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Ledermanniella yiben sp. nov. (Podostemaceae), Critically Endangered at the proposed Yiben Reservoir, Sierra Leone

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Summary. *Ledermanniella yiben* Cheek is described from the Seli (Rokel) river bed at a single rapid to be flooded by the proposed Yiben hydroelectric dam and reservoir in Sierra Leone. It is assessed as Critically Endangered using the IUCN categories and criteria. The species appears to be unique among African Podostemaceae in bearing dimorphic shoots having either cupuliform or short ribbon-like leaves.

Key Words. Dimorphy, extinction, homology, hydroelectric reservoir, point-endemic.

Introduction

In the course of a botanical baseline survey for the proposed Yiben Hydroelectric Dam on the Seli River, upriver of the Bumbuna Dam, Sierra Leone, in April 2016, the second and third authors encountered a species of Podostemaceae, *van der Burgt* 1992. The plants were scattered densely along the gneissic rock bed of the river, then at its seasonal lowest level, largely dry, and with only a small channel of moving water, it being the end of the dry season. The plants were 20 – 50 cm diameter, spaced at distances of up to 50 cm apart from each other, with bare gneissic base rock in between, and appear restricted to the vicinity of a single set of rapids.

The 8-ribbed, non-compressed, unilocular, terete ovaries and fruits, each with two stigmas, the flowers inverted within the spathellum and the absence of flattened scale-leaves, indicate that this plant is placed within the genus *Ledermanniella* Engl. in the sense of Schenk *et al.* (2015), or, *Ledermanniella* subgenus *Ledermanniella* in the sense of Cusset (1984). Identification work at K failed to match *van der Burgt* 1992 with any known species of the genus (see Results, below). Consequently in this paper it is formally named as *Ledermanniella yiben* Cheek.

Podostemaceae are a pantropical family of annual or perennial herbs. All species of the family are restricted to rocks in rapids and waterfalls of clear-water rivers, and are therefore rheophytes. However this very habitat is being increasingly exploited for hydropower at some risk to the survival of the Podostemaceae they contain (Schenk *et al.* 2015; Cheek *et al.* 2015; Cheek & Ameka 2016). Most of the African species of Podostemaceae are narrow endemics, many being known from only a single waterfall. New discoveries of species are still being made frequently (Schenk *et al.* 2015; Cheek & Haba 2016; Cheek *et al.* 2015; Cheek & Ameka 2008, 2016; Kita *et al.* 2008; Beentje 2005; Schenk & Thomas 2004; Cheek 2003, Rial 2002). Important characters in defining genera in Podostemaceae are the position of the flower in the unruptured spathellum, and the shape, and sculpture of the ovary. At species level, important characters are the shape and relative proportions of spathellae, stigmas, anthers, filaments, gynophores, pedicels, and leaves.

The current generic classification of African Podostemaceae is based on the framework established by Cusset (1973, 1974, 1978, 1983, 1984, 1987). This work has been compiled and updated by Rutishauser (2004). Recently, combined morphological and molecular phylogenetic studies of African Podostemaceae have shown that *Ledermanniella* (as delimited by Cusset) is paraphyletic, including all other sampled genera of Podostemaceae recognised in Africa. This was revealed by Thiv *et al.* (2009), employing plastid markers *mat*K, *trn*D-*trn*T, *rpo*B-*trn*C in sampling 9 genera and 17 species of African Podostemaceae, and Schenk *et al.* (2015), employing plastid markers *mat*K, *trn*L, *rpo*B-*trn*C, *ndh*F, *rbc*L and *mat*R in sampling 10 genera and 27 species of African Podostemaceae.

In recent years the accumulated molecular phylogenetic data (Thiv *et al.* 2009; Schenck *et al.* 2015) has shown that *Ledermanniella* subg. *Phyllosma* C. Cusset

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(1984) merits elevation to genus level as the resurrected genus *Inversodicraea* Engl. The transfer of names to effect this was recently completed (Cheek & Haba 2016). The generic status of the remaining African taxa is not clear, since most of the recognised African genera are embedded within the remainder of *Ledermanniella* (formerly *Ledermanniella* subg. *Ledermanniella*). Additional molecular sampling and analysis of taxa is needed to resolve relationships further.

