

A new genus and new species of eriophyid mites from Papua New Guinea: a potential biological control agent of *Falcataria moluccana* (Fabaceae)

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Original research

ABSTRACT

A new genus and species of the subfamily Nothopodinae, Colopodacini from Papua New Guinea are described and illustrated. *Solenidiversum falcatariae* **gen. nov. sp. nov.** infests *Falcataria moluccana* (Miq.) Barneby & Grimes (Fabaceae) and causes erineum on both the leaf surfaces. *Solenidiversum* **gen. nov.** has the solenidion on the inner side of tarsus I, tibiae of both legs completely fused with tarsus, all leg and ventral opisthosomal setae present, empodium entire and scapular tubercles on rear shield margin. With this new genus and species, the current number of Colopodacini is 16 genera and 41 species. A key to the genera of the Colopodacini tribe is given.

Keywords Eriophyidae; Colopodacini; taxonomy COI

Zoobank <http://zoobank.org/F92CDDEF-9C2A-489E-8166-895DE352D43C>

Introduction

Eriophyidae Nalepa (Acariformes: Prostigmata), as one of the smallest arthropods (body length around 200 µm) are obligate phytophagous species (Lindquist and Oldfield 1996). About 80% of described species are monophagous, registered on only one host plant (Skoracka *et al.* 2010). Some of them are significant pests in agriculture (Lindquist *et al.* 1996) at the same time, a certain number of species are considered potential agents for classical biological control of weeds (Smith *et al.* 2010; Marini *et al.* 2021). The attributes of eriophyid mites that qualify them as classical biological control agents of weeds are their high host specificity, dispersal by wind, high rates of reproduction, short generation times and their significant impact on plants (Lindquist *et al.* 1996; Cullen and Briesse 1998).

Batai wood, *Falcataria moluccana* (Miq.) Barneby & Grimes (Fabaceae) is a large, fast-growing deciduous tree, native to parts of Indonesia and Papua New Guinea (PNG) (Wagner *et al.* 1999). It was introduced into Hawaii in 1917 for reforestation and as an ornamental plant, but it became invasive as well as on other Pacific and Indian Ocean islands (Hughes *et al.* 2011).

In the pursuit of a potential biological control agent for batai wood, eriophyid leaf gall mites have been identified and selected for further examination due to their potentially significant destructive capabilities. To date, a total of 47 eriophyid mite species have been described on

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host plants belonging to genera within the mimosoid clade (subfamily Caesalpinioidea DC.). The species described are from the genera *Abacarus* Keifer, *Aceria* Keifer, *Aculops* Keifer, *Aculus* Keifer, *Heterotergum* Keifer, *Paratetra* ChannaBasawanna, *Pentamerus* Roivainen, *Phyllocoptes* Nalepa, *Porcupinotus* Mohanasundaram, *Tegonotus* Nalepa, *Tetra* Keifer and only one species has been described from the genus of the subfamily Nothopodinae; tribe Nothopidini – *Cosella deleoni* (Keifer) on the host plant *Pinthecollobium guadalupense* (Pers.) Chapm. (Amrine & Stasna 1994; Chandrapatya et al, 2017).

The current literature has no records of eriophyid mites on *Falcataria moluccana* (syn. *Albizia moluccana* Miq.).

In this paper, one new genus and one new species of the subfamily Nothopodinae, tribe Colopodacini, are described. The mites were associated with *Falcataria moluccana*, causing erineum on both surfaces of the leaf, and were collected in Papua New Guinea. A key to the genera of the tribe Colopodacini described to date is provided.

Material and methods

Collection and morphological measurements

Plant samples of *Falcataria moluccana* were collected at Fanamafai Village, along Fangalao Crossing, Kavieng District of New Ireland Province in Papua New Guinea. (02°52'19.21"S; 151°09'20.37"E).

