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Fine Structure of Trichobothria in the Salticid Spider Marpissa calcuttaensis

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Abstract

The fine structure of trichobothria in the salticid spider Marpissa calcuttaensis (Tikader 1974) was investigated by scanning electron microscopy (SEM). The specimens were collected from the New College Campus, Chennai, India and kept in the laboratory before processing. The specimens were then fixed in Trump's fixative followed by post fixation in 2% osmium tetraoxide at room temperature for 90 minutes. After that, the specimens were dehydrated in the graded ethanol series and hexamethyldisilazane dried. Lastly, the specimens were mounted on aluminum rods with araldite adhesive and coated with a thin layer of gold in a sputter coating unit and viewed under SEM. The SEM photomicrographs revealed the presence of trichobothria on the dorsal aspect of the first leg segments. The trichobothria were observed to be long and slender, embedded in special sockets. The articulation of the trichobothria in response to air deflections corresponds to that of other spider species. In addition, the slit-sensilla and lyriform organ were noticed on the tarsal area of the first leg may react to substrate vibrations which are in accordance to other arachnids. Thus, the structural characteristics features of the mechanoreceptors were compared with other arachnids to decipher their possible functional role and physiological significance

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Trichobothria,
Mechanoreceptors,
Lyriform organ.

Introduction

The Arachnida is the largest and most important class of chelicerates. It includes spiders, scorpions, ticks, mites, harvesters, solifuges and other forms that are less known (Cracraft, 2004). The largest group of arachnids is the spiders, which comprise the Araneae order and whose bodies are divided into two segments rather than three. There may be more than 45,700 different types of spider species worldwide (World spider catalogue, 2016). Spiders are cosmopolitan in distribution and help to manage several crop pests effectively, particularly in rice fields. They serve as potential candidates for the biological control of many farm insect pests and thus considered as friends of farmers.

Spiders are widespread in India and have been recorded in a variety of habitats, such as building walls, grasslands, paddy fields, etc. The specimen chosen for this study belongs to the salticidae family, *Marpissa calcuttaensis* (Tikader, 1974) consisting of the spiders. These spiders often live in close competition for resources within the habitat. They normally live in moist microclimates and show a preference for high humidity. However, due to evaporation from the tracheal opening, they lose water quickly in dry air. They are often brown in color with black spots on the back of the opisthosome. The cephalothorax is wide and has large eyes in the anterior row, while the abdomen is long and the legs are stout and strong. The most characteristic feature is the presence of different patterns of spines and filiform hairs or trichobothria throughout the body. The filiform hair or trichobothria vary in size and diversity. On the other hand, all the leg segments are covered with different sensory hairs. Most sensilla are movable, articulated setae or bristles that act as mechanoreceptors (touch and vibration). Each leg receptor is associated with several sensory cells and, as a result, thousands of separate sensory fibers build up the sensory nerves. The slit sensilla, which occurs in all leg segments individually or in groups, are less conspicuous mechanoreceptors. The slits of the lyriform organs are located near the leg joints measure the stress in surrounding cuticle while the proprioreceptors gather information or the position of a specific leg joint (Rathmayer, 1967; Rathmayer & Koopman, 1970).

The trichobothria are extremely fine hairs embedded within the special sockets. They are much less numerous than the common tactile hairs usually arranged in regular rows on certain segments of the legs. The most striking feature is their extreme sensitivity. The long slender hair shaft is embedded in a thin cuticular membrane, so that the slightest air currents will make it quiver. Four dendritic nerve endings attached to the specialized hair base and three of the four have specific sensitivity. The air vibrations that an insect produces with its wings suffice to trigger a directed capture response from the spider. They serve the spider to detect and localize prey and predators by sensing the air flow around them with tremendous efficiency (Humphrey & Barth, 2008). This could be attributed to the presence of numerous trichobothria found on the pedipalps and walking legs of spiders. Each leg in *Agelena labyrinthica* bears 25 trichobothria (Gorner & Andrews, 1969a), while in *Cupiennius salei* each leg consists of 50 trichobothria (Barth, 1982). The measurements on spider trichobothria are used in physical and mathematical modeling studies on mechanical hair behavior for fluctuating air flows in biologically relevant frequencies of 10 to 950 Hz (Barth, 1993). Trichobothria was previously thought to represent hearing organs (Dahl, 1883), but now it is considered to be a "touch at a distance "receptor because it reacts to air currents and low air vibrations (Gorner & Andrews, 1969b).

