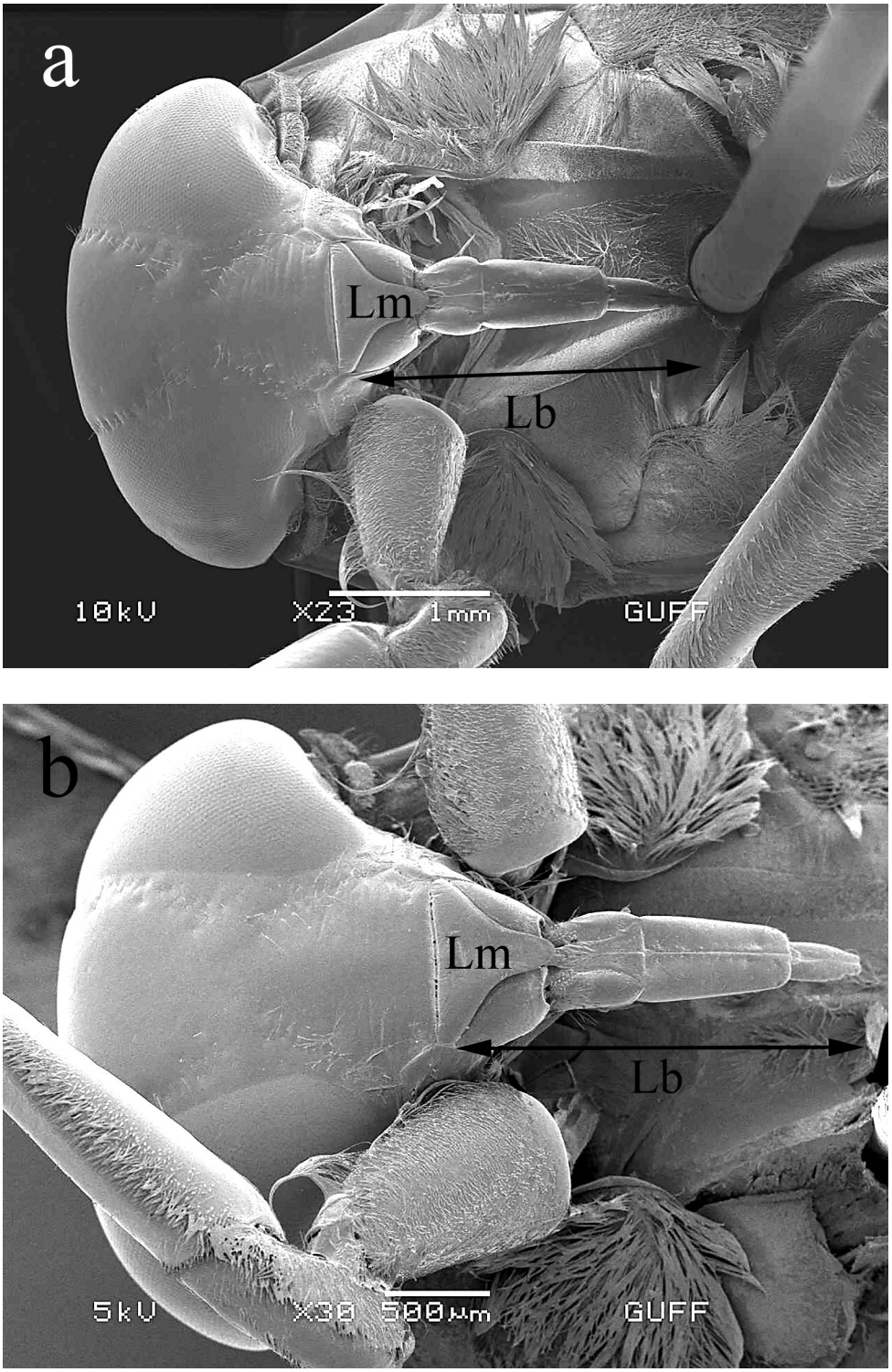

Figure. 2. The general view of the head and the mouthparts of *N. viridis*. a. Female, b. Male. Lm: labrum, Lb: labium (SEM images)

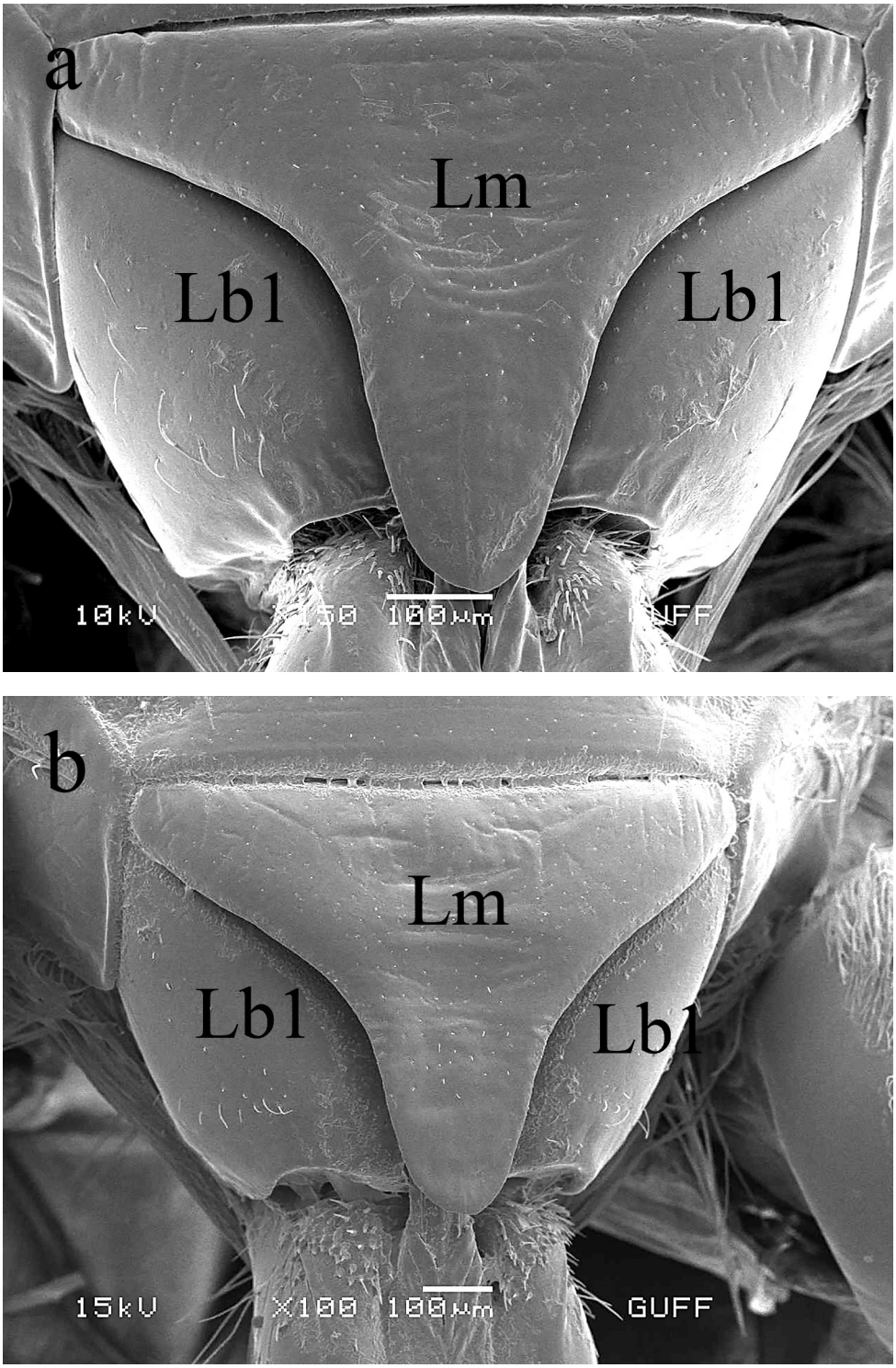

Figure. 3. a. The general view of the mouthparts of female *N. viridis*. b. The general view of the mouthparts of male *N. viridis*.(SEM images)

