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RESEARCH ARTICLE

Chili pestiferous thrips *Thrips parvispinus* (Karny, 1922) and *Thrips tabaci* (Lindman, 1889) (Thripidae: Thysanoptera) antennal structural characterisation

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Abstract

Thrips are among the most serious pests attacking many economically important crops. They causes significant damage to plants by lacerating and sucking sap from the leaves, growing tips, flowers and fruits leading to silvery spots, stunted growth, flower drop and fruits deformation, ultimately resulting in severe economic yield losses in many crops. In addition to the damage caused, they act as vectors for various viral plant diseases. Antennal sensilla plays a crucial role in the chemical communication of thrips. However, studies on the types of sensilla in thrips are limited to a few species. Therefore, using scanning electron microscopy (SEM), this study examined the different types of sensilla in two pestiferous thrips species, *Thrips parvispinus* Karny and *Thrips tabaci* Lindman. The antenna of the thrips were found to consist of nine types of sensilla viz., bohm bristles (BB), microtrichia (MT), sensilla basiconica (SB), sensilla campaniformia (SCa), sensilla cavity (SCav), sensilla chaetica (SCh), sensilla coeloconica (SCo), sensilla styloconica (SSt) and sensilla trichoidea (ST). The microscopy observations revealed that all these sensilla were present in *T. parvispinus* while SSt was absent in *T. tabaci.* Sensilla chaetica were more abundant in *T. tabaci* than in *T. parvispinus.* Based on the results, the types of antennal sensilla and their functions in thrips are also discussed.

Keywords

antenna; sensilla; *Thrips parvispinus; Thrips tabaci*

Introduction

Antennae are primary sensory organs that detect chemical, tactile and environmental signals. Insect antennae have various types of sensilla, comprising cuticular sensory structures and sensory cells (1, 2). Antennal sensilla are fundamental components embedded in chemoreceptors, mechanoreceptors and hygroreceptors and they have unique adaptations that allow them to detect and transmit signals or stimuli to the central nervous system (3). These structures, known as sensoria or cuticular sensory organs, comprise bipolar neurons and surrounding cells (4). They play an important role in gathering information from their surrounding biotic and abiotic environments (5). Thrips, like many other herbivorous insects, use their antennal sensilla to detect chemical signals from plant surfaces, volatile blooms and species-specific pheromones for host recognition, feeding, oviposition and mating (6-8). However, compared to other insect orders, research on the antennal sensory structures of Thysanoptera remains limited (9-12).

A wide range of shapes and structural modifications in the antennal sensory units of thrips vary among the genera and these differences need to be explored across different genera. The genus *Thrips* (Linnaeus, 1758) (Thripidae: Thysanoptera) contains 301 species worldwide, of which 44 species are reported from India (13). Chili, *Capsicum annuum* L (Solanaceae) harbours thrips species viz., *Frankliniella schultzei* (Trybom), *Haplothrips verbasci* (Osborn), *Scirtothrips dorsalis* (Hood), *Thrips hawaiiensis* (Morgan) and *Thrips palmi* (Karny) (14). Chili cultivation in peninsular India has recently witnessed devastation by thrips complex, particularly the invasive species, chili black thrips *T. parvispinus* Karny. *T. parvispinus* has been reported earlier from France, Greece, the Hawaii Islands, India, Mauritius, the Netherlands, Reunion Island, Spain and Tanzania (15, 16). In India, *T. parvispinus* was first reported on papaya (*Carica papaya* L.) (15). *T. parvispinus* was also observed on other host plants, but the population escalated in mango *Mangifera indica* L. and chili inflorescence, causing significant damage and yield loss (17, 18). *T. parvispinus* causes significant damage to plants by scraping and sucking sap from the leaves, growing tips, flowers and fruits, leading to deformation, curling and drying out of the foliage (14). The destructive pest severely damages plants by feeding on them, leading to silvery spots, followed by browning leaves, stunted growth, flower drop and fruit deformation, ultimately resulting in complete loss of economic yield. The yield loss in chili has been documented as high as 60% (19).

Globally, *T. tabaci* Lindeman causes considerable damage to onion (*Allium cepa* L.) (20). The adults and nymphs of *T. tabaci* feed on the leaves, affecting the plants' photosynthetic ability (21). It is also a vector of the Iris Yellow Spot Virus, which results in premature plant death and reduced bulb size in onion (22). In insects, olfactory, tactile and auditory receptors are classified according to their functional role in perceiving stimuli. Despite their functional classification, these receptors often exhibit different structural characteristics. For example, receptors involved in olfactory responses are characterized by the presence of pores. In Coleoptera (beetles), these olfactory receptors include structures like SB and sensilla placodea (2, 23), which aid in detecting chemical stimuli. The pores found in SB are crucial for conducting stimuli effectively. Mechanoreceptors includes various structures such as sensilla campaniformia, SCh and sensilla trichodea (24). In many arthropod species, a single sensillum has more than one function, *i.e.*, it is mechanoreceptory in function as in thrips (10), aids in pheromone detection in beetles (1) and acts as an olfactory chemoreceptor in bugs (25). The present study is aimed to provide insight into the external features and distribution of various types of sensilla on the antennae of two thrips species, viz., *T. parvispinus* and *T. tabaci*, through SEM.

Materials and Methods

Insect collection

Adults of *T. parvispinus* were collected from the flowers and leaves of the chili crop from farmers' fields at Thondamuthur (10° 58'37.2" N 76°48'18.0" E). In contrast, *T. tabaci* were collected from the farms (11°00'28.8" N 76°55'48.7" E) of the Department of Vegetables, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. The collected thrips specimens were placed in a mixture of ethyl alcohol, glycerol and acetic acid (8:1:1) solution and slides were prepared (26). The thrips under study were morphologically differentiated by examining the thrips-mounted slides under a phase contrast microscope (DM750, Leica Microsystems, Switzerland). They were photographed with a camera (Flexcam c5) under the microscopic field and the species were identified using relevant literature. The study was conducted at the Tamil Nadu Agricultural University (TNAU) Insect Museum, Department of Agricultural Entomology, TNAU, Coimbatore.

