

Nest Associated Mites (Acari: Winterschmidtidae) of Stingless Bee *Tetragonula fuscobalteata* in Central Sulawesi, Indonesia

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Abstract

Stingless bees are essential pollinators in tropical ecosystems and play an important role in sustaining biodiversity and agricultural productivity. In Central Sulawesi, Indonesia, *Tetragonula fuscobalteata* is widely cultivated in small-scale meliponiculture systems. However, information regarding mites associated with its nests remains limited. This study aimed to identify and describe nest-associated mites found in *T. fuscobalteata* colonies. The research was conducted in Dolago Village, Parigi Moutong Regency, Central Sulawesi. Nest samples were collected from five active colonies. Mites were observed under a stereo microscope, collected using a fine brush, and mounted on slides with polyvinyl alcohol. Identification was based on morphological characteristics using standard taxonomic keys, and morphometric measurements were obtained using Image Raster 3.0. All specimens were identified as deutonymphs of the genus *Saproglyphus* (Acari: Winterschmidtidae). Mites were found in storage pots and cerumen structures but were absent from brood cells. The deutonymphs exhibited a well-developed sucker plate, reduced chelicerae, and fused coxae III, indicating phoretic adaptation. The mean body length was $192.72 \pm 22.14 \mu\text{m}$ and width was $145.78 \pm 12.62 \mu\text{m}$. These findings provide baseline data on mite associations in *T. fuscobalteata* nests and contribute to understanding arthropod interactions in meliponiculture systems.

Keywords: Meliponini; Mites; Stingless bee; Sulawesi; *Tetragonula*.

INTRODUCTION

Stingless bees (Hymenoptera: Apidae: Meliponini) are key pollinators in tropical and subtropical ecosystems, contributing significantly to plant reproduction, biodiversity maintenance, and agricultural productivity (Hernandez *et al.*, 2022). Through their foraging activities, they facilitate cross-pollination in a wide range of wild and cultivated plant species, thereby supporting ecosystem resilience and food security (Patil *et al.*, 2024). In Indonesia, stingless beekeeping (meliponiculture) has increasingly developed as a sustainable livelihood strategy due to the high economic value of honey, propolis, pollen, and other hive products (Humaida *et al.*, 2023). Compared to honey bees, stingless bees are well adapted to tropical climates and can be maintained with relatively simple management techniques, making them suitable for small-scale rural enterprises (Cortopassi-Laurino *et al.*, 2006). Among the commonly cultivated species in Sulawesi is *Tetragonula fuscobalteata*, a stingless bee adapted to humid tropical environments and frequently maintained by small-scale beekeepers in rural landscapes. This species constructs nests composed of cerumen, storage pots, brood cells, and protective involucrum layers, forming a complex

internal architecture. Despite the growing interest in meliponiculture and the economic importance of this species, ecological interactions within stingless bee nests, particularly with arthropod associates such as mites, remain poorly documented (Aziz, 2023).

Mites (Acari) are among the most diverse and ecologically versatile arthropods associated with insect nests (Da-Costa *et al.*, 2021). With thousands of described species occupying a broad range of ecological niches, mites exhibit remarkable adaptability to microhabitats characterized by high humidity, organic matter, and stable temperatures conditions typical of social insect nests (Da-Costa *et al.*, 2021). They may function as scavengers feeding on organic debris, fungivores consuming fungal growth, predators of small arthropods or eggs, commensals utilizing nest resources without harming the host, or parasites directly affecting the host organism (Potapov *et al.*, 2022). In bee colonies, mites can inhabit nest substrates, storage pots, brood cells, and cerumen structures, exploiting available food sources such as pollen residues, microorganisms, and decomposing materials. Some species establish neutral or even mutualistic relationships by feeding on detritus and microorganisms, potentially contributing to nest hygiene and nutrient recycling. In contrast, other species may

negatively affect colony health by competing for food resources, damaging brood, or acting as vectors of pathogens (Rosa-Fontana *et al.*, 2022). Consequently, understanding mite diversity, developmental stages, and spatial distribution within bee nests is essential for evaluating colony stability, potential risks, and appropriate management practices in meliponiculture (Da-Costa *et al.*, 2021).

