Fine structure and distribution of antennal sensilla of stink bug *Arma chinensis* (Heteroptera: Pentatomidae)

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Scanning electron microscopy was used to examine the morphology, ultrastructure, and distribution of antennal sensilla of the stink bug *Arma chinensis*. Two types of sensilla trichodea (ST 1–2), four types of sensilla basiconica (SB 1–4), one type of sensilla chaetica (SCH), one type of sensilla cavity (SCA) and one type of sensilla coeloconica (SCO) were distinguished on the antennae in both sexes. ST1 and ST2 were absent from the scape and pedicel. SB1 were absent from the scape. SB2 were distributed throughout the antennae. SB3 were located on the second pedicel and the two flagellomeres. SB4 were absent from the second flagellomere. SCH was observed on the second pedicel and the two flagellomeres. SCA and SCO occurred only on the second flagellomere. SB1 clusters occurred on the distal part of the second flagellomere. We compared the morphology and structure of these sensilla to other Heteroptera and discuss their possible functions.

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1. Introduction

*Arma chinensis* (Fallou) (Heteroptera: Pentatomidae) is an important predaceous insect species that is widely distributed throughout eastern Asia. It is an important and a broadly-applied biological control agent of forest pests in China. They are usually found on elm and poplar, and in cotton and soybean fields (Xu et al. 1981, Song et al. 2010, Zou et al. 2012). They prey upon a large variety of species, and can effectively suppress agricultural and forest pests in the orders Lepidoptera, Coleoptera, Hymenoptera and Hemiptera (Xu et al. 1984, Zou et al. 2013). Knowledge of the host location mechanism employed by this species would be useful for developing methods for applying them as biological control agents.

Abundant information is available on biological characteristic, predatory behavior, and artificial rearing of predaceous stink bugs (Streams et
al. 1963, Zahn et al. 2008, De Bortoli et al. 2011, Helmey-Hartman & Miller 2014). Mechanisms underlining mate location and recognition are still unknown for most stink bugs. Research on stink bug mating behavior has indicated the importance of antennae in mate location and recognition. Numerous studies have characterized antennal sensilla of various insects (Zacharuk 1980, Keil & Steinbrecht 1984, Städler 1984, Cônsoli et al. 1999, Bleeker et al. 2004, Bourdais et al. 2006, Yu et al. 2013) whereas very few of such studies have focused on Pentatomidae (Rani & Madhavendra 1995, Brézot et al. 1997, Silva et al. 2010).

Insect antennae play important roles in various behaviors, including habitat searching, host location, discrimination, courtship and mating behavior (Schneider 1964). Antennae of insects contain sensory sensilla, which function in the detection of various stimuli involved in the host habitat and mate location (Chapman 1998). As part of our ongoing research on mate and host location mechanisms of A. chinensis, we characterized and determined the abundance and distribution of the antennal sensilla of this stink bug using the techniques of scanning electron microscopy (SEM). This work is a prerequisite for future electrophysiological studies of the antennal sensory system involved in intraspecific chemical communication. The types of sensilla of A. chinensis are also compared with those described for other heteropteran insects (e.g., Rani & Madhavendra 1995, Brézot et al. 1997, Chinta et al. 1997, Rani & Madhavendra 2005, Silva et al. 2010).

2. Material and methods

The morphology and distribution of sensilla on the antennae of A. chinensis were investigated. Sensilla on the dorsal and ventral surfaces of the antennae of both sexes were identified, counted, and measured. To characterize the sensilla we used the nomenclature proposed by Schneider (1964) and Zacharuk (1980, 1985). The following abbreviations are used for different types of sensilla:

ST1: Sensilla trichoidea 1, ST2: Sensilla trichoidea 2, SB1: Sensilla basiconica 1, SB2: Sensilla basiconica 2, SB3: Sensilla basiconica 3, SB4: Sensilla basiconica 4, SCH: Sensilla chaeticia, SCA: Sensilla cavity, SCO: Sensilla coeloconic.

2.1. Insects

Adults of A. chinensis were initially collected from Ulmus macrocarpa Hance trees, located in Qian’an County, Jilin Province, northeastern China, and subsequently maintained in the laboratory for several generations. Arma chinensis were fed with Chinese oak silk moth, Antheraea pernyi, pupae and reared at 27 ± 1°C, RH of 75 ± 5%, and a 16:8 (L:D) hour photoperiod. The insects were provided regularly with water. Only adult insects, 1 week old or older, were used in the experiments. The heads of the test insects were excised from the live insects and prepared for examination under the scanning electron microscope. Voucher specimens were deposited in Institute of Forest Protection, Jilin Provincial Academy of Forestry, Changchun, China.

