

Exploring Chiococceae (Rubiaceae) in Mexico: Morphology, Diversity, and Endemism

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INTRODUCTION & AIM

The Rubiaceae family, most known as the coffee family, consists of approximately 600 genera, over 14,000 species, and 65 tribes (Govaerts et al. 2018). Although Rubiaceae is found on all continents, it is especially diverse in tropical and subtropical regions. Despite several efforts to characterize the diversity of Rubiaceae in Mexico, the number of genera and species recognized by different authors varies greatly from 80 to 113 genera and from 510 to 707 species (Villaseñor 2003, 2016, Borhidi 2006, 2012). This disparity highlights the need to critically review the principal studies of diversity of Rubiaceae in Mexico.

One of the taxonomically disputed lineages is the Chiococceae tribe of the Cinchonoideae subfamily (Bremer et al. 1995, 1999, Bremer & Eriksson 2009, Kainulainen et al. 2013). This tribe cannot be distinguished by synapomorphic characteristics; rather it is defined by a combination of two homoplastic features: insertion of the stamen on the basal area of the corolla or on the disc, and spinulose pollen. These characters are homoplasies, as they are also present in other Rubiaceae genera such as Hamelieae, Sipaneeae, and Spermacoceae (Motley et al. 2005, Manns & Bremer 2010, Paudyal et al. 2014, 2018).

Thus, this study aims to: (1) review the generic diversity and species richness of Chiococceae in Mexico; (2) map the distribution of all genera currently recognized for Chiococceae; (3) identify geographical areas with the greatest Chiococceae richness; (4) provide a morphological synthesis for the main characters used for diagnosing Mexican genera; and (5) provide a comparison of genera of Chiococceae in Mexico

METHOD

A database of Mexican Chiococceae was built using three main sources: literature review, examination of about 4,250 herbarium specimens (including types), and fieldwork. Specimens were studied both from online virtual collections and from physical material in several herbaria. When available, the database includes geographic coordinates, date, phenology, country, locality, and endemism, and identifications were checked using specialized literature.

For the geographical analysis, generic distributions were complemented with floristic lists, and about 3,800 records were georeferenced using Google Earth. Using QGIS, species richness per $1^{\circ} \times 1^{\circ}$ grid cell was calculated for all genera of Chiococceae.

For the morphological synopsis, only reproductive characters were used. These characters follow standard terminology and were coded from published taxonomic descriptions and confirmed by examining herbarium specimens.

RESULTS & DISCUSSION

- Out of 30 known genera, nine occur in Mexico; two genera are endemic *Coutaportia* (5 spp) and *Nernstia* (1 sp), and three are shared with Guatemala and the U.S.
- *Chiococca* is the most diverse genus in Mexico (16 spp), followed by *Coutaportia* (5 spp), and *Hintonia* (3 spp).
- Mexico is the main center of diversity for *Chiococca* (17 of ~20 species).
- In total, 27 Chiococceae species occur in Mexico, 13 of them endemic.
- Three of the nine genera in Mexico include at least one endemic species.

