ASIAN MYRMECOLOGY Volume 5, 113–120, 2013
ISSN 1985-1944

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

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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 semiarid 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.

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

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.

Sensilla on the antenna		**Female (n=5)**			**Male (n=5)**			**Worker (n=25)**		
		Type	Size (**µm**)		Type	Size (**µm**)		Type	Size (**µm**)	
			L	W		L	W		L	W
Scape	Ball	**SB-I**	**41±5.21**	**3.4 ±0.045**	**SB-I**	**19.05± 3.61**	**2.39± 0.055**	**SB-I**	**43.12± 3.51**	**3.6± 0.05**
		SB-II	**19.2± 2.65**	**22.6± 3.45**	**SB-II**	**11.37± 1.52**	**1.43± 0.042**	**SB-II**	**18.9± 2.45**	**24.8± 3.23**
		SB-III	**5.25± 0.12**	**5.1± 0.175**	**SB-III**	**0.95± 0.001**	**3.81± 0.065**	**SB-III**	**5.89± 0.056**	**5.3± 0.066**
	Shaft	**ST-I**	**64.5± 7.45**	**2.6± 0.032**	**ST-I**	**19.05 ±1.85**	**1.82± 0.0052**	**ST**	**30.3± 2.55**	**2.54± 0.042**
		ST-II	**36.1± 4.24**	**2.3± 0.084**	**ST-II**	**9.53± 1.16**	**0.91± 0.0012**			
Funiculus	Pedicel	**ST-I**	**66.6± 5.51**	**3.5± 0.03**	**ST-I**	**21.2± 0.14**	**1.17± 0.002**	**ST**	**78.3± 12.3**	**5.54 ±0.42**
		ST-II	**30.5± 4.21**	**2.54± 0.02**	**ST-II**	**8.5± 0.16**	**1.05± 0.002**			
		SB	**19.5± 4.21**	**4.76± 0.65**	**---**					
	Flagellum	**STC**	**32.3± 3.52**	**1.9± 0.001**	**STC**	**18.4± 3.45**	**1.86± 0.003**	**STC**	**30.4± 4.21**	**1.91± 0.0028**
		ST	**21.8± 8.91**	**1.3± 0.007**	**ST**	**10.2± 1.05**	**1.15± 0.006**	**ST**	**19.4± 2.52**	**1.34± 0.001**
		SB	**5.89± 0.142**	**5.31± 0.112**	**--**			**SB**	**5.72± 0.21**	**1.15± 0.002**
		SC	**25.18 ±4.53**	**2.49± 0.095**	**SC**	**10.12 ±1.25**	**1.12± 0.002**			

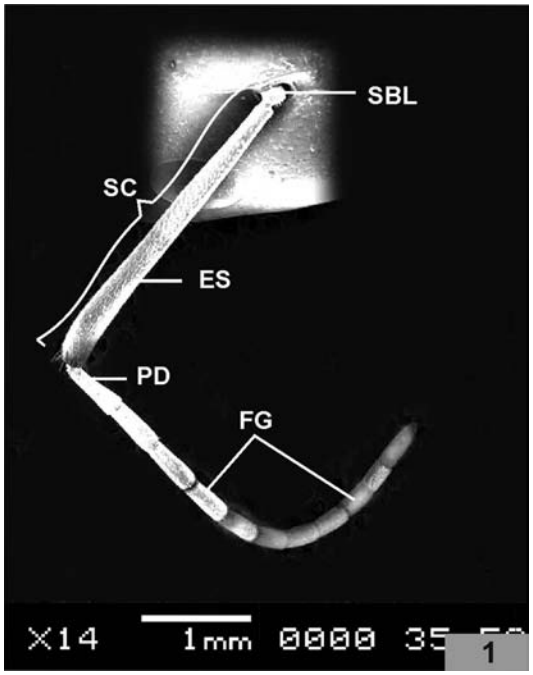

Fig. 1. SEM structure of antenna of worker ant. ES- Elongated scape shaft, FG-Flagellum, PD- Pedicel, SBL- Scape ball, SC- Scape.

