Microscopic structure of antennal sensilla in the carpenter ant
*Camponotus compressus* (Fabricius) (Formicidae: Hymenoptera)

Deepak D. Barsagade*, Dnyaneshwar B. Tembhare and Seema G. Kadu

Department of Zoology, RTM Nagpur University, Nagpur (MS), India-440033

*Corresponding author's email address: dr_ddbars@rediffmail.com

ABSTRACT. The antennae in all castes of the carpenter ant *Camponotus compressus* were examined using scanning electron microscopy. The antennae are of geniculate type, consisting of a scape and funiculus. The funiculus is subdivided into the pedicel and flagellum. The flagellum consists of a number of segments, ten in females and workers and 11 in males. In all castes the scape is differentiated into a basal ball covered with three types of sensilla and a shaft with sensilla trichodea. The pedicel bears sensilla trichodea densely in all castes, and sensilla basiconica in the female only. The flagellum contains sensilla trichodea curvata, sensilla trichodea, sensilla basiconica and sensilla chaetica in females, sensilla basiconica in workers and sensilla chaetica in males.

Keywords: social insect, *Camponotus*, antenna, sensilla, SEM

INTRODUCTION

Light and scanning electron microscopic (SEM) studies on the antennae of hymenopteran insects reveal the presence of various types of sensilla, showing wide ultrastructural variation among the polymorphs (Agren & Svensson 1972; Esslen & Kaissling 1976; Agren 1977). The castes play sex-specific roles in colonial life and communicate using chemical signals, and the antennae are major sense organs that receive environmental information and specific communication through a variety of sensillum receptors (Hölldobler & Wilson 1990). The antennal sensilla contain outer cuticular apparatus specialised for chemoreceptive, olfactory, hygro-thermoreceptive and mechanoreceptive functions (Altner & Prillinger 1980; Steinbrecht 1997; Keil & Steiner 1990). Several types of sensilla, including sensilla basiconica (SB), sensilla trichodea (ST), sensilla trichodea curvata (STC) and sensilla chaetica (SC), are recognised, with differences in their function. The Camponotini ants often show species-specific sexual and polymorphic diversity in fine morphology of the antennal sensilla (Richards & Davies 1988; Hashimoto 1990, 1991; Wcislo 1994; Renthal et al. 2003; Ozaki et al. 2005; Okada et al. 2006; Mysore et al. 2009; Nakanishi et al. 2010). The present SEM studies were undertaken to elucidate the surface micro-morphology of the antennal sensilla in all three castes (male, female and worker) of *Camponotus compressus* (Fabricius).

MATERIAL AND METHODS

A colony of *C. compressus* was excavated from the semi-arid soil in the vicinity of RTM Nagpur University Campus, Nagpur, India. Five males, an equal number of queens and 25 workers were used for the SEM study. The ants were immobilised on ice and the antennae were carefully removed and fixed in 70% alcohol for 12 h. The material was dehydrated in ethanol and cleared in acetone. The air-dried antennae were fixed on metallic stubs at different angles with the help of Fevikwick glue (Pidilite Industries Ltd., Mumbai, India) and gold-coated separately. Finally, the material was scanned at a desirable magnification under a Jeol scanning electron microscope (JSM 6380 A) at the SEM Centre of Visvesvaraya National Institute of Technology Nagpur, India.
Table 1: Morphometry of antenna of *Camponotus compressus*. Given are the measurements of the organs, the castes of the ants and the number of measured specimens.

