Rodriguésia 66(2): 305-328. 2015
http://rodriguesia.jbrj.gov.br
DOI: 10.1590/2175-7860201566203

Overview of the systematics and diversity of Poales in the Neotropics with emphasis on the Brazilian flora

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Abstract

Poales represents a major part of Angiosperm and Monocot diversity. The families encompass ca. 20,000 species which is about 7% of the Angiosperms and 33% of the Monocots. Bromeliaceae, Cyperaceae, Eriocaulaceae, Juncaceae, Mayacaceae, Poaceae, Rapateaceae, Thurniaceae, Typhaceae, and Xyridaceae are the families represented in the Neotropics. In general terms some areas in the Neotropics could be considered hotspots for Poales with a high number of species in several genera and several centers of endemism – the Guayana Shield, Espinhaço Range and Atlantic Forest are highly diverse in Poales. In terms of the Brazilian flora, the order is well represented in the entire country with almost 4,400 species. It represents more than 50% of the total number of species of Monocotyledons in Brazil. The main goal here is to summarize the available information and provide an overview of the Poales in the Neotropics. The state of knowledge for each family, focused on the Brazilian flora, is provided and reinforces the importance of new studies in key-groups looking beyond the understanding of their diversity on the continent but also the conservation of the species.

Key words: Bromeliaceae, Cyperaceae, Eriocaulaceae, Juncaceae, Mayacaceae, Rapateaceae, Thurniaceae, Typhaceae, Xyridaceae.

Introduction

Monocot classification has faced major changes over recent decades, especially as the result of phylogenetic advances (Chase *et al.* 2000; Dahlgren *et al.* 1985; Stevens 2001 onwards). Relations among orders have changed while new insights and data on Monocot evolution are continuously updated (Chase 2005; Chase *et al.* 2006; Davis *et al.* 2004). After the most recent molecular and morphological data compilations, clades in some groups are more stable (Davis *et al.* 2004; Chase *et al.* 2006; Givnish *et al.* 2010). Clustered within the commelinids clade, Poales is sister to the clade formed by Commelinales + Zingiberales, and now includes 16 families. Among them, Bromeliaceae, Cyperaceae, Eriocaulaceae, Juncaceae, Mayacaceae, Poaceae, Rapateaceae, Thurniaceae, Thyphaceae, and Xyridaceae are represented in the Neotropics. One species of Restionaceae, *Apodasmia chilensis* (Gay) B.G. Briggs & L.A.S. Johnson, is found in South America (in a subtropical area of southern Chile).

The phylogenetic relationships in Poales are moderately to strongly supported (Givnish *et al.* 2010). However, the high rate of heterogeneity in the order and poor sampling in some genera may cause problems for the interpretation of evolution within this group (Bouchenak-Khelladi *et al.* 2009, 2104; Givnish *et al.* 2010).

Poales represents a major part of Angiosperm and Monocot diversity. The families encompass ca. 20,000 species which comprises about 7% of the Angiosperms and 33% of the Monocots (Bouchenak-Khelladi *et al.* 2014; Givnish *et al.* 2010). Poaceae is the most species-rich family with ca. 11,000 species, while six other families have fewer than 10 species each. Species in Poales are also of outstanding ecological and economic

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significance. Many biomes and open vegetation areas are dominated by grass-like species, such as some of the savanna formations. Several Bromeliaceae species are also of significant ecological importance as epiphytes forming water tanks (Benzing 2000; Bouchenak-Khelladi *et al.* 2009, 2104; Givnish *et al.* 2010).

Local economies, as basic resources for several poor communities, use species of Poales in many countries in the Neotropics. The activities are usually associated with exploitation without conservation and management approaches and are often related to production of hand-crafts and also fresh and dried flowers. These intensive procedures can produce high levels of pressure on the conservation of some species (Balslev 1998; Giulietti *et al.* 1996; Goetghebeuer 1998; Kubitzki 1998; Stützel 1998).

Human evolution and the history of civilization are closely related to agricultural practices in early settlement. Poaceae constitutes the most economically important plant family and the main source of food for humans. Major food sources throughout history including the present, are based mainly on species of the family, such as rice, corn, wheat, barley, oats, rye, and sugarcane, among others, besides other small sources used locally for different proposes and from several species (Judd *et al*. 2007; Dahlgren *et al.* 1985). Poaceae also forms extensive grasslands in natural environments worldwide and are the basis of primary productivity in several ecosystems (GPWG 2012).

The circumscription of Poales as comprising 16 families involves several controversies and the phylogenetic affinities among its families are still being debated by the specialists (Bouchenak-Khelladi *et al.* 2014; Givnish *et al.* 2010). Linder & Rudall (2005) suggested a late Cretaceous origin during the Paleogene with major diversification in the Neogene. The most recent and more comprehensive phylogenies of Poales achieved significant and quite different evolutionary trees. The authors recover the Cyperid, Restid, and Graminid clades and define Bromeliaceae and Typhaceae as belonging to an early diverging branch within the order. However, the consistency of the Xyrid clade is doubtful, and the positions of both Mayacaceae and Xyridaceae are not well established yet. The Cyperid clade, which is not strongly supported by Bouchenak-Khelladi *et al.* (2014), has been well supported in previous studies (Michelangeli *et al.* 2003; Givnish *et al.* 2010). The phylogenetic positions of Rapateaceae and Typhaceae are also not clear, and their definition may change some concepts of the Cyperid clade and a possible bromeliad clade (Bouchenak-Khelladi *et al.* 2014; Givnish *et al.* 2010). Among the phylogenies available, clades within the Poales have clearly been well supported but often with high variation in their family composition, sampling and methodology used (Bouchenak-Khelladi *et al.* 2014; Davis *et al.* 2004; Givnish *et al.* 2010).

The information on the systematics and diversity of Neotropical Poales, especially related to the Brazilian species, are roughly divided into large historical reviews, such as *Flora Brasiliensis* and *Das Pflanzenreich*, performed by several authors, and recently published advances. In this case, the updated information is available from a variety of sources, such as articles in several scientific journals, books (local and regional floras) and checklists, besides unpublished theses and dissertations.

Our goal is to provide an overview of the knowledge of the Neotropical families of Poales with an emphasis on Brazil. For that purpose, the relevant bibliography related to systematics and diversity was reviewed and summarized here.

Overview

An overview of the systematics and diversity of Poales is a great challenge even if it is restricted to the Neotropical region and focused on the Brazilian species. The families related to the order are different in several aspects including the availability of updated taxonomic reviews and phylogenies.

The order comprises families considered morphologically very distinct, such as Bromeliaceae, Eriocaulaceae and Rapateaceae. For some of them, Cyperaceae and Poaceae for instance, a set of specialized terminology is almost unique. Additionally, there is a huge difference in number of species (ca. 10,000 spp. in Poaceae versus 2–5 spp. in Mayacaceae and Thurniaceae). Extremes in geographic distribution are also found among the families. Cyperaceae, Eriocaulaceae, Juncaceae, Poaceae, Typhaceae and Xyridaceae are examples of families with world-wide occurrence; distinctly different from Bromeliaceae, Mayacaceae and Rapateaceae, which are mostly restricted to the American continent (one species of each family grows in West Africa), and Thurniaceae (not considering the genus *Prionium*), which is a narrow-endemic to a small area in northern South America.