2.2. Scanning electron microscopy (SEM)

Antennae of specimens were carefully excised from the antennal sockets with fine forceps under a stereomicroscope (Olympus SZX12, Japan). The antennae were first kept in 70% ethanol for 24h and then dehydrated in a graded alcohol series of 75, 80, 85, 90, and 100% in each case for 10 min each. The antennae were individually mounted with dorsal or ventral sides on aluminum stubs with double-sided sticky tapes. Before examination the antennae were sputter-coated with gold (20 nm) in a Hitachi E-102 high resolution sputter coater. The specimens were examined in a Hitachi S-570 scanning electron microscope (Hitachi, Tokyo, Japan) set at 20kV. 10 antennae of each sex were examined under the SEM.

2.3. Statistical analysis

The data were analyzed using the t-test with the statistical program SPSS version 17.0 (SPSS Inc., Chicago, IL) for Windows.
Fig 1. General view of antenna of *Arma chinensis* showing scape (Sc), segments of pedicel (P1–2) and flagellum (F1–2). – a. Male. – b. Female.

Table 1. Means (± SD) of lengths (mm) of antennal segments of *Arma chinensis* (*n*=10 per sex).

| Sex   | Scape       | Pedicel 1 | Pedicel 2 | Flagellum 1 | Flagellum 2 | Total*  |
|-------|-------------|-----------|-----------|-------------|-------------|---------|
| Female| 0.402±0.015 | 1.772±0.062 | 0.730±0.045 | 1.158±0.077 | 0.946±0.034 | 5.008±0.233 |
| Male  | 0.368±0.031 | 1.535±0.031 | 0.772±0.034 | 1.163±0.025 | 1.055±0.032 | 4.893±0.153 |

* Significant difference between the sexes (Student's t-test, *p* <0.05).

Table 2. Means (± SD) of lengths and diameters (µm) as well as morphological characteristics of different types of antennal sensilla in *A. chinensis* (*n*=10 per sex).

| Type* | Sex   | Length** | Diameter** | Morphological characteristics |
|-------|-------|----------|------------|-------------------------------|
|       |       |          | Tip        | Wall | Shape                  | Socket   |
|       |       |          |            |      |                       |          |
| ST1   | Female| 44.60 ± 1.75 | 3.31± 0.22 | Blunt Smooth | Straight or curved | Wide |
|       | Male  | 45.46 ± 2.73 | 3.02 ± 0.05 | Blunt Smooth | Straight or curved | Wide |
| ST2   | Female| 38.70 ± 1.25 | 1.91 ± 0.07 | Blunt Smooth | Straight or curved | Wide |
|       | Male  | 40.66 ± 2.77 | 2.13 ± 0.11 | Blunt Smooth | Straight          | Tight |
| SB1   | Female| 16.96 ± 2.64 | 2.55 ± 0.22 | Blunt Smooth | Straight          | Tight |
|       | Male  | 15.45 ± 4.33 | 2.28 ± 0.48 | Blunt Smooth | Straight          | Tight |
| SB2   | Female| 35.48 ± 11.37 | 3.35 ± 0.47 | Blunt Smooth | Curved            | Tight |
|       | Male  | 37.23 ± 4.77 | 3.88 ± 0.53 | Blunt Smooth | Curved            | Tight |
| SB3   | Female| 13.17 ± 3.83 | 2.29 ± 0.47 | Blunt Grooved | Curved or straight | Tight |
|       | Male  | 11.3 ± 2.55  | 2.14 ± 0.33 | Blunt Grooved | Curved or straight | Tight |
| SB4   | Female| 6.87 ± 2.02  | 1.73 ± 0.34 | Blunt Smooth | Straight          | Tight |
|       | Male  | 8.41 ± 1.12  | 1.69 ± 0.21 | Blunt Smooth | Straight          | Tight |
| SCH   | Female| 55.49 ± 12.01 | 4.58 ± 0.43 | Blunt Grooved | Straight or curved | Wide |
|       | Male  | 43.66 ± 14.86 | 4.25 ± 0.90 | Blunt Grooved | Straight or curved | Wide |
| SCA   | Female| –         | 1.61 ± 0.21 | –        | –                  | –        |
|       | Male  | –         | 1.55 ± 0.30 | –        | –                  | –        |
| SCO   | Female| 1.20 ± 0.07  | 2.38 ± 0.23 | –        | –                  | –        |
|       | Male  | 1.16 ± 0.15  | 2.35 ± 0.20 | –        | –                  | –        |

