

# Herbarium of Vascular Plants Collection of the University of Extremadura (Spain)

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## Abstract

The herbarium of University of Extremadura (UNEX Herbarium) is formed by 36451 specimens of vascular plants whose main origin is the autonomous region of Extremadura (Spain) and Portugal, although it also contains a smaller number of specimens from different places, including the rest of peninsular Spain, the Balears Islands, the Macaronesian region (Canary Islands, Madeira and Azores), northwest of Africa (Morocco) and Brazil. 98% of the total records are georeferenced.

It is an active collection in continuous growth. Its data can be accessed through the GBIF data portal at <http://data.gbif.org/datasets/resource/255> and <http://www.eweb.unex.es/eweb/botanica/herbario/>. This paper describes the specimen associated data set of the UNEX Herbarium, with an objective to disseminate the data contained in a data set with potential users, and promote the multiple uses of the data.

## Keywords

Extremadura, herbarium collection, Liliopsida, Magnoliopsida, Spain, Portugal, Balears islands, Macaronesian region, Morocco, Brazil, UNEX Herbarium, vascular plant taxonomy

## The UNEX Herbarium

Established in 1986, the specimens that the herbarium of vascular plants collection of University of Extremadura (UNEX Herbarium) incorporates is the result of the work of collections and identifications by different researchers, associated with the Botany Area (Department of Plant Biology, Ecology and Earth Sciences) of the University of Extremadura. Chief amongst these individuals include: Professor Juan Antonio Devesa, founder and director of the herbarium until 2004, and Dr. Trinidad Ruiz, curator and current director of the UNEX Herbarium. Significant contributions have also been made by Professor Ana Ortega-Olivencia, Dr. Rafael Tormo, Dr. Josefa López, and Dr. Tomás Rodríguez-Riaño. Other researchers who contributed to the growth of the UNEX Herbarium includes, M<sup>a</sup> Carmen Viera, Jacinto Pedro Carrasco, Adolfo Muñoz, Inmaculada Montero, and Francisco M<sup>a</sup> Vázquez. In addition, the disinterested work developed throughout time by a lot of students of the University of Extremadura, especially, M<sup>a</sup> Luisa Navarro Pérez and Dr. Francisco Javier Valtueña.

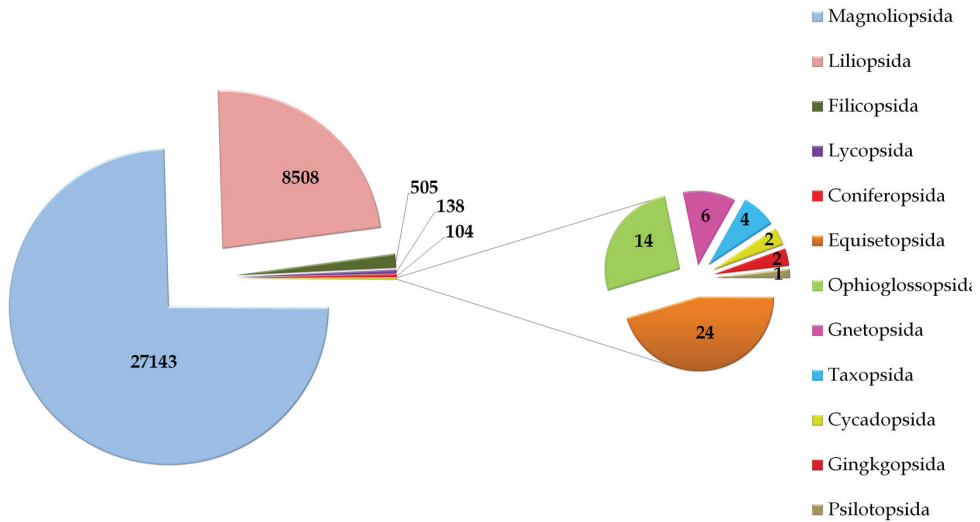
The development of different research projects has made it possible to improve the quality of the herbarium. Among them, the numerous compilations carried out by different members of the Botany Area in order to elaborate the first flora of the Extremadura region (Devesa 1995) or the synthesis of different taxonomic families or genera for Flora Ibérica (<http://www.floraiberica.org/>). Additionally, 4.5% of the material comes from the purchase of part of the herbarium of Dr. J.V.C. Malato-Beliz.

Limited and unpredictable funding has always pose challenge for ensuring sustained growth of the collection facility since its establishment.

## General taxonomic coverage description

As depicted in Figure 1, majority of the specimens in UNEX Herbarium belong to class Magnoliopsida (27143 specimens) and Liliopsida (8508 specimens). These classes are followed by Filicopsida (505 specimens), Lycopsidea (138 specimens), Coniferopsida (104 specimens), Equisetopsida (24 specimens), Ophioglossopsida (14 specimens), Gnetopsida (6 specimens), Taxopsida (4 specimens) Cycadopsida and Gingkgopsida (both with 2 specimens), and Psilotopsida (1 specimen).

UNEX herbarium represents 210 families, of which 22% and 21% of the specimens belongs to Poaceae and Fabaceae family respectively. This is followed by Asteraceae (15%), Scrophulariaceae (6%), Lamiaceae (6%), Caryophyllaceae (5%), Brassicaceae (4%), Cyperaceae (4%), Rubiaceae (3%), Ranunculaceae (3%), Liliaceae (3%), Boraginaceae (3%), Apiaceae (3%), and Cistaceae (2%). The herbarium includes 1253 genera (Figure 3), significant ones amongst them are *Trifolium* (1345 specimens), *Ranunculus* (623 specimens), *Scrophularia* (583 specimens), *Vicia* (537 specimens), *Stipa* (505 specimens), *Galium* (479 specimens), *Juncus* (439 specimens), *Vulpia* (381 specimens), *Medicago* (365 specimens) and *Bromus* (342 specimens).



**Figure 1.** Taxonomic coverage (as per classes) of the UNEX Herbarium.

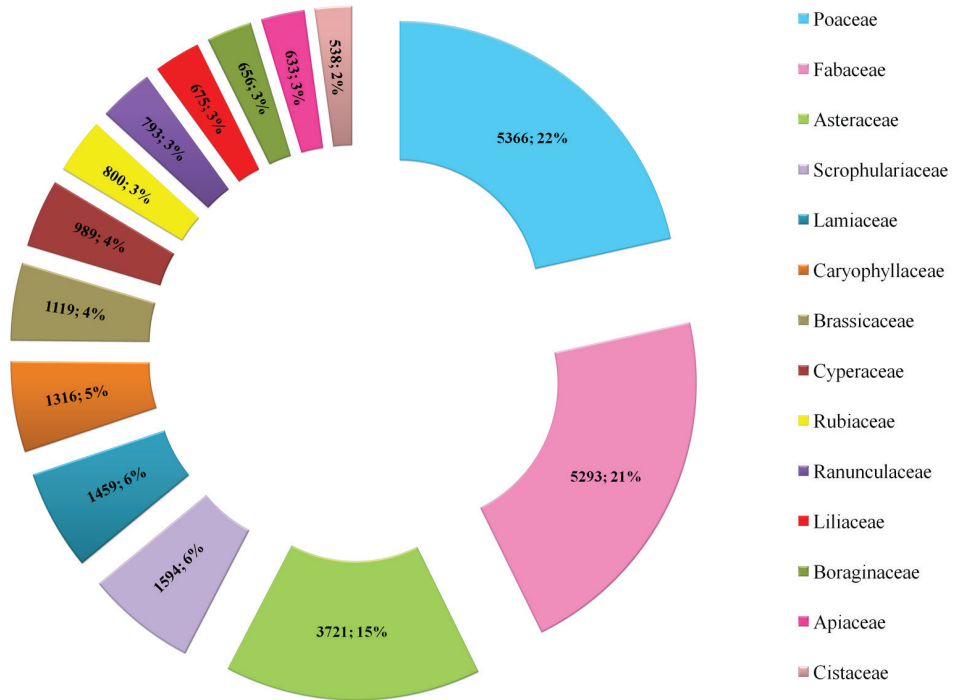
## Taxonomic ranks

**Kingdom:** Plantae

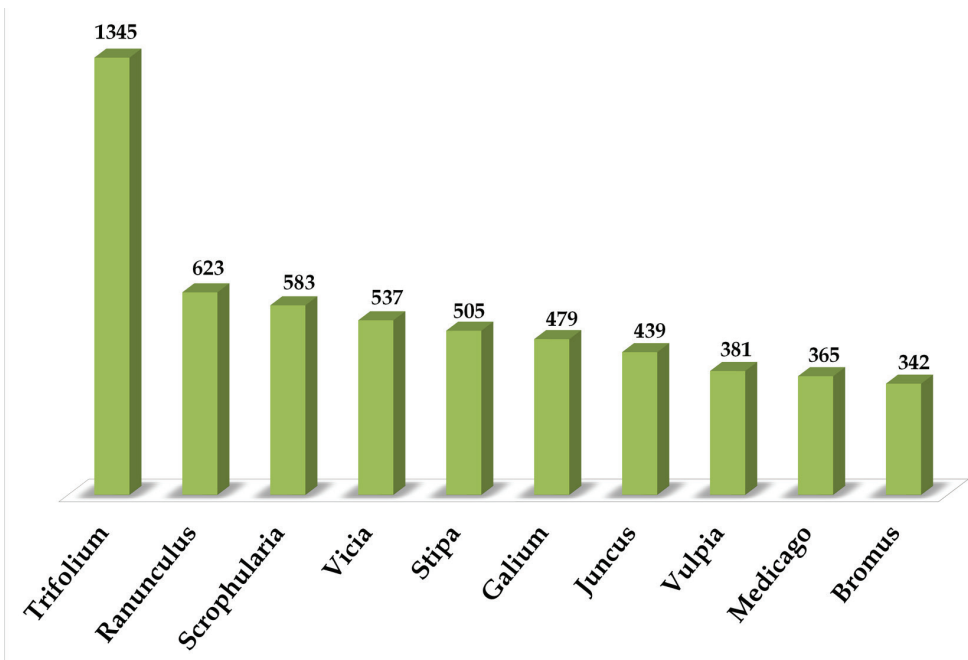
**Phylum:** Pteridophyta, Spermatophyta

**Class:** Magnoliopsida, Liliopsida, Filicopsida, Lycopsidea, Coniferopsida, Equisetopsida, Ophioglossopsida, Gnetopsida, Taxopsida, Cycadopsida, Gingkgopsida, Psilotopsida.

**Family:** Acanthaceae, Aceraceae, Adiantaceae, Agavaceae, Aizoaceae, Alismataceae, Amaranthaceae, Amaryllidaceae, Anacardiaceae, Apiaceae, Apocynaceae, Aquifoliaceae, Araceae, Araliaceae, Araucariaceae, Arecaceae, Aristolochiaceae, Asclepiadaceae, Aspidiaceae, Aspleniaceae, Asteraceae, Athyriaceae, Azollaceae, Balanophoraceae, Balsaminaceae, Basellaceae, Begoniaceae, Berberidaceae, Betulaceae, Bignoniaceae, Blechnaceae, Boraginaceae, Brassicaceae, Buddlejaceae, Butomaceae, Buxaceae, Cactaceae, Callitrichaceae, Calycanthaceae, Calyceraceae, Campanulaceae, Cannabaceae, Cannaceae, Capparaceae, Caprifoliaceae, Caryophyllaceae, Casuarinaceae, Celastraceae, Ceratophyllaceae, Characeae, Chenopodiaceae, Cistaceae, Clethraceae, Clusiaceae, Cneoraceae, Commelinaceae, Convolvulaceae, Coriariaceae, Cornaceae, Crassulaceae, Cryptogrammeae, Cucurbitaceae, Cunoniaceae, Cupressaceae, Cyathaceae, Cycadaceae, Cyperaceae, Davalliaceae, Dicksoniaceae, Dioscoreaceae, Dipsacaceae, Droseraceae, Ebenaceae, Elaeagnaceae, Elaphoglossaceae, Elatinaceae, Empetraceae, Ephedraceae, Equisetaceae, Ericaceae, Euphorbiaceae, Fabaceae, Fagaceae, Flacourtiaceae, Fontinalaceae, Frankeniaceae, Fumariaceae, Gentianaceae, Geraniaceae, Gesneriaceae, Ginkgoaceae, Globulariaceae, Grossulariaceae, Guttiferaceae, Haloragaceae, Hamamelidaceae, Hemionitidaceae, Hippocastanaceae, Hy-



**Figure 2.** Taxonomic coverage (as per families) of the UNEX Herbarium.



**Figure 3.** Taxonomic coverage (as per genus) of the UNEX Herbarium.



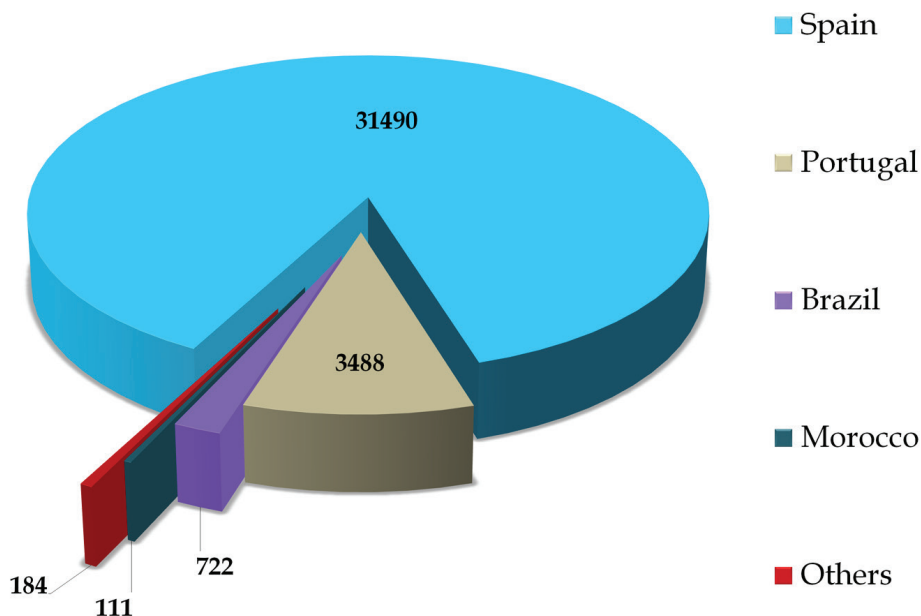
drangeaceae, Hydrophyllaceae, Hymenophyllaceae, Hypolepidaceae, Iridaceae, Isoetaceae, Juglandaceae, Juncaceae, Juncaginaceae, Lamiaceae, Lauraceae, Lemnaceae, Lentibulariaceae, Liliaceae, Linaceae, Loranthaceae, Lycopodiaceae, Lythraceae, Magnoliaceae, Malpighiaceae, Malvaceae, Maranthaceae, Marsileaceae, Melastomataceae, Meliaceae, Melianthaceae, Mimosaceae, Molluginaceae, Monimiaceae, Moraceae, Myoporaceae, Myricaceae, Myrsinaceae, Myrtaceae, Najadaceae, Nyctaginaceae, Nymphaeaceae, Oleaceae, Onagraceae, Ophioglossaceae, Orchidaceae, Orobanchaceae, Osmundaceae, Oxalidaceae, Paeoniaceae, Papaveraceae, Passifloraceae, Phytolaccaceae, Pinaceae, Piperaceae, Pittosporaceae, Plantaginaceae, Platanaceae, Plumbaginaceae, Poaceae, Podocarpaceae, Polemoniaceae, Polygalaceae, Polygonaceae, Polypodiaceae, Pontederiaceae, Portulacaceae, Potamogetonaceae, Primulaceae, Proteaceae, Psilotaceae, Pteridaceae, Punicaceae, Pyrolaceae, Rafflesiaceae, Ranunculaceae, Resedaceae, Rhamnaceae, Rosaceae, Rubiaceae, Ruppiaceae, Rutaceae, Salicaceae, Santalaceae, Sapindaceae, Saxifragaceae, Scrophulariaceae, Selaginellaceae, Simaroubaceae, Sinopteridaceae, Solanaceae, Sparganiaceae, Sterculiaceae, Styracaceae, Symplocaceae, Tamaricaceae, Taxaceae, Theaceae, Theligonaceae, Thelypteridaceae, Thymelaeaceae, Tiliaceae, Tropaeolaceae, Typhaceae, Ulmaceae, Umbelliferaceae, Urticaceae, Valerianaceae, Verbenaceae, Violaceae, Vitaceae, Zannichelliaceae, Zingiberaceae, Zygophyllaceae

## General spatial coverage

Specimens deposited in the UNEX Herbarium have been collected mainly from Iberian Peninsula (Spain and Portugal) northwest of Africa (Morocco) and Brazil. As indicated in Figure 4, maximum number of specimens included in the dataset are collected from Spain (31490) followed by Portugal (3488), Brazil (722) and Morocco (111) respectively. With regards to collections from Spanish provinces, Badajoz contributes 16910 specimens, followed by Cáceres (6855 specimens) and Cádiz (1012 specimens). Other sampling areas include Almería (711 specimens), Jaén (495 specimens), Málaga (411 specimens), Gerona (388 specimens), Huesca (371 specimens), León (308 specimens), Oviedo (293 specimens), Granada (290 specimens), Huelva (260 specimens) and Lérida (249 specimens).

The specimens better represented in the database correspond to elements of the Mediterranean forest and/or scrubland. These specimens are developed under a seasonal climate of mild winters and hot and dry summers, with abundant rainfall in autumn and spring. Frequent in this climate are forest fires, to which the vegetation is adapted. Specimens from Brazil (except one specimen collected in the state of Santa Catarina), are collected in the state of Rio Grande do Sul. This state has a humid subtropical climate and a hydrography classified into three major regions: Uruguay River Basin, Guaiba River, and Litoral.

**Coordinates:** 38°0'0"S and 52°0'0"N Latitude; 115°0'0"W and 65°0'0"E longitude.



**Figure 4.** Geographic coverage of the UNEX Herbarium.

## Temporal coverage

1911 – 2013. As shown in Figure 5, earliest collection event is dated back to 1911. Maximum number of specimens are collected during 1986–2000 (24833), followed by 2001–2012 (5038), 1971–1985 (4556), 1956–1970 (979), 1941–1955 (270), and 1911–1940 (16). There are 759 specimens for which period of collection cannot be ascertained.

**Collection name:** UNEX Herbarium, University of Extremadura.

**Collection identifier:** <http://data.gbif.org/datasets/resource/255>

**Formation period:** 1986–2013

**Specimen preservation method:** Dried and pressed

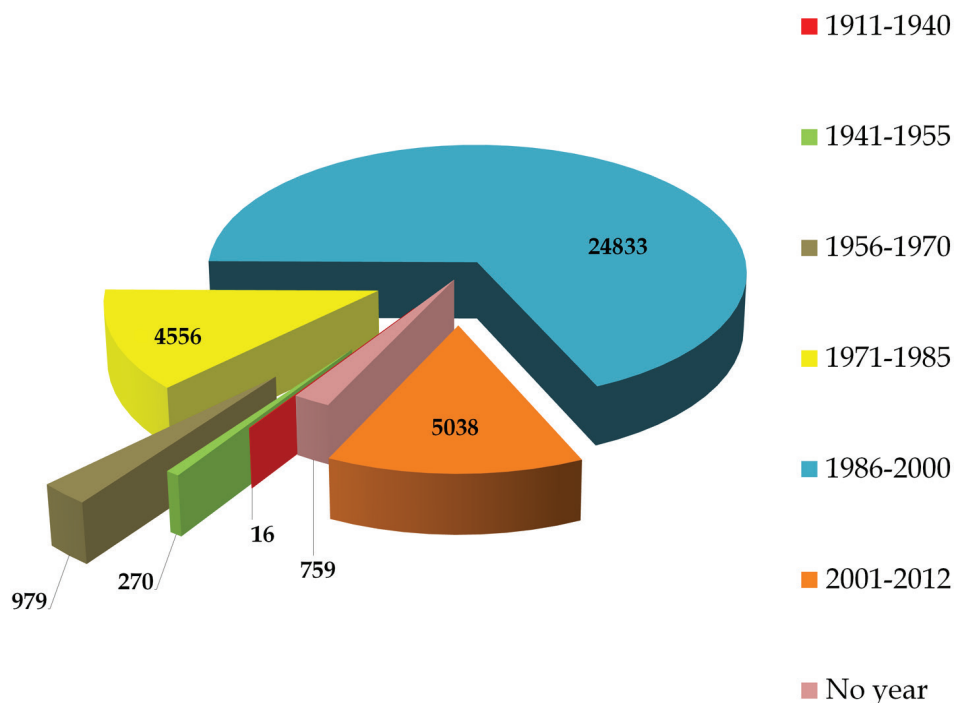
**Curatorial unit:** 36451 with an uncertainty of 0 (Sheets)

**Curatorial unit:** 1253 with an uncertainty of 0 (Genera)

## Methods

### Method step description

Dried and pressed method has been adopted for preservation of the specimens deposited in the collection. After collection of specimens in the field (see “sampling description” for the collection protocol) they are pressed and dried with the aim of adapting



**Figure 5.** Temporal coverage of the UNEX Herbarium.

them to a flat surface and remove water from the tissue, thereby preventing their degeneration or attacks by bacteria, fungi or insects that would destroy them.

**Assembly of specimens:** The dried material is mounted on a holder constituted by an A3 cardboard ( $42 \times 29.7$  cm) and a resistant paper (so-called jacket) dimension A2 ( $42 \times 59.4$  cm) that perfectly covers the cardboard, thus protecting the specimen. The assembly is made on the cardboard with transparent tape, allowing both that the specimen be tight to the holder and that the assembly be aesthetic.

**Registration of herbarium specimens:** After assembly, specimens are registered and labeled. Registration is done in a database (Microsoft Office Access Database → DarwinCore 1.2) in which each specimen is assigned a reference number allocated consecutively. The information contained in the record of each specimen is: institution owner of the herbarium, reference number, scientific name of the family and species, date of collection, georeferencing data (country, province, town), habitat, Legitimavit, and Determinavit. All log data are printed and constitute the sheet label.

