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Scanning Electron Microscopy Studies of Antennal Sensilla of *Ooencyrtus phongi* (Hymenoptera: Encyrtidae)

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KEY WORDS egg parasitoid; *Tessarotoma papillosa*; litchi; behavior; antennal sensilla; scanning electron microscopy

ABSTRACT *Ooencyrtus phongi* (Hymenoptera: Encyrtidae) is an important egg parasitoid of the litchi stink bug, *Tessaratoma papillosa* (Drury) (Hemiptera: Tessaratomidae). Antennae of parasitic Hymenoptera are important sensory organs and play an important role in host location, host discrimination, courtship, and mating behavior. In this article, we examined the external morphology of the antennal sensilla of female and male of *O. phongi* using scanning electron microscopy. Twelve morphological sensillar types were recognized in both sexes, including the placoid sensilla, basiconic sensilla, two types of sensilla trichodea, and eight types of sensilla chaetica. Major differences were found between the sexes, in number, distribution, shape, structure, and size of the identified sensilla. These results are discussed in relation to the possible role of these sensilla in the host location behavior of *O. phongi*. *Microsc. Res. Tech. 74:936–945, 2011.* © 2011 Wiley-Liss, Inc.

INTRODUCTION

The litchi stink bug, *Tessaratoma papillosa* (Drury) (Hemiptera: Tessaratomidae), is one of the major pests of litchi (*Litchi chinensis* Sonn.) and longan (*Dimocarpus longan* Lour.) (Sapindaceae) in southern China (Hu et al., 2005; Peng, 2003; Xie et al., 2001, 2004). It also widely occurs in other tropical countries of Asia, that is, Vietnam, Thailand, Myanmar, the Philippines, Nepal, and India (Menzel, 2002; Papademetriou and Dent, 2002). Other than litchi and longan, the bug can attack orange, pomegranate, pomelo, and other economically important plants (Hu et al., 2005; Waite, 2005). It can develop on virtually all parts of the plants (young branch lets, flowersfruits) (Boontam and Leksawasdi, 1994; Waite and Hwang, 2002) and can also transmit plant viruses such as witches' broom disease (Xu et al., 1993).

Ooencyrtus phongi (Hymenoptera: Encyrtidae) is an important biocontrol agent of *T. papillosa* (Liu and Gu, 1998; Liu et al., 2000; Wu and Tang, 2000; Zhou and Xian, 1994) whose field parasitism rate on bug's eggs may vary from 23.5 to 30.4% (Liu and Gu, 1998) to 66.8% (Zhou and Xian, 1994) and to 54.5–83.3% in some areas of South China (Wu and Tang, 2000).

Previous studies have shown that antennal sensilla of parasitic Hymenoptera play an important role in host location, host discrimination, courtship, and mating behaviors (Guerrieri et al., 2001; Hays and Vinson, 1971; Hoballah et al., 2002; Ochieng et al., 2000; Turlings et al., 1995; Weseloh, 1972; Wibel et al., 1984). Nonetheless, only a few of these studies deal with the family of Encyrtidae (Guerrieri et al., 2001; van Baaren et al., 1996; Weseloh, 1972), and none is about the genus *Ooencyrtus*. Wu and Tang (2000) reported that the female of *O. phongi* contacts the host eggs with the tip of the antennae before initiating the oviposition sequence but provided no information about the morphology of the sensorial structures involved. Number and distribution of sensorial structures can be relevant for the correct identification of species. For example, close species in the genus *Metaphycus* can be reliably separated on the basis of funicular segments with linear sensilla [see Guerrieri and Noyes (2000)]. In some cases, the distribution of sensillar and glandular structures is of great help in understanding both the species and the behavior during mating and host acceptance. Given the importance of the genus *Ooencyrtus* in the biological control of economically important pests, in this work, we investigated for the first time the external morphology of the antennal sensilla of the females and males of a species of this genus, namely, *O. phongi* using scanning electron microscopy (SEM). The results will constitute a basis for further studies, biological or taxonomical, dealing with the genus *Ooencyrtus*. The possible roles of the sensillar types in the behavioral ecology of the parasitoid are also discussed.

MATERIALS AND METHODS

Insects

More than 1,000 eggs of *T. papillosa* were collected in Hainan Province, China, between April 26 and May 10, 2007 on litchi trees (*L. chinensis* Sonn.). After collection, the eggs were immediately transported to the Institute of Zoology, Chinese Academy of Sciences, Beijing, and kept in an incubator at the following

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conditions: temperature: 25°C ± 3°C, relative humidity: 60% ± 10%; photoperiod: 12L:12D) until the emergence of parasitoids, which were immediately killed in ethanol (75%).

Electron Microscopy

Antennae (*N* = 6, 3 females and 3 males) of *O. phongi* were carefully excised from the antennal sockets under a stereomicroscope (Leica 12.5 at 20× magnification), kept in 75% ethanol for 24 h and then dehydrated in a graded alcohol series from 80 to 99.9% (30 min each passage). Subsequently, they were mounted on a holder using double-sided adhesive tape and sputter-coated with gold. Examinations were done with a FEI Quanta 200F SEM at 12.5 kV.

All sensilla on the dorsal and ventral surfaces of the antennae of *O. phongi* were identified, counted, and measured. Final measurements (μm) were obtained by using mean measurements from photomicrographs of at least 16 individual sensilla of the same type.

Terminology

Different names and terminologies have been used in the literature for the classification of antennal sensilla of parasitic Hymenoptera (Amornsak et al., 1998; Bleeker et al., 2004; Cônsoli et al., 1999; Dweck, 2009; Gao et al., 2007; Isidoro et al., 1996; Meyhöfer et al., 1997; Miller, 1972; Onagbola and Fadamiro, 2008; Pettersson et al., 2001; Ryan, 2002; Weseloh, 1972; Wibel et al., 1984). On the basis of morphological appearance, in this study, we will follow van Baaren et al. (1996), unless specifically indicated.