The variety of habitats (e.g. aquatic, rupicolous, epiphytic, terricolous), vegetation types (e.g. grasslands, understory of moist forests, rocky outcrops) and location (sea-level to 4,000 m high) support a range of narrow-endemic species and genera to widespread ones, such as some weeds and subspontaneous species mainly found in Cyperaceae, Poaceae and Typhaceae.

Natural hybridization and economic use (agricultural and ornamental varieties) also play a major role in Poales, especially in Bromeliaceae and Poaceae. These conditions are key problems to species delimitation in some genera, list of taxa and conservation, but also to more accurate phylogenies.

These factors have had visible effects on the level of information that has been built and made available today for the families in Poales and the understanding of their evolutionary relationships (infrafamiliar level and below). Phylogenies with different approaches (based on morphological and/or molecular markers) have been published for the families but each of them addresses a unique set of morphological and systematic questions aimed at different genera and groups of species.

In general terms some areas in the Neotropics could be considered hotspots for Poales with a high number of species in several genera and several centers of endemism.

The Guayana Shield is located in the northern part of South America and includes parts of Colombia, Venezuela, Guyana, Suriname, French Guyana, and northern Brazil, especially the northern part of the states of Roraima, Amazonas, Pará, and Amapá (Gibbs & Barron 1993 *apud* Huber 1995). It is mainly covered by open vegetation (savanna-like) with flat mountains (*Tepuis*) and humid forest. The rocky outcrops, geographic isolation and climatic conditions are peculiar and play a major role in the diversity and endemism found for Bromeliaceae, Cyperaceae, Eriocaulaceae, Rapateaceae and Xyridaceae in the region.

The Espinhaço Range goes from the states of Bahia (Senhor do Bonfim) to Minas Gerais (Ouro Branco), Brazil and is a group of mountains with latitudinal orientation and altitudinal ranges from 800 to 1,500–1,800 m. It is surrounded by *Cerrado* (southwestern and southern sides), *Caatinga* vegetation (northwestern and northern sides) and dry forest as part of the Atlantic Forest Domain (eastern side). Rocky outcrops, locally called *Campos Rupestres* predominate in the area (Fiaschi & Pirani 2009; Giulietti & Pirani 1988) and are highly rich in species of Bromeliaceae, Cyperaceae. Eriocaulaceae, Poaceae and Xyridaceae. Disjunct areas of *Campos Rupestres* can be found in the state of Goiás (e.g. Chapada dos Veadeiros) as well as in Minas Gerais (e.g. Serra da Canastra, Carrancas, Tiradentes and Ibitipoca, among others).

The Atlantic Forest goes from the drier northern part (states of Ceará as fragmented areas and Rio Grande do Norte) to more humid areas in southern Brazil (state of Rio Grande do Sul) and northeastern Argentina and eastern Paraguay (Fiaschi & Pirani 2009; Ribeiro *et al.* 2009; Thomas & Barbosa 2008). The most humid and diverse section goes from southern Bahia to São Paulo, where high-altitude (up to 3,000 m) grasslands with exposed rocks (locally called *Campos de Altitude* or Brazilian *Páramos* by Safford 1999) are common and house many species with several centers of endemism for Bromeliaceae, Cyperaceae and Poaceae.

The Andes Mountains can also be considered a hotspot with several cases of endemism in groups of Bromeliaceae, Cyperaceae, Juncaceae and Poaceae. It is a system of high-altitude mountains which goes from southern Chile and Argentina to Colombia and Venezuela with a south-north orientation and distinct vegetation types and physiognomies from the northern to the southern part, including the *Páramos* and *Punas*, which are mostly around 3,000 m altitude, as well as montane forests (Luteyn & Churchill 2000).

Other areas are also important for some taxonomic groups. The lowland Amazon Forest, for instance, occupies a large part of South America - Trinidad and Tobago, French Guiana, Suriname, Guyana, Venezuela, Colombia, Peru, Ecuador, and Bolivia (Daly & Mitchell 2000; Fiaschi & Pirani 2009). It is particularly rich in some groups of Cyperaceae, Poaceae and Rapateaceae. Finally, the *Pampas*, comprising grassland vegetation with dispersed rocky outcrops and flooded areas is limited to a small geographic area in the subtropical part of South America, including southern Brazil, Uruguay and northeastern Argentina (Fiaschi & Pirani 2009; Veloso *et al.* 1991). This area includes many species of Bromeliaceae, Cyperaceae, Juncaceae and Poaceae.

In terms of the Brazilian flora, Poales is well represented in the country with almost 4,400 species. It represents more than 50% of the total number of species (ca. 8,400) of Monocots cited by LEFB (2014). Four of the five most species-rich families of Monocots (excluding Orchidaceae) in Brazil are members of Poales: Poaceae (1,485 spp.), Bromeliaceae (1,341 spp.), Cyperaceae (673 spp.), and Eriocaulaceae (624 spp.). Almost 1,500 species of Poales are endemic to the country, including ca. 80% of the total number of species cited to Bromeliaceae, Eriocaulaceae, and Xyridaceae and 30% of Cyperaceae and Poaceae. Among the 322 genera of Poales confirmed in Brazil, 32 are considered endemic and belong, for the most part, to Bromeliaceae (ca. 40% of the number of genera of the family are endemic) and Poaceae.

The main goal here is to summarize the available information and provide an overview of the order in the Neotropics. Furthermore, this paper provides the state of knowledge for each family focused on the Brazilian flora and reinforces the importance of new studies in key-groups, aiming beyond the understanding of their diversity on the continent but also the conservation of the species.

Bromeliaceae

The Bromeliaceae is one of the largest families of flowering plants essentially Neotropical. It is a prominent example of adaptive radiation and one of the most diversified Monocots with respect to habit, ecological range, and habitat (Benzing 2000; Smith & Downs 1974). Three centers of diversity can be recognized for the bromeliads: the Atlantic Forest in eastern Brazil, the Guayana Shield and the Andes (Martinelli *et al.* 2008; Smith & Downs 1974).

Comprising 58 genera and ca. 3,400 species (Luther 2012), Bromeliaceae is one of the typical elements of Neotropical forests (Benzing 2000). Givnish *et al.* (2007) demonstrates that modern lineages of bromeliads started to diverge around 19 million years ago. The origin of the group was traced back to the Guayana Shield in northern South America and from there spread throughout the Neotropics. *Pitcairnia feliciana* (A. Chev.) Harms & Mildbraed is the only species outside the continent and reached western Africa through relatively recent long-distance dispersal, around 10 million years ago (Givnish *et al.* 2007).

Brazilian bromeliads are outstanding in their diversity and endemism, with 43 genera and 1,341 species, of which 1,172 are endemic to the country. The Atlantic Forest is a well-known center of diversity for the family and holds ca. 900 species. A secondary center is the *Campos Rupestres* with almost 200 species, most of which are endemic (Forzza *et al.* 2014). Bromeliads are also highlighted by their unfortunate situation in terms of conservation, being the second plant group in absolute number of threatened species in the country (202 spp.), behind Asteraceae, which is in fact the largest flowering plant family in Brazil (Martinelli *et al.* 2013). The overall population size is often small, with restricted distributions and highly specific habitats. Such attributes, combined with accelerated habitat loss, degradation of remaining native vegetation and exploitative practices have pushed many species close to extinction, mainly in the Atlantic Forest (Forzza *et al.* 2013).

