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Morphology, distribution and abundance of antennal sensilla of the oyster mushroom fly, *Coboldia fuscipes* (Meigen) (Diptera: Scatopsidae)

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ABSTRACT

We investigated the distribution, morphology and abundance of antennae sensilla of *Coboldia fuscipes* (Meigen) using scanning electron microscopy. Antennae of *C. fuscipes* consisted of scape, pedicel, and flagellum with eight flagellomeres. Antennal scape and pedicel had only one type of sensillum, i.e., sensilla chaetica. Significant differences were found between the number and distribution of these sensilla. Four types of morphologically distinct sensilla on the flagellum were identified, including sensilla chaetica, sensilla trichoidea, sensilla coeloconica, and sensilla basiconica (three subtypes). Significant differences were found in the abundance and distribution of sensilla among the antennal flagella and diverse flagellomeres in both sexes. Sensilla trichoidea is the most abundant of sensilla discovered on the antennal flagellum. Sensilla chaetica is the largest and longest sensilla among all the types of sensilla found on the antennal surface of *C. fuscipes*. Sensilla coeloconica is widely distributed all over the flagellum surface except for the first of female. Some significant differences in the abundance and distribution were also observed among sensilla basiconica of flagellum. The probable biological function of each sensillum type was deduced based on the basis of their structure. These results serve as important basis for further studies on the host location mechanism and mating behavior of *C. fuscipes*.

Introduction

Oyster mushroom (*Philomycus* spp.), considered as one of the most important economic fungi worldwide (Oh et al., 2004), is seriously damaged by mushroom flies. *Coboldia fuscipes* (Meigen, 1830) is one of the most important fly pests of oyster mushroom (Yi et al., 2008). *C. fuscipes* belongs to the family Scatopsidae and to the genus *Coboldia* (Cook, 1974). This fly species is cosmopolitan and also closely associated with human life, and its larva is usually found in decaying plant or animal materials (Cook, 1974; Amorim, 2007). *C. fuscipes* larvae can ingest the mycelium, mushroom bed, and sporophore of mushroom, resulting in reduced of quality and productivity (Choi et al., 2000). Secondary damage to the mushroom is also introduced through transported pathogen, mites, and nematodes (Bae et al., 2001).

The type-species of *C. fuscipes* is deposited in the National Museum of Natural History, Smithsonian Institution (USNM) (McAtee, 1921). The species total length is 1.34–2.40 mm, the tergum of segment 7 of abdomen with a long process, rather variable and usually asymmetrical, and a dull blackish species which posses R3 reaching scarcely beyond middle of wing (Cook, 1974). Scatopsidae includes 33 genera (Amorim, 1994), whose segmented antennae varies significantly (Cook, 1969), such as in *Anapausis inermis* (Ruthé) with 9 segments (Cook, 1965), and *Scatopse notata* (L.) with 10 segments (Yang and Lv, 1992). Antenna of *C. fuscipes* contains 10 segmented, and flagellum with 8 flagellomeres, which is considered as a typical for many Scatopsidae (Cook, 1971, 1974). In insects, antennae possess various sensilla with different functions important in life behaviors, including searching for foods, mating, and oviposition (Setzu et al., 2011; Zhang et al., 2013). Moreover, antennae are organs of chemoreception, thermoreception, and hygroreception (Liang and Fletcher, 2002), enabling their owner to perceive various environmental signals, such as host volatility, temperature, humidity, and communication signals (Ramdya and Benton, 2010; Liu et al., 2013). Olfactory

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sense plays an important role in guiding the behavior of the flies. Antennal sensilla have been extensively recorded to bear several olfactory receptors in many insects (Merivee et al., 2002; Sukontason et al., 2004). Therefore, understanding the morphology and type of chemosensilla would contribute to the elucidation of a comprehensive model of olfactory systems (Zacharuk, 1980). However, despite the crucial functions of antennae, little is known about their function, morphology, and distribution of antennal sensilla of *C. fuscipes*.

Our study aimed at investigating and describing the morphology, type, and distribution of sensilla on the antenna of male and female *C. fuscipes* using scanning electron microscopy (SEM). Detailed characterization on the sensilla of this species was reported for the first time. We speculated the functions of various *C. fuscipes* sensilla and compared them with those that have been discussed based on morphology and ultrastructure. Knowledge of such functions could benefit the understanding of the probable biological role of these organ components in chemical communication, and also provide baseline information for further sex-communication studies of this species.

Material and methods

Insects

Male and female adults of *C. fuscipes* were collected from the nursing house of the edible fungi in Wuhan (Hubei Province, China) in September 2011. Insects were reared in plastic cages (10 cm × 6 cm × 4 cm) on the mushroom chunks as described by Choi et al. (2000). Cages were placed in controlled laboratory conditions of 25 ± 1 °C with a 16:8 (light:dark) photoperiod and 75 ± 5% relative humidity. Mushroom chunks with eggs were kept in a new cage until hatching.