RESULTS

General Description of Antennae

The antenna (Figs. 1 and 2) of *O. phongi* is typical of the majority of Chalcidoidea, composed of radicula, scape, pedicel and flagellum, the latter divided in funicle and clava. The funicle of *O. phongi* is always 6-segmented (Fig. 1F1–1F6) while the clava is 3-segmented in the female (Fig. 1C1–1C3) and solid in the male (although incomplete segmentation can be seen in some specimens, e.g., Fig. 2). In the female, the apex of the last segment of the clava is obliquely truncated, forming a generally flattened area where numerous types of antenna1 sensilla are scattered. The total antennal length is 999.9 ± 10.4 μm (mean ± S.E., *N* = 6) and 953.4 ± 7.6 μm (mean ± S.E., *N* = 6) in females and males, respectively.

Sensilla Types

We recognized 12 types of sensilla on the antennae of both female and male. These include placoid sensilla (PS), basiconic sensilla (BS), two types of trichoid sensilla (TS-1 and 2), and eight types of sensilla chaetica (SCh-R, SCh-1, 2, 3, 4, 5, 6, and 7). The approximate number and distribution of the different sensillar types on each antennal segment of the two sexes are reported in Table 1.

Placoid Sensilla. Placoid sensilla (PS; Figs. 3 and 7) are elongate, platelike sensory organs distributed on all the flagellar segments of female and male antennae. They are the largest of all other sensillar types. Each sensillum arose from an elevated cuticular rim, tapers toward the apex, and is covered in numerous pores (PS; Fig. 5). PS are generally aligned parallel with the antennal axis and showing a ringlike distribution. They have a mean length of 41.3 ± 0.9 μm and width of 4.7 ± 0.1 μm in the female. In the male, they have a mean length of 37.1 ± 1.4 μm and width of 4.8 ± 0.3 μm. As reported in the Table 1, they are more numerous on the female than on the male antenna (Table 1).

Basiconic Sensilla. Basiconic sensilla (BS) are bulblike structures, which set into a shallow cuticular depression. In both female and male, the BS is located in the distal part of the flagellum (BS; Figs. 3 and 7). The surface of the BS stalk is smooth both in the female (BS; Fig. 4) and in the male (BS; Fig. 20). This type of sensillum measures 5.1 ± 0.3 μm in length and 2.3 ± 0.1 μm in width in the female and 3.9 ± 0.3 μm in length and 1.9 ± 0.2 μm in width in the male, respectively.

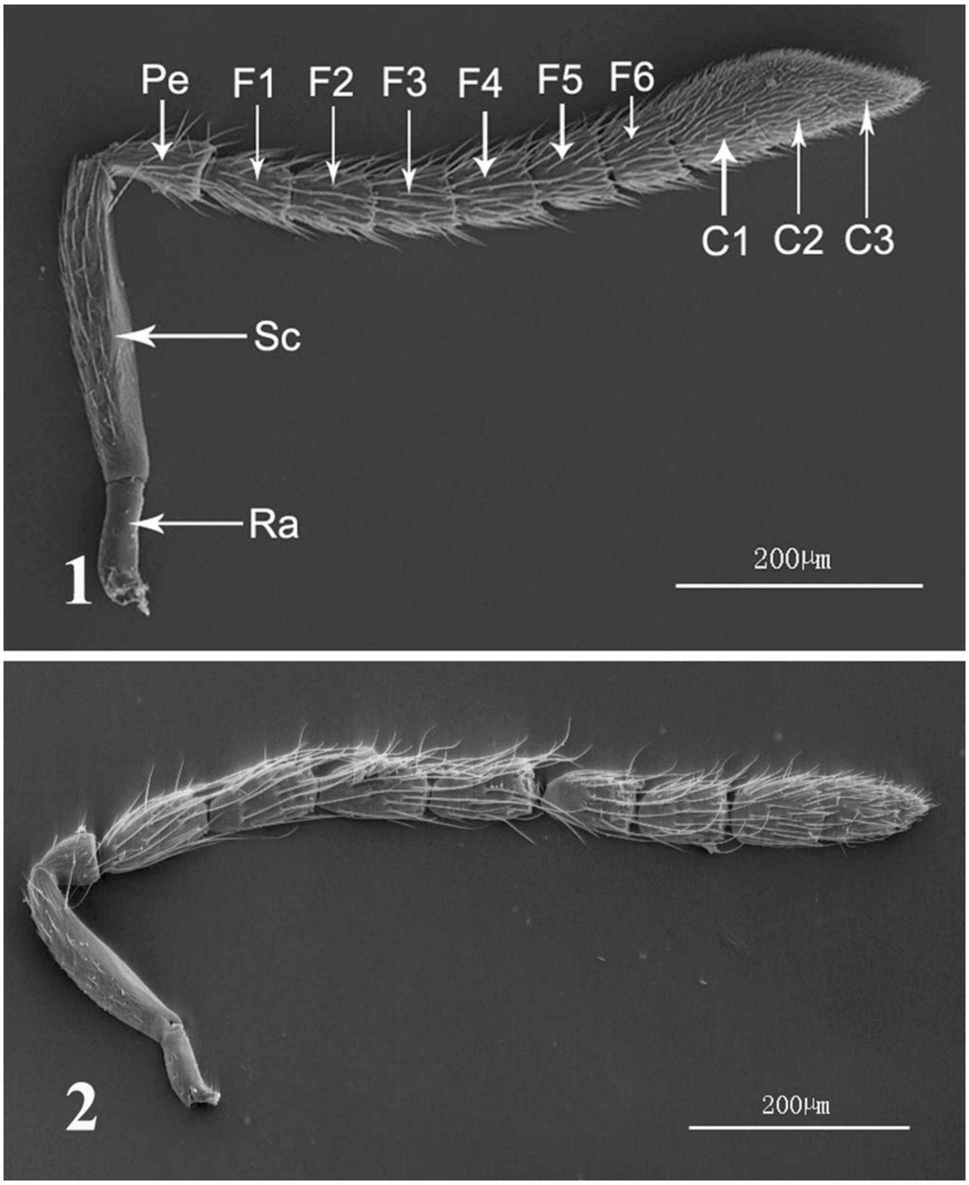
Trichoid Sensilla Type 1. Trichoid sensilla type 1 (TS-1; Figs. 3 and 6) occur on all antennomeres of the female except radicula. They are elongated and sharply pointed, inserted in a small conical socket, with longitudinal grooves that spiral slightly around its surface, laying somewhat parallel to the longitudinal axis of the antenna. The surface of this type of sensillum is smooth and without pores (Fig. 7). The length of these sensilla varies from 7.6 ± 0.4 μm to 37.1 ± 0.5 μm. It is the most abundant sensillar type on the female antenna (up to 1,549 on a single antenna).

