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Contribution to the knowledge of the oribatid mite genus *Kalloia* (Acari, Oribatida, Carabodidae), with description of a new species from Indonesia

Sergey G. Ermilov[a] , Dorothee Sandmann[b] , Stefan Scheu[b,c]

[a] Tyumen State University, Tyumen, Russia.
[b] University of Göttingen, JF Blumenbach Institute of Zoology and Anthropology, Göttingen, Germany.
[c] University of Göttingen, Centre of Biodiversity and Sustainable Land Use, Göttingen, Germany.

Original research

ABSTRACT

The genus *Kalloia* (Oribatida, Carabodidae) is recorded in the Oriental region for the first time. A new species — *Kalloia gerdweigmanni* **n. sp.** — is described from litter of oil palm plantations and jungle rubber agroforests from Sumatra, Indonesia. It differs from *Kalloia simpliseta* Mahunka, 1985 by the presence of a transverse ridge in the mediodistal part of the lamellae, translamella and two thick, diagonal, convergent ridges forming a triangular structure in the medioanterior part of the notogaster, and by the localization of notogastral setae *da*, *dm*, *la*, *lm*, *lp* and h_1. The generic status of *Kalloia* is discussed and supported. *Kalloia mahunkai* Pérez-Íñigo and Baggio, 1989 and *Machadocepheus foveolatus* Mahunka, 1978, which were considered representatives of *Kalloia*, are removed from this genus and combined preliminarily in *Gibbicepheus*. Revised generic diagnosis and data on ecology and distribution of known species of *Kalloia* are presented.

Keywords carabodid mites; systematics; morphology; Sumatra; Oriental region
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Introduction

The oribatid mite genus *Kalloia* of the family Carabodidae (Acari, Oribatida) was proposed by Mahunka (1985) with *Kalloia simpliseta* Mahunka, 1985 as type species from the Caribbean. He listed the following generic traits: "Prodorsum normal, lamellae simple, running marginally. Lamellar and interlamellar setae thin, simple. Sensillus slightly lanceolate. Dorsosejugal suture present, but a deep hollow lying between prodorsum and notogaster. Latter with some very highly extruding tubercles. Fifteen pairs of thin notogastral setae. Epimeral setal formula: 3–1–3–3. Four pairs of genital, one pair of aggenital, two pairs of anal and three pairs of adanal setae, ad_3 in preanal, ad_1 and ad_2 in postanal position" (Mahunka 1985). According to Subías's catalogue (2019), the genus is included as subgenus in the genus *Gibbicepheus* Balogh, 1958, and comprises three species (*K. simpliseta*, *Kalloia mahunkai* Pérez-Íñigo and Baggio, 1989 and *Machadocepheus foveolatus* Mahunka, 1978).

In the course of the study of carabodid mites from Indonesia, we found a new species of *Kalloia*. This paper aims to describe and illustrate this new species under the name *K. gerdweigmanni* **n. sp.**, to update the generic diagnosis, to discuss the taxonomic status of *Kalloia* and the systematic placement of *K. mahunkai* and *M. foveolatus* (to include both species in *Gibbicepheus*), and to present data on the ecology and distribution of *Kalloia* species.

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Corresponding author
Sergey G. Ermilov:
ermilovacari@yandex.ru

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Material and methods

Material

This study was carried out within the framework of the interdisciplinary project "Ecological and socioeconomic functions of tropical lowland rainforest transformation systems (Sumatra, Indonesia)" – EFForTS on Sumatra Island (http://www.uni-goettingen.de/en/310995.html). See the *Material examined* section for detailed location data of the new species.

In order to study the morphology of the genus *Kalloia*, besides the new species, the specimens of *Kalloia simpliseta* from S.G. Ermilov's collection, from Cuba (Ermilov 2016) and the Caribbean (Ermilov and Smit 2017), were used.

Methods

Specimens were mounted in lactic acid on temporary cavity slides for measurement and illustration of the new species. Body length was measured in lateral view, from the tip of the rostrum to the posterior edge of the notogaster. Notogastral width refers to the maximum width of notogaster in dorsal view. Lengths of body setae were measured in lateral aspect. All body measurements are presented in micrometer. Formulas for leg setation are given in parentheses according to the sequence trochanter–femur–genu–tibia–tarsus (famulus included). Formulas for leg solenidia are given in square brackets according to the sequence genu–tibia–tarsus.

Drawings were made with a camera lucida using a Leica transmission light microscope "Leica DM 2500". SEM photos were made with the aid of a FEI Quanta 250 SEM microscope.

The general morphological terminology used in this paper mostly follows that of F. Grandjean: see Travé and Vachon (1975) for references, Norton (1977) for leg setal nomenclature, and Norton and Behan-Pelletier (2009) for overview.