Materials and Methods

A total of 10 adult spiders were collected from their natural habitat at The New College Campus, Chennai, India. The specimens were kept in a screened aquarium and maintained in the laboratory before processing. The specimens were fixed in Trump's fixative (Sodium cacodylate buffer, formalin and glutaraldehyde) followed by post fixation in 2% Osmium tetraoxide for 90 minutes at room temperature. Specimens were then dehydrated with graded ethanol series and chemically dried using hexamethyldisilazane (Nation, 1983).

The specimens were mounted on aluminium stubs with araldite adhesive and coated with a thin layer of gold in a sputter coating unit and viewed under SEM. Photomicrographs were captured using JEOL-JSM: 5300 SEM and JFC-1100 E/Fine at Metallurgy Department, Indian Institute of Technology, Chennai, India.

Results and Discussion

Phylum : Arthropoda
Class : Arachnida
Order : Araneae
Family : Salticidae
Genus : *Marpissa*
Species : *Marpissa calcuttaensis* (Tikader, 1974)

The spiders collected from The New College Campus were identified and authenticated at the Post Graduate and Research Department of Zoology, The New College, Chennai-600014, India. The spider identified as *Marpissa calcuttaensis* sp. belongs to the family salticidae. Their body size ranged from 1.0 to 1.2 cm in length and 0.3 to 0.4 cm in width. The cephalothorax is wide and bears large prominent eyes on the anterior row. The abdomen is long and the legs are found to be short, stout and strong. The body is brown in color with black spots on the back of the opisthosoma (posterior part of the body) and covered by spines and filiform hairs or trichobothria. The image of the jumping spider *M. calcuttaensis* sp. is presented in Figure1.

1

Figure 1. *Marpissa calcuttaensis*.
(Araneae: Salticidae)

The diagnosis of the spider *M. calcuttaensis* sp. are in accordance to the characteristic features outlined in family salticidae. In fact, salticidae is considered to be the largest spider family in terms of number of species. The vast majority of species are active hunters and only a few make webs (Shear, 1986).

M. calcuttaensis commonly known as jumping spider is a small, brightly colored, enclothed with numerous filiform hairs on the body. The enlarged eyes possess the best eye sight responsible for acute daytime vision. In addition, jumping spiders react very definitely to visual stimuli like passing insects or the approaching finger of an observer. The short stout legs comprising of front and hind legs used to leap off an edge. In the jumping spider *Heliophanus*, the front legs are raised but only the hind legs provide the thrust for jump (Foelix, 1982a).

The specimen distribution map from The New College Campus, Chennai, India calculated to be 13° 03′ 10°N, 80°15′ 36°E and altitude 6 m.. The site shows a variety of habitat which includes shrubs, grasses and walls of the building. In addition, the jumping spiders live in close competition for resources within the habitat. They inhabit microclimates and show a preference towards high humidity (Figure 2).

Figure 2. Distribution of *Marpissa calcuttaensis* sp. from The New College Campus, Chennai, India (Source: Google Earth)

In the present study, scanning electron micrographs revealed a variety of sensory hairs across the entire leg surface of *M. calcuttaensis*. The leg segments were mostly composed of fine filiform hairs or trichobothria, tactile hairs, spines, slit sensory organs or sensilla and scopulae (Figure 3).

Figure 3. External morphology of the entire first leg of M. calcuttaensis sp. showing different kinds of hairs and spines. SP-spines. Scale bar = 500µm

The trichobothria are slender and incorporated in special sockets that are randomly arranged on the dorsal aspect of the leg segments. Alternatively, they are more or less regularly arranged on the femur and metatarsus region (Figure 4).