A most remarkable feature of *van der Burgt* 1992 is that the shoots arising from the massive, long, branched main stems are dimorphic in their leaves and phyllotaxy. The two shoot types are:

1. Vegetative shoots of distichous phyllotaxy with narrowly ribbon-like and slightly channelled leaves.
2. Fertile shoots terminating in a spathellum subtended by opposite and decussate, very inconspicuous, cupuliform leaves.

These features are treated at length in the Discussion section.

Methodology

Abundant herbarium material, with photographs, was collected as *van der Burgt* 1992. Duplicates were deposited in Sierra Leone at FBC and SL and once authorisations had been obtained, the specimens were exported to K for identification by specialists, with other specimens resulting from the baseline botanical survey of the proposed Yiben dam area. Here it was examined with a Leica Wild M8 dissecting binocular microscope fitted with an eyepiece graticule measuring in units of 0.025 mm at maximum magnification. The drawing was made with the same equipment with a Leica 308700 camera lucida attachment.

The key used to attempt identification of the specimen was that of Cusset (1984). The specimen was compared with authoritatively named reference material at K, or illustrations and descriptions, of every known species of *Ledermanniella*. The format of the description follows Cusset (1984). All specimens cited have been seen. The conservation assessment follows the IUCN (2012) standard. Herbarium codes follow Index Herbariorum (continuously updated). Plant names and authorities follow IPNI (continuously updated).

Results

The first couplet of the key to the species of *Ledermanniella* subg. *Ledermanniella* of Cusset (1984) is "Leaves with sheath very enlarged, cupuliform, membranous" (lead 1), vs "leaves with sheath non cupuliform" (lead 2). *Ledermanniella yiben* is unusual, possibly unique, in having both types of structure on the same plant.

If the first lead of couplet 1 is taken, we are led to the second couplet, the first lead of which fits our material: "blade reduced to a small mucron on the back of the sheath; flowers sessile on the thallus" leading to *Ledermanniella aloides* (Engl.) C. Cusset. However, *van der Burgt* 1992 (*L. yiben*) differs from this species in that it appears to lack an extensive thallus, but possesses instead massive lengthy aerial stems (Fig. 1), which do not occur in *L. aloides*. It also differs in that the cupuliform leaves lack stipules and that the mucro (reduced blade) is rarely seen, while in *L. aloides* stipules are present and the blade, while reduced, is conspicuous in over 90% of the leaves. The new species also differs in having one stamen (vs two in *L. aloides*) and in having short, sterile shoots with ribbon-like leaves (absent in *L. aloides*).

If the second lead of couplet 1 is followed ("leaves with sheath non cupuliform") and we set aside the cupuliform leaves seen in our material, *Ledermanniella yiben* keys out to couplet 14, by virtue of the bases of its ribbon-like leaves being non-cupuliform, the leaf apices being entire, the leaves arising along the length of a well-developed stem, leaves less than 2 cm long, and stamens one, closely matching the lead to *L. jaegeri* C. Cusset of Mt Loma (Sierra Leone): "Leaves filiform, base not enlarged, 3 – 5 mm long, stamen shorter than the ovary, pollen in dyads". Despite the fact that in *van der Burgt* 1992 (*L. yiben*) the stamen is longer than the ovary, *L. jaegeri* seems to be the species which most closely matches it. However, the differences, set out in Table 1 below, are so numerous that there is no doubt that they are different species. Accordingly, the species represented by *van der Burgt* 1992 is formally described and named below as *Ledermanniella yiben*.