While the delimitation of the family does not seem to raise any controversy, the circumscription of infra-familiar categories continues to be widely questioned and changed over time. Pitcairnioideae, Tillandsioideae and Bromelioideae (Smith & Downs 1974) have shown to be artificial under a phylogenetic approach (Gilmartin & Brown 1987; Horres *et al.* 2000; Terry *et al.* 1997). In order to clarify the relationships within the family, Givnish *et al.* (2004, 2007) widened the number of terminal taxa in the analysis. Following this approach, Bromelioideae and Tillandsioideae were confirmed as monophyletic in contrast with the already suspected polyphyletic Pitcairnioideae. Givnish *et al.* (2007) proposed each clade of Pitcairnioideae as distinct subfamilies, increasing to eight the total number.

However, the progress in understanding bromeliad evolution at the higher levels is not reflected at the generic and species levels. Most phylogenetic studies, even with large sets of molecular markers, have demonstrated that the generic circumscription is far from being well-supported (e.g. Almeida *et al*. 2008; Barfuss *et al.* 2005; Faria *et al.* 2004; Givnish *et al.* 2011; Gomes-da-Silva *et al.* 2012; Louzada *et al.* 2014; Sass & Specht 2010; Schulte *et al*. 2009; Versieux *et al.* 2012). The low variability of the molecular markers (Krapp *et al.* 2014) might be overcome by combining the data set with morphological characters, a possibly good alternative as stressed by some authors (Almeida *et al.* 2008; Costa *et al.* 2014; Gomes-da-Silva 2009; Horres *et al.* 2007;

Mantovani *et al.* 2012; Monteiro 2009; Monteiro *et al.* 2010; Santos-Silva *et al.* 2013; Saraiva 2013; Sousa *et al.* 2007; Venda 2012). Such an approach may offer valuable input regarding the evolution of the family despite being affected by high rates of homoplasy.

Regardless of the difficulty in recognizing monophyletic genera (e.g. Escobedo-Sarti *et al.* 2013), remarkable progress has been made in the last two decades in terms of taxonomic revisions and local floras. Since the major works by Mez (1894, 1896) and Smith and Downs (1974, 1977, 1979), knowledge of the Brazilian species has been greatly increased.

Recent revisions of exclusively Brazilian genera of Bromelioideae have been carried out: *Canistrum, Canistropsis, Cryptanthus, Edmundoa, Eduandrea, Nidularium, Lymania, Portea, Lapanthus, Orthophytum* and *Wittrockia* (Coffani-Nunes 2004; Leme 1997, 1998, 2000, Louzada 2012; Louzada & Versieux 2010; Louzada & Wanderley 2010; Ramirez 1996, 2000; Sousa & Wendt 2008). Species-groups within *Aechmea* have also been revised (Abondanza 2012; Faria *et al.* 2010; Siqueira Filho & Leme 2006; Sousa 2004). For Tillandsioideae, *Alcantarea* is the only genus that has been fully revised (Versieux 2009), however several studies of species-groups within *Vriesea* and *Tillandsia* have been carried out (e.g. Costa *et al.* 2009; Gomes-da-Silva & Costa 2011; Moura 2011; Moura & Costa 2014; Silva 2014; Sousa 2012; Tardivo 2002; Uribbe 2014). For Pitcairnioideae, revisions of *Encholirium*, *Deuterocohnia* and *Fosterella* (Forzza 2005; Peters 2009; Peters *et al.* 2008; Schütz 2011) have been published, however, the most diverse genera, *Pitcairnia* and *Dyckia*, are still limited to floristic studies and descriptions of new species (e.g. Buneker *et al.* 2013; Esteves & Gouda 2014; Leme *et al.* 2010; Martinelli & Forzza 2006; Saraiva & Forzza 2012; Wanderley *et al.* 2014).

Most of the published local floras are from areas in southeastern and southern Brazil, mainly from *Campos Rupestres* and the Atlantic Forest region (e.g. Barros & Costa 2008; Coffani-Nunes *et al.* 2010; Coser *et al.* 2010; Costa & Wendt 2007; Forzza & Wanderely 1998; Guarçoni *et al.* 2010; Luiz-Santos & Wanderley 2012; Machado 2012; Monteiro & Forzza 2008; Moura *et al.* 2007; Siqueira Filho & Leme 2006; Versieux *et al.* 2008, 2010; Versieux & Wendt 2007; Wanderley & Forzza 2003; Wanderely & Martins 2007). There is a clear lack of this kind of information from the central and northern parts of the country.

Several taxa still present a challenge because they are often poorly delimited and seldom represented in herbarium collections. This makes a better understanding of their morphological variation harder. *Aechmea*, *Neoregelia, Cryptanthus*, *Hohenbergia*, *Billbergia*, *Vriesea* and *Dyckia* are examples of the challenges ahead. Endemic genera from the Guayana Shield (Venezuela, Guyana, Suriname, French Guiana, and northern Brazil), which are poorly known and very seldom collected, also deserve more attention.

Species delimitation should include different approaches, such as morphology, genetics, and also reproductive and ecological studies which are relevant for conservation. Recently, studies combing new tools with taxonomic studies have increased information on the complexity of the evolutionary processes involved in bromeliads (e.g. Barbará *et al.* 2007, 2009; Hmeljeski *et al.* 2014; Lavor *et al.* 2014; Louzada *et al.* 2014; Palma-Silva *et al.* 2011; Schulte *et al.* 2010; Versieux *et al.* 2012; Zanella *et al.* 2011). In order to support a better understanding of the phenotypic plasticity in the family, continuous improvement in collections and their availability for researchers is mandatory. Finally, studies focusing on species-complexes are crucial to fully comprehend the micro-evolution and to find informative molecular markers for lower hierarchic levels which are probably the new paths for taxonomic studies.

Cyperaceae

The Cyperaceae is a more or less cosmopolitan family with South America as one of its major centers of diversity (Goetghebeur 1998; Govaerts *et al.* 2007). Most recent checklists include around 5,300–5,500 species in 100–110 genera, which puts it as the 3rd largest family in the Monocots and 7th among the angiosperms (Alves *et al.* 2009, 2014; Govaerts et al. 2007; Guaglianone *et al.* 2008). *Carex* and *Cyperus* are the most diverse genera. *Carex* comprises ca. 2,000 species, mostly from subtropical and temperate zones in the Northern Hemisphere and less well represented in the Neotropics while *Cyperus s.l.* has ca. 1,000 species and is a cosmopolitan genus with numerous species associated with flooded areas and many others considered weeds. The Neotropical region supports ca. 1,500–2,000 species based on several non-integrated checklists (Adams 1994; Alves *et al.* 2009, 2014; Camelbecke *et al.* 2007, Govaerts *et al.* 2007; Guaglianone *et al.* 2008; Kearns *et al.* 1998; Strong & Acevedo-Rodriguez 2005, 2012), and Brazil accounts for almost 700 of these (Alves *et al.* 2014).