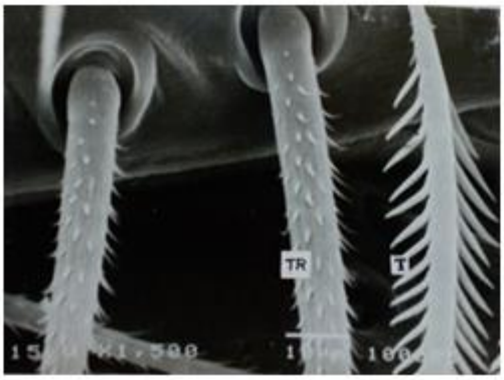

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Figure 4. Trichobothria and cuticular teeth embedded within special sockets of tibia. Tr-trichobothria, T-cuticular teeth. Scale bar = 10µm.

In fact, a large number of filiform hairs or trichobothria was observed in a definite pattern on the dorsal side of the first leg of *M. calcuttaensis*. In fact, their occurrence and pattern of distribution is unique to each species and therefore of immense taxonomic value. Moreover, several investigators have shown a wide range of applications of trichobothria extending from taxonomy to behavioral studies. For instance, in the phylogeny of spiders the trichobothrial count and arrangement has great significance. Earlier studies on insect karyotyping showed a correlation between the number of chromosomes and the arrangement of trichobothria (Grozeva, 1995). Similarly, in adults Podopinae, meristic and topographical aspects of trichobothrial pattern showed a reduction of the typical 5+5 ground plan to 2+2 trichobothria per abdominal sternites (Foelix, 1970).

The filiform hairs or trichobothria also form one dorsal row on each tarsus. Moreover, there are three rows of trichobothria present in tibia with different lengths of hair shafts. In addition, cuticular teeth were observed arranged in the form of rows on each side of the tactile hair emerging from underdeveloped sockets. Consequently, the length of these hair shafts increases gradually to the end of the leg (Figure 5).

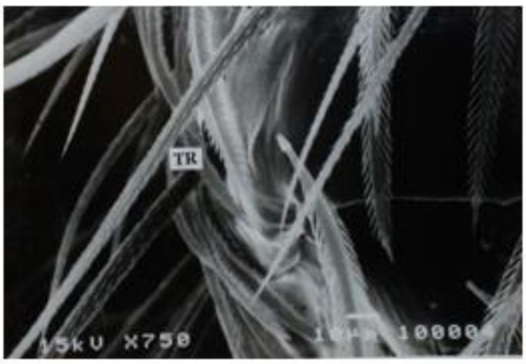

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Figure 5. Trichobothria with hair shafts of different length, increasing towards the tip of the first leg region. Tr-trichobothria. Scale bar = 10µm.

The trichobothria are mechanosensory in function. They are slender and embedded in special sockets randomly arranged on the dorsal aspect of leg segments. Moreover, the long slender hair shaft is suspended in very thin (0.5µm) cuticular membrane (Foelix, 1982a). Therefore, even the slightest air current will disturb and triggers the movement of these specialized hairs. For this reason, a spider is always alert and capable of exploring the environment very efficiently.

According to Harris and Mill (1977), spiders' trichobothria is ideally suited to detect the presence and direction of prey-stimulated air currents. Similarly, *C. salei* can locate a crawling fly up to 20 cm away by orienting itself towards the fly-triggered air current, by means of its trichobothria Barth (1982b). In the same way, *Sericopelma rubronitens* trichobothria present on the dorsal area of tibia and more distal articles in the legs and pedipalps are sensitive enough to detect the movement of the cricket leg which is 2cm away (Den Otter, 1974). However, in pseudoscorpions enhanced predatory behaviour and feeding rate is directly related to the trichobothrial count and its length (Davidova & Stys, 1993).

The spiders are therefore considered as good hunters and voracious feeders. Simultaneously, we also found the tactile hairs emerging from underdeveloped sockets bearing numerous cuticular teeth arranged in rows on each side of the hair shaft. These tactile hairs are strong in nature compared to trichobothria, which is similar to the tactile hairs of the wolf spider *Lycosa gulosa* (Foelix, 1970).

The slit sensory organs or sensilla are fine hairs seen on the dorsal surface of the leg. The fine hairs were observed in the form of groups on the tarsal area. Hence, they are also called as a lyriform organ (Figure 6). At the end of the tarsus a pair of claws was seen with a tuft of fine hair called scopulae (Figure 7).