Ledermanniella yiben *Cheek* **sp. nov.** Type: Sierra Leone, Koinadugu Distr., proposed Yiben Reservoir area, large rapids in Seli R., N of Yara village, 9°16' 9.0"N; 11°34'50.6"W, 300 m a.s.l., fl., fr., 6 April 2016, *van der Burgt* 1992 (holotype K; isotypes BM, BR, FBC, G, MO, P, SL, WAG, Z).

http://www.ipni.org/urn:lsid:ipni.org:names:77161646-1

Rheophytic, probably perennial *herb*; forming mounds 20 – 50 cm diam., composed of numerous sprawling or suberect stems radiating from a central holdfast (thallus) when exposed in dry season by low water. *Stems* 10 – 30 cm long, fleshy-rubbery, brown outside, green inside, drying black, irregularly cylindrical 0.5 – 1 cm diam., each with one or two main branches which in the distal parts branch repeatedly; rarely with naked filiform extension shoots 3 – 7 cm long, c. 2 – 3 mm diam. Shoots and leaves dimorphic, thickly covering upper parts of the stem surface. *Vegetative*

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Fig. 1. *Ledermanniella yiben* at its only known locality in the Seli (Rokel) river within the proposed Yiben reservoir, 6 April 2016. **A, B** dried plants on flat bedrock in the river bed; **C** several individual plants; **D** part of a half-submerged plant in flower and fruit. PHOTOS: XANDER VAN DER BURGT.

shoots infrequent, erect (Fig. 2A & B), most numerous towards the apex of the main stems, 5 – 10 (– 30) mm long, (3 –) 5 (– 7) leaves per shoot, each leaf sheathing that above, arranged distichously, 3 – 7 mm long, erect, narrowly ribbon-shaped and shallowly canaliculated (channelled), tapering towards the acute apex, base sheathing, but lacking stipule lobes, elongated and not cupular. *Fertile shoots* sessile, erect, sometimes intermixed with sterile shoots, but usually in dense crustose masses completely covering large sections of the stem up to 10 or 15 cm long; each with a single terminal spathellum subtended by 2 – 3 pairs of inconspicuous approximately opposite and decussate cupuliform (shallowly concave), suborbicular leaves 1 mm long, best observed in the developing shoots (Fig. 2G). *Spathellum* (with inverted flower bud)

Table 1. Diagnostic characters separating *Ledermanniella jaegeri* and *L. yiben*.

Character	*Ledermanniella jaegeri*	*Ledermanniella yiben*
Stamen length	Shorter than ovary	Longer than ovary
Cupuliform leaves	Absent	Subtending spathellum
Elongate leaves: insertion	Spirally inserted on short shoots which terminate in a spathellum	Distichous on short shoots which are sterile: spathellae absent
Elongate leaves: shape	Terete (filiform)	Dorsiventrally flattened (ribbon-like) and slightly channelled.
Styles	Filiform, 0.2 – 0.3 mm long, not united at base	Ellipsoid, 0.3 – 0.4 mm long, united at base
Spathellum shape	Subobovoid	Ellipsoid-cylindrical
Pollen	Dyads	Monads