Trichoid Sensilla Type 2. Trichoid sensilla type 2 (TS-2; Fig. 17) occur on the pedicel and on all flagellar antennomeres of male antenna. They are sharply pointed, with a central hollow and a smooth surface covered with small pores (Figs. 18 and 19). They arose directly from the cuticle (no socket is present) and lie parallel to the longitudinal axis of the antenna. Their length varies from 56.9 ± 1.6 μm to 108.2 ± 1.7 μm. It is the most abundant sensillar type on the male antenna (up to 340 on a single antenna).

Sensilla Chaetica Type Ra. Sensilla chaetica type Ra (SCh-Ra; Fig. 6) occur on the radicula of both female and male antennae. This type of sensillum arises from a pit and is characterized by a smooth surface and a sharp tip (Fig. 9). In length, sensillum measures 6.7 ± 0.3 μm in the female and 6.5 ± 0.5 μm in the male, respectively. It is not very abundant in comparison with the other types of sensilla (see Table 1).

Sensilla Chaetica Type 1. Sensilla chaetica type 1 (SCh-1; Fig. 10) are characterized by a longitudinally grooved shaft and inserted perpendicularly with respect to antennal surface in a large pit of 3.6 ± 0.2 μm in diameter. They have an apical pore, and in the female, they are located in the distal part of F5, F6, and the clava, measuring about 10.1 ± 0.5 μm in length and about 1.1 ± 0.1 μm in diameter at the base (Fig. 11). In male, this type of sensilla was found only at the apex of clava, measuring about 11.9 ± 0.7 μm in length and about 1.7 ± 0.1 μm in diameter at the base (Fig. 21).

Sensilla Chaetica type 2. Sensilla chaetica type 2 (SCh-2; Fig. 10) are only found on female antennae. They are set in a socket and present a smooth shaft, a few longitudinal grooves on the cuticular surface, and a subapical pore with an overhanging fingerlike cuticular projection (Fig. 12). They measure about 4.5 ± 0.2



Figs. 1–2. **Fig. 1:** The scanning electron micrograph of an excised geniculate antenna of *O. phongi* female, showing the radicula (Ra), scape (Sc), pedicel (Pe), funicle (F1, F2, F3, F4, F5, and F6), and the clava (C1, C2, and C3). **Fig. 2:** The male antenna is generally similar in shape and morphology but usually has a single clava segment.

μm in length and 1.5 ± 0.0 μm in diameter at the base. They are distributed ventrally on the second and the third segments of the clava.

Sensilla Chaetica Type 3. Sensilla chaetica type 3 (SCh-3; Fig. 3) occur only on female antenna. This type of sensillum arises directly from the cuticle (no socket is present), presents a smooth surface covered with small pores visible only at very high magnification (Fig. 8), and is particularly sharp at apex. Mean length is about 21.9 ± 0.7 μm, and mean basal diameter is about 2.1 ± 0.2 μm. They lie parallel to the longitudinal axis of the antenna as reported for the trichoid sensilla type 1. They were only found on the outer side of apical part of F4, F5, F6, C1, and C2. They were not as abundant as other types of sensilla (see Table 1).

