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ATTACHMENT ABILITY OF *COCCINELLA SEPTEMPUNCTATA* MALE AND FEMALE BEETLES TO A SMOOTH SUBSTRATE

Fig. 1. Dorsal (left) and ventral (right) views of the beetle *C. septempunctata.*

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Fig. 2. Position of the male on the female during mating.

The aim of this study was to investigate the effect of micromorphological differences in attachment organs (adhesive pads) of males and females of the seven-spotted ladybird beetle *C. septempunctata* (Figs. 1, 2) on their attachment. We employed scanning electron microscopy (SEM) to examine the microstructure of adhesive pads in adult male and female beetles. Additionally, we conducted centrifugal force measurements on insects placed on a smooth glass surface to quantify their attachment strength.

Micromorphology of adhesive pads

- **Adhesive pads.** In *C. septempunctata*, adhesive pads are classified as hairy locomotory devices [1], characterized by numerous microscopic tenent setae on the ventral side of the first two proximal tarsomeres (Fig. 3A–F,K,L).

- **Setal types**. The setae are of different types: (i) with a pointed, usually sharp tip (Fig. 3G), (ii) with a flattened and widened end plate called spatula (Fig. 3I), (iii) a transitional type, often with a pointed tip and rather narrow elongated end plate (Fig. 3H), and (iv) with a flat discoid end plate (Fig. 3J).

- **Sexual dimorphism**. There is a distinct sexual dimorphism in the morphology of adhesive pads: males have all four setal types, whereas females possess only the first three types.

- **Females.** The 1st tarsomere of each leg bears pointed-tipped/transitional setae, which are rather similar in appearance (Fig. 3E). The 2nd tarsomere has pointed-tipped setae on its proximal and lateral margins, spatula-bearing setae on the distal margin and various transitional setae in the middle (Fig 3F).

- **Males.** Setae with discoid terminal elements occur in the central part of either both tarsomeres (fore- and midlegs, Fig. 3A,K) or only the 2nd one (hindlegs, Fig. 3L) and occupy 10–50% of the total tarsomere area (Fig. 3A–C,K,L). The distribution of other setal types in males' pads is similar to that in females.