* Abbreviations: ST1: Sensilla trichoidea 1; ST2: Sensilla trichoidea 2; SB1: Sensilla basiconica 1; SB2: Sensilla basiconica 2; SB3: Sensilla basiconica 3; SB4: Sensilla basiconica 4; SCH: Sensilla chaetica; SCA: Sensilla cavity; SCO: Sensilla coeloconic.

** No significant differences between the sexes (Student's t-test, all *p*>0.05).
3. Results

3.1. General structure of the antennae

Antennae of both sexes of *A. chinensis* were morphologically similar. The filiform antennae were comprised of a basal scape (Sc), a two-segmented pedicel (P1, P2) and a two-segmented flagellum (F1, F2) (Fig. 1). Female adults bear much longer antennae than the males. The mean lengths of the antennal segments of *A. chinensis* are summarized in Table 1.

3.2. Types of sensilla

Based on their morphology, two types of sensilla trichodea (ST1-2), four types of sensilla basiconica (SB1-4), one type of sensilla chaetica (SCH), one type of sensilla cavity (SCA) and one type of sensilla coeloconica (SCO) were distinguished on the antennae in both sexes. The characteristic morphological features of the antennal sensilla of *A. chinensis* are summarized in Table 2. The type and size of the sensilla covering the different parts of the antenna were similar in the female and male stink bugs, and no sexual dimorphism was found in these sensitive structures (Table 2). The counts of sensilla were made from both the dorsal and ventral sides.

3.2.1. Sensilla trichodea 1 (ST1)

ST1 were long, straight or curved hairs, with their bases tightly inserted in an elevation of the cuticle, with a pointed tip (Fig. 2a). The sensilla stood up perpendicularly to the antennal surface and when viewed at a high magnification their wall was smooth with no pores or grooves on the sur-
face (Fig. 2b). They were found scattered on the flagellum of the antennae. ST1 was absent from the scape and the pedicel. This type of sensillum had a mean length and basal diameter (± SD) of 44.60 ± 1.75 µm and 3.31 ± 0.22 µm (female) and 45.46 ± 2.73 µm 3.02 ± 0.05 µm (male), respectively.

3.2.2. Sensilla trichodea 2 (ST2)

ST2 were long and slender hairs with straight or slightly curved shafts, and tapering to a sharp point apically (Fig. 2c). The shaft of this sensillum was smooth, arose from an elevated base and did not show any pores (Fig. 2d). They were located only on the flagellum of the antennae. ST2 were on average (± SD) 38.70 ± 1.25 µm (female) and 40.66 ± 2.77 µm (male) in length and 1.91 ± 0.07 µm (female) and 2.13 ± 0.11 µm (male) in basal diameter.

3.2.3. Sensilla basiconica 1 (SB1)

SB1 were stout pegs with slightly curved shaft having numerous pores on the walls (Figs. 3a, b). These blunt-tipped sensilla inserted into sockets often formed by slightly elevated craters. These sensilla were found on the central axis of the surface of the terminal antennal segments (Fig. 3c). SB1 measured on average (± SD) 16.96 ± 2.64 µm (female) and 15.45 ± 4.33 µm (male) in length, 2.55 ± 0.22 (female) and 2.28 ± 0.48 µm (male) in basal diameter.

3.2.4. Sensilla basiconica 2 (SB2)

SB2 had blunt tips and a well defined socket at the base. They were shorter and thicker at the base than SB1 (Fig. 3c). They were present along the entire length of the antennae of both sexes. But
analyzing the SB2 at high magnification we observed some longitudinal grooves on the cuticle (Fig. 3d). They measured on average (± SD) 35.48 ± 11.37 µm (female) and 37.23 ± 4.77 µm (male) in length and 3.35 ± 0.47 (female) and 3.88 ± 0.53 µm (male) in basal diameter.