The following abbreviations are used: *lam* = lamella; *tlam* = translamella; *r* = ridge; *dep* = depression; *tu* = tutorium; *ro*, *le*, *in*, *bs* = rostral, lamellar, interlamellar and bothridial setae, respectively; *bo* = bothridium; *hlp* = hump-like process; *c*, *la*, *lm*, *lp*, *h*, *p* = notogastral setae; *ia*, *im*, *ip*, *ih*, *ips* = notogastral lyrifissures; *gla* = opisthonotal gland opening; *a*, *m*, *h* = subcapitular setae; *rbr* = rutellar brush; *v*, *l*, *d*, *cm*, *acm*, *ul*, *sul*, *vt*, *lt* = palp setae; ω = palp and leg solenidion; *cha*, *chb* = cheliceral setae; *Tg* = Trägårdh's organ; *Pd I*, *Pd II* = pedotecta I and II, respectively; *1a*, *1b*, *1c*, *2a*, *3a*, *3b*, *3c*, *4a*, *4b*, *4c* = epimeral setae; *dis* = discidium; *g*, *ag*, *an*, *ad* = genital, aggenital, anal and adanal setae, respectively; *iad* = adanal lyrifissure; *p.o.* = preanal organ; *Tr*, *Fe*, *Ge*, *Ti*, *Ta* = leg trochanter, femur, genu, tibia and tarsus, respectively; *p.a.* = porose area; σ, φ = leg solenidia; ε = leg famulus; *v*, *ev*, *bv*, *l*, *d*, *ft*, *tc*, *it*, *p*, *u*, *a*, *s*, *pv* = leg setae.

Systematics

Generic diagnosis of *Kalloia*

Adult — With character states of Carabodidae (e.g., Mahunka 1986; Norton and Behan-Pelletier 2009). *Body size*: Medium to large (length 500-800). *Body form*: Body slightly pear-shaped, notogaster dilated posteriorly, wider than prodorsum and anterior part of notogaster. Body ratio (length/width) ≈ 1.6-1.7. *Integument*: Body surface microtuberculate, notogaster sparsely foveolate. *Prodorsum*: Rostral margin rounded. Rostrum with median internal light semi-oval structure. Lamellae long, broad, well separated, rounded or triangular distally, located dorsolaterally. Translamella and transverse mediodistal ridge on lamellae present or absent. Interlamellar hump-like processes absent. Tutoria strong, ridge-like. Rostral setae thick or phylliform, located ventrolateral on lamellae. Lamellar setae setiform or thickened, located in anteromedial parts of lamellae. Interlamellar setae setiform, located on prodorsal surface in interbothridial region. Bothridial setae thickened, heavily barbed. Bothridia cup-shaped, closed, not connected with margins of the lamellae. *Notogaster*: Narrow furrow between notogaster and prodorsum present or not observed. Humeral shoulders slightly developed, rectangular.

Dorsoanterior and dorsoposterior parts of notogaster deeply depressed. Dorsocentral part of notogaster with high hump-like process. Fifteen pairs of medium size, setiform notogastral setae widely spaced. Setae c_1 and c_2 located in anterior notogastral depression; c_3 on humeral shoulders; *da*, *dm*, *dp*, *la*, *lm*, *lp* and h_1 on tubercles/ridges of notogastral hump-like process; five pairs of setae (h_2, h_3, p_1–p_3) in posterior position of notogaster; posterior notogastral depression without setae. *Gnathosoma*. Subcapitulum diarthric. Adoral setae and their alveoli absent. Palps with setation 0–2–1–3–9(+ω). Solenidion of palptarsi long, bacilliform, not attached to *acm*. Axillary saccule absent. Chelicerae chelate-dentate. *Lateral podosomal and epimeral regions*: Pedotecta I represented by large lamina, pedotecta II by small lamina. Discidia well developed. Epimeral setal formula 3–1–3–3; setae *1a*, *1c*, *2a* and *3a* short, spiniform, others setiform. *Anogenital region*: With depressions. Four pairs of genital, one pair of aggenital and three pairs of adanal setae setiform; ad_1 posterior, ad_2 posterolateral, ad_3 anterolateral to anal plates. Two pairs of anal setae spiniform. Adanal lyrifissures removed from anal aperture. *Legs*: Tarsi IV with incomplete setation (11 setae; *pv"* absent). Setae *u* on all tarsi thick mediobasally and setiform distally. Genua I with two setae (*l'*, *l"*), genua II with three setae (*l'*, *l"*, *v'*). Porose area present on all femora.

Juvenile instars — Not known.

Kalloia gerdweigmanni n. sp.

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(Figures 1–6)

Diagnosis — Body size: 531–564 × 298–332. Lamellae mediodistally abruptly bent ventrad, with thicker cuticle appearing as a transverse ridge. Lamellar ends with anterolateral triangular projection. Translamella present. Rostral setae of medium size, thick, spinose. Lamellar setae comparatively short, slightly thickened. Interlamellar setae of medium size, setiform, slightly barbed. Bothridial setae long, setiform, densely barbed. Notogastral setae of medium size, setiform, slightly barbed. Notogastral hump-like process with two medioanterior convergent ridges, forming a triangular structure, bearing setae *da* and *dm*; with one pair of medioposterior tubercles, bearing setae *dp*; with one pair of large, elongate posterolateral tubercles bearing setae *la*, *lm*, *lp* and h_1. Epimeral and anogenital setae (except minute *1a*, *1c*, *2a* and *3a* and anal setae) setiform, barbed.

Description — Measurements – Body length: 531 (holotype: female), 531–564 (four paratypes: all females); notogaster width: 307 (holotype), 298–332 (four paratypes).

Integument (Figs 1a, 2a, 3c, 3d, 4a, 4b, 5a, 5c, 6a) – Body color light brown to brown reddish and dark brown. Body covered by thick layer of gel-like cerotegument. Body surface (including subcapitular mentum and genae, genital and anal plates) microtuberculate (diameter of tubercles less than 1). Notogaster and dorsoantiaxial part of leg femora III, IV and trochanters III, IV sparsely foveolate (diameter of foveoles up to 12). Projecting parts of lamellae and tutoria slightly foveate.