Scanning electron microscopy (SEM)

Preparation for SEM was modified according to the method previously described by Chen and Fadamiro (2008). Freshly emerged adults of *C. fuscipes* (females = 6, males = 6) were killed by placing in −4 °C for 20 min. The entire antenna was cut off under a microscope and processed immediately, then carefully removed and fixed in 3% glutaraldehyde (0.1 M sodium phosphate buffer, pH 7.4) for 24 h at 4 °C. Antennae were rinsed for twice in glutaraldehyde and then dehydrated in a graded alcohol series as follows: 30, 50, 70, 80, 90 and 100%, in each case for 12 h (Zhang et al., 2012). After treatment by a graded alcohol series, antennae were critical point drying. Finally, specimens were coated with gold to be observed under a JSM-6390/LV SEM at the microscopy core facility, Huazhong Agricultural University (Wuhan, China).

Data analysis

The terminology and nomenclature of antennae were used to describe in this study follow Liu et al. (2013). The type, form, distribution and density of antennal sensilla were documented by SEM. The distribution and density of various types of sensilla were determined using the grid technique described by Kelling (2001), all results were scaled to 1000 μm^2 (Zhang et al., 2013). The density of sensilla on male or female was compared for significance ($P < 0.05$) by ANOVA (Bisotto-de-Oliveira et al., 2011). The length, width of 3 segments of antenna, and mean numbers of the different types sensilla found on male and female antenna were calculated before the Student's test was used to determine any significant sexual differences occurred (Ahmed et al., 2013).

Results

General description

As with other dipterans, antennae of adult *C. fuscipes* are situated on the frontal region of head between the large compound eyes (Fig. 1a). Each antenna consists of three segments, basal scape (Sc), pedicel (Pd), and flagellum (Fl) with 8 flagellomeres, respectively (Fig. 1b). No sexual dimorphism exists in *C. fuscipes* male and female antennae. Microscopic observations indicate that all antennal segments are composed of sensilla and microtrichia. Four types of sensilla are found on the flagellum and classified as: sensilla chaetica (SCh), sensilla trichoidea (STr), sensilla coeloconica (SCo) and sensilla basiconica (SBa). In particular, SCh are found on all antenna segments.

Scape

Scape, the most proximal and shortest antenna segment, measures approximately 43.63 ± 2.05 μm in length and 38.20 ± 2.58 μm in width of basal regions in female flies ($n = 5$), and 38.36 ± 1.99 μm in length and 45.28 ± 3.54 in width μm in males ($n = 6$) (Table 1). The length and width are no difference between sex. Sensilla on the scape are SCh and microtrichiae 1 (Mt1) (Fig. 2a). However, the surface of the base is extremely smooth. SCh is located on the median and proximal of the cuticular surface of the antennal scape (Table 2). Moreover, higher numbers are found on proximal than that on median and distal. Mt1 has

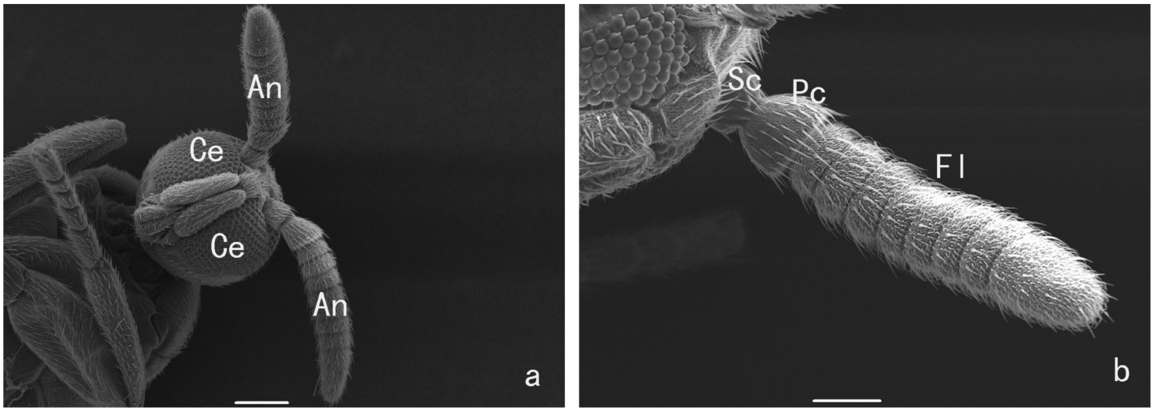

Fig. 1. SEM micrographs of *C. fuscipes* antennae. (a) The features of adult *C. fuscipes* antennae; (b) anterior surface of the whole antenna. Ce, compound eyes; An, antennae; Sc, scape; Pc, pedicel; Fl, flagellum. Scale bar = 100 μm in (a) and 50 μm in (b).