Previous studies have reported various mite taxa associated with both stinging and stingless bees worldwide, demonstrating that bee nests represent important habitats for mite colonization (Goh *et al.*, 2023). Members of the suborder Astigmata, particularly those within the family Winterschmidtidae, are frequently encountered in association with Hymenoptera (Barbosa & Moraes, 2021). Many astigmatid mites exhibit phoretic deutonymphal stages (hypopi), which are morphologically specialized for dispersal. These deutonymphs possess attachment organs that allow them to temporarily adhere to adult insects, facilitating transportation to new nesting sites. Such phoretic adaptations are considered evolutionary strategies for surviving unstable or spatially isolated habitats (Klimov *et al.*, 2025). However, information regarding mite assemblages in nests of Indonesian stingless bees, including *T. fuscobalteata*, remains limited. Most available data focus on economically important species such as *Apis mellifera*, particularly in relation to parasitic mites that impact apiculture (Efin *et al.*, 2019). This emphasis has resulted in a substantial knowledge gap concerning nest-associated mites in native meliponine bees, especially in biodiverse tropical regions (Vit *et al.*, 2025).

Central Sulawesi, Indonesia, represents a region of high biological diversity and increasing meliponiculture activities (Salatnaya *et al.*, 2023). Rural areas such as Dolago Village in Parigi Moutong Regency are characterized by mixed agricultural landscapes, home gardens, secondary vegetation, and patches of natural forest. These heterogeneous environments provide

abundant floral resources and suitable nesting habitats for stingless bees (Rasyiid *et al.*, 2025). At the same time, such environmental conditions create stable, resource-rich microhabitats within bee nests that may support diverse mite communities (Rasyiid *et al.*, 2025). Factors such as humidity, temperature stability, organic substrate availability, and the presence of pollen and honey residues may influence mite colonization and persistence. Investigating mite presence in this ecological setting is therefore important not only from a taxonomic perspective but also for understanding the broader ecological interactions occurring within managed stingless bee colonies (Vilarem *et al.*, 2021). Comprehensive documentation of mite occurrence in *T. fuscobalteata* nests will contribute to baseline biodiversity data and support the sustainable development of stingless beekeeping in Central Sulawesi. This study aimed to identify mites associated with the nests of the stingless bee species *T. fuscobalteata*.

MATERIALS AND METHODS

Study area

This study was conducted in November 2025 in Dolago Village, South Parigi District, Parigi Moutong Regency, Central Sulawesi, Indonesia (Figure 1). The research site is characterized by small-scale stingless bee farming activities, where colonies of *Tetragonula fuscobalteata* are traditionally maintained by local beekeepers. The managed nests are placed in close proximity to agricultural fields, home gardens, and areas of mixed vegetation. The surrounding landscape consists of a mosaic of cultivated crops, flowering ornamental plants, shrubs, and naturally growing vegetation, providing a heterogeneous microhabitat structure around the bee colonies. Such environmental conditions create suitable nesting and foraging habitats for stingless bees while also supporting diverse arthropod communities, including nest-associated mites.

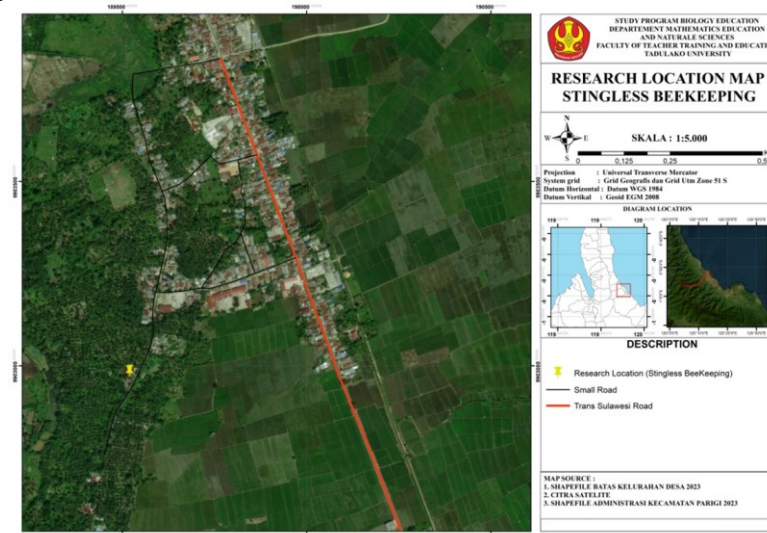


Figure 1. Map of the research location in Dolago Village, South Parigi District, Parigi Moutong Regency, Central Sulawesi, Indonesia.