Scanning electron microscopy

Ten adults of *T. parvispinus* and *T. tabaci* were used for SEM analysis (Model FEI Quanta 250, Czech Republic). The thrips were placed in ethanol (70%) for 24 h and transferred through a series of ethanol concentrations (60%, 70%, 80%, 90% and 100%) for 20 mins each. Later, thrips specimens were allowed to dry under room conditions (25^{0}C and RH (relative humidity) 60%). Dried specimens were subsequently affixed to a holder on both their dorsal and ventral sides using double-sided adhesive tape (Ted Pella, Inc., Redding, Canada). Finally, the specimens were subjected to gold sputter coating for 10 min in a sputter coater (SC7620® Emitech, Montigny-lebretonneux, France) and the specimens were examined under SEM (Quanta 250, FEI, Czech Republic) with the acceleration voltage set as 10 kV (11). The SEM facility at the Department of Chemical Engineering and Materials Science, Amrita Vishwa Vidyapeetham University, Ettimadai, Coimbatore, India was utilized.

Characterization of sensilla and terminology

The antennal sensilla on both dorsal and ventral surfaces of *T. parvispinus* and *T. tabaci* were identified and measured using ocular measurement under the microscopic field of SEM (FEI, Software version 4.1.4.2010). Additionally, the average length and width of each sensilla type were measured from SEM photomicrographs of ten specimens. Data on the distribution and abundance of different types of sensilla on the antennae of each species were also observed. The types of sensilla viz., BB, MT, SB, SCa, SCav, SCh, SCo, SSt and ST terminology and categorization, followed as per standard criteria (27, 28).

Statistical data analysis

The length and breadth of antennal segments and the mean length and breadth of the antennal sensilla obtained from SEM were measured by using Image J software. Data obtained on the number of antennal sensilla, their distribution and abundance were counted directly from SEM images. Significant differences between *T. parvispinus* and *T. tabaci* were calculated using T-test and analysis of variance (ANOVA). Tukey's honestly significant difference (HSD) test was performed per each sensilla measurement using R-software (version 1.0.136).

Results and Discussion

General morphology of antennae

Antennae: Adults of *T. parvispinus* and *T. tabaci* possessed moniliform antennae characterized by a cube-shaped scape, a robust pedicel and a distal flagellum divided into five sub-segments (Fig. 1). The length and breadth of the antennal segments varied between the species. The mean length of the scape was significantly longer in *T. tabaci* (16.14 ± 0.26 µm) than

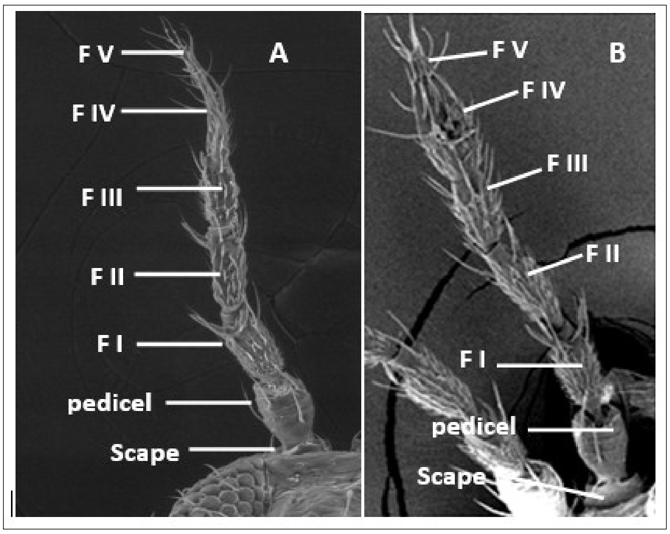

Fig. 1. Antennae of A) *T. parvispinus* B) *T. tabaci*under SEM showing scape (S), pedicel (P), five sub segmented flagellum (FI-FV). Dorsal view.

in *T. parvispinus* (8.39 ± 0.15 µm) (t = - 25.46; p < 0.05). The pedicel was longer than the scape. The mean length of the pedicel didn't show any significant difference in both *T. tabaci* and *T. parvispinus* (t = 1.25; p > 0.05; Table 1). The flagellum, a slender whip-like appendage, was segmented and varied in length and diameter in the two thrips species (Table 1). There was a significant difference in the mean length of flagellar segments, i.e., flagellum (I, II, III), between two thrips spp. (t = 8.07; p < 0.05 in FI, t = 10.47; p < 0.05 and t = 17.70; p < 0.05 in FII and FIII respectively), while flagellum IV and V exhibited no significant difference in mean length (t = 2.19; p > 0.05 in F IV; t = -2.23; p > 0.05 in FV). The total length of the antenna was found to be significantly different (t = 14.67; p < 0.05) between the two species, with *T. parvispinus* having a longer antennal length (182.68 ± 0.45 µm) than *T. tabaci* (161.63 ± 1.36 µm) (Table 1). Similar antennal segment measurements were reported in *Megalurothrips usitatus* and *Thrips palmi* (9).

Antennal sensilla: There were nine different types of sensilla on the antenna of *T. parvispinus*. This included BB, MT, SCo, ST, SSt, three types of SB (SB I, SB II, SB III), SCa, SCav and two types of sensilla chaetia (SCh I, SCh II and SCh III). Simlar number of sensilla were observed in *Odontothrips loti*, *Megalurothrips distalis* and *Sericothrips kaszabi* (11). In *T. tabaci,* eight types of sensilla were present, with SSt being absent. The sensilla density was higher in *T. parvispinus*, which has a wider host range than *T. tabaci*. *T. parvispinus* mainly feeds on the floral parts and depends on its antennal sensilla to locate its host. Antennal sensilla exhibit a wide array of shapes and vary significantly in structure, even among species of thrips belonging to the same genus (12). The length and breadth of these sensilla varied between the thrips species. Sensilla are the main structures that allow insects to sense and respond to semiochemicals (29). In addition to mechanoreceptors, insects also possess a variety of chemoreceptors, particularly olfactory receptors, which play a major role in perceiving chemical stimuli. These receptors are important for insect survival as they influence insect behaviour such as mating, host-seeking, positioning and feeding (27, 30-32).

Mechanoreceptors

Mechanosensory sensilla: The pedicel and flagellum of two thrips were covered by mechanosensory sensilla viz., Mt, BB, SCh, SCa and ST. These sensilla are found in similar sites to other Thysanoptera species, i.e., *Frankliniella occidentalis* (33) and *Dendrothrips minowai* (34). The receptors on these sensilla help the thrips avoid predators and respond to external stimuli such as touch, pressure, vibration and the internal force generated by the muscles (35, 36).