Table 1
Mean ± SE of the length and width (1000 μm^2), at the larger diameter, in the antennae segments of females and males *C. fuscipes*.

	Length (μm)		Width (μm)		
	Female	Male	Region	Female	Male
Scape	43.63 ± 2.05 a	38.36 ± 1.99 a	Basal	38.20 ± 2.58 a	45.28 ± 3.54 a
			Apical	43.00 ± 0.49 a	47.84 ± 4.01 a
Pedicel	58.64 ± 1.25 a	49.96 ± 0.88 b	Basal	34.00 ± 0.32 a	31.50 ± 0.86 b
			Apical	55.57 ± 1.48 a	58.28 ± 3.89 a
Flagellum	275.26 ± 19.28 a	282.30 ± 13.67 a	Basal	49.60 ± 2.74 a	55.75 ± 3.32 a
			Apical	43.50 ± 5.02 b	58.22 ± 1.48 a

Means followed by the same lower-case letter on the lines are not statistically significant different (*t*-test, $P < 0.05$, $n = 5$). F, female; M, male.

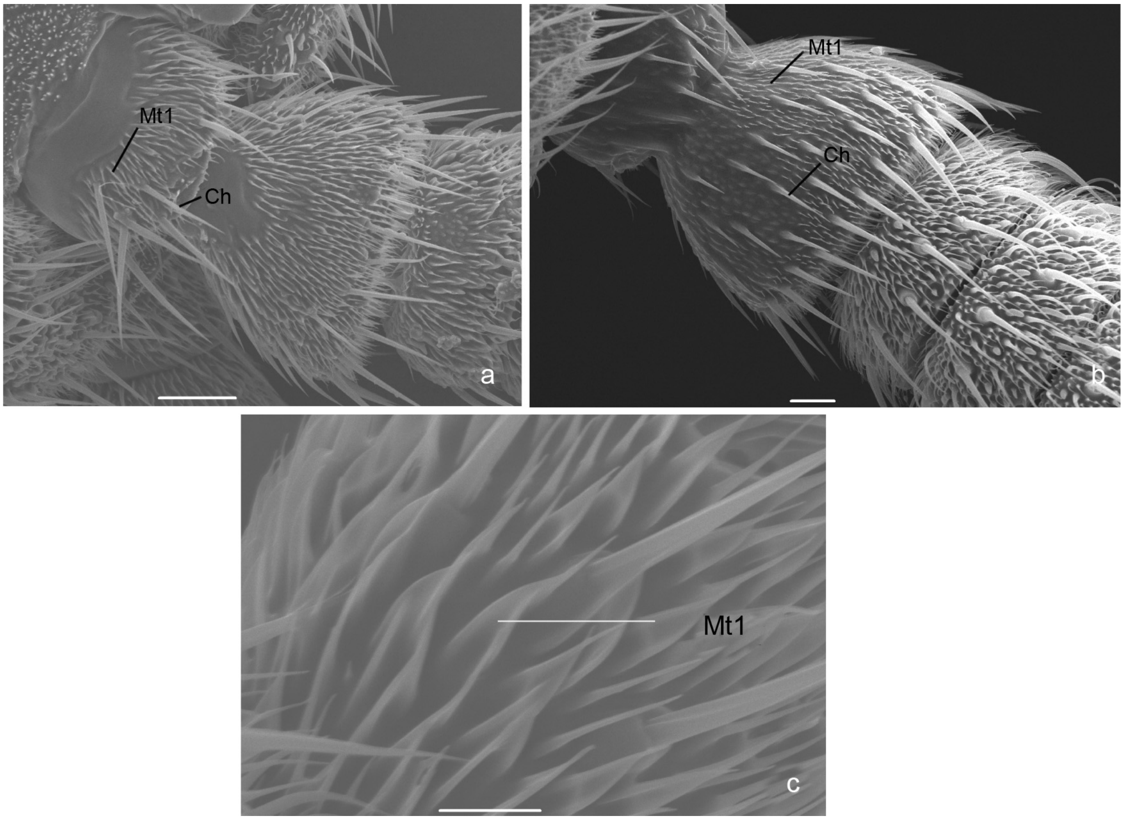

Fig. 2. SEM micrographs of scape and pedicel. (a) Scape of *C. fuscipes* antennae; (b) pedicel of *C. fuscipes* antennae. Ch, Chaetie sensilla; Mt1, microtrichiae. Scale bar = 20 μm in (a), 10 μm in (b) and 2 μm in (c).

small ear-like structures with sharp-pointed tips and are densely located on the cuticular surface of scape (Fig. 2c).

Pedicel

Pedicel, the second segment of antenna, measures approximately 58.62 ± 1.24 μm in length and 34.00 ± 0.31 μm in width of basal regions in female flies ($n = 5$), and 51.24 ± 0.46 μm in length and 32.60 ± 0.72 μm in width in males ($n = 6$) (Table 1). The type of sensillum and distribution on pedicel is the same as that on scape (Fig. 2b and Table 2). And Mt1 is located on the two sides of cuticular surface (Fig. 2c).

