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Injurious effects on the exoskeleton of *Musca domestica* L. (Diptera) of phoresy by *Lamprochernes nodosus* (Schrank) (Pseudoscorpiones, Chernetidae) and the possible functional significance of accessory teeth on the chelal fingers

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Summary

Injury to the exoskeleton of *Musca domestica* L. (Diptera) by the pedipalp of *Lamprochernes nodosus* (Schrank) (Pseudoscorpiones) is described. The reasons for, and results of, these injuries are discussed. The fly injures itself, unintentionally, by its attempts to brush the pseudoscorpion off. *Lamprochernes nodosus* appears to be particularly capable of forming an effective attachment to the limbs of insects with the pedipalp and of resisting the carrier's attempts to brush it off, because of the accessory teeth laterad of the regular (marginal) teeth.

Introduction

Pseudoscorpions are sometimes transported by other animals. They are found not only on insects such as Diptera, Hymenoptera, Coleoptera (Jones, 1978), Odonata (Dunkle, 1984), and even certain Orthoptera and Lepidoptera (Muchmore, 1971), but also on harvestmen (Opiliones), spiders (Hoff & Jennings, 1974), birds and small mammals (Jones, 1978; Vachon, 1940).

It is generally thought that this behavioural complex is an example of phoresy (Beier, 1948; Weygoldt, 1969). Beier (1948) listed over 30 species of pseudoscorpions which disperse phoretically. Since then, many species have been added to Beier's list (Muchmore, 1971). Recent results have suggested that dispersal by means of other animals plays an essential part in the life cycle of certain species of pseudoscorpions and is determined by complex patterns of behaviour such as mating strategies (Zeh & Zeh, 1992a,b).

It thus appears to be a matter of fundamental importance for the existence of many species of pseudoscorpions that an individual should establish itself on the carrier in such a way that it cannot then be dislodged by the carrier, either passively by the activity of movement or flight or actively by being brushed off by the carrier. Pseudoscorpions have developed two strategies to circumvent this problem. On the one hand, many species conceal themselves beneath the elytra of large insects (e.g. longhorn beetles), among the feathers of birds, or in the fur of small mammals (Haack & Wilkinson, 1987; Jones, 1978; Muchmore, 1971; Zeh & Zeh, 1992a). Thus protected they do not need to make any great exertion to remain on the carrier. On the other hand, certain species grasp the limbs or hairs of the carrier with their pedipalps and are able to resist the airstream during flight and the efforts of the carrier to brush them off (Beier, 1948; Dunkle, 1984; Weygoldt, 1969).

When the pedipalps are used for gripping, a not inconsiderable pressure is exerted upon the part of the carrier's body that is involved (generally the legs or antennae), and in some cases involving *Musca domestica* L. this has caused lameness of the leg (Beier, 1948). The present paper shows for the first time that pressure from the pedipalp can cause visible mechanical damage to the exoskeleton of the carrier. Damage to the exoskeleton of the fore tibia of *Musca domestica* by *Lamprochernes nodosus* (Schrank) is demonstrated with the aid of SEM micrographs, and the causes of these injuries together with their consequences are discussed.

Materials and methods

Carrier: *Musca domestica* 1♂ (Diptera), Wabern (48° 10′ N, 10° 58′ E), Germany, July 1990.

Epizoite: *Lamprochernes nodosus* 3♀♀ (Pseudoscorpiones).