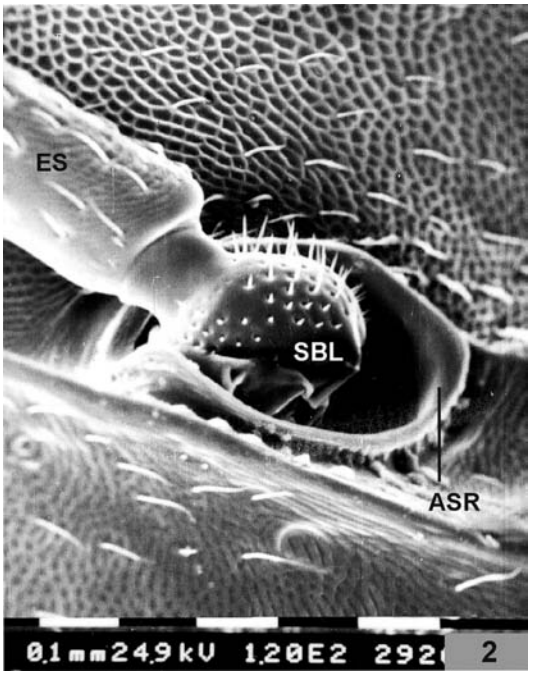

Fig. 2. Magnified SEM of basal region of antenna. ASR-Antennal sclerotic ring, ES- Elongated scape shaft, SBL- Scape ball.

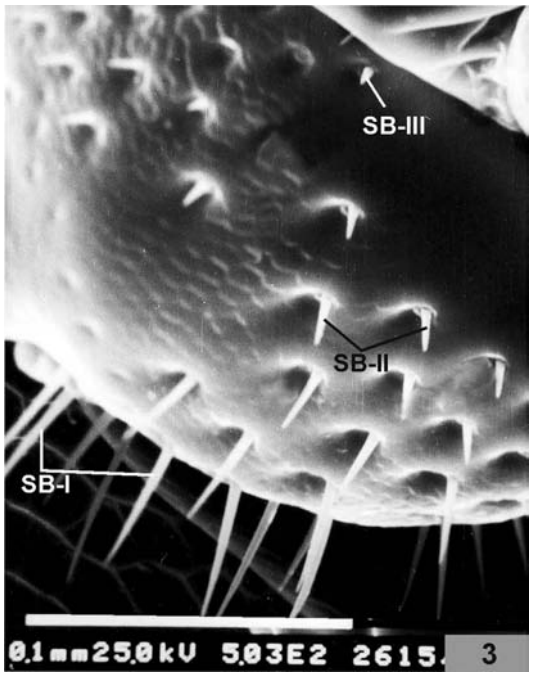

Fig. 3. SEM structure of Scape-ball (SBL) showing SB-I, SB-II, SB-III- three types of sensilla basiconica.

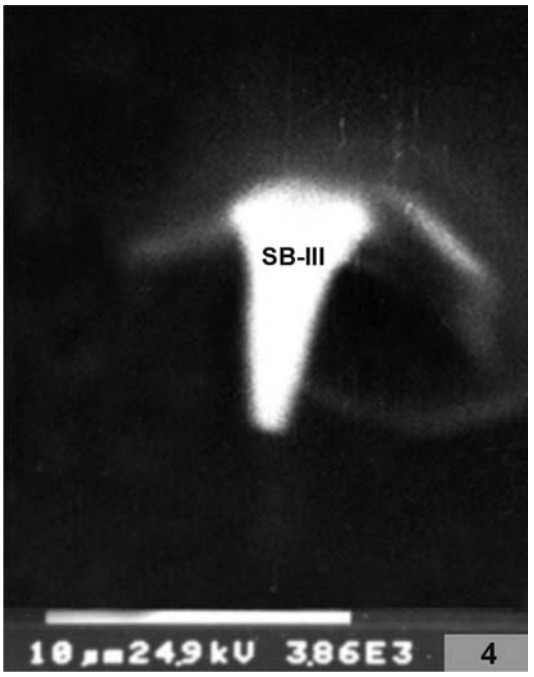

Fig. 4. Magnified view of SB-III.