Prodorsum (Figs 1a, 1b, 2a, 4a, 4b, 5a, 5b, 6a) – Rostrum broadly rounded. Lamellae long (slightly shorter than prodorsum), mediodistally abruptly bent ventrad, with thicker cuticle appearing as a transverse ridge (these regions of lamellae slightly convex, illusory forming the unclear hump-like processes – Figs 4a, 5a, which are really absent – see Figs 4b, 6a), with lateral triangular projection. Translamella broad. Tutoria (3/4 length of prodorsum) strong, ridge-like. With elongate depression between lamellae and tutoria, and two depressions ventrally to tutoria. Rostral setae (41–45) thick, with numerous spines. Lamellar setae (28–32) slightly thickened, roughened, located on translamella. Interlamellar setae (53–61) setiform, thin, slightly barbed. Bothridial setae (77–82) thickened, heavily barbed, curved semiovally in mediodistal part. Exobothridial setae and their alveoli not observed. Interlamellar region slightly depressed.

Notogaster (Figs 1a, 1b, 2a, 4a, 4b, 5b, 5c, 5a) – Anterior notogastral margin straight. Anterior and posterior notogastral depressions and dorsocentral hump-like process well-developed. Medioanterior region of notogastral hump-like process with two thick, diagonal,

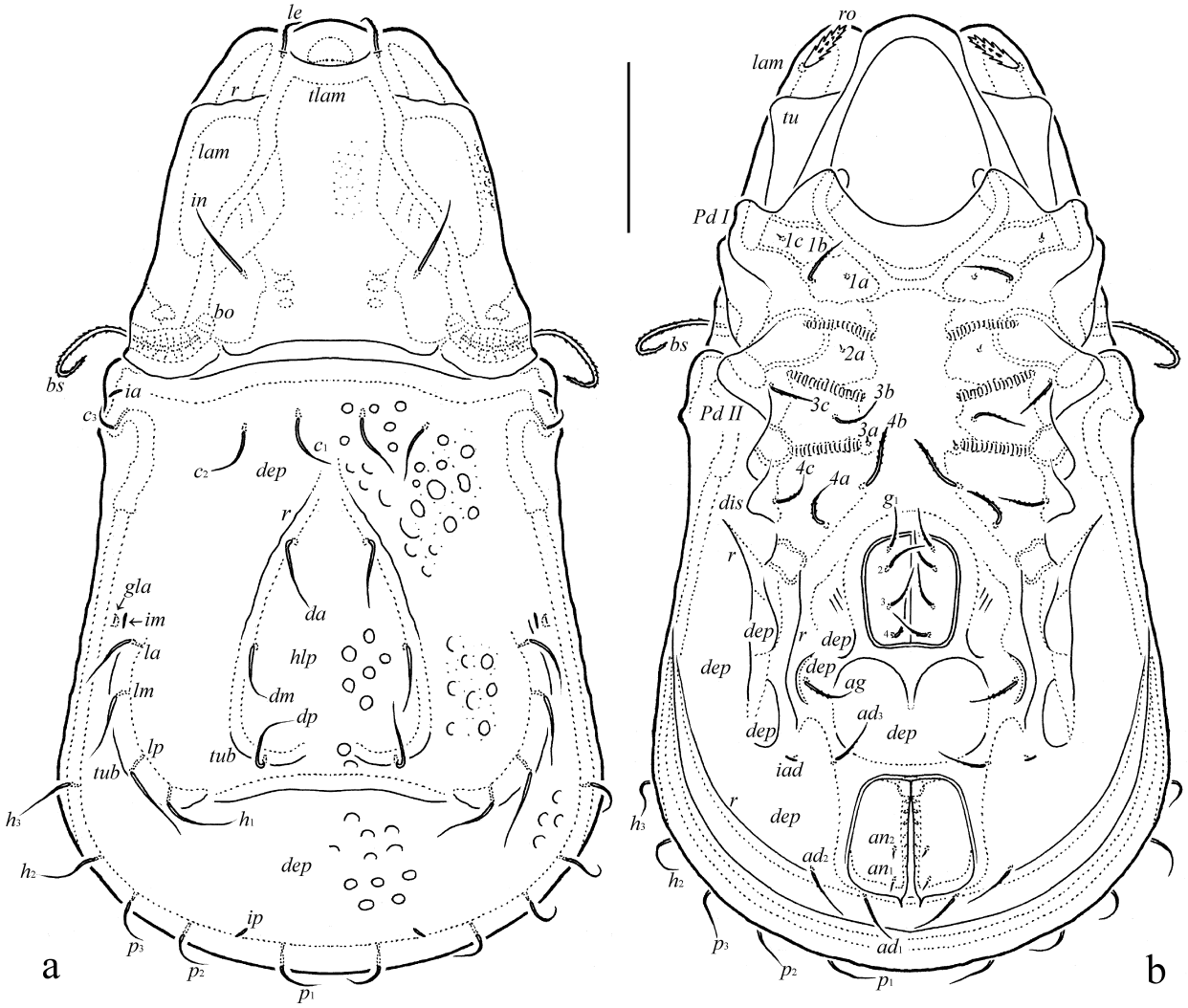

Figure 1 *Kalloia gerdweigmanni* **n. sp.**, adult: a – dorsal view; a – ventral view (gnathosoma and legs omitted). Scale bar 100 μm.