Flagellum

Flagellum measures approximately 297.06 ± 21.45 μm in length and 58.73 ± 3.76 μm in width of basal in female flies ($n = 5$), and 308.03 ± 57.03 μm in length and 48.01 ± 3.25 μm in width in males ($n = 6$) (Table 1). Four major types of sensilla exist on the cuticular surface of flagellum: SCh, STr, SBa and SCo (Fig. 3a). Microtrichiae

Table 2
Mean ± SE of sensilla chaetica, in a defined area (1000 μm^2) on the distal, median, and proximal regions on the scape and pedicel of *C. fuscipes*.

Sex	Scape			Pedicel		
	Distal	Median	Proximal	Distal	Median	Proximal
F	0 c	5.69 ± 1.36 b	10.56 ± 2.94 a	1.52 ± 0.63 c	6.36 ± 1.52 b	11.65 ± 2.06 a
M	0 c	4.33 ± 1.52 b	8.33 ± 2.08 a	1.43 ± 0.86 c	5.67 ± 0.58 b	12.33 ± 2.51 a

Means followed by the same lower-case letter on the lines are not statistically significant different (ANOVA, $P < 0.05$, $n = 5$), F = Female; M = Male.

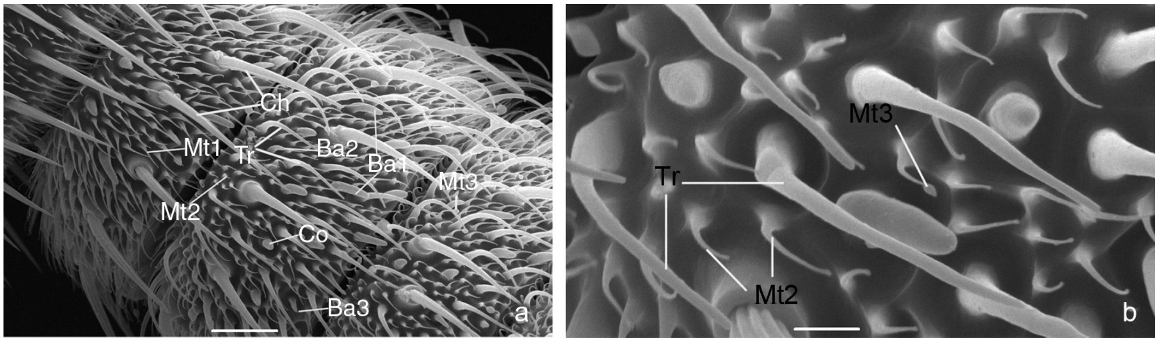

Fig. 3. SEM micrographs showing sensilla subtypes of the flagellum of *C. fuscipes*. (a) Sensilla subtypes of the flagellomere of *C. fuscipes*; (b) magnification of Trichoid sensilla, Mt2 and Mt3. Mt, microtrichiae; Ba, Basiconica sensilla; Ch, Chaetie sensilla; Tr, Trichoid sensilla; Co, Coeloconic sensilla. Scale bar = 10 μm in (a) and 2 μm in (b).

Table 3
Sensilla length of *C. fuscipes* on antennal flagellomere (mean ± SE).

Sensilla	Sex	length	Basal diameter
Tr	F	15.10 ± 1.63 a	1.88 ± 0.22 a
	M	16.39 ± 1.28 a	2.10 ± 0.22 a
Ch	F	25.09 ± 1.68 a	4.31 ± 0.54 a
	M	24.02 ± 2.38 a	4.99 ± 0.44 a
Co	F	3.98 ± 0.58 a	1.95 ± 0.23 a
	M	3.29 ± 0.06 a	1.85 ± 0.11 a
Ba1	F	8.10 ± 1.13 a	1.92 ± 0.34 a
	M	8.52 ± 2.06 a	1.75 ± 0.36 a
Ba2	F	4.91 ± 0.89 a	1.39 ± 0.26 a
	M	4.75 ± 0.76 a	1.32 ± 0.54 a
Ba3	F	3.89 ± 0.39 a	1.32 ± 0.40 a
	M	3.90 ± 0.80 a	1.03 ± 0.19 a

Means followed by the same lower-case letter on the lines are not statistically significant different (*t*-test, $P < 0.05$, $n = 5$). Tr, sensilla trichoidea; Ch, sensilla chaetica; Co, sensilla coeloconica; Ba, sensilla basiconica; F, female; M, male.

2 (Mt2) has small hair-like structure with sharp-pointed tips and densely distributes on the cuticular surface of flagellum (Fig. 3b). However, Microtrichiae 3 (Mt3) has small hair-like structure with globular-shape on fore-end (Fig. 3b).

