



# Systematics, taxonomy and floristics of Brazilian Rubiaceae: an overview about the current status and future challenges

Sistemática, taxonomia e florística das Rubiaceae brasileiras: um panorama sobre o estado atual e futuros desafios

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## Abstract

The Rubiaceae is the fourth Angiosperm family in number of species in the World and in the Neotropics. Its overwhelming diversity and presence in most biomes, and at most vegetation layers, makes this family one of the most important components of tropical vegetation. During the last two decades, family classification went through several reorganizations, mostly influenced by the advent of molecular phylogenetic studies, and many taxonomic revisions and floristic studies on Brazilian Rubiaceae have become available. In view of the considerable amount of literature that has recently been produced on Neotropical Rubiaceae, the present work has two main objectives: the first is to offer an overall view of the most recent family classification with emphasis on the genera of Rubiaceae occurring in Brazil, and to indicate particular taxa that are still in need of phylogenetic and taxonomic studies; the second objective is to present a short discussion on the state of floristic and taxonomic knowledge with respect to the various regions of Brazil, indicating the taxa and the geographic areas that need to be studied.

**Key words:** Rubiaceae, Brazil, classification, floristics, systematics, taxonomy.

## Resumo

Rubiaceae é a quarta família em número de espécies entre as Angiospermas no Mundo e no Neotrópico. A grande diversidade de espécies com representantes na maioria dos bioma, ocupando os diferentes estratos vegetacionais, fazem desta família um dos mais importantes componente da vegetação tropical. Durante as duas últimas décadas a classificação da família sofreu várias reorganizações, principalmente pela influência de estudos filogenéticos moleculares, e muitos estudos florísticos e revisões taxonômicas foram recentemente produzidos sobre Rubiaceae Neotropicais. Considerando a grande quantidade de literatura que foi recentemente produzida sobre estes assuntos, o presente trabalho tem dois objetivos principais: o primeiro é fornecer uma visão geral sobre a mais recente classificação da família com ênfase nos gêneros de Rubiaceae que ocorrem no Brasil, indicando os táxons que necessitam de estudos filogenéticos e taxonômicos; o segundo, é apresentar uma breve discussão sobre o estado de conhecimento florístico e taxonômico nas várias regiões do Brasil, indicando os táxons e as áreas geográficas que precisam de mais estudos.

**Palavras-chave:** Rubiaceae, Brasil, classificação, florística, sistemática, taxonomia.

## Introduction

The Rubiaceae is the fourth family in number of species in the Angiosperms (Tab. 1), after Orchidaceae, Asteraceae and Leguminosae. Delprete (2004a) esteemed that the family is made of about 650 genera and 13,000 species worldwide; these numbers were later confirmed by Govaerts *et al.* (2007), in their world checklist, by reporting

611 genera and 13,100 species. The difference in number of genera between these two accounts is partly due to advent of molecular phylogenies and recent morphological comparisons that resulted in the reduction to synonymy of many genera. According to Delprete (2004a), in the Neotropics are present by about 217 genera and 5,000 species of Rubiaceae.

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**Table 1** – Summary of the five largest families of flowering plants, with approximate number of species in the world (Mabberley 2008; Govaerts *et al.* 2007), in the Neotropics (Delprete 2004), and in the Guyana Shield (Funk *et al.* 2007).

World		Neotropics		Guyana Shield	
Asteraceae	23,600	Asteraceae	8,000	Leguminosae	1,032
Orchidaceae	22,500	Orchidaceae	7,000	Orchidaceae	1,020
Leguminosae	19,500	Leguminosae	6,700	<b>Rubiaceae</b>	<b>742</b>
<b>Rubiaceae</b>	<b>13,100</b>	<b>Rubiaceae</b>	<b>5,000</b>	Melastomataceae	534
Poaceae	10,550	Poaceae	3,300	Poaceae	526

**Distribution and habitat** – The Rubiaceae is a cosmopolitan family, predominantly pantropical, and with a small portion of species of extra-tropical distribution. Almost one half of the species (and about one third of the genera) occur in the Neotropics. In South America, they are adapted to virtually every habitat: from *páramo* to arid and desertic environments. Rubiaceae are especially diverse in the Amazon Basin, Andean cloud forests, *cerrados* (including *campos rupestres*), *caatingas*, *restingas*, and the Atlantic forests of Brazil. The two main centers of endemism in the Neotropics are the Guyana Highlands and the Greater Antilles.

**Habit** – The Rubiaceae is well represented at all layers of tropical vegetation, with all kinds of habits, as herbs, shrubs, lianas, and from small trees to tall canopy trees, and all dimensions, ranging from 5 mm tall (*Spermacoce* spp.) to 55 m tall (*Chimarrhis* spp.). Most species of *Hillia* Jacq., *Cosmibuena* Ruiz & Pav., and several species of *Notopleura* (Benth. & Hook. f.) Bremek. and *Psychotria* L. are epiphytic shrubs adapted to live in the forest canopy. *Limnosipanea* Hook. f. is a short-seasonal, semi-aquatic herb endemic to seasonally inundated habitats of central Brazil and the Venezuelan *llanos*. Many members of the *Spermacoceae* are herbs and subshrubs frequently found in disturbed habitats (e.g., cow pastures and forest edges).

**Ecological importance** – Because of their abundance, diversity, and presence at all vegetational layers, the Rubiaceae are an important factor for ecological studies in tropical regions, in terms of floristic and sociological composition, comparison among floristic composition of world tropical vegetation, observation and comparison of different vegetational layers (herbs, shrubs, trees, lianas), comparison of different habitats (savanna, restinga, open fields, forests, etc.), and particularly important at the undercanopy layer of tropical forests. Also,

when compared with the other large flowering plant families (Orchidaceae and Leguminosae), the Rubiaceae are the family better fitted to be used in ecological analysis, because the Orchidaceae are mostly herbaceous, and the Leguminosae are probably taxonomically less studied than the Rubiaceae. Also, the Rubiaceae, along with the Melastomataceae, is the family that supplies most edible fruits to tropical birds (Bremer & Eriksson 1992). In conclusion the Rubiaceae is an important indicator to be used as a proxy for ecological studies and conservation status of tropical vegetation.

**Diagnostic characters** – Field recognition of the family Rubiaceae is relatively easy, because of the following diagnostic characters:

- 1) leaves commonly opposite, rarely whorled (3–6 per node), or appearing whorled because of leaf-like stipules (*Galium* L.) or axillary short shoots (e.g., *Spermacoce* L.);
- 2) leaf blades undivided (exceptionally deeply lobed in *Genipa infundibuliformis* Zappi & Semir and several species of *Pentagonia* Benth.);
- 3) leaf margins always entire (never dentate);
- 4) stipules intrapetiolar (interpetiolar in *Elaeagia* Wedd. and *Capirona* Spruce; rarely reduced to a line in *Perama* Aubl.);
- 5) flowers commonly actinomorphic, rarely zygomorphic;
- 6) corollas gamopetalous (except for *Dialypetalanthus* Kuhlm., with distinct petals), (3)4–5(11–13(–15))-merous (*Riodocea* Delprete has 13-15-merous corollas, being the highest merosity in the Rubiaceae);
- 7) stamens commonly as many as corolla lobes (except for *Dialypetalanthus*, with two rows of 15–25 stamens);
- 8) ovary inferior, rarely some fruits becoming falsely half-superior (e.g., *Gleasonia* Standl., *Platycarpum* Bonpl.) or superior (*Pagamea* Aubl.) at maturity.

### Past and present of the family position and delimitation

Cronquist (1981) positioned the Rubiaceae in the Class Asteridae, Order Rubiales, near the Theligonaceae, family with only the genus *Theligonum* L. (Wunderlich 1971). He considered the Rubiales as narrowly related with the orders Gentianales and Dipsacales, and sister family of the Caprifoliaceae (but he erroneously supposed that the Asteraceae originated from the Rubiaceae). The phylogenetic studies of Chase *et al.* (1993), Struwe *et al.* (1994) and Backlund *et al.* (2000) demonstrated that the family Rubiaceae is a monophyletic group of the order Gentianales, along with the families Gentianaceae, Loganiaceae, Gelsemiaceae and Apocynaceae *s.l.* (incl. Asclepiadaceae). These results were integrated in the last Angiosperm classification proposed by Takhtajan (1997). The positioning of the Rubiaceae in the Gentianales was later confirmed by the phylogenies produced by the Angiosperm Phylogeny Group (APG 1998, 2003, 2009), where the family is positioned on a basal clade. According to these studies, the Rubiaceae is the family with the highest number of species in the order, with about 66% of the species, followed by the Apocynaceae with ca. 4700 spp., the Gentianaceae with ca. 1650 spp., the Loganiaceae with ca. 400 spp., and the Gelsemiaceae with 11 spp. (Struwe & Albert 2002).

A few genera previously positioned in other families, have recently been shown to belong to Rubiaceae. The genus *Theligonum*, characterized for having leaves apparently alternate (in fact, an extreme case of anysophyly) and unilocular, uniovulate ovary, was historically positioned in its own monotypic family. Darwin (1976) transferred this genus to the Rubiaceae, in the monotypic tribe Theligoneae of the subfamily Rubioideae, a decision that was followed by Robbrecht (1988) using morphological data, and that was supported by the molecular phylogenies of Bremer *et al.* (1995).

The genus *Dialypetalanthus* was initially positioned in the Rubiaceae by Kuhlmann (1925), and subsequently transferred to the Dialypetalanthaceae by Rizzini & Occhioni (1949), who suggested a systematic position in the Order Myrtales. Cronquist (1981) positioned this genus and family in the Order Rosales, and Nicholas & Baijnath (1994) in the Order Cornales. Piesschaert *et al.* (1997), after a detailed analysis with morphological and anatomical characters were unable to indicate a definitive family position of *Dialypetalanthus* and suggested a relationship with the orders Myrtales or Gentianales,

and a probable relationship with the Rubiaceae. Delprete (1998d) after a morphological analysis confirmed that it should be returned to the original position suggested by Kuhlmann (1925), and more precisely in the tribe Rondeletieae *sensu* Delprete (1999d). Fay *et al.* (2000) with a phylogenetic analysis using *rbcL* confirmed its positioning in the Rubiaceae, subfamily Ixoroideae, near *Condaminea* DC., *Pogonopus* Klotzsch and *Calycophyllum* DC. (Tribe Condamineae *sensu* Kainulainen *et al.* 2010), as was indicated by Delprete (1998d).