convergent ridges, forming triangular structure directed in anterior notogastral depression. Medioposterior region of notogastral hump-like process with one pair of tubercles, located behind diagonal ridges; these ridges and tubercles fused or indistinctly connected. Posterolateral regions of notogastral hump-like process with one pair of large, elongate tubercles. Fifteen pairs of notogastral setae (32–36) setiform, thin, slightly barbed; of these, *da* and *dm* located on diagonal notogastral ridges; *dp* on medioposterior tubercles; *la*, *lm*, *lp* and h_1 on posterolateral tubercles. Lyrifissures and opisthonotal gland openings well visible; *ia* located on humeral shoulders, *im* and *gla* close to each other and anterolateral to posterolateral tubercles, *ip* between p_1 and p_2, *ips* and *ih* on lateral sides of notogaster.

Gnathosoma (Figs 2b-d) – Subcapitulum longer than wide (114–123 × 98–106). Subcapitular setae (*a*, 18–20; *m*, 16–18; *h*, 12–14) setiform, slightly barbed, *h* thinnest. Postpalpal setae (4) spiniform. Palps (71–73) with setation 0–2–1–3–9(+ω). Solenidion of palptarsi long, bacilliform. Chelicerae (123–135) with two setiform, barbed setae, *cha* (41) longer than *chb* (16–18). Trägårdh's organ of chelicerae elongate triangular.

Lateral podosomal and epimeral regions (Figs 1b, 2a, 4b, 5b, 6a) – Pedotecta II rounded in ventral view. Discidia triangular, rounded distally. Two depressions behind acetabula IV. One

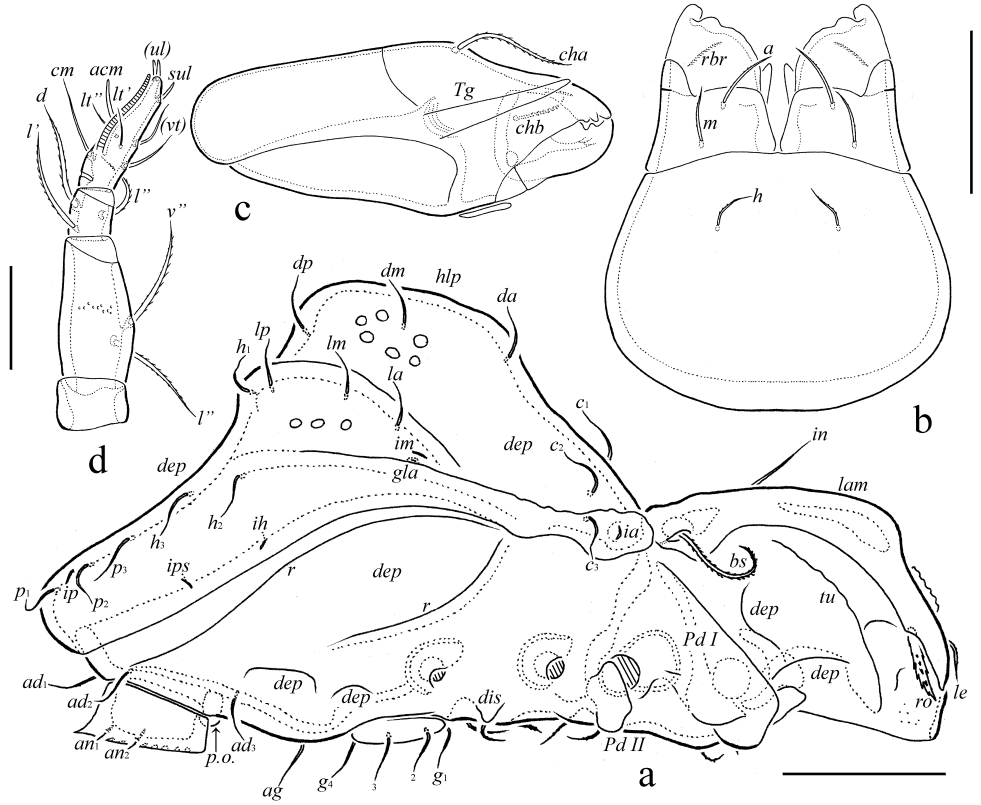

Figure 2 *Kalloia gerdweigmanni* **n. sp.**, adult: a – lateral view (gnathosoma and legs omitted); b – subcapitulum, ventral view; c – chelicera, left, paraxial view; d – palp, left, paraxial view. Scale bar 100 µm (a), scale bar 50 µm (b, c), scale bar 20 µm (d).

pair of large depressions bordered by a strong diagonal ridge. With typical epimeral setation: 3-1-3-3. Epimeral setae *1a*, *1c*, *2a* and *3a* minute (4), spiniform, *1b*, *3b*, *3c*, *4a*, *4b* and *4b* (32–36) setiform, barbed; *4b* thickest.

