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Research Note

Mouthparts of ladybird beetles (Coccinellidae: Coleoptera): A comparative analysis

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ABSTRACT: This study delves into the mouthpart morphology of ladybird beetles belonging to the Coccinellidae family, Coleoptera, with a focus on three representative species: *Henosepilachna vigintioctopunctata* (phytophagous), *Harmonia octomaculata* (predatory) and *Illeis cincta* (mycophagous). The research reveals distinct variations in mouthpart structures among these species, illuminating the connection between mouthpart morphology and host preferences. Predatory beetles, exemplified by *Harmonia octomaculata*, showcase specialized features such as bifid mandibular apices and larger mandibles (0.80 mm in length, 0.34 mm in width). In contrast, phytophagous ladybird beetles like *Henosepilachna vigintioctopunctata* exhibit multidentate mandibles with smaller dimensions. Additionally, the outer galea (0.30 mm) and inner lacinia (0.43 mm) of maxillae are significantly more substantial in phytophagous beetles compared to their predatory and mycophagous counterparts. These findings underscore the intricate relationship between mouthpart morphology and feeding habits in ladybird beetles, shedding light on their ecological roles, evolutionary adaptations and potential implications for pest management and entomological research.

KEYWORDS: Coccinellids, *Gnatha*, predatory and fungivory, phytophagous

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Mouthparts play a crucial role in the feeding process and have evolved differently among ladybird beetles (Coccinellidae: Coleoptera). Ladybird beetles exhibit a diverse range of feeding behaviours, employing biting and chewing-type mouthparts. While most ladybird beetles are predators, preying on soft-bodied insects like aphids, whiteflies, leafhoppers, scales and mites, some feed on plants (phytophagous) or fungi. These beetles possess typical mandibulate mouthparts, consisting of the labrum, mandible, maxillae and labium. The feeding process in ladybird beetles is intricate, involving stages such as hunting, feeding, cleaning, resting, wing maintenance and excretion (Luo *et al*., 2006; Wei *et al*., 2015).

In predatory beetles, the maxillary palpi and labial palpi serve as contact receptors (Seo & Youn, 2000). During the chewing process, the maxillary palpi retract, allowing the labial palpi to engage with the food (Wang *et al*., 2000). Each of these mouthparts plays a vital role in the feeding process, and their morphological variations are closely associated with differences in food sources and feeding behaviours (Hao *et al*., 2019). This study aims to observe ladybird beetles with various feeding habits, including phytophagous (*Henosepilachna vigintioctopunctata*), predatory (*Harmonia octomaculata*) and fungal-feeding beetles (*Illeis cincta*). Consequently, this research presents a detailed examination of the mouthpart morphology and morphometrics of these three types of ladybird beetles.

The study was carried out in a laboratory setting at the Department of Entomology, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad, during the *Kharif* season of 2019. The investigation involved the following beetle species: *Henosepilachna vigintioctopunctata* (Fabricius, 1775), found on brinjal (*Solanum melongena* L.); *Harmonia octomaculata* (Fabricius, 1781) and *Illeis cincta* (Fabricius, 1798), both associated with okra (*Abelmoschus esculentus*) (as detailed in Table 1). To prepare the specimens for examination, they were first immobilized using ethyl acetate. Subsequently, the specimens were treated with a 10 per cent KOH solution for 15-20 minutes and then allowed to cool at room temperature. Following this, a 2 per cent lactophenol solution was added to dissolve any remaining body tissues and certain semi-transparent, compact body structures. The mouthparts were carefully dissected and precise measurements of each part, including the labrum,

Table 1. Hosts for three different ladybird beetles

Sl. No.	Species	Host
1.	*Henosepilachna vigintioctopunctat*a (Phytophagous)	Feeds on the leaves of *Solanum melongena* and *Momordica charantia*.
2.	*Harmonia octamaculat*a (Predatory)	Preys upon *Amrasca biguttula biguttula*, *Bemisia tabaci* and *Aphis gossypii*.
3.	*Illies cincta* (Mycophagous)	Feeds on powdery mildew- *Erysiphe cichoracearum* in *Abelmoschus esculentus* and *Phyllactinia corylea* in *Morus alba*.

mandible, maxillae and labium, were recorded using TCapture 4.3.0.605 software. Data were collected from 10 specimens of each species to determine average measurements in millimetres.

Phytophagous (*Henosepilachna vigintioctopunctata*)

The mandible was subdivided into three distinct regions: the distal incisor region, the inner cutting region and the molar region. The incisor region is characterized by having three to four large, blunt or rounded teeth at the apex, which exhibit denticulations along their inner margins. Along the inner edge of the mandibles, used for cutting food, there are serrations present for approximately one-third of their length, extending from the apical teeth to the molar region. The molar region of the mandible is rounded and lacks a basal tooth. On the ventral side of each mandible, there exists a soft lobe known as the prostheca, although it remains inconspicuous in this particular species. The labium exhibits a narrowing towards its interior, and the point of antennal insertion is notably distant from the compound eyes (Figure 1).