**Treatment of specimens:** Before putting the specimens in the herbarium they are stored in hermetic plastic boxes and kept for 72 hours in cold storage (freezers) at  $-40^{\circ}\text{C}$ . In this way the material is decontaminated from possible attacks of pathogens that can destroy them and the rest of material already in the herbarium.

Storage of specimens: Finally, the specimens are kept inside compact enclosures in shelves where they are arranged taking into account the four main groups: pteridophytes, gymnosperms, monocots, and dicots. Within each main group the specimens are alphabetical arranged by families and genera.

### Study extent description

Iberian Peninsula is the most significant geographic zone represented in UNEX Herbarium. Figure 6 depicts the collections from various provinces of Iberian Peninsula. Over 5000 specimens are collected from two provinces (Badajoz and Cáceres). Two provinces (Cádiz and Almería) contributed specimens in the range of 500-1500. The specimens collected from morocco (111 sheets) are representatives for an area greater than 50% of the country (Fig. 7a). Conversely, specimens from Brazil (721 sheets) cover not more than 3% of the area of the country (Fig. 7b).

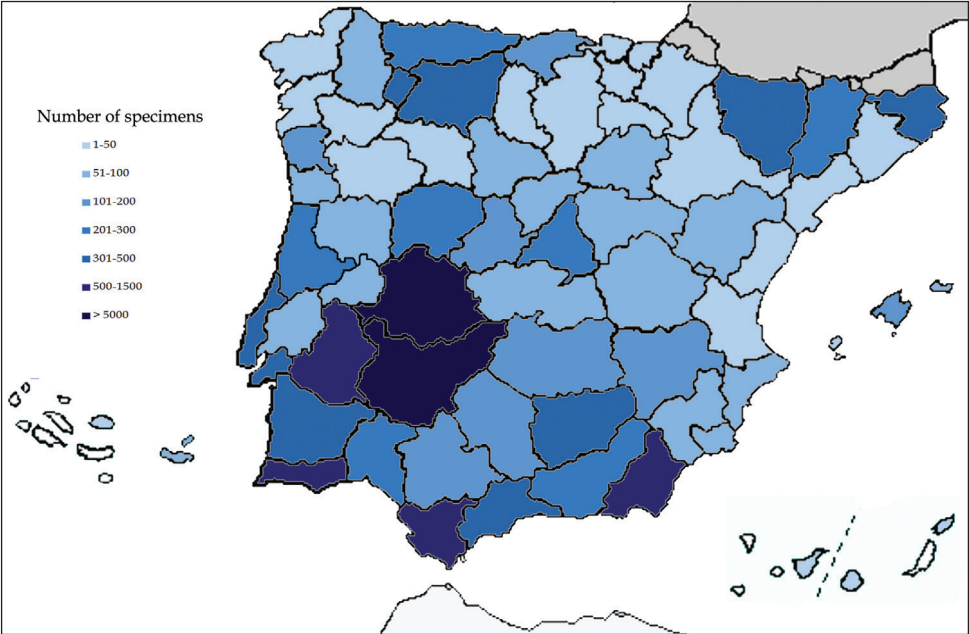
### Sampling description

As evident from the previous section, the specimens deposited in the UNEX Herbarium comes from diverse regions, which is outcome of several research projects depositing the specimens. As a result, specimens are not collected using a single, uniform protocol. Of the materials from donations or purchases (e.g. herbarium of Dr. J.V.C. Malato-Beliz) the protocol followed for the collection of specimens is unknown. The methodology used in collecting plants by researchers from the Botany Area may change depending on the objectives pursued by the work they are carried out for.

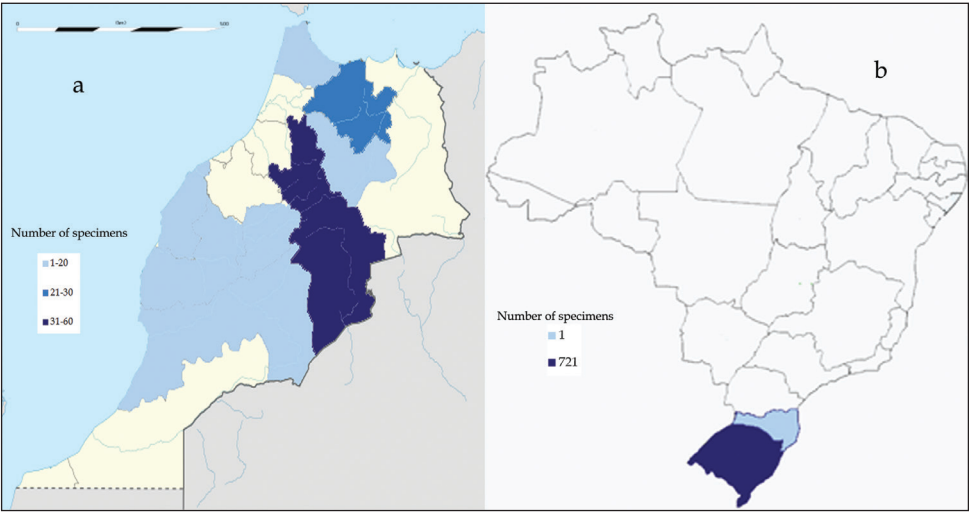
In general, collection takes place following previous available references drawn from scientific works, herbarium material or indications from reliable collectors. The collection campaigns are designed to be more or less exhaustive of different available areas depending on the purpose of the collection (e.g. for taxonomic works, we do exhaustive inspections of whole territories with expansion of the collection area beyond known indications).

### Quality control description

Each specimens and associated data record was subjected to two quality procedures; (a) taxonomic determination or identification and (b) geo-referencing. For taxonomic identification, trusted experts were contacted, the 85% of the material has been identified by investigators of the Botany Area of the University of Extremadura. These experts have authored number of monographs, which include *Vegetación y Flora de Extremadura* (Devesa 1995) in which 2050 taxa's are described. Other includes *Las Gramíneas de Extremadura* (Devesa 1999) or the volumes of *Flora iberica XV* (Devesa et al. 2007) com-



**Figure 6.** Geographical distribution of specimens in the Iberian Peninsula, Balearics, Canaries, Madeira and Azores.



**Figure 7.** Geographical distribution of specimens in (a) Morocco and (b) Brazil.

prising the taxonomic synthesis of families Adoxaceae, Caprifoliaceae, Dipsacaceae, Rubiaceae and Valerianaceae, and XVI (under edition, see <http://www.floraiberica.org/>) in which these experts are responsible for the genera *Arctium*, *Atractylis*, *Carlina*, *Crupina*,

*Cynara*, *Echinops*, *Onopordum*, *Rhaponticum*, *Saussurea*, *Staezelina*, and *Xeranthemum*. It is worth also to note the publications of new species of flora (*Centaurea bethurica*, Devesa and López 2008; *Scrophularia fontqueri* Ortega-Olivencia and Devesa 1998; *Galium moralesianum* and *G. talaveranum* Ortega-Olivencia and Devesa 2003; *Galium belizianum* Ortega-Olivencia et al. 2004), whose *typus* are preserved in UNEX Herbarium.

Besides the above mentioned authoritative literature, experts have also relied upon the biology of the reproduction of different taxa of the family Fabaceae (López et al. 1998, 1999a, 1999b, 2000, Ortega-Olivencia and Devesa 1997, Ortega-Olivencia et al. 1997, 2005, Rodríguez-Riaño et al. 1999a, 1999b, 1999c, 2004, 2006, Valtueña et al. 2007, 2008a, 2008b, 2010a, 2010b, 2011, 2012) or the genera *Drosophyllum* (Ortega-Olivencia et al. 1995, 1998) or *Scrophularia* (Ortega-Olivencia and Devesa 1993a, 1993b, Ortega-Olivencia et al. 2012, Valtueña et al. 2013). Use of these literature resources and long standing experience of the researchers high degree of confidence to the taxonomic identification of the specimens.

The 98% of the records in the collection are georeferenced. A total of 58.38% have MGRS coordinates and the rest geographical coordinates. The MGRS coordinate system has been transformed into geographical coordinates through a geographic calculator (<http://www.asturnatura.com/sinflac/calculadora-conversiones-coordenadas.php>), while at the same time maintaining the MGRS coordinates in the database. The accuracy of these coordinates grids varies from 1 km<sup>2</sup> to 10 km<sup>2</sup>. The geographical coordinates have been taken through the description of localities and search of these localities in Google Earth (<http://www.google.com/earth/index.html>). The accuracy of geographic coordinate values also varies between 2 and 12 km depending on the number of decimal places contained.

## Datasets

**Object name:** Herbarium of Vascular Plants Collection of the University of Extremadura (Spain)

**Character encoding:** UTF-8

**Format name:** Darwin Core Archive format

**Format version:** 1.0

**Distribution**

<http://www.gbif.es:8080/ipt/resource.do?r=collectionherbariumextremadura>

**Publication date of data:** 2013-05-18

**Language:** English

**Licenses of use:** This database “Herbarium of Vascular Plants Collection of the University of Extremadura (Spain)” is made available under license Open Data Commons Attribution: <http://www.opendatacommons.org/licenses/by/1.0/>

**DarwinCore elements:** Twenty two (22) DarwinCore (<http://purl.org/dc/terms/>) elements included in the dataset published through the GBIF network. These are (a) modified, (b) infraspecificEpithet, (c) eventDate, (d) family, (e) basisOfRecord, (f) kingdom, (g) typeStatus, (h) collectionCode, (i) catalogNumber, (j) scientificName,

(k) locality, (l) individualCount, (m) scientificNameAuthorship, (n) institutionCode (o) decimalLongitude, (p) country, (q) preparations, (r) identifiedBy, (s) stateProvince, (t) recordedBy, (u) recordNumber, (v) decimalLatitude, (w) genus, (x) specificEpithet and (y) occurrenceRemarks.

**Character encoding:** iso-8859-1

**Format name:** Access

**Format version:** 1.0

**Distribution:** <http://data.gbif.org/datasets/resource/255>

**Metadata language:** English

**Date of metadata creation:** 2013-03-20

**Hierarchy level:** Dataset

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# *Ridleyandra chuana* (Gesneriaceae), a new species from Peninsular Malaysia

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## Abstract

*Ridleyandra chuana*, a new species of Gesneriaceae, is described and illustrated. It is endemic in Peninsular Malaysia and known from two small and restricted populations in montane forest. Its conservation status is assessed as vulnerable.

## Keywords

*Ridleyandra chuana*, Gesneriaceae, Peninsular Malaysia, endemic, conservation

## Introduction

This species was first encountered in 1932 at Fraser's Hill, Pahang. However, it was only in 1999 when another population was discovered by L.S.L. Chua on Gunung Ulu Kali, Pahang, that sufficient material was available for its description. Since then both these localities have been revisited and the Gunung Ulu Kali population is now the focus of conservation. This species is unusual in *Ridleyandra* in occupying a very narrow niche, which probably contributes to its rarity and small population size. This is clearly seen at the Fraser's Hill locality where a small population of less than 30 plants is confined to a small area where moss-covered granite rock just emerges above the soil surface but is absent from the surrounded area of soil where *Codonoboea curtisii* (Ridl.) C.L.Lim (Gesneriaceae) is plentiful.

It is a distinctive species among *Ridleyandra* species in its mammillate leaf surface with hairs on raised conical bases. Indeed, when sterile with its dark green leaves it more resembles *Codonoboea crinita* (Jack) C.L.Lim than *R. atrocyanea* (Ridl.) A.Weber, the only other *Ridleyandra* species with a mammillate leaf surface. Two species, *R. kelantanensis* Kiew and *R. longisepala* (Ridl.) A.Weber, have similar white corollas with purple lines and toothed leaves. In fact Weber (1998) listed Corner's Fraser's Hill specimens under *R. longisepala* but it is different from this species that has bracts immediately below the sepals, longer petioles and sepals. It more resembles *R. kelantanensis* in their shorter petioles and sepals.

## Taxonomy

### *Ridleyandra chuana* Kiew, sp. nov.

urn:lsid:ipni.org:names:77129808-1

[http://species-id.net/wiki/Ridleyandra\\_chuana](http://species-id.net/wiki/Ridleyandra_chuana)

Figure 1

**Diagnosis.** In its leaf surface with mammillate hairs and its narrowly lanceolate bracts, *Ridleyandra chuana* resembles *R. atrocyanea* (Ridl.) A.Weber but it differs in its shorter peduncles 6–8.5 cm long (not 8–12 cm), pedicels 5–7 mm long (not 10 mm) and its shorter 3–5 cm long white corolla with purple lines (not purple-black and 5–7 cm long). In flower colour and pattern it is similar to *R. kelantanensis* Kiew but differs not only in its mammillate leaf surface but also in its longer petioles (2.3–3 cm long not 1–1.75 cm in *R. kelantanensis*), smaller teeth on the leaf margin (2.5–3 × 1.5–3 mm not 4–5 × 3.5 mm), larger bracts (4–6 mm long not 2–3 mm), and corollas with a much narrower lip ca 13 mm wide (not 24 mm wide).

**Type.** Peninsular Malaysia. Pahang: Gunung Ulu Kali, 27 Jan 1999 (fl.) LSL Chua FRI 40758 (holotype: KEP!; isotype: KEP!).

**Description.** Perennial herb. **Stem** woody, usually unbranched, rarely 2-branched, erect, 12–19 cm tall, 3–5 mm diam., upper part of stem, petiole, leaf margin, lower surface of veins, peduncle and pedicel and sepals hispid; hairs reddish brown, dense, unbranched, multiserial, ca. 2 mm long and on the margin and veins 3–4 mm long. **Leaves** in unequal pairs clustered in a rosette at the top of the stem, lowermost to 7 mm apart, deep green above, whitish green beneath; subsessile or lower leaves with petiole 2.3–3 cm long, ca. 6 mm diameter; lamina oblanceolate, 11–12.5(–14.5) × 2.7–4.5 cm, narrowed to base, margin serrate, teeth tip rounded, 2–3 × 1.5–3 mm, towards the base teeth divided almost to midrib, 5–9 × 2.5–4.5 mm, apex acute to acuminate, above hairs dense, surface mammillate with hairs raised on narrow cones, minutely punctate beneath; midrib impressed above, prominent beneath, lateral veins 17–18 pairs. **Inflorescence** 1-flowered, rarely 2-flowered then flowers open in succession, peduncle 6–8.5 cm long, dark maroon-purple, slightly curved upward; bract pair pale green, positioned 5–10 mm below the calyx, narrowly lanceolate, 4–6 × 0.75–2



**Figure 1.** *Ridleyandra chuana* Kiew. **A** habit **B** flower.

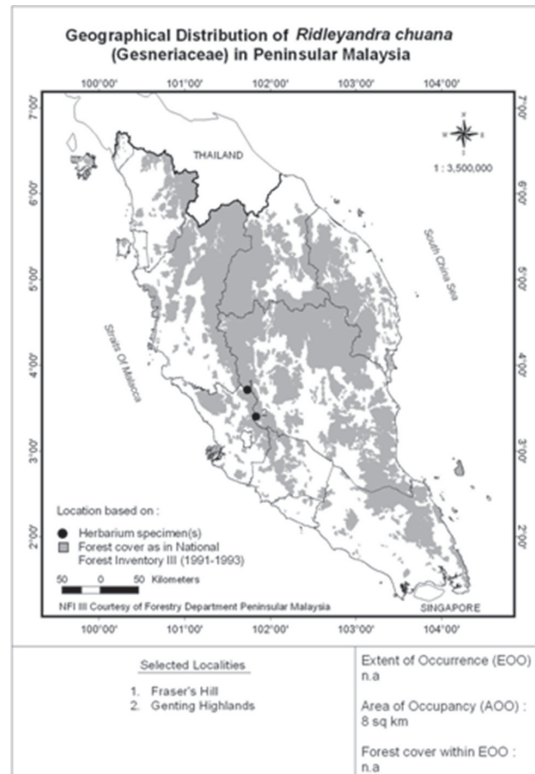
mm, pedicel dark maroon-purple, 5–7 mm long. **Flowers** with sepals divided to base, dull purple or pale green with a red midrib, lanceolate, 4–7.5 × 1.5–2.5 mm, hispid; corolla funnel-shaped, 3–4 cm to tip of lower lip, tube 2–3 cm long, ca. 2 mm diam. at base dilating to 10 mm at the mouth, outside minutely pubescent, white at the base becoming tinged purple at the tube dilates, inside white with mauve or purple lines with 3 lines extending into each of the three lobes where they spread and coalesce leaving a white margin around each lobe, lobes projecting ca 10 mm beyond the tube, lateral lobes ca. 4 × 5 mm and the centre lobe ca. 5 × 6 mm; stamens 4 in 2 pairs, filaments white, lower pair ca. 23 mm long, upper pair ca. 26 mm long, anthers creamy white, ca 1 mm long, joined in pairs, staminode ca. 3 mm long; nectary annular, ca. 1 mm high; ovary ca. 3 cm long, pale mauve, stigma white, broadly spatulate, ca. 2 × 1.5 mm long, apex emarginated. **Capsules** glossy, deep purple, slightly curved upward, glabrous, 5–6.5 cm long, 2.5–4 mm diam., sepals persistent and clasping the base.

**Distribution.** Endemic in Peninsular Malaysia, Pahang (Fraser's Hill and Gunung Uli Kali) (Map 1).

**Ecology.** On moss-covered granite rock embedded in soil or on low moss-covered granite boulders, in extremely damp, deeply shaded conditions on steep slopes in valleys. One population occurs in lower montane forest at 1250 m and the other in upper montane forest at 1570 m.

**Etymology.** Named in honour of Dr Lillian Swee Lian Chua, botanist and conservationist, who first discovered this species on Gunung Kali while making an ecological inventory of the summit flora (Chua and Saw 2001).

**Conservation status.** EN B2ab(ii,iii). Following the 2001 IUCN Red List Categories and Criteria, (IUCN, 2001) this species is assessed as Endangered because it is known from two localities, one of which is threatened and only 130 known individuals. The population at Fraser's Hill falls within a Totally Protected Area (Chua 2010)



**Map I.** Distribution of *Ridleyandra chuana* in Peninsular Malaysia.

and consists of about 30 plants that grow in an undisturbed site away from tourist trails and is too remote to be affected by development. The other population consists of less than 100 plants at Gunung Ulu Kali, which is on private land in a hill resort that is severely threatened by road widening and associated landslips, by changes in microclimate due to edge effect as the forest becomes more and more fragmented and from and that is in danger of encroachment from future development. The chance of this latter population surviving is very slim. On the other hand, the rediscovery of the Fraser's Hill population after a hundred years illustrates the resilience of species to survive if the habitat remains undisturbed.

**Other specimens examined. Peninsular Malaysia.** Pahang: Gunung Ulu Kali– 26 Nov 2007 LSL Chua & R Kiew FRI 46936 (KEP!); Fraser's Hill– 4 Nov 1932 EJH Corner s.n. (SING!), 16 Aug 1937 EJH Corner s.n. (SING!), 18 Nov 2007 MY Chew et al. FRI 53772 (KEP!), 24 Feb 2008 R Kiew RK 5412 (KEP!).

**Discussion.** Plants in both populations are identical in all characters except for sepal length (6.5–7.5 mm in the Ulu Kali population and ca. 4 mm in the Fraser's Hill population).

In both the original collections (Chua FRI 40758 and Corner s.n. 1932) only a single flowering specimen was collected suggesting that this is not a free-flowering

species. Monitoring over a longer period by JPC Tan suggests that there is a low level of flowering throughout the year with periodic bursts of more intense flowering. This same pattern is seen in some species of *Codonoboea*, such as *C. platypus* (C.B.Clarke) C.L.Lim (Kiew 2009b).

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# Utility of QR codes in biological collections

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## Abstract

The popularity of QR codes for encoding information such as URIs has increased exponentially in step with the technological advances and availability of smartphones, digital tablets, and other electronic devices. We propose using QR codes on specimens in biological collections to facilitate linking vouchers' electronic information with their associated collections. QR codes can efficiently provide such links for connecting collections, photographs, maps, ecosystem notes, citations, and even GenBank sequences. QR codes have numerous advantages over barcodes, including their small size, superior security mechanisms, increased complexity and quantity of information, and low implementation cost. The scope of this paper is to initiate an academic discussion about using QR codes on specimens in biological collections.

## Keywords

Barcode, catalogue, collection, database, hard-linking, matrix code, museum, QR code

## Introduction

There are 55,000 museums in 202 countries containing a variety of collections from art to zebras (De Gruyter 2012). More than 7,000 biological collections worldwide (CBoL et al. 2013) preserve 1.2–2.1 billion specimens (Ariño 2010), although only ~405 million have been digitized (GBIF 2013). With such a large number of specimens, it is critical that the information be made available for research. However, the best way to link specimens to databases and other materials is still under discussion. Some options include *unique specimen identifiers* (USIs), *globally unique identifiers* (GUIDs), *life science identifiers* (LSIDs).

Currently, one of the most frequently used methods is *Barcoding*. This method was implemented in biological collections in the 1990s at INBio and the Smithsonian Institution (Janzen 1992, Thompson 1994). Barcodes are one-dimensional optical representations, where widths and spacing of parallel lines are translated primarily into numeric data. Electronic devices decode the information (usually a 13-digit number and a few letters), which is linked to a database. The idea for modern barcodes arose in 1948 in response to the need from industry to develop a system to quickly capture product data at supermarkets during the check-out process (Brown 1997). By 1949, Bernard Silver and Norman J. Woodland, both from Drexel University, filed a patent application with the prototypes of barcodes called “Classifying Apparatus and Method”, issued in 1952 (Brown 1997, Woodland et al. 1952). By 1966 the first barcodes started to be used commercially (Brown 1997); in 1973 George J. Laurer proposed a standardized barcode system called Uniform Product Code (UPC), and in 1974 the first UPC scanner was installed in a Marsh supermarket in Troy, Ohio (Brown 1997). A 10-pack of Wrigley’s Juicy Fruit chewing gum, today preserved at the National Museum of American History, was the first product in history to have a barcode on it, and their use in commercial situations increased rapidly.