3.2.5. Sensilla basiconica 3 (SB3)

SB3 abruptly curved in the direction of the antennal surface and were on average (± SD) 13.17 ± 3.83 µm (female) and 11.3 ± 2.55 µm (male) long pegs with a smooth wall and blunt tip (Figs. 4a, b). Their diameter at the base was 2.29 ± 0.47 µm (female) and 2.14 ± 0.33 µm (male). They were usually situated as a dense group (Fig. 4c) of 3–7 sensilla and there were usually 8.34 ± 3.20 µm between separate sensilla.

3.2.6. Sensilla basiconica 4 (SB4)

The mean (± SD) lengths of SB4 were 6.87 ± 2.02 µm (female) and 8.41 ± 1.12 µm (male). They were blunt-tipped pegs with basal diameters of 1.73 ± 0.34 µm (female) and 1.69 ± 0.21 µm (male) and possessed no grooves or pores on the antennal surface (Fig. 4d, e). They were typically inserted into a small dome, bore no articulating socket, and were oriented perpendicularly to the antennal surface. They were situated on the surface of the scape, pedicel, and the first flagellomere.

3.2.7. Sensilla chaetica (SCH)

SCH were long sickle-shaped strong bristles with longitudinal grooves accumulating toward the tip, which were located in an open articulating
socket (Figs. 5a, b). These sensilla lay parallel to the surface and point towards the tip of the antenna. They covered the second pedicel and the two flagellomeres (Fig. 5c). On average (± SD), SCH measured $55.49 \pm 12.01 \mu m$ (female) and $43.66 \pm 14.86 \mu m$ (male) in length and $4.58 \pm 0.43 \mu m$ (female) and $4.25 \pm 0.90 \mu m$ (male) in basal diameter.

3.2.8. Sensilla cavity (SCA)

SCA were single large pores that occurred at the base of the second flagellomere (Fig. 5d). They were on average (± SD) $1.61 \pm 0.21 \mu m$ (female) and $1.55 \pm 0.30 \mu m$ (male) in the diameter. They were situated not only on the dorsal, but also on the ventral side of the second flagellomere. Due to their small numbers these sensilla were not considered in the sensilla counts.

3.2.9. Sensilla coeloconic (SCO)

SCO were short peg-like sensory structures sunk into a pit with the apex of the peg not projecting out of the pit (Fig. 6a). They occurred exclusively on the second segment of the flagellum and had a mean (± SD) diameter of $2.38 \pm 0.23 \mu m$ (female) and $2.35 \pm 0.20 \mu m$ (male). These sensilla were not considered in the sensilla counts because of their limited number.

3.3. Abundance and distribution of antennal sensilla

The mean numbers and distribution of sensilla on the segments of *A. chinensis* are recorded in Table 3. Sensilla were absent on the segmental joint between the second pedicel and the first flagellomere.
re of both sexes (Fig. 6b). Large amounts of different types of sensilla were distributed on the dorsal and ventral side of the flagellum (Fig. 6c). The distribution patterns of sensilla on the antennae of both sexes of the stink bug were similar. ST1 and ST2 were more abundant than the other types of sensilla on the antennae. SB1 were absent from the scape. SB2 were distributed throughout the antennae. SB3 were distributed on the second segment of the pedicel and the two segments of the flagellum. SB4 were absent from the second flagellum. ST1 and ST2 were absent from the scape and pedicel. SC were located on the second segment of the pedicel and the two segments of the flagellum. SCA and SCO only occurred on the second segment of the flagellum.

4. Discussion

The various types of sensilla and their distribution on the antennae of male and female *A. chinensis* as revealed in this study were similar with those reported for other heteropteran insect species (Rani & Madhavendra 1995, Catalá, 1997, Onagbola et al. 2008). The antennae of insects have been typically described as consisting of the three usual components: scape, pedicel, and flagellum (Chapman 1998). The flagellum of *A. chinensis* is formed of two segments that hold the largest number of sensilla among the different segments of the antenna. Similarly, two segments were observed in *Neomegalotomus parvus* (Westwood) (Ventura & Panizzi 2005) (Alydidae), *Panstrongylus megistus* (Burmeister) (Villela et al. 2005) and *Rhodnius prolirus* (Stal) (Akent’eva 2008) (Reduviidae), *Coreus margi*
natus (Linnaeus) (Akent’eva 2008) and Leptoglossus zonatus (Dallas) (Gonzaga-Segura et al. 2013) (Coreidae), and Nezara viridula (Linnaeus) (Brézot et al. 1997) (Pentatomidae). Gonzaga-Segura et al. (2013) inferred that this could be an adaptation to improve olfaction. Our study revealed nine morphologically different types of sensilla on the antennae of both sexes of *A. chinensis*, similar to those described for other stink bugs (Brézot et al. 1997, Chinta et al. 1997, Rani & Madhavendra 2005, Silva et al. 2010).

