Structural Organization and Statistical Analysis of Pedipalps in Two Salticid Spider Species: *Salticus scenicus and Plexippus petersi*

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KEYWORDS

Conformation, Embolic duct, Suprategular apophysis, appendages.

ABSTRACT

This study focuses on jumping spiders of the family Salticidae, specifically *Salticus scenicus and Plexippus petersi*, known for their exceptional visual acuity and distinct sexual dimorphism. Males of both species possess modified pedipalps used for sperm transfer, with variations in palpal structure that influence mating. The palpal organ includes the genital bulb, haematodochae, subtegulum, tegulum, and embolus, which differ in complexity between species. The embolus varies in length with longer emboli linked to more intricate palpal structures. Morphometric analysis explored the relationship between pedipalp length and body dimensions (prosoma and opisthosoma). Spiders were collected, fixed, and examined under a microscope. Statistical analysis revealed significant correlations, with notable variation between species. In the *Salticus scenicus*, the prosomal length was less significant, whereas in the *Plexippus petersi*, the prosomal length had a highly significant correlation with the pedipalp length. These findings suggest that larger pedipalps are generally associated with longer body parts, with species-specific constraints at greater pedipalp lengths. The diversity in palpal morphology supports sexual selection and species diversity, contributing to our understanding of taxonomy and phylogeny in salticid spiders.

1.0 Introduction

The class Arachnida is the largest and most important phylum in the Arthropoda. It includes common forms of spiders, scorpions, ticks, and mites (Little, 1972). Spiders are unique in many aspects viz. feeding and breeding behavior, characteristic physiology, and anatomy. Their weaving skills, dragline patterns, and acute speciation systematics are significant. These chelicerate arthropods belong to the order Araneae, which has about 39,000 recorded species in 110 families and are cosmopolitan in distribution. The presence of poison glands, silk glands, and trichobothri are all some of the specialized organs of adaptation in spiders (Platnick et al., 2005).

The present study is on the jumping spiders belonging to the family Salticidae, their visual acuity is comparatively more efficient than other spiders (Coddington and Levi, 1991). Nearly 4000 species of this family have been identified. Visual cues about pair identity, size, and distance orientation of salticidae are higher as Salticids have huge anterior median eyes that exhibit their characteristic eye pattern. Chaubey (2017) examined the predatory abilities, and prey preferences of the zebra jumper, *Plexippus petersi*. The deep phylogeny of jumping spiders was explored by Maddison et al. (2014).

Mating behavior and breeding strategy differ in different families of spiders. A drastic modification of the palps in the second pair of appendages in matured males makes a striking distinct sexual dimorphism. The male palpal organ is the extremely modified and specialized tarsal segment of the pedipalp is modified to carry a copulatory organ. The palpal organ is a complicated structure constituting the tarsus and tibia which compose the apophysis of the palp which comes in varying shapes and sizes in different species of spiders. The Tarsus is the basic structure of the palpal organ, bearing the various units and subunits of structural entities of palpal panorama viz. the genital bulb. The genital bulb is an inflatable membrane (hematodochae) and has a set of sclerites (subtegulum, tegulum, and embolus).

The experimental specimens of study are *Salticus scenicus* and *Plexippus petersi*. *Salticus scenicus* also known as the zebra spider, is found in a wide range of locations. Males of the species have larger chelicerae than females. As part of the Salticidae family, zebra spiders are distinguished by their large anterior median eyes, which, along with the relatively large anterior and posterior lateral eyes, help provide excellent vision. They have eight eyes with prominent anterior median eyes offering binocular vision. These small spiders are typically black, with white hairs forming striped patterns across their bodies.

Plexippus petersi, a species of jumping spider native to Asia, exhibits ranging from 6 to 10 mm in length. The spider's head features four pairs of eyes, with one larger, forward-facing, and movable pair, while the remaining pairs are smaller and fixed. The cephalothorax is longer than it is wide. The lighter areas of the abdomen are covered with whitish bristles, while the darker areas are decorated with brown setae. The legs also have scattered setae, with a dense patch of brown hairs on the femur.

The palpal organ is an intromittent organ that transfers the sperm during coitus. The male inserts the tip of the genital bulb in its genitalia and fills the palp with sperm drops. The exact filling method and mode of transference of the sperm to the female genitalia differ markedly in different species of spiders (Miller, 1971; Platnick and Shadab, 1983). Sperm storage, transference, and the exact nature of intromission are all various functional attributes that vary depending upon the magnitude and modification of the palpal organ. Thus, to understand the copulatory mechanism of the salticid spider the study of genitalial compatibility between sexes in spiders is vital.