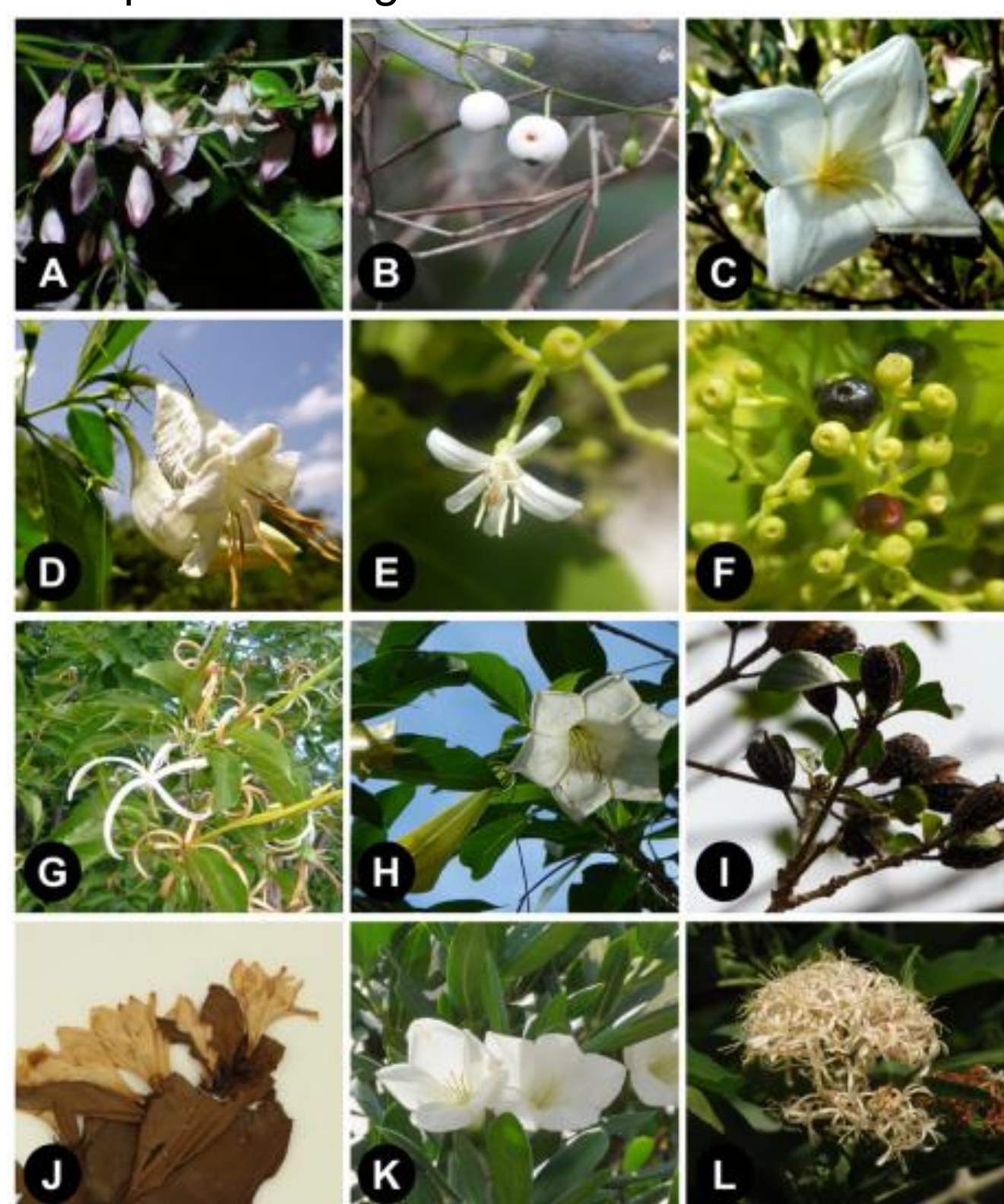


FIGURE 1. Genera of Chiococceae in Mexico. (A–B) *Chiococca alba*: (A) Inflorescence (photo A. Castro); (B) Fruits (photo N. Ramírez). (C) *Coutaportia ghesbreghtiana* (photo I. Morales); (D) *Coutarea hexandra* (photo A. Molina); (E–F) *Erithalis frutescens*: (E) Flower (photo O. Jiménez-Oroci); (F) Fruits (photo O. Jiménez-Oroci); (G) *Exostema caribaeum* (photo L. H. Vicente-Rivera); (H–I) *Hintonia latiflora*: (H) Flowers (photo F. Sarabia); (I) Fruits (photo F. Sarabia); (J) *Lorencea guatemalensis* (Specimen Alush Méndez 5113, MEXU); (K) *Nernstia mexicana* (photo E. Mendiola); (L) *Solanandra mexicana* (photo A. Dorantes).

