Materials for a Taxonomic Revision of *Geostachys* (Baker) Ridl. (Zingiberaceae) in Peninsular Malaysia

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Abstract

Materials for a taxonomic revision of the *Geostachys* (Baker) Ridl. in Peninsular Malaysia, resulting from recent fieldwork are presented, with notes on the threat assessment of extant species. Twelve of the 13 previously known species were studied in situ, and two newly described species have also been found (*Geostachys belumensis* C.K. Lim & K.H. Lau and *G. erectifrons* K.H. Lau, C.K. Lim & K. Mat-Salleh), bringing the current total to 15 taxa, all highland species, found in hill, sub-montane and upper montane forests ranging from 600 m to 2000 m a.s.l. Thirteen out of 15 of the known species are believed to be hyper-endemic, found so far only in their respective type localities.

Introduction

Geostachys (Baker) Ridl. is a relatively small genus within the Zingiberaceae family, with only 21 species previously recorded. Its distribution ranges from Vietnam, Thailand, Sumatera, Peninsular Malaysia and Borneo. Peninsular Malaysia is the home for most of the species, with 15 taxa scattered in the rain forest of this country (Holttum, 1950; Stone, 1980; Lau *et al*., 2005).

The name *Geostachys* was introduced by Baker (1892) as a subgenus of *Alpinia* when he first described two species, *Alpinia decurvata* Baker and *A. secunda* Baker, both from Perak. In his pioneering work, The Scitamineae of The Malay Peninsula, Ridley (1899) elevated *Geostachys* as a genus, with five species, adding three new ones: *G. elegans* Ridl., *G. rupestris* Ridl. and *G. penangensis* Ridl. In 1920, Ridley described two other new species, namely, *G. primulina* Ridl. and *G. densiflora* Ridl., bringing the total to seven. He had

earlier also described two taxa under separate genera: *Carenophila montana* Ridl. in 1909 and *Conamomum sericeum* Ridl. in 1915, both of which were subsequently transferred to *Geostachys* by Holttum (1950) in his important monograph, The Zingiberaceae of The Malay Peninsula. Holttum further added three new species: *G. megaphylla* Holttum, *G. taipingensis* Holttum and *G. tahanensis* Holttum, all relatively unknown or not recollected until recently. Stone (1980) discovered another taxon, *G. leucantha* B.C. Stone, making a total of 13, prior to our studies.

As a consequence of fieldwork to study the genus in their type localities, all but *G. montana* (Ridl.) Holttum have been recollected, and two new species found and published by the authors (Lau *et al.*, 2005): *Geostachys belumensis* C.K. Lim & K.H. Lau and *G. erectifrons* K.H. Lau, C.K. Lim & K. Mat-Salleh.

Holttum's account of *Geostachys* within the Zingiberaceae of Peninsular Malaysia was made more than 50 years ago, and he intimated that there were still several taxa based on incomplete data, also mentioning that several species seemed rather closely allied, while other new species may yet be discovered. We were encouraged to work on the revision of this genus, to provide fresh data and updates on conservation status in the wild. Further extension studies on the Bornean records of the genus may follow, currently outside the scope of our study.

Studies on the *Geostachys* in other parts of the region have been carried out by Gagnepain (1906), Valeton (1921) and Larsen (1962), in which they had done various studies on this genus in Indo-China, Sumatera and Thailand respectively.

Materials and Method

Field study and living plant collections

Observations were carried out during the recorded flowering and fruiting season of the *Geostachys* species. Fieldwork was conducted at the type or other known localities (Fig. 1) of each species to study and collect living specimens and herbarium topotypes, and the *in situ* information proved valuable in ascertaining characters and other attributes, such as coloration and morphological variations, with reference to particular populations and/or those in different localities. Field observations were also important to analyze the habitat of each species.

Comparative morphology based on herbarium collections

Herbarium specimens or images of collections from the year 1884 to 2001 (in addition, the authors' recent collections) preserved at five major herbaria: K, KEP, KLU, SING and UKMB, were scrutinized. A total of 98 specimens,

including types were examined. Selected main morphology characters of each species were investigated and compared. The characters include habit of the plant, root and rhizome, leafy shoot, leaves, peduncle, stalk of cincinni, bracts, pedicel, calyx, corolla tube, labellum, staminode, anthers, stamen, fruit and seed where available.