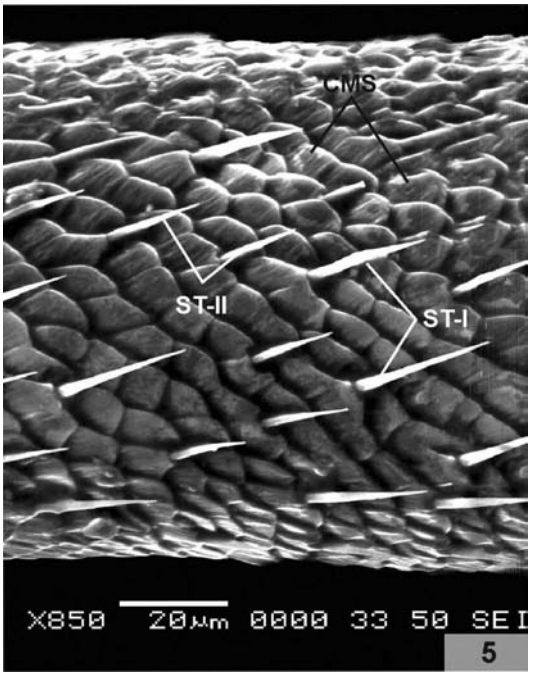

Fig. 5. SEM structure of scape shaft of the female showing sensilla trichodea, ST-I and ST-II arising from cuticular micro-sculpturing (CMS).

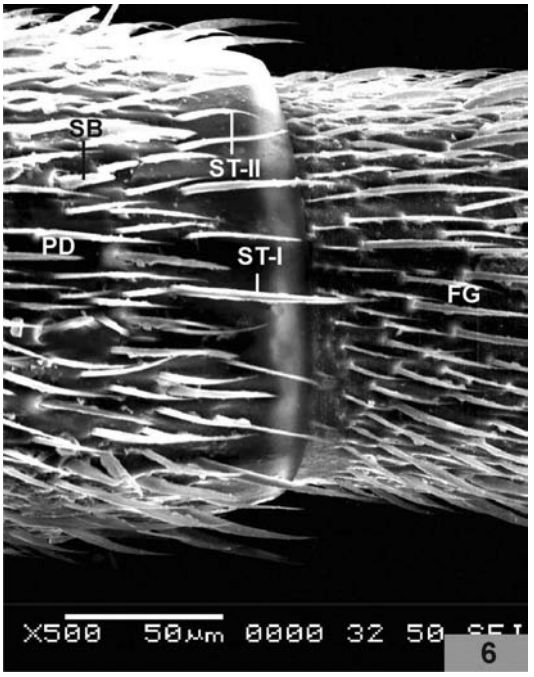

Fig. 6. SEM structure of pedicel (PD) and 1st flagellar segment (FG) showing sensilla trichodea, ST-I, ST-II and SB in the female.

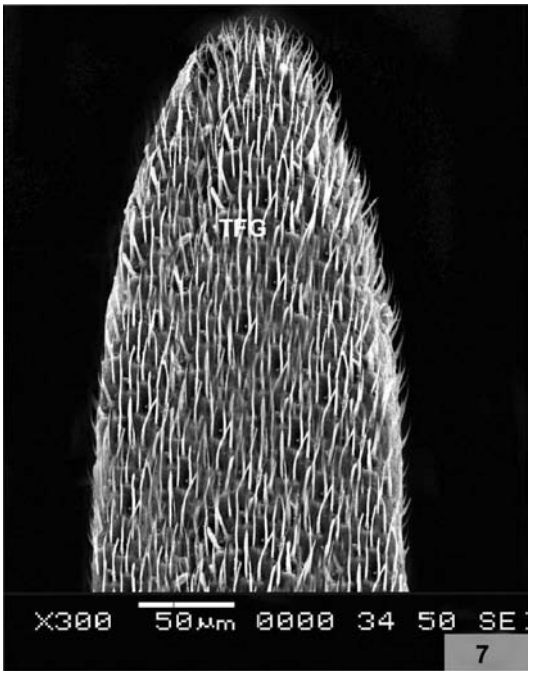

Fig. 7. SEM structure of terminal flagellar segment (TFG) of the female.