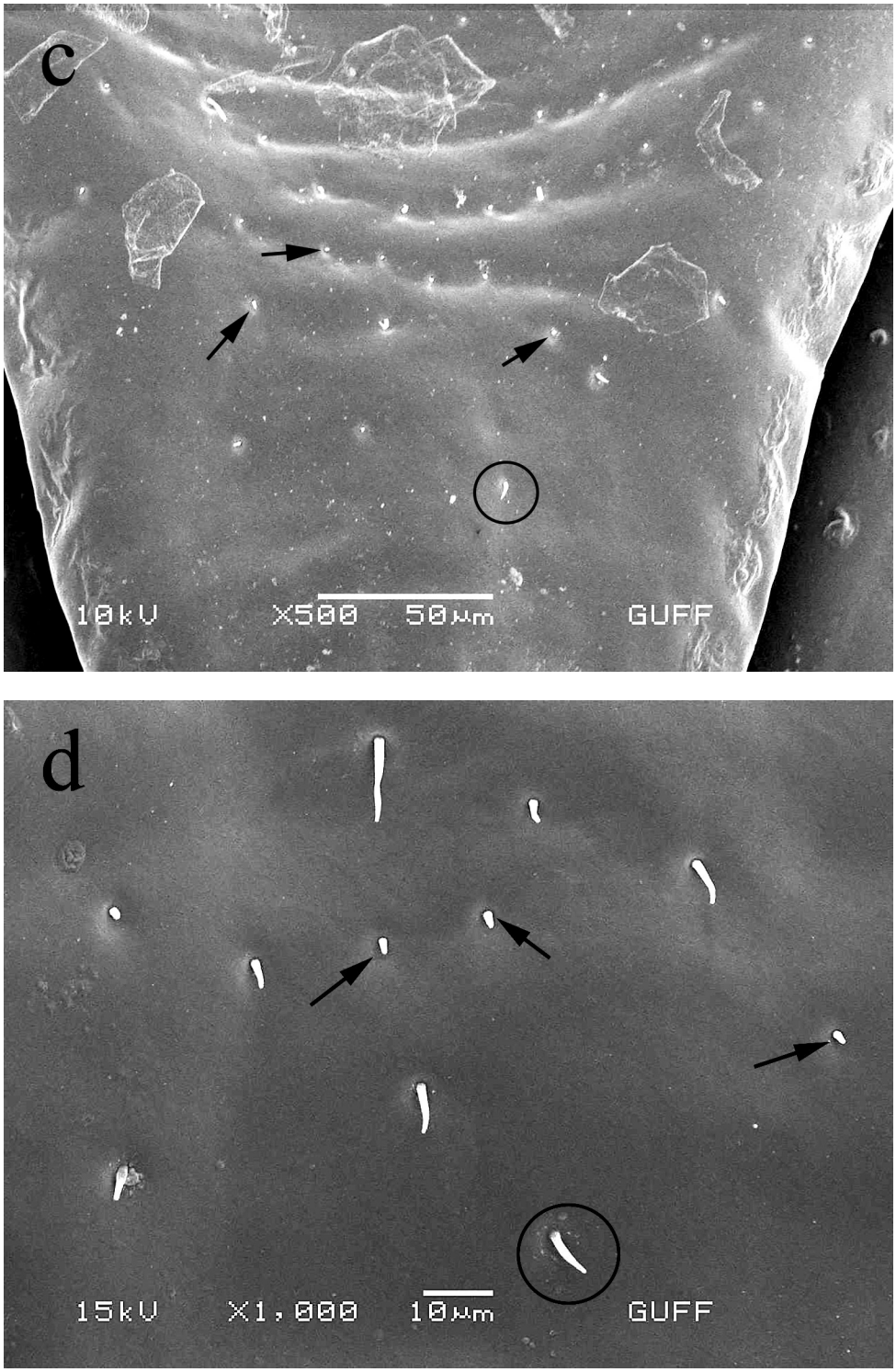

Figure. 3. c. The detailed view of the Lm of female. d. The detailed view of the Lm of male. Lm: labrum, Lb: labium, arrows: SCo, encircled: SB (SEM images)

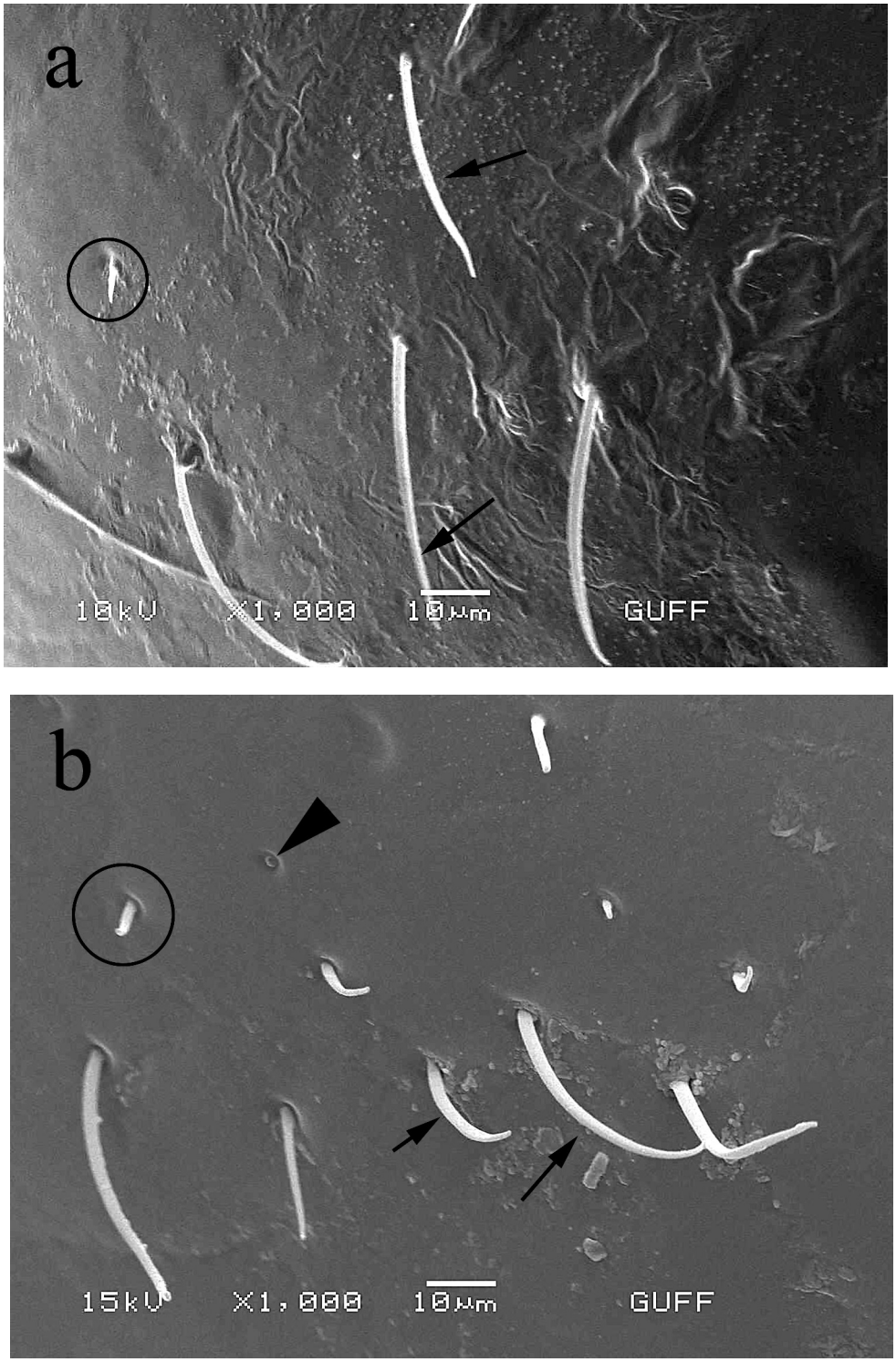

Figure. 4. a. Long STs (arrows) and short STs (encircled) on the first segment of labium (Lb1) of female. b. Long STs (arrows), short STs (encircled), and SCo (arrowhead) on the first segment of labium (Lb1) of male (SEM images)