The presence of sensilla campaniform and sensilla placoid found on other heteropteran insects (Gonzaga-Segura et al. 2013) were not found on *A. chinensis*. Sensilla trichodea 1 (ST1) resemble the “type 5 sensilla” in the green stink bug, *N. viridula* (Brézot et al. 1997) and “thick-walled trichoid sensilla” in the *P. megistus* (Catalá 1997). They are the most abundant type of sensilla present on the antenna of these and many other stink bugs. Shorter or longer blunt-tipped hairs, which do not articulate at their base, like the sensilla trichodea (ST) in *A. chinensis*, occur abundantly on the antennae of many wasps, beetles and moths (Bleeker et al. 2004, Merivee et al. 1999, Lopes et al. 2005, Castrejón Gómez & Carrasco 2008). Sensilla trichodea have traditionally been thought of as the contact chemoreceptors (Schneider 1964). In *N. viridula*, they have been reported to be good candidates for contact chemoreception based on their external structure (Brézot et al. 1997). Bioassay experiments of the mating behavior on *Phoracantha semipunctata* (Fabricius) demonstrated that sensilla trichodea served as a contact chemoreceptor (Lopes et al. 2005). Because accounting for more than 50% of the total number of the antennal sensilla, sensilla trichodea can be considered the main sensory receptors involved in the chemical sense in neotropical bugs (Silva et al. 2010). ST was the most abundant of all sensillum types on the antennae of both sexes of *A. chinensis*, and they were also thought to function as chemoreceptors (Zacharuk 1985).

Large articulated bristles with blunt tip, SCH

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### Table 3. Mean numbers per segment (± SD) and distribution of different types of antennal sensilla of female and male *A. chinensis* (*n* = 5 antennae per sex). For abbreviations, see Table 2.

| Type | Sex | Scape | Pedicel 1 | Pedicel 2 | Flagellum 1 | Flagellum 2 | Total |
|------|-----|-------|----------|----------|-------------|-------------|-------|
| ST1ns | Female | 0 | 0 | 0 | 242.0 ± 21.5 | 270.0 ± 19.5 | 542.3 ± 44.0 |
| | Male | 0 | 0 | 0 | 193.3 ± 10.5 | 420.0 ± 30.4 | 613.3 ± 40.9 |
| ST2ns | Female | 0 | 0 | 0 | 493.6 ± 20.5 | 521.6 ± 19.8 | 1015.3 ± 40.3 |
| | Male | 0 | 0 | 0 | 317.6 ± 21.1 | 611.3 ± 25.4 | 928.9 ± 46.5 |
| SB1ns | Female | 0 | 110.6 ± 11.1 | 63.3 ± 6.0 | 20.6 ± 2.5 | 127.6 ± 12.5 | 322.3 ± 32.1 |
| | Male | 0 | 114.3 ± 11.0 | 26.0 ± 6.0 | 58.6 ± 17.0 | 148.6 ± 12.1 | 347.6 ± 46.1 |
| SB2ns | Female | 6.0 ± 0 | 65.0 ± 8.0 | 96.6 ± 8.7 | 306.3 ± 19.2 | 124.3 ± 5.1 | 598.3 ± 41.1 |
| | Male | 5.0 ± 0 | 41.0 ± 7.2 | 99.0 ± 5.5 | 186.6 ± 10.7 | 144.0 ± 5.5 | 475.6 ± 29.1 |
| SB3* | Female | 0 | 0 | 7.0 ± 2.0 | 26.6 ± 1.5 | 8.3 ± 1.5 | 41.9 ± 5.0 |
| | Male | 0 | 0 | 8.3 ± 2.5 | 19.6 ± 1.5 | 45.0 ± 11.1 | 72.9 ± 15.1 |
| SB4ns | Female | 30.3 ± 3.0 | 81.0 ± 4.0 | 23.6 ± 2.1 | 15.6 ± 3.1 | 0 | 120.3 ± 9.1 |
| | Male | 31.6 ± 3.1 | 59.3 ± 13.2 | 6.0 ± 0 | 35.6 ± 4.0 | 0 | 132.6 ± 20.2 |
| SCH* | Female | 0 | 0 | 16.0 ± 3.0 | 49.3 ± 8.1 | 75.6 ± 13.0 | 140.9 ± 24.0 |
| | Male | 0 | 0 | 12.6 ± 2.5 | 108.3 ± 11.0 | 92.6 ± 6.5 | 213.6 ± 20.0 |