Anogenital region (Figs 1b, 2a, 5b, 6b, 5c) – With one pair of long, longitudinal ridges lateral to genital aperture and posterior to epimere IV and several anogenital depressions (one large depression between genital and anal apertures; one pair of small depressions close and posterolateral to genital aperture; one pair of small depressions bearing aggenital setae; one pair of large and indistinct depressions lateral to anal aperture; two pairs of medium depressions posterior to acetabula IV). Usually with three poorly visible short, thin, parallel diagonal furrows lateral to genital aperture. Four pairs of genital, one pair of aggenital and three pairs of adanal setae similar in length (32–36), setiform, slightly barbed. Two pairs of anal setae (8) spiniform. Adanal lyrifissures removed from anal aperture and located lateral to ad_3. Circumventral ridge poorly developed, interrupted posteriorly.

Legs (Figs 3a-d, 5b, 6a) – Claw of each leg strong, sparsely barbed dorsally and with tooth ventrobasally. Porose area distinct on all femora, not observed on trochanters III, IV. Formulas of leg setation and solenidia: I (1–4–2–4–16) [1–2–2], II (1–4–3–3–15) [1–1–2], III (2–3–1–2–15) [1–1–0], IV (1–2–2–2–11) [0–1–0]; homology of setae and solenidia indicated in Table 1. Famulus of tarsi I short, erect, blunt-ended, inserted posterior to solenidion ω_1. Solenidion φ_1 on tibiae I very long, setiform; ω_2 on tarsi I and φ_2 on tibiae I comparatively long, thickened, blunt-ended; other solenidia short (except long ω_2 on tarsi I), bacilliform. Dorsoanterior apophysis of tibiae I (bearing φ_1) slightly developed.

Material examined — Holotype (female) and two paratypes (two females): Indonesia, Sumatra, Bukit Duabelas landscape, oil palm plantation, research site BO3a, 02°04’15.2”S,

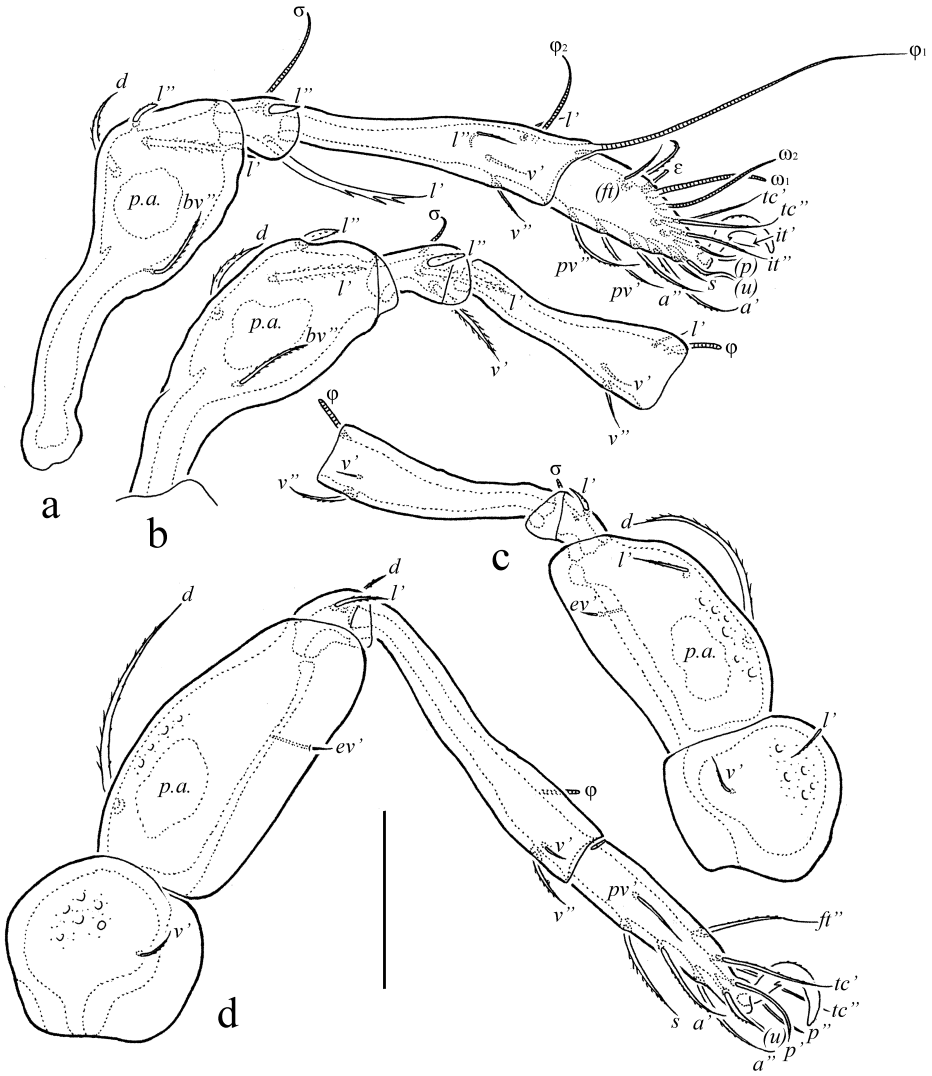

Figure 3 *Kalloia gerdweigmanni* **n. sp.**, adult: a – leg I, without trochanter, right, antiaxial view; b – femur, genu and tibia of leg II, right, antiaxial view; c – leg III, without tarsus, right, antiaxial view; d – leg IV, left, antiaxial view. Scale bar 50 µm.