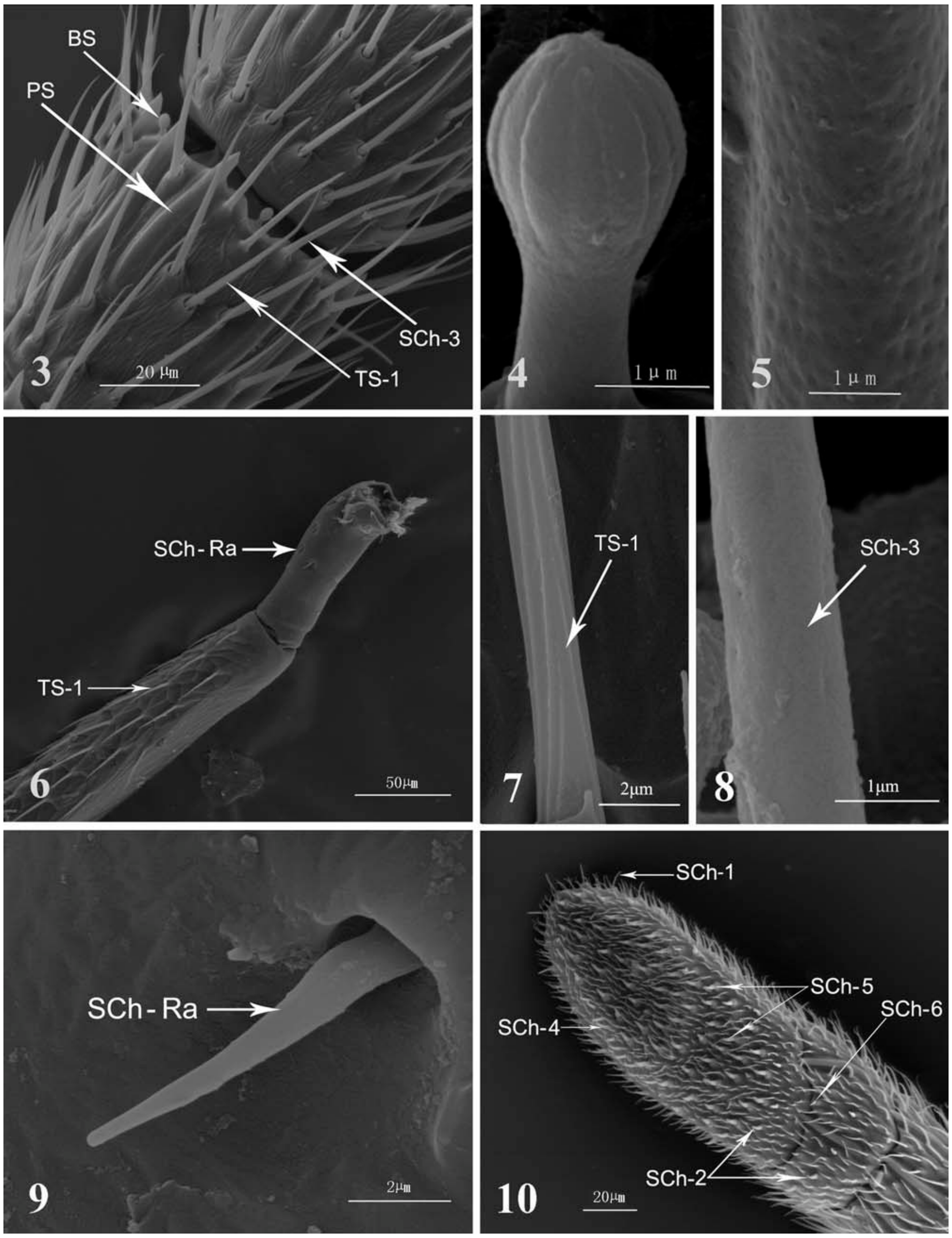
Sensilla Chaetica Type 4. This type of sensillum (SCh-4; Fig. 10) is somewhat related to sensilla chaetica type 2 but lacks the overhanging fingerlike cuticular projection. They have several pores at the apex (Fig. 15) and were found on the apical part of the clava of the female (within the ventral sensorial area). These sensilla are about 5.5 ± 0.3 μm in length and about 1.3 ± 0.1 μm in diameter at the base, respectively.

Sensilla Chaetica Type 5. Sensilla chaetica type 5 (Figs. 10 and 21; SCh-5) are only present on the ventral sensorial area of both female and male clavae. They are awl-like structures, arising from half-walled sockets, with blunt tips. This sensillum has a smooth surface except in the middle, where there are numerous longitudinal cuticular grooves (Figs. 13 and 14). The

TABLE 1. Abundance and distribution of different sensilla on the antennae of female and male Ooencyrtus phongi

Sensilla	Sex	Antennal segment												Total
		Rd	Sc	Pd	F1	F2	F3	F4	F5	F6	C1	C2	C3	
PS	Female				2 ± 0.2	4 ± 0.1	7 ± 0.6	9 ± 1.3	8 ± 1.1	8 ± 0.7	8 ± 1.0	8 ± 0.9	3 ± 0.3	57 ± 3.0
	Male				1 ± 0.0	1 ± 0.0	2 ± 0.0	4 ± 0.6	4 ± 0.3	4 ± 0.4	16 ± 1.0			32 ± 1.2
BS	Female				4 ± 0.2	4 ± 0.3	5 ± 0.3	4 ± 0.4	4 ± 0.2	4 ± 0.4	3 ± 0.1	4 ± 0.2	2 ± 0.0	34 ± 1.3
	Male				4 ± 0.2	3 ± 0.1	3 ± 0.1	2 ± 0.1	2 ± 0.2	3 ± 0.1		10 ± 0.8		27 ± 1.7
TS-1	Female		78 ± 3.7	46 ± 2.2	57 ± 2.1	55 ± 2.5	54 ± 2.0	66 ± 2.8	80 ± 2.6	89 ± 2.9	186 ± 6.0	188 ± 6.4	650 ± 7.0	1549 ± 67.9
	Male													
TS-2	Female													
	Male			3 ± 0.1	23 ± 1.2	40 ± 2.9	32 ± 2.0	18 ± 1.2	29 ± 3.0	40 ± 2.6		155 ± 4.3		340 ± 2.9
SCh-Ra	Female	15 ± 2.3												15 ± 2.3
	Male	12 ± 2.0												12 ± 2.0
SCh-1	Female								1 ± 0.0	1 ± 0.0	3 ± 0.1	3 ± 0.3	16 ± 2.0	24 ± 3.1
	Male											10 ± 0.5		10 ± 0.5
SCh-2	Female											5 ± 0.3	10 ± 0.4	15 ± 1.8
	Male													
SCh-3	Female							1 ± 0.0	4 ± 0.2	4 ± 0.0	1 ± 0.0	1 ± 0.0		11 ± 1.0
	Male													
SCh-4	Female											5 ± 0.6		5 ± 0.6
	male													
SCh-5	Female											61 ± 4.0		61 ± 4.0
	Male											14 ± 1.0		14 ± 1.0
SCh-6	Female											4 ± 0.4		4 ± 0.4
	Male													
SCh-7	Female													
	male		28 ± 2.6	11 ± 0.9	3 ± 0.0	4 ± 0.2	3 ± 0.3	1 ± 0.0	3 ± 0.7	1 ± 0.0	8 ± 0.9			62 ± 3.8