The collected leaf pinnae of the plant were kept in sealed sample bottles containing 95-96% ethanol. The plant material thus collected was sent to Serbia and in the laboratory the mites were removed from the leaf samples by direct examination under a stereomicroscope and/or by extraction methods (de Lillo 2001; Monfreda *et al.* 2007), they were then mounted in Keifer's F medium (Amrine and Manson 1996). Structures relevant for taxonomic identification were examined using an Olympus BX53 research microscope with phase contrast and measured using the software package cellSens Entry 2 (CS-EN-V2) on the same microscope. Specimens were illustrated using a camera lucida on a Leica DMLS research microscope with phase contrast.

The morphology and nomenclature follow Lindquist (1996), the genus classification is based on Amrine *et al.* (2003) and the nomenclature of the internal female genitalia follows Chetverikov (2014). Measurements and illustrations were made according to Amrine and Manson (1996) and de Lillo *et al.* (2010). All measurements are given in micrometers (µm) and, unless otherwise stated, signify the length of the structure.

Plant names are in accordance with The Plant List (2013) on-line database. The holotype and the paratype slides are deposited in the collections of the Acarology Laboratory, Department of Entomology and Agricultural Zoology, Faculty of Agriculture, University of Belgrade, Serbia.

Scanning electronic microscopy

Scanning electron micrographs (SEM) were taken according to Alberti and Nuzzaci (1996) by the technique of reconstructing eriophyids from dry plant material. The mite specimens are first transferred to Keifer's medium I in a cavity slide and heated to about 140°C on an electric plate to bring the mites to their more or less original shape. The specimens are then transferred briefly, about 1 minute, into a KCl-glycerol solution. Excess solution is sucked off with philtre paper and the mites are then placed on the SEM holder. For specimen preparation before being placed on the SEM stage, mites were sputter-coated with gold for 100 s under 30 mA ion current. The mites were then studied in the vacuum chamber of a JEOL Scanning Electron Microscope (JEOL-JSM6390, Peabody, MA, USA) at the Laboratory of Electron Microscopy, Faculty of Agriculture, University of Belgrade, Serbia

DNA extraction, PCR amplification and sequencing

For molecular analysis, mites were removed by direct examination under a stereomicroscope from leaves of *F. moluccana* collected in Papua New Guinea, preserved in 96% ethanol, and stored at 4 °C until DNA extraction, which was performed in Serbia.

Total DNA was extracted from individual specimens in three replicates using the QIAGEN DNeasy® Blood & Tissue Kit, following the manufacturer's instructions, with modifications based on Dabert *et al.* (2008); the mites were not crushed. Amplification of the mitochondrial cytochrome c oxidase subunit I gene (COI) barcode region was performed using primers LCO1490 and HCOd (Folmer *et al.*, 1994; Chetverikov *et al.*, 2015). Polymerase chain reactions (PCR) were conducted using High Yield Reaction Buffer A with Mg (1x), 2.5 mM MgCl₂, 0.6 mM of each dNTP, 0.5 µM of each primer and 1 U of KAPA Taq DNA polymerase (Kapa Biosystems, MA, USA) in a 25-µL final volume. PCR cycles were carried out in a Mastercycler ep Gradient S (Eppendorf, Germany), applying reaction conditions as described in Cvrković *et al.* (2016). PCR amplicons were visualized in a 1% agarose gel and purified using the QIAquick PCR purification Kit (QIAGEN, Germany) according to the manufacturer's instructions. Sequencing was performed in both directions with the same primer pairs as in the initial PCR procedure by Macrogen Europe (Amsterdam, Netherlands).

Results

Family Eriophyidae Nalepa 1898

Subfamily Nothopodinae Keifer 1956

Tribe Colopodacini Mohanasundaram 1984

Genus *Solenidiversum* gen. nov. Vidović

Zoobank: 1D18B589-59F1-4E76-988C-167423810536

(Figs. 1 & 2)

Type species — *Solenidiversum falcataariae* sp. nov.

Diagnosis — The subfamily Nothopodinae Keifer 1956 are distinguished from the other subfamilies of Eriophyidae by: the tibia of the legs is reduced or completely fused with the tarsus, tibia I without setae and tarsus without spatulate projections.

