



## Revisiting *Mayacaceae* Kunth towards to future perspectives in the family

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### Abstract

Mayacaceae Kunth is an aquatic plant family that currently comprises a single genus, and four to six accepted species. Most of them are widely distributed in the Neotropics, with the exception of *Mayaca baumii* Gürke, which is endemic to Africa. This family still encompasses taxonomical problems involving mostly nomenclatural issues and the positioning of the family within the Poales, which remains not definite, though several efforts have been made in this direction. Besides all this, the family also suffers from limited studies with different approaches, such as embryological, palinological, phylogenetic and ecological ones. Considering all these problems, the present work makes an overview of Mayacaceae to show the main problems that still surround the family and to indicate some directions for future studies.

**Key words:** *Mayaca*, monocots, Poales, taxonomic history.

### Introduction

Mayacaceae is a family of monocots, encompassing herbs that inhabit swampy areas, lakes and rivers (Carvalho 2007; Souza & Lorenzi 2012). The family is distributed within the Neotropics, with species occurring from the south-western United States to Paraguay, with the exception of *Mayaca baumii* Gürke, which is found only in Africa (Dahlgren *et al.* 1985). Disregarding this later species, there is no consensus about the real number or even the names that should be considered as valid for the family.

Besides, differences among species have not always been clear, which have led to taxonomic misinterpretation and the proliferation of several new names (Carvalho 2007). As a result, 22 to 26 names can be found for Mayacaceae in global databases (IPNI 2014; MOBOT 2014), besides the name of the family itself (Horn Af Rantzien 1946; Lourteig 1952, 1968; Carvalho 2007).

Furthermore, there is no consensus regarding the position of the family among monocots. Recently, Mayacaceae is recognized as a distinct and unique family in Poales (APG III 2009) and

relationships among this family and its possible sister-groups remain unclear (Givnish *et al.* 1999; Chase *et al.* 2000; Stevenson *et al.* 2000; Michelangeli *et al.* 2003; Jansen & Bremer 2004; Linder & Rudall 2005; Givnish *et al.* 2010; Bouchenak-Khelladi *et al.* 2014).

In addition to its nomenclatural and phylogenetic issues, the time of origin and diversification of the family remain unclear (Carvalho 2007). Due to the disjoint pattern of distribution of this family, some authors believe that Mayacaceae might be part of the same branch that originated other groups in Poales (Venturelli & Bouman 1986; Linder & Rudall 2005; Carvalho *et al.* 2009). Some authors hypothesize that this family has its center of genetic diversity in the Brazilian Amazon (Dahlgren *et al.* 1985; Heywood 1993; Stevenson 1998; Wanderley & Giullieti 2002), but studies corroborating it are still lacking in the literature.

Considering this scenario, we present an overview of Mayacaceae with the main unsolved issues related to the family systematics and evolutionary history, providing new insights into future studies in this group.

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### Recalling a complex taxonomic history

The genus *Mayaca* was described by Aublet, in 1775, considering only *Mayaca fluviatilis* Aubl. as a species. The etymology of the name is often regarded as a tribute to the “Maiaca River” located in Northern Brazil (see Lourteig 1952; Pott & Pott 2000). However, this hypothesis seems to be controversial, since the type specimen was collected in the French Guiana in Sinemari River and furthermore, there is a river in the British Guiana called “Mahaica” that might have inspired Aublet in the genus designation.

Few years later after Aublet’s description, two other new genera were described and identified as close to *Mayaca*, *Biaslia* Vand. (Vandelli 1788) and *Syena* Schreb. (Schreber 1789). In spite of the descriptions, these authors did not designate types for the newly described genera, which were in charge of Gmelin (*Syena mayaca* Gmel. 1791) and Roemer (*Biaslia vandellii* Roem. 1796). In addition, Willdenow (1797) proposed the inclusion of *Mayaca* in *Syena* Schreb., as a new combination *Syena fluviatilis* (Aubl.) Willd.

Early in the nineteenth century, three other authors (Michaux 1803; Shultes 1822; Vellozo 1827) described and synonymized two new species and one genus to *Mayaca*, respectively: *Mayaca aubletii* Michx., *Syena nuttaliana* Schult., and *Coletia madida* Vell. Almost at the same time, Schott and Endlicher (1832) proposed new combinations to *Biaslia vandellii* Roem. and *Mayaca aubletii* Michx., respectively, *M. vandellii* Schott & Endl. and *Syena aubletii* (Michx.) Schott & Endl. and also described *M. michauxii* Schott & Endl. as a new species.