Bohm bristles: Bohm bristles were characterized by a thorn-like thin structure in circular sockets present at the base of the scape and at the junction of the scape and pedicel. They were similar to SCh, but they were sharper and shorter. A similar type of small thorn-like structure was observed in other thrips species, viz., *Echinothrips americanas* (10), *Odontothrips loti*, *Megalurothrips distali* (8) and *Megalurothrips usitatus* (9). The number of BB was significantly different in both the thrips (t = -0.023, p < 0.05) (Fig. 2a-b, Table. 2). No significant difference was observed in the mean length of BB in *T. parvispinus* and *T. tabaci* (p > 0.05; Table. 3). A significant difference was observed in mean breadth of *T. tabaci* (0.89 ± 0.073 µm) and *T. parvispinus* (0.63 ± 0.040 µm) (p < 0.05; Table. 3). Bohm bristles are present on the base of the scape interconnected between the head and pedicel and respond to physical contact (24, 36). Bohm bristles found in *T. parvispinus* were smaller in number compared to *T. tabaci*, which may be characteristic of both species. The presence of BB on the scape makes their function associated with detecting the position of the scape and pedicel and regulating their movement, serving as a proprioceptor (27).

Microtrichia: Microtrichia is the most abundant structures present in all the segments except at the scape and terminal segment of the antenna in both species. These sensilla were small and smooth with cupsate tips (Fig. 2c-d). Similar types of sensilla were observed in *Odontothrips loti*, *Megalurothrips distalis* and *Sericothrips kaszabi* (11). There was a significant difference in the mean length and breadth of Mt. The mean length of Mt was significantly longer in *T. parvispinus* (9.93 ± 0.74 µm) than in *T. tabaci* (8.29 ± 0.89 µm) (p < 0.01). In comparison, the mean breadth of Mt was observed to be maximum in *T. tabaci* (0.46 ± 0.036 µm) than *T. parvispinus* (0.33 ± 0.021 µm) and

Table 1. Mean length and breadth of antennal segments in two thrips species

Antennal segments	Length (µm)		Breadth (µm)	
	T. parvispinus	***T. tabaci***	***T. parvispinus***	***T. tabaci***
Scape	8.39 ± 0.15^{a}	16.14 ± 0.26^{b}	7.71 ± 0.17^{ns}	20.34 ± 0.27^{ns}
Pedicel	32.32 ± 0.69^{a}	31.38 ± 0.29^{b}	23.85 ± 0.24^{a}	23.6 ± 0.51^{b}
F 1	43.98 ± 0.49^{a}	38.35 ± 0.48^{b}	14.72 ± 0.17^{a}	19.57 ± 0.38^{b}
F 2	45.92 ± 0.46^{a}	39.22 ± 0.44^{b}	13.79 ± 0.21^{ns}	13.48 ± 0.19^{ns}
F3	37.43 ± 0.33^{a}	26.61 ± 0.50^{b}	15.59 ± 0.21^{a}	10.62 ± 0.23^{b}
F 4	43.50 ± 0.63^{ns}	41.43 ± 0.69^{ns}	18.49 ± 0.16^{a}	10.74 ± 0.25^{b}
F5	17.66 ± 0.29^{ns}	18.60 ± 0.30^{ns}	8.03 ± 0.10^{a}	5.20 ± 0.028^{b}
Total	182.68 ± 0.45^{a}	161.63 ± 1.36^{b}	_	_

Values are presented as the means ± SE.m of five individuals of each species. Means followed by the same letter in the row are statistically not significant (t-test, p < 0.05), ns- non significant and "-" indicate values are not measured.

they were significantly different ($p < 0.05$; Table. 3). These sensilla are associated with mechanosensory function in *Bactocera dorsalis* (37).

Sensilla chaetica: Sensilla chaetica was similar to ST in appearance, but they were located within a circular, flexible socket. SCh were found in all antennal segments of the thrips species. *T. tabaci* had a maximum number of SCh compared to *T. parvispinus* (Table 2). These sensilla were characterized by straight, elongated bristles with sharp or blunt tips and were significantly longer compared to other sensilla types. SCh observed in *T. parvispinus* and *T. tabaci* were identical to those of *Frankliniella intonsa* (Trybom), *F. tenuicornis* (Uzel), *F. occidentalis* (38), *Scirtothrips dorsalis* (12). Sensilla chaetica was reported to have a single distal hole at the apex of the outer epidermis (28, 39). These sensilla act as mechanoreceptors and help the thrips perceive differences in substrate texture, movement and wind direction (40).

Based on external morphology, these sensilla are divided into three subtypes: SCh I, SCh II and SCh III. SCh I was found on the scape and pedicel with a pointed curved tip (Fig. 2a-b). In *T. parvispinus* and *T. tabaci* Sch I were widely distributed on scape and pedicel. The number of SCh I showed no significant difference in the thrips species (Table 2). The mean length and breadth of SCh I were statistically non-significant, as indicated in Table 3. Similar findings are reported in *Scirtothrips dorsalis*, but they varied in length (12).

Sensilla chaetica were present in domal like-sockets of *T. parvispinus* and *T. tabaci* (12). SCh II was slender, pointed, sharp and tapered towards the tip, with conspicuous longitudinal ridges and were situated in shallow pits and were widely distributed on the dorsal, lateral and ventral sides, from pedicel to flagellum IV except at the terminal flagellomere in both the thrips species (Fig. 2c-d). The number of SCh II showed a significant difference between the two thrips species ($t = -4.06$; $p < 0.05$) (Table 2). A significant difference was observed in relation to the mean length of SCh II in both the thrips species ($p < 0.01$), with the maximum length observed in *T. parvispinus* (23.87 ± 0.64 µm) and minimum in *T. tabaci* (19.34 ± 0.88 µm). The mean breadth of SCh II was non-significant (Table 3).

The Sch III was primarily located on flagellum V in both *T. parvispinus* and *T. tabaci*, (Table 2). These sensilla were distinguished from SCh I and SCh II based on their position and location in cuticular sockets (Fig. 2e-f). These sensilla were slender, tapering towards a sharp tip adorned with longitudinal grooves. The mean length and breadth of SCh III showed no significant difference in the two thrips species (Table 3). Based on the morphological features of SCh I and SCh II, particularly those located on the scape and pedicel with sharp tips, they are more likely to come in contact and sense mechanical stimulation. In contrast, long, finger-like SCh III with intense grooved surfaces helps the thrips to respond to chemicals, such as water, amino acids and sugar, on the surface of the plant (12, 39) and they also play a role in perceiving taste (41). *T. tabaci* had more SCh than *T. parvispinus*. The presence of abundant SCh aids thrips in their search for the ideal hiding sites. These sensilla are innervated by mechanosensitive and chemosensitive neurons (4), hence they function as mechano and contact chemosensitive receptors.