Within the subfamily Nothopodinae, it is possible to distinguish two tribes, Nothopodini Keifer 1956 and Colopodacini Mohanasundaram 1984. The characteristics of **tribe Colopodacini** are the presence of coxal setae *Ib*, coxae of leg I usually weakly divided and tibia of leg I completely fused with the tarsus, except in the genus *Thaicesa* Koçak & Kemal, which has very small tibiae. The characteristics of **Nothopodini** are the absence of coxal setae *Ib*, coxae and tibiae of leg I variable.

Solenidiversum gen. nov. belongs to Colopodacini with coxal setae I (*Ib*) present, tibiae of legs I and II completely fused with tarsus; empodium entire; solenidion on tarsus I on inner side of tarsus; solenidion on tarsus II in dorsal position; all leg setae present; scapular tubercles on rear shield margin; setae *sc* projecting backward; prodorsal shield with small subtriangular frontal lobe; body vermiform; opisthosoma evenly round and with annuli subequal dorsoventrally, entirely microtuberculated; all ventral opisthosomal setae present; accessory setae (*hl*) absent.

Remarks — It should be noted that fifteen genera have been described from the tribe Colopodacini. From nine of those genera, the tibia of leg I is completely fused with the tarsus (*Colopodacus* Keifer, *Apontella* Boczek & Nuzzaci, *Paracolopodacus* Kuang & Huang, *Adenocolus* Meyer & Ueckermann, *Pseudocolopodacus* Kuang, *Dicolopodacus* Huang, *Kuangella* Wei, *Taicolopodacus* Huang & Wang, and *Juxtacolopodacus* Flechtmann & De Queiroz) and in the other six (*Thaicesa* Koçak & Kemal 2008, *Calliparus* Li, *Setibia* Duarte & Navia, *Aricolopodos* Duarte & Navia, *Calareolata* Han & Zhang and *Reginesus* Reis &

Navia) the tibia is reduced and very short, but not completely fused with the tarsus (Keifer 1960; Boczek and Nuzzaci 1988; Kuang and Huang 1994; Boczek and Chandrapatya 1996; Meyer and Ueckermann 1997; Kuang 1997; Huang 2001; Wei and Quin 2002; Koçak and Kemal 2008; Huang and Wang 2009; Flechtmann and De Queiroz 2010; Li *et al.* 2010; Reis *et al.* 2012; Duarte *et al.* 2017; Han and Zhang 2019).

Therefore, it is necessary to emphasize that the fusion of the tibia with the tarsus is not a distinguishing characteristics of the tribe Colopodacini, as specified in the Revised Keys to the World Genera of the Eriophyoidea (Amrine *et al.* 2003). The character that distinguishes the Colopodacini tribe from the Nothopodini tribe within the subfamily Nothopodinae is the presence (in Colopodacini) versus the absence of *Ib* coxal setae (Nothopodini).

Differential diagnosis — The new genus is placed in Colopodacini, Nothopodinae, Eriophyidae, Eriophyoidea. There are sixteenth genera in Colopodacini. This new genus has the solenidion on the inner side of tarsus I, differentiating it from all other genera of the tribe.

The feature of displaced solenidia of leg I has so far been recorded in the genus *Juxta-colopodacus* (tribe Colopodacini), where the solenidion is displaced laterally, and in the genus *Floracarus* (Nothopodini) with a solenidion on the inner side of the tarsus (Flechtmann *et al.* 2010, Meyer & Ueckermann 1997).

This new genus, like *Thaicesa*, *Adenocolus*, *Caliparus* and *Setibia*, has scapular tubercles and setae on rear prodorsal shield margin. It differs from *Thaicesa* and *Adenocolus* in the presence of *bv* setae on both legs (absent on both legs in *Thaicesa*, absent on leg II in *Adenocolus*). It differs from *Caliparus* by the fused tibia and tarsus (distinct tibia and tarsus in *Caliparus*). This new genus is most similar to *Setibia*, because only these two genera within the tribe Colopodacini have a worm-like body shape, unlike the other fourteen genera of this tribe. It differs from this genus, however, in the complete fusion of the tibia with the tarsus on both legs (in *Setibia* the tibia is reduced, but distinct) and in the absence of a prominent frontal lobe as in *Setibia*.