Soon various sectors demanded smaller codes, capable of storing more information and more character types. Matrix codes, also called two-dimensional (2D) codes, were the ideal solution. Among them, QR codes (abbreviation from Quick Response Codes) have increased in popularity during the last few years. They were originally invented in 1994 by a Toyota subsidiary Denso Wave Incorporated (2013), which has chosen not to exercise their patent rights (Denso Wave Incorporated 2013).

QR codes have nine standard features (Denso Wave Incorporated 2013):

1. Capacity to handle different types of data: numeric and alphabetic characters, Kanji, Hiragana, Katakana, symbols, binary and control codes.
2. Large capacity: up to 7,089 numeric and 4,296 alphanumeric characters can be encoded (hundreds of times more than in a barcode).
3. Small printout size: the same information can be encoded in a QR code one-tenth smaller than a barcode.
4. High speed scan: omni-directionally readable, with position detection patterns circumventing the negative effects of background interference.
5. Universal standardization: AIM International Standard, Japanese Industrial Standard and ISO International Standard (ISO/IEC18004).
6. Dirt and damage error correction: QR codes allow a maximum of 30% of damage without losing information, with four levels of security (L (7% of tolerance), M (15%), Q (25%) and H (30%)).
7. Compartmentalization: QR codes can be divided into multiple data areas (as many as 16), allowing smaller printouts.
8. Flexible representation: shapes and colors of modules can be changed, even allowing for artistic representations (QR code Art).
9. Readability: QR codes can be read by any smartphone, tablet or laptop with a camera, using freely available software.

A few remarkable uses of QR codes go beyond the codes themselves. For instance, websites linked in QR codes can be displayed in the user's preferred language. This was first implemented by QRpedia (<http://qrpedia.org>) in 2011, to deliver a Wikipedia article in the user's language using just one QR code. This is how it works:

1. The QR code has to encode an URL containing the domain name "qrpedia.org" and the path (final part) to the title of a Wikipedia article. For example, if the Wikipedia article's URL in Spanish is <http://es.wikipedia.org/wiki/Asteraceae>, the QR code should encode the URL <http://es.qrpedia.org/Asteraceae>.
2. When the device navigates to the URL contained in the code, its language setting is sent to the QRpedia web server as well (e.g. English).
3. The QRpedia server then uses Wikipedia's API to look for a version of the article in the language specified (e.g. English), and if it finds one, returns it in a mobile-friendly format. If none are found, then the QRpedia server offers a choice of the available languages, or a Google translation. In the example above the resolved URL would be <http://en.m.wikipedia.org/wiki/Asteraceae>.

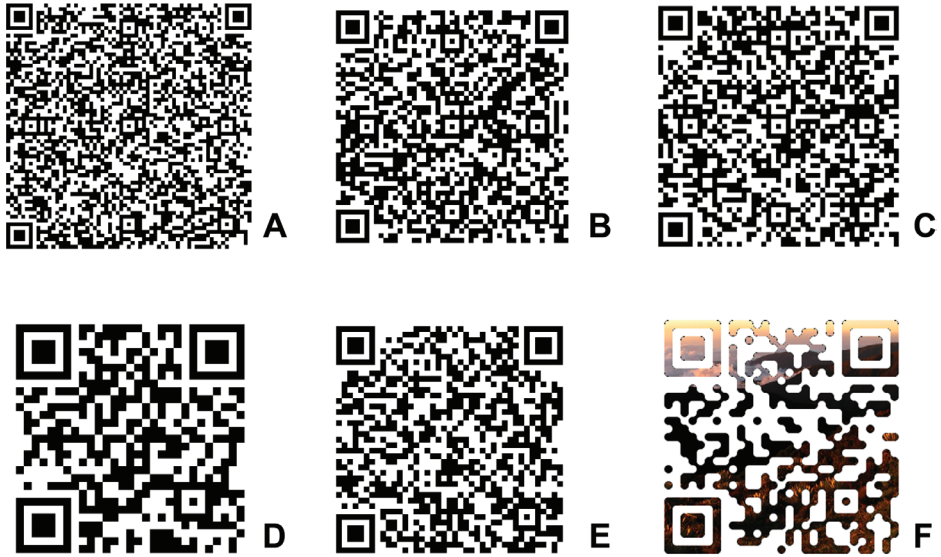
Another relevant characteristic is the possibility of providing statistics (e.g. with Google Analytics) about usability of each code: how many times a code has been scanned, location of individuals who scanned it, user's interest (i.e. where code was located), economic utilities associated to a particular code when transactions are generated, etc. For the statistics to be accurate, a unique URL has to be encoded in a QR code, so that the only way to visit the website is by scanning the QR code (e.g. statistics for Fig. 1D can be checked in the website provided in Fig. 1E).

Applications of QR codes range from commercial tracking, transport and entertainment ticketing, visa and passport information, delivering of Wikipedia articles (QRpedia), songs downloading, to encrypted government data (Denso Wave Incorporated 2013). QR codes are also being implemented in libraries in different ways (Ashford 2010). Information that is typically encoded includes vCard contacts, Uniform Resource Identifiers (URI), e-mail addresses, map directions and text.

Despite the fast expansion and popularization of QR codes, they have not been openly incorporated into natural history collections. Their use as USIs or to replace labels in small specimens (e.g. insects) has been briefly suggested in previous works (Blagoderov et al. 2012, Mantle et al. 2012, Schuh 2012), without giving details about advantages or implementation. Currently botanical gardens, a few zoos and various museums are using QR codes to link, for instance, specimens in exhibits to Wikipedia articles.

Some of the reasons to explain their reluctant appearance in natural history collection are:

1. Lack of general knowledge about potential and implementation of QR codes: according to eMarketer (2013), 23–36% of adults (25 to 34 years old) in USA and Europe have scanned a QR code. People usually associate QR codes with URLs, but that is only a limited use.



**Figure 1.** Examples of potential uses of QR codes in Natural History collections. **A** “*Ruitlopezia cardonae* (Cuatrec.) Cuatrec. (coll. M.Diazgranados & R.Sánchez 3257). Cited in: Diazgranados M (2012) A nomenclator for the frailejones (Espeletiinae Cuatrec., Asteraceae). *PhytoKeys* 16: 1–52 (<http://www.pensoft.net/journals/phytokeys/article/3186/abstract/>)” **B** “Genbank Accession JN837330: <http://www.ncbi.nlm.nih.gov/nuccore/JN837330.1>” **C** “Photographs of this collection: [http://espeletia.org/galleries/main.php?g2\\_view=tagtree.VirtualAlbum&g2\\_tags%5B0%5D=815&g2\\_albumId=7](http://espeletia.org/galleries/main.php?g2_view=tagtree.VirtualAlbum&g2_tags%5B0%5D=815&g2_albumId=7)” **D** “<http://en.qrwp.org/Sunflower>” **E** “Statistics of Fig. 1 D: <http://qrwp.org/stats.php?path=Sunflower>” **F** “<http://espeletia.org/>”. Readability of these QR codes was tested using an iPhone 4 with Qrafter and Quick Scan.

2. Concerns about the permanence of this technology: collection managers are often unwilling to invest time and resources in a new technology, if they are unsure about its long-term permanence. This is part of the reason there was a lag time of 26 years between the original commercial use of barcodes and their use in natural history collections. But there is also a concern that with technology changing so fast, the long-term permanence of QR codes is difficult to predict.
3. Security concerns (i.e. malicious links or websites). Since QR codes are illegible for the human mind, curators are afraid to link their devices to undesirable websites.
4. Implementation costs: as discussed below, implementing a new technology can be expensive. According to Green (2010), implementing a barcode tracking solution in a middle-size organization costs in average €40,000 (including software licenses, barcode and wireless mobile computer equipment and professional services).

We intend to show the advantages of using QR codes to hard-link specimens to digital resources associated with them. In addition to hundreds of millions of iPods (Apple Inc.) and tablets, there are more than one billion smartphones in use, projected to double by 2017 according to Sui (2013). Virtually any curator or visitor could use one of these devices to quickly access digital information related to the specimen.

QR codes have numerous potential uses in Natural History collections: 1) to provide metadata (e.g., rights of use, proposed citations, projects or particular collections, references, collector contact information); 2) to provide supplementary specimen or species information (e.g., chromosome counts, additional field notes, ecosystem details); 3) to link to digital resources (e.g., photographs, maps, videos, audios, supplementary information); and 4) to provide this information in multiple languages (see examples in Fig. 1). Even though multiple methods have been used in the past to do all this, QR codes provide a unique opportunity to use a personal device (e.g., a smartphone) to perform these tasks in a fast, simple, and graphical way. With QR codes the user would not have to write the collection identifier in a notebook, find a computer, and search in a database, they would only need to point their devices at the code to obtain the links for photographs, maps, etc. When the Internet is accessible through the telephone network (the usual situation in smartphones and tablets), Wi-Fi is not even necessary. Because traditional Barcodes require special scanners plugged to computers with access to the database the information is accessible only by staff. QR codes, however, can contain links that will allow any user to access all the information and some applications allow users to scan multiple QR codes and save results in numerous formats, which would speed up data gathering. Finally, QR codes could be even used to backup digital information from specimens.

## General considerations and recommendations

Projects that implement QR codes on natural history specimens require clear goals. For instance, if Uniform Resource Locators (URLs) are going to be encoded, long-term permanence of URLs must be guaranteed. An alternative for small institutions is the creation of Persistent Uniform Resource Locators (PURLs) that point to other URLs (OCLC 2013). Various PURLs resolvers such as OCLC (2013) are available for free on the Web. Examples of PURLs are the digital object identifiers (DOIs), commonly used in scholarly materials (journal articles, books, etc.). The creation of PURLs is simple and batches of PURLs can be created via API or with Java, Perl or Python codes available online (e.g. Arase 2009, Kaszuba 2013, Perl Training Australia 2013). The resulting URLs should be thumb-interactive, purpose-driven and easy to read using smartphones or any other mobile scanning device.

QR codes follow strict standards (Fig. 2). The minimum unit of information is called a module. The number of modules affects size and amount of information, ranging from version 1 ( $21 \times 21$  modules) to version 40 ( $177 \times 177$  modules). The minimum size of a module is usually established depending on the printer and reader capabilities. The symbol area requires a 4-module wide margin or “quiet (clean) zone” around it (Fig. 2).

Code size and printer resolution are important to generate readable QR codes. The minimum size of the QR code modules depends on printer head density. Higher density improves quality printing, diminishing the effect of paper width and quality,



**Figure 2.** QR code structure and tolerance. Left: QR code with the maximum level of error correction (H: 30% of tolerance to damage). Right: Structure of the same QR code: yellow: quiet zone; red: position; orange: alignment; blue: timing; green: format information; cyan: version; grey and white: data and error correction modules.

Encoded text (including returns):

“US National Herbarium

Montanoa josei V.A. Funk (Asteraceae)

US Sheet No.: 2325539 | Barcode: 00128657

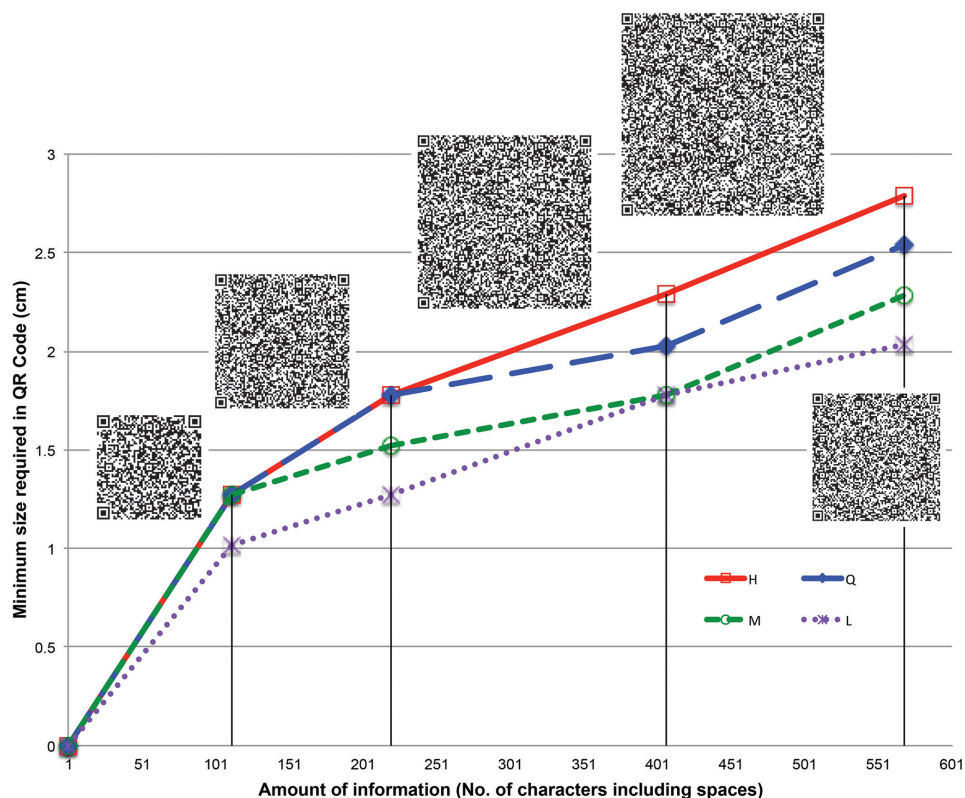
Specimen photographs: <http://collections.mnh.si.edu/search/botany/search.php?action=10&irn=10076557&width=495&height=640>”

feed speed fluctuations, distortion of axis, blurring, etc. The minimum module size in a Laser printer at 600 dpi (24 dot/mm) assuming a 4-dot/module configuration is 0.17 mm. A thermal printer at 200 dpi (8 dot/mm) and a 4-dot/module configuration prints a module of minimum 0.5 mm of side. Therefore a version 1 QR code (21 × 21 modules) with 30% of error correction (level H) should have a minimum printed size of 1.05 cm per side, leaving a quiet zone of 2 mm around the margins.

Another factor to consider is the scanner resolution. Standard scanners and smart-phone cameras have a resolution of 0.25 mm or less. Roughly 90% of these devices read QR codes of 26 × 26 mm, and the latest phones (2011 or newer) have usually macro capabilities allowing them to scan QR codes of 10 × 10 mm.

To determine minimum size, we tested readability of QR codes with 568, 406, 219 and 111 alphanumeric characters (including spaces), with the four levels of error correction (Fig. 3). All the codes were printed on rough-textured archival paper. Codes were scanned with an iPhone 4<sup>®</sup> and an iPad 2<sup>®</sup> using the free version of the software Qrafter (<http://keremerkan.net/downloads/>). Readable QR codes level H required a minimum size ranging from 1.27 cm (0.5 in) for 111 characters to 2.79 cm (1.1 in) for 568 characters. The minimum size required when using level L ranges from 1.02 cm (0.4 in) for 111 characters to 2.03 cm (0.8 in) for 568 characters. We recommend printing QR codes at least 2 mm bigger than the minimum size readable (e.g. 3 cm/side for codes encoding ~600 characters), and preferably using level H when coding information on specimens of natural history collections.





**Figure 3.** QR code size (side) vs. information for the four levels of error correction (L (purple line): 7% of tolerance; M (green line): 15%; Q (blue line): 25%; and H (red line): 30%). Below the lines QR codes are unreadable by most scanners; above the lines they are all readable.

Encoded text (including returns):

- 111 characters:

“Photographs: <http://collections.mnh.si.edu/search/botany/search.php?action=10&irn=10076557&width=495&height=640>”

- 219 characters:

“US National Herbarium

Montanoa josei V.A. Funk (Asteraceae)

US Sheet No.: 2325539 | Barcode: 00128657

Specimen photographs: <http://collections.mnh.si.edu/search/botany/search.php?action=10&irn=10076557&width=495&height=640>”

- 406 characters:

“US National Herbarium

Montanoa josei V.A. Funk (Asteraceae)

Collection: Cuatrecasas, J., Romero Castañeda, R.; 24768; Holotype; 1959-10-10; Colombia; Magdalena; Sierra Nevada de Santa Marta, Hoya del Rio Donachui, Cancrura. Elevation: 2400-2650 m.

US Sheet No.: 2325539 | Barcode: 00128657

Specimen photographs: <http://collections.mnh.si.edu/search/botany/search.php?action=10&irn=10076557&width=495&height=640>”

- 568 characters:

“Smithsonian Institution

National Museum of Natural History

US National Herbarium

Montanoa josei V.A. Funk

Family: Asteraceae

Collection: Cuatrecasas, J., Romero Castañeda, R.; 24768; Holotype; 1959-10-10; Colombia; Magdalena; Sierra Nevada de Santa Marta, Hoya del Rio Donachui, Cancunua.

Elevation: 2400-2650 m

Verification: Original publication and alleged type specimen examined

US Sheet No.: 2325539

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Specimen photographs: <http://collections.mnh.si.edu/search/botany/search.php?action=10&irn=10076557&width=495&height=640>

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When space is limited (e.g., small labels), lower security codes could be used, and even mini-QR codes.

The cost associated with the implementation of QR codes in biological collections needs to be considered carefully. Programming code for creating QR codes is freely available, and there are numerous QR code generation packages (including an API in Google), most of them free (see Appendix 1). With some free applications it is possible to develop thousands of QR codes for free. However, generating hundreds of thousands or millions of codes would require the purchase of specialized software (prices varying from € \$5 to \$1,000) or the development of an application using the available programming code. At those scales, even if the price of production is small, the investment in time and resources can be significant.

General considerations and recommendations are summarized in Table 1.

**Table 1.** Important considerations and recommendations for the implementation of QR codes

Topic	Attribute	Considerations & recommendation
Content	Amount of information	The more text included, the larger the size. A QR code encoding ~600 characters will require a minimum size of ~3cm/side.
	Type of information	QR codes can be use to provide metadata, label information, supplementary information, and links to digital resources.
	Language of content	To deliver content in different languages, a web server such as QRpedia has to identify the language of the scanning device.
	Statistics	URLs encoded in QR codes have to be unique to produce accurate statistics of readability.
	Long-term permanence of URLs	Always use permanent URLs (PURLs)
Design	Size	Size is affected by amount of text, error correction level, paper quality, and printer and scanner resolution. We recommend printing QR codes at least 2 mm bigger than the minimum readable size.
	Error correction	An error correction of 30% (level H) is recommended. This, however, increases the size of the QR code.



Topic	Attribute	Considerations & recommendation
	Paper quality	Consider long-term preservation when choosing paper quality. Archival paper has a rough texture, which slightly distorts shapes, affecting the minimum size required for readability. Printing QR codes on labels of new specimens is an inexpensive option. Another more expensive option is using the same materials currently used for Barcodes.
	Cleanness	QR codes require a “quiet” area around them and prefer black/dark print on a white/clear background.
	Printer resolution	Prefer high-quality printers. Test the minimum readable size of QR codes with your printer.
Bulk generation	Generation	Various resources can be used to produce thousands of QR codes for free. The production of batches of hundreds of thousands of QR codes requires adapting available programming code, or purchasing expensive software.
	Cost	The implementation of QR codes in large collections with millions of specimens can be extremely expensive. In those cases we suggest implementing them primarily for the new accessions.
Scanning	Scanner resolution	Most scanning devices (90%) read QR codes of 26 × 26 mm or bigger. For scanning smaller codes macro capabilities are often required.
	Scanning speed	The scanning speed is inversely related to the amount of information in the codes.
	Scanning tips	The device should be kept parallel to the code and as close as possible while still allowing it to focus. Edges of the code must be visible. It requires a few minutes of practice.
Security		QR codes could be used to direct the device to websites with malicious codes. We recommend: 1) collection managers should check QR codes and links from unverified sources before making them available; 2) users should only scan QR codes that have been approved by collection managers; 3) users should deactivate the automatic website launch option in their scanning software so they have the option of declining before it opens.

## Possible utility

QR codes provide a bridge between the digital and the physical world by delivering content to the most used electronic devices. The critical question is, what kind of information would a curator or visiting researcher find useful? QR codes can deliver plain text information combined with multiple links to online content. Plain text information could include institutional information, the label information, rights of use, or additional information not printed on the label, such as agencies and name of the project funding the collecting expeditions. Links to online resources can cover a broad spectrum, from information associated to the specimen itself to data related to the taxonomic entity, locality, research project, etc.