Surface sensilla on the antennal funiculus

Sensilla trichoid

STr are shorter and slender in width and length than SCh (Fig. 3b and Table 3). However, it is the most abundant sensilla type found on antennal flagellum (Table 4). STr are elongated, curved, and hair-like structures and arise from deeply sunken depressions of the integument called sacculus. STr are a basal swelling and gradually tapers to an acute tip distally. The wall of STr is smooth and no pores or grooves are found on the surface. No significant differences in width and length exist between sexes (Table 3). At higher magnification, these sensilla are distributed over the cluster surface of antennal flagellum except for 1st. However, sensilla on 5th, 6th, 7th, and 8th flagellum in male flies are more abundant than those of female, whereas the number of sensilla on 4th is opposite results (Table 4). Sensilla on 4th are more abundant than those on other flagellum in female except for 8th (Table 4). Furthermore, the number of sensilla on 7th is more abundant than those on other flagellum in male (Table 4).

Sensilla chaetica

SCh are the largest and longest sensilla among all types found on the antennae surface of *C. fuscipes* (Fig. 4a and Table 3). SCh, which emerge from an elevated conspicuous cylindrical base, are characterized by elongated, straight, and gradually taper with some distinct incised longitudinal grooves on the surface of their wall. The longitudinal grooves stretch from the base to the tip. No significant difference is found in width and length between sexes (Table 3). However, the number of sensilla on 1st, 5th, 8th flagellum in male is more abundant than that of female (Table 4). Moreover, the number of sensilla on 1st flagellum is more abundant than that of 5th, 7th and 8th in female. Similarly, the number of sensilla on 1st flagellum is more abundant than those of other flagellum in male except for 3rd (Table 4).

Sensilla coeloconica

SCo is a short, cone-shaped peg with a relatively pointed tip, situated centrally in a deep sacculus on the antennal flagellum surface, and stand up perpendicularly (Fig. 4b). Their wall is rough when viewed at high magnification. No significant differences in width and length exist between sexes (Table 3). SCo is widely distributes all over the flagella surface of antennae except for 1st of female (Table 4). Sensilla on 4th and 5th flagellum in male is more

Table 4
Mean ± SE of sensilla chaetica, trichoidea and coelonica on flagellomere, in a defined area (1000 μm^2) on every flagellomere of *C. fuscipes*.

	Ch		Tr		Co	
	F	M	F	M	F	M
1	4.68 ± 0.47 a	5.82 ± 0.09 a*	0 c	0 e	0 b	1.45 ± 0.02 d
2	3.44 ± 0.28 abc	3.52 ± 0.09 c	26.87 ± 4.48 b	18.55 ± 3.53 cd	4.66 ± 2.52 ab	1.49 ± 0.51 d
3	3.66 ± 0.28 abc	4.82 ± 1.61 ab	19.04 ± 2.50 b	23.36 ± 5.45 d	4.74 ± 1.59 ab	3.79 ± 1.17 b
4	3.98 ± 0.51 abc	4.45 ± 0.18 bc	16.19 ± 1.27 b*	26.72 ± 3.14 cd	4.09 ± 0.51 ab	5.77 ± 0.25 a*
5	2.72 ± 0.45 c	4.31 ± 0.28bc*	18.62 ± 4.04 b	29.17 ± 1.78 c*	1.19 ± 0.23 ab	3.37 ± 0.97 bc*
6	4.45 ± 0.95 ab	4.39 ± 0.01 bc	27.54 ± 2.82 a	34.63 ± 0.77 b*	3.36 ± 0.36 ab	2.44 ± 0.85 bcd
7	3.08 ± 0.49 bc	3.61 ± 0.53 c	21.73 ± 0.08 b	41.58 ± 2.34 a*	4.95 ± 1.15 a*	1.88 ± 1.01 cd
8	2.94 ± 0.80 bc	4.42 ± 0.09bc*	23.47 ± 3.11 ab	30.67 ± 1.29 bc*	1.99 ± 0.65 ab	2.93 ± 1.24 bcd

Means followed by the same lower-case letter on the lines are not statistically significant different between flagellomere (ANOVA, $P < 0.05$, $n = 3–5$).
Means followed by the same * on the lines are not statistically significant different between sex (*t*-test, $P < 0.05$, $n = 3–5$). Ch, sensilla chaetica; Tr, sensilla trichoidea; Co, sensilla coeloconica; F, female; M, male.