Etymology — The genus name *Solenidiversum* is a combination of *Soleni* (from the Latin *solenidion* – optically inactive chemosensory seta) and *diversum* (from the Latin *diversus*, meaning opposite). It refers to the opposite positions of the solenidion on the tarsus of leg I (ventral positions) in relation to the positions of the solenidion on the tarsus of leg II (dorsal positions). Gender: neutral

***Solenidiversum falcatariae* sp. nov. Vidović**

Zoobank: CC826E3B-ABBB-4C5F-B47F-363DF1699A7B

(Figs. 1 & 2)

Description

FEMALE (n=10). Body vermiform 187 (166–194), 41 (38–45) wide, whitish in color.

Gnathosoma 15 (12–16) projecting slightly downwards, chelicerae 9 (8–9), dorsal pedipal genual setae *d* 3. **Prodorsal shield** 22 (17–22) including the small subtriangular frontal lobe, 21 (20–22) wide. Triangular with a rounded frontal lobe over the gnathosoma; median and admedian lines complete; I pair of submedian lines present on anterior half, incomplete; II and III pair of submedian lines incomplete, extending from anterior margin and ending ahead of prodorsal shield tubercles; in the lower half of the shield there are numerous dashes between all lines of prodorsal shield; on both lateral margins, of the rear of shield, there are areas with more numerous and densely dashes. Tubercles *sc* on rear shield margin 12 (11–12) apart, scapular setae *sc* 24 (22–26). **Leg I** 24 (19–24); femur 10 (8–10), ventral basifemoral setae *bv* 6 (4–6); genu 4 (3–4), antaxial genual setae *l''* 15 (12–16); tibiotarsus 7 (5–8), paraxial fastigial tarsal setae *ft'* 9 (8–11), antaxial fastigial tarsal setae *ft''* 17 (14–18); tarsal solenidion ω 4 (3–4); tarsal empodium 5 (4–6), 6-rayed. **Leg II** 20 (16–20); femur 9 (7–9), ventral basifemoral setae *bv* 5 (5–7); genu 3 (3–4), antaxial genual setae *l''* 6 (5–7); tibiotarsus 6 (5–6), paraxial fastigial tarsal setae *ft''* 4, antaxial fastigial tarsal setae *ft'* 16 (14–17); tarsal solenidion ω 7 (6–8); tarsal