102°47'30.6"E, litter, November 2013 (B. Klarner). Two paratypes (two females): Indonesia, Sumatra, Harapan landscape, jungle rubber agroforest, research site HJ4a, 01°47'07.3"S, 103°16'36.9"E, litter, November 2013 (B. Klarner).

Type deposition — The holotype is deposited in the collection of LIPI (Indonesian Institute of Science) Cibinong, Indonesia; one paratype is deposited in the collection of the Senckenberg Museum of Natural History, Görlitz, Germany; three paratypes are deposited in the collection of the Tyumen State University Museum of Zoology, Tyumen, Russia. All in ethanol with a drop of glycerol. Additional pictures are available in the online repository www.ecotaxonomy.org.

Etymology — The species name is dedicated to our colleague, the well-known acarologist Prof. Dr. Gerd Weigmann (Free University of Berlin, Institute of Zoology, Berlin, Germany), for his extensive contributions to our knowledge of oribatid mites.

Remarks — *Kalloia gerdweigmanni* **n. sp.** differs from the type species of the genus — *Kalloia simpliseta* Mahunka, 1985 — by the presence of a transverse ridge in the mediodistal part of lamellae (versus ridge on lamellae absent), translamella (versus translamella absent) and two thick, diagonal, convergent ridges, forming a triangular structure in the medioanterior

Figure 4 *Kalloia gerdweigmanni* **n. sp.**, adult, SEM photos: a – dorsal view; b – dorsolateral view. Scale bar 200 μm.

part of the notogaster (versus notogastral ridges absent), and the localization of each pair of notogastral setae *da* and *dm* on one ridge (versus setae located on separate tubercles) and *la*, *lm*, *lp* and h_1 on one large elongate tubercle (versus *la* and *lm* on one small tubercle; *lp* and h_1 on another small tubercle).

Discussion

Mahunka (1985) proposed the monotypic genus *Kalloia* with *Kalloia simpliseta* from the Caribbean. Later, he confirmed the generic status (e.g., Mahunka 1986, 1998), and this was also supported by other authors (Balogh and Balogh 1988, 1992, 2002; Fujikawa 1991; Ermilov 2016; Ermilov and Smit 2017; Ermilov and N'Dri 2018). Subías (2004) included