Cyperaceae is nested with Juncaceae in recent phylogenies (Bouchenak-Khelladi *et al.* 2014) in a clade with well-known morphological support. The first one has two accepted subfamilies: Mapanioideae and Cyperoideae, each one with several tribes and subtribes (Goetghebeur 1998; Muasya *et al.* 2009a; Simpson 1995b) Current research aims to better understand and organize the family classification. *Carex* is monophyletic, however *Cyperus s.l.* (including *Lipocarpha*, *Kyllinga*, *Pycreus*, *Oxycaryum* and *Remirea* among others) and *Rhynchospora* (with *Pleurostachys* as a separate genus) are clearly non-monophyletic but widely cited as independent genera in checklists and herbarium collections (Bauters *et al.* 2014; Larridon *et al.* 2013, 2014; Muasya *et al.* 2009b; Reid *et al.* 2014; Thomas *et al.* 2009).

Taxonomic reviews and local floras have been intensively produced in recent decades but not at a scale sufficient to understand the full level of diversity in the Neotropics. *Bulbostylis*, *Cyperus s.l.*, *Eleocharis*, *Hypolytrum*, *Kyllinga*, *Machaerina*, *Mapania*, *Rhynchospora*, and *Scleria* have been the focus of recent studies but are still far from being fully understood in terms of their diversity and evolutionary relationships.

Several hotspots in the Neotropics can be indicated for Cyperaceae: the Guayana Shield, the Espinhaço Range and the central-southern part of the Atlantic Forest (from Bahia to Santa Catarina, including Minas Gerais). The Andes Mountains can also be considered a hotspot for the family as well as the grasslands (*Pampas*) in southern South American, but this latter biome mainly supports genera and species of subtropical and temperate zones.

These hotspots account for almost 75% of the diversity found on the continent and hold very distinct physiognomies and vegetation types, which are often unique in terms of genera and endemic groups.

The Guayana Shield has 413 species of Cyperaceae recorded so far (Camelbecke *et al.* 2007; Kearns *et al.* 1998). It also houses small and endemic genera, such as *Cephalocarpus* (4 spp.), *Everardia* (11 spp.) and *Koyamaea* (monospecific). This area is also an important site for subgroups of *Cryptangium*, *Lagenocarpus*, and *Rhynchospora* (Alves *et al.* 2014; Camelbecke *et al.* 2007). The Espinhaço Range is a hotspot for several genera including *Bulbostylis*, *Cryptangium*, *Cyperus*, *Lagenocarpus*, *Rhynchospora* and *Scleria* (Simpson 1995a). The central-southern part of the Atlantic Forest from southern Bahia to São Paulo holds some highly diverse genera. In this narrow stretch of humid and shady forest with several high-altitude and exposed rocky outcrops, ca. 25 endemic species of *Hypolytrum*, *Machaerina*, and *Pleurostachys* can be found (Alves *et al.* 2014). The most diverse genera in the Andes region are *Bulbostylis*, *Carex*, *Scirpus* and *Uncinia* (Guaglianone *et al.* 2008).

Brazil, as the largest country in the tropical part of the South American continent, plays a major role in the diversity of Cyperaceae (Luceño & Alves 1997; Alves *et al.* 2014), mainly because of its large variety of biomes, ecosystems and vegetation types.

The available checklists for the Amazon Forest as a whole comprise at least 800–850 species names including almost 300 from the Brazilian portion (Alves *et al.* 2014; Camelbecke *et al.* 2007; Kearns *et al.* 1998). The forested area has genera typically not found in savanna vegetation, such as *Bisboeckelera*, *Calyptrocarya*, *Diplacrum*, *Diplasia*, *Hypolytrum* and *Mapania*. Several examples of geographic disjunction among genera and species between the Amazon and Atlantic Forest have been recorded (Alves *et al.* 2003; Alves & Thomas 2015; Luceño *et al.* 1999).

Caatinga is a semi-arid vegetation exclusive to northeastern Brazil and a naturally poor habitat for Cyperaceae as well as other families of Poales. However, more than 130 species are cited, most of which are associated with temporary streams, islands of humid forest and rocky outcrops (Alves *et al.* 2014; Luceño *et al.* 1999). *Cerrado*, *Chaco* and *Pantanal* are found in southwestern Brazil, Bolivia and Paraguay and are connected ecosystems which share several vegetational similarities including species. It is a very rich area for Cyperaceae especially for *Bulbostylis*, *Cyperus*, *Eleocharis*, *Fuirena*, *Rhynchospora* and *Scleria* related to fire-tolerance and rocky outcrops (common in *Cerrado*) and floods (*Pantanal*). Including the species recently cited for Brazil (Alves *et al.* 2014; Araújo *et al.* 2009), the diversity of Cyperaceae in the area easily reaches 450 species.

The grassland-like vegetation from the *Pampas* is highly rich in species of Cyperaceae as pointed out by Guaglianone *et al.* (2008) and Alves *et al.* (2014) with ca. 200 recorded taxa. *Bulbostylis*, *Eleocharis* and *Rhynchospora* are among the most species-rich genera.

Central America (including Mexico) and the Caribbean Islands also comprise a peculiar combination of ecosystems (lowland forest to subalpine vegetation in high altitudes and volcanic areas) and species of Cyperaceae. More than 100 species are considered endemic to the area which supports a total of 450–500 taxa recorded so far (Adams 1994; Goméz-Laurito 2003; Strong & Acevedo-Rodriguez 2012). The most species-rich genera are *Cyperus*, *Rhynchospora* and *Scleria*.

Eriocaulaceae

The Eriocaulaceae is a pantropical family consisting of ca. 1,200 species with ca. 850 species and nine genera concentrated in South America, especially in Brazil. The main centers of taxonomic and morphological diversity are the Espinhaço Range and the Guayana Shield, comprising more than 80% of the species (Giulietti & Hensold 1990; Giulietti *et al.* 2000, 2005, 2012; Stützel 1998). Secondary centers of diversity are located in the central savannas, especially in Goiás and Mato Grosso, and in the Amazon Forest domain. In these two areas diversity is greatly underestimated, as they have been poorly collected and barely studied (Giulietti *et al.* 2005, 2012).

The evolutionary relationships among the genera of Eriocaulaceae have only been partially elucidated. Both subfamilies and most of the genera are monophyletic, except for *Paepalanthus* (Andrade *et al.* 2010; Giulietti *et al.* 2000, 2012; Trovó *et. al.* 2013). In order to resolve the polyphyly of *Paepalanthus*, a broad sense of the genus would have to include *Actinocephalus*, *Tonina*, and *Lachnocaulon*. However, more detailed studies are required to justify keeping *Paepalanthus* in a broad sense or to split it into a few, more robust genera. The systematic position of *Syngonanthus*, *Comanthera* and *Leiothrix* is somewhat unstable and *Rondonanthus* is still poorly sampled. Published phylogenies within the genera have been restricted to *Comanthera, Leiothrix,* and *P.* subg. *Xeractis* and all of them highlighted the importance of biogeography in the evolution of species of Eriocaulaceae (Echternacht *et al*. 2011, 2014; Giulietti *et. al* 1995).