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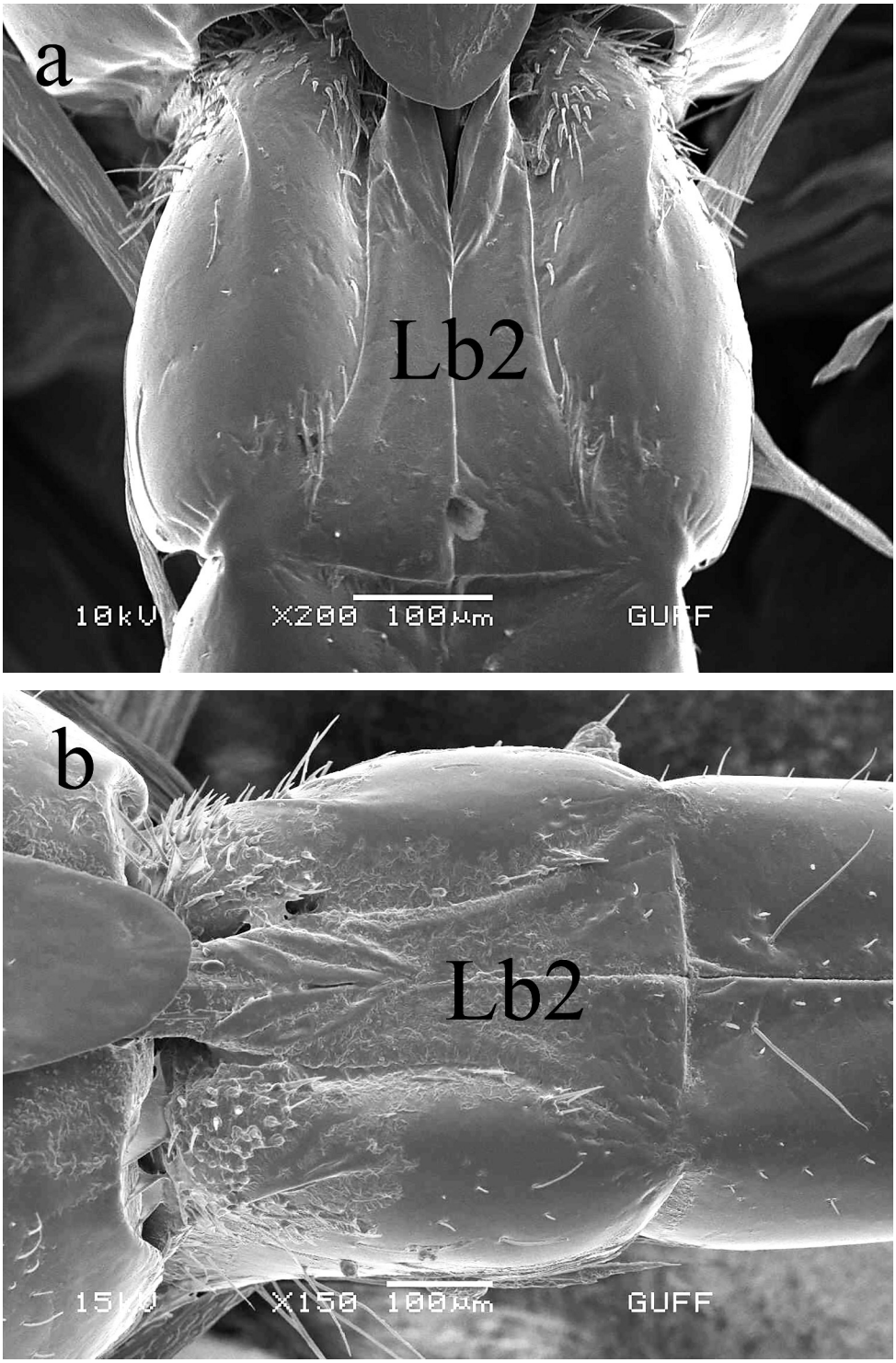

Figure. 5. a. The general view of the second segment of labium (Lb2) of female. b. The general view of the second segment of labium (Lb2) of male.

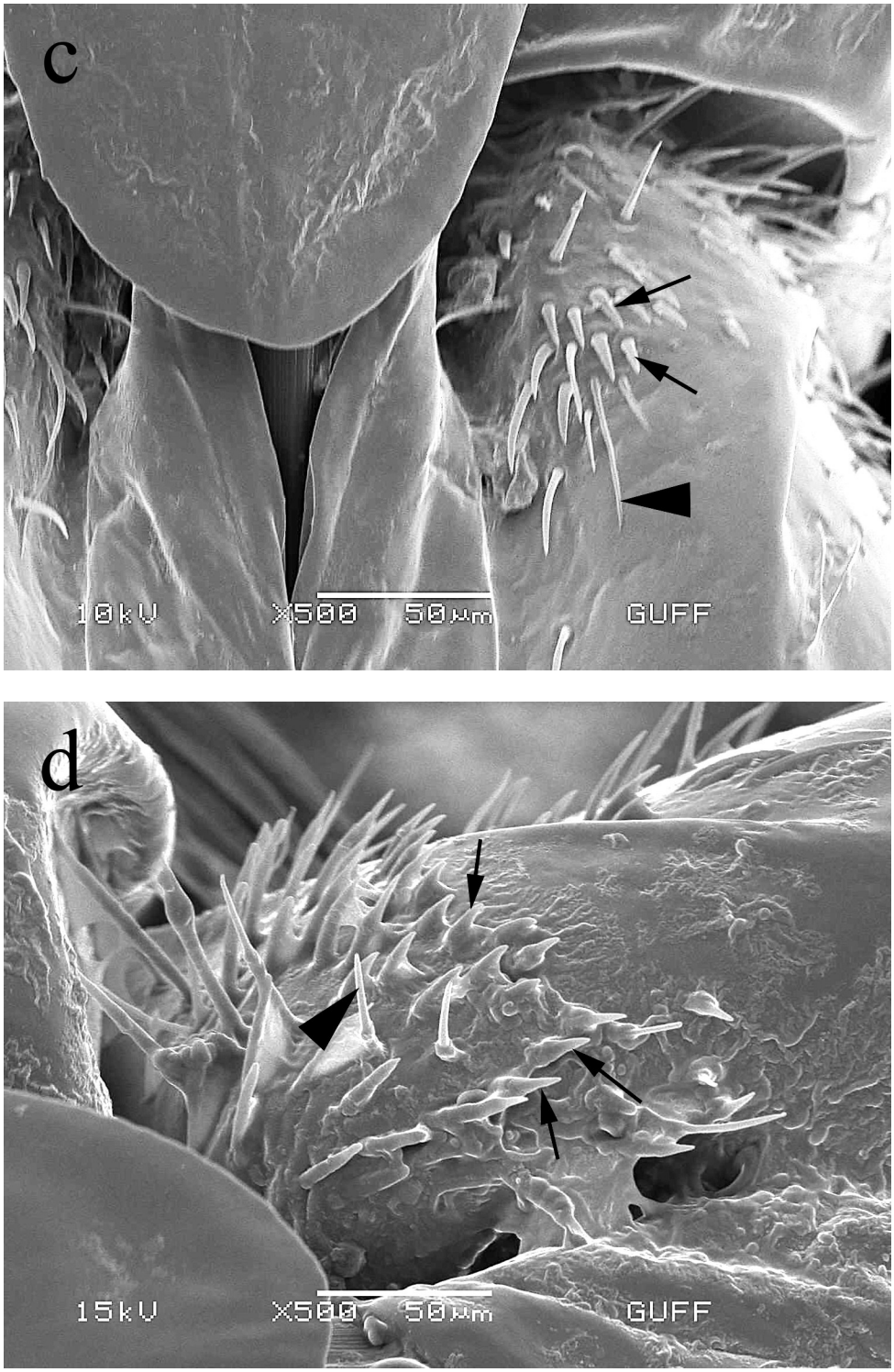

Figure. 5. c. The detailed view of the SB (arrows) and ST (arrowhead) in females. d. The detailed view of the SB (arrows) and ST (arrowhead) in males (SEM images)