According to the phylogenies published by Backlund *et al.* (2000), the Rubiaceae represent the basal group in the Order Gentianales. For this reason, the dating with the help of molecular phylogenies could also indicate the age and the center of origin of the Order Gentianales. As suggested by several authors (e.g., Struwe & Albert 2002), the Rubiaceae, and therefore the Gentianales, originated at least 70 millions years ago. However, Bremer & Eriksson (2009), using molecular phylogenies calibrated with carbon-dating of several fossils, estimated that the Rubiaceae originated about 90 millions years ago.

In conclusion, following the results of the molecular phylogenies above cited, the Rubiaceae where demonstrated to be a monophyletic group distinguishable from the other families in the Order Gentianales by the following set of morphological and anatomical characters: 1) inferior ovary (with some exception in the remainder of the order); 2) lack of internal phloem (present in the remainder of the order, with a few exceptions); 3) obturator; 4) casparian thickening; and 5) anticipated sympetaly (Erbar 1991).

### Internal classification of the family Rubiaceae

Rubiaceae classification at the subfamilial and tribal levels went through several important rearrangements during the last decades. Bremekamp (1934) published an article that had a great influence by contemporary botany, where he criticized the systems proposed by Baillon (1880) and Schumann (1891), because they were made of paraphyletic groups obtained through the utilization of a dichotomic classification based on unique characters. He declared that the groups defined by a sole character cannot be natural and that the seed wings of several general genera do not represent an important taxonomic character, in contrast with Baillon (1880), who divided the family into two

groups, one with uni-ovulate taxa, and the other with multi-ovulate taxa. Bremekamp (1934) was also the first rubiologist treating the ixoroid mechanism of pollen presentation as an important taxonomic character. A few years later, Bremekamp (1940) emphasized his skepticism against the classification proposed by Schumann (1889, 1891), declaring it to be non-satisfactory and with artificial and ill-defined tribes. In this little known publication, Bremekamp (1940) predicted the path towards the Rubiaceae classification of the following decades, declaring that fruit fleshiness should be regarded as a secondary character and that the taxonomic characters of primary importance will be found in “...presence or absence of hairs in the corolla throat; the place where the stamens are inserted in the tube; the presence or absence of floral dimorphism; the uni- or bisexuality of the flowers; the insertion and the shape of the placenta; the number of ovary cells and the presence or absence of false septa (septa); the nature the stipules; the position of the inflorescences, etc. These characters, however, are at present but imperfectly known, and therefore a satisfactory subdivision can be given, the genera themselves will have to be studied in more detail.”

Verdcourt (1958), deeply influenced by Bremekamp, was the second rubiologist to classify the Rubiaceae based on total evidence, studying a new series of taxonomic characters, including the observation of chromosomes, vestiture of reproductive parts, of the stipules, presence or absence of calcium oxalate crystals, presence of albumen in the seeds, embryo structure, and mechanism of pollen presentation. He divided the Rubiaceae into three subfamilies (Rubioidae, Cinchonoideae and Guettardoideae), and 28 tribes.

In his last work published on Rubiaceae classification, Bremekamp (1966) analyzed the innovations proposed by Verdcourt, with which he was generally in agreement. But, in contrast with his previous classification (Bremekamp 1934) and with that proposed by Verdcourt (1958), he divided the Rubiaceae into eight subfamilies and 43 tribes.

The last comprehensive classification proposed before the instars of molecular phylogenies was that of Robbrecht (1988, 1993). This classification was generally influenced by those of Verdcourt and Bremekamp. According with Verdcourt, he recognized four subfamilies, by dividing the Guettardoideae *sensu* Verdcourt into the two subfamilies Ixoroideae and Antirheodeae, and, similarly to Bremekamp, he recognized 44 tribes (one more than Bremekamp). Robbrecht's (1988,

1993) classification was used in most contemporary treatments, as the Plant-Book (Mabberley 1997) and the Flora of Ecuador, sometimes with some modifications (Andersson 1993, 1994).

With the advent of molecular phylogenies, during the last decades was demonstrated that the Rubiaceae are better divided into three subfamilies: Cinchonoideae, Ixoroideae and Rubioideae. Many studies were dedicated to phylogenetic studies of the family internal classification, subfamilies, tribes, or even smaller groups in order to have a general picture of the family backbone, and subsequently to clarify tribal and generic delimitations (*rbcL*, Bremer & Jansen 1991; *rbcL* and *ndhF*, Andreasen & Bremer 1996; Bremer 1996; Bremer *et al.* 1999; *rps16* and *trnL-F*, Rova *et al.* 2002). These studies showed that many characters used by Bremekamp (1934, 1954, 1966), Verdcourt (1958) and Robbrecht (1988, 1993) to define subfamilies and tribes, are highly plastic in an evolutionary sense, and that, for example, mesocarp fleshiness, placentation type, and number of ovules per locule are much more easily interchangeable than previously thought. This does not mean that these characters should be abandoned, but, to the contrary, the morphology, anatomy, and palynology of the Rubiaceae should be re-evaluated in order to understand their true evolutionary and taxonomic importance in an evolutionary contest.

During the last fifteen years, many other molecular phylogenetic studies were published (Achille *et al.* 2006; Andersson & Antonelli 2005; Andersson & Rova 1999; Andersson *et al.* 2001; Andreasen & Bremer 1996; Andreasen & Bremer 2000; Andreasen *et al.* 1999; Bremer & Manen 2000; Bremer & Thulin 1998; Bremer *et al.* 1999; Cortés-B. 2003; Delprete & Cortés-B. 2004; Dessein 2003; Lantz 2003; Motley *et al.* 2005; Persson 2000a,b; Piesschaert *et al.* 2000; Razafimandimbison & Bremer 2001, 2002; Rova *et al.* 2002; Stoffelen *et al.* 1996), with the intent of clarifying the subfamilial, tribal and generic delimitation in the Rubiaceae. Following these studies, a family classification for a general overview on the systematic significance of pollen in the Rubiaceae was published by Dessein *et al.* (2005), where significant correlations with tribal delimitations were detected.

A new family classification was proposed by Robbrecht & Manen (2006), based on *rbcL*, *rps16*, *trnL-trnF* and *atpB-rbcL*. In the phylogenies obtained, *Luculia* Sweet and *Coptosapelta* Korth. were found (as in previous phylogenies of Bremer

and collaborators) at a basal position, as sister taxa to the remainder of the family, which they included in the tribe Coptosapelteae. The “supertree” classification proposed by Robbrecht and Manen (2006) was innovative, by proposing only two subfamilies, the Cinchonoideae and the Rubioideae. The subfamily Cinchonoideae was further divided into three groups: the tribe Coptosapelteae, the supertribe Ixoridinae (14 tribes and alliances) and the supertribe Cinchonidinae (7 tribes and complexes). The subfamily Rubioideae was divided into three groups: basal Rubioideae (*Colletoeceema* E.M.A. Petit and 5 tribes), the supertribe Psychotriidinae (6 tribes), and the supertribe Rubiidinae (8 tribes). Summarizing, this classification proposed the division into two groups, a total of 40 tribes and several genera at unresolved positions (although many genera were not even mentioned in the classification), and reducing several previously recognized tribes to the level of subtribes.

The last comprehensive family classification based on molecular phylogeny of 534 taxa and 329 genera (about half the genera recognized in the family), with sequences of five chloroplast regions (*rbcL*, *trnT-F*, *rps16*, *atpB-rbcL*, *ndhF*), was published by Bremer and Eriksson (2009) that produced a highly resolved tree, and with the main goal of dating the main clades with the available fossil records. Based on the phylogeny obtained, the authors maintained the division of the family into three subfamilies (Cinchonoideae, Ixoroideae and Rubioideae) and 44 tribes. Because several data sets used in this analysis were in common with

those used by Robbrecht & Manen (2006), most of the groups recognized are quite similar, but Bremer and Eriksson (2009) positioned them at different taxonomic ranks, following previous classifications proposed by the Bremer’s working group. Because this latest classification seems to be widely accepted (although not yet comprehensive, as usable DNA is not yet available for all the genera), it is here chosen as the main frame for our discussion of taxonomic groups of Rubiaceae present in Brazil. The main morphological characters of the three subfamilies currently recognized in the Rubiaceae are presented in Table 2.

### Classification of the Rubiaceae and status of taxonomic groups present in Brazil

This presentation is an updated summary on the current status of the genera of Rubiaceae present in Brazil, organized according to Bremer & Eriksson (2009) classification, and recent phylogenetic studies of several tribes (as indicated in the text). This presentation is intended to help the Rubiaceae specialists with the updates of recent literature, and to indicate taxonomic groups present in Brazil that need particular attention for possible phylogenetic, taxonomic, and floristic studies.

**Tribes Coptosapelteae and Luculiae:** *Coptosapelta* and *Luculia* are located at a basal position in the Rubiaceae, at a sister position, with respect to the rest of the family; they are both Asiatic genera that do not occur in Brazil.

**Table 2** – Table summarizing the main characters of the three subfamilies currently recognized in the family Rubiaceae, with emphasis on Neotropical genera (from Delprete 2004).

	<b>Cinchonoideae</b>	<b>Ixoroideae</b>	<b>Rubioideae</b>
<b>Habit</b>	trees, shrubs, lianas	trees, shrubs, herbs, vines	mostly herbs and shrubs, rarely trees
<b>Stipules</b>	entire, rarely bifid (not fimbriate)	entire, rarely bifid (not fimbriate)	entire, bifid, or fimbriate ( <i>Spermacoceae sensu lato</i> )
<b>Calycophylls</b>	absent (present in <i>Kerianthera</i> )	present in many genera (or absent)	absent (present in <i>Oreopolus</i> )
<b>Flora symmetry</b>	actinomorphic (zygomorphic in <i>Coutarea</i> and <i>Hillia</i> )	actinomorphic (zygomorphic in <i>Henriquezieae</i> and <i>Posoqueriae</i> )	actinomorphic (corolla tube basally gibbous in <i>Palicourea</i> )
<b>Stamens insertion</b>	at base, middle of tube or near corolla mouth	at middle of corolla tube or near mouth	at middle of tube or near corolla mouth
<b>Raphides of Ca-oxalate</b>	absent (present in <i>Hillia</i> and <i>Hamelia</i> )	absent	present

## 1. Subfamily Cinchonoideae

### 1.1 Tribe Chiococceae *sensu lato* (Chiococceae-Catesbaeae-Complex; Motley *et al.* 2005)

A tribe of about 28 genera and 190 species (Motley *et al.* 2005), with the main center of diversity in the Greater Antilles, several genera in Central and South America, and a few genera in the islands of the South Pacific. In Brazil are present the following genera: *Chiococca* P. Browne, *Coutarea* Aubl., *Erithalis* P. Browne, *Exostema* (Pers.) P. Browne, and *Salzmannia* DC.

