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A new classification for *Lipocarpha* and *Volkiella* as infrageneric taxa of *Cyperus s.l.* (Cypereae, Cyperoideae, Cyperaceae): insights from species tree reconstruction supplemented with morphological and floral developmental data

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Abstract

Recent molecular phylogenetic analyses showed that *Lipocarpha* and *Volkiella* are nested in a paraphyletic *Cyperus s.s.* and therefore should be viewed as part of a broadly circumscribed genus *Cyperus* (Cyperaceae). In this paper, molecular phylogenetic analyses of *Lipocarpha* and *Volkiella* based on nuclear ribosomal ETS1f and plastid *rpl32-trnL* and *trnH-psbA* markers are presented. Separate gene trees as well as a species tree were constructed. Results indicate a polyphyletic *Lipocarpha s.l.* consisting of a paraphyletic core *Lipocarpha s.s* in which the monotypic *Volkiella* is included, and a small non-related clade with species formerly placed in the genus *Rikliella*. Core *Lipocarpha s.s.* encompasses six clades, which can be distinguished based on morphological characters. Floral developmental data for *Lipocarpha rehmannii* (the type of *Rikliella*) confirms that this species is not a true *Lipocarpha s.s*. Based on our findings, *Lipocarpha s.l.* and *Volkiella* are here included in *Cyperus* subg. *Cyperus*. New names and combinations for *Lipocarpha s.l.* and *Volkiella* species and a new sectional classification for these species are proposed.

Introduction

Lipocarpha (Brown 1818: 459) (35 spp., Govaerts *et al.* 2014) and the monotypic *Volkiella* (Merxmüller & Czech 1953: 318) (1 sp., Govaerts *et al.* 2014) are two highly specialised taxa from tribe Cypereae. Cypereae sensu Goetghebeur (1998) forms a monophyletic group based on recent molecular phylogenetic studies of Cyperaceae (Simpson *et al*. 2003, 2007, Muasya *et al.* 2009a), and is characterised by the *Cyperus*-type embryo or the similar *Ficinia*-type embryo (Van der Veken 1965, Goetghebeur 1986, 1998, Muasya *et al.* 2009a, b). Usually, the inflorescence is an anthela of spikelets, but also highly condensed forms of the anthela are common. In some taxa, such as *Lipocarpha* and *Ascolepis* (Steudel 1855: 105, Vrijdaghs *et al.* 2010), the anthela is reduced to a head of spikelets. In Cypereae, flowers are usually bisexual and trimerous and subtended by a papery glume. However, reduction of the number of stamens often occurs, as well as dimerisation of the gynoecium (Reynders & Vrijdaghs *et al.* 2012). These glumes may be arranged spirally or distichously, while in some species the number of the glumes in the spikelet is reduced to one, as is the case in *Lipocarpha*, or few.

Cypereae consists of two clades, the *Ficinia* clade and the *Cyperus* clade (Simpson *et al.* 2007, Muasya *et al.* 2009a, b). Recent molecular phylogenetic studies (e.g. Muasya *et al.* 2002, 2009b, Larridon *et al.* 2011a, 2013) showed that *Cyperus* (Linnaeus 1753: 44) *s.s.* (Table 1 in this paper, Goetghebeur 1998, Govaerts *et al.* 2007) is not monophyletic. The *Cyperus* clade (Table 1) consists of a C_3 *Cyperus* grade in which the monophyletic C_4 *Cyperus* clade is nested (Fig. 1A). C_3 *Cyperus* includes three segregate genera, i.e. *Courtoisina* (Soják 1980: 193), *Kyllingiella* (Haines & Lye 1978: 176) and *Oxycaryum* (Palla 1908: 169), which were recently included in *Cyperus*

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