<table>
<thead>
<tr>
<th>Structure</th>
<th>Size (mm)</th>
<th>Female (n=5)</th>
<th>Male (n=5)</th>
<th>Worker (n=25)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antennal socket (D)</td>
<td></td>
<td>0.465 ± 0.0076</td>
<td>0.209 ± 0.0084</td>
<td>0.405 ± 0.012</td>
</tr>
<tr>
<td>Socket ring (T)</td>
<td></td>
<td>0.001 ±0.0005</td>
<td>0.007 ±0.00021</td>
<td>0.0018 ± 0.0008</td>
</tr>
<tr>
<td>Scape (L)</td>
<td></td>
<td>3.105 ± 0.542</td>
<td>2.015 ± 0.421</td>
<td>3.836 ± 0.542</td>
</tr>
<tr>
<td>Pedicel (L)</td>
<td></td>
<td>0.731 ± 0.006</td>
<td>0.311 ± 0.005</td>
<td>0.84 ± 0.012</td>
</tr>
<tr>
<td>Flagellum (L)</td>
<td></td>
<td>5.15 ± 0.13</td>
<td>3.95 ± 0.053</td>
<td>4.55 ± 0.085</td>
</tr>
<tr>
<td>Antenna (TL)</td>
<td></td>
<td>11.505 ± 0.48</td>
<td>6.205 ± 0.851</td>
<td>8.862 ±0.57</td>
</tr>
</tbody>
</table>

D- Diameter, T- Thickness, L- Length, TL- Total length, ± - standard error, n- Number of species

Table 2: Size of antennal sensilla in *Camponotus compressus*. Given are the measurements of the organs (mean ± range), the castes of the ants and the number of measured specimens. L = length; W = width, n = number of species. SB = sensilla basiconica; SC = sensilla chaetica; ST = sensilla trichodea; STC = sensilla trichodea curvata.

<table>
<thead>
<tr>
<th>Sensilla on the antenna</th>
<th>Female (n=5)</th>
<th>Male (n=5)</th>
<th>Worker (n=25)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type</td>
<td>Size (µm)</td>
<td>Type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L  W</td>
<td></td>
</tr>
<tr>
<td>Ball</td>
<td>SB-I</td>
<td>41±5.21</td>
<td>3.4±0.045</td>
</tr>
<tr>
<td></td>
<td>SB-II</td>
<td>19.2±2.65</td>
<td>22.6±3.45</td>
</tr>
<tr>
<td></td>
<td>SB-III</td>
<td>5.25±0.12</td>
<td>5.1±0.175</td>
</tr>
<tr>
<td>Scape</td>
<td>ST-I</td>
<td>64.5±7.45</td>
<td>2.6±0.032</td>
</tr>
<tr>
<td></td>
<td>ST-II</td>
<td>36.1±4.24</td>
<td>2.3±0.084</td>
</tr>
<tr>
<td></td>
<td>ST-I</td>
<td>66.6±5.51</td>
<td>3.5±0.03</td>
</tr>
<tr>
<td></td>
<td>ST-II</td>
<td>30.5±4.21</td>
<td>2.5±0.02</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>19.5±4.21</td>
<td>4.76±0.65</td>
</tr>
<tr>
<td>Pedicel</td>
<td>STC</td>
<td>32.3±3.52</td>
<td>1.9±0.001</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>21.8±8.91</td>
<td>1.3±0.007</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>5.89±0.142</td>
<td>5.31±0.112</td>
</tr>
<tr>
<td>Flagellum</td>
<td>SC</td>
<td>25.18±4.53</td>
<td>2.49±0.095</td>
</tr>
</tbody>
</table>
Fig. 1. SEM structure of antenna of worker ant. ES- Elongated scape shaft, FG-Flagellum, PD- Pedicel, SBL- Scape ball, SC- Scape.

Fig. 2. Magnified SEM of basal region of antenna. ASR-Antennal sclerotic ring, ES- Elongated scape shaft, SBL- Scape ball.

Fig. 3. SEM structure of Scape-ball (SBL) showing SB-I, SB-II, SB-III- three types of sensilla basiconica.

Fig. 4. Magnified view of SB-III.
Fig. 5. SEM structure of scape shaft of the female showing sensilla trichodea, ST-I and ST-II arising from cuticular micro-sculpturing (CMS).