**Literature:** A study of the pollen of most genera of this tribe was presented by Huysmans *et al.* (1999), and a molecular phylogeny of this tribe was recently published by Motley *et al.* (2005). A species realignment and a new species of *Chiococca* for coastal Brazil was recently published by Delprete (2004b).

### 1.2 Tribe Cinchoneae (defined as Bremer & Eriksson 2009, with the genera included by Andersson & Antonelli 2005)

A Neotropical tribe of 6–7 genera (Andersson & Antonelli 2005). In Brazil is represented by *Ciliosemina* Antonelli, *Cinchonopsis* L. Andersson, *Ladenbergia* Klotzsch, and *Remijia* DC. (incl. *Cephalodendron* Steyerl.). The genus *Maguireocharis* Steyerl. was positioned in the Cinchoneae by Andersson (1995), but Andersson & Antonelli (2005) where unable to test its position due to lack of useful DNA; it is tentatively maintained in this tribe, pending molecular phylogenetic studies to confirm its position.

**Literature:** A molecular phylogeny was recently published by Andersson & Antonelli (2005). A synopsis of the species of *Ladenbergia* was published by Andersson (1997).

**Taxonomic revision needed:** The genus *Remijia*, with about 40 species widely distributed in South America, and many species in the Amazon basin, is in need of a taxonomic revision.

### 1.3 Tribe Guettardeae

A Pantropical tribe with many Neotropical genera. The generic delimitations within the tribe have been recently tested by Achille *et al.* (2006), where *Guettarda* L. and *Antirhea* Juss., as traditionally defined, were shown to be paraphyletic; however, several taxa need to be added to these phylogenies in order to have a general view about the definition of the tribe and its generic delimitations. Following the phylogenies produced by Achille *et*

*al.* (2006), Delprete *et al.* (2010) proposed a re-delimitations of the genera of this tribe, and Taylor & Gereau (2010a) and Delprete *et al.* (2010) proposed several new combinations in *Chomelia* Jacq. and *Stenostomum* C.F. Gaertn. Additionally, some genera have been transferred from the Rondeletieae to this tribe, based on molecular phylogenies, by Rova *et al.* (2009). According to these recent generic rearrangements, in Brazil are present the following genera of the tribe Guettardeae: *Chomelia*, *Gonzalagunia* Ruiz & Pav., *Guettarda*, *Machaonia* Bonpl., *Malanea* Aubl., and *Stenostomum*.

### 1.4 Tribe Rondeletieae (as defined by Rova *et al.* 2009)

A tribe of about 15 genera occurring mostly in the Neotropics, with center of diversity in Central America and the Greater Antilles, many species in Colombia and Ecuador, and a few genera in the South Pacific. A recent molecular phylogenetic analysis focused on this tribe was published by Rova *et al.* (2009). Although a few genera are present in northern South America, no species of this tribe has been reported from Brazil.

### 1.5 Tribe Hamelieae

A Neotropical tribe, with center of diversity in Mexico, Central America, and the South America Andes. In Brazil is represented by a few species of *Deppea* Cham. & Schltdl., *Hamelia* Jacq., *Hoffmannia* Sw., and *Patima* Aubl.

**Literature:** A revision of *Hamelia* was published by Elias (1976). Delprete *et al.* (2005) revised *Patima*, and synonymized *Hoffmannia megistophylla* Standl. (from Northern Brazil) with *Patima guianensis* Aubl., a species previously know only from the Guianas; in this work, Delprete also proposed a list of the genera to be included in the Hamelieae, based on overall morphological similarities. A second species of *Patima*, from Guyana, was recently described by C.M. Taylor (in Taylor & Lorence 2010).

**Revision needed:** The genus *Hoffmannia*, with many species in Mexico, Central America, and the South America Andes, and a few species in Brazil, is in need of a taxonomic revision.

### 1.6 Tribe Hillieae

A Neotropical tribe, that includes *Hillia* and *Cosmibuena*, both present in Brazil.

**Literature:** Taxonomic revisions of these two genera were published by C.M. Taylor (1992, 1994).

### **Chione**

According with the phylogenies of D.W. Taylor (2003) and Bremer & Eriksson (2009), *Chione* DC. is positioned as sister taxon of the tribes Hamelieae and Hillieae. One species of this genus has been reported from western Amazonian Brazil (Delprete & Taylor 2008).

**Literature:** A taxonomic revision of *Chione* has recently been published by D.W. Taylor (2003).

**Work needed:** Further phylogenetic studies are needed to clarify the tribal position of this genus.

### **1.7 Tribe Hymenodictyeae**

A paleotropical tribe, absent in Brazil.

### **1.8 Tribe Naucleaeae**

A pantropical tribe. In Brazil is represented by *Cephalanthus* L. and *Uncaria* Schreb.

**Literature:** The only species of *Cephalanthus* present in Brazil, *C. glabratus* (Spreng.) K. Schum., has been fully described by Delprete *et al.* 2004. The two species of *Uncaria* present in South America, *U. guianensis* Aubl. and *U. tomentosa* (Willd. ex Roem. & Schult.) DC., have been fully described by Steyermark (1974).

### **1.9 Tribe Isertiaeae**

A Neotropical tribe, with two genera: *Isertia* Schreb. (incl. *Yutajea* Steyermark) and *Kerianthera* J.H. Kirkbr., both present in Brazil. Bremer & Thulin (1998) with a phylogenetic analysis using *rbcL* restricted the tribe to *Isertia* (incl. *Yutajea*) and *Kerianthera* (confirming the conclusions of Delprete 1996). *Isertia* is a genus of about 15 species ranging from Mexico through Brazil, and *Kerianthera* is a genus of two species, both endemic to Brazil, one Amazonian (only found in a small area north of Manaus), and the other from the Atlantic Forest of states of Espírito Santo and Minas Gerais (Oliveira *et al.* 2011).

**Literature:** A revision of *Isertia* was published by Boom (1984), which is still valid, as no additional new species have been published in this genus. *Kerianthera* was extensively described by Kirkbride (1985) and Delprete (1996b) and its floral features and pollination biology were studied by Marques-Souza *et al.* (1993) and Oliveira *et al.* (2011).

## **2. Subfamily Ixoroideae**

**2.1 Tribe Condamineaeae** (*sensu* Rova *et al.* 2002; Bremer & Eriksson 2009; Kainulainen *et al.* 2010)

A pantropical tribe, with most genera in the Neotropics. In Brazil are present the

following genera: *Alseis* Schott, *Bathysa* C. Presl, *Bothriospora* Hook. f., *Calycophyllum* DC., *Capirona*, *Chimarrhis* Jacq., *Condaminea* DC., *Dialypetalanthus*, *Elaeagia* Wedd., *Ferdinandusa* Pohl, *Macrocnemum* P. Browne, *Parachimarrhis* Ducke, *Pentagonia*, *Pogonopus* Klotzsch, *Rustia* Klotzsch, *Semaphyllanthe* L. Andersson, *Simira* Aubl., *Sommerera* Schltdl., *Warszewiczia* Klotzsch.

**Literature:** A phylogeny of the tribe Condamineae has recently been published by Kainulainen *et al.* (2010), which is here adopted as the reference for tribal definition and generic delimitations within the tribe. A revision of the genera *Condaminea*, *Chimarrhis*, *Parachimarrhis*, *Pogonopus* and *Rustia* (and several other genera not occurring in Brazil) was published by Delprete (1999). Taxonomic revisions of Brazilian species are available for *Alseis* (Moura 2001), *Bathysa* (Germano Filho 1998), *Ferdinandusa* (Anunciação 2005) and *Warszewiczia* (Pantoja 1994).

**Work needed:** New taxonomic revisions and comparative morphological studies are needed for *Bathysa*, *Calycophyllum*, *Elaeagia*, *Macrocnemum*, *Pentagonia* and *Semaphyllanthe*, in vision of the new generic delimitations proposed by Kainulainen *et al.* (2010).

### **2.2 Tribe Posoquerieae**

A Neotropical tribe recently described by Delprete (in Delprete *et al.* 2004), with only *Posoqueria* Aubl. and *Molopanthera* Turcz., both present in Brazil. A review about the taxonomic history, morphological characters, and observations about the pollen catapult mechanism in this tribe was published by Delprete (2009).

**Literature:** The taxonomic revision of the Brazilian species of *Posoqueria* was completed by Macias (1998). A couple of new, non-zygomorphic species of *Posoqueria* have recently been published by Taylor & Cortés-B. (1999) and Taylor (in Taylor & Gereau 2010b). A revision of the monotypic genus *Molopanthera* was published by Delprete (1999).

**2.3 Tribe Henriquezieae** (based on Bremer & Eriksson, 2009, and Delprete & Cortés-B. 2004; Cortés-B. & Motley 2006)

A Neotropical tribe of three genera, all present in Brazil: *Gleasonia*, *Henriquezia* Spruce ex Benth., and *Platycarpum*, which are mostly restricted to white-sand Amazonian areas.

**Literature:** A taxonomic revision of the genera of this tribe was published by Rogers (1984), which continues to be valid, as no additional species of these taxa have been described.

**2.4 Tribe Sipaneeae** (based on Bremer & Eriksson 2009; Delprete & Cortés-B. 2004)

A Neotropical tribe of about 10 genera and 50 species, with 3 species in Central America, 47 species present on the Guayana Shield, and 5 species on the Brazilian Shield. Delprete & Cortés (2004) published a molecular phylogeny using on *trnL-F* sequences, which clearly positioned this tribe in the Ixoroideae, closely related to the Posoquerieae, and demonstrated the monophyly of the tribe Sipaneeae. The second portion of the work of Delprete & Cortés-B. (2004) was dedicated to the internal phylogeny of the tribe, with a molecular phylogeny using *trnL-F* e ITS sequences, separated and combined. *Sipanea* Aubl. and *Limnosipanea* were found in two separated clades, demonstrating that the herbaceous habit originated two times in the tribe. In the Sipaneeae, they included *Chalepophyllum* Hook. f., *Dendrosipanea* Ducke, *Limnosipanea*, *Maguireothamnus* Steyererm., *Neobertiera* Wernham, *Sipanea* e *Sipaneopsis* Steyererm. Due to the impossibility of obtaining valuable sequences from herbarium specimens, the genera *Neblinathamnus* Steyererm., *Pteridocalyx* Wernham and *Steyermarkia* Standl. were not included in the phylogenetic analysis, but were tentatively maintained in the tribe because of their morphological similarities with the other genera. According to Delprete & Cortés-B. (2004), in Brazil are present the following genera of this tribe: *Dendrosipanea*, *Limnosipanea*, *Neblinathamnus*, *Sipanea*, and *Sipaneopsis*.