Predacious (*Harmonia octomaculata*)

The distal incisor region of the mandible can be either simple or bifid, featuring a division in the terminal part (Figure 1). The inner cutting edge is smooth, while the molar region is characterized by the presence of a basal tooth, consisting of two teeth i.e., dorsal and ventral, that project outward. Typically, the dorsal basal tooth is larger, with variations in shape ranging from small and blunt to large and pointed. The prostheca extends ventrally from the mandible's base, attaching to it along half of its length and adorned with setae. The labium possesses a broad mentum and the point of antennal insertion is situated between the compound eyes and the mandibles.

Mycophagous (*Illeis cincta*)

The mandibular apex is bifid (Figure 1), featuring a ventral apical tooth adorned with a series of serrations, forming a comb-like structure utilized for gathering fungal spores. This process involves inserting the comb between the spore-bearing fungal hyphae and moving it upwards to detach and ingest the spores. The labium possesses a broad mentum and the point of antennal insertion is positioned between the compound eyes and the mandibles.

The morphometrics of mouthparts, such as the mandible in predatory beetles, exhibited greater dimensions with a length of 0.804 mm and a width of 0.336 mm compared to their phytophagous and fungal-feeding counterparts. Additionally, the outer galea (0.30 mm) and inner lacinia (0.413 mm) of the maxillae were considerably larger in phytophagous beetles in comparison to both predatory and mycophagous beetles (Table 2).

The mouthparts of Coleoptera, which encompass a wide range of beetle species, are characterized by their chewing type, playing pivotal roles not only in feeding but also in other crucial biological activities such as creating holes for oviposition, as highlighted by Moon *et al*. (2008). While the fundamental components of mouthparts remain consistent within a specific insect group, their morphology can diverge among species within that group, a phenomenon driven by adaptations to different food sources, as observed by Karolyi *et al.* (2016) and Kuznetsov (1997). Interestingly, Samways *et al*. (1997) pointed out that the shape of a ladybird beetle's mandible is often employed to differentiate between phytophagous (plant-eating), mycophagous (fungus-eating) and carnivorous (prey-eating) species. This distinction in mandible shape signifies the method of feeding rather than the specific diet, underlining the significance of mouthpart adaptations in the context of ecological niches.

Intriguingly, Hao *et al.* (2019, 2020) conducted a detailed examination of sensilla types on the mouthparts of *Coccinella transversoguttata* and *Hippodamia variegata*, revealing diverse sensilla variations in terms of their length and distribution. These sensilla structures play essential roles in the feeding mechanisms of these ladybird beetles. Moreover, Pradhan (1938) noted disparities in the mandibles of predatory and phytophagous species, particularly in the incisor and molar regions. Similarly, Smith (1893) documented variations in the mandibles of *Coccinella*

Table 2. Morphometrics of mouthparts of phytophagous, predatory and mycophagous ladybird beetles

Sl. No.	Mouthparts of ladybird beetles	Phytophagous *Henosepilachna vigintioctopunctata* (mm)	Predacious *Harmonia octomaculata* (mm)	Mycophagous *Illeis cincta* (mm)	CD (P=0.01)	CV (%)	SEm (±)
1.	Body length	8.90	8.20	5.50	0.938	4.114	0.179
2.	Body width	5.30	5.40	3.80	0.604	4.127	0.115
3.	Interocular distance	0.80	0.60	0.40	0.068	3.737	0.013
4.	Labrum-length	0.30	0.30	0.20	0.030	3.661	0.006
5.	Labrum-width	0.51	0.53	0.51	0.056	3.606	0.011
6.	Mandible-length	0.70	0.80	0.60	0.077	3.630	0.015
7.	Mandible-width	0.32	0.34	0.20	0.032	3.688	0.006
8.	Maxillae-length	0.60	0.62	0.59	0.066	3.606	0.013
9.	Galea-length	0.30	0.24	0.19	0.027	3.667	0.005
10.	Lacinea-length	0.43	0.27	0.23	0.035	3.743	0.007
11.	Maxillary palpi- length	0.80	0.80	0.70	0.084	3.612	0.016
12.	Labium-length	0.26	0.35	0.37	0.036	3.644	0.007
13.	Labial palpi-length	0.33	0.26	0.29	0.032	3.623	0.006

novemnotata and *Epilachna borealis*, shedding light on the intricate relationship between mouthpart morphology and feeding strategies within the diverse world of ladybird beetles.

The most notable distinction in mandible morphology within the Coccinellidae family lies between phytophagous (plant-feeding) and predatory beetles. Phytophagous Coccinellidae, often found in the subfamily Epilachninae, possess multidentate mandibles of the chewing type. These mandibles are designed for scraping the surface of leaves, allowing the beetles to ingest plant juices while avoiding solid plant material. The setal areas of their mouthparts serve as traps for the plant juices, aiding in their consumption. In contrast, carnivorous Coccinellidae have mandibles resembling the typical biting type found in beetles. However, ladybirds employ a distinct feeding method by piercing and sucking their prey rather than crushing it. This is accomplished using a bifid or unidentate (single-pointed) tip, which enables them to pierce their prey rather than chewing it. This specialized adaptation, exemplified in species like *Chilocorus nigritus*, allows ladybirds to feed on hard and mature female diapsid scales, making them effective biocontrol agents (Samways & Wilson, 1988).