Sensilla campaniformia: Sensilla campaniformia were present mostly at the dorsal end of the antennal pedicel of *T. tabaci* while it was present on flagellum I of *T. parvispinus* (Fig. 3a-b). This aligns with the findings of a previous study (12). The number of SCa showed no significant difference between the two thrips species (Table 2). A similar report on the location of SCa was documented in *Frankliniella* spp. (38) and *Dendrothrips minowai* (34) are involved in monitoring mechanical deformations of the body cuticle. The mean area of SCa was significantly higher in *T. tabaci* (11.97 ± 0.43 µm) than in *T. parvispinus* (6.75 ± 0.33 µm) ($p < 0.01$; Table 3). Different types of sensory SCa were also discovered on the flagella of many insects, likely functioning as proprioceptive mechanoreceptors in *Calliphora vicina* (42) and *Apanteles cypris* (43).

Sensilla trichodea: Sensilla trichodea in *T. parvispinus* and *T. tabaci* were wider at the base and narrow towards the tip, with slight curvature. They were mostly located on the terminal antennal segment, i.e., on flagellum V. A similar type of sensilla was noticed in both *Echinothrips americanus* (35) and *Scirtothrips dorsalis* (12). However, they varied in number and length.

Table 2. Distribution and abundance of antennal sensilla in two thrips species

Sensilla	*T. parvispinus*	*T. tabaci*	Porosity	Shape	Tip
BB	4.60 ± 0.24^{a}	3.60 ± 0.24^{b}	Aporous	Bristle - like	Sharp
SCa	1.00 ± 0.00^{ns}	1.0 ± 0.00^{ns}	-	Circular	-
SCav	4.60 ± 0.24^{ns}	4.0 ± 0.31^{ns}	-	Circular	-
SCh I	5.20 ± 0.2^{ns}	5.40 ± 0.4^{ns}	Aporous	Bristle - like	Blunt
SCh II	15.40 ± 0.50^{a}	18.80 ± 0.66^{b}	Aporous	Bristle -like	Blunt
SCh III	4.80 ± 0.2^{ns}	4.60 ± 0.24^{ns}	Aporous	Bristle -like	Blunt
SB I	1.0 ± 0.0^{ns}	1.0 ± 0.0^{ns}	Multiporous	Bifurcate	Sharp
SB II	$1.0 \pm 0.^{ns}$	1.0 ± 0.0^{ns}	Multiporous	Sickle shaped	Blunt
SB III	1.0 ± 0.0^{ns}	1.0 ± 0.0^{ns}	Multiporous	Whip-like	Sharp
SCo	1.8 ± 0.37^{ns}	2.6 ± 0.24^{ns}	Multiporous	Conical	Sharp
SSt	1.0 ± 0.0	-	Aporous	Conical	Blunt
ST	4.40 ± 0.24^{a}	3.60 ± 0.24^{b}	Multiporous	Bristle- like	Blunt

Values are presented as the means ± SE.m of five individuals of each species. "-" denotes

values are not measured, ns- non significant , The averages followed by the same letter in the row did not differ statistically by the student t-test at 5% probability.

BB- Bohm bristles **MT-** Microtrichia
Sca- Sensilla campaniformia **SCav-** Sensilla cavity
SCh- Sensilla cheatica **SCo-** Sensilla coeloconica
SSt- Sensilla styloconica **ST-** Sensilla trichodea, **"–"** indicates absence of Sensilla