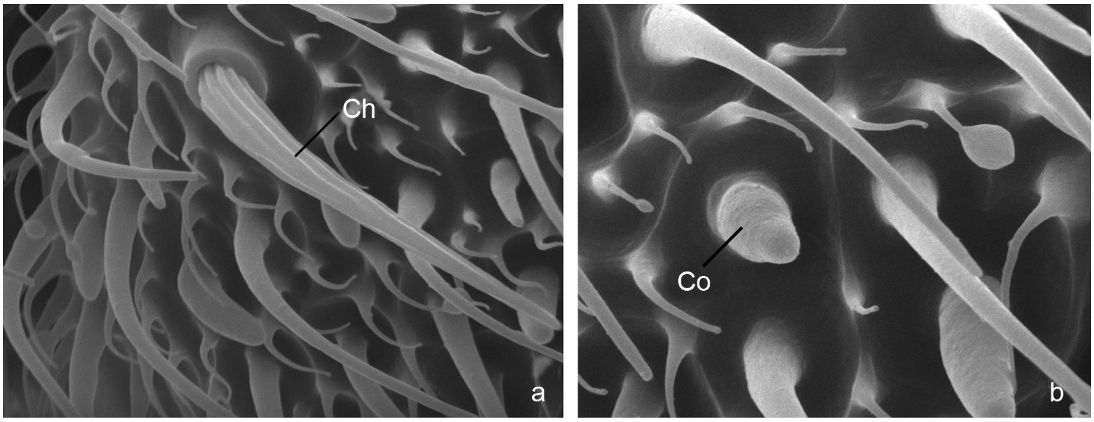

Fig. 4. SEM micrographs of Chaetie sensilla and Coeloconic sensilla of *C. fuscipes*. (a) Ch; (b) Co. Ch, Chaetie sensilla; Co, Coeloconic sensilla. Scale bar = 2 μm in (a) and 2 μm in (b).

abundant than those in female, and sensilla on 7th yields opposite results (Table 4), and no significant differences in other flagella exist between sexes. The number on the 2nd is no significantly difference than that of other flagella in female except for 1st. The number of sensilla on 4th is more abundant than those of other flagellum in male (Table 4).

Sensilla basiconic

SBa is blunt-tipped and shorter than STr, and widely distributed all over the flagellum surface of antennae (Table 3). SBa are found three subtypes on *C. fuscipes* flagellum: SBa1, SBa 2 and SBa3, which could be distinguished by shape and size (Fig. 5a and b). SBa1 is longer, curved, with a relatively pointed digitiforms and smooth with the surface, whereas SBa2 is shorter and thinner than SBa1 (Table 3). SBa2 is curved, sharp-tipped digitiform. SBa3 is short and small, located on a deep and big sacculus and straight with an acute tip (Fig. 5b). No significant difference is found in width and length between sexes (Table 3). However, some significant differences in the number are found between flagella of male and female (Table 5). In female, SBa1 on 6th flagellum are more abundant than those on 2nd, 7th and 8th; SBa2 on 3rd flagellum are more abundant than those of 1st, 2nd, 7th and 8th; SBa3 on 3rd flagellum are significantly difference than those of other flagellum except for 8th. However, SBa1 and SBa2 on 7th flagella are significantly difference than those of other flagellum in male. And no significantly difference is found about Ba3 (Table 5).

Discussion

In this study, the morphology, ultrastructure, and distribution of antennal sensilla of *C. fuscipes* are investigated using SEM. Results show that microtrichiae and sensilla are also densely distributed on the surface of segments. Cook (1974) has reported that *Colobostema* (Enderlein) (Diptera) and *Holoplagia* (Enderlein) (Diptera) antennae are covered with microtrichia, and each flagellomere with setae is arranged in an irregular double ring. However, the setae on flagellomeres of Swammerdamellini is arranged in a whorl (Amorim, 2007). Previous research has showed that the number of sensory setae in the flagella of *Anapausis* (Enderlein) (Diptera) and *Colobostema* (Diptera) are different (Cook, 1965, 1974). Our results show that the morphology of microtrichiae 2 on flagellomere surface resembles that of sensilla found on *Pseudacteon tricuspis* (Borgmeier) (Diptera) (Chen and Fadamiro, 2008). And findings Microtrichiae 3 are the first report on the morphological structure. Four types of surface sensilla, including chaetica, trichoidae, coeloconic and three subtypes of basiconica are observed on *C. fuscipes* antennae. The general function of the sensilla is deduced from their microstructure.

Sensilla chaetica are the most prominent found on both male and female antennae and seem to be widely distributed on all