2.0 Materials and Methods

The specimens were preserved and examined. The pedipalps were kept in 5% KOH for 24 hours, dehydrated with 100% ethanol, and cleared in xylene, for temporary mounts. Photographs were made with the dissection microscope (Nikon). Specimens were measured according to Metzner (1999) in millimeters.

2.1 Statistical Analysis

Morphometric studies were made to understand the allometric growth of the two species of spiders namely *Salticus scenicus and Plexippus petersi*. The mean value of 15 individual observations was taken. Their prosomal and opisthosomal dimensions were correlated with the length of the pedipalp and the significance of the variables with the pedipalp length was studied from 't' test statistical treatments.

3.0 Results

The Palpal organ in *the Salticus scenicus* **(Fig. 1)** shows the hematodochae are well developed. The tegulum is a coiled spiral spooned sclerite. Its distal end overlaps with its proximal part and creates a distinct distal tegular projection that forms a characteristic hump on the unexpanded bulb. The organization of the embolus division of the bulb is significantly more complex. It consists of a sclerotized tube, an embolus, and a group of accessory sclerites. The distal sclerotized tube is massive, connected with the distal end of the tegulum through the distal tubular membrane. At the border between the tegulum and the distal sclerotized tube, and a narrow sperm duct. The seminal duct passes through the distal tubular membrane which enters the inner side of the embolic division (ED) and extends to form a long embolus. The apical division of the bulb encloses some of the proximal part of the embolus which is very likely to act as a protective sheath.

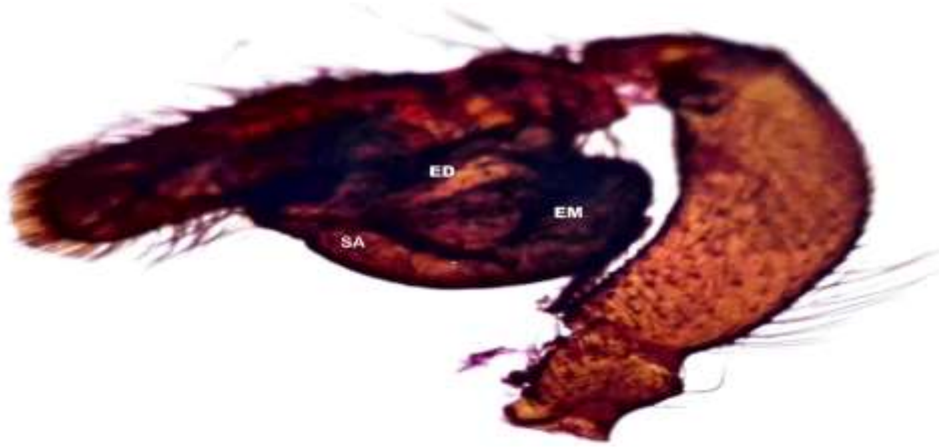

Fig. 1. Pedipalp with palpal organ (*Salticus scenicus*)
(ED -Embolic division, EM -Embolus, SA -Suprategular Apophysis)

The palpal organ of *Plexippus petersi* **(Fig. 2)** shows well-developed basal and median hematodochae connected to the cymbium. The subtegulum and tegulum form open spirals with a single loop, with the distal tegulum overlapping the proximal part, creating a projection. The suprategulum features a rudimentary apophysis, where the seminal duct runs from it to the embolic division, opening into a long embolus. The tibial segment has several setae or trichobothria.

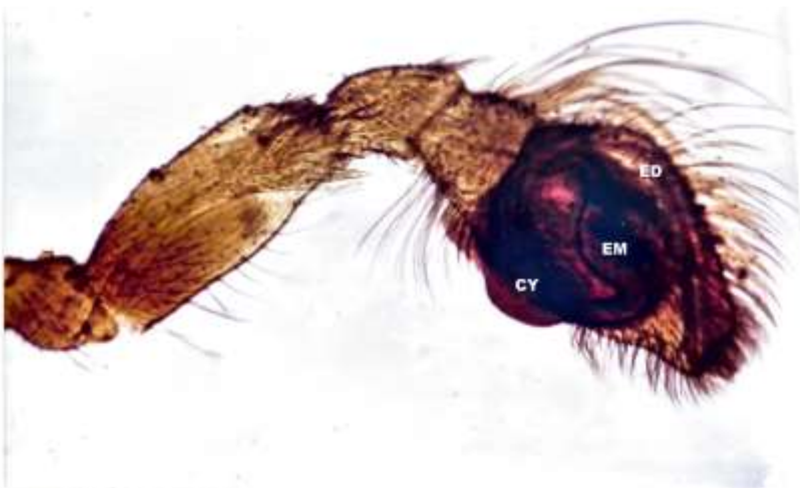

Fig. 2. Pedipalp with Palpal organ (*Plexippus petersi)*
(ED -Embolic division, EM -Embolus, CY-Cymbium)