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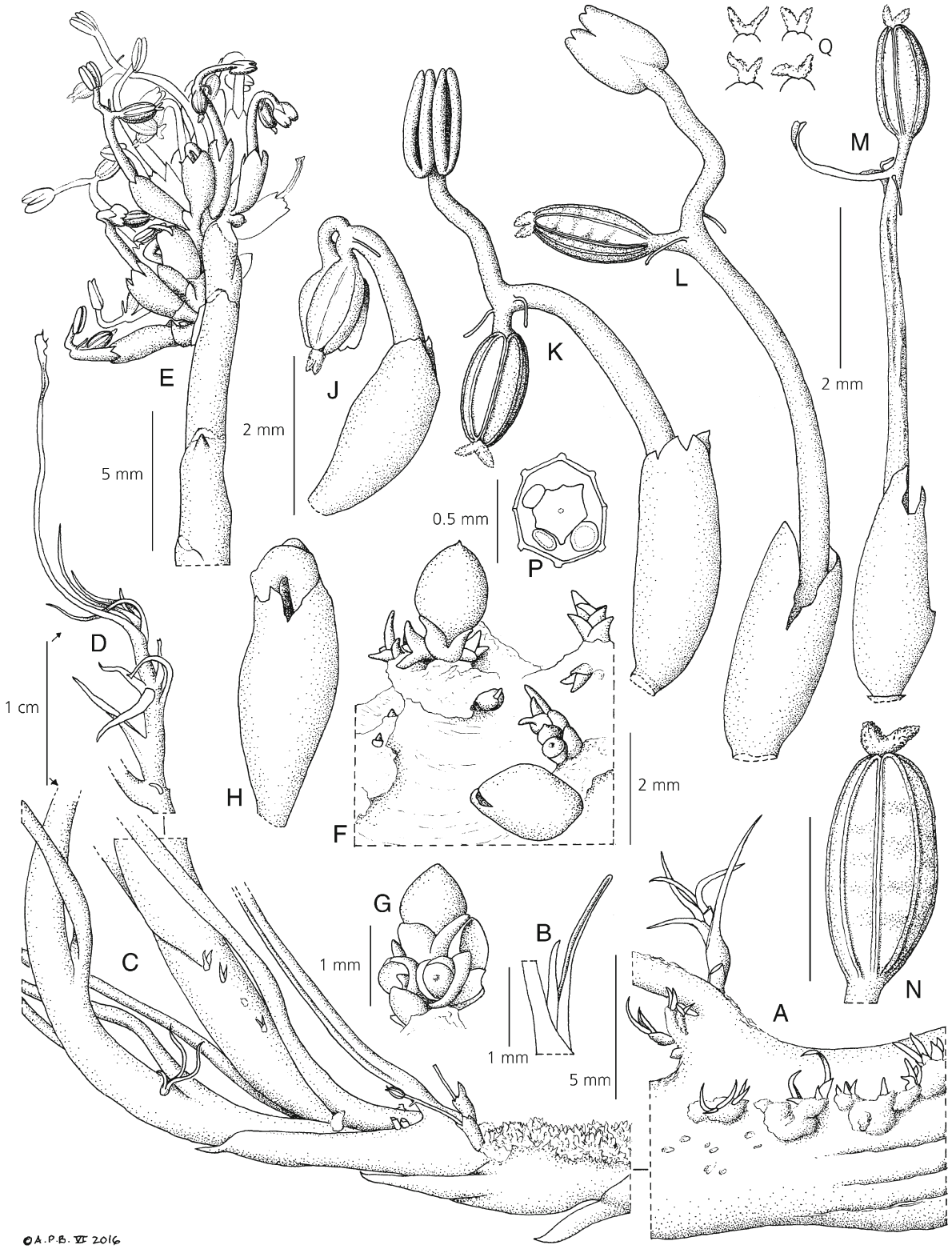

Fig. 2. *Ledermanniella yiben*. **A** habit, mid region of main axis of plant showing lateral vegetative short shoots; **B** detail of vegetative short shoot, showing distichous, slightly channelled leaves; **C** main axis, distal region, showing dense mass of fertile shoots (right) and numerous branches (left); **D** apex of main axis showing branches and vegetative short shoot; **E** stem branch with mass of fertile shoots terminating in flowers at anthesis; **F** detail from C showing multiple fertile shoots; **G** cluster of immature fertile shoots; **H** – **M** spathellum with flowers showing stages from spathellum rupture to post-anthesis; **N** detail of gynoecium; **P** transverse section of ovary; **Q** variation in stigma size, shape and orientation. All from *van der Burgt* 1992. DRAWN BY ANDREW BROWN.

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elliptic-cylindrical 1.4 – 2.4 (– 3.2) × 0.7 – 1.2 mm, apex rounded, very rarely with a mucro, base contracted, rarely with a short stipe, opening at the apex by three more or less equal triangular lobes or sometimes irregularly, each c. 0.4 × 0.4 mm; pedicel erect, angular-terete, white, 6.0 – 6.8 mm long, 0.2 – 0.3 mm diam. Tepals two, patent, cylindric, 0.3 – 0.5 × 0.02 mm long, inserted opposite filament at base of gynophore. Androecium exceeding ovary, with a single stamen, filament 1.8 – 2.5 mm long, about as long as ovary; anther 4-celled, drying black, suboblong, c. 1 × 0.6 mm. Pollen white, in monads. Gynophore 0.2 – 0.3 mm long. Ovary light green-brown, elliptic-oblong, 1.4 – 1.6 × 0.8 mm, not laterally compressed, apex and base rounded, side with 6 main longitudinal ribs, commissural ribs 2, each paired and reduced, not as prominent as the main ribs and with a central longitudinal groove. Stigmas 2, diverging by c. 90 degrees, united at the base, elliptic, 0.3 – 0.4 × 0.1 mm, (Fig. 2E, J – N) widest towards base, tapering gradually to the acute apex, surface densely covered in minute acute papillate projections. *Fruit* dehiscing by a single valve. *Seeds* ellipsoid, pale brown, c. 0.6 × 0.4 mm. Figs 1, 2.