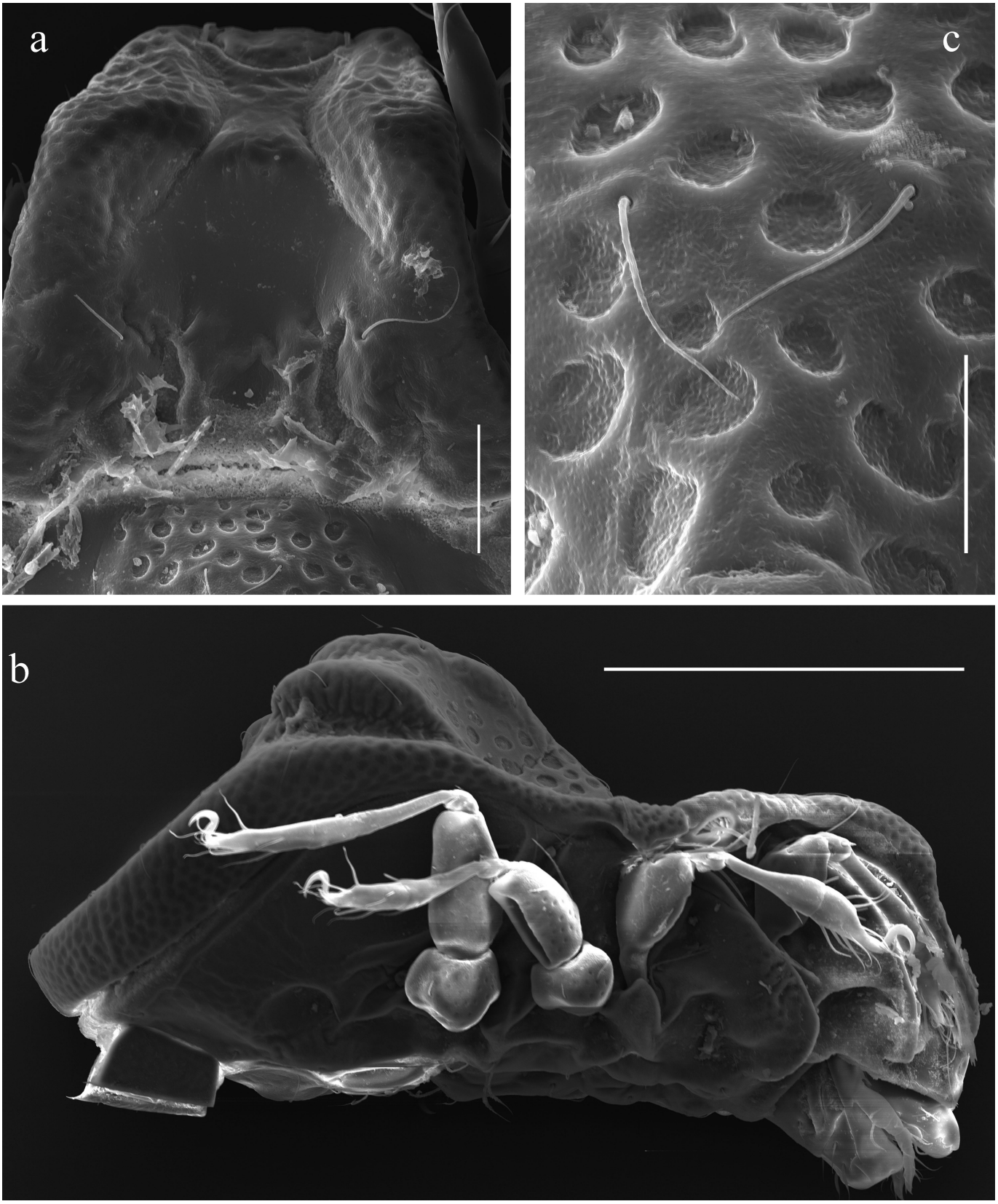

Figure 5 *Kalloia gerdweigmanni* **n. sp.**, adult, SEM photos: a – prodorsum dorsal view; b – lateral view; c – notogastral ornamentation and setae c_1. Scale bar 50 µm (a), scale bar 200 µm (b), scale bar 20 µm (c).

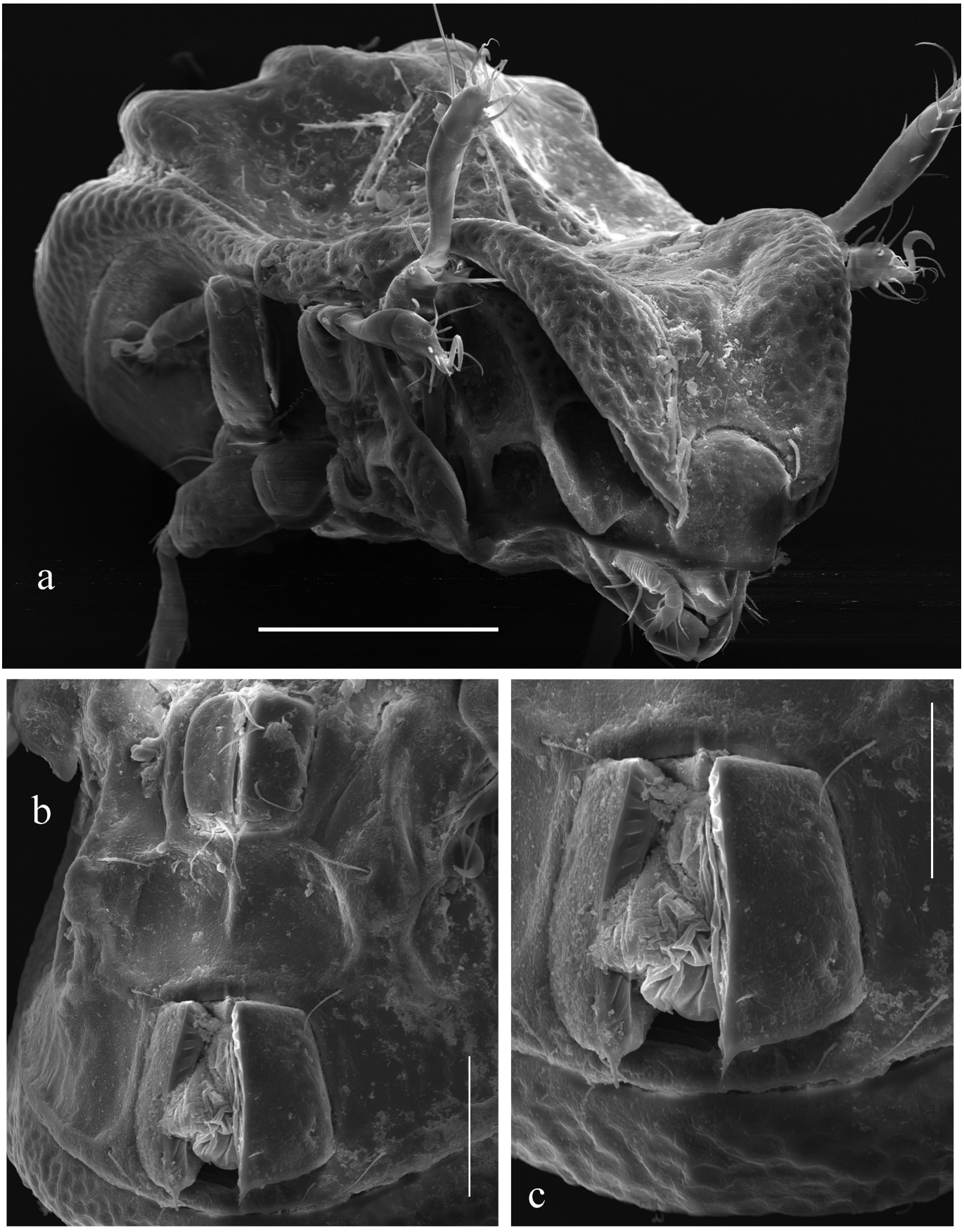

Figure 6 *Kalloia gerdweigmanni* **n. sp.**, adult, SEM photos: a – laterofrontal view; b – anogenital region, ventral view; c – anoadanal region, ventral view. Scale bar 100 µm (a), scale bar 50 µm (b), scale bar 40 µm (c).