Procedures

Stingless Bee Nest Sampling

Nest samples were collected from five colonies of *T. fuscobalteata* (Figure 2). Portions of the nest material were carefully removed using sterile forceps to minimize disturbance to the colony structure and to prevent contamination. Each sample was immediately placed into a transparent plastic bag and properly labeled with

relevant information, including colony code, date of collection, and sampling location. The collected nest materials were subsequently transported to the laboratory for mite examination and further morphological analysis. These samples served as the primary material for observing the presence, distribution, and developmental stages of mites associated with the nests.

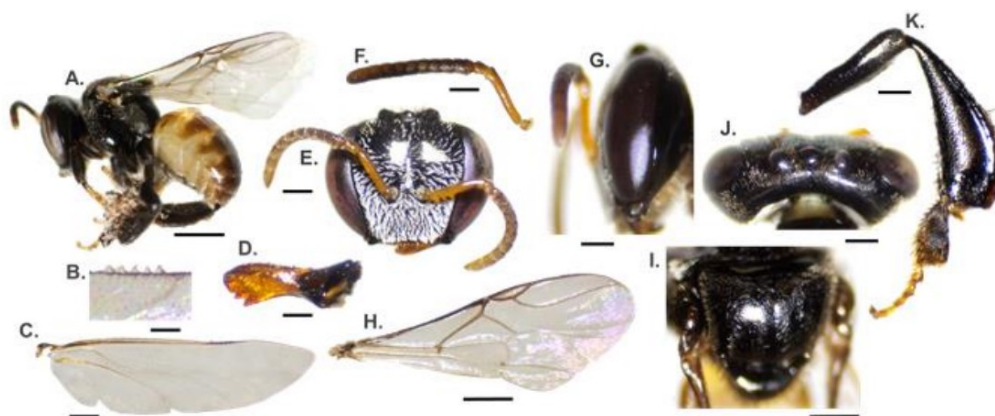


Figure 2. *Tetragonula fuscobalteata* (Cameron, 1908). A. Habitus, lateral view; B. Hamulli; C. Hindwing; D. Mandibles; E. Head; F. Antenna; G. Compound eye; H. Forewing; I. Mesoscutum; J. Ocelli; and K. Hind leg. Scale bar = 1 mm (Trianto *et al.*, 2024).

Collection, Preservation, and Identification of Mites

Nest samples obtained from each bee species were examined under a stereo microscope to detect the presence of mites. Observed mites were carefully collected using a fine brush to avoid damaging their body structures. The collected specimens were transferred onto microscope slides and rinsed with several drops of 70% ethanol to remove residual nest debris and other adhering materials. Excess ethanol was gently absorbed using tissue paper. The mounting medium was then replaced with polyvinyl alcohol (PVA), and the specimens were covered with a cover slip. The prepared slides were placed on a hot plate until the polyvinyl alcohol completely dried, ensuring proper fixation and clarity of morphological structures for microscopic examination. Mite specimens were subsequently identified based on morphological characteristics using the taxonomic keys and descriptions provided by Kranz (1978) and Klimov *et al.* (2016).

Data analysis

Six morphological parameters of the mites were measured: body length, body width, and the lengths of legs I, II, III, and IV. All measurements were performed using the Image Raster 3.0 application to ensure accuracy and consistency. Body length was measured from the anterior margin of the propodosoma to the posterior margin of the hysterosoma. Body width was determined by measuring the maximum distance across the body at the level of the sejugal furrow, from one lateral edge to the opposite edge. The lengths of legs I–IV were

measured from the distal tip of the tarsus to the proximal base of the femur. These standardized measurement criteria were applied to all specimens to obtain comparable morphometric data for subsequent analysis.