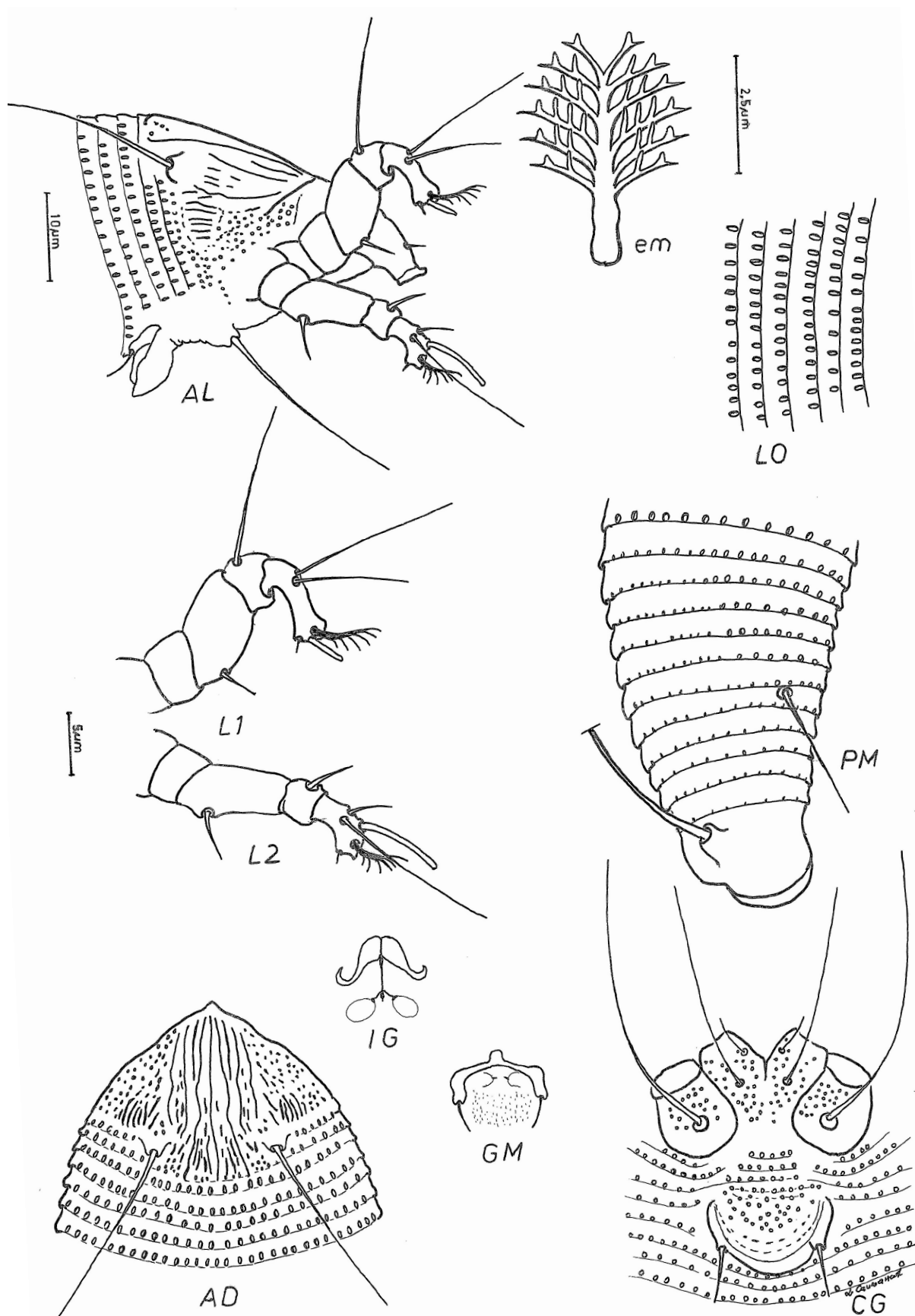


Figure 1 Line drawings of *Solenidiversum falcatariae* sp. nov.: AD—prodorsal shield; AL—lateral view of anterior body region; CG—female coxigenital region; em—empodium; GM—male genital region; IG—internal female genitalia; LO—lateral view of annuli; L1—leg I; L2—leg II; PM—lateral view of posterior opisthosoma. Scale bar: 10 µm for AD, AL, CG, GM, IG, PM; 5 µm for L1; 2.5 µm for em.