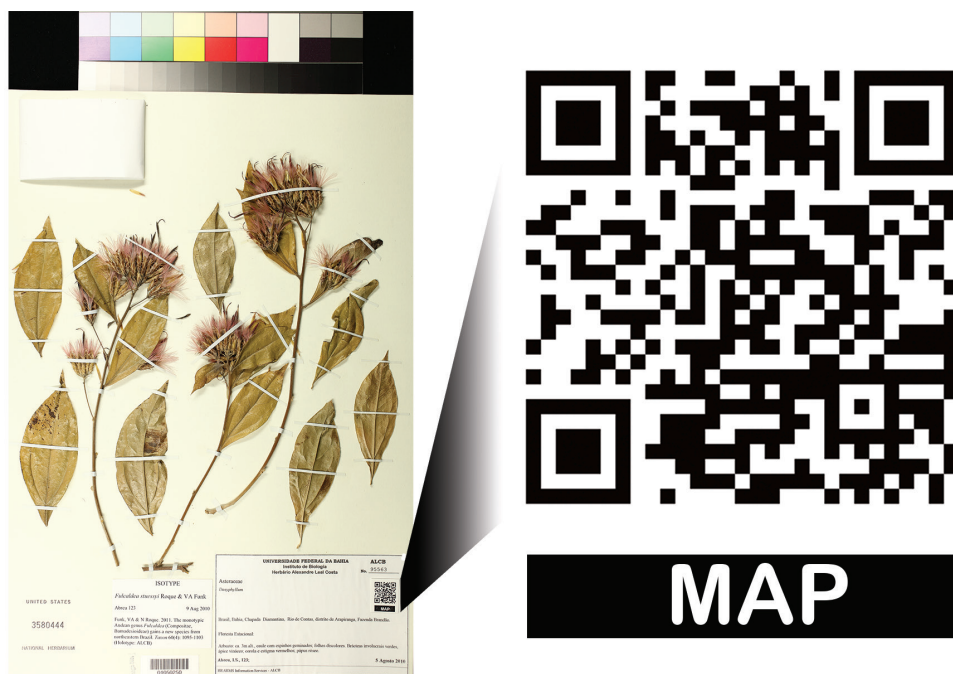
Some examples:

- Voucher-additional information (e.g., photographs, illustrations, maps, information in collector’s field books)

- Voucher-repositories for duplicates (e.g., Biorepositories: <http://www.biorepositories.org/>; Index Herbariorum: <http://sciweb.nybg.org/science2/IndexHerbariorum.asp>)
- Notes on conservation status (e.g., species in the IUCN Red List: <http://www.iucnredlist.org/>; or in CITES: <http://www.cites.org/>)
- Genetic information (e.g., Barcode of Life Database: <http://www.barcodinglife.org/>; NCBI Genbank: <http://www.ncbi.nlm.nih.gov/>)
- Data (e.g., Dryad: <http://datadryad.org/>)
- Nomenclatural resources, digital keys and databases (e.g., Lucid keys: <http://www.lucidcentral.com/>; Tropicos: <http://www.tropicos.org/>; International Plant Names Index: <http://www.ipni.org/>; Integrated Taxonomic Information System: <http://www.itis.gov/>; Global Names: <http://www.globalnames.org/>; The Plant List: <http://www.theplantlist.org/>)
- Checklists, catalogues and encyclopedias (e.g., Catalogue of Life: <http://www.catalogueoflife.org/>; Encyclopedia of Life: <http://eol.org/>; Species 2000: <http://www.sp2000.org/>; eFloras: <http://www.efloras.org/>; Global Biodiversity Information Facility: <http://www.gbif.org/>; NCBI Taxonomic Browser: <http://www.ncbi.nlm.nih.gov/taxonomy>; and regional and local faunas and floras)
- Links to Wikipedia articles, using QRpedia to deliver content in the user's preferred language.
- Morphological databases (e.g., Morphbank: <http://www.morphbank.net/>, Paldat: <http://www.paldat.org/>)
- Online maps or geographic gazetteers (e.g., Google Maps: <https://maps.google.com/>, Google Earth: <http://www.google.com/earth>, Mapquest: <http://www.mapquest.com/>, Yahoo! Maps: <http://maps.yahoo.com/>; Geographic Names Information System: <http://geonames.usgs.gov/>; GeoNames: <http://www.geonames.org/>; GEOnet Names Server: <http://earth-info.nga.mil/gns/html/>). See example in Fig. 4.
- Links to protocols and libraries (e.g., Biodiversity Heritage Library: <http://www.biodiversitylibrary.org>; JSTOR Plant Science: <http://about.jstor.org/global-plants>)
- Phylogenies (e.g., Tree of Life: <http://tolweb.org/tree/>, TreeBASE web: <http://treebase.org/>)
- Links to funding agencies (e.g., projects funded using national and international resources could display that information)

## Final remarks

Are the QR codes going to be outdated soon? Are they going to be replaced by another 2D code? Similar questions were asked in the '60s concerning barcodes, and five decades later we are still using them. While there is no immediate answer to these questions, it must be pointed out that QR codes have rapidly inundated vast sectors of



**Figure 4.** Example of plant specimen at the US herbarium with a QR code linking to a Google map of the collection locality. Encoded text: “<http://bit.ly/130tnzO>”.

the industry. Long-term permanence of QR codes depends largely on popularity, and not even the High Capacity Color Barcodes (HCCB) released by Microsoft in 2007 acquired similar popularity in such a relatively short time.

Small institutions with tight budgets can still implement this technology, without having to spend preposterous amounts of money. If there is no Wi-Fi, users can still connect to the Internet through their phone networks. If there are no phone networks available, devices can be used to record the information contained in QR codes as text (e.g. label information from large batches of specimens).

One concern that has been expressed about QR codes is the potential presence of malicious code either in the codes themselves or on the websites they link to. Most of the scanning applications now have URL safety check services to detect malicious content. Recommendations for countering this problem are mentioned in Table 1.

Scanning QR codes using smartphones, iPods and digital tablets has become a common practice and there are more than 25 applications for doing this, most of them free of charge (see Appendix 2). QR codes are quickly penetrating the mainstream and represent an opportunity to facilitate access to specimen information. We already have a critical mass of the population with devices capable of using this technology, and in the near future people may be pointing their phones and tables to QR codes on natural history specimens to obtain more information.

## Acknowledgements

We want to thank Tom Hollowell, John Keltner, Daniel Mietchen and two anonymous reviewers for their valuable comments to this manuscript.

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## Appendix 1

List of URLs for QR Code generators. (doi: 10.3897/phytokeys.25.5175.app1) File format: Adobe PDF file (PDF).

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**Citation:** Diazgranados M, Funk VA (2013) Utility of QR codes in biological collections. *PhytoKeys* 25: 21–34. doi: 10.3897/phytokeys.25.5175 List of URLs for QR Code generators. doi: 10.3897/phytokeys.25.5175.app1

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## Appendix 2

List of URLs for QR Code scanning applications. (doi: 10.3897/phytokeys.25.5175.app2) File format: Adobe PDF file (PDF).

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**Citation:** Diazgranados M, Funk VA (2013) Utility of QR codes in biological collections. *PhytoKeys* 25: 21–34. doi: 10.3897/phytokeys.25.5175 List of URLs for QR Code scanning applications. doi: 10.3897/phytokeys.25.5175.app2

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# From introduced American weed to Cape Verde Islands endemic: the case of *Solanum rigidum* Lam. (*Solanaceae*, *Solanum* subgenus *Leptostemonum*)

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## Abstract

A *Solanum* species long considered an American introduction to the Cape Verde Islands off the west coast of Africa is identified as *Solanum rigidum*, a member of the Eggplant clade of Old World spiny solanums (*Solanum* subgenus *Leptostemonum*) and is probably endemic to the Cape Verde Islands. Collections of this species from the Caribbean are likely to have been introduced from the Cape Verde Islands on slave ships. We discuss the complex nomenclatural history of this plant and provide a detailed description, illustration and distribution map. The preliminary conservation status of *S. rigidum* is Least Concern, but needs to be reassessed in light of its endemic rather than introduced status.

## Keywords

Africa, aubergine, Cape Verde Islands, Caribbean, description, eggplant, typification

## Introduction

*Solanum* L. (*Solanaceae*) is the largest genus of *Solanaceae*; with some 1400 species, it is one of the largest angiosperm genera (Frodin 2004). Species of *Solanum* occur on all temperate and tropical continents, with the highest diversity of both groups and

species in tropical South America, concentrated in circum-Amazonia (Knapp 2002). The last time *Solanum* was monographed in its entirety was in De Candolle's *Prodrromus* (Dunal 1852), which included 901 species (with an additional 19 incompletely known). *Solanum* taxonomy has proceeded in a piecemeal fashion until relatively recently and the genus has acquired a reputation of being intractable. A project funded by the United States National Science Foundation's Planetary Biodiversity Inventory (PBI) program begun in 2004 seeks to redress this situation by accelerating species-level taxonomic work across the entire genus. Current work by participants of the "PBI Solanum" project (see [www.nhm.ac.uk/solanaceaesource](http://www.nhm.ac.uk/solanaceaesource)) will result in a modern monographic treatment of the genus available online. This contribution is part of that collaborative effort.

Although *Solanum* is predominantly a New World group, two clades of Old World species are resolved in molecular phylogenetic analyses (Bohs 2005). The largest of these is the "Old World Clade" of the spiny (prickly) solanums (subgenus *Leptostemonum* Bitter) which comprises approximately 100 species across Asia and Africa, plus an additional ca. 100 species endemic to Australia (Symon 1981). We have recently completed a monograph of the spiny solanums of continental Africa and Madagascar (Vorontsova and Knapp in press) and although species from the offshore African islands such as the Canaries and Cape Verdes were not included, their status and morphology were reviewed as part of the larger work. In so doing, we found that a species from the Cape Verde Islands that was considered an introduction from the New World was in fact a member of the Old World Clade of the spiny solanums. In addition, the name by which it had been identified for over 70 years was ambiguous and confusing and was proposed for rejection (Knapp 2011) under the rules of the *International Code of Nomenclature for algae, fungi, and plants* (McNeill et al. 2012). Here we provide a description of this species, ascertain its correct name and discuss its probable relationships.

## Materials and methods

This study is based on examination of herbarium specimens from the herbaria listed in the text, and comparison with a large (>5000) number of specimens of *Solanum* species from the African continent used in the preparation of our monograph on the prickly *Solanum* of continental Africa and Madagascar (Vorontsova and Knapp in press). Type specimens were obtained on loan from the relevant herbaria, or examined digitally through JSTOR Global Plants (<http://plants.jstor.org/>) and Sonnerat (<http://coldb.mnhn.fr/colweb/form.do?model=SONNERAT>). We cite all specimens examined that have locality data here, and full details can be found on the Solanaceae Source website (<http://www.solanaceaesource.org>).



## Taxonomic treatment

### *Solanum rigidum* Lam., *Tabl. Encycl.* 2: 23. 1794.

urn:lsid:ipni.org:names:820779-1

[http://species-id.net/wiki/Solanum\\_rigidum](http://species-id.net/wiki/Solanum_rigidum)

Figs 1–3

*Solanum latifolium* Lam., *Encycl. (Lamarck)* 4: 303. 1797.

urn:lsid:ipni.org:names:819759-1

Type: Cultivated in the Jardin du Roi in Paris, “Cette plante a été cultivée au jardin des Plantes. Ce soupçonne originaire d’Amérique” (no specimens cited, none found; synonymy ex descr., see Discussion).

*Solanum heteracanthum* Dunal, *Encycl. Suppl. [Poiret]* 3: 773. 1814.

urn:lsid:ipni.org:names:819434-1

Type: “Africa?”, sin. loc., *DuPuis s.n.* (lectotype, designated here: P [P00344411]).

Type: Cultivated in the Jardin du Roi in Paris, origin unknown, *Anon. s.n.* (lectotype, designated here: P [P00357615]).

**Description.** Herbaceous subshrub to shrub, 0.6–1.5 m tall, armed; stems erect, densely (occasionally sparsely) pubescent with sessile or short-stalked translucent stellate trichomes < 0.5 mm long, the rays 4–6, ca. 0.5 mm long, the midpoints equal to the rays, prickly with straight to slightly curved broad-based prickles of varying lengths, 2–6 mm long, these sparsely stellate-pubescent; new growth densely stellate-pubescent, yellowish-brown in dry plants; bark of older stems dark greyish brown, not markedly glabrescent. Sympodial units difoliate and usually geminate, the leaves of a pair equal in size and shape. Leaves simple, 4.5–14(18) × 3.5–8.5(14) cm, elliptic, membranous to somewhat chartaceous, concolorous; upper surfaces sparsely pubescent with sessile (with some short-stalked) translucent stellate trichomes, the rays 3–4, ca. 0.3 mm long, the midpoint equal to the rays or occasionally somewhat longer; lower surfaces more densely pubescent with short-stalked or occasionally sessile translucent stellate trichomes to 0.3 mm long, the rays 4–5(–6), to 0.6 mm long, the midpoint equal to the rays, the lamina still easily visible; primary veins 3–5 pairs, drying yellowish, with 2–6 pale tan prickles to 6 mm long on both surfaces; base attenuate, usually decurrent onto the petiole; margins shallowly lobed, the lobes 3–4 on each side of the midrib, lobed 1/4–1/3 of the way to the midrib, the apices acute; apex acute; petioles usually somewhat winged from the decurrent leaf bases, 1.5–4.5 cm long, densely stellate-pubescent like the stems, usually with a few pale tan prickles of varying lengths, to 6 mm long, these straight or very slightly curved. Inflorescence 1–2.5 cm long, internodal (lateral) or opposite the leaves, simple or only once branched, with 5–6(10) flowers, the lowermost flower(s) hermaphroditic and the plants andromonoecious, densely pubescent with sessile or short-stalked translucent stellate trichomes with rays to 0.3 mm long like those of the stems; peduncle (0–)1–2 cm long, the lowermost flower often borne at the very base of the inflorescence; pedicels 1–1.5 cm long, 1–2 mm in diameter, densely stellate-pubescent like the rest of



**Figure 1.** Habit of *Solanum rigidum* on the Cape Verde Islands. Photograph courtesy of MC Duarte.

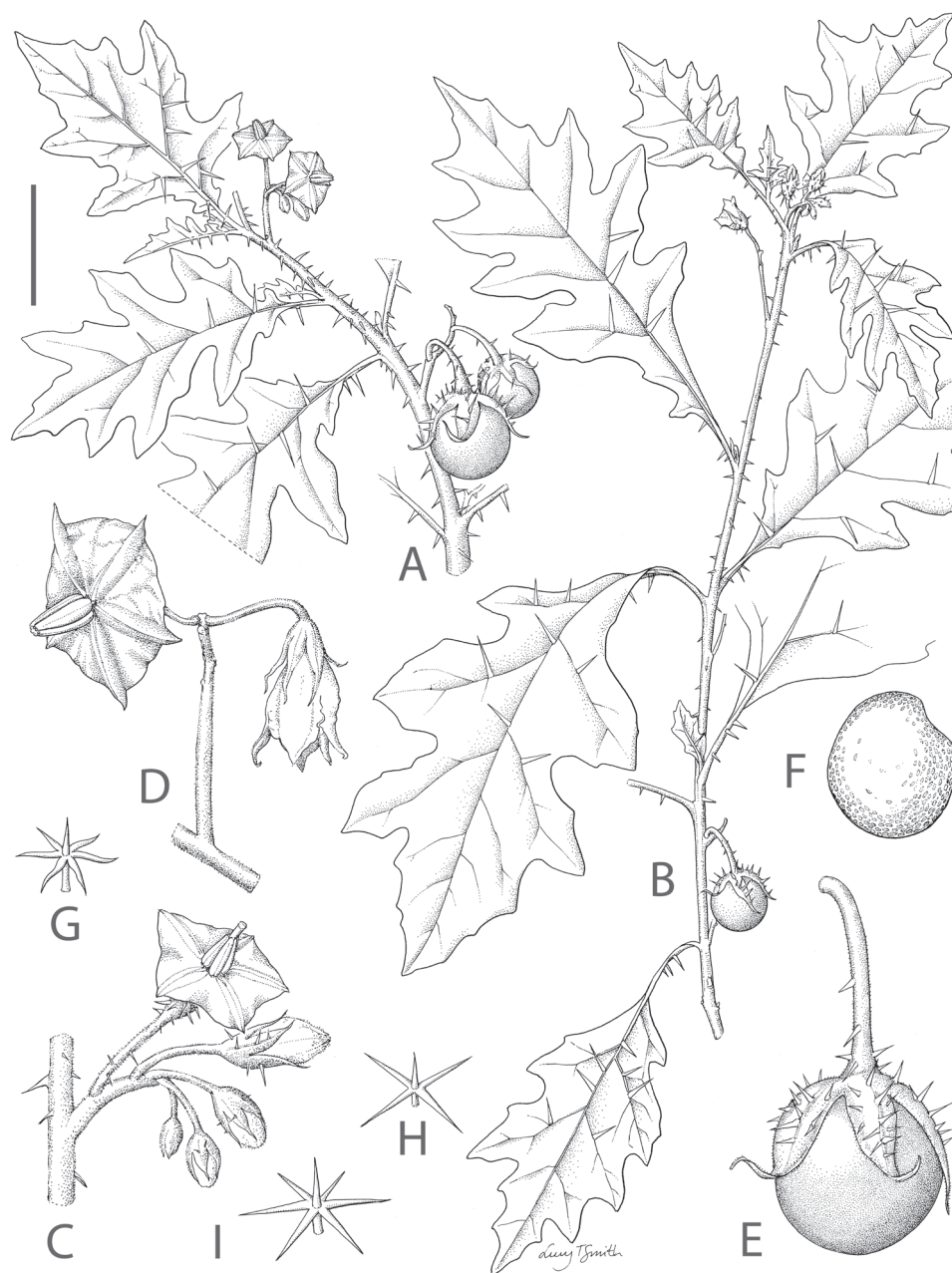
the inflorescence, that of the lowermost hermaphroditic flower usually somewhat stouter and usually with >10 pale tan prickles to 4 mm long, usually nodding at anthesis, articulated at the base; pedicel scars unevenly spaced 1–5 mm apart, the distance greatest between the lowermost flower and the rest. Buds elongate ellipsoid, the corolla approximately halfway exerted from the calyx before anthesis. Flowers 5-merous, strongly heterostylous, the lowermost (or lowermost 2–3) flower long-styled and hermaphroditic, usually slightly larger than the rest, the distal flowers short-styled and functionally male. Calyx tube 4–4.5 mm long, cup-shaped, the lobes 6–7 mm long, narrowly triangular with attenuate tips, densely pubescent with sessile and short-stalked stellate trichomes like those of the rest of the inflorescence, those of the hermaphroditic (long-styled) flowers usually with 5–25 yellowish prickles to 4 mm long. Corolla 2.5–3 cm in diameter, violet or white (type only), pentagonal with abundant interpetalar tissue, lobed less than 1/4 of the way to the base, the lobes 2–5 × 2–5 mm, usually with small acumens, planar at anthesis, glabrous adaxially, occasionally with a few stellate trichomes on the tips and margins, densely stellate-pubescent abaxially in a band 1.5 mm wide on either side of the petal midvein (exposed area in bud), the interpetalar tissue glabrous and thinner. Stamens equal, the filament tube ca. 0.5 mm long, the free portion of the filaments ca. 1.5 mm long, glabrous; anthers 6–7 × ca. 1.5 mm, usually slightly longer in hermaphroditic flowers, tapering, yellow, poricidal at the tips, the pores directed distally. Ovary densely pubescent with translucent stellate trichomes with 3–5 rays ca. 0.25 mm long; style 12–15 mm long in long-styled flowers, 1–1.5 mm long in short-styled flowers, sparsely pubescent with stellate trichomes like those of the ovary, these denser near the base; stigma expanded, bi-lobed. Fruit a globose berry, 2.5–3.5 cm in diameter, usually only 1 per infructescence, when immature mottled green and whitish green, maturing yellow, the pericarp leathery, ca. 1 mm thick, glabrous when mature; fruiting pedicels 2–2.5 cm long, 2–3 mm in diameter, thick and woody, pendent, pubescent and prickly as in the flowering pedicels; fruiting calyx splitting to the base, the lobes to 1 cm long, the tips usually reflexed at fruit maturity. Seeds > 100 per berry, 3–4 × 2.5–3 mm, reniform and slightly ovoid, not thickened at the margins, pale yellow or yellowish tan, the testal cells sinuate in outline. Chromosome number not known.

**Distribution.** (Fig. 4) Endemic to the Cape Verde Islands, known from seven of the ten islands of the archipelago, on both the windward and leeward arcs; a few old collections from the Caribbean (see Discussion). Like most prickly solanum species, *S. rigidum* is a plant of disturbed and open areas and is somewhat weedy; it grows from sea level to 100 m.

**Common names and uses.** Olho de vaca; olho de boi (cow's eye, bull's eye – perhaps in reference to the globose fruits).

**Discussion.** *Solanum rigidum* has long been treated as *S. fuscatum* L. (Linnaeus 1762), and as an American introduction to the Cape Verde Islands, rather than the endemic species that it is. Use of the name *S. fuscatum* (proposed for rejection due to its inconsistent and complex usage since its first description, Knapp 2011; rejection supported by Committee on Vascular Plants [17 for, 0 against, 1 abstention], see Applequist 2012) began in the early 20<sup>th</sup> century with Chevalier's (1935: 904) treatment





**Figure 2.** *Solanum rigidum*. **A** habit with dense prickles and small deeply lobed leaves **B** habit with sparse prickles and larger more shallowly lobed leaves **C** inflorescence with a single lowermost hermaphroditic long-styled flower at the base **D** inflorescence with distal functionally male short-styled flowers **E** immature fruit and fruiting calyx with attenuate calyx lobe tips **F** seed **G** stellate trichome from the stem **H**, **I** stellate trichomes from the lower surface of the leaf. **A**, **C**, **G–I** drawn from *Martins et al* 468 **B**, **F** drawn from *Barbosa & Silva* 14072 **D**, **E** drawn from photographs of MC Duarte. Drawn by Lucy T. Smith.

of the plants of the Cape Verde archipelago; he assumed that this spiny solanum species was an introduction from the Americas, presumably from Linnaeus' indication of origin of *S. fuscatum*, or Dunal's (1814) suggestion that his *S. heteracanthum* was similar to "*S. fuscatum*", and that assumption has persisted in floristic work since that time.

We have lectotypified *S. rigidum* with a sheet in the Lamarck herbarium (P00357615, online at <http://tinyurl.com/rigidum-LT>) that is annotated with a reference to "illustr.", the original place of publication (Lamarck 1795). *Solanum latifolium* was also described by Lamarck (1797) a few years after *S. rigidum*; he stated "Cette espèce a de très-grandes rapports avec le precedente [S. rigidum], dont elle differe par beaucoup moins de roideur, par sa tige droite, beaucoup plus élevée, par de très grandes feuilles large, & par ses grappes de fleur disposées le long de branches, & moins terminales" [This species has great affinity with the preceding, but differs in that it is less rigid, its straight stem that is much taller, its large leaves and its inflorescences disposed along the branches and less terminal]. We have not found specimens that match the protologue, but have not yet exhaustively searched the herbarium at P, where such a sheet, if it exists, should be found; we therefore include this name in synonymy from the description, and postpone lectotypification until an exhaustive search has been made. *Solanum latifolium* has been attributed to Abbé Jean Louis Marie Poiret by some authors (e.g., Gooding 1965), and many specimens of the Cuban endemic *S. gundlachii* Urb. (see Knapp 2009) were annotated as such. The epithet *latifolium* clearly is attributable to Lamarck; Poiret was responsible for volumes 5–8 of the *Encyclopedie Methodique*, not volume 4 in which the epithet appears. A fragment of leaf at F (F-676645) labelled "*Solanum latifolium* Poir." in Macbride's hand with a stamp indicating it originated from P matches the pubescence and prickliness of *S. rigidum*, but there are no flowers or fruits or leaf bases to be certain of its identity.