In the Neotropics, *Paepalanthus* is the most species-rich genus. It comprises 337 species in Brazil, of which 322 are endemic to the country (Giulietti *et al.* 2005, 2012). Most of the species occur in Minas Gerais (265 spp.) and Bahia (40 spp.) and often on rocky outcrops (Giulietti *et al.* 2014). As the most morphologically and taxonomically diverse, the genus also encompasses the majority of the taxonomic and nomenclatural issues. After the historical manuscripts (Bongard 1831; Koernicke 1864; Ruhland 1903) and descriptions of hundreds of species and varieties by Álvaro da Silveira and Harold Moldenke, some revisionary studies have addressed ca. 25% of the valid names. *Paepalanthus* ser. *Paepalanthus* (=*P.* ser. *variabiles*), which contains ca. 60% of *Paepalanthus* species, is still poorly studied.

Hensold (1988, 1991, 2004) revised *P.* subg. *Xeractis* and *P.* subg. *Monosperma*. Tissot-Squalli (1997a,b,c) revised *P.* subg. *Platycaulon* and Trovó & Sano (2011a), *P.* sect. *Diphyomene*. Trovó and Stützel (2013) transferred *P.* subg. *Psilandra* to *Syngonanthus*. Additionally, some isolated nomenclatural changes and species descriptions have been published quite recently (Echternacht *et al.* 2012; Trovó & Sano 2009, 2010a,b, 2011, 2014; Trovó *et al.* 2011, 2012a, 2013, 2014).

Syngonanthus is also quite a diverse genus, comprising ca. 100 species distributed mainly in South America, but with some African and North American species as well (Giulietti & Hensold 1990; Giulietti *et al.* 2005; Stützel 1998). The 95 Brazilian species are distributed all over the country, but concentrated in the *Cerrado*. It is the most diverse genus of Eriocaulaceae in the Amazon. In addition to new species and nomenclatural updates (Hensold 2004; Hensold *et al.* 2012; Parra & Giulietti 1997), a synopsis is about to be published (Echternacht pers. comm.).

Eriocaulon is the largest genus of Eriocaulaceae with ca. 450 species usually associated with humid or aquatic habitats. Its distribution is truly pantropical, with at least one species reaching temperate areas in Europe (Giulietti & Hensold 1990; Giulietti *et al.* 2005, 2012; Stützel 1998). However, it is less diverse in South America, with 57 species occurring in Brazil, of which 40 are endemic (Giulietti *et al.* 2014). *Leiothrix* is almost exclusive to Brazil with only *L. flavescens* (Bong.) Ruhland also found in Venezuela. The rocky outcrops of Minas Gerais hold 35 endemic species among its total of 48. *L. fluitans* (Mart.) Ruhland is the only aquatic taxon in the genus (Giulietti *et al.* 2014). Recent taxonomic information is scarce for *Eriocaulon* and *Leiothrix*, except for nomenclatural notes and new species descriptions (Giulietti 1978; Giulietti & Hensold 1990; Giulietti & Miranda 2009; Giulietti *et al.* 1995; Oliveira & Bove 2011).

Actinocephalus and *Comanthera* were fully revised quite recently. *Actinocephalus* was established from *P.* sect. *Actinocephalus* (Sano 2004) and amended with *P.* subsect. *Aphorocaulon* (Costa & Sano 2013). It comprises 49 species endemic to Brazil and mostly distributed in the Espinhaço Range in Minas Gerais. *Comanthera*, recircumscribed based on *Syngonanthus* sect. *Eulepis* and *S.* sect. *Tysanocephalus*, has 34 species with a similar geographic distribution to that of *Actinocephalus.* However, some species are restricted to the savannas of northern South America and others are endemic to Bahia. New species have also been recently published in both genera (Costa 2006; Echternacht *et al.* 2011; Trovó & Costa 2009; Trovó & Sano 2010b; Trovó *et al.* 2012b).

Hensold & Giulietti (1991) transferred *P.* subg. *Bostrychophyllum* to a recircumscribed *Rondonanthus*. With six species, three of them restricted to the *Tepuis* and surroundings, the genus is poorly known because of the scarce herbarium specimens available (Giulietti *et al.* 2014; Hensold & Giulietti 1991). *Tonina*, a monotypic genus (*T. fluviatilis* Aubl.), is aquatic and occurs in South and Central America. In Brazil, it is mainly found in freshwater streams or lakes of coastal forests from São Paulo to Piauí (Giulietti *et al.* 2014).

Juncaceae

Juncaceae is a family of seven genera and ca. 440 species, most of them are limited to temperate or cold regions of the world, while in the tropics members of the family are often found above (800–)–1,500 m above msl (Balslev & Zuluaga 2009). They usually grow in alpine meadows and in grasslands and can be weeds in fields and along roads and trails. Most of the species are placed under *Juncus* and *Luzula* and less than 60 of them are found in the subtropics of the American continent and in the southern Andes (Alves & Luz 2014; Balslev 1996, 1998, 2004; Balslev & Zuluaga 2008; Novara 1996). *Distichia*, *Patosia* and *Oxychloe* comprise a total of 10 species endemic to high-altitude areas in the Andes from Venezuela and Colombia to Argentina and Chile; *Marippospermum* (3 spp.) occurs in Patagonia (southern Argentina) while *Rostkovia* (2 spp.) can be found on sub-Antarctic islands, in Patagonia and at high-altitudes (*Paramos*) in Ecuador and is an interesting example of geographic disjunction (Balslev 1996, 1998; Balslev & Zuluaga 2008; Novara 1996). Balslev (1996) pointed out how poorly diverse *Luzula* (8 spp.) is in the Neotropics compared to *Juncus* (41 spp.).

Several species of *Juncus* are halophytic while the cushion-forming genera *Distichia*, *Patosia* and *Oxychloe* are adapted to harsh diurnal freezing and thawing in the Andes and sometimes reach the altitudinal limit of vegetation (Balslev 2004; Balslev & Zuluaga 2008). In Brazil most of the 22 species of *Juncus* and *Luzula* cited (Alves & Luz 2014) are found in the southern region with some of them occurring at high altitude areas such as the Mantiqueira Range, which is located along the border of the states of São Paulo, Rio de Janeiro and Minas Gerais. Both genera are also found in Central America and the Caribbean (total of ca. 10 spp.). They are cited from lowland forests to high altitudes in volcanic areas up to 3,000 m above msl where bogs with swampy soils and ponds are common (Acevedo-Rodriguez & Strong 2012; Hammel 2003).

The species are often grass-like herbs with herbaceous culms, linear leaves, and usually many-flowered inflorescences of small, glumaceous flowers, similar to those found in Poaceae and Cyperaceae. However, Juncaceae emerges with Cyperaceae in the same clade which was previously called Cyperales (Bouchenak-Khelladi *et al.* 2014). Both families share diffuse centromeres as does Thurniaceae (Simpson 1995b; Balslev 1998; Goetghebeur, 1998).

The family has not been formally split into tribes or subfamilies, but three natural groups have been informally recognized (Balslev 2004). Recently, some molecular evidence has suggested replacing *Prionium*, a monospecific genus endemic to South Africa, with Prioniaceae or moving it to Thurniaceae (Balslev 2004; Bouchenak-Khelladi *et al.* 2014).

