

## ***Moona*, a new genus of tetrastichine gall inducers (Hymenoptera: Eulophidae) on seeds of *Corymbia* (Myrtaceae) in Australia**

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### **Abstract**

*Moona spermophaga* Kim & La Salle gen. & sp. nov. (Hymenoptera: Eulophidae: Tetrastichinae) is described from eastern Australia. This species induces galls on the seeds of two species of *Corymbia* (Myrtaceae), can achieve quite high levels of infestation, and has the potential to become another invasive species associated with eucalypts which has escaped Australia. *Moona* is related to *Quadrastichodella*, and similarities and differences between these genera are discussed.

**Key words:** Tetrastichinae, *Moona*, *Corymbia*, *Eucalyptus*, *Quadrastichodella*

### **Introduction**

Eucalypts have been established for wood production and reforestation in more than 100 countries. Planted eucalypt forests around the world produce more wood than that harvested every year in Australia and make eucalypts the worlds most utilized broad-leaved plantation trees. Eucalypts planted outside of Australia are most commonly used for either firewood or pulpwood (Eldridge *et al.*, 1993). Australian eucalypts are used throughout the world because of their significant advantages over other forest species. They are relatively pest-free and are capable of high growth rates in infertile soils and with a fluctuating moisture supply, and many of them are fire tolerant (Jacobs, 1955).

A eucalypt seed export program was initiated by the Australian Government under the auspices of the Food and Agriculture Organization of the United Nations (e.g., FAO, 1980). Since the 1960s, the export of eucalypt seed from Australia has intensified in response to an upsurge in world demand for seeds to start firewood plantation. For exam-

ple, aid programs funded by the Australian Government supply seeds of eucalypts into numerous developing countries (Cooper, 1983, excerpted from FAO website).

In some countries, special legislative restrictions on seed export/import exist as a follow up to the Convention on Biological Diversity; a likely export restriction in the future may relate to the issue of protection of forest genetic resources. As this restriction is applied, a Phytosanitary Certificate will be demanded commonly by the importing country in order to avoid the risk of introducing dangerous seed-borne pests and pathogens into a nation where they are not found (Cooper, 1983, excerpted from FAO website).

In Tetrastichinae, several genera are known to be involved in gall induction, and this behavior probably evolved on several separate occasions in this subfamily (La Salle, 2005). Species can induce galls on leaves, twigs, flower buds and even on seeds of host plants. In recent years, several Australian gall-inducing eulophids have become invasive pests in other regions, causing damage to eucalypts and other myrtaceous plants (Timberlake, 1957; Bouček, 1988; Graham, 1987; Headrick *et al.* 1995; Schauff and Garrison, 2000; Mendel *et al.* 2004; La Salle, 2005). Recently, *Quadrastichus erythrinae* Kim was described as the gall inducing pest on *Erythrina* (Fabaceae) in Singapore, Mauritius and Reunion; however, its exact area of origin is unknown (Kim *et al.* 2004).

There are only a few cases of seed-gall-induction known among eulophids. Several species of *Quadrastichodella* have been recorded as gall inducers or seed gallers on various eucalypts in Australia and some other regions (Bouček, 1988; Ikeda, 1999; La Salle, 2005; unpublished data). *Quadrastichodella nova* Girault (= *Flockiella eucalypti* Timberlake; *Q. eucalypti*) is known to be introduced in California, Argentina and New Zealand (Noyes, 2002; 2003). Adult females oviposit into young flower buds of *Eucalyptus* species, transforming them into seed-like galls in the seed capsules (Timberlake, 1957; Flock, 1957; both as *Flockiella eucalypti*). *Quadrastichodella neglectae* Ikeda and *Q. pilosa* Ikeda were reared from the seeds of *Eucalyptus neglecta* Maiden and *Eucalyptus* sp. respectively in Australia (Ikeda, 1999). Valentine (1970) reported two unidentified species (as *Flockiella*) from seed capsules of *E. radiata* and *E.* sp in New Zealand. Additionally, another unidentified *Quadrastichodella* sp. was found with galled seeds of *Eucalyptus* sp. among collections in the Victoria Museum (unpublished data).