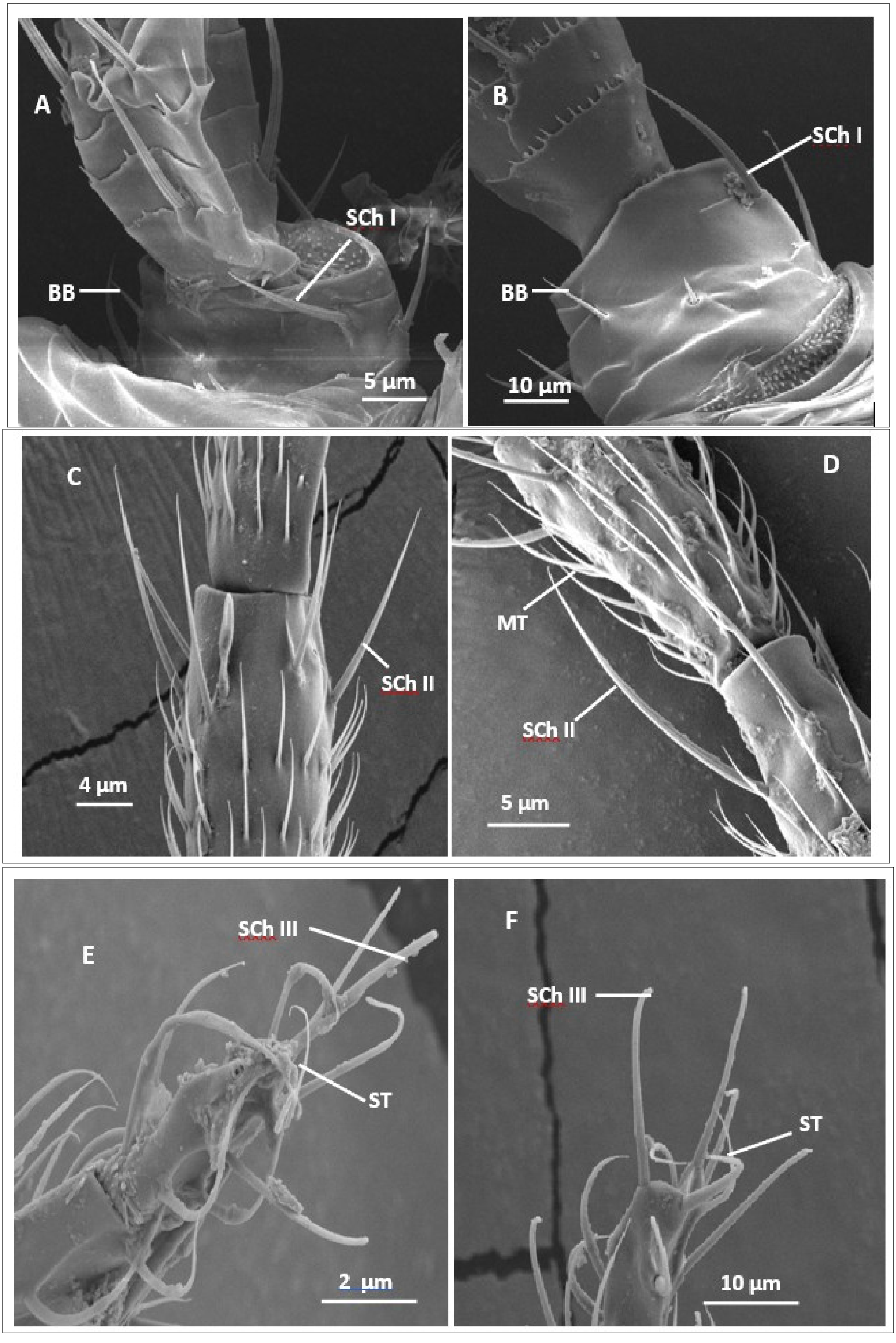

Fig. 2. Scanning electron microscopy images of bohm bristles (**BB**) characterized by thorn-like structures are present on the scape of (A) *T. parvispinus* and (B) *T. tabaci.* Microtrichia (**Mt**) was observed to be present on all antennal segments with varying lengths and sensilla chaetica I (SCh I) characterized by straight elongated bristles with blunt tips present on all antennal segments except the terminal segments in all the three species with pointed curved tip present on (A) *T. parvispinus* (B) *T. tabaci* sensilla chaetica II (SCh II) are long with slender sharp tips of (C) *T. tabaci* (D) *T. parvispinus*. Sensilla chaetica III (SCh III) with blunt tips and longitudinal grooves in *T. tabaci* (E) and *T. parvispinus* (F).

The number of ST showed a significant difference in both *T. parvispinus* and *T. tabaci* ($t = -2.30$; $p < 0.05$; Table 2, Fig. 3c-d). ST were Fewer in number in *Thrips parvispinus* than in *Thrips tabaci* when compared to other types of sensilla, which aligns with observations of similar sensilla found in *Scirtothrips dorsalis* (12). The mean length of ST in *T. parvispinus* (13.19 ± 0.63 µm) was significantly longer than *T. tabaci* (9.06± 0.37 µm) ($p < 0.01$) and the mean breadth of ST was also found to be significantly wider in *T. parvispinus* (1.04 ± 0.085 µm) than in *T. tabaci* (0.689 ± 0.063 µm) ($p < 0.01$; Table 3). We observed no grooves around the sensilla, which may function as a tactile receptor (10).

It was previously studied that sensilla is involved in sensing mechanical changes caused by external stimuli or the activities of internal muscles (44). Sensilla trichodea can detect semiochemicals and find mates in some lepidopteran insects, as ST located on the antennae can receive sex pheromones, triggering various behavioural responses to these chemical signals (45). A detailed study is needed regarding the function and role of ST in thrips.

Thermo-hygroreceptive sensilla

Sensilla cavity: Sensilla cavity has small, circular, aporous structures present at ventrolateral margins of the pedicel, formed by the invagination of the antennal cuticle. These were observed in both pedicel and flagellum of *T. parvispinus* and *T. tabaci.* Similar aporous sensillum (SCav) have been reported in *F. intonsa* (Trybom), *F.occidentalis* and *F. tenuicornis* (38) and *Dendrothrips minowai* Priesner (34). The number of SCav showed no significant difference between the species (Table 2). The external structure and distribution suggest that SCav likely serves a mechano-receptive or thermo-neurosensory function in the members of the Thripidae family (34, 38). Sensilla cavity showed a significant difference in relation to the mean area between the two thrips species (Fig. 3e-f) with maximum area in *T. parvispinus* (0.678 ± 0.043 µm) and minimum in *T. tabaci* (0.210 ± 0.024 µm) ($p < 0.01$; Table 3) was observed. In the present study, the SCav was small and round without dendritic branches in both thrips species. It might help in the perception of environmental humidity and temperature changes (12).

Olfactory chemoreceptor

Olfactory and chemosensory cues are vital in identifying plants and ovipositional sites for many phytophagous insects (46). As phytophagous thrips have evolved to disperse and find new host plants during changes in their host plant's growth stages, their landing behaviour may be influenced by plant volatiles detected by the olfactory sensilla on their antennae.

Sensilla basiconica: In the present study, three types of single-walled multiporous SB were observed: SB I, SB II and SB III. Similar types of sensilla have been reported in *Scirtothrips dorsalis* (12) and *Frankliniella* spp. (38). The SB were generally thick, featuring prominent longitudinal ridges. Sensilla basiconica I exhibited a U-shape with two arms and were recessed, aligning with the U-shaped sensilla of *Frankliniella occidentalis*, although their lengths differed (33). It was observed on flagellum I in both *T. parvispinus* and *T. tabaci*; furthermore, the quantity of SB I was uniformly distributed across the two species and exhibited no significant variation ($t = 0$; $p > 0.05$; Table 2). The length and breadth of SB I varied in the thrips species (Fig. 4a-b). The length of SB I showed a significant difference, measuring *T. parvispinus* (22.11 ± 0.29 µm) compared to *T. tabci* (17.82 ± 0.67 µm); $t = 5.83$; $p < 0.01$). Similarly, the mean breadth of SB I in *T. parvispinus* (2.62 ± 0.031 µm) was significantly wider than *T. tabaci* (2.04 ± 0.062 µm) ($p < 0.01$; Table 3).

A blunt shape characterized SB II without sharp tips on the flagellomeres of both *T. parvispinus* and *T. tabaci* (Fig. 4c-d). A similar type of SB II was observed in *Frankliniella* spp. (47), although its length varied compared to *T. tabaci*. In *T. parvispinus* SB II was located on flagellum I; in contrast, *T. tabaci* SB II was present on flagellum III. The number of SB II showed no significant difference in the two thrips species (Table 2). The length and breadth of SB II differed among the species. The mean length and breadth of SB II showed no significant difference (Table 3).