In describing *S. heteracanthum* Dunal (1814) cited a specimen in the Richard herbarium ("Dunal, in herb. Rich.") now held at P (P00344411). This is likely to be the holotype specimen but we prefer to designate this the lectotype as no specific sheet nor collector were cited in the protologue. This sheet is of a particularly prickly and possibly juvenile plant of *S. rigidum*; it has the characteristic elongate calyx lobes of this species.

A few collections from the Caribbean have confused understanding of the origins and distribution of this species; these plants may represent early introductions via the transatlantic routes used to transport the enslaved from Africa to the New World; these routes all passed through the Cape Verde archipelago from about 1560. Gooding et al. (1965) included the species (as *S. latifolium* Poir.) in their *Flora of Barbados*, and recorded its presence on Antigua and Barbados. We have seen no material referable to *S. rigidum* from later than 1935 nor collections from elsewhere in the West Indies (Knapp 2012); if it were a widespread introduction from the Caribbean we would expect collections from the Windward Islands, as most *Solanum* species from that region are found on multiple islands. Some records of "*S. latifolium*" may be prickly individuals of the cultivated eggplant, *S. melongena* L.; careful examination of specimens is necessary to determine the status of these records. Other members of the Eggplant clade are used medicinally in Africa and Asia (Meyer et al. 2011; Vorontsova and Knapp 2012) and this may account for the occurrence of *S. rigidum* in the Caribbean.

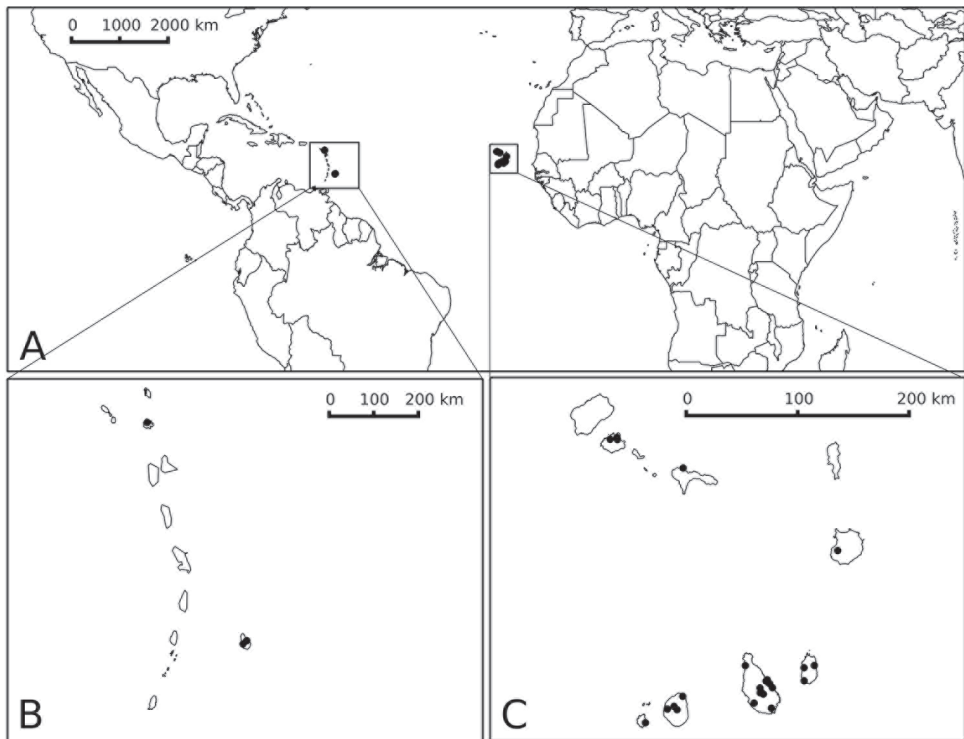


**Figure 3.** *Solanum rigidum* on the Cape Verde Islands. **A** immature fruit with upturned sepal lobes, **B** functionally staminate flower with copious interpetalar tissue. Photographs courtesy of MC Duarte.

Morphologically, *S. rigidum* does not resemble any American species or species group of solanums, but it is more similar to African species of the Eggplant clade such as *S. cerasiferum* Dunal and *S. campylacanthum* A.Rich. in its greyish green leaves (Fig. 1), violet flowers and spherical fruits with tough pericarp that is green-striped when immature (see Fig. 3A) and yellow when ripe. *Solanum rigidum* differs from those species in its densely pubescent ovaries and long acuminate calyx lobes that are upturned in fruit (Fig. 3A). It shares with those taxa a strongly andromonoecious breeding system, with a single or few hermaphroditic flowers at the base of the inflorescence and the distal flowers with short styles and functioning as males (Fig. 3B). Andromonoecy is common in the spiny solanums (subgenus *Leptostemonum* Bitter) and is found in both New and Old World species.

Two other *Solanum* species occur on the Atlantic islands off the African coast (Macronesia): *Solanum verspertilio* Aiton and *S. lidii* Sunding, both from the Canary Islands. Both those species have strongly zygomorphic flowers with strongly unequal anthers while the flowers of *S. rigidum* are actinomorphic with anthers of equal size.

Preliminary DNA sequence data (S. Stern and M.S. Vorontsova pers. comm.) also indicate that *S. rigidum* is a member of the Eggplant clade, a large group of mostly East African taxa that includes the cultivated eggplant *S. melongena* L. *Solanum rigidum*



**Figure 4.** Distribution map of *S. rigidum*. **A** global distribution in the Caribbean and the Cape Verdes **B** distribution on Antigua and Barbados **C** distribution on the Cape Verde Islands. Prepared by Paweł Ficinski.



may be of hybrid origin; in preliminary plastid analyses it is sister to *S. campylacanthum* while in trees based on the nuclear ITS region it is sister to *S. macrocarpon* L. (the gboma eggplant, a continental African species). The chromosome number of *S. rigidum* is not known, but *S. campylacanthum* is tetraploid in some parts of its range (see Knapp et al. 2013), while *S. macrocarpon* is diploid. The preliminary relationships based on molecular data may indicate hybrid origin, or introgression; further work on the cytogenetics of all members of the Eggplant clade is a priority (see Knapp et al. 2013).

The Cape Verde islands are geologically linked with the Canary Island archipelago (Patriat and Labails 2006) and have similar histories with the main volcanic episodes resulting in island emergence in the Cenozoic, although the basement igneous rocks are much older. The endemic *Solanum* species of the Canary Islands, *S. vespertilio* Aiton and *S. lidii* Sunding, are not closely related to the Eggplant clade but to South African taxa (Anderson et al. 2006) such as *S. capense* L. or to the paraphyletic “Anguivi grade” (Vorontsova et al. 2013). This supports a scenario where *S. rigidum* is the result of dispersal from the African mainland to the Cape Verdes, a distance of only 570 kilometres. Further molecular work, however, will be necessary to understand its origins and detailed relationships.

The discovery that *S. rigidum* is not an introduction from the Americas but instead an endemic species in the Cape Verde islands highlights the need for conservation assessment on the islands in order to determine its range and population sizes. *Solanum rigidum* occurs on both of the main island groups of the Cape Verdes, on São Vicente, São Nicolau and Boa Vista of the Ilheus de Barlovento, and on Maio, Santiago, Fogo and Brava of the southern Ilheus de Sotaventos (Fig. 4). Label data indicate *S. rigidum* occurs in disturbed habitats, often at the edges of washes and riverbeds, so it may be a weedy species despite its narrow geographic range and endemic status. Applying the IUCN criteria (IUCN 2001) results in a preliminary conservation status of Least Concern, given its occurrence on many of the islands of the archipelago, but given the endemic status of *S. rigidum* this should be re-assessed in the light of more accurate population and threat status levels with better field data.

**Specimens examined.** CAPE VERDE ISLANDS. **Boa Vista:** sin. loc., 7 July 1934, *A. Chevalier* 44897 (P). **Brava:** Cachaço, Cova do Mar, 200 m, 29 October 1983, *G. Cardoso de Matos* 5434 (LISC); on the Ponton Road to the Fort, 26 March 1864, *R. T. Lowe* s.n. (P); **Fogo:** entre as povoações de Lomba e Ribeira Filipe, 900 m, 1 November 1983, *G. Cardoso de Matos* 5505 (LISC); San Filipe, 18 July 1934, *A. Chevalier* 44800 (P); Mosteiros, junto a pista de aviação, 10 m, 13 October 1991, *Martins* 468 (LISC); Curral da Chão, entre Achada Furna e Miguel Gonçalves, 15 October 1991, *Martins* 510 (LISC). **Maio:** Pedro Vaz, 17 May 1956, *L.A. Grandvaux Barbosa* 7437 (LISC); Calheta, 9 November 1964, *J. Malato-Beliz* 141 (LISC); Pedro Vaz, 11 November 1964, *J. Malato-Beliz* 244 (LISC); Vila da Maia, Dunas de Morrinho, 17 November 1964, *J. Malato-Beliz* 360 (LISC). **Santiago:** São Jorge dos Orgãos, Ribeirão Galinha, 350 m, 22 October 1983, *G. Cardoso de Matos* 5304 (LISC); Ribeira Grande de Santiago, a longo de leito seco da Ribeira de Fundão depois de passar os regadios que estão junto as casas, 540 m, 15 July 1993, *M.C. Duarte* 540 (LISC); estrada Praia-Tarrafal, 1.1 km

depois Porto Fundo, 65 m, 9 December 1955, *L.A. Grandvaux Barbosa 5909* (LISC); Santa Cruz, aluviões do Ribeira da Cruz, 16 November 1982, *L.A. Grandvaux Barbosa 14072* (LISC); Ribeira de Santa Cruz, 20 March 1983, *L.A. Grandvaux Barbosa 14486* (LISC); between S. Domingo and Os Orgãos, 31 January 1866, *R.T. Lowe s.n.* (BM, LE); Villa do Praia, January 1861, *F.M.J. Welwitsch 6086* (BM); Pedra Badejo, 10 m, 17 October 1992, *M.C. Duarte 56* (LISC); Chã de Vaca, 277 m, 16 October 1994, *M.C. Duarte 701* (LISC); Foz da Ribeira de Mangue, 30 m, 11 July 1993, *M.C. Duarte 502* (LISC); Baia de Chão Bom, 2 m, 23 October 1994, *M.C. Duarte 1189a* (LISC); sin. loc, *C. Peters s.n.* (LE). **São Nicolau:** am Weg von Estancia Bras zum Ribeira Quameros, 50 m, 3 January 1986, *N. Kilian 1014* (B). **São Vicente:** Monte Verde, September 1934, *A. Chevalier 45744* (P); Porto Grande, 22 November 1894, *E.H.L. Krause 17687* (B); ascent of Monte Verde, 609 m, 5 January 1866, *R.T. Lowe s.n.* (BM).

**ANTIGUA AND BARBUDA.** *Antigua:* sin. loc, *Anonymous 16* (K).

**BARBADOS.** *Barbados :* Foster Hall Spring, January 1890, *H.F.A. Eggers 7226* (P); near Welches, St. Thomas, June 1935, *A.C.S. McIntosh 195* (P); Bathsheba and Hastings, April 1895, *J.F. Waby 53a* (BM, K).

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# ***Lettowia*, a new genus of Vernoniaeae from East Africa (Asteraceae)**

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## **Abstract**

A new genus, *Lettowia* H. Rob. & Skvarla is named for the single East African species originally described as *Vernonia nyassae* Oliv. Its pollen is lophate and triporate, with a perforated tectum restricted to the muri. The new genus is placed near *Vernoniastrum* in the subtribe Erlangeinae.

## **Keywords**

East Africa, *Lettowia*, new genus, triporate pollen

## **Introduction**

Since *Vernonia* Schreb. is a strictly American and mostly eastern North American genus (Robinson 1999a, b), a continuing effort is under way to properly reassign the species of the Eastern Hemisphere that have been erroneously placed in that genus. In previous efforts to resolve the species of Vernoniaeae from Africa, one species, *Vernonia nyassae* Oliv., was examined but left untreated. In a careful analysis of East African Vernoniaeae, Jeffrey (1988) keyed *V. nyassae* among species that are now mostly placed in the subtribe Erlangeinae, and the species was listed among those now mostly placed in the genus *Vernoniastrum* H. Rob. Robinson (1999a) studied but did not treat the spe-

cies; however, its possible relation to *Vernoniastrum* had been considered. The failure to include the species in that genus was because of the lack of the distinctive bands of idioblasts in the achene walls, and the presence of an inflorescence of single elongate unbranched erect scapes each bearing a single capitulum. *Vernoniastrum* has branched inflorescences with cauline leaves, and has bands of idioblasts in the achene wall that are visible with a hand-lens. For these reasons, the species is considered here to be related to *Vernoniastrum* but placed outside of that, hence in need of recognition as a new genus.

The present review includes a full description of the plant, including SEM studies of pollen, and a formal description of the new genus.

### Preparation of pollen

Pollen from dried buds was obtained from herbarium sheets at the U.S. National Herbarium in Washington, D.C. Detailed light microscope analyses under a Wild light microscope using oil and immersion optics were made of pollen in the dry condition as well as after immersion in Hoyer's solution (Anderson 1954). Scanning electron microscope (SEM) observations were made after acetolysis treatment (Erdtman 1960). *Lettowia nyassae* pollen was examined with a Hitachi S-570 SEM (at the United States National Museum of Natural History) after coating with gold/palladium. *Vernoniastrum nestor* pollen was examined with a Zeiss Neon 40 EsB dual beam SEM/FIB after metal coating treatments with osmium thiocarbonylhydrazide and gold/palladium (Chissie et al. 1995, 1996). Images were digitally processed and the final plates prepared using Adobe Photoshop 7.

### Taxonomic treatments

#### *Lettowia* H. Rob. & Skvarla, gen. nov.

urn:lsid:ipni.org:names:77130232-1

<http://species-id.net/wiki/Lettowia>

Figs 1, 2A, B

**Type.** *Vernonia nyassae* Oliv.

**Description.** Erect or decumbent perennial herbs from creeping rhizome or perennial root crown, all becoming erect, rosetteform, with erect pedunculate scapiform inflorescence; hirsute or pilose with long white hairs, hairs of stems, leaves and peduncles with cells uniseriate and with few short basal cells and long, acicular, rather stiff apical cell. Leaves alternate in loose basal rosette, mostly 2–4 cm long, petiole narrow, blade obovate, to 9 cm long and 1.5 cm wide, apically obtuse, cuneate into petiole at base, margins entire, slightly paler abaxially, pilose on margins and both surfaces, more densely pilose abaxially, few glandular dots adaxially, numerous dots abaxially. Scape





**Figure 1.** Herbarium specimen of *Lettowia nyassae* (Oliv.) H. Rob. & Skvarla (A. Stolz 103, US).

mostly 5–11 cm long, densely and stiffly hirsute, sometimes with small bract near middle, bearing 1 terminal head. Heads broadly campanulate, up to 2 cm high, 1.5–1.8 cm broad. Involucre with ca. 15–20 persistent, mostly subequal ovate-lanceolate bracts in ca. 2 series, up to ca. 1.5 cm long, apices acute, without acumination, densely pilose outside with long simple hairs, with 3 longitudinal veins, margins narrowly scarious, sometimes reddish. Receptacle epaleaceous; florets ca. 40 in a head; corollas lavender,

ca. 12 mm long, narrowly funnelform distally from slender basal tube, tube ca. 7 mm long, with stalked narrowly capitate glands outside, throat ca. 0.7 mm long, lobes linear, ca. 4.3 mm long, with glandular dots outside and numerous stiff uniseriate hairs distally; anther thecae ca. 3 mm long, with tapering bases, with short clavate tails, apical appendage oblong, glabrous, with tenuous cell walls; style base with narrow annular node; with acicular sweeping hairs restricted almost completely to branches; achenes weakly 5-costate, densely sericeous on and between ribs with long setulae, setulae slightly split at tips, glandular dots present near base, without evident idioblasts, raphids linear; carpopodium narrowly annuliform, with small quadrate cells; pappus of ca. 40 persistent barbellate bristles ca. 8 mm long, mostly of even width, tapering at extreme tips, with outer series of short narrowly lanceolate squamae. Chromosome number not known. Chemistry not known.

Pollen grains of *Lettowia nyassae* (Fig. 2A, B) ca. 55  $\mu\text{m}$  in diam in fluid, ca. 45  $\mu\text{m}$  dry, echinolophate, triporate, muri shortly echinate with 2–3 spicules on each mural segment, perforated tectum restricted to the muri. The lacunae are irregular in position and rather irregular in shape. The baculae are elongate, in a mostly single partially unaligned series under each murus, and they are firmly attached to the footlayer. In these features, the pollen is nearly like that of *Vernoniastrum* (Fig. 2A, B), and the relationship to that genus in the subtribe Erlangeinae is assumed. In direct comparison with the single species of *Vernoniastrum* for which SEM study of the pollen is available (Fig. 2C–F), a number of subtle differences can be seen. In *Lettowia*, the lacunae are larger in general and less numerous (ca. 25–30 in *Lettowia* versus 35–40 in *Vernoniastrum*), the spicules on the muri are shorter and less numerous, and the baculae under the muri are mostly in a single row. In both genera there are lacunae that are elongate as if two lacunae are joined, but these do not seem to be aligned in positions where colpi might be located.

**Etymology.** The genus is named for Colonel Paul von Lettow-Vorbeck, 1870–1964 (Gunther 1956; Hoyt 1981; Lettow-Vorbeck 1920), who led the defense of German East Africa in WWI until the surrender of Germany, and was remembered fondly by the people of the former German colony on a return visit after WWII.

The genus contains the following single species.

***Lettowia nyassae* (Oliv.) H. Rob., comb. nov.**

urn:lsid:ipni.org:names:77130233-1

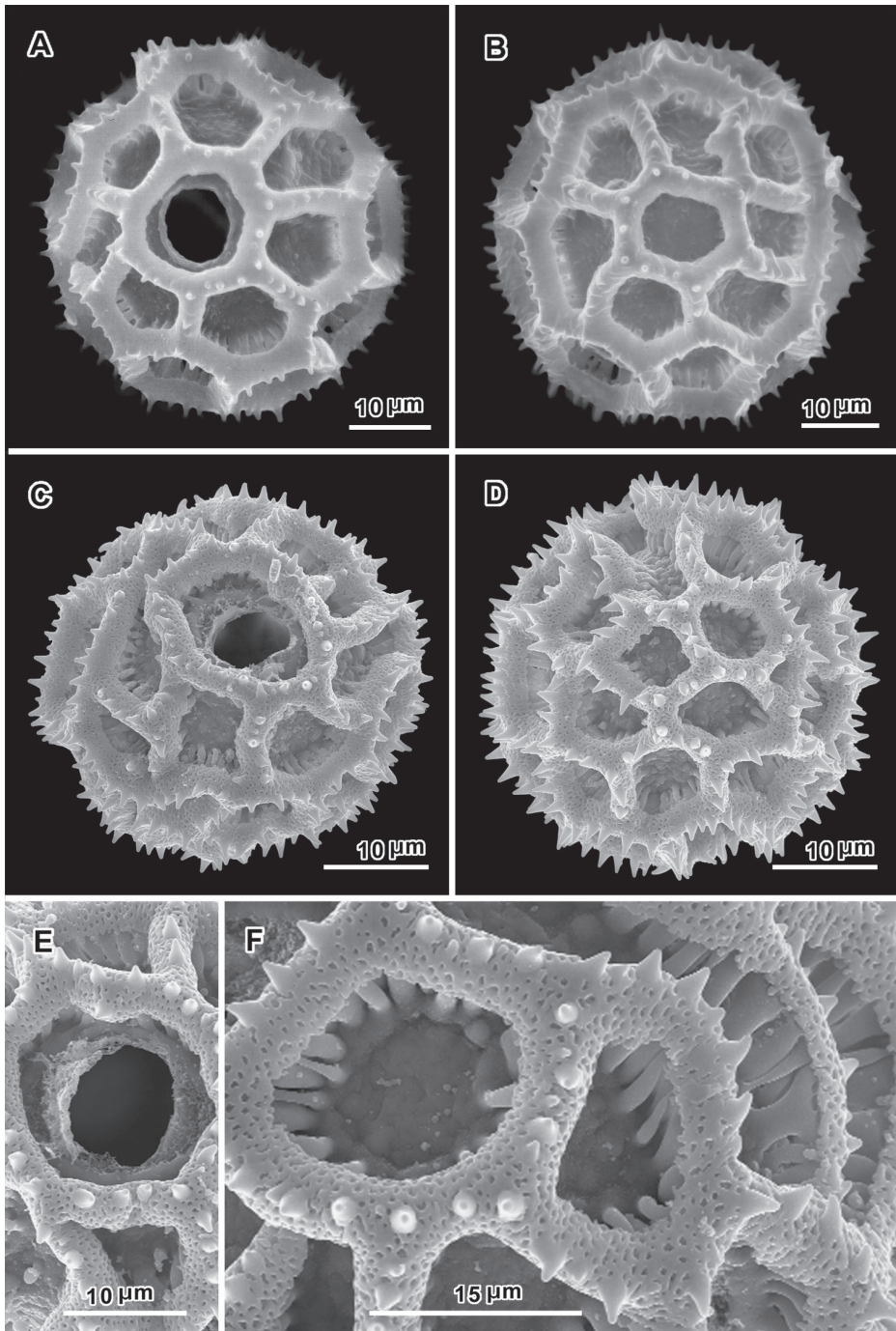
[http://species-id.net/wiki/Lettowia\\_nyassae](http://species-id.net/wiki/Lettowia_nyassae)

Figs 1, 2A,B

*Vernonia nyassae* Oliver in J.D. Hooker, Icon. Pl. 14(2): 36, t. 1349B. 1881. Type: Tanzania, Higher plateau north of Lake Nyassa, *Thomson s.n.* (K, photo in Smith 1971: 65–67, fig. 45A–E).