In 1841, Kunth established Mayacaceae as a monogeneric family (Kunth 1841; Lourteig 1952), based on *Mayaca fluviatilis* Aubl. At the same time, this author considered *Biaslia* Vand., *Coletia* Vell. and *Syena* Schreb. as synonyms of the typical genus (Kunth 1841). A couple of years later, Kunth proposed two additional new species for this family, *M. sellowiana* Kunth and *M. vandellii* Kunth, being the latter, a posterior homonymous of *M. vandellii* Schott & Endl. (Kunth 1843).

Even with the recognition of the family, some authors continued to include the taxa previously recognized in different families, such as Xyridaceae (e.g. Grisebach 1866 and Van Tieghem 1898) and Commelinaceae (Hutchinson 1934), creating some taxonomic instability (Lindley 1856; Bentham & Hooker 1883; Engler 1888; Van Tieghem 1898; Wettstein 1901).

In spite to the controversial position of the species of *Mayaca*, Seubert (1855) also recognized Mayacaceae as a family with six species, three of them described by this author as new to science (*Mayaca vandellii* Schott & Endl., *M. aubletii* Schott & Endl., *M. kunthii* Seub., *M. sellowiana* Kunth, *M. longipes* Mart. ex Seub. e *M. endlicheri* Pöpp ex Seub.). Almost ten years later, two other species were described by Grisebach (1866) and Warming (1867): *M. wrightii* Griseb. and *M. lagoensis* Warm. The first one was later considered as a variety of *M. fluviatilis* (*M. fluviatilis* var. *wrightii* (Griseb.) M. Gómez.) by Gómez (1893).

In the early 1900s, Gürke (1902) described a new species, *M. baumii* Gürke (1902), based on a collection from Angola from Baum Benguela, considering a possible disjunction for the genus. Chodat and Hassel (1903) found a different morphotype for *M. sellowiana*, which according to these authors could be differentiated by the larger stem and by the elongated pedicel that held the flower (Chodat & Hassel 1903). They described it as a form of *M. sellowiana* f. *longipedicellata* Chodat & Hassl. (1903).

Some years later, another species was described by Hoehne (1937) - *M. brasillii* Hoehne but later indicated as a “*nomen nudum*” by Lourteig (1952) for Mayacaceae. At the same time, Gandoger (1920) described two additional species under *Mayaca*: *M. caroliniana* Gand. and *M. longipes* Gand., but the latter is a homonym of *M. longipes* Mart. ex. Seub. (Lourteig 1952).

In the first taxonomic revision for Mayacaceae, Lourteig (1952) described the family comprising just five species - *M. baumii*, *M. fluviatilis*, *M. longipes*, *M. sellowiana*, and *M. fluviatilis* f. *kunthii* (Seub.) Lourt. According the author, they could be differentiated by the presence of a lobed appendix slot in the anthers. Some years later, Stellfeld (1967) proposed a new combination for *Coletia madida*: *Mayaca madida* (Vell.) Stellf. and he rejected *M. sellowiana*, claiming the priority for *Coletia madida* (Stellfeld 1967). However, this proposal was refuted by Lourteig (1968) and not accepted by the botanical community.

Recently, Venturelli and Bouman (1986) pointed out some embryological features as diagnostic for the family delimitation.

### Old problems remain

In the early twenty-first century, the research involving Mayacaceae focused basically on

regional and local floras, and among them, the most important ones were the Brazilian (Vandelli 1788; Seubert 1855), Venezuelan (Lourteig 1971), Cuban (Cruz 2001) and the north American floras (Faden 2007). Additionally, other regional works were also important in the family recognition, especially in Brazil (Vellozo 1827; Lourteig 1965; Wanderley 1981; Pedralli 1981; Jaszczerski 1987; Giulietti & Wanderley 1995; Pedralli 1995; Bove 2001; Wanderley & Giulietti 2002; Bove 2006) and the United States (Thieret 1975).

Besides them, different studies regarding morphology and anatomy (Uphof 1933; Tomlinson 1969; Stevenson 1998), embryology (Venturelli & Bouman 1986), physiology (Roberts & Haynes 1985) and ecology (Souza *et al.* 2001) were important to provide morphological support to Mayacaceae as a family.