Fig. 6. SEM structure of pedicel (PD) and 1st flagellar segment (FG) showing sensilla trichodea, ST-I, ST-II and SB in the female.

Fig. 7. SEM structure of terminal flagellar segment (TFG) of the female.

Fig. 8. Magnified view of TFG in the female showing sensilla basiconica (SB), sensilla chaetica (SCH), sensilla trichodea (ST), sensilla trichodea curvata (STC).
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Fig. 9. SEM photomicrograph of basal region of antenna of male showing scape (SC) and elongated scape shaft (ES), scape ball (SBL) and antennal sclerotic ring (ASR).

Fig. 10. Magnified view of SBL showing sensilla, SB-I, SB-II, SB-III.

Fig. 11. Magnified SEM structure of SB-III on SBL.

Fig. 12. SEM structure of pedicel and 1st flagellar segment (flagellar segment) of female, showing sensilla trichodea (ST), sensilla basiconica (SB) on pedicel.

Fig. 13. SEM structure of terminal flagellar segment (TFG) showing sensilla trichodea curvata (STC) of male.

Fig. 14. Magnified view of TFG of female showing STC, ST, SB, and SC.
RESULTS

In *C. compressus*, the antennae are lodged in an elliptical-shaped socket on the dorso-lateral side of each frontal carina. The socket was narrower towards the anterior and broader towards the posterior end. The antenna is broadly divided into two parts, the scape and funiculus, the latter consisting of the pedicel and flagellum; we observed the pedicel was smaller in females and workers than in the male ant, while the flagellum was longer in the female than in the male and worker. The flagellum was folded up against the scape, representing the elbowed geniculate type of antenna in adult ants of all castes (Fig. 1). There were ten flagellar segments in the female and worker, and 11 in the male. Morphology under the SEM varied distinctly in different castes (Table 1).

1 Scapal sensilla

The dorsal and ventral surfaces of the scape were found to be covered with polygonal cuticular plates which cause the cuticular micro-sculpturing (Fig. 2). Three types of basiconic sensilla, sensilla basiconica I (sB-I), sensilla basiconica II (SB-II) and sensilla basiconica III (SB-III), were observed on the postero-dorsal region of the scape, in worker (Fig. 1-2), female (Fig. 3-4) and male (Fig. 9-11). The SB-I were smooth on the dorsal as well as the ventral surface, long and straight with a tapering end and broad at the base. The sensilla were longer in the female and worker than in the male. The SB-II were arranged in four rows and were smaller than the SB-I. The shaft of the SB-II sensilla was smooth, pointed and projecting from a bulbous basal cuticular sculpture. The SB-III were short and present in a number of rows ventral to the SB-II. The shaft of these sensilla was short, pointed and projecting from a broad bulbous base. The basal dorsal and ventral areas were covered with polygonal cuticular plates, forming cuticular micro-sculpture.

On the entire surface of the elongated filamentous shaft of the scape, micro-sculpturing of polygonal cuticular plates was observed. Along these plates, two types of trichoid sensilla, ST-I and ST-II, were observed, in the female (Fig. 5), male (Fig. 9) and worker ants (Table 2).

The ST-I were long and originated from the large cuticular plates on the dorso-ventral surface of the pedicel. The sensilla were pointed terminally and broad at the base. The ST-II on the contrary were short, small and distributed throughout the entire surface. These antennal sensilla differ distinctly in size between the female, male and worker ants (Table 2).

2 Pedicellar sensilla

Trichoid sensilla were present throughout the dorsal and ventral surface of the pedicel in the female (Fig. 6, 12), and worker ants, while sensilla basiconica were observed on the dorso-ventral region of the pedicel in the female ant only.

3 Flagellar sensilla

Sensilla trichodea curvata (STC) and sensilla trichodea (ST) were present densely on the dorsal and ventral surfaces of the flagellar segments. Besides these two types, the last two flagellar segments showed two other types of sensilla, SB and SC in the female (Fig. 7, 8, 14), SC in the male (Fig. 13), and SB in the worker (Table 2).