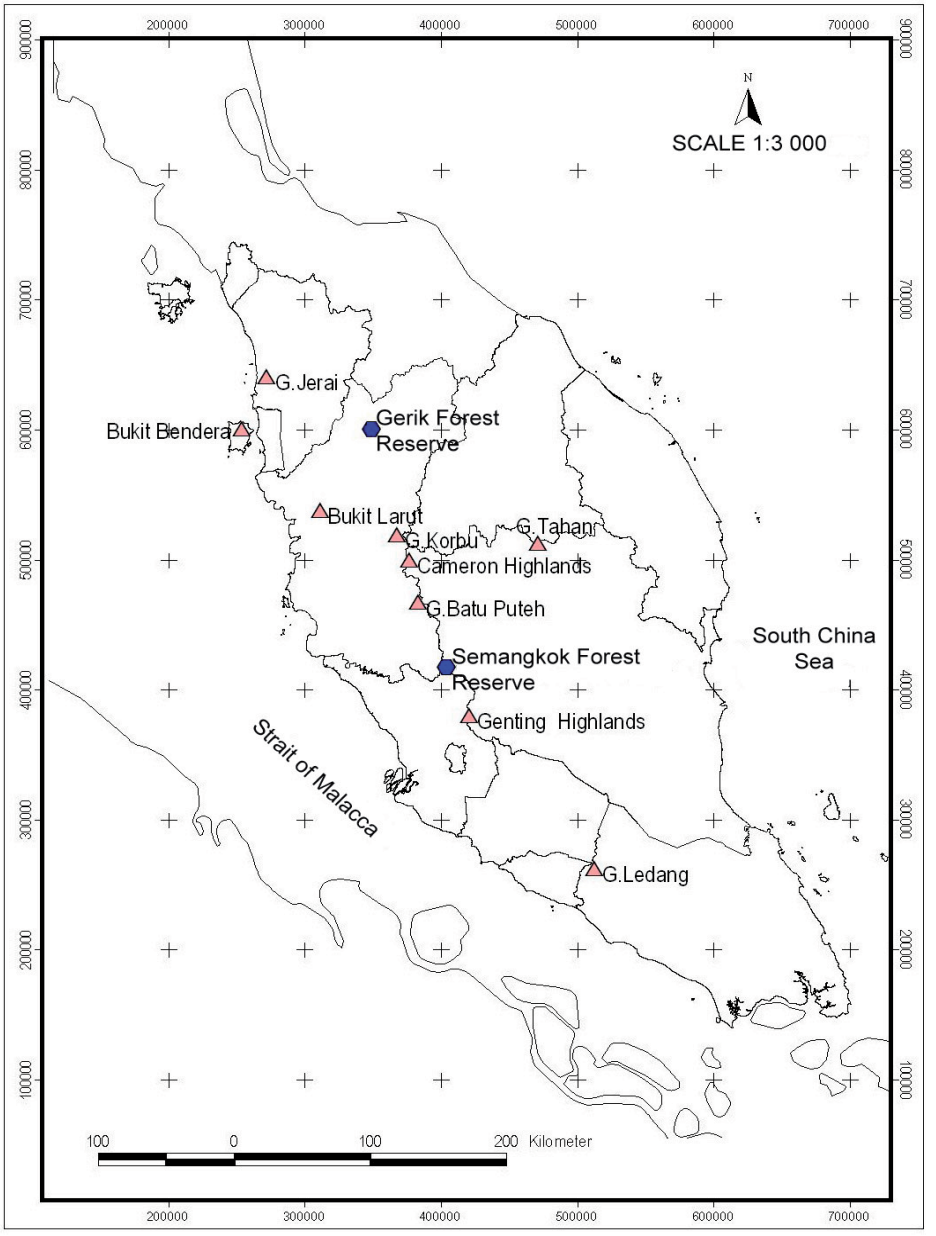

Figure 1. Study areas at type localities of species of *Geostachys*.

Results and Discussion

Typification of the generic name Geostachys

Studies made on literature (Baker, 1892; Ridley 1899, 1920, 1924; Holttum, 1950) and as reported by Turner (2000) and Newman *et al.* (2004), have shown that no type species has been designated for the genus to date. To remedy this, and after due consultations, one of the two early taxa recognised by Baker, *Geostachys decurvata* (Baker) Ridl., is proposed as the type species. It displays all the essential characters of the genus, and can still be conveniently referred to in its original type location at Bukit Larut, Perak.