**2.5 Tribe Sabiceae**

A pantropical tribe. A molecular phylogeny of this tribe was recently published by Khan *et al.* (2008); based on these phylogenies, they recognized four genera and about 180 species. According to their re-delimitation, *Sabicea* Aubl. (incl. *Ecpoma* K. Schum., *Pseudosabicea* N. Hallé, *Schizostigma* Arn., and *Stipularia* Haw., all paleotropical taxa) is the largest genus of the tribe, with about 170 species of pantropical distribution. In the Neotropics, this tribe is represented only by the genus *Sabicea*, with many species occurring in Brazil.

**Literature:** A taxonomic revision of the Neotropical species of *Sabicea* was recently concluded by Khan (2007).

**2.6 Tribe Mussaendeae**

A paleotropical tribe. In Brazil is only represented by several cultivated species of *Mussaenda* Burm. ex L.

**2.7 Tribe Retiniphyllae** (based on Bremer & Eriksson 2009, and Cortés-B. *et al.* 2009)

A monotypic tribe, endemic to South America, represented only by *Retiniphyllum* Bonpl., with many species present in Brazil, mostly in white-sand areas of the Amazon Basin. The tribal position and monophyly was recently demonstrated by Cortés-B. *et al.* (2009)

**Literature:** A taxonomic revision of *Retiniphyllum* was recently completed by Cortés-B. (2003).

**2.8 Tribe Ixoreae**

A pantropical tribe, with only *Ixora* present in the Neotropics. *Ixora* L. is a pantropical genus of ca. 350 species, with most of them in tropical Asia and islands of the South Pacific, ca. 37 species in continental Africa, ca. 35 species in Madagascar, and ca. 45 species in the Neotropics.

**Literature:** A revision of the species of *Ixora* present in Central and Southern Brazil was published by Delprete (2003b) and a few new species from the state of Tocantins were published by Delprete (2008a). A taxonomic revision of extra-Amazonian species of *Ixora* is available from Di Maio (2003).

**2.9 Tribe Vanguerieae**

A paleotropical tribe, absent in Brazil.

**2.10 Tribe Alberteae**

A paleotropical tribe, absent in Brazil.

**Augusta-Wendlandia-complex**

Two sister genera of uncertain taxonomic position (Rova *et al.* 2002; Bremer & Eriksson 2009), related to the tribe Alberteae, of which only one species of *Augusta* Pohl is present in Brazil. According to Kirkbride (1997) and Delprete (1997b), *Augusta* is a genus of four species, divided into two subgenera. Subgenus *Lindenia* is composed of three species, *A. rivalis* (Benth.) J.H. Kirkbr., endemic to Central America, and *A. austrocaledonica* (Brongn.) J.H. Kirkbr. and *A. vitiensis* (Seem.) J.H. Kirkbr., endemic to the islands of the South Pacific. Subgenus *Augusta* is represented by only one species, *A. longifolia* (Spreng.) Rehder, endemic to Brazil, where Delprete (1997b) recognized two varieties: var. *longifolia*, occurring in the torrents and small

rivers of the Cerrado Biome, and var. *parviflora* (Pohl) Delprete, occurring in the torrents and small rivers of the Atlantic Forest in the state of Rio de Janeiro.

**Literature:** A revision of the only species of *Augusta* present in Brazil, *A. longifolia* (Spreng.) Rehder, was published by Delprete (1997b).

### 2.11 Tribe Bertiereae

A monotypic tribe. *Bertiera* Aubl. is a genus of about 50 species mostly present in Africa, Madagascar and the Mascarene Islands, and with a few species in the Neotropics, including Brazil. The taxonomic position of this genus is not yet entirely clarified, but it seems that most contemporary rubiologists agreed to keep it in its own tribe, closely related to the Gardenieae (Bremer & Eriksson 2009).

**Literature:** A worldwide survey of *Bertiera* was published by Robbrecht *et al.* (1993).

**Work needed:** A detailed revision of *Bertiera* in the Neotropics is needed, as the South American species have never been the subject of a detailed taxonomic study.

### 2.12 Tribe Coffeae

A paleotropical tribe, with several species of *Coffea* L. cultivated in Brazil.

### 2.13 Tribe Cremasporeae

A tribe present in Africa, Madagascar and nearby islands. Absent in Brazil.

### 2.14 Tribe Octotropideae

A tribe present in Africa, Madagascar, nearby islands, and Indomalaya. Absent in Brazil.

### 2.15 Tribe Gardenieae

According to Persson (2000a,b) and Bremer & Eriksson (2009), this tribe is not monophyletic, and additional work remains to be done in order to detect its natural delimitation. In the phylogenies obtained by Bremer & Eriksson (2009), members of this tribe are intermixed with members of several other tribes. Persson (2000a,b), with molecular phylogenies, palynological and anatomical data demonstrated that *Alibertia* A. Rich. ex DC., as traditionally recognized, should be divided into two genera: *Alibertia* and *Cordia* A. Rich. ex DC., and that *Borojoa* Cuatrec. should be synonymized with *Alibertia*. Persson (2000a,b) also demonstrated that *Ibetrulia* Bremek. should be synonymized with *Kutchubaea* Fish. ex

DC., for which he published a new combination (Persson 2005). A molecular phylogeny for *Randia* L. and allied genera was published by Gustafsson & Persson (2002). Several informal groups have been proposed for the Gardenieae. In Brazil are found several genera of the “Alibertia group”: *Agouticarpa* C.H. Perss., *Alibertia* (incl. *Borojoa*), *Amaioua* Aubl., *Botryarrhena* Ducke, *Cordia*, *Duroia* L.f., *Genipa* L., *Kutchubaea* (incl. *Ibetrulia*), *Melanopsidium* Colla, *Riodocea*, *Sphinctanthus* Benth., *Stachyarrhena* Hook. f., *Tocoyena* Aubl.; and two genera of the “Randia group”: *Randia* and *Rosenbergiodendron* Fagerl.

**Literature:** Taxonomic revisions are available for *Agouticarpa* (Persson 2003), *Melanopsidium* (Delprete 2000), *Riodocea* (Delprete 1999a), *Rosenbergiodendron* (Gustafsson 1998), and *Tocoyena* (Prado 1987; Silberbauer-Gottsberger *et al.* 1992; Delprete 2008b).

### 2.16 Tribe Pavettae

A paleotropical tribe, absent in Brazil.

## 3. Subfamily Rubioideae

### 3.1 Tribe Ophiorrhizae

A tribe present in Tropical Asia, absent in Brazil.

### 3.2 Tribe Urophylleae

A paleotropical tribe, but of uncertain limits, as some genera have been suggested to belong to this tribe, but this has not been tested by phylogenetic studies. Bremer & Manen (2000) and Robbrecht & Manen (2006) positioned *Amphidasya* Standl. in this tribe, and it is here maintained, with the hope that future phylogenies will confirm this position. *Amphidasya* is a Neotropical genus, with one species, *A. neblinae* Steyermark, occurring in Amazonian Brazil (Serra da Neblina; Steyermark 1972).

### 3.3 Tribe Perameae

A Neotropical tribe, including only the genus *Perama* Aubl., with most species present in Brazil. This tribe was not included in the study by Bremer & Eriksson (2009); however, it is here positioned near the Lasiantheae, according to the phylogenies obtained by Andersson & Rova (1999) and Robbrecht & Manen (2006). Bremekamp (1934, 1966) treated *Perama* as exceptional in the Rubiaceae because of absence of stipules; however, in this genus the stipules are very small or reduced to a line between the leaves of the same nodes (Delprete, pers. obs.).

**Literature:** A revision of *Perama* for the Neotropics was published by Steyermark & Kirkbride (1977) and additional taxa were published by Kirkbride (1980) and Steyermark (1987).

### 3.4 Tribe Lasiantheae

A tribe mostly Paleotropical, with a few species in the Neotropics. *Lasianthus* Jack, the largest genus of this tribe, has about 170 species occurring in the Old World and two species in the Neotropics, one in Dominican Republic and the other in Panama, but it has never been reported from South America. According to our current knowledge, this tribe is represented in Brazil only by *Ronabea* Aubl. Taylor (2004) recognized three species in *Ronabea*: *R. emetica* (L.f.) A. Rich. (Nicaragua to western Ecuador), *R. isanae* (J.H. Kirkbr.) C.M. Taylor (Amazonian northwestern Brazil), and *R. latifolia* Aubl. (from Belize to Ecuador, the Guianas to northeastern Brazil).

**Literature:** A revision of *Ronabea* was recently published by Taylor (2004).

**Work needed:** As *Ronabea* is quite similar to *Psychotria* L. (and it has been traditionally synonymized with), it is possible that a detailed analysis of South American species of *Psychotria* might detect additional taxa belonging to *Ronabea*.

### 3.5 Tribe Coussareeae

A Neotropical tribe. Bremekamp (1951) tentatively positioned the African genus *Schizocolea* Bremek. within this tribe; however, in the phylogenetic studies of Rydin *et al.* (2008) this genus was found at an intermediate position between the Coussareae and the Psychotriaceae alliance. Therefore, all the genera this tribe are present in Brazil: *Coussareae* Aubl., *Coccocypselum* P. Browne, *Declieuxia* Kunth, *Faramea* Aubl., and *Hindsia* Benth. Additionally, *Bradea* Standl. and *Standleya* Brade are tentatively included in the Coussareae, based on morphological similarities and on DNA sequences of *Standleya* (Jardim *et al.*, unpubl. data).

**Literature:** Taxonomic revisions are available for *Coccocypselum* (Costa 2004), *Declieuxia* (Kirkbride 1976, 1983, 1997), and *Hindsia* (Di Maio 1996). Taxonomic revisions of the Brazilian species of *Coussareae* and *Faramea* are in progress by Gomes (2003a,b), Pereira & Barbosa (2004), and Jardim & Zappi (2008a,b).

### 3.6 Tribe Danaideae

A Paleotropical tribe, absent in Brazil.

### 3.7 Tribe Knoxiaceae

A tribe present mostly in Africa and Madagascar. In Brazil is represented by *Pentas lanceolata* (Forssk.) Deflers, cultivated for its ornamental values.