RECOGNITION. Similar to *Ledermanniella jaegeri*, differing in that cupuliform, approximately opposite and decussate leaves subtend the spathellae (not filiform spirally inserted leaves) and in the presence of sterile shoots with distichously arranged, tapering, ribbon-like leaves (absent in *L. jaegeri*), also in the stamen being longer than the ovary and monad pollen (not shorter than ovary and dyads).

DISTRIBUTION. Sierra Leone. Only known from the river bed of the Seli River in Koinadugu District, where it occurs in the proposed Yiben Reservoir area, to be permanently submerged when the construction of the proposed hydroelectric reservoir is implemented.

SPECIMEN EXAMINED. SIERRA LEONE. Koinadugu Distr., proposed Yiben Reservoir area, large rapids in Seli R., N of Yara village, 9°16'29.0"N; 11°34'50.6"W, 300 m a.s.l., fl., fr., 6 April 2016, *van der Burgt* 1992 (holotype K; isotypes BM, BR, FBC, G, MO, P, SL, WAG, Z).

HABITAT & ECOLOGY. Growing in a colony on bare, gneissic rocks forming the base of a river bed at a single set of rapids, submerged for most of the year, exposed and flowering only at end of dry season. Growing with no other vascular plant species.

CONSERVATION STATUS. *Ledermanniella yiben* is here assessed as Critically Endangered, using the Categories and Criteria of IUCN (2012), since a single global location is known on current evidence, containing, so far as is known, the entire world population of the species, which will be destroyed by permanent submergence under the waters of the reservoir of the proposed Yiben Hydroelectric Project if construction is realised. The area occupied by the species on the ground has been estimated by the second author as 0.25 Hectare (c. 50 m × 50 m). The area of occupancy (AOO) can be calculated using the preferred IUCN cell size for riverine species of 1 km^2. The second and third authors have spent weeks surveying plants in the Yiben area but only found this species in an area of the Seli (Rokel) river bed about 50 m wide, and about as long, corresponding to a single rapid on the river. *L. yiben* was absent at rapids up and down the river from this location. The authors have also searched other fast flowing river systems in Sierra Leone for rheophytic species over the last seven years, yet have never before encountered this species. Many species of Podostemaceae in Africa are only known from a single waterfall or set of rapids (Cheek & Haba 2016; Cheek *et al.* 2015; Cheek & Ameka 2016; Cusset 1983, 1984).

It is hoped that searching further upriver (which has not been exhaustive) from the type and only known locality of *Ledermanniella yiben* might discover additional locations for the species but this is by no means a certainty. Such searches are now underway (March 2017) and attempts will be made at the same time to establish the species at other, secure sites in order to avoid its extinction. Establishing the species at another location will be a challenge. Translocation of species of Podostemaceae in Africa is not yet known to have been achieved successfully, yet it is not known that it has ever been attempted before.

ETYMOLOGY. *Ledermanniella yiben* is named for the proposed Yiben hydroelectric dam in Sierra Leone; the construction of which is likely to result in the extinction of the new species.

Discussion

The homology of cupuliform leaves in African Podostemaceae

In the first couplet of her key to the species of *Ledermanniella* subg. *Ledermanniella*, Cusset (1984) divides those species with "Leaves with sheath very enlarged, cupuliform, membranous" (that is, *L. aloides* (Engl.) C. Cusset, *L. thalloidea* (Engl.) C. Cusset and *L. batangensis* (Engl.) C. Cusset) from those without, including those with leaf sheaths which are oblong, such as *L. sanagensis* C. Cusset. In fact, intermediates occur, such as the elliptic leaf sheaths of *L. lunda* Cheek. *L. aloides* itself often has laterally compressed leaf sheaths which are then not truly cupuliform. In *L. thalloidea* and *L. batangensis* the leaf-sheath origin of the cupuliform structure is especially clear since a filiform leaf-blade arises peltately from near the apex of the dorsal surface of the cupuliform structure. The presence of a pair of short triangular stipules on each side of the apex of the cupuliform structure in *L. batangensis* (Cusset 1987) further confirms the homology, since these stipules are typical of those that appear sporadically on the margins of leaf sheaths in

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other African Podostemaceae, such as in *Saxicolella marginalis* (G. Taylor) Cheek.