The shafts of STC are long, tapered, and slightly curved apically, while those of ST are long, narrow towards the apex and continuously tapering terminally. The SB are short and were observed on the dorso-ventral surface of the terminal flagellar segments of female and worker ants only. The SC were concentrated on the mid-dorsal and ventral surfaces of the terminal flagellar segments in the male ants. Their shafts were long, flattened and tapered towards the terminal tip. The SC were less numerous than the ST.

DISCUSSION

The geniculate type of antennae found in *Camponotus compressus* are characteristic of the aculeate Hymenoptera (Michener 1974; Richards & Davies 1988; Okada et al. 2006; Mysore et al. 2009; Nakanishi et al. 2009). In *C. compressus* the antennae are longer in the male than in female and worker ants. The number of flagellar segments (11) in male *C. compressus* is same as that in the honey bee *Apis mellifera* Linnaeus (Esslen & Kaissling 1976) and other species of *Camponotus*.
(Mysore et al. 2010; Nakanishi et al. 2009, 2010). The varying antennal morphology in different castes of ant is often correlated with varying density of antennal sensilla, particularly the flagellar sensilla (Nakanishi et al. 2009). Okada et al. (2006) described a ball-like modification at the base of the scape in the ants, Diacamma sp. and in Camponotus japonicus Mayr (Nakanishi et al. 2009), and a similar modification is evident in C. compressus. The pedicel in C. compressus is long and broad with an imbricate surface and covered with patches of sensilla, similar to that in bees (Wcislo 1994) and the ants, C. japonicus and C. sericeus (Fabricius) (Nakanishi et al. 2009; Mysore et al. 2009).

While various types of antennal sensilla have previously been noticed in the ants, Lasius fuliginosus (Latreille) (Dumpert 1972a) and Diacamma sp. (Okada et al. 2006; Ozaki et al. 2005), the present study reveals diversity within each of the four basic types of antennal sensilla of C. compressus, viz. the SB, ST, STC and SC in the female and worker, and the ST, STC and SC in the male. The presence of two subtypes of SB and three of ST evident in C. compressus is similar to the pattern in other Hymenoptera (Dumpert 1972a; Esslen & Kaissling 1976; Martini & Schmidt 1984; Zacharuk 1985; Ozaki et al. 2005; Moreau et al. 2006; Okada et al. 2006; Nakanishi et al. 2009, Mysore et al. 2009).

While ST are known to be located on the pedicel of antennae in all castes of various species of ants (Callahan 1975; Wcislo 1994; Okada et al. 2006; Nakanishi et al. 2009, Mysore et al. 2009), in C. compressus the SB were present on the pedicel only of the female and absent in male and worker castes. SB are completely lacking in fire ant, Solenopsis invicta males and honey bee drones (Renthal et al. 2003) and are considered to be female-specific sensilla, which is supported by the present study.

The SB on the antennae of C. compressus exhibit similar morphological structure to previously studied ant species, and may function as contact gustatory receptors, perhaps involved in nestmate recognition (Ozaki et al. 2005; Nakanishi et al. 2009; Mysore et al. 2010). Antennal SB of fire ants, Solenopsis invicta are also known to function as contact chemoreceptors (Renthal 2003). Nakanishi et al. (2009) categorised two types of trichoid sensilla along with the sensilla trichodea curvata in C. japonicus which do not always respond to stimulation by alarm pheromones (Nakanishi et al. 2010; Mysore et al. 2010) and it is possible that they have a similar function in C. compressus. The SC in C. compressus resemble with those in other ant species (Dumpert 1972b; Hashimoto 1990; Nakanishi et al. 2009) and may perform a contact chemosensory function (Altner & Prillinger 1980; Nakanishi et al. 2009).

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REFERENCES


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