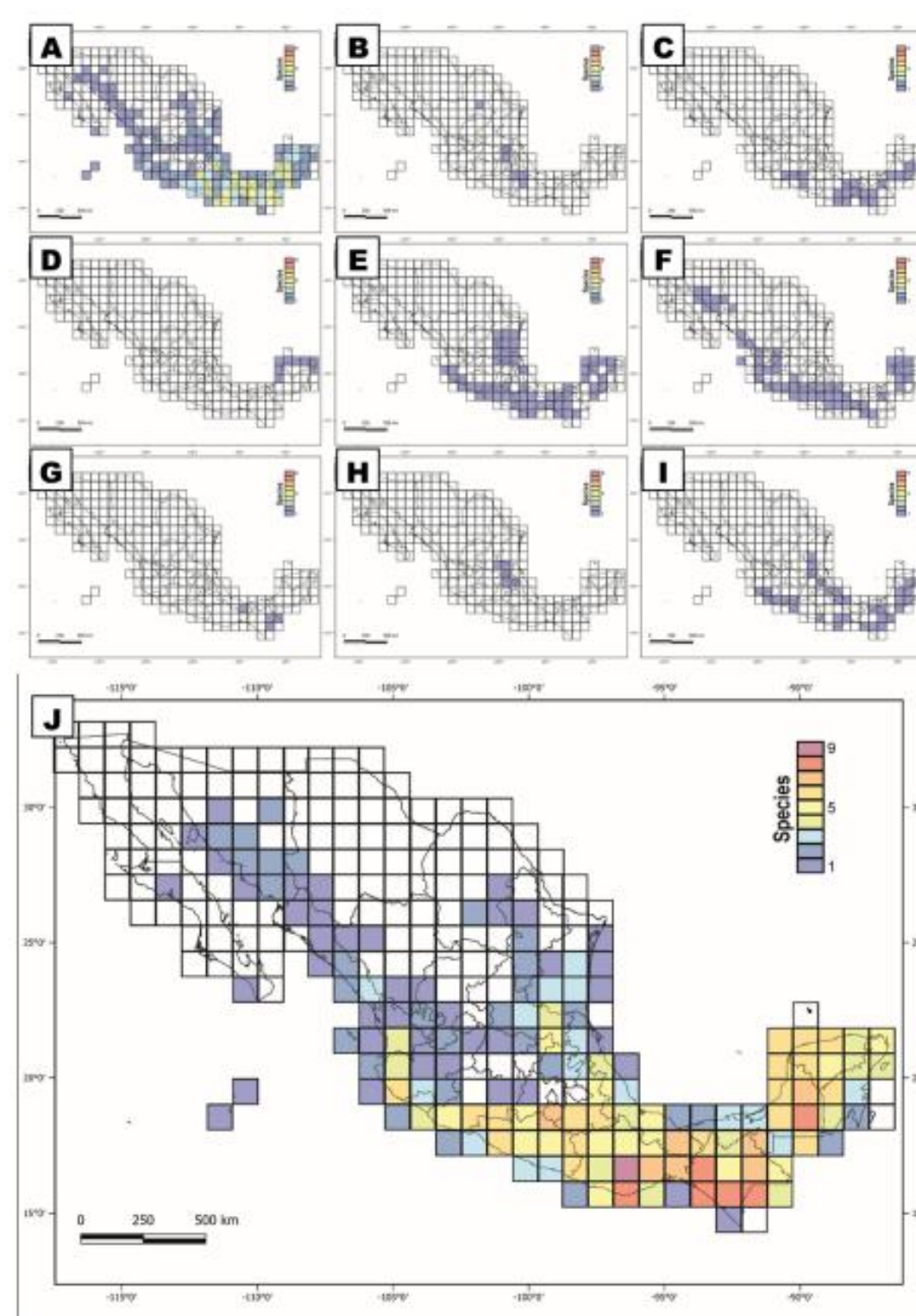


FIGURE 2. Heat maps of diversity of genera of Chiococceae presented as $1^{\circ} \times 1^{\circ}$ grid cells in Mexico. (A) *Chiococca*; (B) *Coutaportia*; (C) *Coutarea*; (D) *Erithalis*; (E) *Exostema*; (F) *Hintonia*; (G) *Lorencea*; (H) *Nernstia*; (I) *Solanandra*; (J) *Chiococceae* tribe.

Of all tribes of Rubiaceae, Chiococceae is not one of those with the most species in Mexico, unlike Spermacoceae and Guettardeae, which have approximately 117 and 92 species, respectively (Villaseñor, 2016). However, Chiococceae is one of the most diverse tribes in Mexico at the generic level, with nine genera, two of which are endemic, surpassed only by Spermacoceae (24 genera, four endemic), Hamelieae (13 genera, seven endemic), and Guettardeae (10 genera, none endemic). Additionally, Chiococceae has a varied morphology, particularly with respect to reproductive traits, and is widely distributed in many ecosystems, both arid and humid.