GEOSTACHYS (Baker) Ridl., J. Straits Branch Roy. Asiat. Soc. 32 (1899) 158; *Alpinia* subg. *Geostachys* Baker, in Hook. f. Fl. Brit. India 6 (1892) 257. TYPE: *Geostachys decurvata* (Baker) Ridl. (selected here).

A checklist and distribution of the Geostachys

Fourteen of the 15 species were found and studied by us in the field. *Geostachys montana* could not be found in the type area, and remains in doubt, as to whether it is truly distinct. A checklist of all the species in Peninsular Malaysia is provided in Appendix 1.

All *Geostachys* species are highland species found in hill, sub-montane and upper montane forests ranging from 600-2000 m a.s.l. in the forest of Gunung Jerai (Kedah), Gunung Korbu (Perak), Gunung Ledang (Johore), Gunung Mering (Malacca), Gunung Tapis (Pahang), Gunung Benom (Pahang), Gunung Tahan (Pahang), Gunung Brinchang (Pahang), Gunung Berembun (Pahang), Bukit Bendera (Penang), Bukit Larut (Perak), Bukit Kedondong (Malacca), Bukit Fraser (Pahang), Genting Highlands (Pahang), Cameron Highlands (Pahang), and on the hills of Semangkok Forest Reserve (Selangor) and Belum Forest Reserve (Perak).

There have been records of *G. penangensis* from Borneo (Sarawak) and some other *Geostachys* spp. in Sabah (C.K. Lim and K. Mat-Salleh, pers. comm.). Initially, it was believed that *G. penangensis* was endemic to Penang (Lau, 2004). However, the current revision only targetted on species from Peninsular Malaysia. Nonetheless, the authors feel that further investigation on the genus should also include other species from Borneo, as well as in Thailand and Sumatera.

Morphological observations

Generally, all the species have stilt roots, or at least stilt roots-like coming out from the rhizomes. Some species have true stilt roots, whereas some are just having long and reticulated roots.

As for the leaves, there are few characters that are quite useful especially for field identification. The colours of the upper and lower surfaces of the leaves are important as there are few species with maroon colour underneath. The lamina comprises of four different types; widely elliptic, narrowly elliptic, lanceolate and oblong. The other less prominent but useful character is the presence of hairs at the ligule.

The structure of the inflorescence consists of two very different types: decurved and erect. As for the decurved inflorescence, the curving of the inflorescence starts at the peduncle and run through the whole rachis. Each of the flowers curved at a very peculiar upwards manner, as if all of the flowers are growing at one side only. However, for the erect type, the flowers grow closely and in whorled-like manner. The flowers can either be single, 1-2 per cincinnus, 1-3 per cincinnus, or 1-5 per cincinnus.

The flowers of *Geostachys* can be either yellow or white. However, majority of the species have yellow labellum with only 3 species having white. Some of the species have flowers with crumpled margin whereby some have smooth margin. Few species have staminodes on their flowers and can be seen with red markings. Another distinct attribute that is quite useful in recognizing between species is the presence of the anther crest. The anther crest can be very prominent and is trilobed-like.

The shape of the fruits of this genus is either ovoid or ellipsoid. The shape can be sometimes not so obvious, but in a particular species, the shape is more or less constant. Table 1 summarizes the characteristic of each species.

Endemism of Geostachys

Among the 15 recognised species, 13 are hyper-endemic to their respective type localities. Some are observed as rare, and several species were found only in few and small clumps at their habitats, e.g., *G. primulina, G. tahanensis, G. secunda, G. taipingensis, G. megaphylla, G. sericea, G. leucantha, G. decurvata* and *G. belumensis.* Attempts have been made to search for more populations of these endemic species, but as yet to no avail. Adding to this critical situation is the threat to their habitat. Except for *G. tahanensis, G. sericea* and *G. erectifrons* whose habitats are within a National Park, those of other species are rather exposed to hazards that entire populations could be wiped out in a short period of time. As an example, the population of *G. taipingensis* was no longer to be found on the second visit to a known locality near the type area. Conversely, however, other successful rediscoveries of the *Geostachys* have been made, such as that of *G. primulina* after 80 years since it was first collected (Lau, 2006 and C.K. Lim, pers. com.). A particular study of the hyper-endemics, *G. rupestris* and *G. penangensis,* at their type areas have shown that they are well able to survive under relatively protected

Table 1. Summary of important characters of species of *Geostachys*.