The cupuliform structures of *Ledermanniella yiben* lack filiform blades, but occasionally a small peltate protuberance can be found on their dorsal surface which may indicate a vestigial leaf-blade. This same condition occurs in *Macropodiella pellucida* (Engl.) C. Cusset, in which the cupuliform structures (leaf-bases), as in *L. yiben*, also occur in short shoots and which also subtend a terminal spathellum.

It is difficult not to conclude that these last two species have a sister relationship despite their current placement in different genera. This generic placement is based on a single floral character, the presence of laterally flattened ovary or not, which further research may show to be labile. Vegetative and architectural characters may be as important or sometimes a better indicator of evolutionary relationships of species than floral characters hitherto exclusively used in defining the genera of African Podostemaceae (Cusset 1973, 1974, 1978, 1983, 1984, 1987). Genera such as *Macropodiella* may be artificial as currently defined (Cheek & Ameka 2016) as is *Ledermanniella* (Thiv. *et al.* 2009).

We have seen that cupuliform leaves of leaf sheath origin occur in African Podostemaceae and that they may be a modification of the widespread leaf type that occurs in the group, in which the leaf is long and slender, ribbon-like or terete, with a dilated, sheathing base attaching it to the stem. That these cupuliform leaves always occur on short shoots and subtend spathellae suggests that their function is to protect the developing spathellum rather than to photosynthesise. Essentially, they function as bracts.

Dyad and monad lineages of *Ledermanniella*

Thiv *et al.* (2009) and Koi *et al.* (2012) showed that *Ledermanniella* is divided into *Ledermanniella*-Monad and *Ledermanniella*-Dyad lineages based on molecular phylogenetic evidence. *L. yiben* has monad pollen. Attempts to find morphological synapomorphies that support the monad lineage have not yet been successful.

Recent botanical novelties in Sierra Leone

Ledermanniella yiben is among a host of new species that have been brought to light and published from Sierra Leone in recent years, following decades of relative inactivity in plant species discovery in that country and its neighbours. This has mostly been driven by increased industrial activity and associated Environmental Impact Assessment work, but also greater ease of accessibility following reduced conflict. Examples of such newly discovered species in Sierra Leone are: *Dactyladenia globosa* Jongkind (2012), *Pseudovigna sulaensis* R. Clark & Burgt (Clark *et al.* 2012), *Xysmalobium samouritourei* Goyder (2009), *Stylochaeton pilosus* Bogner (2011), *Isoglossa dispersa* I. Darbysh. & L. J. Pearce (Darbyshire *et al.* 2011), *Gilbertiodendron tonkolili* Burgt & Estrella (Estrella *et al.* 2012), *Eriocaulon cryptocephalum* S. M. Phillips & Mesterházy and *E. tingilomum* S. M. Phillips & Mesterházy (2015), *E. sulanum* S. M. Phillips & Burgt and *E. petraeum* S. M. Phillips & Burgt (Phillips *et al.* 2012), *Napoleonaea alata* Jongkind (Prance & Jongkind 2015) and *Psychotria samoritourei* Cheek (Cheek & Williams 2016). Just over the border in Ivory Coast examples include *Macropodiella cussetiana* Cheek (Cheek & Ameka 2016), and in Guinea *Striga magnibracteata* Eb. Fisch. & I. Darbysh. (Fischer *et al.* 2011) and *Gymnosiphon samoritoureanus* Cheek (Cheek & van der Burgt 2010). Even a new rheophytic genus, *Karima* Cheek & Riina has recently been discovered in Sierra Leone (Cheek *et al.* 2016).

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