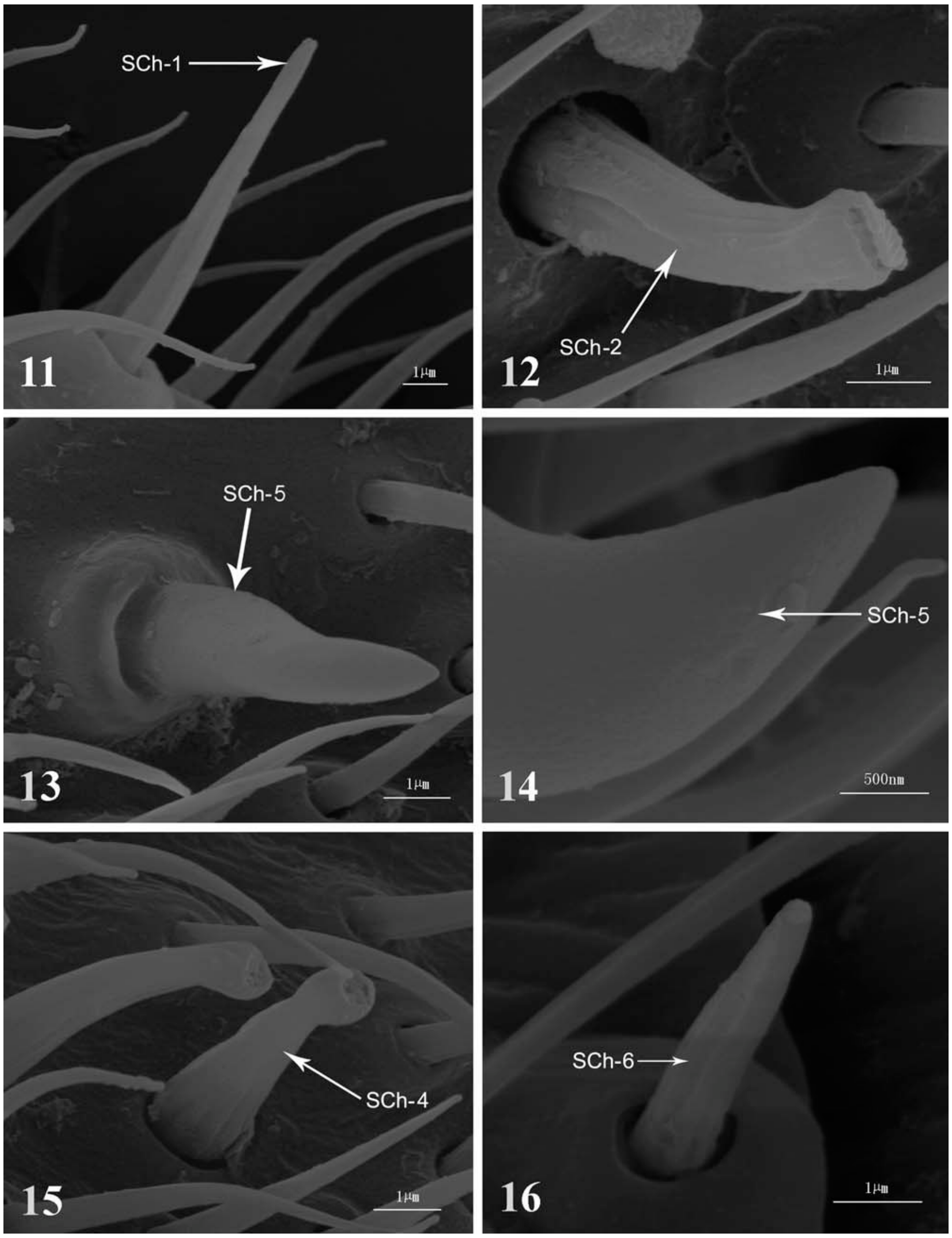
Data are presented as mean ± S.E. (N = 6). PS, placoid sensilla; BS, basiconic sensilla; TS-1, trichoid sensilla type 1; TS-2, trichoid sensilla type 2; SCh-Ra, sensilla chaetica type Ra; SCh-1, sensilla chaetica type 1; SCh-2, sensilla chaetica type 2; SCh-3, sensilla chaetica type 3; SCh-4, sensilla chaetica type 4; SCh-5, sensilla chaetica type 5; SCh-6, sensilla chaetica type 6; SCh-7, sensilla chaetica type 7.