RESULTS AND DISCUSSION

Morphological of Mites

The mites discovered in the nests of *T. fuscobalteata* were identified as belonging to the genus *Saproglyphus* (suborder Astigmata) (Figure 3). All observed individuals were in the deutonymphal stage, which represents a dispersal or phoretic phase in many astigmatid mites. Members of the genus *Saproglyphus* exhibit a small, rounded body form. The deutonymph measured approximately 191 μm in total body length. On the dorsal surface, a distinct sejugal furrow is present, clearly demarcating the propodosoma from the hysterosoma. This morphological feature serves as an important taxonomic characteristic within Astigmata. The ventral surface is characterized by the presence of a well-developed sucker plate (attachment organ), which functions in adhesion to substrates or host organisms during phoresy. A single median eye (ocellus) is also present, with clearly visible pigmentation and lens structure. Several diagnostic morphological traits distinguish *Saproglyphus* from related taxa. The chelicerae are reduced and associated with palps, reflecting adaptations related to feeding or attachment. Coxae III on both the right and left sides are fused

medially. Additionally, the mite possesses two apical setae that are approximately twice the length of leg IV. The legs progressively decrease in size toward the posterior region of the body, with the fourth pair being

the shortest. These morphological characteristics collectively confirm the identification of the specimens as *Saproglyphus* deutonymphs and provide essential diagnostic features for taxonomic and ecological studies.

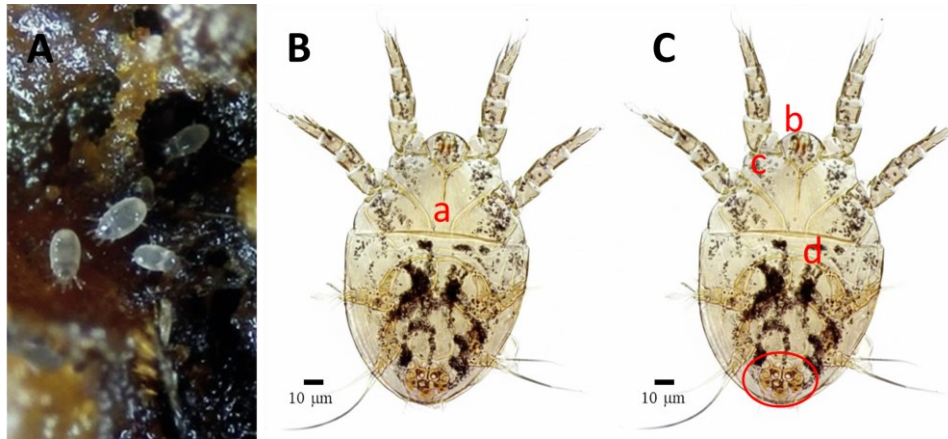


Figure 3. A. *Saproglyphus* mites found in the nest of *T. fuscobalteata*, B. Dorsal and C. Ventral views of the mite body morphology: a. Sejugal furrow, B. Chelicerae with palps, c. Single eye (ocellus), d. Coxa of leg III, and e. Sucker plate.

Saproglyphus mites possess four pairs of legs supported by four apodemes. Legs I–II and apodemes I–II are located on the propodosoma, whereas legs III–IV and apodemes III–IV are situated on the hysterosoma. This regional distribution reflects the typical segmentation pattern observed in astigmatid mites. Each leg is composed of distinct segments, namely the femur, genu, tibia, and tarsus, which together facilitate locomotion and attachment. Legs I to III are equipped with an empodial claw and a well-developed pulvillus, structures that function in grasping and maintaining adherence to

substrates or host surfaces. In contrast, leg IV lacks both the empodial claw and pulvillus, indicating functional differentiation among the posterior appendages. Notably, leg IV bears two elongated apical setae that are approximately twice as long as the leg itself (Figure 4). These elongated setae may play a sensory role or contribute to attachment and stability during phoretic behavior. The morphological differentiation among the leg pairs highlights structural specialization associated with movement, attachment, and ecological adaptation in the deutonymphal stage of *Saproglyphus*.