Very recently, an unidentified tetrastichine species was reported emerging from eucalypt seeds in Australia and it was suggested this species might be closely related to *Quadrastichodella* (La Salle, 2005). In the present paper, this unidentified species is described as *Moona spermophaga* Kim & La Salle gen. & sp. nov.

*Moona spermophaga* was found first from galls on seeds of Spotted Gum, *Corymbia maculata* (Hook.) K.D. Hill & L.A.S. Johnson; later collections found this wasp on seeds of *Corymbia citriodora* subsp. *variegata* (F.Muell.) A.R. Bean & M.W. McDonald. These eucalypts, recently segregated from *Eucalyptus* L'Hérit as a separate genus by Hill and Johnson (1995), are tall forest trees native to the coast and adjacent ranges of eastern Australia, extending from tropical regions of central Queensland, south to eastern Victoria.

The specimens were supplied by the CSIRO Forestry and Forest Products, Australian Tree Seed Centre (ATSC) which has living seed accessions collected for use in the domestication of Australian native tree species. The ATSC has strong links with numerous overseas countries that focus on the domestication of eucalypts for wood production. The wasp first came to the attention of ATSC staff in July 2000 via a seedlot of *C. maculata* dispatched to Argentina. When the seeds were sown for germination in Argentina, adult wasps emerged from infested seeds. This was despite ATSC seedlots being routinely fumigated in CO<sub>2</sub> for two weeks in a sealed laminated plastic bag prior to dispatch and that some of the infected seedlots sent to Argentina were up to 10 years old. Samples of the infested seed and adult wasps from Argentina were procured by ATSC and sent to CSIRO Entomology for identification. There was concern that the wasp had the potential to be another invasive species escaping Australia because seeds with such small galls may be difficult to notice among thousands of healthy seeds. The pupae of the wasp also appear to be immune from fumigation in CO<sub>2</sub> and have the ability to remain dormant in galled seed for at least 10 years. This must be a matter of concern when exporting and importing seeds. Further seedlots of *C. maculata* and its relatives (collected from natural populations) were supplied to CSIRO Entomology by the ATSC for further study. *Moona* was identified as a common seed galling wasp in the *C. maculata* seedlots.

Another important fact is that *Moona* represents a second genus with a seed galling biology. This was mentioned by La Salle (2005) as an undetermined species reared from eucalypt seeds whose relationships to *Quadrastichodella* required further study. The question remains as to whether the evolution of gall induction on seeds in Tetrastichinae is a single event, or occurred more than once. Further studies are planned to investigate this phenomenon.

*Format.* A single diagnosis and description are offered for a new genus and species combination. This is done to avoid repetition in the species and genus description because it is not yet clear what are generic or species level characters.

*Terminology* used in this paper is taken from Gibson (1997) and Graham (1987); OOL, ocellarocular distance; POL, post-ocellar distance; CC, costal cell; SMV, submarginal vein; MV, marginal vein; STV, stigmal vein.

*Acronyms* used in the text are as follows. ANIC, Australian National Insect Collection, CSIRO Entomology, Canberra, Australia; BMNH, The Natural History Museum, London, UK; CNC, Canadian National Insect Collection, Ottawa, Ontario, Canada; QMB, Queensland Museum, Brisbane, Australia; USNM, United States National Museum of Natural History, Washington, D.C., USA.

***Moona* Kim & La Salle gen. nov.**

**Type species:** *Moona spermophaga*. Gender feminine.

**Etymology.** The genus name *Moona* comes from an Australian aboriginal word, meaning “gum tree” (Cooper, 1979). We have chosen this name to signify the relationship of this wasp with gum trees.

***Moona spermophaga* Kim & La Salle sp. nov.**

(Figs 1–13)

**Diagnosis.** Submarginal vein with 3–5 setae; postmarginal vein about 0.5 length of stigmal vein. Antenna with 4 anelli in female and 3 anelli in male; all funicular segments longer than broad. Scape and pedicel without rasp-like reticulation. Face with very weak frontofacial suture and scrobal depression with weak median carina ventrally. Gena swollen with malar sulcus slightly curved. Clypeal margin strongly bilobed. Pronotum long in lateral view. Mesoscutal midlobe without median line. Precoxal suture weak or absent. Propodeum without distinct median carina and paraspircular carina; outer rim of propodeal spiracle partially covered by raised lobe of callus; spiracular depression open wide to anterior margin of propodeum. Gaster lanceolate; last tergum longer than broad.