Figs. 3–10. **Fig. 3:** Electromicrograph of sensilla on the female antenna of *O. phongi*. View of the antennomeres F5 and F6 of the funicule showing placoid sensilla (PS), basiconic sensilla (BS), trichoid sensilla type 1 (TS-1), and sensilla chaetica type 3 (SCh-3). **Fig. 4:** Electromicrograph of sensilla on the female antenna of *O. phongi*. View of a basiconic sensilla (BS). **Fig. 5:** Electromicrograph of sensilla on the female antenna of *O. phongi*. View of placoid sensillum (PS) showing pores. **Fig. 6:** Electromicrograph of sensilla on the female antenna of *O. phongi*. View of the radicle and part of antennal scape showing sensilla chaetica on radicula (SCh-Ra) and trichoid sensilla type 1 (TS-1). **Fig. 7:** Electromicrograph of sensilla on the female antenna of *O. phongi*. View of trichoid sensilla type 1 (TS-1). **Fig. 8:** Electromicrograph of sensilla on the female antenna of *O. phongi*. View of sensilla chaetica type 3 (SCh-3). **Fig. 9:** Electromicrograph of sensilla on the female antenna of *O. phongi*. View of sensilla chaetica on radicula (Sch-Ra). **Fig. 10:** Electromicrograph of sensilla on the female antenna of *O. phongi*. Ventral view of the two terminal antennomeres of female clava showing sensilla chaetica type 1 (SCh-1), sensilla chaetica type 2 (SCh-2), sensilla chaetica type 4 (SCh-4), sensilla chaetica type 5 (SCh-5), and sensilla chaetica type 6 (SCh-6).

cuticular surface of this sensillum has no pores. In females, sensilla chaetica type 5 have a mean length and diameter of 7.2 ± 0.2 μm and 2.8 ± 0.1 μm, respectively; the cuticular grooves extend for about one-sixth of its length. Most of them are generally parallel to the longitudinal axis of the antenna but a few appear more perpendicular. In the male, sensilla chaetica type 5 have a mean length and diameter of 10.8 ± 0.3 μm and 3.3 ± 0.2 μm, respectively; the cuticular grooves extend for about one-third of the length of sensillum (Fig. 22).

Sensilla Chaetica Type 6. Sensilla chaetica type 6 (SCh-6; Fig. 10) are found exclusively on female



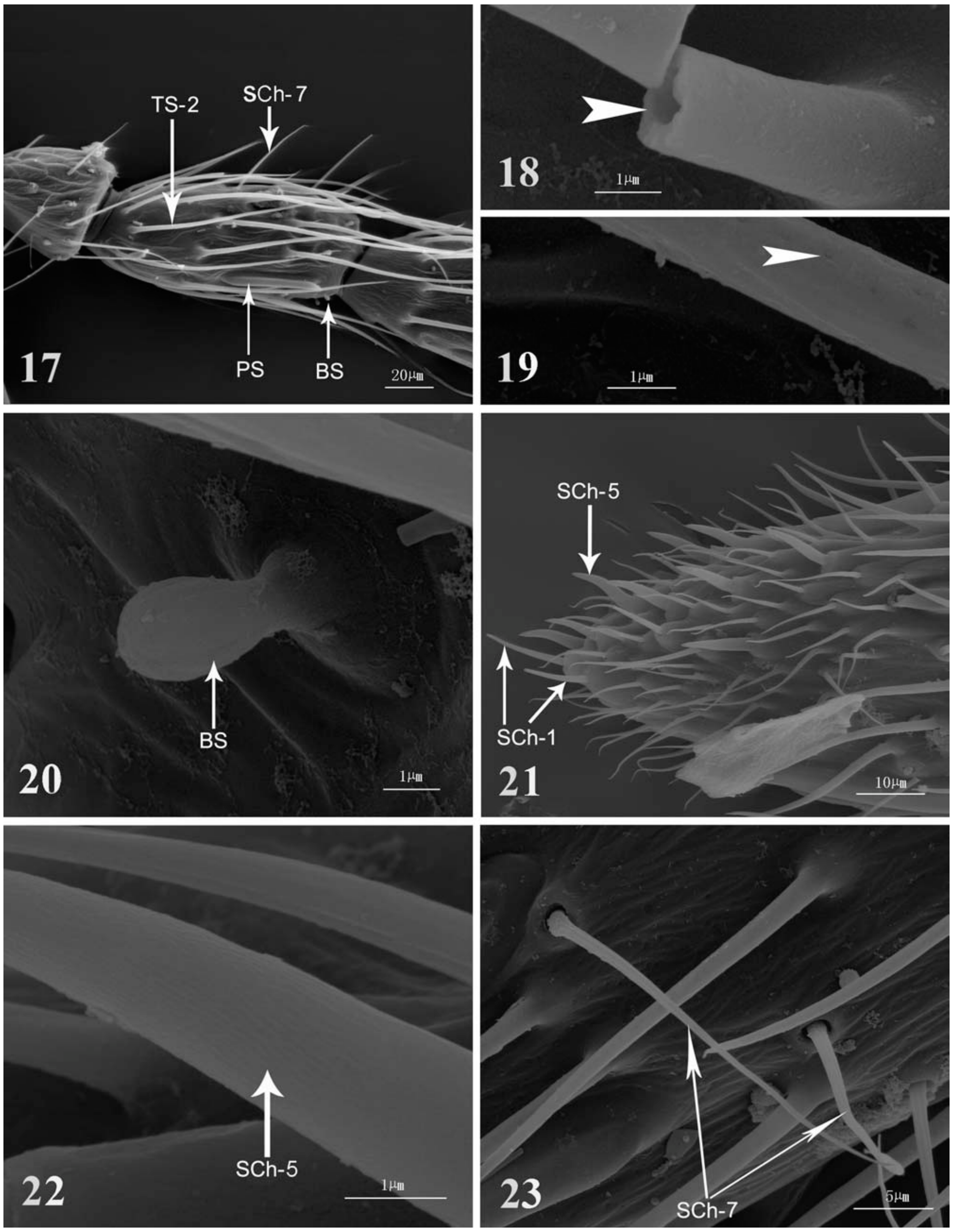
Figs. 11–16. **Fig. 11:** Electromicrograph of sensilla on the female antenna of *O. phongi*. Sensilla chaetica type 1 (SCh-1). **Fig. 12:** Electromicrograph of sensilla on the female antenna of *O. phongi*. Sensilla chaetica type 2 (SCh-2). **Fig. 13:** Electromicrograph of sensilla on the female antenna of *O. phongi*. Sensilla chaetica type 5 (SCh-5). **Fig. 14:** Electromicrograph of sensilla on the female antenna of *O. phongi*. View of sensilla chaetica type 5 showing no pores present in the cuticular grooves. **Fig. 15:** Electromicrograph of sensilla on the female antenna of *O. phongi*. View of sensilla chaetica type 4 (SCh-4) showing apical pores. **Fig. 16:** Electromicrograph of sensilla on the female antenna of *O. phongi*. View of sensilla chaetica type 6 (SCh-6).