Interestingly, when it comes to feeding on pollen, many carnivorous coccinellid species do not exhibit significant morphological changes in their mandibles. These beetles often turn to pollen as an alternative food source when their usual prey is scarce. In the genus *Bulaea*, which exclusively feeds on pollen, the mandibles closely resemble those of aphid or coccid-feeding coccinellids, featuring a bifid tip and a typical basal tooth.

Conversely, mycophagous (fungus-feeding) coccinellids appear to have developed distinct adaptations for feeding on fungi. In the tribe Psylloborini, these beetles possess secondary teeth on the ventral apical tooth of their mandibles, which can be effectively employed for combing fungal spores (Sutherland & Michael, 2009). In the tribe Tytthaspini, adult mandibles have evolved a comb-like prostheca, which may serve as a tool for collecting fungal spores (Ricci & Stella, 1988). These adaptations highlight the incredible versatility and diversity in mandible morphology among ladybird beetles as they adapt to different dietary preferences and food sources.

In conclusion, while a comprehensive examination of the mouthparts provides valuable insights into feeding preferences among lady beetles, it is important to recognize its limitations in definitively characterizing specific feeding behaviours. To gain a more precise understanding of these behaviours and their influence on mouthpart adaptations, further investigations and detailed analyses of gut contents are essential. The present study lays the foundation for understanding feeding tendencies based on mouthpart structures, serving as a starting point for more in-depth investigations into the intricate world of lady beetle feeding behaviours.

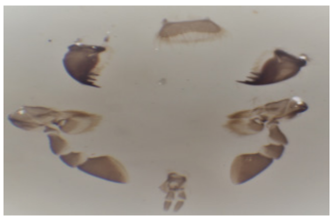
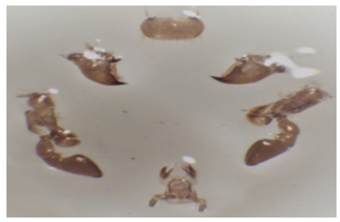
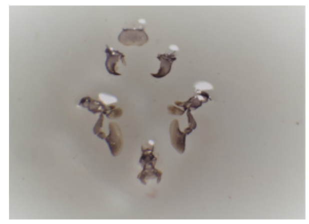
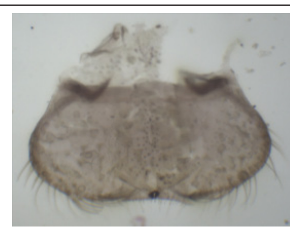
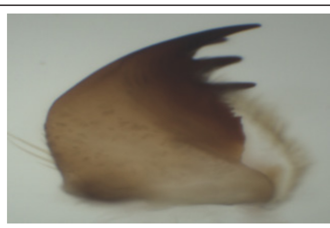
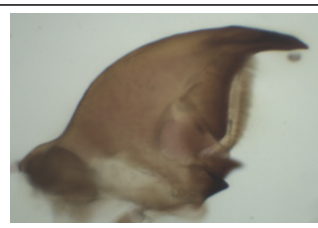
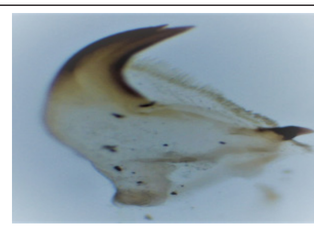
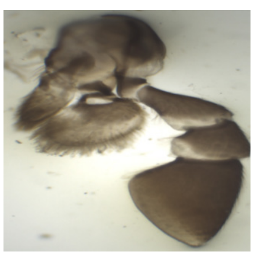
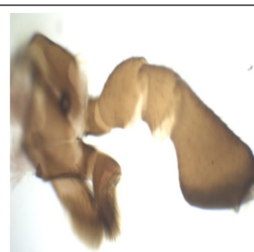
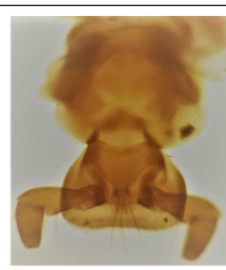
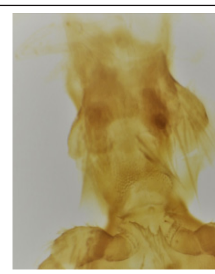
	Henosepilachna vigintioctopunctata	*Harmonia octomaculata*	*Illeis cincta*
			
A. Head			
B. Mouthparts			
C. Labrum (Upper lip)			
D. Mandible (Jaw)			
E. Maxilla with maxillary palpi			
F. Labium (lower lip) with labial palpi			

Figure 1. Mouthparts in phytophagous, predatory and mycophagous ladybird beetles.

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