**3.8 Tribe Spermaceae sensu lato** (including Hedyotideae and Manettieae, according to Bremer & Manen 2000; Dessein 2003; Dessein *et al.* 2005; Karehed & Bremer 2007)

A pantropical tribe of about 1000 species, with a few species occurring in temperate regions of the World. The relationships between the Spermaceae *sensu stricto* and the Hedyotideae have been studied by many rubiologists. Recent molecular phylogenies (Bremer & Manen 2000; Dessein 2003; Dessein *et al.* 2005; Karehed & Bremer 2007) demonstrated that this complex should be treated as a single, monophyletic tribe (including Hedyotideae and Manettieae). Also, the generic delimitations within the Spermaceae *sensu lato* are the most complex and debated within the Rubiaceae, and are still far from being resolved. In a series of multidisciplinary studies Bacigalupo, Cabral and collaborators (Cabral 1991, 1993; Cabral *et al.* 2006; Cabral & Bacigalupo 1997, 2000; Pire 1997; Pire & Cabral 1992) maintained *Borreria* G. Mey. and *Spermaceae* separated, and re-established *Galianthe* Griseb., where they transferred many species previously positioned in *Borreria*. In a successive work, Bacigalupo and Cabral (1999) transferred several species from *Diodia* L. to *Borreria*, *Galianthe* and *Diodella* Samal, based primarily on fruit dehiscence types and inflorescence architecture, restricting *Diodia* to five species with indehiscent fruits. Govaerts (1996) in his contribution to the *World Checklist of Seed Plants* treated *Borreria*, *Galianthe* and *Spermaceae* as synonymous, and published 80 new combinations and new names in *Spermaceae*, mostly of Neotropical taxa. Terrell & Wunderlin (2002) studied the seed morphology of several genera of the tribe Spermaceae, and concluded that *Borreria* and *Spermaceae* (and *Galianthe*) are not sufficiently distinct to warrant taxonomic separation. In the molecular phylogenies of Dessein (2003) and Dessein *et al.* (2006), species with fruit types traditionally attributed to *Borreria* and *Spermaceae* were found to be intercalated within the same clades. Accordingly, Delprete *et al.* (2004, 2005) delimited *Spermaceae* to include species with septicidal fruits with persistent calyx, commonly dehiscent from the top (basipetally) or

exceptionally from the bottom (acropetally; e.g., *S. palustris* (Cham. & Schldl.) Delprete; *S. spicata* (Miq.) Delprete), with both cocci dehiscent, or one dehiscent and the other indehiscent, or both of them indehiscent. A complete description of a widely delimited *Spermacoce* (incl. *Borreria*, *Hemidiodia* K. Schum. e *Spermacoceodes* Kuntze) was recently presented by Delprete & Cortés-B. ("2006" (2007)), as adopted by Adams (in Burger & Taylor 1993), Boom & Delprete (2002), Delprete *et al.* (2005), Delprete (2007, 2010), Dessein (2003), Dessein *et al.* (2003, 2006a,b), Groeninckx *et al.* (2009a,b), Lens *et al.* (2009), De Vré (2000), and Vaes *et al.* (2006). On the other hand, the generic delimitations adopted by Cabral, Bacigalupo and collaborators (Cabral 1991, 1993; Cabral *et al.* 2006; Cabral & Bacigalupo 1997, 2000; Pire 1997; Pire & Cabral 1992), maintaining *Borreria* and *Spermacoce* separated, are still commonly adopted in several floristic treatments in the Neotropics (but not in the Paleotropics). Also, recently Salas & Cabral (2010a) separated *Tessiera* DC. and *Planaltina* R.M. Salas & E.L. Cabral from *Staelia*, based on palynological and morphological comparisons, but no dedicated phylogenetic studies were performed in order to test the monophyly of these taxa. In conclusion, following the generic concepts adopted by Bremer & Manen (2000), Delprete *et al.* (2005), Delprete & Cortés ("2006"), Delprete (2007, 2010c), Dessein (2003), Dessein *et al.* (2005), Groeninckx *et al.* (2009a,b), Lens *et al.* (2009), and Karehed & Bremer (2007), in Brazil are present the following genera: *Anthospermopsis* (K. Schum.) J. H. Kirbr., *Denscantia* E.L. Cabral & Bacigalupo, *Diacrodon* Sprague, *Diodella* Small, *Diodia* L., *Emmeorhiza* Endl., *Galianthe*, *Leptoscela* Hook. f., *Manettia* Mutis ex L., *Mitracarpus* Zucc. ex Schult. & Schult. f., *Oldenlandia* L., *Pentodon* Hochst., *Psyllocarpus* Mart. ex Mart. & Zucc., *Richardia* L., *Spermacoce* s.l. (incl. *Arbulocarpus* Tennat, *Borreria*, *Bigelowia* Spreng., *Dasycephala* Hook. f., *Diacrodon* Sprague, *Dichrospermum* Bremek., *Diodioides* Loefl., *Diphragmus* C. Presl, *Hemidiodia*, *Hexasepalum* Bartl., *Hypodematum* A. Rich., *Jurgensia* Raf., *Octodon* Thonn., *Paragophyton* K. Schum., *Spermacoceodes*, *Tardavel* Adans.), *Staelia* Cham. & Schldl. (incl. *Tessiera* DC.), and *Schwendenera* K. Schum.

**Literature:** Taxonomic revisions of Brazilian species are available for *Anthospermopsis* (Kirkbride 1997), *Bradea* (Brade 1949), *Denscantia* (Cabral & Bacigalupo 2001a,b), *Diacrodon*

(Sprague 1928), *Diodella* (Delprete *et al.* 2004; Bacigalupo & Cabral 2006; Bacigalupo & Cabral in Borhidi 2006), *Diodia* (Bacigalupo & Cabral 1999), *Galianthe* (Cabral 1991, 2002, 2005; Cabral & Bacigalupo 1997; Delprete 2010a), *Leptoscela* (Hooker 1873), *Manettia* (Macias 1998), *Mitracarpus* (Souza 2008; Souza *et al.* 2010), *Psyllocarpus* (Kirkbride 1979), *Richardia* (Lewis & Oliver 1974), *Spermacoce* s.l. (regional treatments for the States of Santa Catarina (Delprete *et al.* 2005), São Paulo (Bacigalupo & Cabral 2007a), Bahia (Cabral *et al.* 2011) and Goiás and Tocantins (Delprete 2010c)], *Staelia* s.l. [regional treatments for the states of Santa Catarina (Delprete *et al.* 2005), São Paulo (Salas 2007), and Goiás and Tocantins (Salas in Delprete 2010c), and for Paraguay (Salas & Cabral 2010a,b)], *Standleya* (Brade 1932, 1949), and *Schwendenera* (Bacigalupo & Cabral 2007b).

**Work needed:** The generic delimitations within the Spermacoceae *sensu lato* are still not entirely elucidated and indicate the need of producing complete molecular phylogenies with the inclusion of important Neotropical species (e.g., *Spermacoce tenuior* L., the type species of the genus). Much work remains to be done in order to definitely clarify the monophyly of most genera in the Spermacoceae *sensu lato*; therefore, it would be desirable to organize a large international, multidisciplinary team do address to these questions.

### 3.9 Tribe Anthospermeae

A tribe present in temperate regions of the world, mostly in the southern hemisphere, but absent in Brazil.

### 3.10 Tribe Argostemmateae

A tribe containing only *Argostemma* Wall., a Paleotropical genus of about 200 species, but absent in Brazil.

### 3.11 Tribe Paederieae

A Paleotropical tribe with only one Pantropical genus, *Paederia* L. According to Puff (1991a, 1991b), *Paederia* is a genus of 30 species, with 16 species in Asia, 12 species in Africa and Madagascar, and two species in tropical America. Puff *et al.* (1991a) proposed that the two American species are a long-distance dispersal event from the ancestral group present in the Old World. The two American species of *Paederia* are *P. ciliata* (Bartl.

ex DC.) Standl. that occurs in Mexico and northern Central America, and *P. brasiliensis* (Hook. f.) Puff, found in South America, including Brazil. Another species of this tribe, *Serissa foetida* (L.f.) Lam., native of Asia, is sometimes cultivated as an ornamental in Brazil.

**Literature:** A taxonomic revision of the two American species of *Paederia* was published by Puff (1991b), and a full description of *P. brasiliensis* was published by Delprete (2010b). A full description of *Serissa* Commers. ex A.L. Juss. and *S. japonica* (Thunb.) Thunb. from material cultivated in Brazil, has recently been published by Delprete (2010c).

### 3.12. Tribe Putorieae

According to Bremer & Eriksson (2009), this tribe includes only the single, widely delimited, genus *Plocama* Ait., distributed throughout the Paleotropics, but absent in Brazil.

### 3.13. Tribe Rubieae

A cosmopolitan tribe represented in Brazil only by *Galium*. *Galium* (incl. *Relbunium* (Endl.) Benth. & Hook. f.) is a cosmopolitan genus of about 300 species, most of them occurring in temperate regions, and about 50 species in the Neotropics (Dempster & Delprete 2004).

**Literature:** The South American species of *Galium* were revised by Dempster (1980, 1981, 1982, 1990), and the species of the state of Santa Catarina (where is found the highest diversity of this genus in Brazil) were revised by Dempster and Delprete (2004).

### 3.14 Tribe Theligoneae

This tribe includes only *Theligonum*, a genus of a few species occurring in Macaronesia, Mediterranean region, China and Japan. It is absent in Brazil.

### 3.15 Tribe Craterispemeae

A tribe present in Africa, Madagascar, and the Seychelles. Absent in Brasil.

### 3.16 Tribe Gaertnerae

A tribe with two genera: *Gaertnera* Retz., endemic to the Paleotropics, and *Pagamea*, endemic to the Neotropics. In Brazil are present several species of *Pagamea*, most of them occurring in white-sand areas.

**Literature:** A taxonomic revision of *Pagamea* has recently been completed by Vicentini (2007).

### 3.17 Tribe Schradereae

A tribe with a geographical disjunct, with two Asiatic genera (*Leucocodon* Gardner and *Lecananthus* Jack), and *Schradera* Vahl, present in the Neotropics, including Brazil.

### 3.18 Tribe Morindeae

A Pantropical tribe with several genera. Traditionally *Morinda* L. has been widely circumscribed to include *Appunia* Hook. f. (e.g., Steyermark 1972, 1974; Taylor & Steyermark 2004); however, some authors preferred to keep the two taxa separated (e.g., Taylor 2001a). Razafimandinbison *et al.* (2009), based on their molecular phylogenies, concluded that *Appunia* should be kept separated from *Morinda*, with separate flowers in fruits in the former and partially or completely aggregated flowers and fruits in the latter. This conclusion has been followed by Parks & McDowell (accepted) and Delprete (2009b). Accordingly, this tribe is represented in Brazil by two genera: *Appunia* (a Neotropical genus), and *Morinda* (*M. citrifolia* L., the famous “noni”), an Asiatic species commonly cultivated in tropical regions of the world for its medicinal properties.