Table 1. Morphometric Measurements of Salticid Spiders (in millimetre)

	Length of Pedipalp (mm)	Prosoma (mm)		Opisthosoma(mm)	
		Length	Width	Length	Width
Salticus scenicus	2.58±0.12	3.16±0.30	2.58±0.12	3.25±0.31	2.08±0.09
Plexippus petersi	3.32±0.32	3.71±0.35	3.11±0.30	4.3±0.42	2.58±0.12

Morphometric studies reveal a positive correlation between the pedipalp length and the prosomal and opisthosomal dimensions. From the study, it is interpreted that as the pedipalp length increases, the length and breadth of the prosoma and opisthosoma also increase **(Table 1)**.

Table 2. Correlation of Pedipalp length with the length and breadth of Prosoma and opisthosoma

	Length of Prosoma	Breadth of Prosoma	Length of Opisthosoma	Breadth of Opisthosoma
Salticus scenicus	0.3809*	0.9900	0.8837	0.9900
Plexippus petersi	0.9898	0.9888	0.9046	0.6134*

**Significant* $P < 0.1$

The 't' test was applied to find out the significance between the length and breadth of prosoma and opisthosoma with that of pedipalp length. In *Salticus scenicus,* the breadth of prosoma and opisthosoma are highly significant at ($P < 0.1$), when compared to the pedipalp length . In *Plexipus petersi,* the breadth of opisthosoma is less significant at ($P < 0.1$), when compared to the pedipalp length **(Table 2)**.

4.0 Discussion

Male spiders possess unique structures for sperm transfer that differ from those of all other animals. Instead of using their primary genitalia, they have evolved to transfer sperm via their pedipalps, a specialized body part not directly associated with reproduction. These pedipalps function as secondary intromittent organs and represent a distinctive synapomorphy of spiders. The inflation of hematodochal membranes—characterized by irregular twists, folds, or fibers with varying elasticity—can generate complex movements of sclerites (Huber, 2004).

In the present study, in the *Salticus scenicus,* the suprategular apophysis enters the seminal duct via a lateral entry into the embolic division, representing a comparatively complex configuration. In contrast , the palpal organ in *Plexippus petersi* is observed to have a simple structure, with the genital bulb containing the suprategular apophysis, which opens into the embolic division through the dorsal entry of the seminal tube. Merrett (1963) noted that the male palpal structure in spiders of the Erigonine genus *Ceratinella* is similar. The linyphiid palp follows a similar basic form, though its embolic division is notably larger and more complex. Millidge (1977) further observed that the palp of *Pocadicnemis pumila*, a common species with a long, whip-like embolus, may be mechanically more efficient for sperm transfer compared to simpler palps. The present study confirms that no plesiomorphic form of the palpal organ is present in salticid species.

The external cuticular sense organs, such as sensilla and setae, appear to be entirely absent in the palpal bulbs of the Theridiidae family (Berendonck and Greven, 2005). SEM micrographs reveal that salticid species also lack innervated setae, which function as tactile organs, on their bulbs (Bond and Platnick, 2007). However,in the present study both the experimental animals of research have the cymbium well-innervated and covered with setae. Similarly, in the male linyphiid *Triplogyna major*, the distal palpal segments and genital bulb are devoid of setae, which are otherwise present on most of the cymbium and other palpal segments (Miller, 2007).

In this study, pedipalp length ranges from 2.5 to 3.3 mm, while the length and width of the prosoma and opisthosoma vary from 2.0 to 4.5 mm. The positive correlation observed at shorter pedipalp lengths suggests that larger pedipalps are generally associated with longer prosoma and opisthosoma, possibly reflecting growth patterns in *Salticus scenicus and Plexippus petersi*. However, the plateau or decline at greater pedipalp lengths may indicate a developmental constraint or a species-specific morphological limit.

To conclude, the male copulatory organ in salticid spiders is intricate and highly adaptable. These spiders exhibit remarkable structural diversity in their intromittent organs, facilitating sexual selection and contributing to species diversity. The specialized nature of the palpal organ enhances its survival, highlighting its evolutionary significance. Further studies on other spider families and their comparative analysis will be valuable for understanding spider taxonomy and phylogeny.

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