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# Comparison of the morphology of the adult males of the rhizoecine, phenacoccine and pseudococcine mealybugs (Hemiptera: Sternorrhyncha: Coccoidea), with the recognition of the family Rhizoecidae Williams

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## Abstract

In the past, the morphology of adult males of Coccoidea has provided strong support for diagnosing the higher taxon status of scale insects (Coccoidea). In particular, studies on adult male morphology have produced some of the strongest evidence for considering the Putoidae and Eriococcidae (as then defined) as separate families from the Pseudococcidae. This paper uses adult male morphology to assess the relationships of the Pseudococcidae and the hypogaeic and myrmecophilous mealybugs. The latter most often are classified as a subfamily (Rhizoecinae) of the Pseudococcidae. In order to diagnose the latter taxa, the adult males of fifteen named species of hypogaeic rhizoecine mealybugs (*Kissrhizoecus hungaricus* Kozár & Konczné Benedicty, *Rhizoecus cacticans* (Hambleton), *Rh. coffeae* Laing, *Rh. dianthi* Green, *Rh. falcifer* Künckel d'Herculais, *Rh. kazachstanus* Matesova, *Ripersiella cryphia* (Williams), *Ri. hibisci* (Kawai & Takagi), *Ri. kondonis* (Kuwana), *Ri. malschae* (Williams), *Ri. puhiensis* (Hambleton), *Capitisetella migrans* (Green) and *Pseudorhizoecus proximus* Green) plus two unidentified *Ripersiella* species are described. In addition, the adult males of a *Xenococcus* sp., three *Eumyrmococcus* spp. and two *Neochavesia* spp. are illustrated from previously published papers and the adult male of another *Neochavesia* sp. is described and illustrated. In order to compare the diagnoses of the above taxa with that of adult males of Pseudococcidae (minus the Rhizoecinae), the adult males of two apterous pseudococcid mealybugs are described or redescribed: *Asaphococcus agninus* Cox and the myrmecophilous *Promyrmococcus dilli* Williams, both belonging to the Pseudococcinae. In addition, three macropterous Pseudococcidae, namely *Phenacoccus solenopsis* Tinsley (Phenacoccinae), *Planococcus glaucus* (Maskell) and *Maconellicoccus hirsutus* (Green) (Pseudococcinae) are also described and/or illustrated. Prior to this study, the hypogaeic and myrmecophilous mealybugs generally were included in the subfamily Rhizoecinae of the Pseudococcidae, with the hypogaeic mealybugs in tribe Rhizoecini and the myrmecophilous mealybugs in Xenococcini. Based on the present study and on phylogenetic data, it is concluded that the rhizoecine mealybugs form a separate family from the Pseudococcidae — Rhizoecidae Williams. This family is considered here to include two subfamilies, Rhizoecinae Williams and Xenococcinae Tang. Based on adult male characters, there is little support for the present generic divisions of the Rhizoecinae. Keys are given for separating the adult males of Rhizoecidae from those of Pseudococcidae, and for separating the known adult males within each subfamily.

## Introduction

*Present classification of the Pseudococcidae*

The mealybugs or Pseudococcidae are the second largest family within the scale insects (Hemiptera: Sternorrhyncha: Coccoidea), with approximately 2000 species (Ben-Dov, 2011). Mealybugs are small and soft bodied, and most species are covered in powdery or mealy wax, thus their common name. The pseudococcids belong to an informal group, referred to as the neococcoids, which contains the "more derived" scale insects, and the mealybugs are generally considered to be sister to most other neococcoids (Gullan & Cook, 2007). The current taxonomy and classification of the pseudococcids is based on the morphology of the adult female, although a few studies have included adult males. Thus, as part of a program to describe the adult males of scale insect families, Afifi (1968) described the adult males of 17 species of mealybugs and seven species of eriococcids (but did not include any hypogaeic or myrmecophilous species). At the time, the status of these two families was still somewhat controversial but it was clear that, on the basis of Afifi's study of adult male morphology, these two groups should be given family status. Since then, phylogenetic studies have supported this view and these two families are now immediately recognisable, although the eriococcids as currently defined are not monophyletic (Cox & Williams, 1987; Cook *et al*. 2002; Cook & Gullan, 2004). The higher classification of the eriococcids requires major revision (Cook & Gullan, 2004) and that of the pseudococcids has not been definitely established (Downie & Gullan, 2004; Hardy *et al*., 2008). Until recently, the genus *Puto* Signoret also was included within the pseudococcids but there is now general agreement that this genus should be placed in its own family, Putoidae Beardsley (Williams *et al*., 2011). The adult males of Putoidae are strikingly different from those of the Pseudococcidae. The remaining mealybug species have been variously placed in about five subfamilies: Pseudococcinae, Phenacoccinae, Trabutininae, Rhizoecinae and Sphaerococcinae, although, as stressed by Downie & Gullan (2004), these subfamily names are not in general use and different authors have recognised different subfamilies. Indeed, Downie and Gullan (2004) only recognised three subfamilies (Pseudococcinae, Phenacoccinae and Rhizoecinae), and Hardy *et al*. (2008) rec-