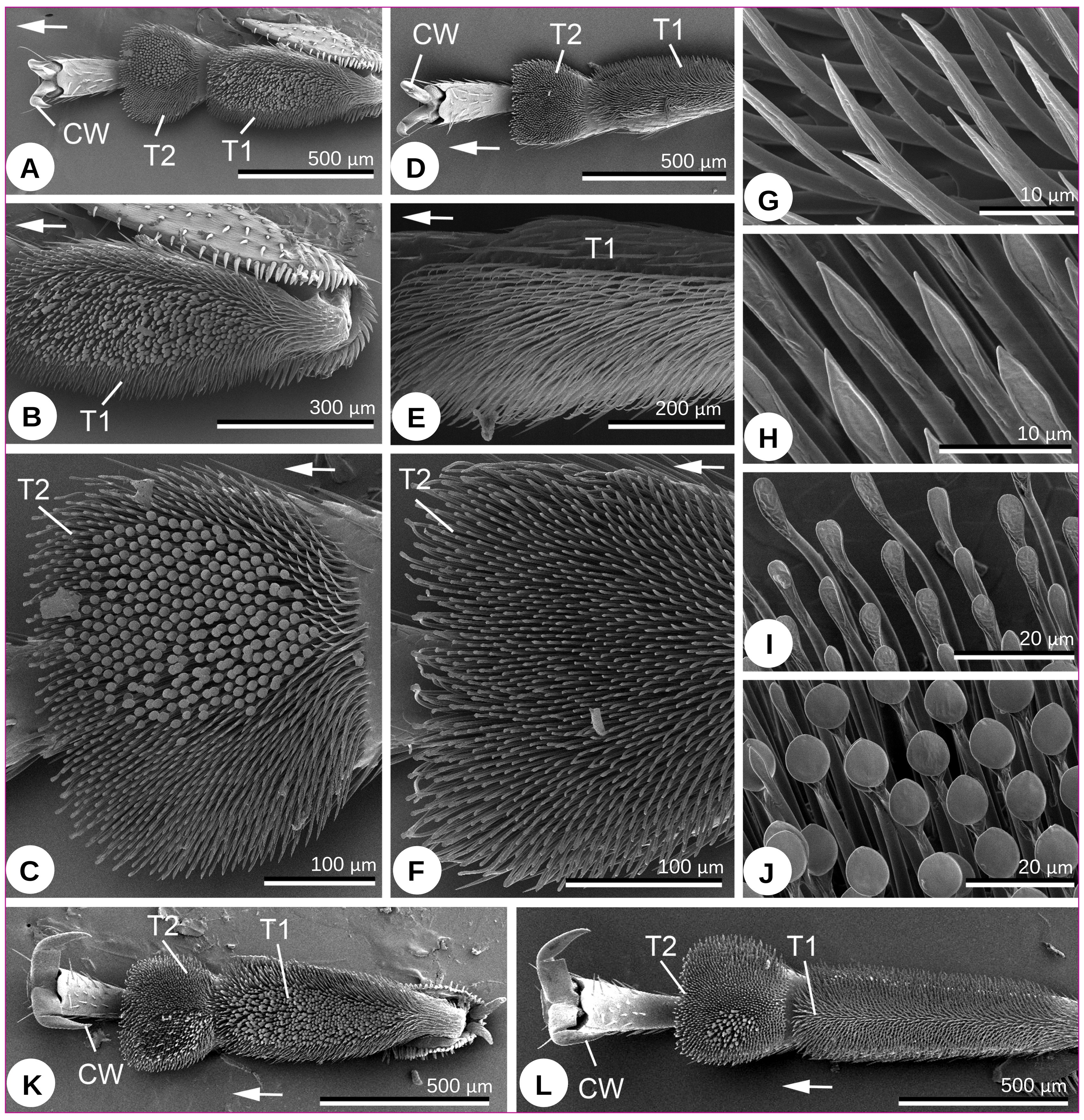
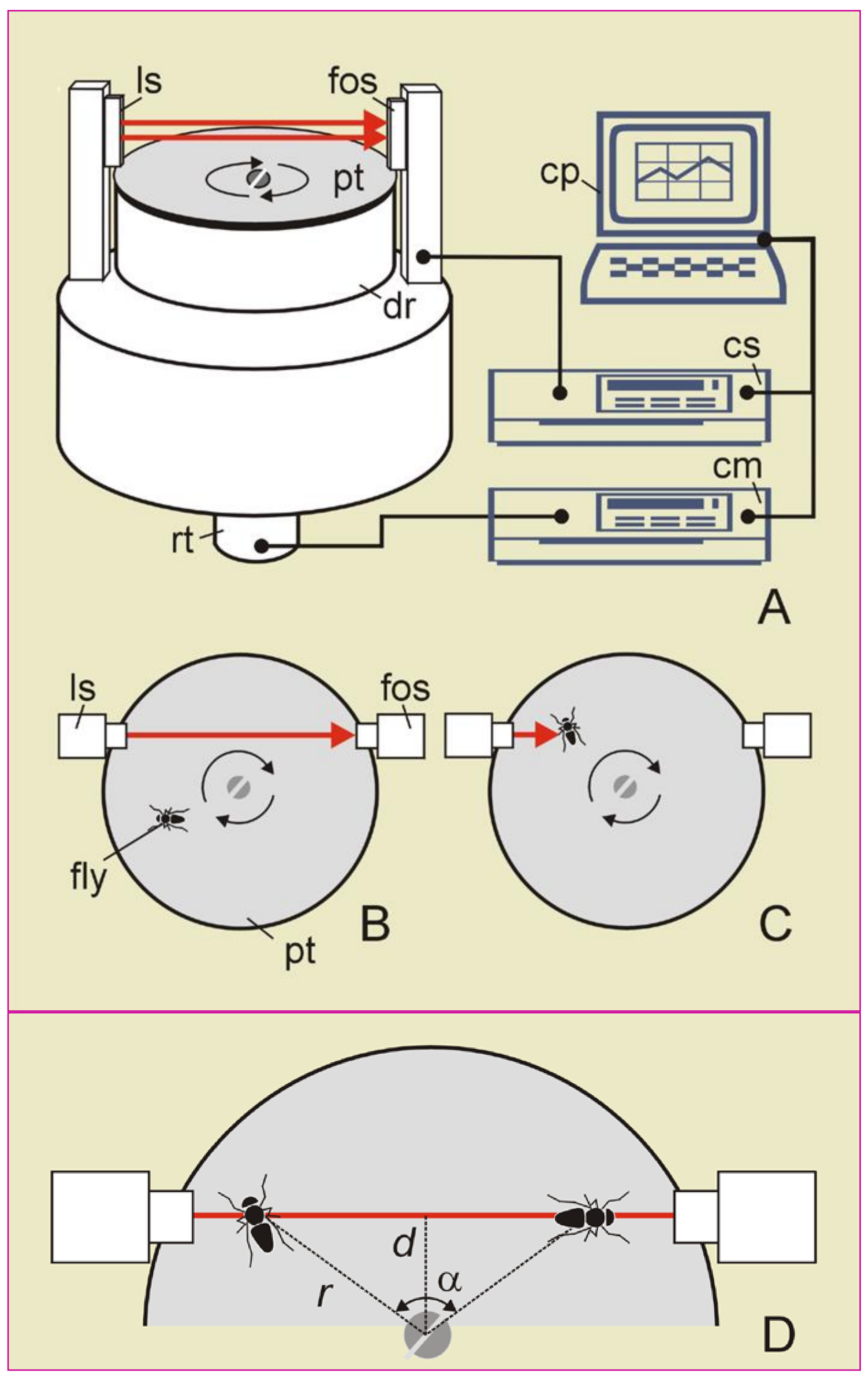