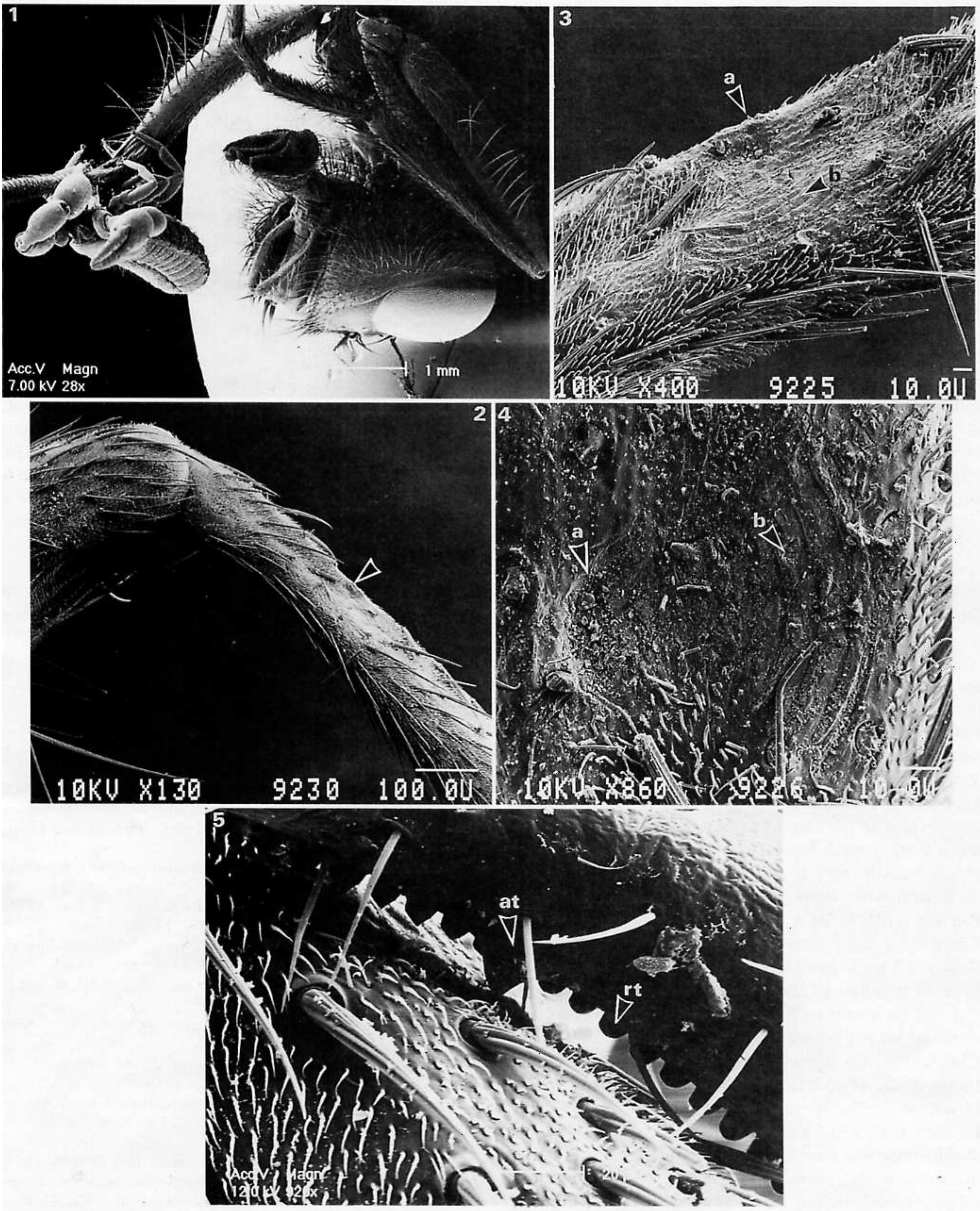
Two of the pseudoscorpions were clinging by one pedipalp to the right and left hind femora respectively. The third was attached by the left pedipalp close to the base of the carrier's left fore tibia (Fig. 1). After the photographs for Figs. 1 and 5 had been taken the pseudoscorpion was carefully removed under a binocular microscope. This presented no difficulty as the method of preservation had already loosened the grip of the pedipalp.

Preparation for SEM photography: preservation in 75% ethanol; transfer to 100% ethanol for 24 hours; transfer to 100% acetone for 24 hours; critical-point drying (CO_2, 1–2 hours); coating with gold, 180 s at 2.5 kV.

Results

The fly, which had been caught with a net, was released into an enclosed space and observed in flight for two hours. On many occasions, when at rest, the fly tried to rid itself of the pseudoscorpion attached to the fore tibia. Each cycle of grooming lasted from a few seconds to one minute. As customary, the fly rubbed the fore legs together, but sometimes also used a middle leg, which was passed between the front legs in an attempt to detach the pseudoscorpion. All attempts to brush it off were fruitless.