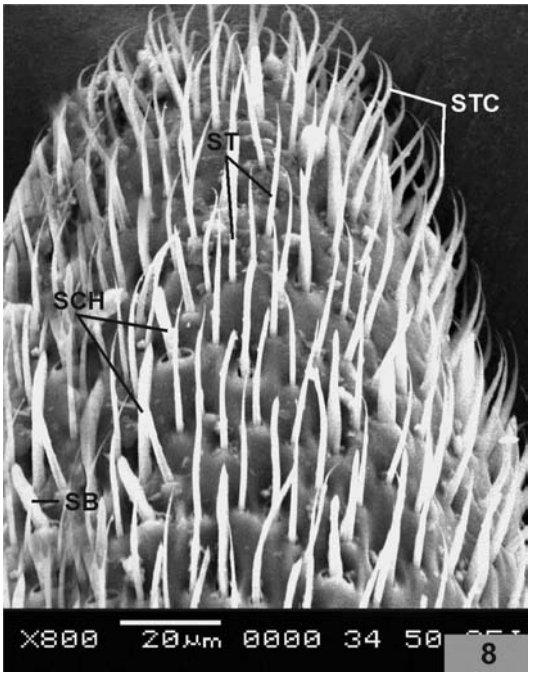

Fig. 8. Magnified view of TFG in the female showing sensilla basiconica (SB), sensilla chaetica (SCH), sensilla trichodea (ST), sensilla trichodea curvata (STC).

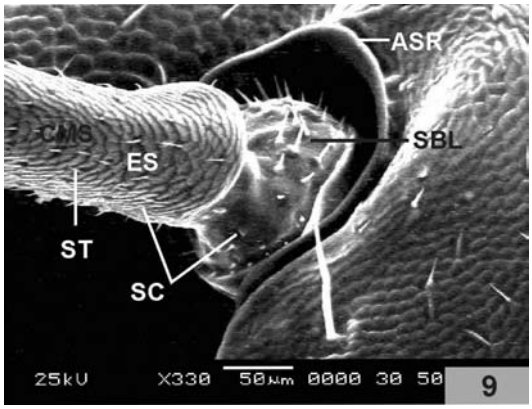

Fig. 9. SEM photomicrograph of basal region of antenna of male showing scape (SC) and elongated scape shaft (ES), scape ball (SBL) and antennal sclerotic ring (ASR).

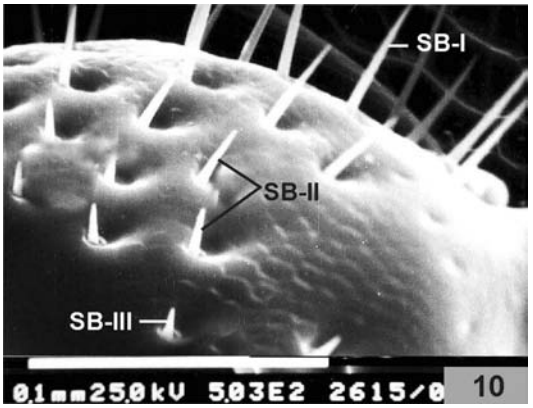

Fig. 10. Magnified view of SBL showing sensilla, SB-I, SB-II, SB-III.