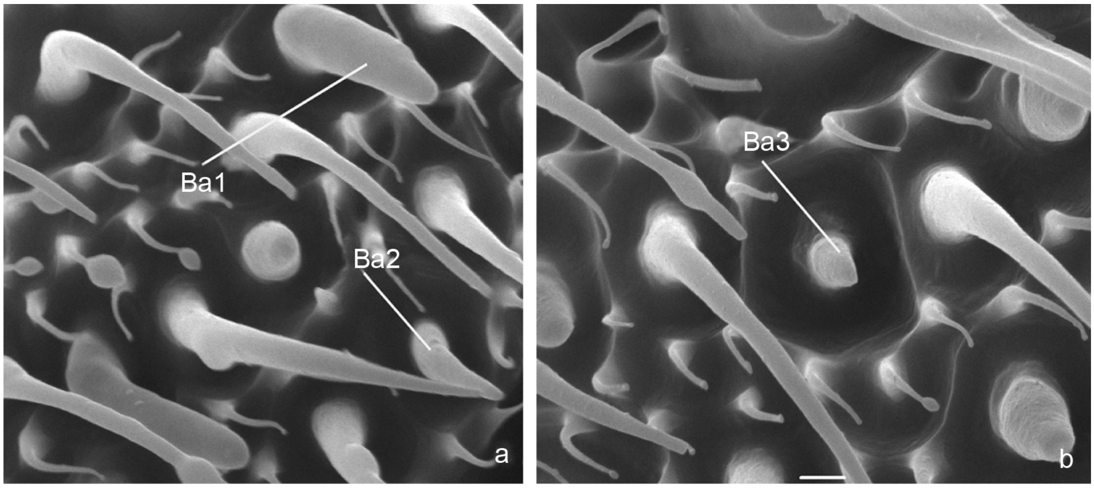

Fig. 5. SEM micrographs of Ba1, Ba2 and Ba3 of *C. fuscipes*. (a) Ba1and Ba2; (b) Ba3. Ba1, Basiconica sensilla1; Ba2, Basiconica sensilla2; Ba3, Basiconica sensilla3. Scale bar = 2 μm in (a) and 1 μm in (b).

Table 5

Mean ± SE of sensilla basiconica on flagellomere, in a defined area (1000 μm^2) on every flagellomere of *C. fuscipes*.

	Ba1		Ba2		Ba3	
	F	M	F	M	F	M
1	13.27 ± 2.17 ab*	5.82 ± 0.09 bc	0.85 ± 0.76 d	2.42 ± 0.87 bc	0.37 ± 0.33 d	4.34 ± 1.39 a*
2	10.54 ± 2.89 b*	5.73 ± 0.47 bc	2.39 ± 0.07 bc	1.89 ± 0.64 bc	0.96 ± 0.88 cd	1.14 ± 0.09 a
3	12.78 ± 4.03 ab*	6.27 ± 0.05 bc	4.02 ± 0.49 a*	2.06 ± 4.81 bc	4.73 ± 1.60 a*	2.16 ± 0.93 a
4	12.17 ± 0.35 ab*	5.43 ± 0.81 bc	2.85 ± 0.41 abc	2.96 ± 0.12 b	1.64 ± 0.67 bcd	2.49 ± 1.79 a
5	12.24 ± 1.95 ab*	7.13 ± 1.0 4 b	3.06 ± 0.94 ab*	2.43 ± 0.95 bc	2.38 ± 0.46 bc	2.82 ± 1.26 a
6	16.27 ± 0.36 b*	5.26 ± 1.05 c	2.97 ± 0.63 ab*	1.46 ± 0.00 c	1.87 ± 0.44 bcd	1.95 ± 0.84 a
7	10.25 ± 1.15 b	10.13 ± 1.01 a	1.74 ± 0.59 cd	4.29 ± 0.25 a*	2.67 ± 0.23 b	2.69 ± 1.29 a
8	10.87 ± 0.51 b*	6.58 ± 2.67 c	2.09 ± 0.75 bc	2.45 ± 0.39 bc*	4.18 ± 0.72 a*	0.86 ± 0.76 a

Means followed by the same lower-case letter on the lines are not statistically significant different between flagellomere (ANOVA, $P < 0.05$, $n = 3–5$).
Means followed by * on the lines are not statistically significant different between sex (*t*-test, $P < 0.05$, $n = 3–5$). Ba, sensilla basiconica; F, female; M, male.

segments surface of antennae of *C. fuscipes* (Tables 2 and 5). This result is consistent with that for *Rhegmoclema* (Enderlein) (Diptera), whose antennae are covered with a number of setae (Cook, 1955). And antennal flagella with the number and distributions of setae possess significant differences (Cook, 1965). The morphology of sensilla chaetica observed in this study resembles those found on *Mayetiola destructor* (Say) (Diptera) (Schneeberg et al., 2013), *Chrysomya nigripes* (Aubertin) (Diptera) (Ngern-Klun et al., 2007), and *Aphidoletes aphidimyza* (Rondani) (Diptera) (Zhang and Yang, 2008). Mechanoreceptors 1 in *Bradysia odoriphaga* (Yang et Zhang) (Diptera) possess the similar fine structure as sensilla chaetica, except a movable cotyloid fossa (Zhang et al., 2009). In contrast to our study, sensilla chaetica are found only on the distal regions of the scape and pedicel in *Anastrepha fraterculus* (Wiedemann) (Diptera) (Bisotto-de-Oliveira et al., 2011) and *B. odoriphaga* (Diptera) (Zhang et al., 2009). Sensilla chaetica were speculated to exhibit either or both mechanotactile or chemosensitive functions (Sukontason et al., 2007). The presence of a mechanical function may also be considered because of the location and structure of *Microplitis pallidipes* (Szepligeti) (Diptera) antennae (Gao et al., 2007).