No injuries could be detected on the hind femora. The left fore tibia of the fly, however, showed distinct traces of the grip by the pedipalp of *L. nodosus*. The tibia had been laterally compressed (Fig. 2). Several large bristles had been broken or pulled from their sockets. The fine ground-hairs had been abraded through rotatory movements of the pedipalp at the point of attachment of the movable chelal finger (Figs. 3, 4), and on the opposite surface of the tibia caused by the fixed finger. The regular teeth (marginal teeth) of the chelal finger had caused damage to at least the epi- and exocuticle in the form of a section of a circle with five parallel grooves (Fig. 4), brought about by the rotatory movements of the pedipalp. The crater-like depression shown in Fig. 3 originated from a tooth-like tubercle situated laterad of the marginal teeth, known as the accessory tooth (Beier,



Figs. 1–5: Damage caused to *Musca domestica* by *Lamprochernes nodosus*. **1** Female of *L. nodosus* attached to fore tibia of *M. domestica*; **2** Laterally compressed fore tibia of *M. domestica* after removing the pseudoscorpion; **3** Damaged part of fore tibia of *M. domestica* (a = crater-like depression caused by accessory tooth, b = parallel grooves caused by rotatory movements of regular (marginal) teeth; **4** Damaged part of fore tibia of *M. domestica* from above (a = crater-like depression caused by one accessory tooth, b = parallel grooves caused by rotatory movements of regular (marginal) teeth; **5** Movable finger of chela of *L. nodosus* clinging to fore tibia of *M. domestica* (at = accessory tooth, rt = regular (marginal) teeth).

1963). In the Chernetidae these accessory teeth are usually found on both lateral and medial surfaces of both fixed and movable fingers on the pedipalpal chela. Above and below the point where the pedipalp was gripping, the fly's tibia was completely undamaged. The cursorial legs of the pseudoscorpion did not clasp the fly's leg in life; instead it propped itself sideways from the fly's leg by means of the angled femur and tibia of the pedipalp (see also Weygoldt, 1969: fig. 106, p. 116).

Discussion

The fact that only the fore tibia was injured, and not the hind femora which were also carrying pseudoscorpions, suggests that the injury was caused by the reciprocal effect of the grooming activity of the fly and the increased pressure of the pedipalp. The strength of these brushing movements was sufficient to shift the pedipalp of the pseudoscorpion some 60 μm along the tibia in a rotatory movement around the accessory tooth (Figs. 3, 4). The crater-like depression caused by this accessory tooth is actually the centre-point of the rotatory movement. The following question then arises in connection with the morphology of the pedipalp: is *L. nodosus* so frequently encountered as an epizoite because the accessory teeth laterad of the row of marginal teeth give it a special ability to grip the limbs of insects with its pedipalp? According to the equation Pressure = Force/ Surface, if the force remains the same then the pressure becomes greater as the surface becomes smaller. In other words, even without additional expenditure of energy, the species can maintain its grip more effectively with a few accessory teeth than with many regular (marginal) teeth (Fig. 5). The present specimen of *L. nodosus* had 1 inner and 1 outer accessory tooth on the movable finger, and 1 inner and 2 outer accessory teeth on the fixed finger (i.e. 5 teeth altogether on the left pedipalp). When compared with the two other pseudoscorpion specimens, the accessory teeth varied in size, position and number (4 and 6 teeth respectively on the left pedipalp).

According to Beier (1932), Chamberlin (1931) and Roewer (1940), only the members of the family Chernetidae have accessory teeth on the chela finger as shown in Fig. 5, but accessory teeth of a different form have been found in the Feaellidae and Geogarypidae. Phoresy on insects in Europe and in the Neotropics is a dispersal strategy used only by some members of the Chernetidae, Chthoniidae, Syarinidae and Cheiridiidae (Beier, 1948; Dunkle, 1984; Haack & Wilkinson, 1987; Muchmore, 1971; Weygoldt, 1969; Zeh & Zeh, 1992a,b). It should also be pointed out that species such as *Pselaphochernes scorpioides* (Hermann) occur in large numbers in the same habitat as *L. nodosus* but are seldom found in phoretic associations (V. Mahnert, pers. comm.). The possession of accessory teeth on the chelal fingers can therefore be interpreted as *one* of the functional morphological prerequisites of *L. nodosus* for dispersal by means of a phoretic attachment to insect limbs, although some members of other families which lack accessory teeth are also apparently capable of phoresy.

It also makes sense for the pseudoscorpion to grip with only one pedipalp because it can then react more flexibly by turning when the fly attempts to brush it off. Beier (1948), Haack & Wilkinson (1987) and Weygoldt (1969) confirm that only one pedipalp is used for gripping. Jones (1978) and Dunkle (1984) have also seen pseudoscorpions gripping with both pedipalps.

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