However, studies on the taxonomy of this family are sparse, with just two revisions being published in the past 60 years. The first one was carried out by Lourteig (1952), which recognized four species for the family (*Mayaca baumii* Gürke, *M. fluviatilis* Aubl., *M. longipes* Mart. ex Seub. and *M. sellowiana* Kunth), besides the designation of several synonyms. Morphological and anatomic characters were not well explored by the author which provided subsidies for a later revision, where previous taxonomic and nomenclatural decisions were contested (Carvalho 2007) (see Table 1).

Anatomical characters of the anthers supported, for example, the reestablishment of a name (*Mayaca kunthii* Seub.) published in 1855 by Seubert (Carvalho 2007; Carvalho *et al.* 2009). Besides this later and *M. baumii*, tree other Neotropical species (*M. fluviatilis*, *M. longipes* and

*M. sellowiana*) were recognized for the family by Carvalho (2007), considering the type of anther dehiscence (slit or pore), the arrangement of the flowers (solitary or umbellate inflorescence) and the colouring of the petals (white or pink).

However, many taxonomic decisions could not be validated by Carvalho (2007) due to the lack of nomenclatural types and protologues available for some species.

The systematic position of Mayacaceae among the Poales remains unresolved and these problems seem to have arisen concurrently with the history of the family. As mentioned above, during a long time *Mayaca* was placed in Xyridaceae (Grisebach 1866; Van Tieghem 1989) or Commelinaceae (Hutchinson 1934). It took a long time before the placement of the family as a distinct group sustained by embryological characters related to the anthers, ovules, endosperm and seeds (Venturelli & Bouman 1986; Carvalho *et al.* 2009), corroborating Kunth (1843). Additional characters such as the axillary isolated flowers associated with a membranous bract; endosperm containing proteins and aeriferous channels in the stem provided morphological support for the family (Carvalho 2007; Souza & Lorenzi 2012; Stevens 2014).

Nowadays, the family is placed within 17 other families in the order Poales (APG III 2009) and supported by molecular (Givnish *et al.* 1999; Chase *et al.* 2000; Stevenson *et al.* 2000; Michelangeli *et al.* 2003; Jansen & Bremer 2004; Linder & Rudall 2005; Givnish *et al.* 2010; Bouchenak-Khelladi *et al.* 2014), and morphological studies (Dahlgren & Clifford 1982; Venturelli & Bouman 1986; Stevenson 1998;

**Table 1** – Comparison of *Mayaca* accepted names in recent publications.

Taxa	Lourteig (1952)	Cruz (2001)	Carvalho (2007)	The Plant list (2014)
<i>M. aubletii</i>	= <i>M. fluviatilis</i>	Accepted	= <i>M. fluviatilis</i>	= <i>M. fluviatilis</i>
<i>M. baumii</i>	Accepted	Accepted	Accepted	Accepted
<i>M. fluviatilis</i>	Accepted	Accepted	Accepted	Accepted
<i>M. kunthii</i>	≡ <i>M. fluviatilis</i> f. <i>kunthii</i>	Not reported	Accepted	Accepted
<i>M. longipes</i>	Accepted	Accepted	Accepted	Accepted
<i>M. madida</i>	= <i>M. sellowiana</i>	Accepted	= <i>M. sellowiana</i>	Accepted
<i>M. sellowiana</i>	Accepted	Accepted	Accepted	= <i>M. madida</i>
<i>M. wrigthii</i>	= <i>M. fluviatilis</i>	= <i>M. fluviatilis</i>	= <i>M. fluviatilis</i>	Accepted

Furness & Rudall 1998; 1999; Rudall & Sajo 1999; Carvalho 2009; Oriani & Scatena 2012, 2014).

However, there is no consensus about which of them is sister-group to Mayacaceae (Givnish *et al.* 1999; Chase *et al.* 2000; Stevenson *et al.* 2000; Michelangeli *et al.* 2003; Jansen & Bremer 2004; Linder & Rudall 2005; Givnish *et al.* 2010; Bouchenak-Khelladi *et al.* 2014). According to some authors, this may be due to the nature of the molecular analysis performed (Givnish *et al.* 1999; Chase *et al.* 2000; Stevenson *et al.* 2000; Michelangeli *et al.* 2003; Jansen & Bremer 2004; Linder & Rudall 2005; Givnish *et al.* 2010; Bouchenak-Khelladi *et al.* 2014).