The third form SB III possessed an elongated straight shaft and was closely positioned on the antennal cuticle with a slightly sharp tip (Fig. 4e-f) compared to SB I and SB II. The same type of sensilla has been reported in *Megalurothrips usitatus* and *Thrips palmi* (9). Both *T. parvispinus* and *T. tabaci* were located on flagellum IV and showed no significant difference in number of SB III (Table 2). A statistically significant difference was observed between the two species regarding the mean length of SBIII (19.71 ± 0.94 µm and 14.86 ± 0.56 µm of *T. parvispinus* and *T. tabaci* respectively; $p < 0.01$), while the mean breadth of SB III showed no significant difference between the two species (Table 3).

Table 3. Mean length and breadth of antennal sensilla in *T. parvispinus* and *T. tabaci*

Sensilla	Length (µm)		Breadth (µm)	
	T. parvispinus	***T. tabaci***	***T. pavispinus***	***T. tabaci***
Mt	9.93 ± 0.74	8.29 ± 0.89**	0.33 ± 0.021	0.46 ± 0.036*
BB	4.37 ± 0.17	5.64 ± 0.67^{ns}	0.63 ± 0.040	0.89 ± 0.073*
SSt	16.03 ± 0.18	-	2.08 ± 0.12	-
SCo	10.72 ± 0.49	8.74 ± 0.68*	2.24 ± 0.098	2.15 ± 0.17^{ns}
ST	13.19 ± 0.63	9.06 ± 0.37**	1.04 ± 0.085	0.689 ± 0.063**
SCav	0.678 ± 0.043	0.210 ± 0.024**	-	-
SCa	6.75 ± 0.33	11.97 ± 0.43**	-	-
SCh I	16.78 ± 0.44	17.62 ± 0.59^{ns}	1.11 ± 0.061	0.970 ± 0.050^{ns}
SCh II	23.87 ± 0.64	19.34 ± 0.59**	1.02 ± 0.10	0.943 ± 0.082^{ns}
SCh III	14.36 ± 0.51	15.16 ± 0.98^{ns}	0.76 ± 0.10	0.910 ± 0.049^{ns}
SB I	22.11 ± 0.29	17.82 ± 0.67**	2.62 ± 0.031	2.04 ± 0.062**
SB II	8.44 ± 0.17	9.20 ± 0.46^{ns}	1.54 ± 0.063	1.62 ± 0.12^{ns}
SB III	19.71 ± 0.94	14.86 ± 0.56**	1.29 ± 0.072	1.40 ± 0.063^{ns}

Values are presented as the means ± SE.m of five individuals of each species. Significant difference in *T. parvispinus* vs *T. tabaci* comparisons (one-way ANOVA test); the average mean values with superscripts in the row ** indicates values are significant (Tukey's test, $p < 0.01$), * indicates values are significant (Tukey's test, $p < 0.05$)."-" denotes the absence of sensilla, ns - not significant.

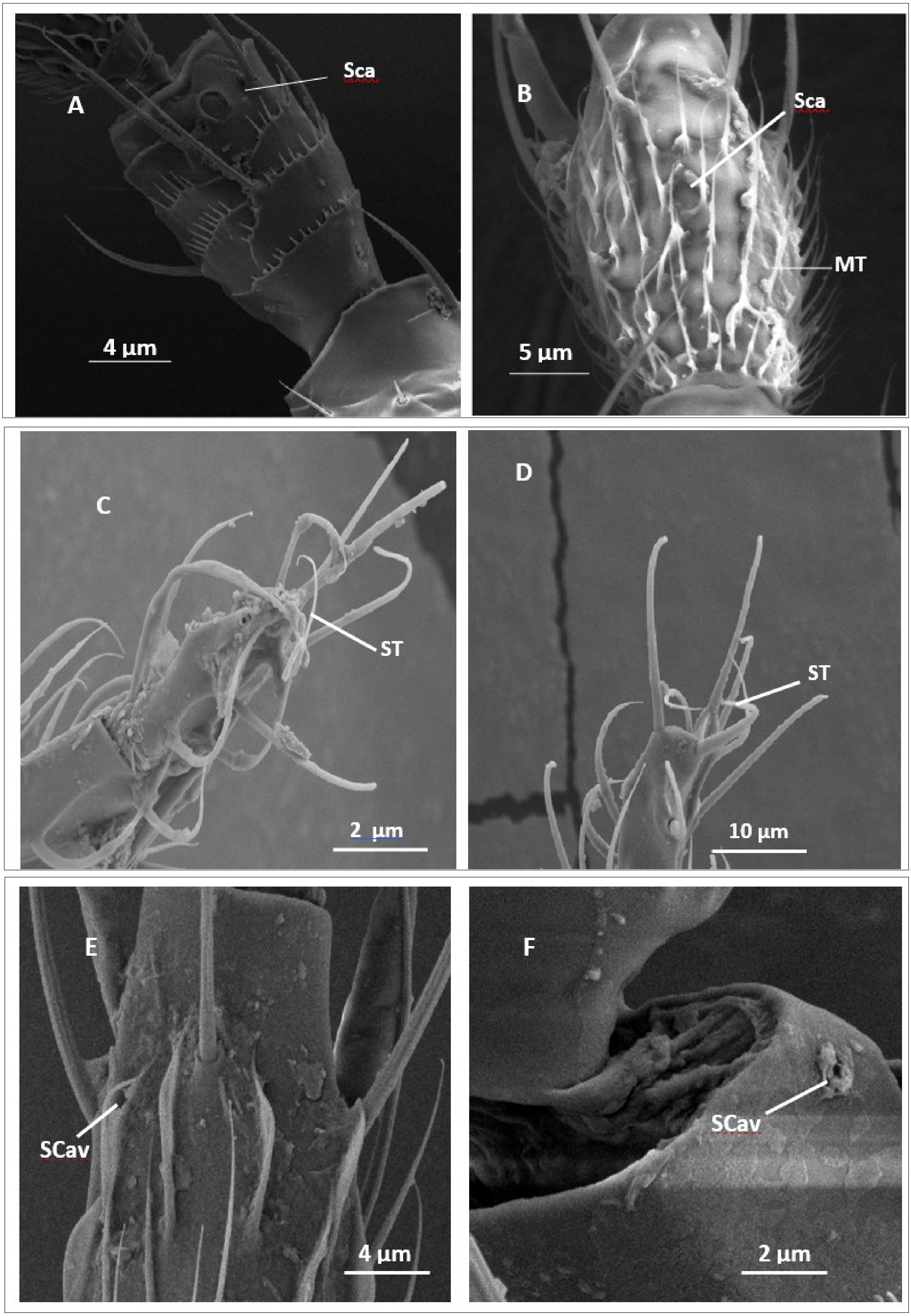

Fig. 3. The microscopy images of sensilla campaniformia (**SCa**) are oval sharped having no pores present on pedicel of (A) *T. tabaci* and (B) *T. parvispinus*. Sensilla trichodea (ST) having blunt curved tip without a socket on F V of (C) *T. parvispinus* and (D) *T. tabaci.* Sensilla cavity (**SCav**) are small circular in shape in (E) *T. parvispinus* (F) *T. tabaci.*