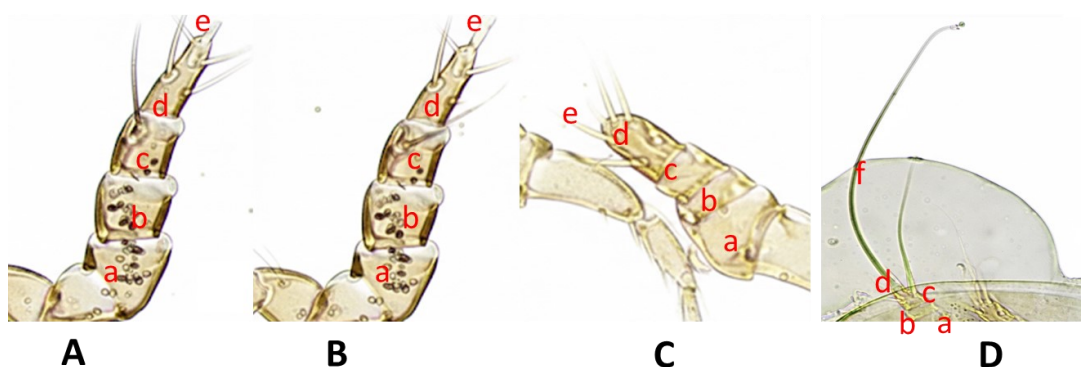


Figure 4. Leg morphology of *Saproglyphus*: A. Leg I, B. Leg II, C. Leg III, and D. Leg IV: a. Femur, b. Genu, c. Tibia, d. Tarsus, e. Empodial claw and pulvillus, and f. Apical seta.

Morphometrics of Mites

Saproglyphus mites exhibited a mean body length of $192.72 \pm 22.14 \mu\text{m}$ and a mean body width of $145.78 \pm 12.62 \mu\text{m}$. The average leg lengths were $95.15 \pm 12.46 \mu\text{m}$ for leg I, $82.87 \pm 19.78 \mu\text{m}$ for leg II, 43.55 ± 9.79

μm for leg III, and $28.31 \pm 5.98 \mu\text{m}$ for leg IV (Table 1). These measurements demonstrate a clear progressive reduction in leg length toward the posterior region of the body, with leg I being the longest and leg IV the shortest. The relatively higher standard deviation observed in leg

It suggests greater variability in the length of this appendage among individuals. Overall, the proportional differences in appendage length reflect morphological

differentiation and structural specialization characteristic of the deutonymphal stage of *Saproglyphus*.

Table 1. Morphometrics of *Saproglyphus*

Individual	Body Length (µm)	Body Width (µm)	Leg Length to- (µm)			
			1	2	3	4
1	226.31	152.32	92.76	75.25	44.08	33.85
2	186.65	135.65	103.11	97.02	57.75	35.74
3	166.63	139.71	100.63	96.34	56.26	27.03
4	179.64	155.93	101.10	95.03	39.67	28.68
5	187.13	137.77	77.67	58.60	41.02	20.27
6	221.84	168.35	108.69	111.14	44.91	29.46
7	171.57	129.79	74.87	57.40	28.33	19.26
8	202.01	146.73	102.35	72.18	36.35	32.18
Average ± SD	192.72 ± 22.14	145.78 ± 12.62	95.15 ± 12.46	82.87 ± 19.78	43.55 ± 9.79	28.31 ± 5.98

Discussion

The nests of *T. fuscobalteata* examined in this study were active colonies, as indicated by the continuous presence of adult worker bees and normal nest activity. The internal nest architecture consisted of storage pots, cerumen structures, involucrum layers, and brood cells containing developing immatures. Mite occurrence was spatially restricted within the nest. Specifically, mites were found inhabiting the storage pots and cerumen, whereas no individuals were detected in the involucrum or within brood cells (Suriawanto *et al.*, 2017). The absence of mites in brood chambers suggests that, under the observed conditions, the mites did not directly associate with immature bee stages or interfere with brood development. Instead, their distribution indicates a preference for nest substrates associated with food storage and wax-like materials (Morin & Giovenazzo, 2023).

All mites collected from the nests were identified as belonging to the genus *Saproglyphus*. Taxonomically, this genus is placed within Class Arachnida, Subclass Acari, Order Acariformes, Suborder Astigmata, Family Winterschmidtidae, Genus *Saproglyphus* (Jacinavicius *et al.*, 2025). The family Winterschmidtidae has historically been treated as synonymous, reflecting revisions in higher-level acarological classification. Members of this family are commonly associated with insect nests and are frequently encountered in close ecological relationships with Hymenoptera (Barbosa & Moraes, 2021).

In the present study, all observed individuals were in the deutonymphal stage. Importantly, mites were not found attached to the bodies of adult bees at the time of sampling, indicating that their primary location within the colony was the nest substrate rather than the host integument. This observation suggests that the deutonymphs may have been in a quiescent or pre-dispersal phase, or that phoretic attachment occurs only temporarily during specific dispersal events (Han *et al.*,

2024). The life cycle of mites generally includes the following developmental stages: prelarva, larva, protonymph, deutonymph, and tritonymph (adult) (Jacinavicius *et al.*, 2018). The prelarval stage is a transitional, non-feeding, and non-motile phase that remains enclosed within the egg chorion. In some species, the prelarva appears smaller than the eggshell itself and lacks developed appendages and functional mouthparts. Development from prelarva to larva in certain mite groups, such as Prostigmata, may occur within approximately 36 hours under favorable environmental conditions (Franz *et al.*, 2000).