**Description.**

**Female (Fig. 1–12).** Body length 3.09–3.63 mm.

Body mainly green metallic or with red metallic tints; scape partially yellow but other antennal segments dark brown; yellow mainly on face except vertex, gena posteriorly, ventral part of lateral panel of pronotum, prepectus, and most parts of legs, except hind coxa; brown with slight greenish metallic tint on gaster.

Head (Figs 1–3). POL about 1.8 times as long as OOL. Face with weak frontofacial suture just ventral to median ocellus, difficult to see in shrunken specimens. Scrobal depression with weak median suture dorsally and median carina or projection ventrally. Torulus located slightly below the middle of face; above the lower margin of eye; scape not exceeding vertex.

Gena swollen and malar sulcus slightly curved. Lower face with a longitudinal groove between torulus and clypeus. Clypeal margin strongly bilobed. Mouth about 2.5 times as long as malar space.

Antenna (Fig. 8) with 4 anelli and 3 funicular segments. All funicular segments slender and longer than broad. F1 almost as long as F2; F2 slightly longer than F3; F3 the shortest (F1: F2: F3 = 1.0: 1.0–1.1: 0.75–0.85). Clava 3 segmented; last segment without distinct terminal spine and slightly asymmetrical with its sutures oblique. Scape and pedicel without rasp-like reticulation.

Mesosoma (Figs 4–5). Pronotum long in lateral view like *Quadrastichodella*. Mesoscutal midlobe without median line; with 5–7 adnotaular setae on each side; notaulus and transscutal articulation quite deep and wide. Scutellum with deep and distinct submedian and sublateral lines; anterior pair of setae located slightly posterior to middle. Mesosternum slightly concave just in front of trochantal lobes. Precoxal suture weak to absent; if traceable, extending up to 0.6 length of mesopleuron. Dorsellum medially about 1.9 times as long as propodeum. Propodeum without distinct median carina; without paraspiracular carina; outer rim of propodeal spiracle partially covered by raised flap from callus; spiracular depression open to anterior margin of propodeum. Callus with 4–6 setae.

Gaster (Figs 6–7) lanceolate and 1.1–1.4 times as long as head plus mesosoma. Apex of gaster acute; the last tergum longer than broad and ovipositor sheath projecting acutely so as to be clearly visible dorsally. Apex of hypopygium situated close to base, extending about 0.27–0.28 length of gaster from base. Cercus with 3–4 setae; cercal setae straight or very slightly curved; the longest seta slightly longer than the other two which are subequal in length.

Wing (Figs 10–11). Submarginal vein with 4–5 dorsal setae; tapering apically and joining parastigma distal to proximal end of parastigma. Marginal vein not swollen. Stigma brown, stigmal veins from light to brown. Postmarginal vein about 0.5 length of stigmal vein. Costal cell: marginal vein: stigmal vein: postmarginal vein = 3.3–4.3: 3.7–4.5: 1.0: 0.5. Basal line of setae absent and cubital line of setae not extending past base of speculum. The area distal to speculum densely setose.

**Male (Fig. 13).** Body length 1.95–2.09 mm.

Body color almost the same as female; sometimes with blue and green metallic tint. Non-metallic parts pale color. Wing veins pale.