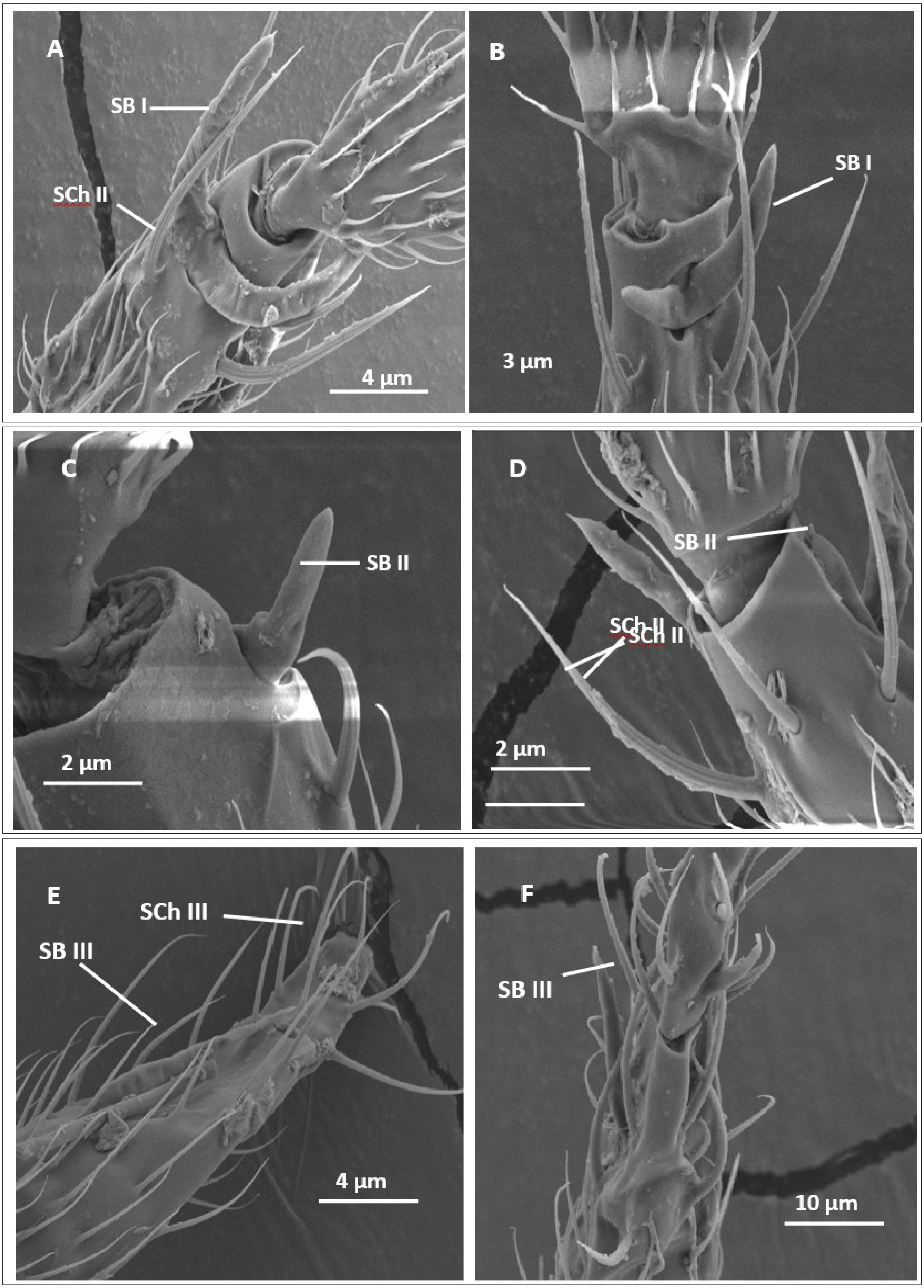

Fig. 4. SEM images describing different features of sensilla basiconica in three thrips. Sensilla basiconica I (SB I) shows a long, robust, curved peg with pointed tips present on flagellum I of (A) *T. parvispinus* and (B) flagellum I of *T. tabaci*. Sensilla basiconica II (Sb II) has short club-shaped structures with bunt ends present on flagellum III in C) *T. tabaci* and flagellum II of D) *T. parvispinus*. Sensilla basiconica III (Sb III) are straight with slightly sharp tips present on Flagellum IV of (E) *T. parvispinus* and (F) flagellum IV of *T. tabaci*.

Sensilla styloconica: Sensilla styloconica was stout, peg or thumb-like, with one or two cone-shaped structures at the tip and slightly swelling at the base. These sensilla were present on flagellum II of *T. parvispinus* but absent in *T. tabaci* (Table 2, Fig. 5a-b). The length and breadth of SSt in *T. parvispinus* was 16.03 ± 0.18 µm and 2.08 ± 0.12 µm respectively. Due to the absence of SSt in *T. tabaci*, no comparative analysis could be conducted between the species (Table 3). While the functional role of SSt has not been reported in thrips, similar structures in other insects, such as *Helicoverpa armigera*, have been shown to respond to sugars, nicotine and amino acids (48).

Sensilla coeloconica: Sensilla coeloconica was a robust structure arising straight from the antennal surface before bending at the apex to align parallel to the antennal axis. They had sharp-tipped cones with deep longitudinal slits and were found in broad, shallow pits resembling those described in other insect orders (49). The position and distribution of SCo varied between the thrips species. These sensilla were present on the flagellomere II and flagellomere III of *T. tabaci*, while in *T. parvispinus*, it was observed in the flagellomere III only (Fig. 5c). No significant difference was observed between the two thrips in relation to the number of SCo (Table 2). The length and breadth of SCo varied between the thrips species. Significant difference was noted in terms of mean length in the thrips species viz., *T. parvispinus* (10.72 ± 0.49 µm) and *T. tabaci* (8.74 ± 0.68 µm) ($p < 0.01$). In contrast, the mean breadth of SCo between the two thrips species showed no significant difference (Table 3). SCo are assumed to play a role in volatile detection in plant-herbivore systems, indicating their potential significance in host plant recognition and selection (12).