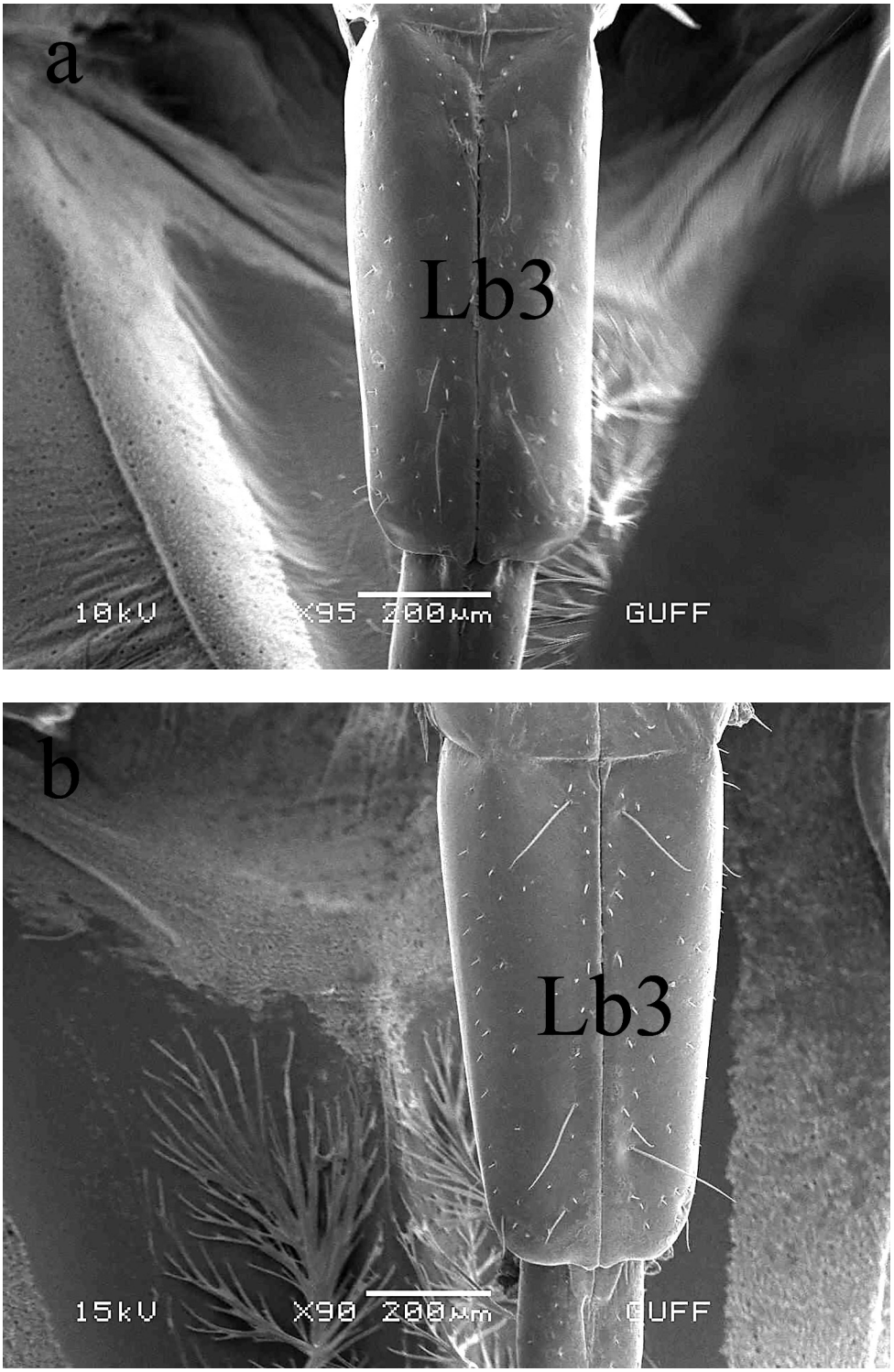

Figure. 6. a. The general view of the third segment of labium (Lb3) of female. b. The general view of the third segment of labium (Lb3) of male.

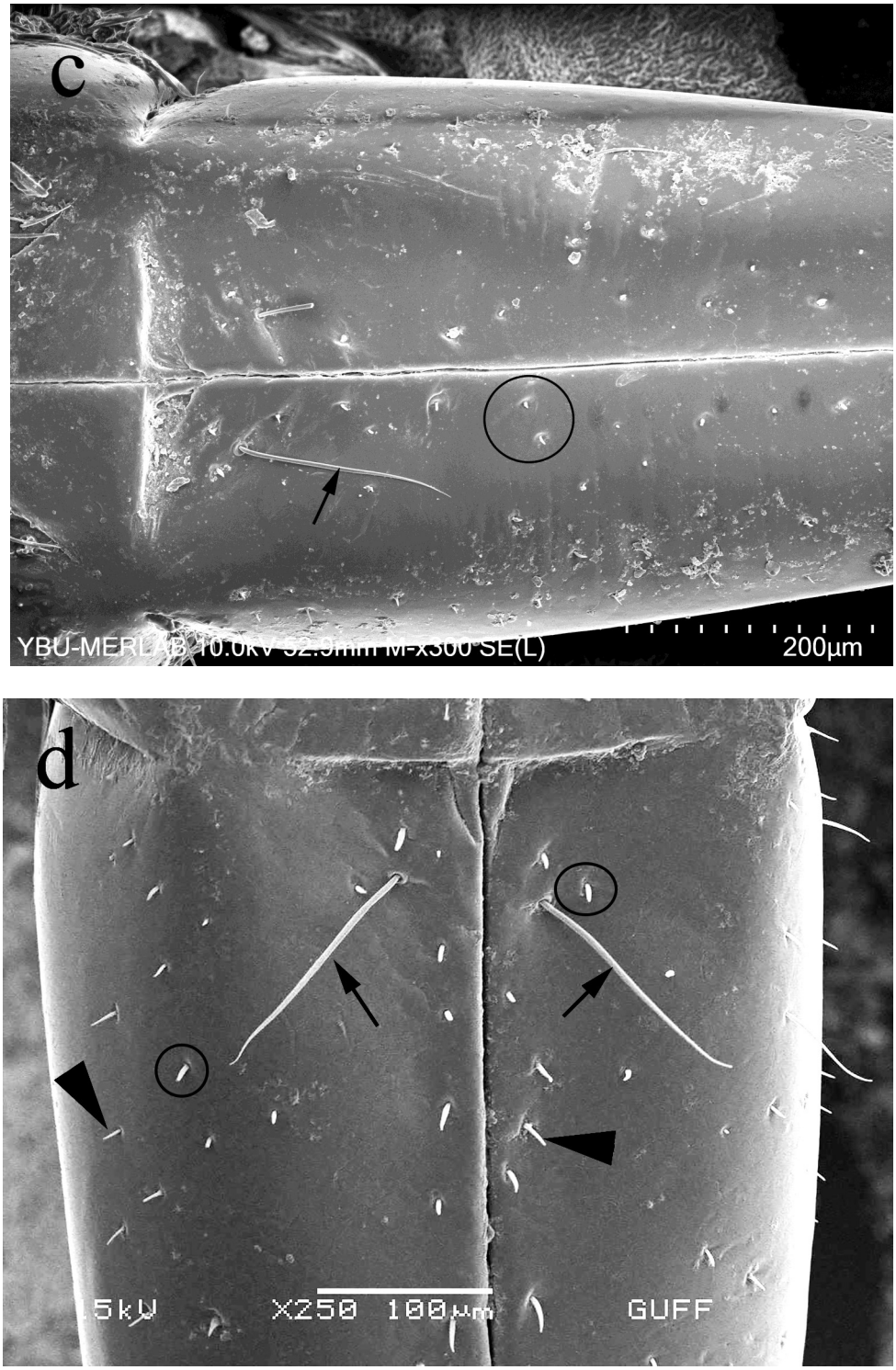

Figure. 6. c. The proximal region of the Lb3 with long ST (arrow) and SB (encircled) of female. d. The proximal region of the Lb3 with long ST (arrow), short ST (arrowhead), and SB (encircled) of male.