Fig. 3. Attachment organs of *C. septempunctata*, SEM: tarsus of forelegs in males (A) and females (D); the 2nd proximal tarsomere of forelegs in males (B) and females (E); the 1st proximal tarsomere of forelegs in males (C) and females (F); different types of tenent setae (G–J); tarsus of mid- (K) and hindlegs (L) in male.
Arrows in A, D, K and L show the distal direction. *CW*, claw; *T1*, the 1st proximal tarsomere; *T2*, the 2nd proximal tarsomere.

Attachment forces



- **Experimental set-up**. A centrifugal force tester (Tetra GmbH, Ilmenau, Germany; [2]) was used to measure the attachment (friction) forces of beetles on a smooth horizontal glass surface (Fig. 4).

- **Results**. Males exhibited significantly higher forces than females (males: 58.27±20.77 mN; females: 41.07±16.01 mN; t-test: d.f.=28, t=2.541, P=0.017). These results corroborate findings from previous traction force experiments on smooth glass and sapphire surfaces, indicating a consistent pattern in attachment ability differences between the sexes [3].

- **Discussion**. The differences in attachment ability between males and females are attributed to the sexual dimorphism in the structure of the terminal elements of tenent setae. Males' mushroom-shaped setae with flat discoid tips are specifically adapted for holding securely onto smooth surface of females during mating (Fig. 2). These discoid tips provide reliable adhesive contact and enhance the ability to resist crack formation at the interface between the setal tip and the substrate (Fig. 5), thereby increasing the attachment force in males.

[1] S. Gorb, *Attachment Devices of Insect Cuticle* (Kluwer, 2001).
[2] E. Gorb, S. Gorb and V. Kastner, *J. Exp. Biol.* 204, 1421 (2001).
[3] E. Gorb, N. Hosoda, C. Miksch and S. Gorb, *J. R. Soc. Interface* 7, 1571 (2010).