**Distribution.** The species occurs primarily in the area of southwestern Tanzania north of lake Nyassa, and also in eastern Zambia, Ndola, Oct 1906, *C.F.E. Allen* 363





**Figure 2.** A–F SEM of pollen. A–B *Lettowia nyassae* (Oliv.) H. Rob. & Skvarla (*A. Stolz 103*, US) **A** View with a pore **B** Surface lacking pores C–F *Vernoniastrum nestor* (S. Moore) H. Rob. (Burundi, Prov. Burundi, Gihofi (Mosso), 20 May 1980, *Reekmans 9185*, US) **C** View with a pore **D** Surface lacking pores **E** Closer view of lacuna with a pore **F** Closer view of surface without pores showing extra rows of baculae.

(SRGH). Smith (1971) cited an outlying population of *Vernonia nyassae* in Transvaal (*Codd & Winter* 3291, K). Examination of the voucher specimen at Kew shows that it belongs to *V. thodei* Phillips (now in *Pseudopegolettia* H. Rob., Skvarla & Funk, in prep.), a totally distinct entity with a different non-lophate form of pollen.

Jeffrey (1988) cited a specimen of *Vernonia nyassae* from the region T4, *Bally* 7496, from Ugalla R. (K), which is “smaller than specimens from T7 in all floral parts; it may be simply depauperate, or may indicate a populational difference.”

Smith (1971) cited the following specimens as seen from within the range of the species: **Tanzania:** Sao Hill, 6200 feet, Feb 1959, *A.M. Watermeyer* 32 (K). Mbeya Distr., Slopes of Mbeya Mt., 9000 feet, 25 Sep 1936, *B.D. Burt* 6331 (K). Southern Highlands Prov., Njombe Distr., Elton Plateau, 8500 feet, 6 Oct 1954, *R.L. Willan* 172 (K). Near Njombe, 2100 m, 17 Jan 1957, *H.M. Richards* 7874 (K). **Zambia:** Highlands, Ndola, Oct 1906, *C.F.E. Allen* 363 (SRGH).

**Specimen examined.** Tanzania, Nyassa Hochland, Station Kyimbila, Rmubya Braubuligebirge, 1300–1500 m Seehöhe, 25 Nov 1907, *A. Stolz* 103 (US).

**Habitat.** Evidently in savannah areas.

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# Database of Vascular Plants of Canada (VASCAN): a community contributed taxonomic checklist of all vascular plants of Canada, Saint Pierre and Miquelon, and Greenland

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## Abstract

The Database of Vascular Plants of Canada or VASCAN (<http://data.canadensys.net/vascan>) is a comprehensive and curated checklist of all vascular plants reported in Canada, Greenland (Denmark), and Saint Pierre and Miquelon (France). VASCAN was developed at the Université de Montréal Biodiversity Centre and is maintained by a group of editors and contributors. For every core taxon in the checklist (species, subspecies, or variety), VASCAN provides the accepted scientific name, the accepted French and English vernacular names, and their synonyms/alternatives in Canada, as well as the distribution status (native, introduced, ephemeral, excluded, extirpated, doubtful or absent) of the plant for each province or territory, and the habit (tree, shrub, herb and/or vine) of the plant in Canada. For reported hybrids (nothotaxa or hybrid formulas) VASCAN also provides the hybrid parents, except if the parents of the hybrid do not occur in Canada. All taxa are linked to a classification. VASCAN refers to a source for all name, classification and distribution information.

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\* see Appendix.

All data have been released to the public domain under a CC0 waiver and are available through Canadensys and the Global Biodiversity Information Facility (GBIF). VASCAN is a service to the scientific community and the general public, including administrations, companies, and non-governmental organizations.

### Keywords

VASCAN, Canadensys, Canada, Greenland, Saint Pierre and Miquelon, checklist, taxonomy, synonymy, hybrids, vernacular names, English, French, distribution, provinces, habit, open data

### Data published through

The Canadensys repository: doi: 10.5886/1bft7W5f

### Project details

#### Project title

Database of Vascular Plants of Canada (VASCAN)

#### Personnel

**Data compilation editors:** Luc Brouillet (Université de Montréal Biodiversity Centre): coordination, taxonomic and geographic compilation, Frédéric Coursol (Montreal Botanical Garden): taxonomic and geographic compilation, Susan Meades (Northern Ontario Plant Database): taxonomic compilation, Marc Favreau (Translation Bureau, Public Works and Government Services Canada): French vernacular names compilation, Marilyn Anions (botanist, Ottawa): English vernacular names compilation.

**Development:** Peter Desmet (Université de Montréal Biodiversity Centre): coordination and web design, Pierre Bélisle (Université de Montréal Biodiversity Centre): development, Christian Gendreau (Université de Montréal Biodiversity Centre): development and maintenance, David Shorthouse (Université de Montréal Biodiversity Centre): coordination, Patrick O'Reilley (Université de Montréal): initial data import.

#### Funding

Partial funding came from Parks Canada, the Canadian Biodiversity Information Facility (CBIF), NatureServe Canada, the Canadian Foundation for Innovation (CFI), and the Gouvernement du Québec (grant to the Université de Montréal Biodiversity Centre and Canadensys). Most of the compilation work, however, was contributed in kind by the home institution of each collaborator.

## Study area description

The study area occupies the northern half of North America (excluding Alaska). The area of Canada is 9,984,670 km<sup>2</sup>, of Greenland (or Kulaalit Nunaat, an autonomous country within the kingdom of Denmark) 2,166,086 km<sup>2</sup>, and Saint Pierre and Miquelon (collectivité territoriale, France) 242 km<sup>2</sup>. The latter is 20 km off the coast of Newfoundland's Burin Peninsula and its characteristics are those of boreal eastern Canada. From west to east, the main physiographic regions are the Western Cordillera, the sedimentary Interior Plains, the Canadian and Greenland Shields (mostly igneous rocks), the sedimentary Great Lakes and St. Lawrence Lowlands, and the Appalachian Mountains. The sedimentary Hudson Bay Lowlands basin lies at the centre of the shield, a northern area of sedimentary plains and mountains. The Canadian Arctic borders the Arctic Ocean in northern Canada and northern Greenland. An ice cap covers 81% of Greenland.

The dominant vegetation type of the area is the boreal forest, which occupies much of Canada from Yukon and northeastern British Columbia to Newfoundland. To the north, Arctic tundra prevails: it can be divided into low Arctic (with a nearly continuous plant cover, sometimes shrubby) and high Arctic (including polar deserts); these types are the only ones found in Greenland. To the south of the boreal forest, from west to east, are the humid Pacific Coastal forest, the Cordilleran forest, the Prairie grasslands, the eastern temperate forests (southern Ontario and Quebec), and the Atlantic or Acadian forests.

The population of Canada is concentrated in a narrow belt along its border with the United States, where most of the impacts on ecosystems (urbanization, agriculture) is concentrated. Logging, mining, and hydroelectric development occur in the boreal forest, and mining is now rapidly developing in the Arctic. About 9.9% (Environment Canada 2011) of the terrestrial area of Canada is protected (7.5% according to the World Bank 2013) and 40% of Greenland. Based on the data in VASCAN, the area harbors a total of 5,124 vascular plant species, 3,829 native and 1,295 introduced (25% of the flora). Of the native species of Canada, 156 are considered legally at risk, with a further 34 of conservation concern (COSEWIC 2009+).

## Design description

The goal of the Database of Vascular Plants of Canada (VASCAN) is to provide an up-to-date, documented checklist of the names of vascular plants in Canada, Greenland, and Saint Pierre and Miquelon, both scientific and vernacular, and the distribution of the plants at the provincial/territorial level.

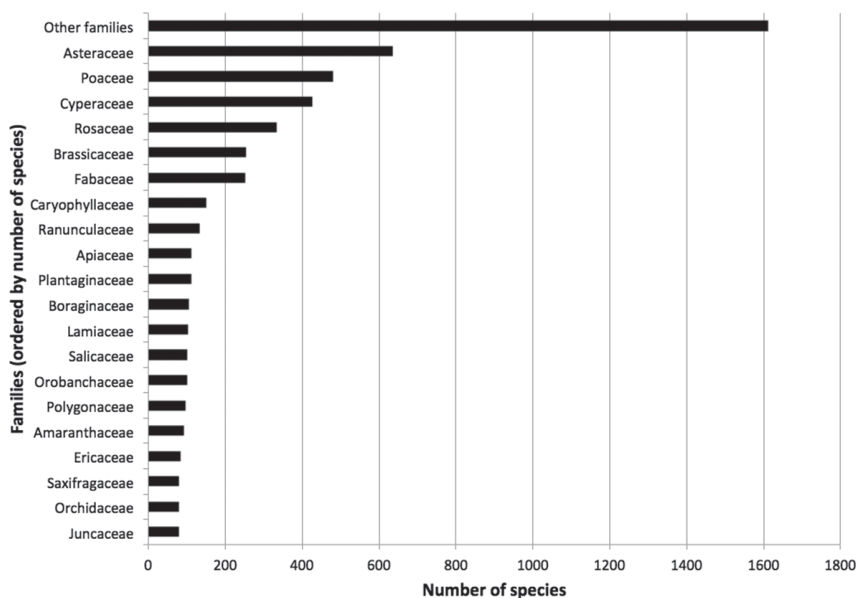
VASCAN was developed from the need to validate vascular plant name and distribution data from eastern Canada (Ontario and eastward), Greenland, and Saint Pierre and Miquelon for the Flora of North America project (FNA) and from the need to provide French vernacular names for taxa present in Quebec in the FNA. It expanded when Parks Canada wanted to harmonize the names from vascular plant species lists of its parks across the country. At the time we also realized that - aside from The



Flora of Canada by Scoggan (1978-1979) that was in need of updating - not only was there no standardized scientific name list for the country - despite worthwhile efforts from Kartesz (1999) and USDA NRCS (2011) - but also no standardized source of Canadian English and French vernacular names. Names used for plants in English Canada are not necessarily those used in the United States, and thus U.S. sources were not always appropriate for this goal. Finally, several national organizations, such as Parks Canada, Forest Canada, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and NatureServe Canada, expressed the need for a web-based list of Canadian taxa, with data on provincial/territorial distribution.

### Taxonomic coverage

This checklist covers all vascular plants (*Equisetopsida*, *Tracheophyta*) reported in the area described in the section ‘Spatial Coverage’ (Figure 1). The core taxa considered are species, subspecies or varieties, and their hybrids. For these taxa, we provide synonyms, the accepted and alternative French and English vernacular names, and the habit (tree, shrub, herb and/or vine) of the plant in Canada. For reported hybrids (nothotaxa or hybrid formulas) we also indicate the hybrid parents, except if the parents of the hybrid do not occur in Canada. This core information is not provided for higher taxa,



**Figure 1.** Taxonomic distribution of accepted species per family from the Database of Vascular Plants of Canada (VASCAN). The families are ordered by total number of species. Families with less than 80 species are grouped in ‘Other families’.

although the calculated distribution based on lower taxa can be consulted and downloaded from the VASCAN website (<http://data.canadensys.net/vscan>).

All taxa are linked to a classification: Chase and Reveal (2009) for the higher classification, Christenhusz et al. (2011a) for lycophytes, Smith et al. (2006) for monilophytes (modified in Rothfels et al. 2012), Christenhusz et al. (2011b) for the gymnosperms, and the Angiosperm Phylogeny Group (2009) for flowering plants. At the generic level and below, the Flora of North America Editorial Committee (1993+) is the main source of classification, unless taxonomic literature more recent than the volume published for a given taxon provides a taxonomy more reflective of current data. The source used is indicated for each taxon in the dataset.

The classification includes 16 ranks. They are, in hierarchical order: class, subclass, superorder, order, family, subfamily, tribe, subtribe, genus, subgenus, section, subsection, series, species, subspecies and variety. Varieties within subspecies are accepted, so quadrinomial names are present, but forms are not included.

## Taxonomic ranks

**Kingdom:** *Plantae*

**Class:** *Equisetopsida*

**Family:** *Acanthaceae, Acoraceae, Adoxaceae, Alismataceae, Amaranthaceae, Amaryllidaceae, Anacardiaceae, Annonaceae, Apiaceae, Apocynaceae, Aquifoliaceae, Araceae, Araliaceae, Aristolochiaceae, Asparagaceae, Aspleniaceae, Asteraceae, Athyriaceae, Balsaminaceae, Berberidaceae, Betulaceae, Bignoniaceae, Blechnaceae, Boraginaceae, Brassicaceae, Butomaceae, Buxaceae, Cabombaceae, Cactaceae, Campanulaceae, Cannabaceae, Caprifoliaceae, Caryophyllaceae, Celastraceae, Ceratophyllaceae, Cistaceae, Cleomaceae, Clethraceae, Colchicaceae, Commelinaceae, Convolvulaceae, Cornaceae, Crassulaceae, Cucurbitaceae, Cupressaceae, Cyperaceae, Cystopteridaceae, Dennstaedtiaceae, Diapensiaceae, Dioscoreaceae, Droseraceae, Dryopteridaceae, Elaeagnaceae, Elatinaceae, Equisetaceae, Ericaceae, Eriocaulaceae, Euphorbiaceae, Fabaceae, Fagaceae, Frankeniaceae, Gentianaceae, Geraniaceae, Grossulariaceae, Haemodoraceae, Haloragaceae, Hamamelidaceae, Hydrangeaceae, Hydrocharitaceae, Hymenophyllaceae, Hypericaceae, Hypoxidaceae, Iridaceae, Isoëtaceae, Juglandaceae, Juncaceae, Juncaginaceae, Lamiaceae, Lauraceae, Lentibulariaceae, Liliaceae, Limnanthaceae, Linaceae, Linderniaceae, Loasaceae, Loranthaceae, Lycopodiaceae, Lythraceae, Magnoliaceae, Malvaceae, Marsileaceae, Martyniaceae, Melanthiaceae, Melastomataceae, Menispermaceae, Menyanthaceae, Molluginaceae, Montiaceae, Moraceae, Myricaceae, Nartheciaceae, Nelumbonaceae, Nyctaginaceae, Nymphaeaceae, Oleaceae, Onagraceae, Onocleaceae, Ophioglossaceae, Orchidaceae, Orobanchaceae, Osmundaceae, Oxalidaceae, Paeoniaceae, Papaveraceae, Penthoraceae, Phrymaceae, Phytolaccaceae, Pinaceae, Plantaginaceae, Platanaceae, Plumbaginaceae, Poaceae, Podostemaceae, Polemoniaceae, Polygalaceae, Polygonaceae, Polypodiaceae, Pontederiaceae, Portulacaceae, Potamogetonaceae, Primulaceae, Pteridaceae, Ranunculaceae, Resedaceae, Rhamnaceae, Rosaceae, Rubiaceae, Ruppiaceae, Rutaceae, Salicaceae, Salviniaceae, Santalaceae, Sapindaceae, Sarraceniaceae, Saururaceae, Saxifragaceae,*

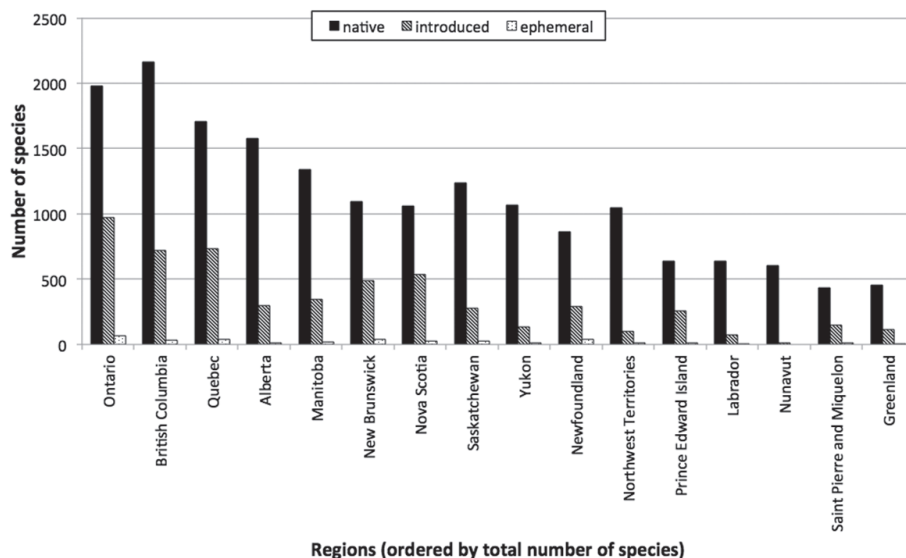
*Scheuchzeriaceae*, *Schizaeaceae*, *Scrophulariaceae*, *Selaginellaceae*, *Simaroubaceae*, *Smilacaceae*, *Solanaceae*, *Staphyleaceae*, *Tamaricaceae*, *Taxaceae*, *Thelypteridaceae*, *Thymelaeaceae*, *Tofieldiaceae*, *Typhaceae*, *Ulmaceae*, *Urticaceae*, *Verbenaceae*, *Violaceae*, *Vitaceae*, *Woodsiaceae*, *Xanthorrhoeaceae*, *Xyridaceae*, *Zosteraceae*, *Zygophyllaceae*.

## Common names

Vascular plants, Lycopods, ferns, conifers, flowering plants. In the dataset, French and English vernacular names are provided for families, species, subspecies, and varieties.

## Spatial coverage

The checklist covers all vascular plants reported in Canada, Greenland (Denmark), and Saint Pierre and Miquelon (France) (Figure 2). The latter two regions are added because their floras are intimately related to that of Canada and it is useful for Canadians and others to know about them. Provincial distributions are provided to help Canadians visualize the relationship among the floras of their provinces and territories. VASCAN does not intend to replace regional or provincial lists but to act as a complement to them. The covered regions are, in alphabetical order: Alberta, British Columbia, Greenland, Labrador, Manitoba, New Brunswick, Newfoundland, Northwest Territories, Nova Scotia, Nunavut, Ontario, Prince Edward Island, Quebec, Saint Pierre and Miquelon, Saskatchewan, and Yukon.



**Figure 2.** Regional distribution of accepted species from the Database of Vascular Plants of Canada (VASCAN). For each region, the number of native, introduced and ephemeral species is shown, i.e. species with a confirmed presence in the region. The regions are ordered by total number of species.

The distribution status of the plant is indicated per region. These can be grouped as present (native, introduced or ephemeral), previously reported but currently considered absent (excluded, extirpated), doubtful or not reported (absent). The latter status is not recorded in the database (null value). Excluded taxa are those considered not currently occurring in a region, due either to non-recurring ephemeralness, misidentification, lack of supporting documentation, or when specimens are old and the taxon has not been observed again in more than 50 years. All distribution statuses are defined at <http://data.canadensys.net/vascan/about/#distribution>.

The VASCAN website (<http://data.canadensys.net/vascan>) provides a distribution map for each taxon. For higher taxa, these are calculated based on lower taxa, with the distribution statuses ordered as such: native, introduced, ephemeral, excluded, extirpated, doubtful, absent. E.g., if two species within the same genus are respectively native and doubtful in a certain region, the genus is considered native for that region.

The website also provides a checklist builder (<http://data.canadensys.net/vascan/checklist>), where users can generate their own list of taxa based on several criteria (taxonomy, region, distribution status, or a combination of these) and download this as a Darwin Core Archive or text file.

### **Bounding box for covered area**

41°40'N and 83°40'N latitude; 141°00'W and 11°19'W longitude

### **Temporal coverage**

17th to 21st century.

### **Sampling methods**

#### **Study extent description**

See the section 'Spatial coverage' and 'Project details - Study area description'.

#### **Sampling description**

The data are sampled manually from literature by the editors, though recent additions are based on specimens maintained at institutional herbaria across Canada (see Thiers).

All floras covering Canada, Greenland, and Saint Pierre and Miquelon were considered for literature-based data entry, but only the most recent provincial and territorial floras (see the section 'References - References used to build the dataset') were

systematically searched to establish the distribution status of each taxon in each region (see the section ‘Spatial coverage’). Scoggan’s *Flora of Canada* (1978–1979) was systematically searched, as were Kartesz (1999) and the *Flora of North America* (FNA Ed. Comm. 1993+). English and French vernacular names are based on usage in Canada and, for introduced taxa, on vernaculars from the countries of origin (when the taxon is from Europe). Alternate (synonym) vernaculars are provided when several names are in usage (notably regional names), but an accepted vernacular is recommended for general usage throughout the country. The method of selection of vernacular names follows Darbyshire et al. (2000). The source of the information is referenced for all scientific names, vernacular names and distributions in the dataset.

### Quality control description

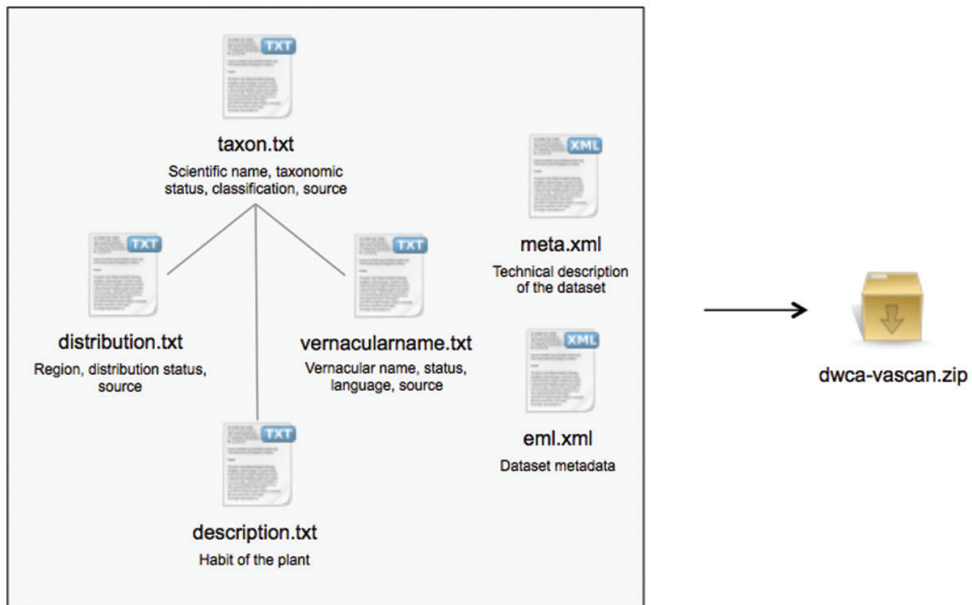
New findings or corrections for plant distributions are communicated to the editors by contributors from each region (Appendix). Contributors are local botanists, often associated with Canadian herbaria or Conservation Data Centers. All new reports must be documented by specimens deposited at institutional herbaria.