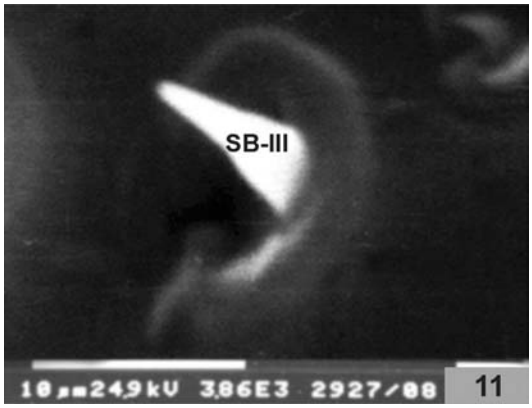

Fig. 11. Magnified SEM structure of SB-III on SBL

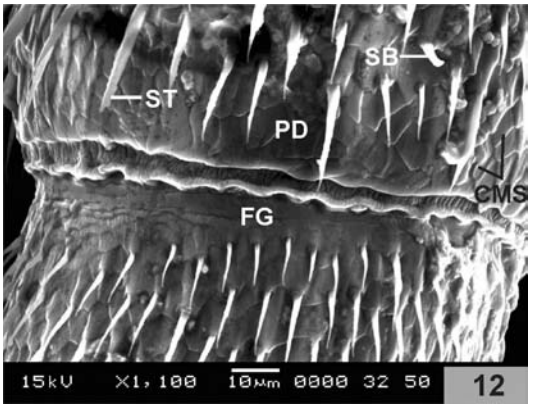

Fig. 12. SEM structure of pedicel and 1st flagellar segment (flagellar segment) of female, showing sensilla trichodea (ST), sensilla basiconica (SB) on pedicel.

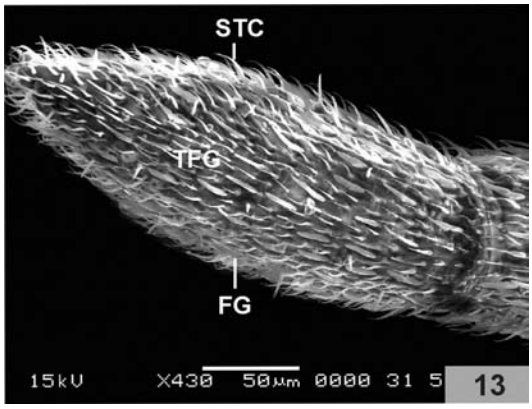

Fig. 13. SEM structure of terminal flagellar segment (TFG) showing sensilla trichodea curvata (STC) of male.

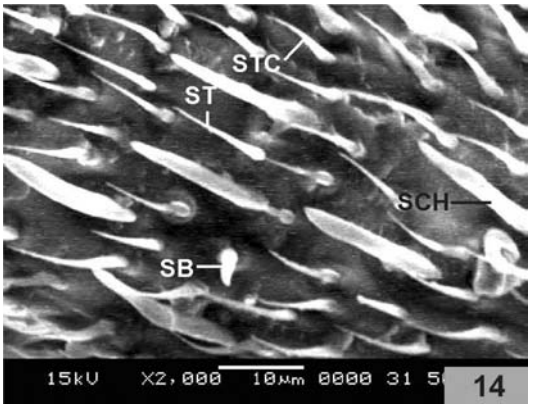

Fig. 14. Magnified view of TFG of female showing STC, ST, SB, and SC.

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).

ACKNOWLEDGEMENTS

We gratefully acknowledge the manuscript reviewers for their helpful suggestions. We are also thankful to Dr John Fellowes and Dr M. S. Wankhede for language-editing of the manuscript and to the Director of Visvesvaraya National Institute of Technology Nagpur, India for generously granting the use of the SEM facility.

REFERENCES

Agren L, 1977. Flagellar sensilla of some Colletidae (Hymenoptera: Apoidea). *International Journal of Insect Morphology and Embryology* 4: 137-146.

Agren L and Svensson BG, 1972. Analysis of the antennal sensilla equipment of the bumble bee. *Apidologie* 13: 247-64.

Altner H and Prillinger L, 1980. Ultrastructure of invertebrate chemothermo, and hygroreceptors and its functional significance. *International Review of Cytology* 67: 69-139.

Callahan PS, 1975. Insect antennae with special reference to the mechanism of scent detection and evolution of the sensilla. *International Journal of Insect Morphology and Embryology* 4: 381-430.

Dumpert K, 1972a. Alarmstoffrezeptoren auf der Antenne von *Lasius fuliginosus* (Hymenoptera: Formicidae). *Zeitschrift für Vergleichende Physiologie* 76: 403- 425.

Dumpert K, 1972b. Bau und Verteilung der Sensillen auf der Antennengeissel von *Lasius fuliginosus* (Latr.) (Hymenoptera, Formicidae). *Zeitschrift Morphologie der Tiere* 73:95-116.

Esslen J and Kaissling KE, 1976. Zahl-und Verteilung antennaler Sensillen bei der Honigbiene (*Apis mellifera L.*). *Zoomorphology* 83: 227-251.