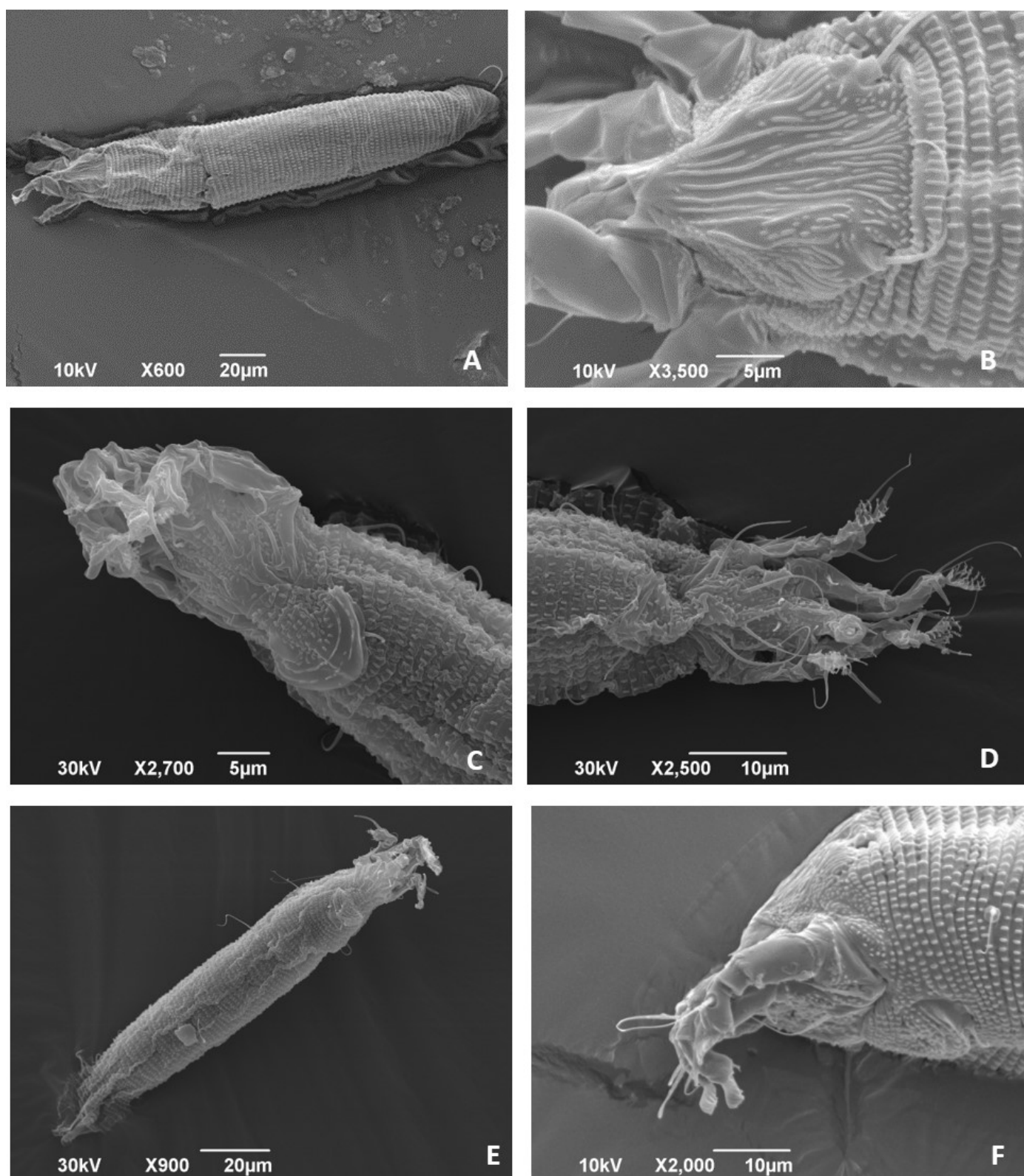


Figure 2 Scanning electron micrographs of *Solenidiversum falcatariae* sp. nov.: A–dorsal view of whole mite; B–dorsal view with the detail of pro-dorsal shield; C–ventral view, anterior part; D–ventral view, anterior part; E–ventral view of whole mite; F–lateral view, anterior part.

empodium 4 (4–5), 6–7-rayed. **Coxigenital region** with 5–6 semiannuli between coxae and genitalia. Coxisternal plates granulated; sternal line 6; proximal setae on coxisternum I (*lb*) 4 (4–5), tubercles *lb* 4 apart; anterolateral setae on coxisternum II (*la*) 20 (18–23), tubercles *la* 6 (5–6) apart, proximal setae on coxisternum II (*2a*) 29 (25–32), tubercles *2a* 12 (11–13) apart. **External genitalia** 10 (8–10), 12 (12–14) wide, granulated proximally and with two transverse curved lines distally, setae *3a* 5 (5–6), 9 (8–11) apart. **Internal genitalia** with anterior, transversal apodeme trapezoidal, longitudinal bridge relatively long, spermathecal tubes directed latero-posterad, spermathecae egg-shaped, globose. **Opisthosoma** with subequal annuli: 55 (53–66) dorsal and 58 (56–68) ventral annuli. Dorsal and ventral opisthosoma with oval, elongated microtubercles close to the rear margins of annuli. Setae *c2* 14 (13–16), 27 (27–33) apart, on annulus 8 (8–9); setae *d* 34 (30–38), 24 (21–26) apart, on annulus 20 (18–22); setae *e* 41 (36–41), 19 (16–20) apart, on annulus 36 (36–42); setae *f* 16 (14–17), 10 (10–12) apart, on annulus 53 (52–63); seta *h2* 76 (74–83), 7 (7–8) apart; setae *h1* absent.