Suggestions or corrections regarding names, taxonomy, or functionality of the VASCAN website are submitted by users and reviewers through a public Google Code issue tracker at <http://code.google.com/p/canadensys/issues/list?can=2&q=label:vascan>. Name suggestions are validated by the editors against names in Tropicos (<http://www.tropicos.org>), IPNI (<http://www.ipni.org>), GRIN (<http://www.ars-grin.gov>), or other plant name databases, before being manually corrected in the database.

### Dataset

The data are stored in a relational database (MySQL), which powers the search, checklist builder, taxon and name pages of the VASCAN website. Editors update a development copy of the database through a secure web application. This allows them to make revisions without affecting the users of the website. Once they agree that the data are consistent, in which they are aided by the application, they can push that version of the database to production.

At that moment, the application will also automatically generate a Darwin Core Archive of the data, using the GBIF GNA Profile (GBIF 2010) and following best practices for publishing checklists (GBIF 2011). This archive (Figure 3) includes all data, except for calculated distributions, hybrid parents, and user credentials. The archive is then manually uploaded to the Canadensys Repository (<http://data.canadensys.net/ipt>), a GBIF Integrated Publishing Toolkit, and republished, at which time it will be assigned a new version number (version 24 at the time of publication). The dataset is registered with the Global Biodiversity Information Facility (GBIF), which allows that organization to harvest, display and distribute the data at any time.



**Figure 3.** The VASCAN Darwin Core Archive, structured following the GBIF GNA Profile. It is a compressed folder containing 4 text files with tab-separated values and 2 xml files. Taxon and scientific name information is provided in *taxon.txt*, with one record for each taxon and child-parent-relationships representing the classification. Records in the extension files *distribution.txt*, *vernacularname.txt* and *description.txt* have a many-to-one relation with the records in *taxon.txt* and provide additional information for each taxon. The archive structure and term definitions are described in *meta.xml*. The dataset metadata are provided in *eml.xml*.

To the extent possible under law, the Université de Montréal Biodiversity Centre has waived all copyright and related or neighboring rights to this dataset, releasing it to the public domain under a CC0 waiver. Users of the data are encouraged to follow the Canadensys norms for data use and publication (<http://www.canadensys.net/norms>):

*Give credit where credit is due:* As is common practice in scientific research, cite the data you are using.

*Be responsible:* Use the data responsibly. The data are published to allow anyone to better study and understand the world around us, so please do not use the data in any way that is unlawful, harmful or misleading. Understand that the data are subject to change, errors and sampling bias. Protect the reputation of the data publisher and clearly indicate any changes you may have made to the data.

*Share knowledge:* Let us know if you have used the data. It helps us to showcase our efforts and it helps you reach a wider audience. Inform us if you have comments about the data, notice errors, or want more information.

*Respect the data license:* Understand and respect the data waiver under which the data are published. To help you make greater use of the data, we have dedicated the data to the public domain (CC0). Do not remove the public domain mark or provide misleading information about the copyright status.

**Object name:** Darwin Core Archive for the Database of Vascular Plants of Canada (VASCAN)

**Character encoding:** UTF-8

**Format name:** Darwin Core Archive format

**Format version:** 1.0

**Distribution:** doi: 10.5886/Y7SMZY5P

**Publication date of data:** 2013-07-22

**Language:** English

**Licenses of use:** <http://creativecommons.org/publicdomain/zero/1.0/> & <http://www.canadensys.net/norms>

**Metadata language:** English

**Date of metadata creation:** 2013-07-22

**Hierarchy level:** Dataset

### Suggested citation for the latest version of the dataset

Brouillet L, Desmet P, Coursol F, Meades SJ, Favreau M, Anions M, Bélisle P, Gendreau C, Shorthouse D and contributors (2010+) Database of Vascular Plants of Canada (VASCAN). Online at <http://data.canadensys.net/vascan>, doi: 10.5886/1bft7W5f, and <http://data.gbif.org/datasets/resource/13558>, released on 2010-12-10. Version [xx]. GBIF key: 3f8a1297-3259-4700-91fc-acc4170b27ce. Data paper ID: <http://dx.doi.org/10.3897/phytokeys.25.3100> [accessed on [date]]

### External datasets

**Object name:** GBIF data portal

**Character encoding:** UTF-8

**Format name:** various formats

**Distribution:** <http://data.gbif.org/datasets/resource/13558>

### Acknowledgements

The authors wish to thank the reviewers and editor for their constructive feedback.

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## **Appendix**

### **Contributors**

The following individuals made a significant contribution to VASCAN, in addition to the personnel listed in the section 'Project details - Personnel': G. Argus (Canadian Museum of Nature), S. Blaney (Atlantic Canada Conservation Data Center), B. Bennett (Environment Yukon), J. Cayouette (Eastern Cereal and Oilseed Research Centre), A. Cuerrier (Montreal Botanical Garden), R. Etcheberry (Saint Pierre and Miquelon), B. Ford (University of Manitoba), B. Fredskild (Denmark), K. Gandhi (Harvard University Herbaria), L. Gillespie (Canadian Museum of Nature), J. Gould (Alberta Tourism, Parks and Recreation), J. Greenall (Manitoba Conservation Data Centre), G. Halliday (Great Britain), C. Hanel (Newfoundland and Labrador Department of Environment and Conservation), V. Harms (University of Saskatchewan), S.G. Hay (Université de Montréal Biodiversity Centre), J. Labrecque (Centre de données sur le patrimoine naturel du Québec), F. Lomers (British Columbia), J. Maunder (The Rooms Provincial Museum, Newfoundland), M. Munro (Nova Scotia Museum), M. Oldham (Ontario Natural Heritage Information Centre), E. Punter (University of Manitoba), and J.C. Semple (University of Waterloo), as well as many people who made single contributions.



# ***Guzmania panamensis* (Bromeliaceae) – a new species from Talamanca Mountain in Veraguas province, Western Panama**

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## **Abstract**

*Guzmania panamensis* (Bromeliaceae), a new species so far endemic to Veraguas province, Western Panama, is described and illustrated. The new species is recognized due to its peduncle much longer than the leaves and its red floral bracts, shorter than the yellow flowers. The new species is compared to morphologically similar species, namely *Guzmania monostachia*, *G. berteroniana*, *G. elvallisensis*, and *G. skotakii*.

## **Keywords**

Epiphyte, Flora of Panama, Santa Fe National Park

## **Introduction**

Bromeliaceae comprise 3,248 species and 58 genera (Luther 2010) which are grouped in subfamilies Brocchinioideae, Bromelioideae, Hechtioideae, Lindmanioideae, Navioideae, Pitcarnioideae, Puyoideae, and Tillandsioideae (Givnish et al. 2011).

According to Luther (2010), the genus *Guzmania* Ruiz & Pav. (Bromeliaceae) has more than 200 species and is one of the most diverse genera in Tillandsioideae.

In Panama, the Bromeliaceae comprise 206 species in 7 genera, of which *Guzmania* includes 45 species, 12 of them endemic (Cáceres González et al. 2011).

After the synopsis of the Bromeliaceae of Panama (see Cáceres González et al. 2011), it is clear that some areas of the country have not been sufficiently collected, principally in Western (Cordillera de Talamanca) and Eastern Panama.

During a botanical excursion made in December 2012, an interesting specimen of *Guzmania* was collected in a premontane rain forest from Santa Fe National Park (Cordillera de Talamanca) in the Veraguas province. These *Guzmania* plants are growing epiphytic, in the interior of the premontane rain forest, a few meters above the soil (close to the understory). It was found that the specimen did not match any of the known species of the genus and hence it is described and illustrated here as a new species of *Guzmania* from Western Panama.

### Taxonomic treatment

#### *Guzmania panamensis* Cáceres González, sp. nov.

urn:lsid:ipni.org:names:77130424-1

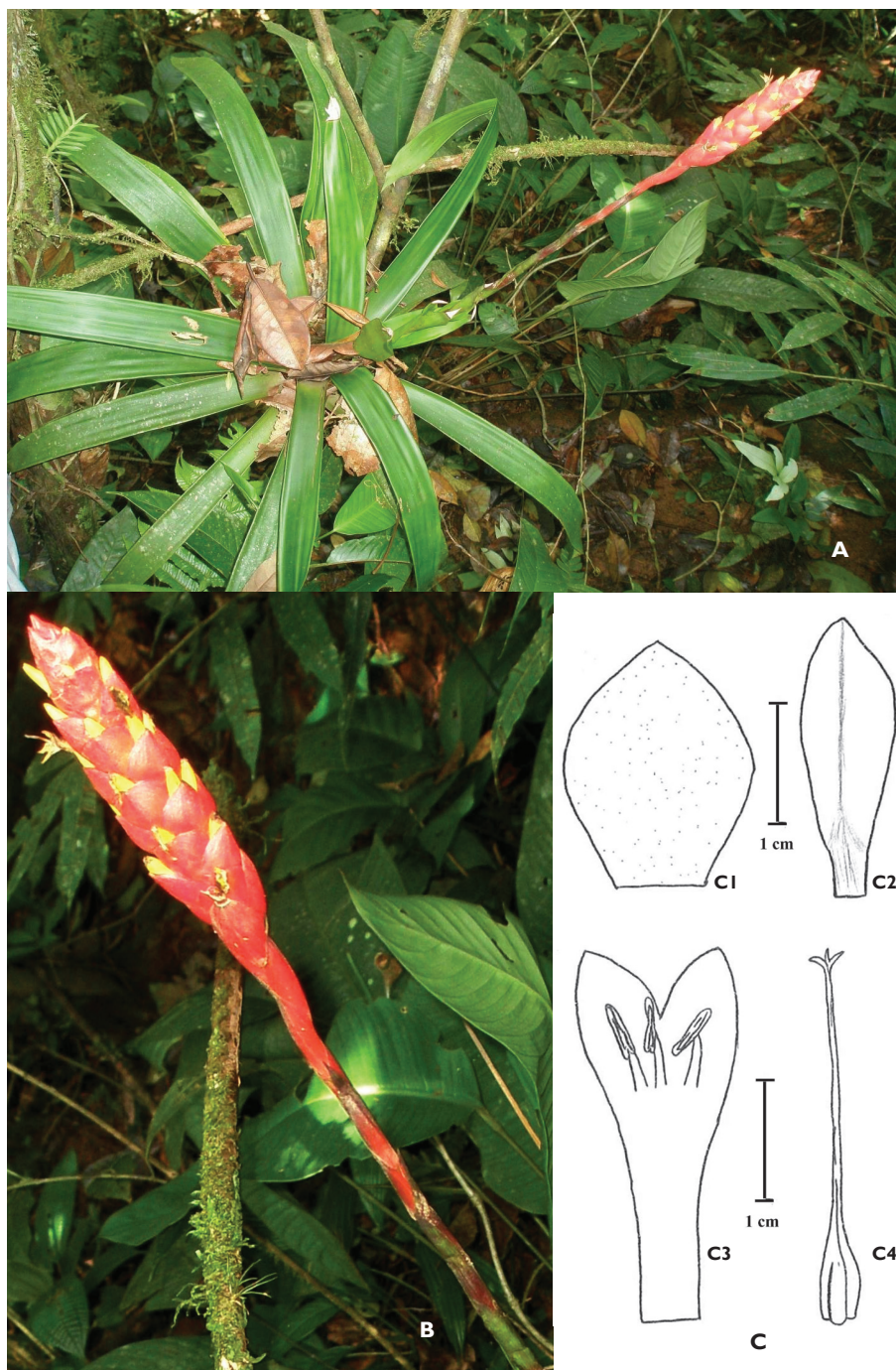
[http://species-id.net/wiki/Guzmania\\_panamensis](http://species-id.net/wiki/Guzmania_panamensis)

**Diagnose.** This new species is similar to *Guzmania skotakii*, but it is characterized by shorter chartaceous leaves, arranged in an open rosette, with sheaths ovate-elliptic (9–11 × 3–5 cm) vs. longer leaves, coriaceous and erect, with sheaths broadly elliptic (20 × 10 cm). In *Guzmania panamensis* the floral bracts are obovate, acuminate 2.0–2.2 × 1.9–2.0 cm, shorter than the sepals, and petals are yellow; whereas in *G. skotakii* the floral bracts are elliptic to oblanceolate, obtuse to subacute 3.0–4.0 × 1.6–2.5 cm, longer than the sepals, with cream colored petals.

**Type. Panama.** Prov. Veraguas: Distr. Santa Fe, Santa Fe National Park, premontane rain forests, trail to Cascada Charco El Conejo close to the Quebrada Loma Grande and ANAM Station, 08°31'48.8"N, 81°08'58.8"W, at 767 m, 4 December 2012, D.A. Cáceres González 4385 (holotype: UCH; isotypes: FR and PMA).

**Description.** Epiphytic herbs growing on the lower branches of the trees, close to the understory, flowering ca. 67 cm tall with the inflorescence extended. Leaves chartaceous, 40–55 cm long, forming an open rosette, green; leaf sheaths ovate-elliptic, 9–11 × 3–5 cm, with prominent longitudinal veins, with hyaline to membranaceous margins, lightly lepidote on the base with small brown scales in the inside and glabrous on the outside surface. Blades linear, ca. 30–45 × 2.8–3.8 cm (usually wider at the top half), strongly nerved in dry specimens (12–20 veins per cm), attenuate, long acuminate, green, glabrous. Peduncle elongate, erect, slender, 55 cm long, 5 mm in diameter, internodes (2.0–3.3 cm long), about equaling the leaves or slightly longer, hidden by the bracts, lepidote, dark brown. Peduncle bracts erect, much longer than the internodes, imbricate, chartaceous, 4.5–10.0 × 0.7–1.0 cm, bracts: the basal ones presenting a similar color to the leaves and glabrous, the distal ones reddish-green and lepidote, triangular ovate, acuminate to cuspidate. Inflorescence (excluding the peduncle) erect, 11.0 × 2.5 cm, simple, nearly cylindric,





**Figure 1.** *Guzmania panamensis*. **A** Habit in Santa Fe National Park (province of Veraguas, Panama) **B** Inflorescence, bracts and flowers **C** Drawing of the flower parts: **C1** Floral bract, **C2** Sepal, **C3** Petals with filaments and anthers, **C4** Pistil. All from D.A. Cáceres González 4385. Photographs and drawing by Daniel A. Cáceres G.

with about 25 flowers, polystichous, normally dense, all bracts bearing flowers. Rachis hidden, sparsely lepidote with minute lightly stellate brown to grayish scales. Floral bracts obovate, acuminate, erect, imbricate, globose, 2.0–2.2 × 1.9–2.0 cm (1 cm on the base), much longer than the internodes, shorter than the flowers, lightly nerved, lepidote at both surfaces, red. Flowers 3.6 cm long, sessile. Sepals joined for about one fourth (6–7/25 mm on the base) of their length, 2.5 cm long, 6–7 mm wide, yellow, asymmetric, elliptic, acuminate, coriaceous, erect, slightly fleshy on the base, with a strong central vein, glabrous. Corolla tubular, yellow, not fleshy, erect, 2.7–3.5 cm long (2.0–2.5 cm connate and adnate to the filaments), lobules 0.7–1.0 cm long and free, 0.4–0.6 cm wide, exceeding the sepals in 0.5–10 mm. Stamens alternate, and opposite to the lobule of the corolla, included, filaments all equaling in length, the free portion 3.5–4.0 mm long. Anthers dorsifixed at the middle. Pistil ca. 2.8–3.0 cm long, nearly as long as the petals, exceeding the stamens. Ovary ovate, 5 mm long, 2 mm in diameter, tapering from the base up to the style. Style slender, 2.5 cm long. Stigma trilobate, spreading, each lobe ca. 1.0–1.5 mm long. Capsule 2.5 cm long, 5 mm in diameter. (Fig. 1)

**Distribution.** *Guzmania panamensis* is only known from Santa Fe National Park, Veraguas province in the Cordillera de Talamanca, Panama.

**Ecology.** The new species grows in primary forest or old secondary forest, usually close to the understory and premontane rain forests at altitudes around 750 m. The common associated plant species are *Guzmania musaica* (Linden & André) Mez (Bromeliaceae), *Zamia* sp. (Zamiaceae), *Palicourea guianensis* Aubl. (Rubiaceae), *Danaea nodosa* (L.) Sm. (Marattiaceae), and *Dichaea* sp. (Orchidaceae). The type specimen of the new species has been collected as epiphyte on a height of one m above the ground on a shrub of *Psychotria* sp. (Rubiaceae) (Fig. 1A). It was observed flowering in December (start of the dry season).

**Etymology.** *Guzmania panamensis* is named in honour of Panama country.

**Conservation status.** *Guzmania panamensis* has been collected only once in Panama. In the type locality area, only three individuals were observed and hence it is assumed to be uncommon. No other specimen could be found among the material that has been collected for seventy years, as part of the project Flora of Panama of the Missouri Botanical Garden, supporting the view that this taxon is rare even inside this national park. Similar habitats, surrounding the park have been visited by the author and no specimen similar to *G. panamensis* has been found in such areas. Therefore, in the conservation assessment presented here (following IUCN 2001 guidelines), *Guzmania panamensis* is categorized as Critically Endangered (CR), represented by only a single distribution record and based on the criterium B2biii.

**Observations.** Four species have a close resemblance with *Guzmania panamensis*: *Guzmania monostachia* (L.) Rusby ex Mez, *G. berteroniana* (Schult. & Schult. f.) Mez, *G. elvallsensis* Luther, and *G. skotakii* Luther.

This new species resembles *Guzmania monostachia* (see Smith and Downs 1977, Mez 1896, Utley 1994), but differs from it by its larger size of the plant and the color of the floral bracts. *Guzmania panamensis* when flowering reaches about 67 cm tall vs.

20–40 cm in *G. monostachia*. The peduncle of the new species is much longer than the leaves with red floral bracts and yellow flowers; while in *G. monostachia* the peduncle is much shorter, the floral bracts are bright red or rarely white, and the flowers are usually white with conspicuous brown longitudinal stripes.

In *Guzmania berteroniana* the floral bracts exceed the sepals, and the sepals are 22 mm long (connate for 2 mm); while in *G. panamensis* the floral bracts are shorter than the flowers (including the sepals), and the sepals are 25 mm long (connate for 6–7 mm).

This new species differs from the similar *Guzmania elvallensis* (Luther 1996), by the color of its petals (yellow vs. pale green). Another important feature is that in *G. panamensis* the floral bracts are red, whereas in *G. elvallensis* they are green.

*Guzmania panamensis* differs from the similar *Guzmania skotakii* (Luther 1991), by its smaller leaves, chartaceous in open rosette with sheaths ovate-elliptic (9–11 × 3–5 cm) vs. longer leaves, coriaceous and erect, with sheaths broadly elliptic (20 × 10 cm). In the first species the floral bracts are obovate, acuminate 2–2.2 × 1.9–2 cm, shorter than the sepals, with yellow petals; whereas in the second species the floral bracts are elliptic to oblanceolate, obtuse to subacute 3–4 × 1.6–2.5 cm, longer than the sepals, with cream petals.

## Acknowledgements

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# Circumscription and lectotypification of *Hedychium villosum* and its variety *H. villosum* var. *tenuiflorum* (Zingiberaceae)

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## Abstract

The nomenclatural confusion between the Indian gingers *Hedychium villosum* Wallich and its variety *H. villosum* var. *tenuiflorum* (Wall. ex Voigt) Wall. ex Baker is discussed. Both taxa are lectotypified in order to stabilize the names and contribute towards a resolution of their confusing nomenclatural past. Both taxa are described in detail to aid identification.

## Keywords

Gingers, India, nomenclature, typification, Nathaniel Wallich, Zingiberaceae

## Introduction

Zingiberaceae are one among the ten largest monocotyledonous families in India, represented by 20 genera and about 200 species, and are mainly concentrated in the Northeastern, Peninsular and Andaman and Nicobar regions. *Hedychium*, commonly called “ginger lily” or “butterfly lily” produces one of the most beautiful and aromatic flowers in the family Zingiberaceae. The genus *Hedychium* was established by Koenig (1783) with *H. coronarium* J.Koenig as the only species, based on Rumphius's (1747) illustration. *Hedychium* includes about 80 species with highest species diversity in the eastern Himalaya region to South China and Southeast Asia. About half the species occur in the Indochinese region (Sirirugsa and Larsen 1995). *Hedychium* is the largest



**Table 1.** Main morphological differences between *Hedychium villosum* and *H. villosum* var. *tenuiflorum*

Characters	<i>H. villosum</i>	<i>H. villosum</i> var. <i>tenuiflorum</i>
Inflorescence	16.5–33 cm long	8.4–12.3 cm long
Flowers	4.7–5.2 cm long, pale yellow	11.8–12.2 cm long, white
<i>Calyx</i>	1.6–1.8 cm long	3.3–3.7 cm long
Corolla tube	1.9–2.1 cm long, densely pubescent externally	5–5.2 cm long, glabrous externally
Corolla lobes	1.5–1.7 cm long, lower half pubescent externally	4–4.4 cm long, glabrous externally
Lateral staminodes	1.3–1.5 × c. 0.15 cm	3.3–3.5 × 0.1–0.15 cm
Labellum	1.3–1.4 × c. 0.5 cm	3.1–3.5 × 1.2–1.5 cm
Filament	2.4–2.6 cm long	5.3–6.3 cm
Anther	c. 1.5 × 1.5 mm	c. 3.5 × 2.5–3 mm

genus of Zingiberaceae in India, with about 43 taxa (Jain and Prakash 1995), mostly restricted to Northeastern India.