Hashimoto Y, 1990. Unique features of sensilla on the antennae of Formicidae (Hymenoptera). *Applied Entomology and Zoology* 25:491-501.

Hashimoto Y, 1991. Phylogenetic study of the family: Formicidae based on the sensillum structure on the antennae and labial palpi (Hymenoptera: Aculeata). *Japanese Journal of Entomology* 59: 125-140.

Hölldobler B and Wilson EO, 1990. *The Ants*. MA: Belknap Press of Harvard University, Cambridge.

Keil TA and Steiner C, 1990. Morphogenesis of the male silk moth, *Antheraea polyphemus*. II. Differentiated mitoses of 'dark' precursor cells create the Anlagen of sensilla. *Tissue Cell* 22(5):705-20.

Martini R and Schmidt K, 1984. Ultra structure and early development of the pore plate sensilla of *Gymnomerus laevipes* (Vespoidea: Eumenidae). *Protoplasm* 119: 197-211.

Michener CD, 1974. *The Social Behavior of the Bees*. Harvard University Press, Cambridge.

Moreau CS, Bell CD, Vila R, Archibald SB and Pierce NE, 2006. Phylogeny of the ants: Diversification in the age of angiosperms. *Science* 312: 101-104.

Mysore K, Subramanian KA, Sarasij RC, Suresh A, Shyamala BV, Vijayraghavan K and Rodrigues V, 2009. Caste and sex specific olfactory glomerural organization and brain architecture in two sympatric ant species *Camponotus sericeus* and *Camponotus compressus* (Fabricius, 1798). *Arthropod Structure and Development* 38: 485-497.

Mysore K, Shyamala BV and Rodrigues V, 2010. Morphological and developmental analysis of peripheral antennal chemosensory sensilla and central olfactory glomeruli in worker caste of *Camponotus compressus* (Fabricius, 1787). *Arthropod Structure and Development* 39: 310-321.

Nakanishi A, Nishino H, Watanabe H, Yokohari F and Nishikawa M, 2009. Sex-specific antennal sensory system in the ant *Camponotus japonicus*: structure and distribution of sensilla on the flagellum. *Cell Tissue Research* 338: 79-97.

Nakanishi A, Nishino H, Watanabe H, Yokohari F and Nishikawa M, 2010. Sex-specific antennal sensory system in the ant *Camponotus japonicus*: glomerural organizations of antennal lobes. *Journal of Comparative Neurology* 518: 2186-2201.

Okada Y, Miura T and Tsuji K, 2006. Morphological differences between sexes in the ponerine ant, *Diacamma* sp. (Formicidae: Ponerinae). *Sociobiology* 48: 527-541.

Ozaki M, Wada-Katsumata A, Fujikawa K, Iwahasi M, Yokahari F, Satoji Y, Nishimura T and Yamaoka Y, 2005. Ant nestmate and nonnestmate discrimination by a chemosensory sensillum. *Science* 309: 311-314.

Renthal RD, 2003. Sensory reception in fire ants, imported fire ant research and management project, Final report, Texas. Downloaded from http://fireant.tamu.edu/research/ProgressReports/01-03 on 2 October 2010.

Renthal R, Velasqueza D, Olmosa D, Hamptona J and Wergin, WP, 2003. Structure and distribution of antennal sensilla of the red imported fire ant. *Micron* 34: 405- 413.

Richards OW and Davies RG, 1988. Classification and biology. In: *Imm's General Textbook of Entomology* 10th Edition (Richards OW and Davies RG, ed), Chapman and Hall, Landon Vol. 1: 123-178.

Steinbrecht RA, 1977. Pore structures in insect olfactory sensilla: a review of data and concepts. *International Journal of Insect Morphology and Embryology* 26: 229-245.

Wcislo W, 1994. Sensilla numbers and antennal morphology of parasitic and non-parasitic bees (Hymenoptera: Apoidea). *International Journal of Insect Morphology and Embryology* 24: 63-81.

Zacharuk RY, 1985. Antennae and sensilla. In: *Comprehensive Insect Physiology, Biochemistry and Pharmacology* (Kerkut GA and Gilbert LI, eds), Pergamon Press, 6: 1-69.