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Insect-world's best kept secret: A tale of silk and webspinners

Rakesh Kumar Behera[1*], Swagatika Sahoo[2], Sanjay Kumar Pradhan[3]

[1] *Division of Entomology, ICAR- Indian Agricultural Research Institute, Pusa, New Delhi-110012, India*

[2] *Department of Entomology, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha-751003, India*

[3] *Department of Agricultural Entomology, University of Agricultural Sciences, Bangalore, Karnataka-560065, India*

Corresponding author: rkb.iari@gmail.com

Introduction:

The fascinating world of insects never fails to amaze us. The reason lies in the interesting behaviour of various insects and the amazing substances they secrete during their life cycle. Among the various beneficial products known to be produced by insects, silk enjoys a prominent position. When anybody says "silk", generally most people tend to connect it with spider silk or the cocoon silk of the domesticated silkworms (*Bombyx mori*), which has been coveted for textiles for millennia. It is from this species that we have learnt themost about silk manufacturing. But as interesting as it sounds, the production of silk can be found in 17 insect orders having 23 lineages based on their production, phylogenetic relationships, and molecular structures of the proteins they contain (Sutherland *et al*., 2010). It is secreted by the insects at some point in their life cycle for various purposes, such as bristletails (sperm transfer), caddisflies (foraging), lacewings (egg stalk production), lepidopterans, and hymenopterans (cocoon and nest building). Apart from these, the webspinners remain a very unique group which can produce silk both in the nymphal and adult periods, unlike others.

Webspinners (Order: Embioptera):

Webspinners belong to the taxonomic order- Embioptera (Greek. *embios*: "lively", *pteron*: "wing"). They are a tiny group of primitively social, poly-neopteran insects, comprising nearly 300 known species from a possible 2000 existing species worldwide (Ross, 2009). They build nest-like galleries on or under the tree bark, rocks, and logs, and sometimes in leaf litter, which serves as a habitat in addition to giving protection against impending predators. They show parental care, which can be classified as "sub-social" and they dwell mostly in the tropics. They have a flexible, thin body that allows fast movements and U-turns in narrow areas. The flexible antennae that avoid tangling in silk and the wings with few veins that fold along a crease running perpendicular to their length also act as adaptations for the life beneath silk walls (Ross, 1970).

Silk glands and sexual dimorphism:

The characteristic feature of Embioptera is the enlarged fore tarsus, which contains numerous silk glands that manufacture fine, strong silk. Because of their location and position beneath the epidermis, the glands are also called dermal glands. Another distinctive feature in Embioptera is the phenomenon of sexual dimorphism. Males and females of this order are visually distinct and can be distinguished morphologically. While nymphs and adult females have normal orthopteroid mandibles, adult male's mandibles are modified considerably to be elongated forceps like those used for clinging females during copulation. The compound eyes can also vary between the sexes, which are sharply curved and larger in males as compared to females. The cerci present at the terminal end of the abdomen are asymmetrical in males as an adaption to their reproductive behaviour.

Silk spinning mechanism:

Embioptera's spinning machinery is made up of a huge number of separate glands that secrete silk into the reservoirs they surround. A secretory channel transports the secretion to the basitarsus' ventral surfaces, from where it is released by silk ejectors. There is a significant positive relationship between body length and the volume of silk reservoirs, as revealed from the analysis of contrast scores of body length and silk gland measurements (Busse *et al*., 2015). It is interesting to note that the silk spinning process in Embioptera is "passive" *i.e*.- pressure-driven and produced by external mechanical stimuli, as there is no special internal organ or musculature for ejecting the silk (Busse *et al*., 2019). The process is supported by specialised behaviours like avoidance of contact with the substratum during forward locomotion. Further, the intricate spinning processes can also be differentiated between males and females, as seen in the case of *Aposthonia ceylonica* when documented with ethograms and discriminant analysis of time spent on various behavioural actions (Edgerly *et al*., 2012).

Properties of silk:

Thanks to their tropical habitat, the silken colonies of webspinners are exposed to the rain on a daily basis, which warrants investigation of their properties upon reaction with water. Studies on interactions between silk and water revealed that silks with larger fibre diameters had greater contact angles when they interacted with water. After being exposed to water, a greater number of hydrophobic amino acids showed permanent changes in hydrophobicity and water adhesion capabilities, transforming silk into film and ultimately slipping off the water particles (Stokes *et al*., 2018). Their molecular architectures might be used to inspire the creation of a material having a hydrophobic property that alters its physical characteristics when wet.

Conclusion and future prospects:

Silk refers to protein filaments secreted by a variety of arthropod lineages. It has reawakened attention in recent years, to duplicate its extraordinary mechanical qualities using modern biotechnology. Though many insects secrete silk, Embioptera stands out for its eccentric characteristics. In Embioptera, silk spinning is performed by a complicated behavioural mechanism with relatively simple anatomy. Webspinners spin around their bodies in a highly characteristic spinning step, releasing silk that is nature's "finest known insect silk". Technological advancements have prompted a renewed interest in producing finer fibres for application in nanoscale medical and optical devices. The webspinners remain one of the least understood orders within the class "Insecta". Discovering a suitable method for understanding the complex behaviour of silk-spinning in this order in a simpler manner is still a great task, which can add tremendously to the scant information that exists in the literature at present. A growing interest in creating bio-nano materials in recent years has also paved the way for the disclosure of many more secrets of this order, which has remained nature's "best-kept secret".

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