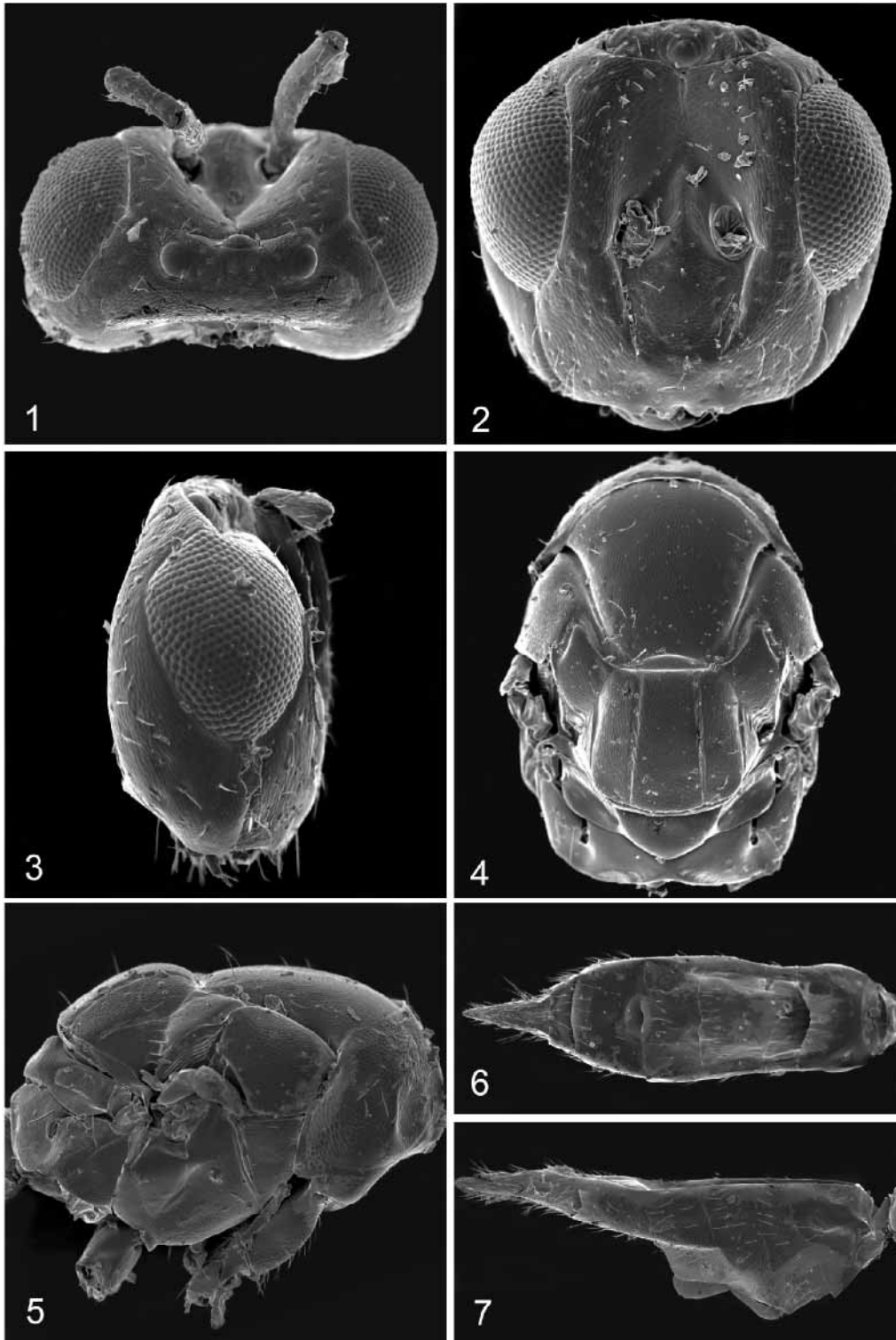
Antenna (Fig. 9) with 3 anelli; 4 funicular segments which all longer than broad; without whorls of long setae. Claval suture of the last segment symmetrical. Ventral plaque 0.32–0.4 length of scape; lower margin of plaque located in the middle of scape. F1 slightly shorter than F2; F2 and F3 almost the same in length; F4 almost the same with or slightly longer than F1 (F1: F2: F3: F4 = about 1.0: 1.1–1.3: 1.1–1.3: 1.0–1.3). Mesoscutal midlobe with 3–5 adnotaular setae. Submarginal vein with 3–5 setae. Gaster 0.95–1.15 as long as head plus mesosoma.