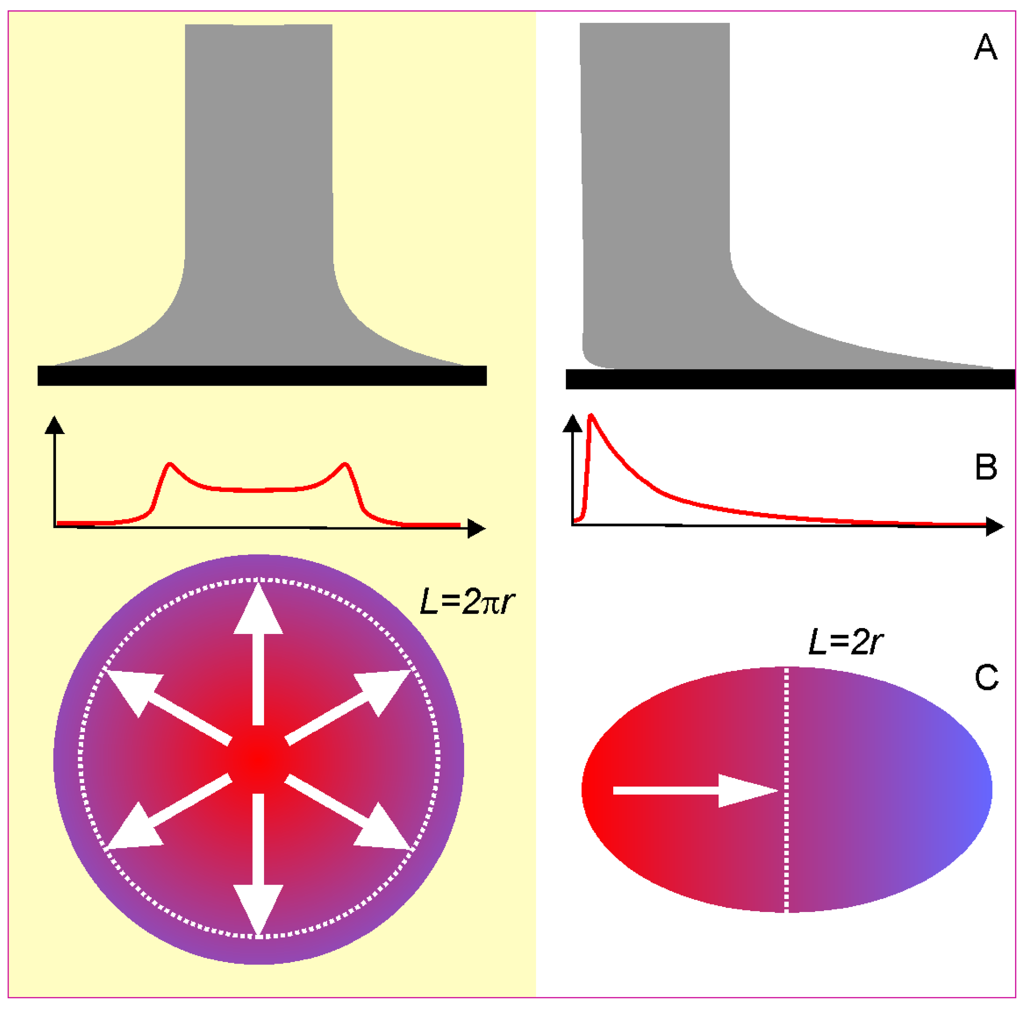


Fig. 5. Diagram showing the stress distribution (B) and crack propagation (C) at the setal tip during detachment in setae with discoid (left panel) and spatula-like (right panel) tips (A).
In C, dotted white line indicates crack propagation line near its maximum. White arrows show the direction of the crack propagation. Red to blue transition indicates contact stress distribution from high to low at the beginning of detachment.

Fig. 4. Centrifugal device for measuring friction force [2]. (A) Layout of the centrifuge. The metal drum (*dr*), covered by a glass disc (*pt*), is driven by the computer-controlled motor. The fibre-optic sensor (*fos*) is adjusted to be just above the disc. The sensor signal is monitored by a computer (*cp*). (B–D) Diagrams showing the technique used to monitor insect position (view onto the disc surface from above). The sensor is shifted to one side of the disc by a distance *d* from its centre. The insect, rotating clockwise, passes the laser beam twice per rotation, thus interrupting the sensor signal twice. Given the speed of the motor and the time between signal interruptions, the position of the insect on the disc can be calculated (D).
α, angle between detected insect positions and the drum centre; *cs*, sensor control electronics; *cm*, motor control electronics; d, displacement of the sensor from the drum centre; *ls*, light source; *r*, radius of the position of the insect from the rotor centre; *rt*, rotor of the motor.