Conclusion

Thrips identify their host plants by perceiving the volatile compounds released by the plants using their antennal sensilla and inflict damage on crops by lacerating the plant tissue and sucking the sap. Antennal sensilla function as external "receivers" that perceive environmental stimuli from various distances, triggering complex behavioral responses in thrips. In this study, we provided a comprehensive morphological

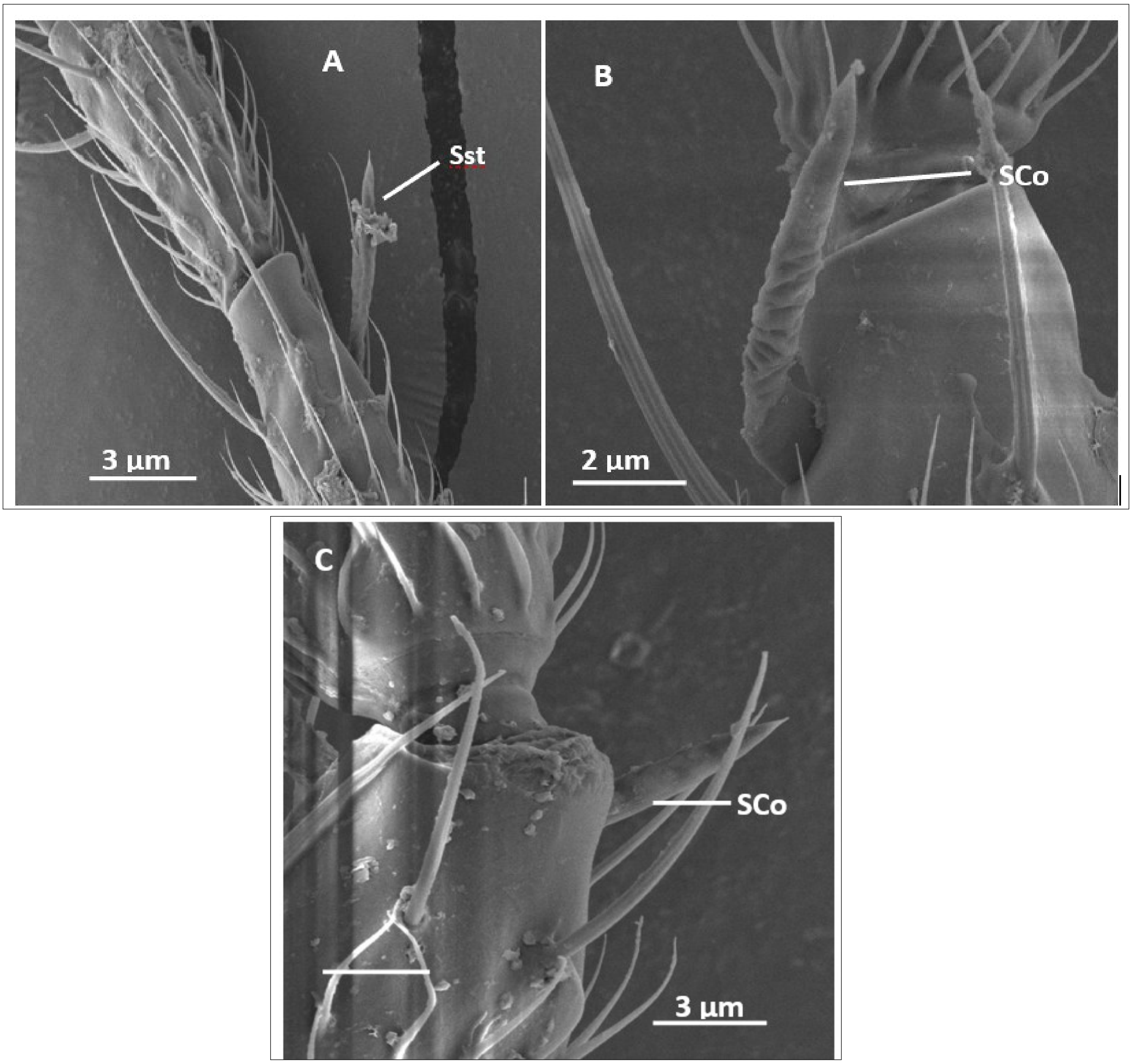

Fig. 5. Sensilla styloconica (SSt) are peg-like with one or two cone-shaped structures on flagellum IV of (a) *T. parvispinus*. Sensilla coeloconica (SCo) having sharp tipped cones and parallel to the antennal axis present on flgellum III of (B) *T. parvispinus* and (C) *T. tabaci*

description of the antennae of *T. parvispinus* and *T. tabaci,* emphasizing sensilla's type, number and location. Mechanosensory SCh was more abundant in *T. tabaci,* aiding concealment, while SB may play a role in long-range host locations. Thermo-hygroreceptors, like multiporous SCo aid the thrips, detect plant odors in the host plant-herbivore system but were absent in *T. tabaci*.

The presence of mechanosensory and chemosensillary structures allows thrips to exploit a wide range of host plants and aids in transmitting viruses among the major plant species. Like other phytophagous insects, thrips rely on semiochemicals, such as host plant volatiles and sex pheromones, to locate feeding sites and mates. Understanding antennal sensilla's structure and distribution can provide insights into the olfactory mechanisms involved in intra- and interspecific chemical communication.

Further studies should explore the function role of each sensilla identified in this study using electrophysiological and molecular methods, such as single-cell recordings of odour-binding proteins, which are essential for validating the precise roles of the sensilla identified in the current study. Moreover, understanding the role and mechanisms of each type of sensilla behind host-finding and oviposition acceptance behavior can provide concepts to explore the use of plant-derived compounds for monitoring and managing thrips populations.

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Authors' contributions

RT carried out the experiment, recorded and analyzed the data. NC assisted in writing, reviewing and approving the manuscript. MM helped in data analysis, editing reviewing the manuscript. RPS suggested ideas and helped in editing and revising the overall manuscript. MK helped in collection of the specimen from the field and carrying out the experiment. DU helped in summarizing and revising the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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