Species	Stilt roots	Leaf abaxial	Leaf adaxial	Leaf shape	Ligule	Inflorescence, flower	Labellum	Staminode	Anther crest	Fruit
G. primulina	long & reticulated	maroon	glaucous	broadly elliptic	glabrous	decurved, single flowered	yellow, margin crumpled	absence	none	ovoid & brownish black
G. erectifrons	long & reticulated	maroon	green	lanceolate	glabrous	decurved, single flowered	yellow	not known	not known	ovoid & brownish red
G. belumensis	long & reticulated	maroon	green	lanceolate	glabrous	decurved, single flowered	yellow with red spots, margin crumpled	presence, with red bands	absence	ellipsoid & dark red
G. tahanensis	long & reticulated	green	green	broadly elliptic	glabrous	decurved, single flowered	yellow	not known	not known	ovoid & chilly red
G. penangensis	stilt roots	green	green	narrowly elliptic	glabrous	decurved, single flowered	yellow, margin smooth	absence	not known	ellipsoid & brownish black
G. secunda	long & reticulated	green	green	broadly elliptic	glabrous	decurved, single flowered	yellow, margin smooth	absence	absence	ellipsoid & dark red
G. elegans	stilt roots	green	green	narrowly elliptic	glabrous	erect, 1-2/cincinnus	yellow	not known	not known	ovoid & orange
G. taipingensis	stilt roots	green	green	oblong	glabrous	erect, single flowered	yellow with red spots, margin crumpled	absence	presence	ovoid & brownish black

G. megaphylla	stilt roots	green	green	oblong	hairy	erect, 1-3/cincinnus	white with pink spots & bands, margin crumpled	absence	presence	ovoid & brownish black
G. sericea	stilt roots	green	green	oblong	hairy	erect, 1-2/cincinnus	yellow with red spots, minutely-hairy silky surface, margin smooth	presence, with red spots	presence	ovoid & light green
G. montana	not known	green	green	elliptic-oblong	hairy	erect-decurved, single flowered	white	presence	not known	ellipsoid & dark red
G. leucantha	stilt roots	green	green	oblong	glabrous	erect-decurved, 1-5/cincinnus	white with pink spots, margin crumpled	absence	presence	ovoid & dark brown
G. rupestris	stilt roots	green	green	broadly elliptic	glabrous	decurved, single flowered	yellow with red marks, margin smooth	absence	absence	ellipsoid & brownish red
G. densiflora	stilt roots	green	green	narrowly elliptic	glabrous	decurved, 1-2/cincinnus	yellow, margin crumpled	absence	absence	ovoid & dark purple
G. decurvata	stilt roots	green	green	narrowly elliptic	glabrous	decurved, single flowered	yellow, margin crumpled	absence	absence	ellipsoid & brownish red

situations. The two widespread species, *G. elegans* and *G. densiflora*, are relatively common and not threatened.

Conservation status of Geostachys
A threat assessment on the genus is being carried out based on the IUCN Red List Categories and Criteria Version 3.1 (IUCN, 2001) and Malaysia Plant Red List (Chua and Saw, 2006). The final result of the assessment is expected to be out together with the full revision of the *Geostachys* which is currently in preparation by Lau *et al.*

List of species of Geostachys *in Peninsular Malaysia*.

G. belumensis C.K. Lim & K.H. Lau
G. decurvata (Baker) Ridl.
G. densiflora Ridl.
G. elegans Ridl.
G. erectifrons K.H. Lau, C.K. Lim & K. Mat-Salleh
G. leucantha B.C. Stone
G. megaphylla Holttum
G. montana (Ridl.) Holttum
G. penangensis Ridl.
G. primulina Ridl.
G. rupestris Ridl.
G. secunda (Baker) Ridl.
G. sericea (Ridl.) Holttum
G. tahanensis Holttum
G. taipingensis Holttum

Acknowledgements

Thanks are due to Dato' Musa Nordin, the Director-General, Department of Wildlife and National Parks for assistance and encouragement for the trips to Gunung Tahan, and to his field guides, Baharim Selat, Tajuddin Mohd. Amin, and Juhari Basri; also to Imin Kamin of FRIM for field assistance. Part of the research program was conducted at Tropical Forest Biodiversity Centre (TFBC) in FRIM; the first author expresses his thanks to TFBC Director, Dr. Saw Leng Guan, and to his staff for their support. Further acknowledgements go to Dr. Lillian Chua and Hamidah Mamat, also from FRIM for their assistance in the Red List Threat Assessment of the genus. The second author acknowledges the contribution by his field team: Azizan Busu, Alus Sarip and Zaidee Hitam. The first author's research and fieldwork

were funded in part by IRPA Research Grant 09-02-02-EA0035. Further thanks are due to the herbarium curators at K, KEP, KLU, SING and UKMB for access to specimens, and also to the Penang Botanic Gardens.