MALE (n=2). Smaller than females and generally similar to them, 130–150, 35–40 wide. **Gnathosoma** 10–12 curved down, cheliceral stylets 6–7. **Prodorsal shield** 17–19, 19–21 wide. Prodorsal shield tubercles on the rear shield margin 12–13 apart, setae *sc* 12–14, projecting posteriorly. Shield design similar to female. **Leg I** 16–18; femur 7, setae *bv* 4; genu 3, setae *l''* 9; tibiotarsus 5, setae *ft'* 8, setae *ft''* 13; solenidion ω 3; empodium *em* 4, and 6-rayed. **Leg II** 16; femur 7, setae *bv* 4; genu 3, genual setae *l''* 5; tibiotarsus 4, setae *ft'* 3–4, setae *ft''* 13; solenidion ω 7; empodium *em* 4. **Coxigenital region** with 5–6 semiannuli between coxae and genitalia. Coxisternal plates granulated; sternal line 3; setae *lb* 3–4, *lb* tubercles 3–4 apart; setae *la* 11–12, *la* tubercles 6 apart; setae *2a* 19–22, *2a* tubercles 13–14 apart. **External genitalia** 13–14 wide, epiandrum typically ornamented with small granules, setae *3a* 3–5, *3a* tubercles 10–11 apart, setae *eu* absent. **Opisthosoma** with subequal annuli: 54–56 dorsal and 54–56 ventral annuli; setae *c2* 12–13, 37 apart, on annulus 6–7; setae *d* 21–22, 24–25 apart, on annulus 15; setae *e* 24–26, 18 apart, on annulus 30–32; setae *f* 11–12, 10 apart, on annulus 49–52; setae *h2* 30–35, 6–7 apart, setae *h1* absent.

NYMPH (n=3). Body vermiform, 123–132, 40–43 wide. **Gnathosoma** 9–12, chelicerae 7–8. **Prodorsal shield** 17–19, 23 wide, scapular tubercles 15–16 apart, setae *sc* 9–10. **Leg I** 12–13, femur 5–6, setae *bv* 3; genu 2–3, setae *l''* 6–8; tibiotarsus 3–4, setae *ft'* 3–4, setae *ft''* 9–11; solenidion ω 2–3; empodium *em* 3–4, and 5-rayed. **Leg II** 11–12; femur 4–5, setae *bv* 2; genu 2, genual setae *l''* 4–6, tibiotarsus 3, setae *ft'* 2–3, setae *ft''* 10–11; solenidion ω 4–5; empodium *em* 3–4. **Coxigenital region** with 5–6 complete annuli, setae *3a* 2, tubercles 4–5 apart. Coxisternal plate granulated; setae *lb* 2, *lb* tubercles 5 apart; setae *la* 4–5, *la* tubercles 5–6 apart; setae *2a* 8, *2a* tubercles 13–14 apart. **Opisthosoma** with subequal annuli: 40–45 dorsal and 44–50 ventral annuli; setae *c2* 4–5, 32–33 apart, on annulus 8; setae *d* 11–13, 22 apart, on annulus 16–17; setae *e* 7, 12–14 apart, on annulus 27–29; setae *f* 10, 11–12 apart, on annulus 40–45; setae *h2* 18–19, 6–7 apart, setae *h1* absent.

Type host plant

Falcataria moluccana (Miq.) Barneby & Grimes (Fabaceae)

Type locality

Papua New Guinea: Fanamafai Village, along Fangaloa Crossing, Kavieng District, New Ireland Province (02°52'19.21"S; 151°09'20.37"E; Alt. 267 m.a.s.l.).

Type material. Female holotype (slides 946/5) and paratypes 37 females, 3 males; 10 nymphs; 10 February 2021, collected by Warea Orapa.