Another explanation given by Bremer (2002) is that disregarding the taxa included in the analysis, Mayacaceae tends to be associated to Xyridaceae and Eriocaulaceae. The idea of Mayacaceae be part of the xyrid clade has been sustained by different authors along the years (Linder & Rudall 2005; Saarela *et al.* 2007; Givnish *et al.* 2010; Stevens 2014). Jansen & Bremer (2004) for example indicated that Mayacaceae is placed in the same clade along with Eriocaulaceae and Xyridaceae, and as sister group of Hydatelaceae and Cyperaceae. Despite the exclusion of Hydatelaceae from the Monocots (Saarela *et al.* 2007), this analysis could be influenced, according to these authors, by the phenomenon of the long branch attraction (Jansen & Bremer 2004), which indicates that the molecular analysis could be affected by other factors depending on the sampling used.

In another study, a different scenario was found for Mayacaceae, which was primarily included in the Cyperid clade and related to Cyperaceae, Juncaceae, Mayacaceae, Rapataceae and Thurniaceae (Bouchenak-Khelladi *et al.* 2014). However, these relationships were weakly-supported, indicating that further studies should be performed.

Morphological studies have also been extensively used to subsidize within Mayacaceae and its sister-groups (Dahlgren & Clifford 1982; Venturelli & Bouman 1986; Stevenson 1998; Furness & Rudall 1998; 1999; Rudall & Sajo 1999; Carvalho 2009; Oriani & Scatena 2012, 2014). This kind of approach was also used to support phylogenetic relationships, but unfortunately, depending on the character selected different topologies were recovered, with no consensus. Characters linked to the stamens, ovules, endosperm, and to the seeds have been

suggested (Dahlgren & Clifford 1982; Venturelli & Bouman 1986; Stevenson 1998; Rudall & Sajo 1999; Carvalho *et al.* 2009; Oriani & Scatena 2014) as some connection between Mayacaceae and Eriocaulaceae and Xyridaceae.

Meanwhile other characters, such as the development of the anthers wall and the reduction of fertile stamens in the inner whorl, would respectively withdraw Mayacaceae from these families (Furness & Rudall 1998; 1999) and place it along Juncaceae and Cyperaceae (Oriani & Scatena 2012).

This examples show that both molecular and morphological evidence might be used to indicate new perspectives for Mayacaceae. Nevertheless, the amount of information is still insufficient to solve many problems that involve the family, and therefore new directions should be taken in order to improve its knowledge.

#### Future perspectives

According to that, we can make some basic assumptions: despite the last advances made in Mayacaceae, little is known about this shadowy family. The morphology has been provided with important subsides to differentiate internal and interfamilial relationships among the family. In addition, different studies have tried to trace its evolutionary history. Here we present some perspectives to guide future studies in Mayacaceae:

1. *Classical Taxonomy*: As a prior study, we consider imperative the compilation of all the data available for the family in a substantial revision work, in order to conclude the studies initiated by Carvalho (2007) and solve the remaining nomenclatural and taxonomic problems. The type of the African species *M. baumii*, the most rare and peculiar species of the family was recently found, examined and identified.

2. *Embriology and palinology*: Despite all the studies published, a special attention should be paid to the developmental of the floral organs, due to their importance in the taxonomy and role in the evolution of the group. To complement that, new studies should involve the analysis of pollen grains in Mayacaceae and possible related families based on its use for low and higher groups, especially in Monocot (Metcalf 1952).

3. *Molecular phylogeny*: Additionally to the studies cited above, we consider that a phylogenetic study with a larger sampling of Mayacaceae and its allies, including morphotypes along its



geographic distribution will be crucial. Improving sampling could provide a better resolution for the group and also elucidate some biogeographical questions involving the family. Nevertheless, phylogeographic studies are also welcome in order to give subsidies for the understanding of species complexes, considering that their wide distribution throughout the Neotropics and the relict in Africa (*M. baumii*) could be related to peculiar events of dispersal and vicariance around the globe.

4. *Ecology*: Finally, ecological studies involving pollination, dispersion and germination are fundamental to understand the evolutionary history of the family. Because of its aquatic habit, its species might have particular ways to promote or avoid cross and self-pollination, to disperse the seeds through the water and germinate its seeds in optimal climate. Its could elucidate patterns of distribution in the family and to give subsidies to understand which evolutionary paths this group might have taken.

### Acknowledgments

The authors thank Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the post doc fellowship grant to MLSC, Fundação de Amparo à Pesquisa do Estado da Bahia (FAPESB) for the Phd fellowship grant to AFPM, and to Marcos C. Dórea for the assistance with type images from Kew Herbarium, as part of the Re flora Project.

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