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Materials Towards a Revision of *Aulotandra* Gagnep. (Zingiberaceae)

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Abstract

Aulotandra Gagnep. has recently been transferred from the subfamily Alpinioideae, tribe Alpinieae, to the subfamily Siphonochiloideae. Materials towards a revision of *Aulotandra* and *Siphonochilus* J.M.Wood & Franks are presented.

Introduction

Harris et al. (2006) have included *Aulotandra* Gagnep. in a phylogenetic analysis in order to determine its correct place in the new classification of Zingiberaceae by Kress *et al.* (2002).

Aulotandra was, until recently, the only African genus of Zingiberaceae which had not been included in a molecular systematic study. Two molecular datasets, chloroplast and nuclear, placed *Aulotandra* closest to *Siphonochilus* J.M. Wood & Franks, showing that genetic divergence levels were smaller between accessions of *Aulotandra* and *Siphonochilus* than between *Aulotandra* and any other taxon included in the analysis.

In addition, phylogenetic analyses of the two data matrices showed that the species of *Aulotandra* and *Siphonochilus* sampled in that study formed a monophyletic group. It was clear from the shared synapomorphies and the high branch support for the clade containing these genera that this relationship was very close. The two data sets showed some discrepancy as to the relationships between these two genera - the ITS analysis indicating that *Aulotandra* was monophyletic, but the *trn*L-F results suggesting that the two genera were paraphyletic.

Accepting that *Aulotandra* and *Siphonochilus* form a monophyletic group led to the transfer of *Aulotandra* from subfamily Alpinioideae, tribe Alpinieae, to subfamily Siphonochiloideae. Taking this study further, it is clear that the species in subfamily Siphonochiloideae must be revised together.

Materials and Methods

A list of the names in *Aulotandra*, *Siphonochilus* and *Kaempferia* L. in Africa was compiled using the International Plant Names Index (www.ipni.org) and the World Checklist of Monocotyledons (http://www.kew.org/wcsp/home.do). Protologues were consulted and details of the type of each name were added. Where possible, the collector, collection number and herbarium location are given but, in some cases, it is not clear from the literature where types are to be found.

Results

In total, there are 30 names to be revised in the Siphonochiloideae, eight in *Aulotandra*, 12 in *Siphonochilus*, and 10 in *Kaempferia*. The majority of names are based on type specimens held at the Muséum national d'Histoire naturelle, Paris. A few are yet to be located; those collected by German botanists may have been lost.

Names in *Aulotandra* Gagnep.

1. *Aulotandra angustifolia* H. Perrier, Bull. Soc. Bot. France 86: 178. 1939.
   Type: *Perrier de la Bâthie 7264* (P).
2. *Aulotandra humbertii* H. Perrier, Bull. Soc. Bot. France 86: 180. 1939.
   Type: *Humbert s.n.* (P).
3. *Aulotandra kamerunensis* Loes., Bot. Jahrb. Syst. 43: 389. 1909.
   Type: *Zenker 3696* (US, WU, WRSL).
4. *Aulotandra madagascariensis* Gagnep., Bull. Soc. Bot. France 48: LXXIX. 1901.
   Type: *Humblot 448* (P).
5. *Aulotandra trialata* H. Perrier, Bull. Soc. Bot. France 86: 181. 1939.
   Type: *Perrier de la Bâthie 1021* (P).

6a. *Aulotandra trigonocarpa* H. Perrier var. *trigonocarpa*. Bull., Soc. Bot. France 86: 179. 1939.
   Type: *Perrier de la Bâthie 19014* (P).

6b. *Aulotandra trigonocarpa* H. Perrier var. *calcicola* H. Perrier, Bull. Soc. Bot. France 86: 180. 1939.
   Type: *Perrier de la Bâthie 1672, 1687* (P).