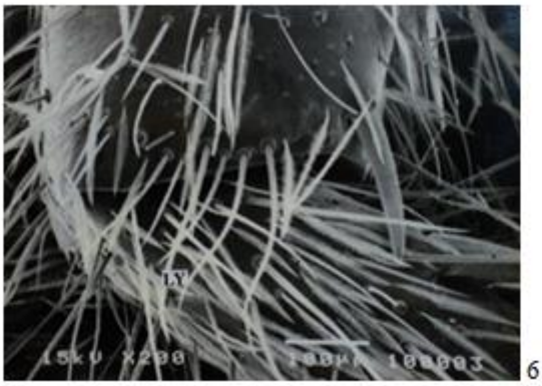

Figure 6. Lyriform organ on the tarsal area of *M .calcuttaensis* sp. LY-lyriform organ. Scale bar = 100µm.

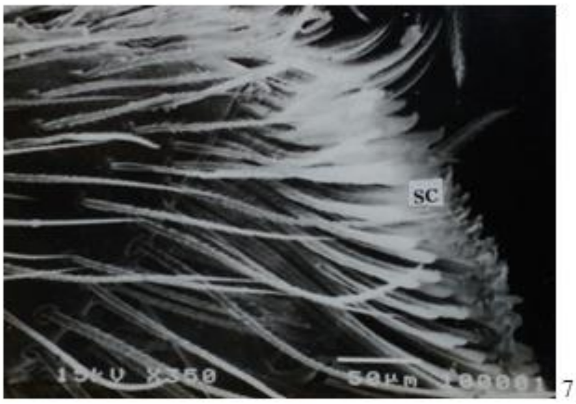

Figure 7 . Scopulae at the tip of the tarsus of *M calcuttaensis*. sp. SC-scopulae. Scale bar = 50µm.

The slit sense organs or sensilla observed over the tarsal area of the first leg are fine hairs occurring either singly or in groups. When they occur in groups it is called as a lyriform organ. Though, all arachnids possess slit sensilla and lyriform organs but only in spiders it reaches the fine sophistication. On the contrary, the slit sensilla function varies in different spiders which is usually classified as proprioreceptive mechanoreceptors, connected with the position and movement of the body. But this is not entirely correct because the stimuli do not have to be related to the movement of the spider itself. In addition, responses to airborne sound were shown electrotrophysiologically for a single tarsal slit sensillum (Barth, 1967). While some slit sensilla act as gravity receptors, as they probably register the relative movements between prosoma and opisthosoma (Barth & Libera, 1970).

Further, in non araneomorph spiders the prey is detected in the pedipalps and legs of these spiders. Whereas, slit sensilla such as lyriform organs and single-slit sensilla are important substratum vibration detectors found on the legs of araneoomorph spiders (Barth 1982; Walcott 1969). Likewise, the wandering araneomorph *C. salei* is able to locate its prey and mates at a range of upto 1 m on banana plants using substrate-vibration detectors (Rovner & Barth 1981). Similarly, Brownell (1977) has shown that sand scorpions' basitarsal compound slit organs are sensitive to substrata vibrations that can detect and locate insect's movement on sand surface up to 50 cm away. In addition to sensilla and trichobothria, spines were also observed throughout the dorsal side of the first leg. In fact these spines become erect when haemolymph pressure increases the nerve impulses of leg spines, unlike those of simple tactile hairs which can be recorded only during the erection phase, but not during the return to the flat resting position. These spines are therefore considered to be haemolymph pressure receptors, rather than touch receptors (Schlegel & Bauer, 1994).

Conclusions

In conclusion, SEM photomicrographs reveal that *M. calcutttaensis* contains different types of sensory receptors on their first leg. These findings provide clear evidence that salticid spider may perceive air currents sensed by their trichobothria during the movements of a prey or predator. The slit-sensilla may play a role in detecting minute mechanical pressures that facilitates in movement and positioning the body. Therefore it is quite evident that mechanoreception, touch, vibration, and the perception of airflow are all different tasks carried out by these sensory hairs. Thus the filiform hairs not only facilitate localization of prey but also help to escape from predation. These characteristics features may significantly contribute to their existence and survival of these spider species.

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