Additional material. Papua New Guinea: Kafa Road, South of Pimaga Government Station, Lake Kutubu District, SHP. (06°31'42.67"S; 143°32'08.88"E; Alt. 933 m.a.s.l) 31 January 2021, 25 slides, collected by Warea Orapa. **Relation to the host.** The infestation caused by this mite results in the formation of white erineum on both surfaces of the leaflets, later the erineum darkens (Fig. 3).



Figure 3 Symptoms of *Solenidiversum falcatariae* **sp. nov.** on *Falcataria moluccana*, erineum on the both surface of leaf.

Etymology

The species name is based on the host plant's generic name, *Falcataria*.

COI sequence

The whole barcode region (658 bp) of mtCOI was generated from three specimens of *Solenidiversum falcatariae* **sp. nov.** As all nucleotide sequences were 100% identical, only one of them was submitted to the GenBank database under accession number OQ401030. The translation of the nucleotide sequences resulted in 219 amino acid positions. Base pair frequencies show that the region is AT-rich (A: 0.242, C: 0.140, G: 0.147, T: 0.471).

Key to the genera of Colopodacini

1. Prodorsal shield lacking scapular tubercles and setae *Pseudocolopodacus* Kuang, 1997
— Scapular tubercles and setae present 2
2. Empodia divided; shield with three anterior lobes *Dicolopodacus* Huang, 2001
— Empodia entire 3
3. Scapular tubercles and setae on rear prodorsal shield margin; antaxial genual setae (*l''*) of leg II and ventral setae (*e*) present 4
— Scapular tubercles and setae not on rear prodorsal shield margin; antaxial genual setae (*l''*) of leg II and ventral setae (*e*) variable 8
4. Tibia completely fused with tarsus 5
— Tibia very small but distinct 6
5. Basiventral femoral seta (*bv*) of leg I present; basiventral femoral seta (*bv*) of leg II absent; dorsal position of selenidion on both tarsus *Adenocolus* Meyer & Ueckermann, 1997
— Basiventral femoral seta (*bv*) present on both legs; solenidion on tarsus I on inner side of tarsus, solenidion on tarsus II in dorsal position *Solenidiversum* **gen. nov.**
6. Basiventral femoral seta (*bv*) absent on both legs *Thaicesa* Koçak & Kemal, 2008
— Basiventral femoral seta (*bv*) present on both legs 7
7. Dorsal opisthosoma flat with weak submedian ridges, dorsal annuli undulated
 *Calliparus* Li, Wang & Wei, 2010
— Dorsal opisthosoma entirely microtuberculated *Setibia* Duarte & Navia, 2017
8. Scapular tubercles and setae on the lateral side of the prodorsal shield 9
— Scapular tubercles and setae ahead of rear prodorsal shield margin 10
9. Opisthosoma with smooth tergites *Kuangella* Wei, 2002
— Opisthosoma with middorsal ridge *Juxtacolopodacus* Flechtmann & de Queiroz, 2010
10. Tibia completely fused with tarsus 11
— Tibia very small but distinct 14
11. Antaxial genual setae (*l''*) of leg II and ventral setae (*e*) absent 12
— Antaxial genual setae (*l''*) of leg II and ventral setae (*e*) present 13
12. Dorsal opisthosoma without ridges *Paracolopodacus* Kuang & Huang, 1994
— Dorsal opisthosoma with median and subdorsal ridges
 *Taicolopodacus* Huang & Wang, 2009
13. Basiventral femoral setae (*bv*) present on both legs; dorsal opisthosoma with median ridge *Colopodacus* Keifer, 1960
— Basiventral femoral setae (*bv*) of leg I absent; dorsal opisthosoma with narrow median furrow *Apontella* Boczek & Nuzzaci, 1988
14. Antaxial genual setae (*l''*) of leg II present; dorsal opisthosoma without ridges
 *Calareolata* Han & Zhang, 2019
— Antaxial genual setae (*l''*) of leg II absent; dorsal opisthosoma with the ridge 15

15. Basiventral femoral setae (*bv*) present on both leg *Aricolopodos* Duarte & Navia 2017
 — Basiventral femoral setae (*bv*) absent on both legs *Reginesus* Rei & Navia 2012

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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