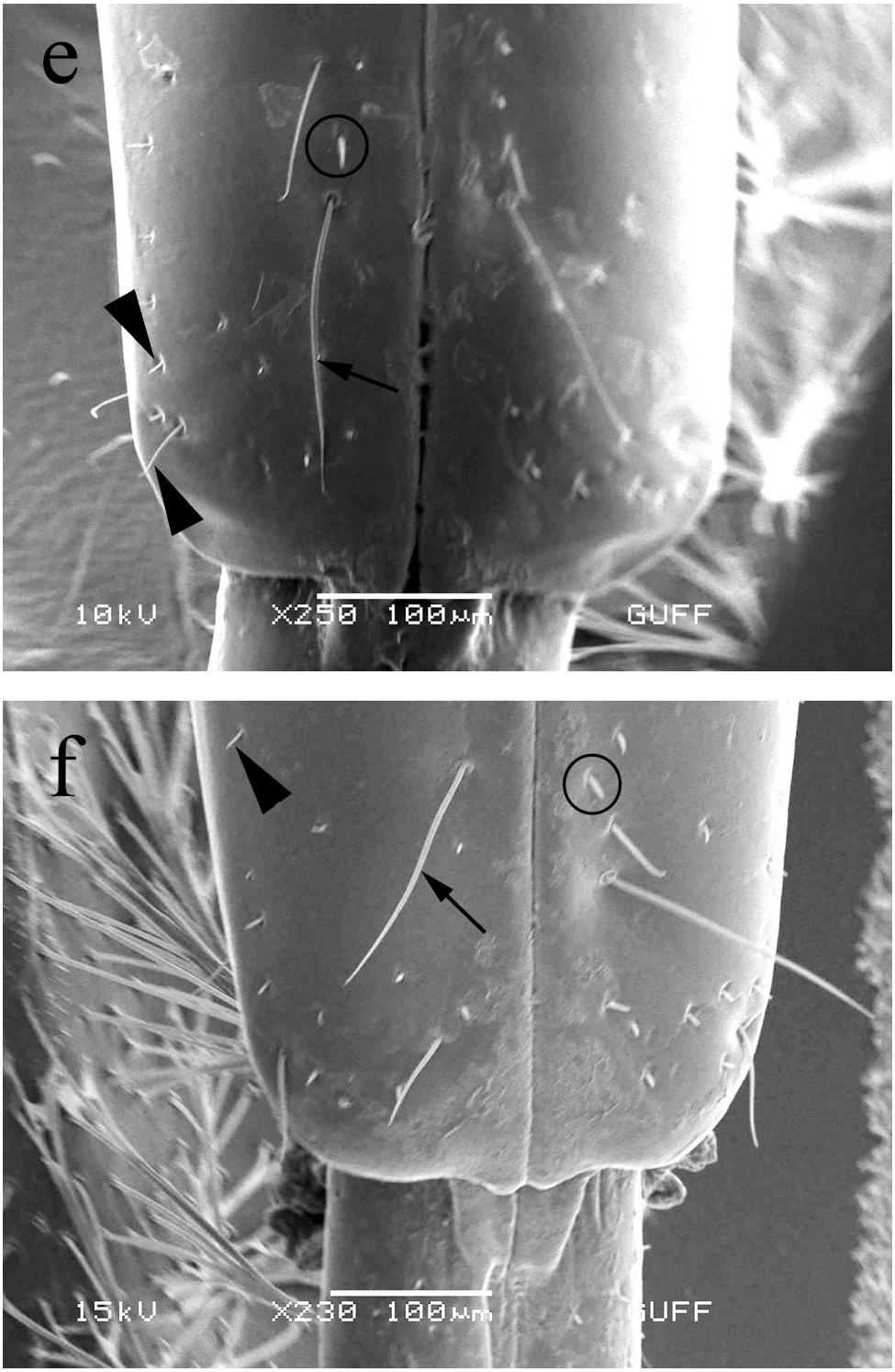

Figure. 6. e. The distal region of the Lb3 with long ST (arrow), short ST (arrowhead), and SB (encircled) of female f. The distal region of the Lb3 with long ST (arrow), short ST (arrowhead), and SB (encircled) of male (SEM images)

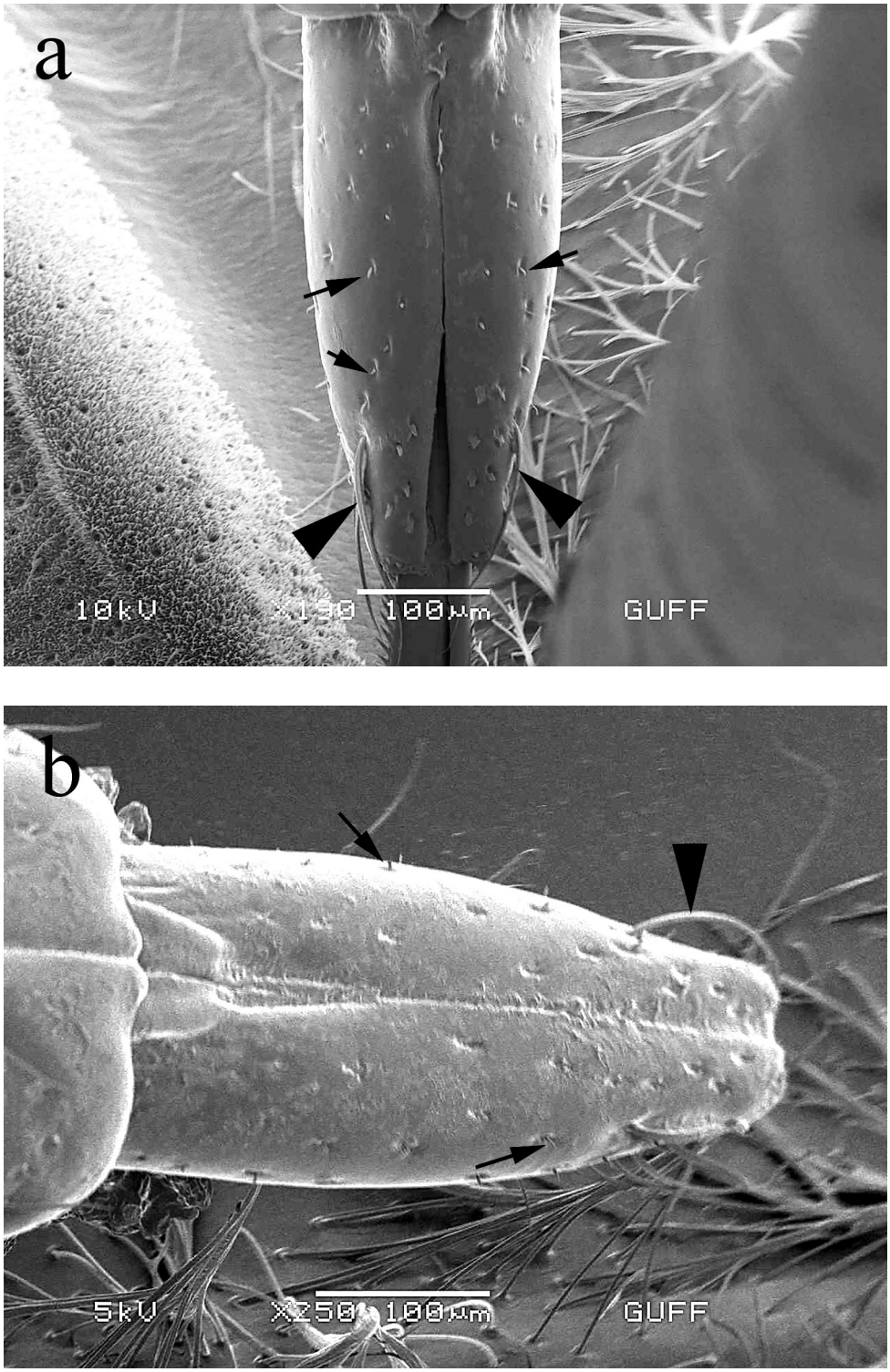

Figure. 7. a. The fourth segment of the labium (Lb4) of female. b. The fourth segment of the labium (Lb4) of male. arrowheads: long ST, arrows: SB (SEM images)