**Work needed:** It would be highly desirable a taxonomic revision of the South American species of *Appunia*.

### 3.19 Tribe Psychotrieae

A Pantropical tribe with many genera, and the most speciose of the Rubiaceae. The generic delimitations within this tribe have gone through several re-arrangements according to the opinions of several rubiologists (Bremekamp 1934a,b, 1936, 1937, 1954, 1966; Steyermark 1972, 1974; Taylor 1996, 1997, 2001a,b, 2004), and continue to be far from resolved. The *Psychotria* complex, with nearly 2,000 species worldwide, has gone through various delimitations, and several satellite taxa have been variably excluded from or included in *Psychotria*. The delimitation of the genus *Psychotria* is still in a state of flux. The first molecular phylogeny on this tribe was published by Andersson & Rova (1996), using *rps16* as molecular marker; this work showed that *Psychotria*, as delimited by Steyermark (1972, 1974), is polyphyletic, supporting the separation of some of the genera, using morphological characters, proposed by Bremekamp (1934) and Taylor (1996a) and the molecular phylogenies of Bremer (1996). In the phylogenies of Andersson & Rova (1996), the species of *Psychotria* subgenus *Psychotria* were found on one clade, and the species of section

*Notopleura* Benth. & Hook. f. in another clade near *Rudgea* Salisb., and the species of subgenus *Heteropsychotria* in yet another clade intermixed with species of *Palicourea* Aubl. (indicating that the two taxa should be synonymized). Based on these results and morphological evidence, Taylor et al. (2010) and Borhidi (2011) transferred several species from Psychotria subgenus *Heteropsychotria* to *Palicourea*. These results were confirmed by Nepokroeff *et al.* (1999) in a study dedicated to the tribe Psychotrieae. Taylor (2001b), following the phylogenies obtained by Bremer (1996) and Nepokroeff *et al.* (1999), complemented by morphological data, elevated the section *Notopleura* to generic level, and transferred 73 Neotropical species to this genus, including many species occurring in Brazil. Andersson (2001), with a phylogenetic analysis using *rps16* molecular sequences and morphological data re-delimited *Margaritopsis* Sauvalle (previously restricted to the Greater Antilles) with a much wider circumscription (to include species of *Chazaliella* E.M.A. Petit & Verdc., *Psychotria*, *Chytropsia* Bremek. and *Readea* Gillespie) with pantropical distribution. Shortly after, Andersson (2002), with a phylogenetic analysis using *rps16* molecular sequences and morphological data, re-instated the genus *Carapichea* Aubl., where he included three species: *C. guianensis* Aubl., *C. ipecacuanha* (Brot.) L. Andersson (the famous Brazilian “*ipecacuanha*”), and *C. affinis* (Standl.) L. Andersson. Following Andersson’s conclusions, Delprete (2001, 2003a), transferred one more species to this genus, as *C. ligularis* (Rudge) Delprete. In conclusion, according to current generic delimitations (although not yet completely clear), in Brazil this tribe is represented by the following genera: *Carapichea*, *Notopleura*, *Psychotria*, *Palicourea* Aubl., *Geophila* D. Don, *Margaritopsis*, and *Rudgea*. The genera *Stachyococcus* Standl. and *Pagameopsis* Steyerl., positioned in this Psychotrieae by Robbrecht (1988, 1993) are tentatively maintained in this tribe, pending future phylogenetic studies to test their position.

**Literature:** The most complete revision of *Psychotria* and *Palicourea* species occurring from Venezuela to Central Brazil was published by Steyerl (1972), which continues to be the most important reference for northern and central Brazil. A conspectus of the genus *Palicourea* was published by Taylor (1997). A floristic account of *Palicourea* and *Psychotria* in the states of Goiás e Tocantins and Santa Catarina was published by Delprete (2010b) and Delprete *et al.* (2005), respectively.

Molecular phylogenies about the generic limits in the Psychotrieae were published by Bremer (1996), Nepokroeff *et al.* (1999), Andersson (2002b). Observations on the interpretation of taxonomic characters in *Psychotria* were published by Delprete (2001). Observations and new combinations of *Carapichea* species were published by Andersson (2002a) and Delprete (2001, 2003a). Two additional species of *Carapichea* have recently been published by Taylor (2006) and Jardim & Zappi (2008c). A synoptic revision of the Neotropical species of *Notopleura* and *Margaritopsis* were published by Taylor (2001b, 2005). A taxonomic revision of *Rudgea* species from southeastern and southern Brazil has recently been published by Zappi (2003).

**Work needed:** As the generic delimitations within the Psychotrieae are still in a state of flux, additional molecular phylogenetic studies are needed for clarifying the monophyletic groups within this tribe. As the Psychotria complex includes about 2000 species worldwide, this project could only be realized by a team of molecular biologists, taxonomists, and field botanists devoted to the collection of necessary material. As for Brazil, considering its large geographic area and the high number of biomes, it would be desirable to have several local specialists focusing their efforts on taxonomic revisions of the members of this tribe. Additionally, as several Neotropical species of *Psychotria* are generally similar to *Carapichea*, a careful revision of *Psychotria* might reveal additional species to be transferred to *Carapichea*. As for Psychotria, additional taxonomic studies are needed in order to enhance the revision supplied in *Flora brasiliensis* and better understand the species occurring in Eastern Brazil and the Amazon Basin.

### Current status of the study of Rubiaceae diversity in Brazil

The flora of Brazil represents one of the biggest challenges in assessing the plant diversity of our planet. The large size of the country and vast areas still to be studied, and the relentless expansion of agriculture in Brazil, place the utmost urgency in assessing and protecting its overwhelming biodiversity. A recent effort dedicated to assess the plant diversity of the country has produced the first work-on-progress checklist of native plant species (Forzza *et al.* 2010). This was a concerted effort of 413 taxonomists that produced a catalogue of 40,989 plants and fungi, of which 31,162 are native species of Angiosperms (and 56% of them endemic to

Brazil). Every species recorded was proven by a cited voucher specimen and the herbarium acronym(s) where is deposited. As part of this project, Barbosa *et al.* (2010) accounted for 112 genera and 1,347 species of Rubiaceae present in Brazil, of which 14 genera and 694 species (51%) endemic to the country. Although this work was performed by a large team of specialists and with an extensive search of literature and consultation of national herbaria, many taxa will certainly be added to the list, as more herbaria and more literature will be consulted. For example, Delprete (1998) calculated (using as a working reference the Provisional Checklist of Neotropical Rubiaceae of Andersson (1992)) that there are about 115 genera and 1,600 species of Rubiaceae in Brazil, and esteemed that, including the species not yet collected (due to the vast unknown areas present in the country, especially the Amazon Region and the Atlantic Forest) and those still undescribed, there might be up to 2,000 species of this family in Brazil; however, these was just a hypothetical projection based on factors of probability related to the vast areas still botanically unknown in the country.

According to commonly accepted generic delimitations (e.g., Bremer & Eriksson 2009, and above cited references), 15 small genera of Rubiaceae are endemic to Brazil: *Anthospermopsis* (1 sp.), *Bradea* (5 spp.), *Denscantia* (4 spp.), *Diacrodon* (1 sp.), *Hindsia* (11 spp.), *Kerianthera* (2 sp.), *Leptoscela* (1 sp.), *Melanopsidium* (1 sp.), *Molopanthera* (1 sp.), *Planaltina* (3 spp.), *Psyllocarpus* (8 spp.), *Riodocea* (1 sp.), *Salzmannia* (1 sp.), *Schwendenera* (1 sp.), and *Standleya* (4 spp.). More information about these genera is presented in Table 3. The highest number of endemic genera pertaining to the tribe Spermaceae *sensu lato* (incl. Hedyotideae), with 7 out of 12 genera. The low number of generic endemism is in contrast with the 56% of specific endemism. This is probably due to the fact that only a few biomes are restricted to Brazil; in fact, most genera endemic to Brazil are present in the Atlantic Forest (*Restinga* and tropical forest), the *Caatinga*, and the *Campos rupestres* (open field of high altitudes) of the *Cerrado* biome.

### Available keys for Rubiaceae genera

A key for all the genera present in Brazil (and a few more that have never been found in the country) was published by Barroso *et al.* (1991); this key is still very helpful, although some of the generic concepts are outdated. Several keys for the identification of Rubiaceae genera are available for the following regions of Brazil: state of São Paulo

(Jung-Mendaçolli 2007), state of Santa Catarina (Delprete *et al.* 2004), states of Goiás and Tocantins (Delprete 2010a), and states of Mato Grosso and Mato Grosso do Sul (Delprete & Cortés-B. 2006). In addition, several generic keys are available for local floristic treatments, as, for example, the Flora da Reserva Ducke (near Manaus, Amazonas; Taylor *et al.* 2007), Flora of the Pico das Almas (Chapada Diamantina, Bahia; Zappi & Stannard 1995), Flora de Grão-Mogol, Minas Gerais (Campos *et al.* 2006).

### Future challenges on Rubiaceae systematics and floristics in Brazil

The overwhelming vastness of its territory, the number of biomes present, and the different realities of the geographical regions of Brazil pose various challenges on the realization of projects dedicated to assessment of the biodiversity of the country. In order to convey our impressions about what is the current status and the future challenges for the study of the systematics and floristics of Brazilian Rubiaceae, our discussion will be organized according to the main regions of the country.

**1. Southern Region** (States of Paraná, Santa Catarina and Rio Grande do Sul) – In this region the flora is fairly well collected and the Rubiaceae are well studied. In the recent Rubiaceae account for the *Flora Ilustrada Catarinense*, Delprete *et al.* (2004, 2005) produced a key to genera, generic and species descriptions, illustrations, and distribution maps for 46 genera and 149 species. The collections studied cited mostly the herbarium specimens collected in the State of Santa Catarina, and many additional specimens for the two contiguous states of Paraná and Rio Grande do Sul; therefore, this publication represents a useful reference for the Rubiaceae of Southern Brazil. On the other hand, the Rubiaceae of the two bordering states have not been completely studied.

**Future challenges:** As the taxonomic revisions of Rubiaceae in this region is at a fairly good stage, the major challenge for this region is the continuation of field work in areas little collected, especially the highest altitudes mountain ranges and the canyons present in the states of Santa Catarina and Paraná.