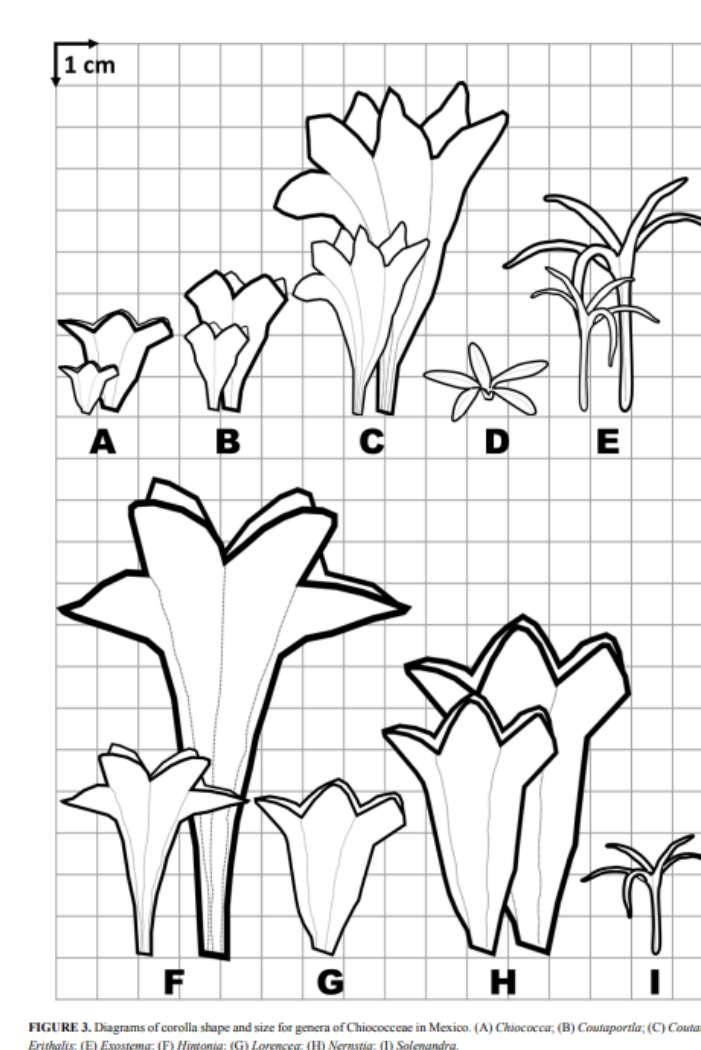


FIGURE 3. Diagrams of corolla shape and size for genera of Chiococceae in Mexico. (A) *Chiococca*; (B) *Coutaportia*; (C) *Coutarea*; (D) *Erithalis*; (E) *Exostema*; (F) *Hintonia*; (G) *Lorencea*; (H) *Nernstia*; (I) *Solanandra*.