* Significant difference in total number of antennal sensilla between the sexes (Student’s t-test, *p*<0.05).
ns = No significant difference in total number of antennal sensilla between the sexes (Student’s t-test, *p*>0.05).
in *A. chinensis*, seem to be identical with the “bristle-like type 3” in *N. viridula* (Brézot et al. 1997), “long curved bristle type 2” in *L. lineolaris* (Chinta et al. 1997). Brézot et al. (1997) suggested that the flexible socketed base, the length of the hair, the dendrite not protruding in the hair, the presence of a cuticular shaft under the cuticle near the base of this type of sensillum indicated its possible involvement in chemoreception in *N. viridula*. In *L. lineolaris*, the presence of a thick cuticle and a single terminal pore of this type of sensillum indicated its possible involvement in chemoreception in contacts (Chinta et al. 1997). In *Monochamus notatus* (Drury) and *M. scutellatus* (Say), they can be considered as the receptors responding to sound, wind, or touch (Dyer & Seabrook 1975). The absence of pores in this sensillum precludes a chemosensory role in *A. chinensis* (Fig. 5b). SCH lacked pores and protruded above all other sensilla, so we assume that they function as mechanoreceptor in *A. chinensis*.

Sensilla basiconica 1 (SB1) with multiple pores and without flexible sockets of *A. chinensis* look like the “sensilla basiconica type I” in the stink bug *O. nigricornis* (Rani & Madhavendra 1995); “type 4 sensilla” in the green stink bug, *N. viridula* (Brézot et al. 1997); “short peg” in the tarnished plant bug, *L. lineolaris* (Chinta et al. 1997); “sensilla basiconica type I” in the ground beetle, *Bembidion properans* Stephens (Merivee et al. 2002); “basiconic sensilla type 3” in *E. heros, P. guildinii* and *E. meditabunda* (Silva et al. 2010). SB1 should correspond to the “thin-walled” (Silfer 1970), “single-walled, wall pore sensilla” (Altner & Prillinger 1980) and “multiporous chemosensilla” (Zacharuk 1980). Sensilla basiconica bear structural features such as a non-flexible base, a thin, multiporous cuticular wall, a pore-tubule system and branched dendritic segments (Zacharuk 1980). The numerous pores and branched dendrites are traditionally considered to provide evidence that these sensilla basiconica function as olfactory receptors (Altner & Prillinger 1980, Zacharuk 1985). The cuticular wall of SB1 bears numerous pores in *A. chinensis* (Fig. 2b). Based on the ultrastructure observed by SEM, SB1s are inferred as the olfactory receptors in *A. chinensis*. Sexual dimorphism in the numbers of these sensilla was observed in *L. lineolaris* (Chinta et al. 1997). In the species studied here the number of SB1 was approximately equal between the males and the females (Table 3). In other insects, these basiconic sensilla are known to be olfactory receptors responding to food and habitat related compounds (Schneider 1964, Zacharuk 1985).

The clusters of SB1 are located on the distal part of the second flagellomere (Fig. 3e). Clusters of olfactory sensilla basiconica have been identified also in many coleopteran species, such as *M. notatus* and *M. scutellatus* (Dyer & Seabrook 1975), *Hypera meles* (Fabricius) (Smith et al. 1976), *Psacothea hilaris* (Pascoe) (Dai & McIver 1990), *Phyllotera cruciferae* (Goeze), *Psylliodes punctulata* Melsheimer, *Epitrix cucumeris* (Haris) and *Psylliodes affinis* (Paykull) (Ritcey & McIver 1990), and *Geotrupes auratus* Motschulsky and *Copris pecuarius* Lewis (Inouchi et al. 1987). It has been inferred that such olfactory sensilla clusters function as sensory fields (Dyer & Seabrook 1975) and may compose an enlarged odor-sensing area that wound be advantageous for long-distance olfactory detection (Inouchi et al. 1987).