**2. Southeastern Region** (States of Minas Gerais, Espírito Santo, Rio de Janeiro, and São Paulo) – This is an extremely variable region, with many biomes, and fairly difficult terrain. In this region are present the biomes of Restinga, Atlantic Forest (both near the coast, and inland in the State of Minas Gerais), Seasonally dry forests (*murundum*),

**Table 3** – Table summarizing the genera endemic to Brazil, with corresponding tribe, number of species, states of occurrence, habitat, habit, and altitude. Tribes are according to the Bremer & Eriksson (2009) and recent molecular phylogenies, as presented in the text. Tribes are abbreviated as follows: CHI-Chiococceae, COU-Coussareeae, GAR-Gardenieae, ISE-Isertieae, POS-Posoquerieae, SPE-Spermacoceae. Brazilian states are abbreviated as follows: AL-Alagoas, AM-Amazonas, BA-Bahia, CE-Ceará, DF-Distrito Federal, ES-Espírito Santo, GO-Goiás, MG-Minas Gerais, PB-Paraíba, PA-Paraná, PE-Pernambuco, RJ-Rio de Janeiro, RN-Rio Grande do Norte, SE-Sergipe, SP-São Paulo.

Genera	Tribe	N. sp.	States	Habitat	Habit	Alt. (m)
<i>Anthospermopsis</i>	SPE	1	BA	<i>Caatinga</i>	subshrub (15–30 cm)	50–100
<i>Bradea</i>	COU	5	RJ, ES	Atlantic forest understory	subshrub (40–50 cm)	50–1000
<i>Denscantia</i>	SPE	4	AL, BA, ES, RJ	Atlantic forest, <i>Restinga</i>	subshrub or scandent (0.4–4 m)	20–1000
<i>Diacrodon</i>	SPE	1	CE	Coastal vegetation	subshrub	0–20 (?)
<i>Hindsia</i>	COU	11	BA, RJ, MG	Atlantic forest, <i>Campos rupestres</i>	subshrub to shrub (0.4–2 m)	500–2400
<i>Kerianthera</i>	ISE	2	AM, ES, MG	Terra firme forest, semideciduous Atlantic forest	tree (6–18 m)	100–200, 300–500
<i>Leptoscela</i>	SPE	1	AL, BA, PB, PE, RN, SE	<i>Cerrado, Caatinga</i>	herb (± 30 cm)	50–1000
<i>Melanopsidium</i>	GAR	1	BA, RJ, ES	<i>Restinga</i>	shrub to treele (1.5–3 m)	0–100
<i>Molopanthera</i>	POS	1	ES, BA, MG, RJ	Atlantic forest	tree (5–10(–30) m)	50–300
<i>Planaltina</i>	SPE	3	DF, GO, MG	<i>Cerrado</i>	subshrub (0.3–1.8 m)	800–1500
<i>Psyllocarpus</i>	SPE	8	AM, PA, RO, BA, MG, GO, DF	Amazonian <i>campinas</i> and <i>campinaranas</i> , <i>campos rupestres</i>	subshrub to shrub (10–120 cm)	100–1600
<i>Riodocea</i>	GAR	1	BA, ES	Seasonal Atlantic forest	tree (10–15 m)	50–900
<i>Salzmannia</i>	CHI	1	AL, BA, PE, RN, SE	<i>Restinga</i>	shrub (1–4 m)	0–70
<i>Schwendenera</i>	SPE	1	PA, SP	Forest understory	subshrub (60–70 cm)	?
<i>Standleya</i>	COU	4	RJ, ES, BA, PA	Atlantic Forest understory	herb	50–1000

and alluvial forest of the Rio Doce, humid forests of high elevation (states of São Paulo and Rio de Janeiro), *campos de altitude* (Rio de Janeiro), and Cerrado and *Campo rupestre* (Minas Gerais). The state least collected, where is expected a high degree of endemism, and where is potentially present the highest number of undescribed Rubiaceae species in this region is the State of Espírito Santo (Delprete, pers. obs.). At the same time, in the State of Minas Gerais is found the highest number of endemic Angiosperm species (Forzza *et al.* 2010), mostly because is where several biomes converge and intergrade, and where are found several mountain ranges (e.g., Cadeia do Espinhaço). Assessing and conserving plant diversity in Minas Gerais is of the utmost urgency, due to the rapid destruction of the environment, mostly due to *Eucalyptus* plantations and mineral exploration.

**Literature:** The most complete Rubiaceae treatment of this region is that published for the *Flora Fanerogâmica do Estado de São Paulo*, produced by a team of 20 botanists and coordinated by Jung-Mendaçolli (2007). The treatment includes a key to genera, generic and species descriptions, and selected illustrations of 48 genera and 254 species. Only a few of the collections studied (only from the state of São Paulo) are cited in full for each species, and the remainder is summarized in an index of exsiccatae at the end of the treatment.

**Future challenges:** Because of the above explained reasons, the biggest challenges for assessing the Rubiaceae diversity of this region are field collections and floristic treatments for the states of Minas Gerais, Espírito Santo, and Rio de Janeiro. As indicated above, the State of Espírito Santo is the area that has the potential to provide the highest number of undescribed Rubiaceae taxa, in this region. The delta of the Rio Doce is a unique area of the Atlantic Coast, where the mountain ranges that run parallel to the coast in this region are much lower, leaving a unique area in terms of climate and soil types, which is still poorly studied. As the Rubiaceae diversity of this region remains imperfectly know, field collections to be realized by family specialists are highly recommended. The second challenge for Rubiaceae taxonomists is to engage in taxonomic revisions of groups particularly speciose in this region, as the tribes Gardenieae, Guettardeae, Psychotrieae, and Spermacoceae.

**3. Central-Western Region** (States of Goiás, Mato Grosso, Mato Grosso do Sul, and Distrito Federal) – The states of Mato Grosso and Mato Grosso do

Sul together represent about 14% of the Brazilian territory. Three major biomes are present in these two states: Cerrado, Pantanal, and the Amazon Basin. Although several expeditions have been made in the Amazonian portion of Mato Grosso, this region remains botanically poorly known, mostly due to the difficulty of access. Within this area, many little-explored white sand areas are also present, which are renowned to be center of diversity for many endemic Rubiaceae species. The Amazonian forests of this state are under the relentless advancement of timber exploitation and extensive soya plantations, and it is probably subject to the fastest destruction rate of any Brazilian state within the Amazon Basin.

**Literature:** A synopsis of the Rubiaceae of the States of Mato Grosso and Mato Grosso do Sul has recently been published by Delprete & Cortés-B. (2006), which accounts for 68 genera and 269 species. In this synopsis are available a key to genera, full description of all genera, and a list of all the species with corresponding full synonymy (but no specimens cited).

The second portion of the floristic project initiated by J.A. Rizzo (Federal University of Goiás, Goiânia, Goiás), was the coordination of a floristic series, *Flora dos Estados de Goiás e Tocantins - Coleção Rizzo*, which today counts with the publications of 40 volumes. As part of this series, the Rubiaceae treatment for the States of Goiás and Tocantins has been recently contributed by Delprete (2010a,b,c), with several collaborators, that counted on the study of about 60,000 herbarium specimens collected in both states, and preserved in 26 Brazilian and international herbaria. This treatment, of 61 genera and 245 species, includes a key to genera, keys, full descriptions and notes about the conservation status of all species, full citation of all the specimens studied, and illustrations of representative species. In the introduction is also presented a detailed discussion of the areas that should be prioritized for botanical collections and conservation.

In the series called *Flora do Distrito Federal*, coordinated by T.B. Cavalcanti (EMBRAPA, Brasília, Distrito Federal), have been published the floristic treatments of many Angiosperm families (the eight volume was published in 2010). The treatment dedicated to the family Rubiaceae is at the final stage, and is being contributed by Delprete and collaborators.

An extensive publication on the ecology, vegetation, and floristics of the Cerrado Biome has recently been coordinated by Sano *et al.* (2008).

In this multi-authored work, it was presented an updated checklist of the Cerrado Biome, with 1,452 genera and 11,238 species of Angiosperms. In this checklist, the Rubiaceae figured as the seventh most diverse family of this biome, with 60 genera and 376 species, after the Leguminosae (108 genera, 1,174 spp.), Asteraceae (155 genera, 1,074 spp.), Orchidaceae (121 genera, 666 spp.), Poaceae (91 genera, 510 spp.), and Eriocaulaceae (7 genera, 473). This low species number of Rubiaceae in the Cerrado Biome is not surprising, as the high diversity of this family is usually found in moist environments, as the Atlantic forest and the Amazon Basin.

**Future challenges:** For the reasons explained above, the northern portion of the state of Mato Grosso merits the highest priority and urgency for the realization of botanical collections, due to the relentless expansion of agriculture. Most likely, many species present in this area have been destroyed before being known to science. The Rubiaceae synopsis of Mato Grosso and Mato Grosso do Sul (Delprete & Cortés-B. 2006) is only the first step towards the study of Rubiaceae diversity of the region; certainly, future collections in the northern portion of Mato Grosso will add more taxa to this list.

**4. Northeastern Region** (States of Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, and Bahia)

The northeastern region of Brazil is a mosaic of different realities in terms of conservation of the natural environment, number of botanical collections, and local concentration of botanists. The eastern portion of the state of Maranhão, the floristic domain of the famous peri-Amazonian forest, and where a high Rubiaceae diversity was certainly present, is largely destroyed (Delprete, pers. obs.) due to extensive lumbering. The devastation in this area is so great that many local sawmills had to close down due to lack of available timber. In other words, the peri-Amazonian forest once presents in Maranhão, a repository of a unique floristic composition, and certainly with a high percentage of Rubiaceae, has been vastly destroyed before being studied. The states of Piauí, Ceará, Rio Grande do Norte, Paraíba, Alagoas, and Sergipe share a common situation in terms of a low number of local botanists and paucity of botanical collections. However, a better knowledge on the plant diversity is available for the State of Paraíba, and a few studies on the local flora are published or in progress (Pereira & Barbosa (2004, 2006). The state with the highest collection density, and therefore with

a better Rubiaceae representation, of the region is that of Pernambuco, due to the historical number of institutions and botanists present in the city of Recife. The State of Bahia presents a different reality from the remainder of the states of northeastern Brazil, mostly for high number of institutions and local botanists. The Botany Department of the State University of Feira de Santana (UEFS) has gone through a rapid evolution in terms of number of botanists, research and botanical collections, since the arrival of A.M. Giulietti, the coordinator of the Botany program of this institution. The UEFS has an active botanical graduate program, and has recently trained several Rubiaceae graduate students (under the supervision of D. Zappi, Kew Botanic Gardens, England) that contributed considerably to the knowledge of the Rubiaceae of Brazil.