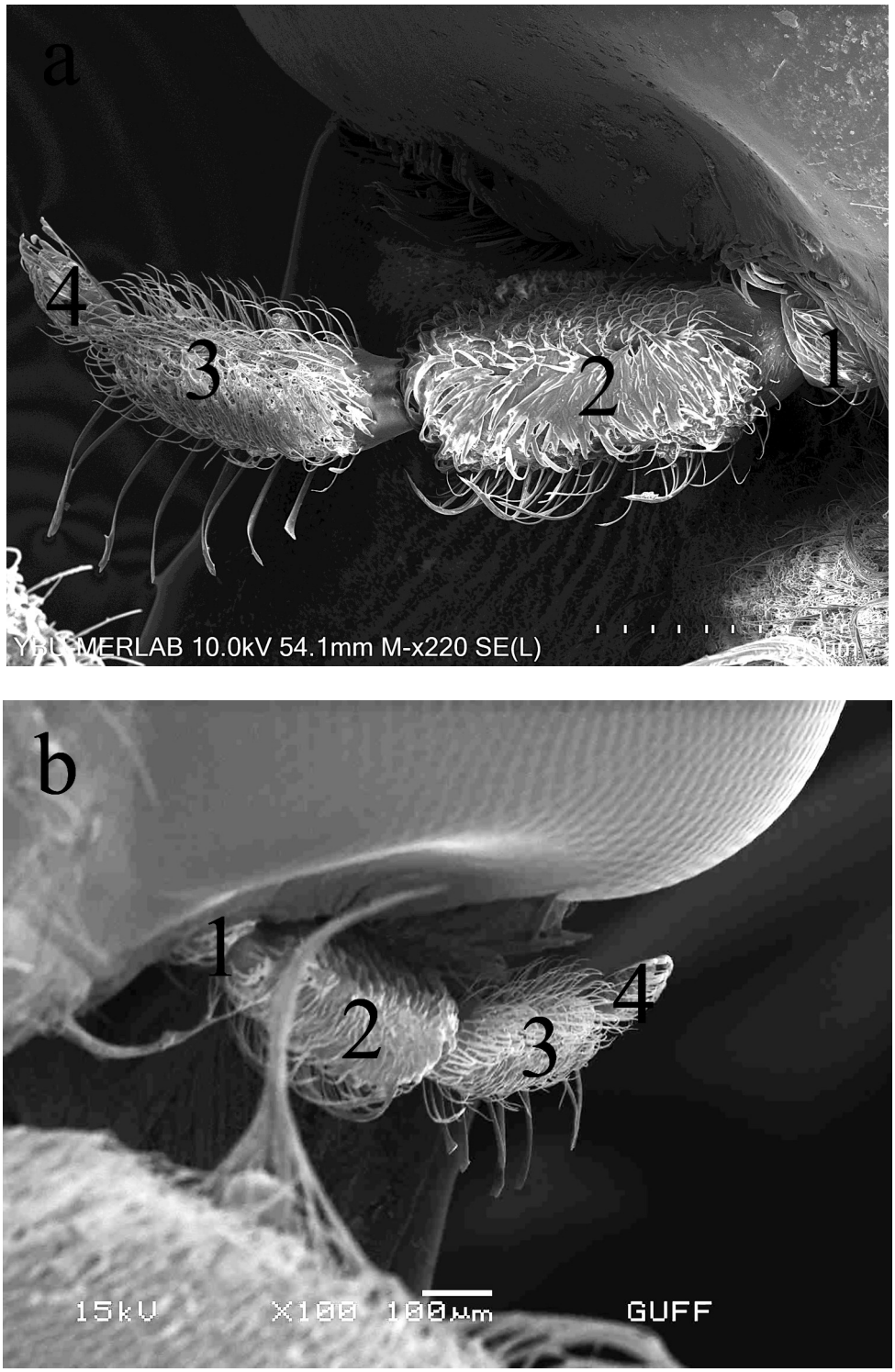

Figure. 8. The general view of the antenna with four segment of female (a) and male (b) *N. viridis* (SEM images)