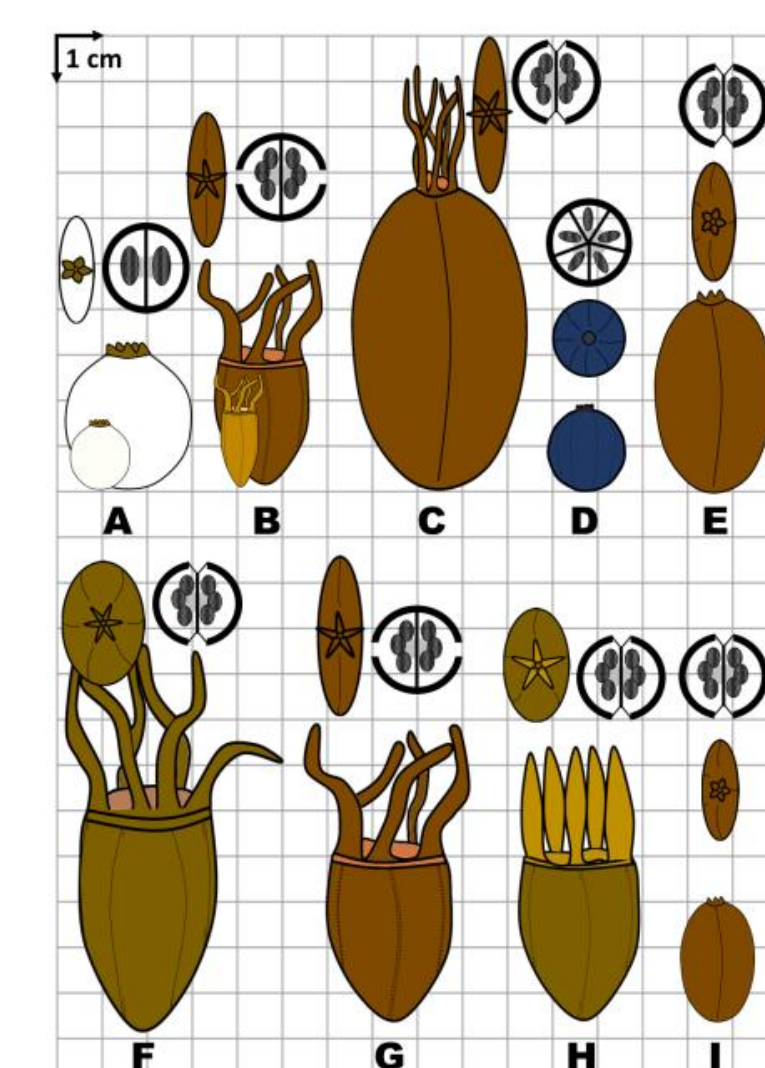


FIGURE 4. Fruit diagrams showing fruit type, size, dehiscent compression, and dehiscence for genera of Chiococceae in Mexico. (A) *Chiococca*; (B) *Coutaportia*; (C) *Coutarea*; (D) *Erithalis*; (E) *Exostema*; (F) *Hintonia*; (G) *Lorencea*; (H) *Nernstia*; (I) *Solanandra*.

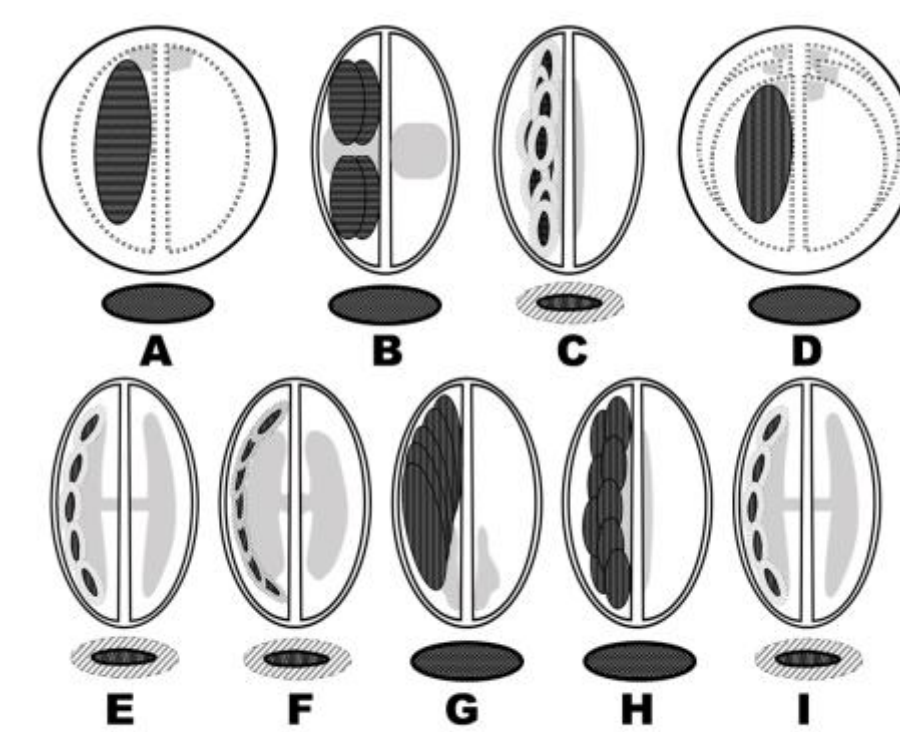


FIGURE 5. Fruit and seed diagrams showing number of locules, seed attachment to the placenta, and seed margin for genera of Chiococceae in Mexico. (A) *Chiococca*; (B) *Coutaportia*; (C) *Coutarea*; (D) *Erithalis*; (E) *Exostema*; (F) *Hintonia*; (G) *Lorencea*; (H) *Nernstia*; (I) *Solanandra*.

The tribe Chiococceae is well represented in Mexican flora, both in terms of the total species diversity and number of the endemic taxa, at both generic and specific levels. Though two genera are endemic and one is shared with a few localities in Central America, Mexican endemic species represent approximately 50% of all Chiococceae, establishing Mexico as one of the most important areas for diversification of the tribe. Analysis of their distribution shows that they are particularly diverse in humid tropical areas of southern Mexico. Thus, among Mexican Rubiaceae, Chiococceae are significant not only in terms of species richness, but also in terms of their morphological diversity, reflected in their wide range of flower, fruit, and seed traits. Additional taxonomic studies should be carried out to define their diversity, including phylogenetic analysis focused on circumscription of certain genera. Also, surveys of population status and additional knowledge of their distribution patterns are necessary to establish their IUCN threat categories for effective conservation of endemic Chiococceae in Mexico.