Mayacaceae

The Mayacaceae is a small and monogeneric family with five aquatic species currently recognized. It is essentially Neotropical with some species reaching temperate zones in the United States and Argentina, while *Mayaca baumii* Gürke is a disjunct West African species found in Angola (Carvalho 2007; Lourteig 1952; Stevenson 1998). The taxonomy of the family is based on the last full revision provided by Lourteig (1952), with some adjustments provided by Carvalho (2007). The phylogenetic position of the family is controversial. Mayacaceae was previously understood to be related to Commelinaceae, but recent phylogenies place the family within the Xyrid clade or even related to the Cyperid clade (Bouchenak-Khelladi *et al.* 2014; Givnish *et al.* 2010). Relations within Mayacaceae remain to be established.

The four Brazilian species of Mayacaceae are spread nearly throughout the country, growing in rivers and perennial or temporary lagoons. Species differentiation is quite a hard task, relying on anatomical features of the androecium, presence or absence of inflorescence and corolla color (Carvalho 2007). For a detailed study, see the overview of Brazilian Mayacaceae published within this volume.

Poaceae

The Poaceae has at least 11,000 species recorded in ca. 700 genera which makes it the fifth largest plant family and the second among the Monocots (a global checklist is available and continuously updated by Soreng *et al.* 2014). Grasses are distributed throughout all continents and are found in almost all continental environments of the planet (Judd *et al.* 2007). *Festuca*, *Poa*, *Stipa*, *Eragrostis* and *Paspalum* are the most diverse genera (Clayrton *et al.* 2006). In the Neotropics, more than 4,000 species of grasses in almost 300 genera are known, with *Paspalum* and *Eragrostis* being especially diverse (Longhi-Wagner & Oliveira 2009).

According to Bouchenak-Khelladi *et al.* 2014, Poaceae is a sister group of a clade composed of two small families, Ecdeiocoleaceae (Australia, monogeneric and with 3 spp.) and Joinvilleaceae (Pacific zone, monogeneric and 4 spp.), and comprises the graminid clade with Flagellariaceae (Paleotropics, monogeneric and 4 spp.). The most updated infrafamilial classification for the Poaceae proposed by the Grass Phylogeny Working Group accepts 12 subfamilies and a long list of tribes and subtribes (GPWG 2001; 2011). Anomochloideae, Pharoideae, and Puelioideae comprise the basal grass clade; Panicoideae, Aristioideae, Chloridoideae, Micrairoideae, Arundinoideae, and Danthonioideae make up the PAC-MAD clade; and Pooideae, Errhartroideae and Bambusoideae are the subfamilies of the BEP clade (GPWG 2011). All of them occur in the Neotropics, except Puelioideae (endemic to Africa).

The diversity of grasses in the New World is noteworthy. The Catalogue of New World Grasses (Judziewicz *et al.* 2000; Peterson *et al.* 2001; Soreng *et al.* 2003; Zuloaga *et al.* 2003) provided a comprehensive update on the knowledge of the family in the region. Although there is still a lot to be clarified about evolutionary relationships, phylogenies have been published supporting new taxonomic circumscriptions toward a more natural family classification. Phylogenies of Panicoideae (Sede *et al.* 2008, 2009a,b; Chemisquy *et al.* 2010; Zuloaga *et al.* 2010; López & Morrone 2012; Morrone *et al.* 2012; Acosta *et al.* 2014), Bambusoideae (Ruiz-Sanchez *et al.* 2008; Fisher *et al.* 2009; Ruiz-Sanchez *et al.* 2011; BPG: Bamboo Phylogeny Group 2012; Tyrrell *et al.* 2012; Fisher *et al.* 2014; Oliveira *et al.* 2014), Chloridoideae (Columbus *et al.* 2007; Peterson *et al.* 2010; Peterson *et al.* 2012; Peterson *et al.* 2014), Danthonioideae (Barker *et al.* 2007; Linder *et al.* 2010), and Pooideae (Schneider *et al.* 2009; Romaschenko *et al.* 2010; 2012; Soreng *et al.* 2010; Cialdella *et al.* 2014) are particularly noteworthy.

Some relevant recent taxonomic rearrangements at the generic level that include Brazilian taxa are cited below.

In Panicoideae, *Trichanthecium* (Zuloaga *et al.* 2011) *Paraodiophyllochloa* (Morrone *et al.* 2008), *Cyphonanthus* (Morrone *et al.* 2007), *Apochloa* (Sede *et al.* 2008), *Renvoizea* (Sede *et al.* 2008), *Stephostachys* (Zuloaga *et al.* 2010), *Osvaldoa* (Grande Allende 2014), *Morronea* (Scataglini & Zuloaga 2013), *Ocelochloa* (Sede *et al.* 2009b) and *Rugoloa* (Acosta *et al.* 2014) have been segregated from the polyphyletic *Panicum* and described as new genera. *Onorachis* (Sede *et al.* 2009a) and *Keratochlaena* (Morrone & Zuloaga 2009) were segregated from *Streptostachys*. *Thrasya* was merged within *Paspalum* (Denham 2005) and *Ophiochloa* was synonymized into *Axonopus* (López & Morrone 2012). *Cenchrus* was transferred to *Pennisetum* (Chemisquy *et al.* 2010), and *Rupichloa* was recircumscribed to accommodate two species previously classified in *Urochloa* (Salariato *et al.* 2009).

In Bambusoideae, *Cambajuva*, a monotypic genus, was established to accommodate a distinctive species of *Aulonemia* (Viana *et al.* 2013). *Olmeca fulgor* and *O. clarkiae* were also segregated from *Aulonemia* (Ruiz-Sanchez *et al.* 2011). *Dydymogonix* was described based on two Andean species previously placed within *Rhipidocladum* (Tyrrell *et al.* 2012); *Neurolepis* was synonymized in *Chusquea* (Fisher *et al.* 2009) and *Parianella* was segregated from *Pariana* (Ferreira *et al.*

2013). In addition, several new species from the Neotropics have been described in many genera in recent years.

Some regions in the Neotropics must be highlighted for the diversity and taxonomic importance they represent for Poaceae. The *Cerrado* (Central Brazilian savannas) holds an impressive diversity, especially of C4 species of Panicoideae and Chloridoideae; the Atlantic Forest, Guayana Shield and Andes are home to several endemic species; the Amazon Forest, although having not been satisfactorily inventoried, is also important for its diversity of habitats and species; and finally the *Pampas* is also highly diverse.