antenna, located in the ventral part of the first and second segments of clava. They are short and bent, inserted into big sockets and with blunt tip. They have smooth surfaces, longitudinal cuticular grooves, and present no pores at the apex (Fig. 16). They measure 3.0 ± 0.2 μm in length and 1.5 ± 0.0 μm in diameter at the base.

Sensilla Chaetica Type 7. Sensilla chaetica type 7 (SCh-7; Fig. 17) was only found on male antenna distributed on the scape and pedicel and on the dorsal part of all flagellar segments. They are inserted in small conical sockets and present in a longitudinally grooved shaft and a sharply pointed apex (Fig. 23). They have a mean length of 41.5 ± 1.1 μm.

DISCUSSION

Our study revealed 12 morphologically different types of sensilla on the antennae of male and female of *O. phongi*. Most of the sensilla found in this study are essentially similar to those previously recorded for other



Figs. 17–23. **Fig. 17:** Electromicrograph of sensilla on the male antenna of *O. phongi*. View of the F1 showing placoid sensilla (PS), basiconic sensilla (BS), sensilla chaetica type 7 (SCh-7), and trichoid sensilla type 2 (TS-2). **Fig. 18:** Electromicrograph of sensilla on the male antenna of *O. phongi*. View of trichoid sensilla type 2 (TS-2) showing hollow base. **Fig. 19:** Electromicrograph of sensilla on the male antenna of *O. phongi*. View of trichoid sensilla type 2 (TS-2) showing hollow base. **Fig. 20:** Electromicrograph of sensilla on the male antenna of *O. phongi*. View of basiconic sensilla (BS) showing the cuticular grooves. **Fig. 21:** Electromicrograph of sensilla on the male antenna of *O. phongi*. View of apex of clava showing sensilla chaetica type 1 (SCh-1) and sensilla chaetica type 5 (SCh-5). **Fig. 22:** Electromicrograph of sensilla on the male antenna of *O. phongi*. View of sensilla chaetica type 5 (SCh-5) showing the cuticular grooves. **Fig. 23:** Electromicrograph of sensilla on the male antenna of *O. phongi*. View of sensilla chaetica type 7 (SCh-7).

species belonging to the superfamily Chalcidoidea (Amornsak et al., 1998; Gong et al., 2004; Isidoro et al., 1996; Miller, 1972; Onagbola and Fadamiro, 2008; Pettersson et al., 2001; Wibel et al., 1984; Xu et al., 2000), including the family Encyrtidae (van Baaren et al., 1996; Weseloh, 1972). Nonetheless, their distribution and the differences reported below between sexes can be of some help in the recognition of the species if a taxonomical revision of this genus will be completed.

Weseloh (1972) recognized seven types of sensilla on the female antennae of *Cheiloneurus noxius* Compere including TS-1, PS, and BS. The slender BS at the terminal part of clava described by Weseloh (1972) is probably corresponding our SCh-5, but to complete a comparison with the results of our study, we need to examine in detail the antennae of *C. noxius*.

Among the 12 types of sensilla recognized in this study, seven have been already reported for two other encyrtids, *Epidinocarsis lopezi* and *Leptomastix dactylopii* (van Baaren et al., 1996). A morphological correspondence exists between trichoid sensilla in these two species and the trichoid sensilla type-1 of *O. phongi*. Similarly, we can consider homologous structures in the PS, BS, SCh-1, SCh-2, SCh-3, and SCh-4 found by van Baaren (1996) and in the present work. However, both the SCh-5 and SCh-6 were not found in females of *E. lopezi* and *L. dactylopii*.

Differences Between Sexes

Sexual dimorphism is very frequent in the parasitic Hymenoptera and Encyrtidae are no exception. In this family, differences between sexes can be extremely evident in antennal structure (e.g., branched antennae of the males in the genus *Tetracnemoidea*) even though, more frequently, males have a solid clava (segmented in the corresponding females, e.g., *Metaphycus*) or present elongated flagellar segments with respect to female ones (e.g., *Cheiloneurus*). However, in *Trichogramma australicum* (Amornsak et al., 1998), *Pteromalus cerealellae* (Onagbola and Fadamiro, 2008) and *Spathius agrili* (Wang et al., 2010), the antennae of males are shorter than those of females.

In *O. phongi*, we found 10 types of sensilla on female antenna and only seven on the male one. This discrepancy can be due to specific behaviors exhibited by females only, such as host location and acceptance and seems to be the rule in parasitic Hymenoptera as confirmed by similar data reported for *Nasonia vitripennis* (Wibel et al., 1984) and *T. australicum* (Amornsak et al., 1998). In *S. agrili*, sensilla styloconica can be found only on female antenna (Wang et al., 2010). However, in *Cotesia glomerata* and *Cotesia rubecula* (Bleeker et al., 2004), *Aphidius rhopalosiphi* (Bourdais et al., 2006), *Microplitis pallidipes* (Gao et al., 2007), and *P. cerealellae* (Onagbola and Fadamiro, 2008), there were no differences in the sensillar types found on the antennae of male and female. It should be noted that a detailed study of male antennal morphology and function in Encyrtidae had been published nearly a decade ago by Guerrieri et al. (2001), focusing on the unique structures named as the "scale-like structures" of Tetracneminae which, in fact, proved to be glandular and not sensorial.