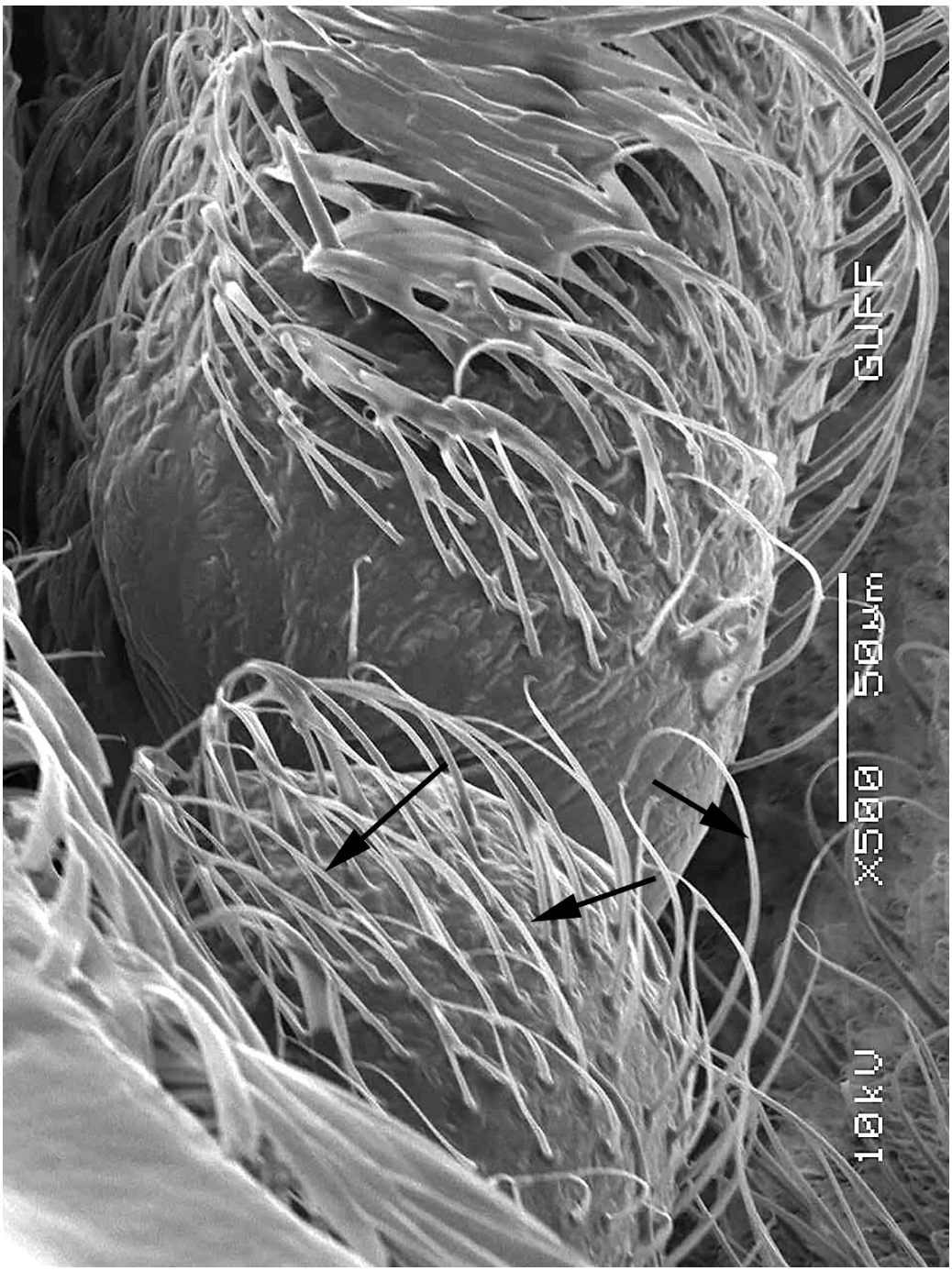

Figure. 9. The first segment of the antenna with ST (arrows) of female (SEM image)

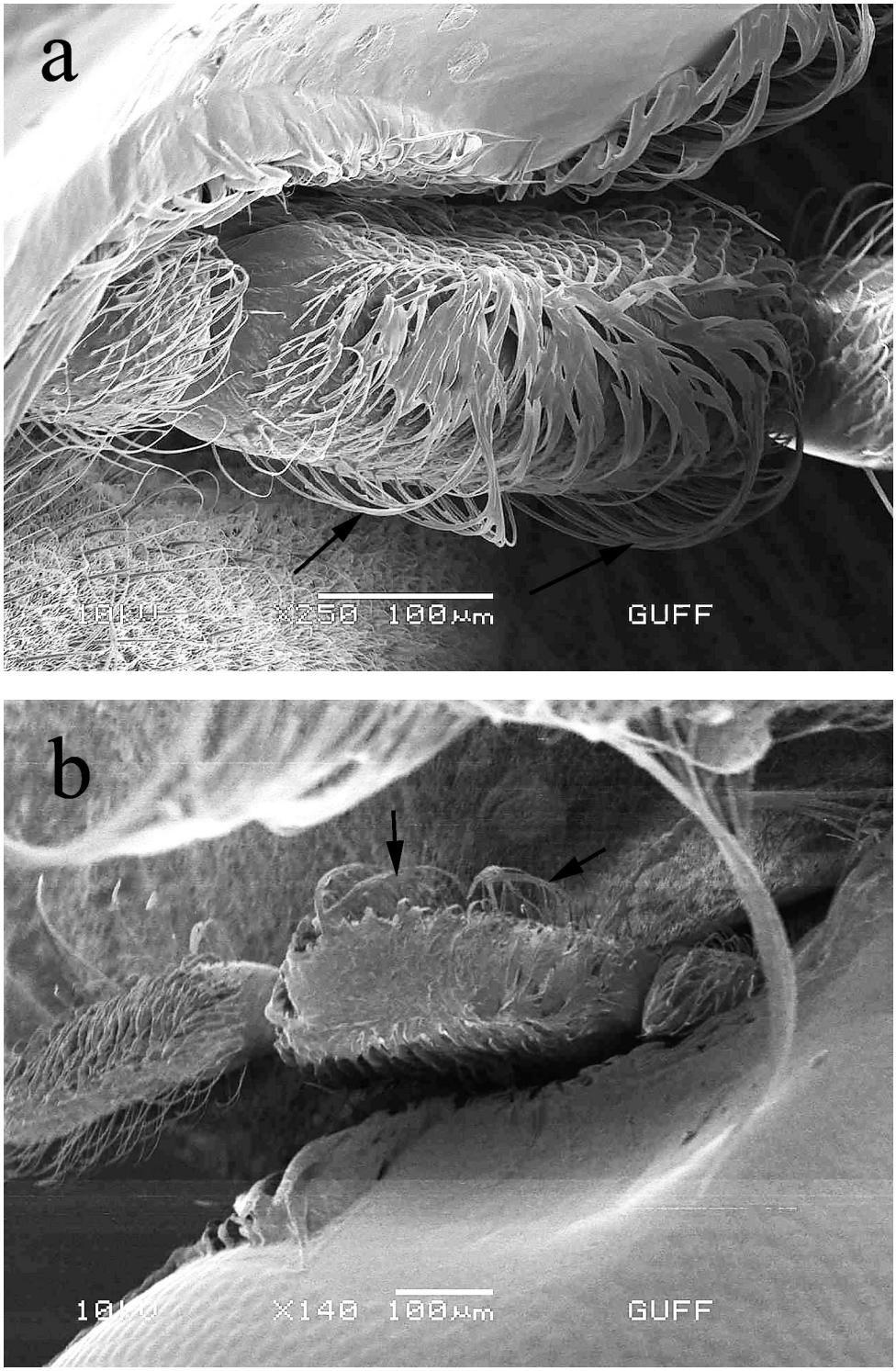

Figure. 10. The ST (arrows) on the second segment of antenna of female (a) and male (b) (SEM images)