**Literature:** A floristic treatment of the Rubiaceae of the Pico das Almas (Chapada Diamantina, Brazil) was published by Zappi & Stannard (1995) that included key to genera, generic and specific descriptions, and specimens cited for 25 genera and 46 species. A Rubiaceae checklist of the *brejos* (wet mountain slopes) of the state of Pernambuco was published by Zappi *et al.* (1998). Preliminary Rubiaceae checklists for Northeastern Brazil were published by Zappi & Nunes (2000, 2002).

**Future challenges:** The main challenge for the entire northeastern region is the continuation of botanical collections throughout the region, and the formation of local Rubiaceae specialists, as most states of this region are still far from being botanically known. Specifically for the Rubiaceae, it is extremely important to start collecting in the forest remnants of the peri-Amazonian in the state of Maranhão, where is mostly likely to find a high diversity of Rubiaceae (and many other plant families). Additional areas of collections, which are significant centers of Rubiaceae diversity, are the wet mountain slopes (locally called “*brejos*”) of this region. Other additional biomes present in the region and that deserve the highest priority in terms of botanical collecting and conservation are the much endangered *Restinga* and Atlantic forest, both of them under threat of complete destruction because of high human pressure. In both of these last biomes the Rubiaceae represent one of the most diverse families, and these are the localities where is most likely do discovered undescribed species. In order to assure the continuation of Rubiaceae studies in this region, it is highly desirable the formation of master and doctoral students with

subjects focusing on members tribes particularly complex in the northeastern region of Brazil, as the Psychotriaceae, Guettardeae and Spermaceae.

**5. Northern Region** (States of Amapá, Pará, Tocantins, Roraima, Amazonas, Acre, and Rondônia) – The states of northern Brazil occupy the majority of the Amazon Basin. This region represents the greatest challenge in assessing the total biodiversity in Brazil. The Amazonian Biome is the largest in Brazil (61% of Brazil surface, and one-third of the tropical rainforest of the planet), and has the lowest number of botanists per unit surface. In this biome, the Rubiaceae represents one of the largest families (Taylor *et al.* 2007; Delprete & Taylor 2008), and one of the most important, in terms of richness, abundance, and presence at all vegetational layers of the forest.

All the states of the Amazon Basin share a similar reality in terms of underrepresentation of botanical collections (in terms of collection density) and presence of very few local botanists. The state of Pará, one of the two giant states of Amazonian Brazil, with a surface of about 1.2 million km<sup>2</sup>, houses two large herbaria in the oldest institutions of the Brazilian Amazon, the Museu Goeldi and the Instituto Agrônômico do Norte (IAN, now part of the EMBRAPA Amazônia Oriental). The two herbaria together preserve a total of 346,000 specimens [data according to *Index herbariorum* (see Thiers, continuously updated); percentage of Rubiaceae unknown], which is the highest number of herbarium specimens of any Amazonian state. Nevertheless, this is far from being representative of the local flora, corresponding to a collection density of 0.28 collections/km<sup>2</sup>, as the northern portion of the state remains poorly collected.

Amapá is one of the least collected states of the Brazilian Amazon. The state is entirely within the Amazon Region (and the Guyana Shield), mostly covered by tall lowland forest, and with a central region of Amazonian savannas (open fields, seasonally or permanently inundated). A few botanical expeditions in Amapá were organized in the XX century by the Museu Goeldi, the New York Botanical Garden, and the IEPA (Instituto de Estudos e Pesquisas do Estado do Amapá). Nowadays, local institutions suffer from lack of botanical personnel and at the only local herbarium (HAMAB) are preserved 9,000 specimens (ca. 500 Rubiaceae specimens; Delprete, pers. obs.). Additionally, the natural environment of central portion of the state is being destroyed by extensive *Eucalyptus* plantations.

The state of Tocantins is also botanically little-collected. The northern portion of the state is

part of the Amazon Basin, and the forests present at river margins are composed by a significant number of Amazonian species. Aside from this, the forests of the northern portion of this state are located in an area of transition between the Cerrado Biome and Amazonian Basin, and therefore with a floristic composition with elements from both biomes, as well as species that are unique to this vegetation. The only herbarium present in the state (HTO) houses 9,700 specimens (data according to Thiers continuously updated), which is well below from being representative of the local flora.

Roraima shares the same reality of Amapá, by being a small state, and the local herbarium (MIRR) houses about 8,000 specimens (ca. 300 Rubiaceae specimens). The paucity of botanists and the difficulty of access to the remote areas of the state are the main factors that hampered the botanical collections in this state. The northern limit of the state (and the northernmost point in Brazil) is an extremely interesting area for botanical collections, and even more for Rubiaceae, because it is part of the *Tepui* region (Guayana Highlands).

Amazonas is the second giant state of the Brazilian Amazon, with a surface of about 1.6 million km<sup>2</sup> (the largest Brazilian state). The main herbarium of the state, housed at the INPA (Instituto Nacional de Pesquisas da Amazonia), counts with a considerable number of botanists and preserves about 205,000 specimens (according to Thiers continuously updated). This state shares the same realities of Pará, because of its huge size and the insufficient botanical collections, due to the difficulties of reaching the remote areas.

Rondônia shares the same reality of Roraima and Amapá, by being a small state, with a few local botanists and even fewer botanical collections, with respect to other Amazonian states. The sole local herbarium, housed at Faculdade São Lucas, preserves about 5,200 specimens (HFSL; data according to Thiers continuously updated).

Acre is the Amazonian state of Brazil with the highest density of botanical collections, in collaboration with many members of the Universidade Federal do Acre and the New York Botanical Garden. The signature of official agreement between the two institutions was made in 1991, and the active team started the botanical explorations shortly after, producing a considerable amount of herbarium specimens. A subsequent successful program, called “Mobilizing Taxonomic Specialists”, coordinated the botanical collections and herbarium identifications of specialists of

the largest plant families of Acre, from 2001 to 2005, and raised the overall index of collection density from 13 to 16 collections/ km<sup>2</sup>. However, as it was well put the Daly & Silveira (2008, p. 77) “Sadly, floristic work in Amazonian Brazil decreased dramatically overall after the end of the Projeto Flora Amazônica, and the Mobilizing Taxonomic Specialists project constituted one of the very few ongoing floristic efforts in the 5,217, 423 km<sup>2</sup> of the Brazilian Amazon. Considering the accelerated pace of change in forest cover and the regional climate, we urge national and international programs of collaborative research to help multiply floristic research programs, generating information and leading to conclusions essential for effective conservation and management of Amazonia’s plant resources.” Nowadays, at the herbarium of the Federal University of Acre are stored about 30,000 specimens, which is considerably representative of the flora of the state, although still far from complete.

**Literature:** A floristic treatment of the Rubiaceae for the Flora da Reserva Ducke was published by Taylor *et al.* (2007), accounting for 36 genera and 99 species, with keys and descriptions for genera and species, and citation of specimens studied; it might seem incredible, but this is most complete floristic treatment of this family for the whole Brazilian Amazon. A checklist of the Rubiaceae for the state of Acre was recently published by Delprete & Taylor (2008), where is recorded as the second most diverse family, with 62 genera and 243 species, after the Leguminosae *sensu lato* (86 genera, 327 spp.). A floristic treatment of the Rubiaceae of the *restinga* vegetation of the reserve of Algodoal/Maiandeuá was recently published by Margalho *et al.* (2009). The Rubiaceae treatments for the Flora of the Guyana Highlands contributed by Steyermark (1964, 1965, 1967, 1972) and that of the Flora of the Venezuelan Guyana by Taylor *et al.* (2004) are the most complete references for this family in the Brazilian Amazon.

**Future challenges:** The study of the floristic diversity in the Amazon basin represents the greatest challenge for the study of the Brazilian vegetation, especially for a large family as the Rubiaceae. This goal could be accomplished only by a large team of specialists. As pointed out above, the two major limiting factors for this region are the paucity of local botanists and the difficulty of access to remote areas. For these reasons, it becomes extremely important the formation of local botanists at all levels, and therefore the training of young

specialists in Rubiaceae projects on taxa particularly speciose and/or taxonomically complex in the Amazon Basin. Potential subjects for master and doctoral projects on Rubiaceae groups occurring in the Brazilian Amazon are the following:

- 1) Tribe Guettardeae: *Chomelia* and *Guettarda*;
- 2) Tribe Condamineae: *Bathysa*, *Calycophyllum*, *Elaeagia*, *Macrocnemum*, *Pentagonia*, and *Semaphyllanth*e (according to the new generic delimitations proposed by Kainulainen *et al.* 2010);
- 3) Tribe Ixoreae: *Ixora*;
- 4) Tribe Bertiereae: *Bertia*;
- 5) Tribe Coussareae: *Coussarea* and *Faramea*;
- 6) Tribe Spermaceae: *Spermace* *sensu lato* (incl. *Borreria*);
- 7) Tribe Morindae: *Appunia*;
- 8) Tribe Psychotriaceae: *Carapichea*, *Notopleura*, *Psychotria*, *Palicourea*, *Geophila*, and *Margaritopsis*.

It is our hope that this work will help promoting systematic, taxonomic and floristic studies of Rubiaceae in Brazil, by pointing out complex groups in need of taxonomic revisions, and particular regions where Rubiaceae studies are still lacking.

As in most tropical regions of the planet, floristic assessments rely heavily on field collections and taxonomic treatments. Monographic treatments contribute towards the clarification of taxonomic units (species) and the information about their geographic distribution, ecology and conservation biology. Nowadays, as we are going through the most important biodiversity crisis known to humanity, the number of taxonomists has been diminishing during the last decades. Because of the combination of massive destruction of the ecosystems and the fast diminishing of taxonomists, many species actually disappear before being known, a process known as the “anonymous extinction” by Campbell (1989). After their extinction, the role of these species in the equilibrium of the ecosystem where they use to live will never be known. For this reason, the disappearing of taxonomists has been called “the secondary crises of biodiversity” (Mori 1992). As the family Rubiaceae is so extremely diverse, present in most Brazilian biomes, and in most vegetational layers, the information supplied by taxonomic treatments represents an important set of data that could be used in ecological studies and in the assessments of phytosociology and conservation

biology (Miatelo 2008; Miatelo *et al.* 2010). At the end of our survey, it became obvious that the region of Brazil that is in most need of local specialists, field work and taxonomic studies of the family Rubiaceae is the Amazon Basin; therefore, it is of cardinal importance the formation of a new generation of local Rubiaceae specialists in order to expand and assure the continuation of the study of this extremely complex family.

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