**Type material.**

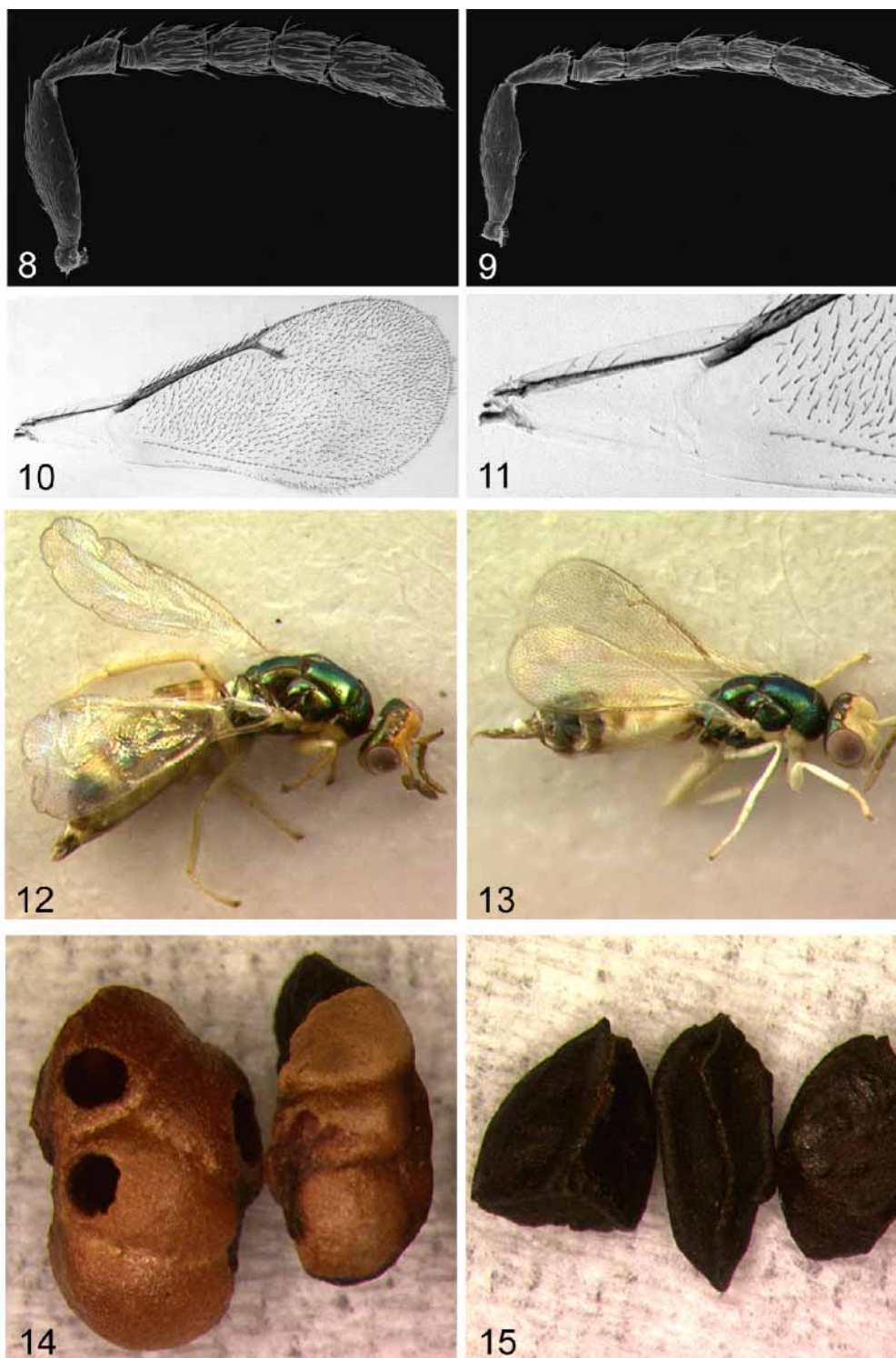
Holotype ♀: Australia, Queensland, near Mount Perry, lat. 251738, lon. 1514150, coll., 6.X.2003, ex 24.III.2004–3.V.2004, reared from seeds of *Corymbia citriodora* subsp. *variegata*. (ANIC).