Table 1 Leg setation and solenidia of adult *Kalloia gerdweigmanni* **n. sp.**

Leg	*Tr*	*Fe*	*Ge*	*Ti*	*Ta*
I	*v'*	*d* , *(l)* , *bv"*	*(l)* , σ	*(l)* , *(v)* , φ_1, φ_2	*(ft)* , *(tc)* , *(it)* , *(p)* , *(u)* , *(a)* , *s* , *(pv)* , ε, ω_1, ω_2
II	*v'*	*d* , *(l)* , *bv"*	*(l)* , *v'*, σ	*l'* , *(v)* , φ	*(ft)* , *(tc)* , *(it)* , *(p)* , *(u)* , *(a)* , *s* , *(pv)* , ω_1, ω_2
III	*l'* , *v'*	*d* , *l'* , *ev'*	*l'* , σ	*(v)* , φ	*(ft)* , *(tc)* , *(it)* , *(p)* , *(u)* , *(a)* , *s* , *(pv)*
IV	*v'*	*d* , *ev'*	*d* , *l'*	*(v)* , φ	*ft"* , *(tc)* , *(p)* , *(u)* , *(a)* , *s* , *pv'*

Note: Roman letters refer to normal setae, Greek letters to solenidia (except ε = famulus). Single prime (') marks setae on anterior and double prime (") setae on posterior side of the given leg segment. Parentheses refer to a pair of setae.

Kalloia as subgenus in *Diplobodes* Aoki, 1958 and later (2016) in *Gibbicepheus*; Fernandez *et al*. (2014) included it in *Machadocepheus* (*Kalloia*) Balogh, 1958. The genus *Kalloia* is morphologically similar to *Diplobodes*, *Gibbicepheus* and *Machadocepheus*, however it differs from *Diplobodes* and *Gibbicepheus* by the distinctly depressed anterior part of the notogaster and by the presence of a centrodorsal notogastral hump-like process (versus anterior part of notogaster not depressed; centrodorsal part of notogaster without hump-like process); and from *Machadocepheus* by the absence of a centrodorsal prodorsal hump-like processes on which the interlamellar setae are located.

Also, the genus *Kalloia* is morphologically similar to the genera *Tuberocepheus* Balogh and Mahunka, 1969 and *Mangabebodes* Fernández, Theron, Leiva, Rollard and Tiedt, 2014 in having especially a centrodorsal notogastral hump-like process and distinctly depressed anterior and posterior parts of the notogaster. However, it differs from both by the presence of 15 pairs of notogastral setae, including the presence of notogastral setae c_1–c_3 and their localization in the depressed anterior part of the notogaster (versus 12 pairs of notogastral setae, setae c_1–c_3 absent, depressed anterior part of the notogaster without setae).

According to recent studies of Carabodidae, the presence or absence of prodorsal and notogastral depressions and hump-like processes and localization of interlamellar and notogastral setae are important morphological traits on generic level (Fernandez *et al*. 2013, 2016, 2018; Ermilov 2018; Ermilov and Starý 2018), therefore we support the generic status of *Kalloia*.

Pérez-Íñigo and Baggio (1989) described the second representative of *Kalloia*, *Kalloia mahunkai* from Brazil. In addition, Subías (2004) included the species *Machadocepheus foveolatus* from Mauritius in *Diplobodes* (*Kalloia)* and later (2016) in *Gibbicepheus* (*Kalloia*), implying that this species is the third representative of *Kalloia*. However, *K. mahunkai* and *M. foveolatus* do not have anterior notogastral depression and no centrodorsal notogastral hump-like process (generic traits of *Kalloia*) and correspond to generic traits of the genus *Gibbicepheus*, therefore we suggest to exclude these two species from the genus *Kalloia*, and to combine them in *Gibbicepheus*.

Distribution and ecology of *Kalloia*

At present, *Kalloia simpliseta* has been recorded from the Neotropical region (Mahunka 1985, 1998; Vázquez-González *et al*. 2015; Ermilov 2016; Ermilov and Smit 2017) and Côte d'Ivoire (Ermilov and N'Dri 2018); *Kalloia gerdweigmanni* **n. sp.** is known only from Indonesia (this study). Thus, the genus is distributed in the Neotropical, Ethiopian and Oriental regions.

Kalloia simpliseta is widely distributed in the Caribbean. It was described from several localities in Saint Lucia (Mahunka 1985): litter with underlying soil from a natural forest in Micoud, Mahaut, Quilesse Reserve; under bark of coastal trees, accumulated rotten material at tree bases in Anse La Raye, Pilori Pt.; sifted litter, wooden debris from various forest sites in Vigie. Later, the species was recorded by Mahunka (1998) in Saint Lucia from forests in the

vicinity of Halcyon Sands Hotel in Vigie, and by Ermilov and Smit (2017) from litter and soil from different Caribbean islands (Antigua, Grenada, Saint-Barthelémy, Trinidad).

Also, *K. simpliseta* was recorded from tropical ecosystems in Cozumel, Quintana Roo, Mexico (Vázquez-González *et al*. 2015), from leaf litter of forests in Parque Nacional Alejandro de Humboldt (Ermilov 2016), and from ferralitic soil of primary forests in Goulikao, Oumé region, Côte d'Ivoire (Ermilov and N'Dri 2018).

Kalloia gerdweigmanni **n. sp.** is recorded from litter of oil palm plantations and jungle rubber agroforests in Bukit Duabelas and Harapan landscapes, Sumatra, Indonesia.

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