In the *Cerrado* ca. 700 species in 126 genera occur, which represents almost 50% of the total number cited to the country (Filgueiras *et al.* 2014). This amazing grass diversity can be associated with the variety of habitats which can be found in the *Cerrado*, such as riparian forests, grasslands, rocky outcrops, wetlands, among others, some of which are subjected to fire (Ribeiro & Walter 1998). The three richest genera belong to Panicoideae: *Paspalum* (153 spp.), *Axonopus* (41 spp.) and *Panicum* (34 spp.), followed by *Eragrostis* (33 spp.; Chloridoideae), *Digitaria* (27 spp.; Panicoideae) and *Aristida* (26 spp.; Aristidoideae) (Filgueiras *et al.* 2014). The *Campos Rupestres* of the Espinhaço Range supports at least 36 endemic species besides peculiar genera such as *Apochloa*, *Dichanthelium*, *Renvoizea* and the monotypic *Plagiantha tenella* (Viana & Filgueiras 2008). The quartzitic mountains of Chapada dos Veadeiros and the serpentine soils of Niquelândia region (state of Goiás) are also remarkable for their high levels of endemism. *Filgeuirasia* species, *Actinonocladum verticillatum* and *Aulonemia effusa* are a few bamboos adapted to fire.

The Atlantic Forest is one of the centers of diversity of bamboos in the world (Clark 1990; Judziewicz *et al.* 1999), with more than 160 native species, 135 of them endemic. It also houses a high diversity of Panicoideae (C3 taxa) adapted to shady habitats, such as *Ichnanthus*, *Parodiophyllochloa*, and *Ocelochloa*. In the high-altitude rocky outcrops some odd plants such as *Glaziophyton mirabile*; *Cambajuva ulei*, *Cortaderia modesta*, *Apochloa lutzii,* as well as several species of *Chusquea* sect. *Swallenochloa* and *Dicahnthelium* are found. The high-altitude forests associated with these mountains are also rich in endemic species of woody bamboo, mainly from *Mesrostachys*, *Chusquea* and *Aulonemia*, and some Panicoideae, such as *Paradiophyllochloa penicillata*, *Ocelochloa latissima*, and *Hymenachne condensata*. *Colanthelia* and *Apoclada*, endemic genera of bamboo, are also found in high-altitude forests. The central part of the Atlantic Forest (southern Bahia and Espírito Santo) is relevant to the diversity of grasses including the narrow-endemic and threatened basal grass *Anomochloa marantoidea* Brongn.; herbaceous bamboo, such as *Raddia*, *Piresia*, *Diandrolyra*, *Olyra*, *Parianella*, and *Eremitis*, and woody ones in *Alvimia, Atractantha,* and *Eremocaulon*.

Davidse *et al.* (2007) cited 526 species to the Guayana Shield and most of the endemic ones are related to the *Tepuis*, such as *Cortaderia roraimensis* and other species in *Arthrostylidium*, *Aulonemia, Dichanthelium, Chusquea, Myriocladus* and *Trichanthecium* (Judziewicz & Clark 1993; Judziewicz 1998; Davidse *et al.* 2007).

The Amazon Forest has not been satisfactorily inventoried but some typical components of the agrostological flora can be highlighted. The lowland forests are the main center of endemism of herbaceous bamboos in *Pariana* (ca. 30 spp.), besides *Guadua* (at least 10 spp.), *Olyra* (14 spp.), *Raddiella* (5 spp.) (Filgueiras *et al.* 2014) and the poorly known genera *Agnesia* and *Froesiochloa* (Judziewicz *et al.* 1999). Other species are typical from open, white-sand savanna vegetation, especially of the Neotropical genera *Axonopus* (Black 1963) and *Paspalum* (Filgueiras & Davidse 1995) and the monotypic *Arundoclaytonia dissimilis* and *Steyermakochloa angustifolia*, which seem to be endemic to this habitat (Davidse & Ellis 1984; Davidse & Ellis 1987). The scarce mountains in the region are also diverse and include several species endemic to the iron rocky outcrops (*canga* vegetation) in the Serra dos Carajás (Burman & Bastos 1988; Bastos 1990; Boechat & Longhi-Wagner 1995), the sandstone formation of Serra do Cachimbo (Davidse *et al.* 2001) and the granitic rocky outcrops of Serra do Tumucumaque in Brazil, French Guiana, Guyana and Suriname.

The Andes are highly diverse in woody bamboo genera including the endemic genera *Aulonemia*, *Arthrostylidium, Chusquea*, *Elytrostachys* and *Rhipidocladum*, which are often associated with high-altitude forests and the *Páramos* (especially *Chusquea* and *Aulonemia*) (Clark 1990; Judziewicz *et al.* 1999). According to these authors, 90% of the bamboo species in the Andes are endemic. Some groups of grasses which are especially rich in temperate regions and belong mainly to Poideae are also well represented in the region, such as *Poa*, *Festuca*, *Piptochaetium,* and *Cortaderia*.

Rapateaceae

The Rapateaceae is a medium-sized family with less than 100 taxa in 17 genera which is mainly distributed in the Neotropical region but for one disjunct and monospecific genus in West Africa (Liberia and Sierra Leone) - *Maschalocephalus* (Berry 2007; Monteiro 2014; Stevenson *et al.* 1998). The hotspot for the taxonomic diversity of the family is the lowlands and highlands of the Guayana Shield. This area holds almost 80 species and some monospecific and endemic genera, such as *Amphiphyllum*, *Marahuacaea*, *Phelpsiella*, *Potarophytum*, and *Windsoria* (Berry 2004, 2007; Stevenson *et al.* 1998). The family is recorded in the Neotropics from Brazil, Bolivia, Colombia, French Guiana, Guyana, Panama, Peru, Suriname and Venezuela (Berry 2007).

The most diverse genera are *Stegolepis* and *Rapatea* with ca. 33 and 20 species, respectively, followed by *Saxofridericia* with 7 accepted species (Stevenson *et al.* 1998). The family is well represented in the understory of the Amazon Forest, where it is found in seasonally and permanently flooded areas and also on sandy soil in open areas. Almost 40 species in 9 genera are cited to Brazil (Monteiro 2014), 25% of them in *Rapatea.* However, this number is probably underestimated because several species have been cited close to the Brazilian border but have not yet been collected in the country. Members of the family are also found in wet grasslands and bogs among rocky outcrops (*Campos Rupestres*) in the *Cerrado* vegetation but these areas are less diverse in number of species than the Amazon Forest.

Rapateaceae was previously placed in Commelinales with several other families that are now under Poales (Dahlgren *et al.* 1985). The family can be recognized by a combination of several embryological characters (Stevenson *et al.* 1998). It shares several anatomical, palynological and embryological features with Eriocaulaceae, Mayacaceae and Xyridaceae, and also with Commelinaceae which are nowadays placed in Commelinales. However, the most recent phylogenies based on molecular evidence have suggested a closer relationship with Bromeliaceae and Typhaceae (Chase *et al.* 2006; Givinish e*t al.* 2010; Stevens 2001 onwards), this result is still not very well supported with morphological synapomorphies. The connection between Rapateaceae and Bromeliaceae emerging from molecular analysis is a revival of Pilger´s (1930) interpretation of the group from almost 100 years ago. Givnish *et al.* (2010) suggest all three families (Bromeliaceae, Rapateaceae and Typhaceae) are part of an early divergent group in Poales.

The family was split by Maguire (1958, 1965) into two subfamilies (Saxofridericioideae and Rapateoideae) based on the number of ovules per carpel, placentation type, and morphology of seed, pollen and inflorescence (Stevenson *et al.* 1998). Givnish *et al.* (2000) pointed out that at least Rapateoideae is paraphyletic in their molecular studies. Later, a new classification for the family based on chloroplast analyses, showing three well supported subfamilies (Rapateoideae, Saxifridericioideae and Monotremoideae), was presented by Givnish *et al.* (2004).