22 ♀, 27 ♂ Paratypes: Same collection date as Holotype (many of the specimen broken or damaged) (15 ♀, 12 ♂ ANIC); NSW, Batemans Bay, ex 17–24.VII.1940, reared from seeds of *Corymbia maculata*. (3 ♀, 11 ♂ ANIC); 1 ♀, 1 ♂: BMNH, CNC, QMB, USNM).

Non-type material: 1 ♀, 1 ♂, loc.?, ex. 10.V.2001, reared from seeds of *Corymbia maculata*.



**FIGURE 1–7.** *Moona spermophaga* sp. n. ♀. 1. Vertex, dorsal view; 2. Face, frontal view; 3. Head, lateral view; 4. Thorax, dorsal view; 5. Thorax, lateral view; 6. Gaster, dorsal view; 7. Gaster, lateral view.



**FIGURES 8–15.** *Moona spermophaga* sp. n. and seeds of *Corymbia macualta*. 8. Antenna, ♀; 9. Antenna, ♂; 10. Forewing; 11. Submarginal vein; 12. *M. spermophaga*, ♀; 13. *M. spermophaga*, ♂; 14. galled seeds, with more than 3 chambers; 15. normal healthy seeds.

**Biology.** Emerged from galls on seeds of *Corymbia maculata* and *Corymbia citriodora* subsp. *variegata* (Figs 14–15). They are main gall inducers on seeds of these species, and they may induce 2–4 chambers on a single seed. Small numbers of wasps emerged intermittently for several months after the majority of emergences had occurred.

**Distribution.** Queensland, New South Wales, Australia

**Etymology.** The species name *spermophaga* is from the Greek *sperma* meaning seed, and *phagein* meaning to eat. It signifies its biology feeding on seeds.

## Discussion

Phylogenetic relationships within the Tetrastichinae remain elusive (La Salle, 1994; Gauthier et al. 2000); and the affinities of *Moona* can not be precisely determined at this time. Using the only existing key to genera of Australian Tetrastichinae (in Bouček, 1988), *Moona* would key to *Aprostocetus* at couplet 112. However, *Moona* appears to be more closely related to *Quadrastichodella* based on several shared derived attributes (all of which differ from those seen in *Aprostocetus*): Transscutal articulation deep and wide. Gena strongly to moderately swollen with malar sulcus curved. PMV around 0.5 length of stigmal vein. Pronotum long in lateral view. Spiracular depression large and deep, extending to the anterior margin of the propodeum. Dorsellum at least as long as propodeum. STV with hyaline break (in *Quadrastichodella* a hyaline break on stigmal vein seems usual, sometimes MV also with a break). Both genera induce galls on eucalypt seeds.

The most significant difference between *Quadrastichodella* and *Moona* is that *Moona* lacks the rasp-like reticulation on the scape and pedicel, which is an apomorphic character of *Quadrastichodella*. Other differences in *Moona* are as follows: the apical end of scape not expanded anteriorly (scape apically expanded anteriorly in *Quadrastichodella*). Protibia not expanded anteriorly and without 2 rows of setose teeth (protibia expanded anteriorly and with 2 rows of setose teeth in *Quadrastichodella*). Precoxal suture present; weak or vague (precoxal suture usually absent in *Quadrastichodella*). POL narrower (POL much widely separated in *Quadrastichodella*). *Moona* is partially metallic in color but *Quadrastichodella* is fully metallic except for some parts of the legs and antennae.

The question remains as to the relationship between *Moona* and *Quadrastichodella*. If they are sister taxa, then it can be assumed that seed gall induction arose only once in Australian Tetrastichinae. Otherwise, two independent derivations must be postulated. Further studies are necessary to clarify this.

Further studies of several aspects of the biology of *M. spermophaga* would also be interesting. One of these is its respiration biology, as it can remain dormant in seeds for long periods, including surviving in a CO<sub>2</sub> saturated atmosphere for two weeks. Questions also arise regarding its host range and specificity. It is reliably recorded from only two species of *Corymbia*; tests of its host range within Myrtaceae would be desirable.



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