The larval stage is characterized by the presence of three pairs of legs, the absence of clearly differentiated sexual organs, and minimal or weak sclerotization of the body (DeWalt *et al.*, 2010). In Astigmatina larvae, sclerotization of the idiosoma is typically limited to the podosoma region, and the ventral shields are indistinct (Griffiths *et al.*, 2009). This relatively soft-bodied morphology reflects a developmental stage focused on growth rather than dispersal specialization. Following the larval stage, mites enter the nymphal phase, which is subdivided into protonymph, deutonymph, and tritonymph stages (Deere & Smallegange, 2023). The protonymph is generally free-moving and, depending on the species, may exhibit reduced feeding activity while adapting to environmental conditions (Deere & Smallegange, 2023). The deutonymph, which was the only stage observed in this study, represents the second nymphal stage and is often regarded as a non-sexual adult form (Seniczak *et al.*, 2022). In Astigmata, the deutonymph is morphologically specialized and commonly referred to as the hypopus (Klimov *et al.*, 2021).

The hypopus is highly resistant to environmental stress, including desiccation and limited food availability. This stage is adapted for dispersal and is equipped with specialized attachment structures, such as a sucker plate or attachment organ, which enable the mite

to adhere to other insects or surrounding substrates (Collins, 2012). Through phoresy, deutonymphs can be transported to new habitats, ensuring colonization of suitable environments such as fresh nests or new host colonies (Seeman & Walter, 2023). The final nymphal stage, the tritonymph, subsequently develops into the sexually mature adult. Adult mites reproduce sexually; sperm is stored within the female's seminal vesicle and later released into the oviduct to fertilize eggs during ovulation (Vidal-Quist *et al.*, 2025).

Previous studies have documented phoretic associations between *Saproglyphus* mites and various insect hosts. Kuhlmann (1998) reported phoretic deutonymphs of *Saproglyphus hagensis* on the bee *Hylaeus nivalis*. Similar deutonymphal stages have been recorded on wood-boring beetles, dung beetles, longhorn beetles, leaf beetles (*Aphthona*), flies, and even rodents, demonstrating ecological flexibility in dispersal strategies. Haragsim *et al.* (1978) documented two *Saproglyphus* species associated with stinging bees in the nests of *Apis mellifera* and *Osmia*, while *S. reticulatus* was found on *Hoplitis*. These findings suggest that deutonymphs may opportunistically attach to bees that enter or interact with the mite's habitat (Michalska *et al.*, 2025).

Furthermore, mites of the subfamily Ensliniellinae (Family Winterschmidtidae) have been reported from various Hymenoptera families, including Vespidae, Sphecidae, Megachilidae, and Colletidae (Borchardt *et al.*, 2024). In these associations, mites typically inhabit the nest environment, while the deutonymphal stage disperses on adult insects (Athias-Binche, 2011). This ecological pattern aligns with the observations in the present study, where mites were located within nest substrates rather than directly on adult bees. Based on the present findings and previously published reports, *Saproglyphus* mites appear capable of inhabiting diverse bee colonies, including both stinging and stingless species. Their presence within storage pots and cerumen suggests a nest-associated lifestyle, potentially linked to organic debris, stored food materials, or microhabitats favorable for development (Ariyaratne *et al.*, 2024). The exclusive detection of the deutonymphal stage highlights the ecological importance of this dispersal form and underscores its adaptive significance in maintaining mite populations across different bee nesting systems (Bowman, 2023).

CONCLUSIONS

The mites found in the nests of *T. fuscobalteata* were identified as belonging to the genus *Saproglyphus*. The morphological characteristics of these mites include reduced chelicerae associated with palps, fused coxae III on the right and left sides, and two apical setae that are approximately twice the length of leg IV. Additionally, the legs progressively decrease in size toward the

posterior region of the body. These mites also possess a sucker plate and a distinct sejugal furrow.

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Competing Interests: The authors declare that there are no competing interests.

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