Sensilla basiconica 2 (SB2) of *A. chinensis* are common on the antennae of many stink bugs. These sensilla resemble the “type 2 sensilla” of *N. viridula* (Brézot et al. 1997), “basiconic sensilla” of *Riptortus pedestris* Fabricius, *Elasmolomus sordidus* (Fabricius), *Cyclopelta siccifolia* Westwood and *Chrysocoris purpurea* (Westwood) (Rani & Madhavendra 2005), and “basiconic sensilla 2” of *E. heros, P. guildinii* and *E. meditabunda* (Silva et al. 2010). Silva et al. (2010) suggested that this type of sensillum may be related to finding food or suitable habitats. Some authors have assigned a thermo- or chemoreception function to these sensilla (Chapman 1982, Zacharuk 1985).

Sensilla basiconica 3 (SB3) of *A. chinensis* are very similar to the “sensilla basiconica type I” of the ground beetle *Platyopus dorsalis* (Pontoppidan) (Merivee et al. 2001) and “sensilla basiconica type 2” in the ground beetle, *B. properans* (Merivee et al. 2002). Non-articulated blunt-tipped basiconic sensilla are common on the antennal flagellum of most insects. In the ground beetle *Nebria brevicollic* (Fabricius) and the cigarette beetle *Lasioderma serricorne* (Fabricius), it was demonstrated that the wall of
these sensilla is perforated by numerous tiny pores (Daly & Ryan 1979, Okada et al. 1992). The numerous pores and branched dendrites are considered to be evidence that these basiconic sensilla function as olfactory receptors (Altner & Prillinger 1980, Zacharuk 1985). In this study, we did not detect pores in the cuticle of SB3 (Fig. 4b). Single cell recording studies and behavioral experiments are needed to confirm their function.

The appearance and small number of sensilla basiconica 4 (SB4) of A. chinensis are similar with “sensilla basiconica type VII” in the click beetle, Agriotes obscurus Linnaeus (Merivee 1992), “sensillum styloconicum” in the cigarette beetle L. serricorne (Okada et al. 1992), “double-walled sensilla” in Ips typographus (Linnaeus) (Hallberg 1982), “sensilla basiconica II” in the ladybird beetle Semiadalia undecimnotata Schneider (Jourdan et al. 1995). Sensilla without pores are either mechanosensitive or thermo/hygro-sensitive in A. chinensis (Altner & Prillinger 1980, Keil 1999).

Sensilla cavity (SCA) in A. chinensis are similar to those of “cavity sensillum” of eight Acrididae species (Li et al. 2007), “sensilla coeloconica” of B. properans (Merivee et al. 2002), “sensilla cavity” of Callosobruchus chinensis (Linnaeus) and C. maculatus (Fabricius) (Hu et al. 2009), “sensilla cavity” of Cnaphalocrocis medinalis (Guenée) (Sun et al. 2011) and probably in other heteropteran species as well. Chemos-, thermo-, or hygroreception is the most probable function for these sensilla (Zacharuk 1985). They were inferred to function as contact-chemoreceptors, allowing the insect to obtain information on the suitability of any plant they touch (Sun et al. 2011).

Sensilla coeloconica (SCO) were found only on the second segment of the flagellum of A. chinensis. Sensilla with similar morphological features were found on the flagellum of N. viridula, C. purpurea (West), E. heros, P. gildivii and L. zonatus (Brézot et al. 1997, Rani & Madhavendra 2005, Silva et al. 2010, Gonzaga-Segura et al. 2013) and Reduviidae (Catalá 1997). In social insects, such as ants and wasps, whose behavior is guided by variations in temperature, sensilla coeloconica are chemoreceptors that respond to air temperature changes (Ruchty et al. 2009). In lepidopterans these sensilla are olfactory receptors, possibly sensitive to volatile plant odors (Van der Pers 1981, Pophof 1997), and in homopterans they function as hygrometers preventing desiccation of the antennae (Kristoffersen et al. 2006).

Further studies on functional antennal morphology and anatomy are needed to confirm the proposed functions of the sensilla identified in this study. The present results provide necessary background information for our ongoing study on electrophysiology and chemical ecology of A. chinensis.

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