Morphologically, Rapateaceae can be easily distinguished from other families in Poales by the inflorescence in a long scape often surrounded at the end by two large and basally broad bracts where the colored and actinomorphic (to slightly zygomorphic) flowers are inserted. The poricidal anthers (apical or subapical pores) and the trichomes which produce copious amount of a clear mucilage are also good characters to recognize the species of the family (Dahlgren *et al.* 1985; Stevenson *et al.* 1998, 2004).

Thurniaceae

The Thurniaceae is another small and traditionally monogeneric family in the Poales but it is poorly known morphologically (Kubitzki 1998). It has been placed in the cyperid clade as a sister-group of Cyperaceae-Juncaceae (Bouchenak-Khelladi *et al.* 2014). All three families share diffuse centromeres which is a unique character within the order (Dahlgren *et al.* 1985). Until very recently, Thurniaceae was considered endemic to the lowland forests of the Guayana Shield and found in eastern Colombia, southern Venezuela, northern Brazil, Guyana and Suriname (Kubitzki 1998; Stevenson 2004). However, *Prionium*, a genus formally placed in Juncaceae, seems to be better placed under Thurniaceae (Stevens 2001 onwards).

Plants are often big and clustered herbs with long and narrow-linear leaves which are strongly serrate along the margins. The inflorescence is glomerule-like at the end of a terminal branched or unbranched axis (scape) which holds hundreds of small, paleaceous flowers.

Only three species are known and all grow on sandy soil in habitats flooded by acidic ("black") waters such as streams and lakes in the Amazon Forest. The specimens have thick rhizomes and often form extensive monospecific stands at the edges of shallow lakes and streams. *Thurnia jenmanii* Hook. f. is a narrow endemic species found only in Suriname, *T. polycephala* Schnee occurs in Venezuela and Guyana while *T. sphaerocephala* (Rudge) Hook. f. is the most widespread species in the family (Alves 2014; Hokche *et al.* 2008; Riina & Berry 2005).

The lack of information on the family is partly a result of its infrequent occurrence and distribution usually in remote areas of the Amazon Forest. Anatomical and molecular studies with *T. sphaerocephala* are under development by different teams in Brazil; however, the results are still preliminary and have not yet been published.

The Typhaceae is a small family in Poales of exclusively marsh and aquatic plants in two genera and 16–30 spp. The systematic position of the family is very controversial: it has been placed among the commelinoid clade, in Pandanales or more recently in Poales, where together with Bromeliaceae, it makes up the "bromeliad" clade (Bouchenak-Khelladi *et al.* 2014; Dahlgren *et al.* 1985; Kubitzki 1998).

It is distributed worldwide, though mainly occurs in North America and Eurasia (Stevenson 2004). In the Neotropics, *Typha* is the only native genus with 3–5 species recognized and widely distributed in different ecosystems. In Brazil, *Sparganium* can be found under cultivation (Bove 2014).

The species are always associated with flooded areas and form stands in shallow, slow-moving water and roadside ditches (Bove 2014; Carvalho *et al.* 2014; Hammel, 2003; Raechal & Strong 2007; Stevenson 2004; Vargas 2007). The most common species in the Neotropics, *T. dominguensis* Pers., often forms extensive monospecific stands. Like the other species, it is a rapid colonizer of disturbed, polluted or newly formed wetlands.

Because of conspicuous morphological synapomorphies, it is not difficult to recognize a specimen as part of the genus but species delimitation has not yet been firmly established and there is frequent occurrence of interspecific hybridization (Kim & Choi 2011). The genus is easily recognized as tall herbs with long, erect and narrow leaves and the typical cylindrical-brownish inflorescence at the end of a long and unbranched axis or scape (Stevenson 2004).

Xyridaceae

The Xyridaceae comprises ca. 425 species organized into five genera (Campbell 2004, 2005; Kral 1998). The family is pantropical with some extensions into the north-temperate zone and four genera restricted to South America. *Xyris* is a truly pantropical taxon, also diversified in Africa and Australia, with some species reaching temperate areas (Kral 1998). In the Neotropics, the family is often associated with wetlands and habitats affected by periodic fires (Campbell 2004) and is highly diverse in the Guayana Shield (Kral 2005; Kral & Strong 2007).

In Brazil, Xyridaceae is represented by four genera and 186 species, of which 136 are endemic to the country. Almost 50% of them occur in the *Cerrado* and mainly in *Campos Rupestres* from Minas Gerais and Bahia. The preferential habitats are seasonal or permanently wet to moist grasslands, such as bogs and savannas and also humid rock outcrops at high elevations of central Brazil (Campbell 2004; Wanderley *et al.* 2014).

Xyridaceae usually emerges as a sister group of Eriocaulaceae, and also related to Mayacaceae in the xyrid clade (Givinish *et al.* 2010). However, its phylogenetic affinities have not been fully established and its monophyly has already been questioned (Davis *et al*. 2004). The most recent phylogenies support the family as a sister group of Eriocaulaceae (Bouchenak-Khelladi *et al.* 2014) or as sister of the clade formed by the restiids and graminids (Givnish *et al.* 2010). The lack of detailed phylogenies focusing on the Neotropical species will be addressed soon with ongoing researche (Motta 2014).

Plants usually have a capitate inflorescence at the end of a long and straight axis (or scape) and colorful, bisexual and zygomorphic flowers (Campbell 2004; Kral 1988, 1992, 1998; Mota 2014).

Xyris comprises ca. 400 species grouped into three sections. *Xyris* sect. *Xyris* is pantropical and has ca. 140 species with parietal placentation; *X.* sect. *Pomatoxyris* is the smallest section with 22 species restricted to Australia and has axillary placentation; *X.* sect. *Nematopus* is the most diverse with ca. 250 species mainly in South America and basal or central placentation (Kral 1998).

From the four genera endemic to South America, *Abolboda* is the most diverse with 23 species concentrated in the Guayana Shield. *Orectanthe* (2 spp.), *Achlyphila* and *Aratitiyopea* (1 sp. each) are also restricted to the same biogeographic area (Kral 2005; Kral & Strong 2007).

The taxonomy of Neotropical Xyridaceae is strongly based on the *Flora Brasiliensis* (Seubert 1855) and Malme (1913a, b) studies. A few revisionary efforts have been done since then but have been mainly related to the Australian and African species (Conn & Dust 1997; Dust & Conn 1994; Lock 1999). Advances in Neotropical Xyridaceae are therefore based on many local floras and new species descriptions (e.g. Kral 1992, 1998, 2005; Kral & Wanderley 1993, 1995; Motta & Wanderley 2013, 2014; Silva & Wanderley 2013; Wanderley 2010, 2011; Wanderley & Silva 2009).

Acknowledgments

Financial support from Capes (M.A.), CNPq (M.A., M.T., R.C.F.), FAPERJ (M.T., R.C.F.), INCT-Herbário Virtual (M.A., M.T.) and NSF (M.A.). Thanks to S. Heald for the English review.

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Artigo recebido em 26/01/2015. Aceito para publicação em 01/04/2015.