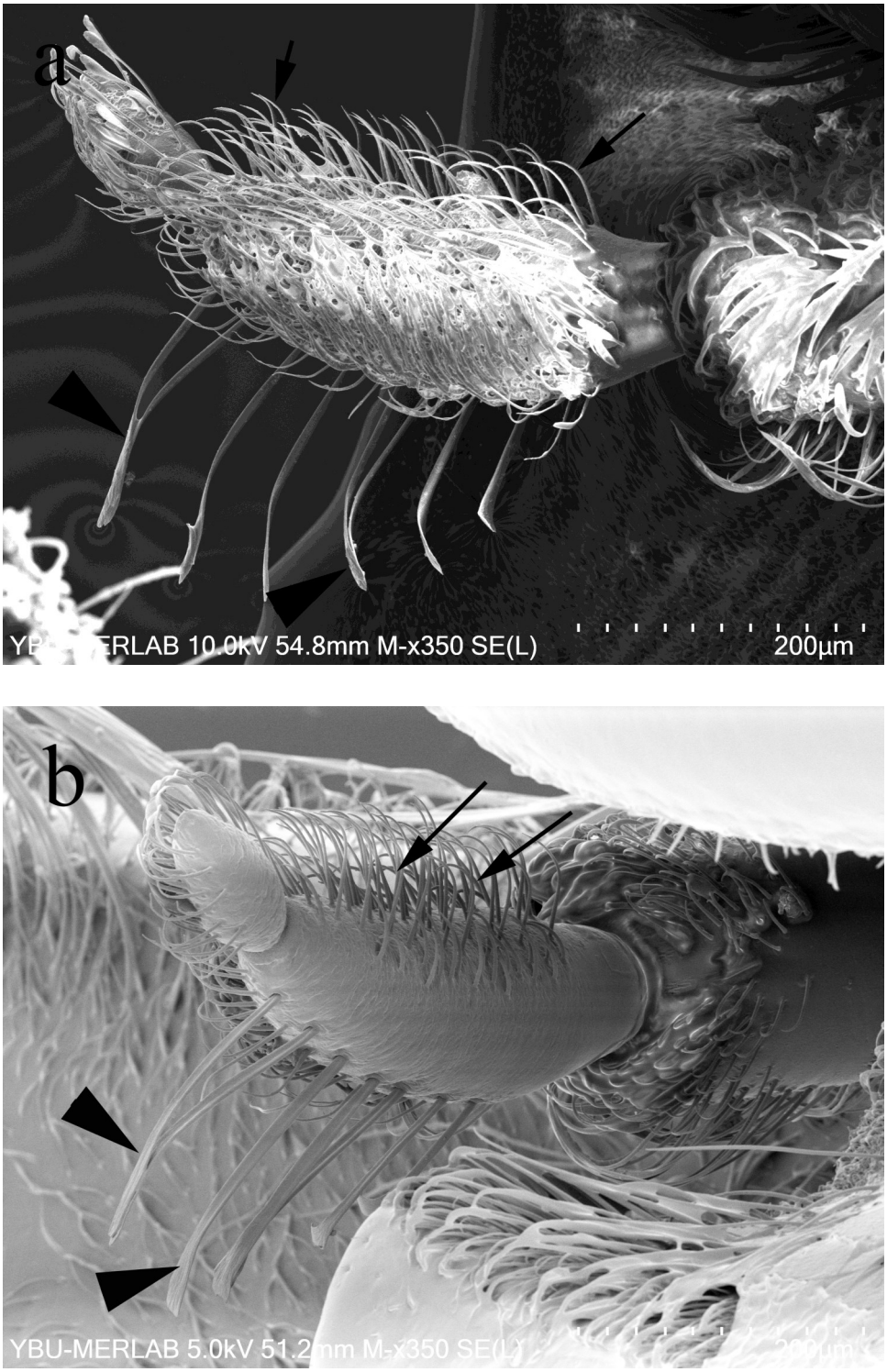

Figure. 11. a. The long ST with flattened end (arrowhead) and bent ST (arrow) on the third segment of the antenna of female. b. The long ST with flattened end (arrowhead) and bent ST (arrow) on the third segment of the antenna of male. (SEM images)

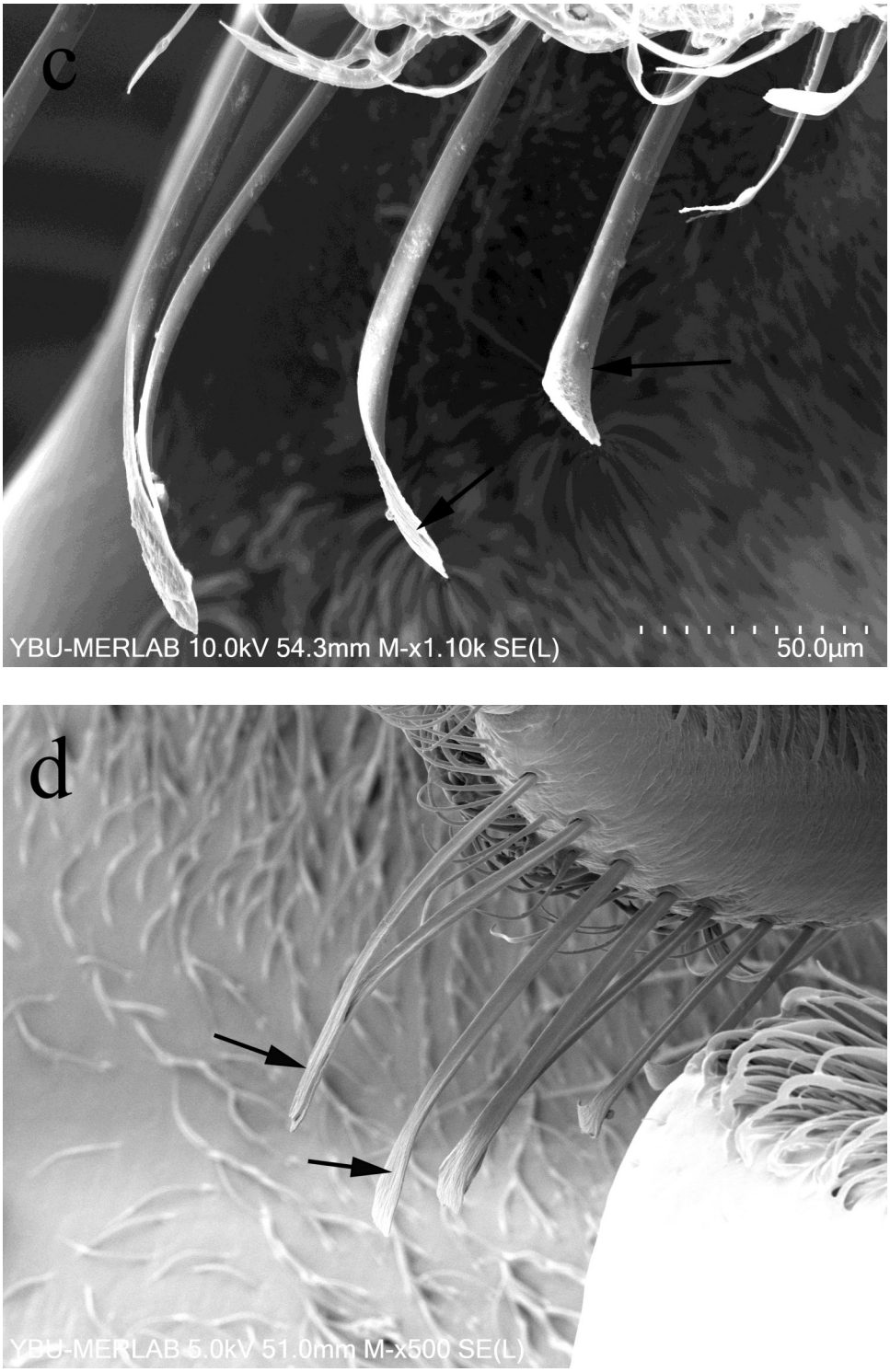

Figure. 11. c. The detailed view of the long ST with flattened end of female. d. The detailed view of the long ST with flattened end of male. SEM images)

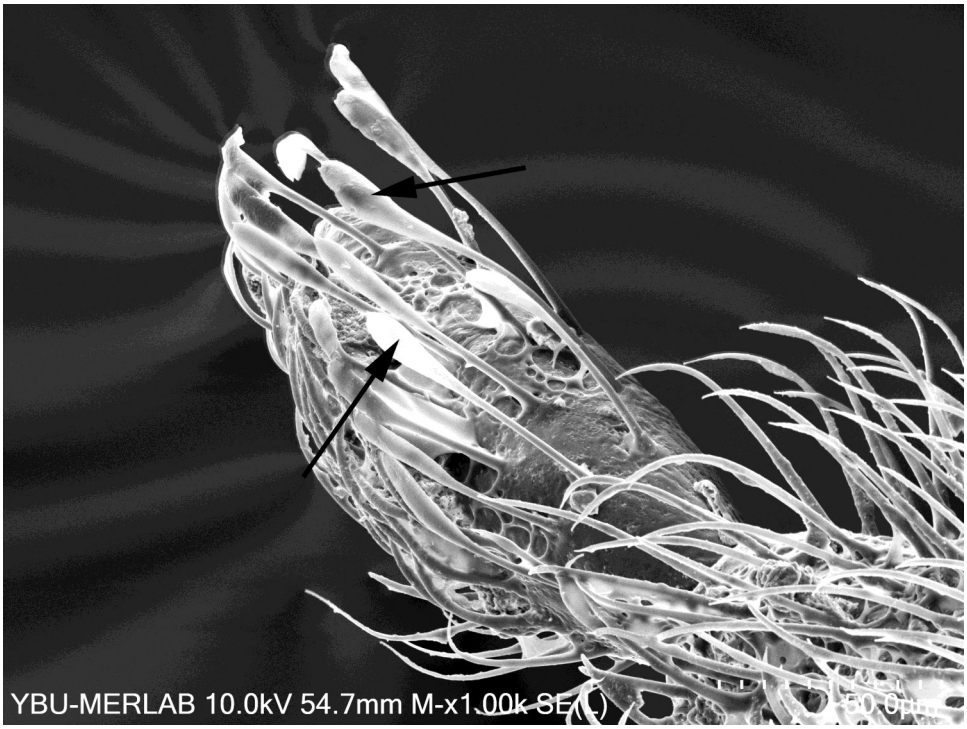

Fig. 12. The fourth segment of antenna and STs with enlarged tip (arrows) (SEM image)