With respect to the same types of antennal sensilla, the sensillar abundance and distribution on the antennae between sexes have been also widely reported in parasitic Hymenoptera. The distribution of PS, BS, and the SCh-5 is about the same in both sexes. However, a greater number of PS and BS are present on female antenna compared to male one, consistent with what has been reported for *N. vitripennis* (Wibel et al., 1984), *P. cerealellae* (Ongabola and Fadamiro, 2008), *A. rhopalosiphi* (Bourdais et al., 2006), *Anaphes victus*, and *Anaphes listronoti* (van Baaren et al., 1999).

As for PS, differences between sexes are thought to be associated with the behavior during the parasitization, composed of different phases during which the female explores the substrate, recognizes the host and oviposits following different types of cues, but mainly chemical ones.

Other than sensillar abundance and distribution, there are also differences in the sensillar morphology and structure between sexes. For example, in the male, the (PS are smaller than in the female. This is consistent with what has been reported for *T. australicum* (Amornsak et al., 1998) and *Itoplectis conquisitor* (Borden et al., 1978). However, in *C. glomerata* and *C. rubecula*, the PS on male antenna are longer than those on female one, and this is correlated to the length of antennal segments (Bleeker et al., 2004). This does not apply to the antennae of *O. phongi*. We also found that both the size and the extension of the grooves of the sensilla chaetica type 5 (SCh-5) are sex-specific (see above).

Function of Sensilla

A thorough study for characterizing the different functions of the sensilla identified in this study is currently in progress [also see Yin et al. (2003)]. For the moment, on the basis of the literature and by considering their position on the antenna, we can only infer their function. The sensilla placodea have been found on the antennae of nearly all parasitic Hymenoptera (Amornsak et al., 1998; Barlin and Vinson, 1981a,b; Dweck and Gadallah, 2008; Hallberg and Hansson, 1999; Olson and Andow, 1993; Pettersson et al., 2001; Richerson et al., 1972; Wibel et al., 1984). It is assumed to be olfactory (van Baaren et al., 1996) and later confirmed by Ochieng et al. (2000). This sensillar type may play a role in host location, possibly in the detection of host-related semiochemicals (Ochieng et al., 2000; Steinbrecht, 1984).

TS-1 is almost always the most abundant sensillar type observed in the species of parasitic Hymenoptera studied so far. Because of their socketlike insertion and to the absence of pores on their surface, they are considered to be mechanoreceptors (Amornsak et al., 1998; Dweck, 2009; Isidoro et al., 1996; Olson and Andow, 1993; Onagbola and Fadamiro, 2008; Pettersson et al., 2001; Roux et al., 2005; van Baaren et al., 1996, 1999; Wang et al., 2010). Conversely, the presence of a central hollow and of a smooth surface covered in small pores suggest that the TS-2 (Figs. 18 and 19) may be olfactory receptors possibly involved in mating behavior (van Barren et al., 1996).

The BS are extremely common in parasitic Hymenoptera. The grooves on bulbous tips of the BS are without punctations suggesting thermo- or hygroreceptive functions (Altner et al., 1983; Onagbola and Fadamiro, 2008; Wibel et al., 1984). However, Van Barren et al. (1996) suggested that the presence of dendrites within the external process and of numerous pores indicate that they may be involved in olfactory perception.

The sensilla chaetica type Ra are present only on the radicula of *O. phongi* but were similarly found on the scape of *Pteromalus puparum* females (Dweck, 2009). This author suggested that they may have a role in proprioception of antennal movement and position (Dweck, 2009).

SCh-7 are only found on the male antenna of *O. phongi* and have been reported to have a mechanoreceptor function (Barlin et al., 1981; Dahms, 1984; Isidoro et al., 1996).

The SCh-1 (Figs. 10 and 11) are characterized by the presence of pores at their tip, by an orientation perpendicular to the antennal cuticle (allowing them to be first contact with the host), and by the location on the flagellar subsegments (indicating a possible double function, chemosensitive and mechanosensitive) (van Baaren et al., 1996).

The SCh-3 arise directly from the cuticle (no socket is present) and present a smooth surface covered with small pores. These characteristics suggest that they are mechanoreceptors, which also have an olfactory function as reported in *E. lopezi* and *L. dactylopii* by van Baaren et al. (1996).

The SCh-2 and SCh-4 are only present on the slant area of the terminal flagellar segments of female antenna. They can play a fundamental role in the host examination and host acceptance, possibly in the detection of host-related semiochemicals and structure (chorion texture and sculpture). Experiment by Weseloh (1972) confirmed that the amputation of both antennal tips led to a complete prevention of oviposition-related behaviors. The pore located at the apical part appears to open and close via a fingerlike projection, which suggest that they are contact chemosensitive sensilla (van Baaren et al., 1996). So far, the SCh-4 have been observed only in the family Encyrtidae (van Baaren et al., 1996), and, although van Baaren et al. (1996) did not assign a function to this sensillar type, the pore located at the apex indicates that they are probably contact chemosensitive sensilla.

As reported for the preceding type of sensilla, the SCh-5 have been reported only for the family Encyrtidae in the event that the "slender BS" described by Weseloh (1972) belong to it. This sensillar type has a smooth surface except in the middle, where there are numerous longitudinal cuticular grooves (Figs. 13 and 14). Because of their structure and presence in both sexes, they are probably gustatory sensilla and may play a role in mating behavior.

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