6c. *Aulotandra trigonocarpa* H. Perrier var. *gypsicola* H. Perrier, Bull. Soc. Bot. France 86: 180. 1939.
   Type: *Perrier de la Bâthie 15943* (P).

Names in *Siphonochilus* J.M. Wood & Franks

1. *Siphonochilus aethiopicus* (Schweinf.) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 40(2): 372. 1982.
   Type: *Cienkowski s.n., Steudner s.n.*
2. *Siphonochilus bambutiorum* A.D.Poulsen & Lock, Kew Bull. 54: 203. 1999.
   Type: *Poulsen & Liengola 1146* (holo, C; iso BR, E, K, MO).
3. *Siphonochilus brachystemon* (K.Schum.) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 40(2): 372. 1982.
   Type: Volkens 201 (B), *Holst 3100* (B).
4. *Siphonochilus carsonii* (Baker) Lock, Kew Bull. 39: 841. 1984.
   Type: *Carson s.n.* (K).
5. *Siphonochilus decorus* (Druten) Lock, Kew Bull. 54: 346. 1999.
   Type: *Schweickert s.n.* (PRE).
6. *Siphonochilus evae* (Briq.) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 40(2): 372. 1982.
   Type: *Prosch 12* (G).
7. *Siphonochilus kilimanensis* (Gagnep.) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 40(2): 372. 1982.
   Type: *Le Testu s.n.* (P).
8. *Siphonochilus kirkii* (Hook.f.) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 40(2): 372. 1982.
   Type: *Kirk s.n.* (K).
9. *Siphonochilus natalensis* (K.Schum.) J.M.Wood & Franks, Natal pl. 6(3): plates 560-561. 1911.
   Type: *Wood 544* (K).
10. *Siphonochilus nigericus* (Hepper) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 40(2): 372. 1982.
    Type: *Dalziel 276* (K).
11. *Siphonochilus parvus* Lock, Kew Bull. 46: 269. 1991.
    Type: Congdon 46 (K).
12. *Siphonochilus rhodesicus* (T.C.E.Fr.) Lock, Kew Bull. 39: 841. 1984.
    Type: *Fries 1146* (UPS).

Names in *Kaempferia* L. in Africa

1. *Kaempferia aethiopica* (Schweinf.) Benth. var. *angustifolia* Ridl., J. Bot. 25: 131. 1887.
   Type: *Welwitsch 683* (K).
2. *Kaempferia ceciliae* N.E.Br. Bull, Misc. Inform. 169. 1906.
   Type: *Cecil 248* (K).
3. *Kaempferia dewevrei* De Wild. & T. Durand, Bull. Soc. Roy. Bot. Belgique

38: 142. 1899.
Type: *Dewèvre 1021*.
4. *Kaempferia ethelae* J.M. Wood, Gard. Chron. 23: 94. 1898.
Type: not known.
5. *Kaempferia homblei* De Wild., Repert. Spec. Nov. Regni Veg. 13: 195. 1914
Type: *Homblé 851, 907*.
6. *Kaempferia montagui* F.M. Leight., S. African Gard. 22: 57, 59. 1932.
Type: *Montagu 888/21* (K).
7. *Kaempferia pleiantha* K. Schum., Bot. Jahrb. Syst. 15(4): 425. 1892.
Type: *Buchner 694, Mechow 559b*.
8. *Kaempferia puncticulata* Gagnep., Bull. Soc. Bot. France 53: 353. 1906.
Type: *Kiener s.n*. (P).
9. *Kaempferia stenopetala* K. Schum., Pflanzenr. IV 46 (Heft 20): 69. 1904.
Type: *Wood 1942*.
10. *Kaempferia zambesiaca* Gagnep., Bull. Soc. Bot. France 53: 355. 1906.
Type: *Le Testu 563* (P).

Recommendations

Preliminary morphological observations and the sequence results presented by Harris *et al.* (2006) suggest that there may be only one genus in subfamily Siphonochiloideae. In order to test this hypothesis, a molecular and morphological study with wider sampling should be carried out to determine the relationships between the species and assess the limits of these two genera. All names listed above should be revised so that the number of accepted species, their distributions and their conservation status may be confidently known.

Acknowledgements

I am grateful to my colleagues, David Harris, Michelle Hollingsworth, Michael Möller and Alexandra Clark, for allowing me to present their results and to build upon them.

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