Sensilla trichoidea belong to an abundant type found on the flagellum of *C. fuscipes* antennae (Table 4). However, sensilla trichoidae are found on the flagellum of both sexes except for 1st flagella (Table 4). Chen and Fadamiro (2008) observed that sensilla trichoidea are the most numerous type on *P. tricuspis* antennae, concordant with some other Diptera species. Sensilla trichoidea are also widely distributed on the scape and pedicel of both *Toxotrypana curvicauda* (Gerstaecker) (Diptera) sexes. Moreover, the function of sensilla trichoidae and coeloconic in *T. curvicauda* male is the detection of host-plant volatiles or sex pheromone released. However, this function is considered as mechanoreceptive in numerous species, including *Dermatobia hominis* (L.) (Diptera), *Bembidion properans* (Stephens) (Coleoptera), *Nebria brevicollis* (Fabricius) (Coleoptera), and *Solenopsis invicta* Buren (Hymenoptera) (Daly and Ryan, 1979; Fernandes et al., 2002; Merivee et al., 2002; Renthal et al., 2003; Sukontason et al., 2004). Bland (1981) suggested that sensilla trichoidae possess dual functions as both mechano- and chemoreceptors in *Hypera postica* (Gyllenhal) (Coleoptera). And sensilla trichoidea also exhibit responses to the pheromone component cisvaccenyl acetate and is confirmed to have pheromone sensitivity based on electrophysiological studies (Clyne et al., 1999; Zhou et al., 2011).

C. fuscipes are found one subtype of sensilla coeloconica, which only occurs on antennal flagellum (Table 4). Shanbhag et al. (1995) reported that sensilla coeloconic are easily distinguishable from other sensilla types based on their fundamental shape and length. Our result showed that the surface of sensilla coeloconica is smooth and without pit depth, as has been found on the flagellum of *Fannia scalaris* (Fabricius) (Diptera) (Zhang et al., 2013). Sensilla coeloconica have been suggested by Roux et al. (2005) to have an olfactory function. Furthermore, Zhang et al. (2012) confirmed that sensilla coeloconica have chemo-, thermo- or hygroreceptive functions. Moreover, Lacher (1964) has affirmed that sensilla coeloconic reacts to CO_2, temperature, and humidity in *Apis mellifica* (L.) (Hymenoptera).

The structure and function of sensilla basiconic in most insect species studies were similar. Three sensilla basiconic subtypes are distinguished by their shapes and sizes. Smallegange et al. (2008) reported that intermediate sizes and shapes of sensilla basiconic exist, making make a clear distinction difficult in *Musca domestica* (L.) (Diptera). The present study shows that several sensilla basiconic subtypes are distinguished, e.g., two in *Protophormia terraenovae* (Robineau-Desvoidy) (Diptera) (Setzu et al., 2011), *F. scalaris* and *F. canicularis* (L.) (Diptera) (Zhang et al., 2013), one in *A. fraterculus* (Diptera) (Bisotto-de-Oliveira, 2011) and *A. aphidimyza* (Zhang and Yang, 2008), and three in *Gasterophilus nigricornis* (Loew) (Diptera) (Zhang et al., 2012). The distribution of sensilla basiconic exhibit sexual dimorphism in *C. fuscipes* (Table 5). Basiconic type 1 in female flagellum are significantly more numerous than the same segments in males except for 7th (Table 5). The numbers of basiconic 1 and 2 on 7th were significantly more numerous than other flagella in males (Table 5). However, no significantly difference is found in female. The shape of basiconic type 1 is similar to that of the small basiconic of *Hydrotaea chalcogaster* (Wiedemann) (Diptera) (Sukontason et al., 2007) and *M. domestica* (Sukontason et al., 2004), which is also longer, curved, and sharp-tipped digitiforms, but no pores. Meanwhile, basiconic 3 observed in our study closely resembles those characterized by basiconic type1 of *G. nigricornis* (Zhang et al., 2012). Shanbhag et al. (1995) proposed that sensilla basiconic are predominantly involved in olfaction in *Drosophila melanogaster* (Meigen) (Diptera). Lopes et al. (2002) also verified an olfactory function of sensilla basiconic in *Phoracantha semipunctata* (Fabricius) (Coleoptera) by electrophysiological recordings.

In conclusion, we performed identification and characterization for the first time in the morphology, distribution, and abundance of the four sensilla types found in *C. fuscipes* by using SEM. In addition to the detailed description of the ultrastructures and distribution of the four sensillum, elucidation of the probable function of each type of sensillum is speculated through comparison with other previous investigations. Our results have significance in studies on host location mechanisms and mating behaviors in *C. fuscipes*. Future functional studies on antennal morphology and electrophysiology would further identify the functional significance of the four sensilla described in this study.

Conflicts of interest

The authors declare no conflicts of interest.

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