Whilst revising the species of *Hedychium* in India, nomenclatural and circumscription problems were encountered in relation to two plant names coined by Nathaniel Wallich, *H. villosum* Wall. and its variety, *H. villosum* var. *tenuiflorum* (Wall. ex Voigt) Wall. ex Baker. The plants of these two taxa are very peculiar in their sagittate anthers and winter flowering (December to April), whereas in other Indian species of *Hedychium* the anthers are oblong and plants flower during the monsoon season (June through October). For a long time, *H. villosum* was identified as *H. villosum* var. *tenuiflorum* or vice-versa or the two taxa were even lumped as a single highly variable species. As a result of extensive studies of the literature, herbarium and live specimens, we are now able to identify and delimit these two taxa, and recognize them as distinct. The variety differs in its shorter inflorescence, larger white flowers and larger anthers (see Table 1, Figs 1A, B). Confusion over taxon identity was in part caused by poor knowledge of the types of these names.

## Nomenclatural discussion

*Hedychium villosum* was originally described by Wallich (in Roxburgh 1820) from a specimen sent to him by Mathew Robert Smith from the “mountains north-east of Bengal”. He described it as a native of northeast of Bengal, flowers in rainy season and “*Kattia Ram Rait*” as its local name (Khasee language). In describing the species he compared it with a live specimen of *H. gracile* Roxb. and differentiated in its larger plant size, length and villosity of inflorescence, copious fascicled flowers, and corolla lobes of equal length. From Wallich’s description, it is evident that this is a species with a cylindrical inflorescence of 25–30.5 cm long, with small, pale yellow flowers (corolla tube c. 3.8 cm long, bracts much shorter than tube, calyx somewhat shorter than tube, filament as long as tube and scarlet). At Kew we located a colour plate drawn for Wallich that closely resembles the description of *H. villosum* Wall. Wallich also incidentally mentioned “var. *tenuiflorum*” under this taxon in his catalogue (Numer. List. 1832) for Wallich 6545C,



but did not formally publish this name nor include it in his later publications under *H. villosum* (Wallich 1853, 1855). Indeed, it is evident from Wallich's own statement ("they differ not even as varieties I believe"), that he preferred not to recognize his "var. *tenuiflorum*" as a distinct taxon. Wallich (1832) cited it as "6545-C: *Hedychium villosum* Wall. ? var. *tenuiflorum* Wall. HBC" (Hortus Botanicus Calcutta) "*e Sylhet*" (from Sylhet).

A few years later, Roscoe (1827) while treating 'Monandrian Plants of the order Scitamineae', accepted Wallich's broad view and did not recognise any infraspecific taxa under *H. villosum*. It is evident from his observation, "the chief diversity we have observed between our plant and that described in the 'Flora Indica', is in the downy margin and mid-rib of the leaves, and in the colour of the flowers, which in the 'Flora Indica' are described as of a pale yellow colour, whilst in ours they are a pure white", that he had not recognized any taxa at intraspecific level probably for the reason that the sagittate anther peculiar to *H. villosum* is also present in the other element (Wallich's "*tenuiflorum*"). He stated further that, "Dr. Wallich has also communicated another species under the name *Hedychium tenuiflorum*, which resembles the present, as well in the deep-lobed, undulated lip, as in the small sagittate anther.....". Interestingly, the description and figure provided by Roscoe (1827, t. 54) under the name *H. villosum* are an excellent match for 'var. *tenuiflorum*' (*sensu* the specimen Wallich 6545C), not for *H. villosum* (*sensu* Roxburgh 1820).

Voigt (1845) recognised *H. villosum* in the strict sense of Wallich (in Roxburgh 1820) by specifically excluding Roscoe's concept ("*H. villosum* Wall. not Roscoe"), and by including *H. tenuiflorum* Wall. as *H. villosum* of Roscoe and not of Wallich ("*H. tenuiflorum* Wall. -*H. villosum* Roscoe, not Wall."). Our study of a large number of both live and herbarium specimens, including consultation of types, protologues and other relevant literature corroborates this view (Voigt 1845). We feel that these two taxa are distinct but that they only warrant recognition at varietal, rather than specific rank. Hence, we recognize two taxa: *H. villosum* var. *villosum* as the nominal species and a distinct variety, *H. villosum* var. *tenuiflorum*.

During herbarium studies of Wallich material we were unable to locate material identifiable as *H. villosum* in the original Wallich herbarium at Kew. However, at BM we located one specimen collected from Sylhet in 1815 that corresponded to that cited by Roxburgh and Wallich. The label on this specimen is in Wallich's hand. Although the specimen lacks a collector name, we infer from the protologue that it was collected by M.R. Smith. It is mounted with another two plant fragments, the right hand material corresponds to *H. villosum* var. *tenuiflorum* and other the central and left hand specimens match what is currently understood as *H. villosum*. Hence, from the elements on this sheet, the middle plant fragment is selected and designated here as the lectotype of *H. villosum*. Because Voigt (1845) referred to Wallich through reference to Roscoe in his description of the species *H. tenuiflorum*, he implicitly included the specimen Wallich 6545C. We did not locate any material unambiguously referable to this collection and locality in the Wallich herbarium at Kew, but we did locate a specimen of Wallich 6545C at BM collected from the Botanic Garden Calcutta, originally from Sylhet; we designate this specimen here as the lectotype of the *H. villosum* var. *tenuiflorum*.

## Taxonomic treatment

***Hedychium villosum* Wall. in W.Roxburgh var. *villosum*, Fl. Ind. (ed. Carey) 1: 12. 1820.**

**Type.** India. “Sylhet”, 1815, *M. R. Smith s.n. pro parte* (middle specimen) (lectotype, designated here: BM! [BM000574717, middle stem only]). Figs 1A, 2.

**Description.** Epiphytic perennial herbs. *Leafy shoots* 60–90 cm high, erect, slender. *Leaves* 8–12 in number, spreading, at a distance of 3.4–7.5 cm, sessile; sheath 1.9–2 cm wide, puberulent at margins; ligule 1.8–2.1 × 0.7–0.8 cm, single-lobed, oblong, membranous, puberulent externally, tip acute; lamina 14–20 × 3.7–4.5 cm, elliptic-lanceolate, dark green and glabrous above, pale green and puberulent below; midrib pubescent below; tip long acuminate; base obtuse; margin non-ciliate, translucent, white tinged. *Inflorescence* 16.5–33 cm long, erect or drooping, lax, cylindrical. *Bract* 1.2–1.4 × 0.4–0.5 cm, one on each flower, convolute, elliptic, boat-shaped, brown, non-tubular, more or less leathery, densely hairy externally, hairs brown; margin non-ciliate; cincinnus 2–3 -flowered. *Bracteoles* 1–1.3 × c. 0.25 cm, brown, tubular, unilaterally split upto 5–8 mm, densely hairy externally, hairs brown; margin non-ciliate. Flower 4.7–5.2 cm long, pale yellow, highly fragrant, many open at a time. *Calyx* 1.6–1.8 × c. 0.15 cm, tubular, unilaterally split up to 5–6 mm, gradually convolute towards the tip, membranous, translucent, densely pubescent externally; hairs brown; obscurely 3 -lobed at tip. *Corolla tube* 1.9–2.1 cm long, c. 1.5 mm wide at mouth, straight, exceeding the calyx and bract, pale yellow, densely pubescent externally, hairs brown, hairy internally. *Corolla lobes* oblong, pale yellow, lower half pubescent externally, glabrous on upper half, margins non-ciliate, non-beaked at tip, lobes 3-nerved; dorsal lobe 1.6–1.7 × c. 0.15–0.2 cm long; lateral lobes 1.5–1.6 × c. 0.15 cm long. *Lateral staminodes* 1.3–1.5 × c. 0.15 cm, linear, straight, pale yellow, tip acute. *Labelium* 1.3–1.4 × c. 0.5 cm, elliptic, narrow towards base, pale yellow, sinus 0.8–0.9 cm deep, lobes tip acute; claw c. 1 mm wide at base. *Stamen* 2.6–2.8 cm long. *Filament* 2.4–2.6 cm long, scarlet, straight, c. 0.5 mm wide at base. *Anther* c. 1.5 × 1.5 mm, sagittate, brown, glabrous, non-crested, pink, truncate at tip, glabrous. *Ovary* c. 3 × 2 mm, oblong, pale green, densely pubescent externally. *Style* filiform, white, glabrous. *Stigma* cup-shaped, margin ciliate, c. 0.5 mm exserted from anther. *Epigynous glands* two, 2.5–3 mm long, oblong. *Fruits* unknown.

**Distribution.** Bangladesh, China, India and Myanmar from 660 to 1400 m (Wu and Larsen 2000).

**Indian specimens examined.** INDIA. **Arunachal Pradesh:** Changlang Dt.: Chenglang to Khela, 666.6 m, 12 Mar 1958, *G.K. Murthy 12939* (ASSAM); Dibang Valley Dt.: Thewarygaon, 1200 m, 20 May 1998, *M. Bhaumik 1922* (CAL); Anini, 1640 m, *M. Bhaumik s.n.* (CAL); Mehao Lake, 1300 m, 1 Dec 1996, *M. Bhaumik & M.K. Pathak 1153* (CAL); 1200 m, 20 May 1998, *M. Bhaumik & M.K. Pathak 1902* (CAL); West Siang Dt.: Nokka to Nagminu, 5 Jul 1961, *D.B. Deb 26547* (ASSAM); **Meghalaya:** Khasia, 4000 ft, *J.D. Hooker & J. Thomson s.n.* (K), Khasia No. 6 (CAL);



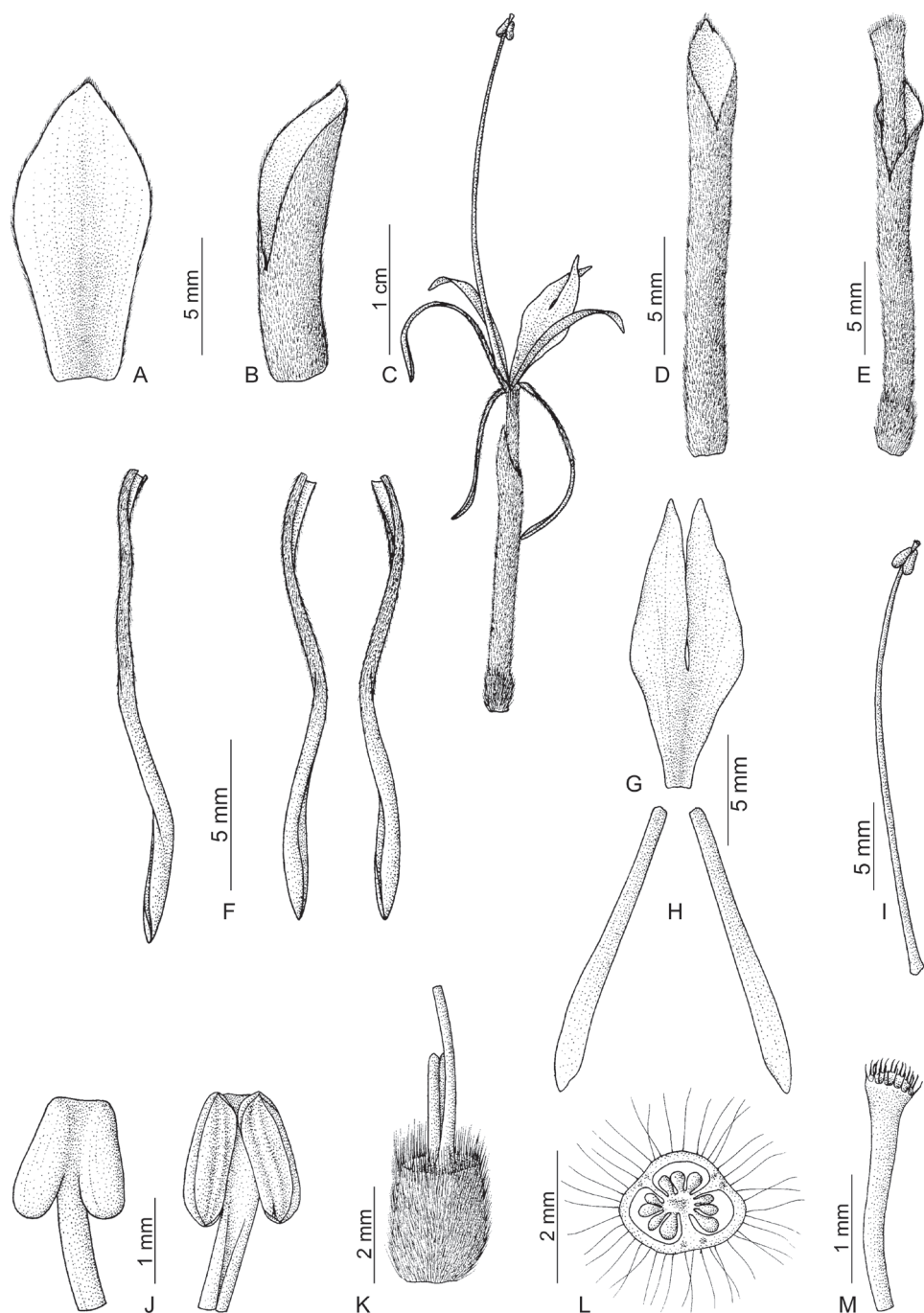
**Figure 1.** Type specimens: **A** *Hedychium villosum* Wall. - Sylhet, 1815, *M. R. Smith s.n. pro parte* (middle specimen; BM000574696) **B** *Hedychium villosum* var. *tenuiflorum* (Wall. ex Voigt) Wall. ex Baker - Botanic Garden Calcutta, originally from Sylhet, *N. Wallich 6545C* (BM).

**Mizoram:** Aizwal Dt.: Sialsuk, Lushai Hills, 4700 ft, 15 Jan 1963, *D.B. Deb 30713* (ASSAM); Lunglei Dt.: Theiriak, Lushai Hills, 25 Jan 1963, *D.B. Deb 31265* (ASSAM); Serchip Dt.: Kheitum, Lushai Hills, 23 Jan 1963, *D.B. Deb 31185* (ASSAM); **Locality unknown.** *Mack s.n.* (K), *Griffith s.n.*

***Hedychium villosum* Wall. var. *tenuiflorum* (Wall. ex Voigt) Wall. ex Baker, Fl. Brit. India [Hooker] 6: 229. 1892 (excl. description).**

**Type.** India. Botanic Garden of Calcutta, originally from Sylhet, *N. Wallich 6545C* (lectotype, designated here: BM!) Figs 1B, 3.

**Description.** Epiphytic perennial herbs. *Leafy shoots* 66–70 cm high, slanting or erect. *Rhizomes* 1.7–3 cm wide, pale green internally, slightly aromatic. *Roots* 0.6–12 mm wide, velamen type. *Leaves* 5–10 in number, at a distance of 4–8.5 cm, sessile; sheath 1.9–2 cm wide, green, margins pink, pubescent externally; ligule 2.9–3.4 × 1.3–1.6 cm, single-lobed, oblong, pale pink, densely pubescent externally, tip acute, margins and tip brown, early dried off; lamina 34–40 × 8–9 cm, elliptic-lanceolate,



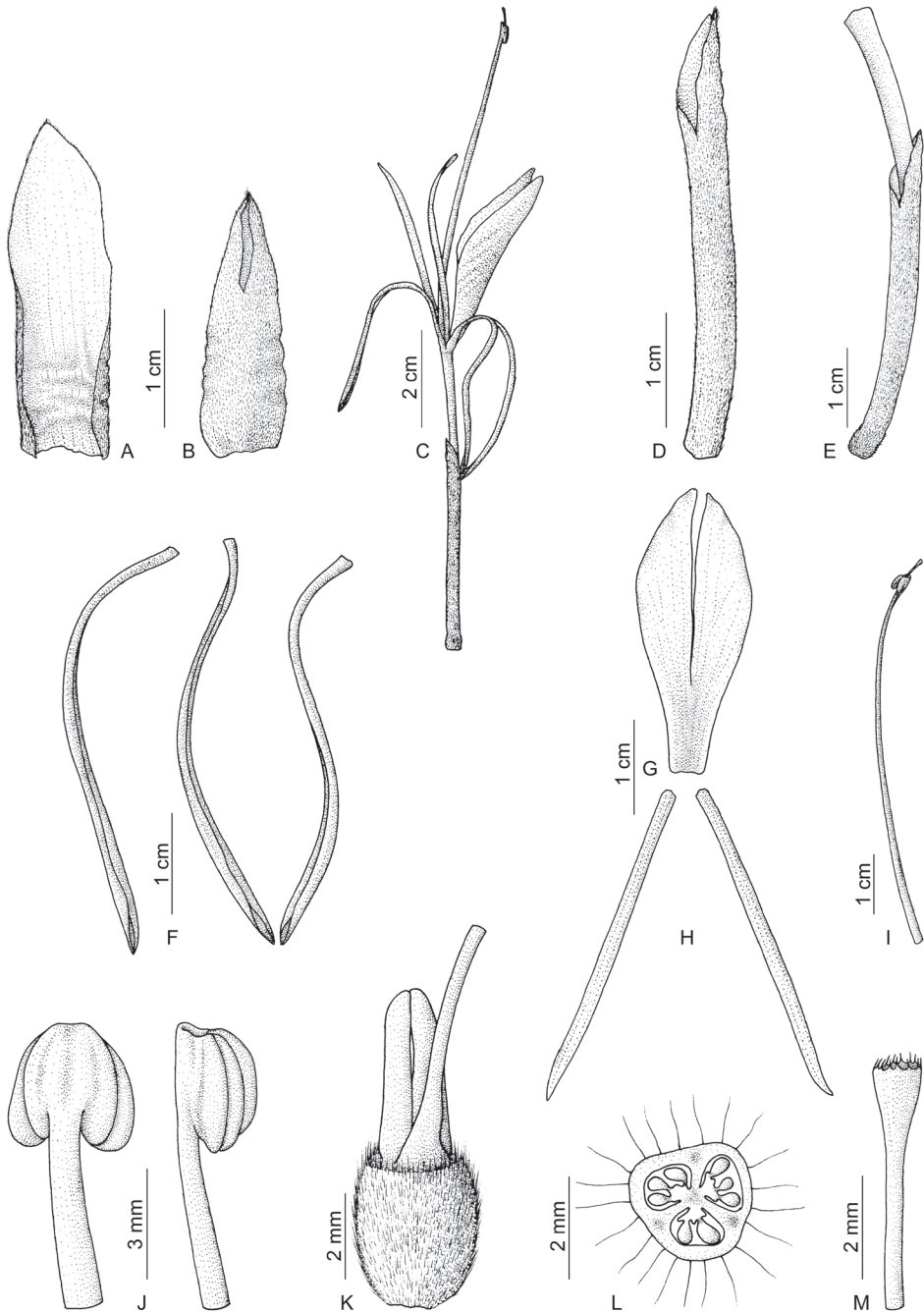
**Figure 2.** *Hedychium villosum* Wall. **A** bract **B** bracteole **C** single flower **D** calyx **E** corolla tube with calyx and ovary **F** corolla lobes **G** labellum **H** lateral staminodes **I** stamen **J** anther, back view (left) and front view (right) **K** ovary with epigynous glands and base of style **L** cross section of ovary **M** stigma with a part of style. Line drawing by E. Sanoj; voucher *M. Bhaumik* 1922 (CAL).



dark green above, pale green below, glabrous; midrib pubescent below, becomes glabrous towards tip; tip long acuminate; base obtuse; margin non-ciliate, translucent, pale pink tinged. *Inflorescence* 8.4–12.3 cm long, erect, lax, cylindrical. *Bract* 2.7–2.9 × 1.1–1.2 cm, one on each flower, convolute, lanceolate, boat-shaped, brown, non-tubular, leathery, easily dried before flowering, densely hairy or villose externally, hairs brown; margin ciliate towards tip; cincinnus 3–4-flowered. *Bracteoles* 2.1–2.2 × 0.7–0.75 cm, lanceolate, brown, tubular, unilaterally split upto 9–10 mm, somewhat leathery, densely hairy or villose externally, hairs brown; margin ciliate towards tip. *Flower* 11.8–12.2 cm long, white with red stamen, mildly fragrant, three-many opens at a time. *Calyx* 3.3–3.7 × 0.2–0.3 cm, pale green, pink tinged towards tip, tubular, unilaterally split up to 5–9 mm, lower 2/3 portion closely appressed to corolla tube, membranous, translucent, densely pubescent externally; tip easily dried while flowering, obscurely 2 or 3-lobed. *Corolla tube* 5–5.2 cm long, 2–2.5 mm wide at mouth, straight, exceeding the calyx and bract, creamy white, translucent towards base, glabrous externally, hairy internally. *Corolla lobes* oblong, greenish white, glabrous, drooping from flower; tip non-pouched, margins non-ciliate, lobes 3-nerved; dorsal lobe 4.3–4.4 cm long; lateral lobes 4–4.1 cm long. *Lateral staminodes* 3.3–3.5 × 0.1–0.15 cm, linear, straight, linear, white with a slight yellow tinge at base; tip acute, rarely forked. *Labellum* 3.1–3.5 × 1.2–1.5 cm, oblanceolate, boat-shaped, white with a yellow tinge at base, sinus 1.9–2.2 cm deep, lobes ensiform, unequal; claw 4–4.5 mm wide at base. *Stamen* 5.8–6.5 cm long. *Filament* 5.3–6.3 cm long, straight, c. 1.5 mm wide at base, red, light red towards tip. *Anther* c. 3.5 × 2.5–3 mm, sagittate, brown, glandular hairy; connective red, glabrous, row of hairy at margin, tip prolonged in to a crest; crest c. 1 mm long, red, truncate or slightly notched at center, glabrous. *Ovary* 2.5–3 × 2–2.5 mm, barrel-shaped, pale green, densely pubescent externally. *Style* filiform, white, glabrous, pale pink spotted towards stigma. Stigma cup-shaped, margin ciliate, 2–5 mm exerted from anther. *Epigynous glands* two, 3.5–5.5 mm long, oblong-lanceolate, yellow, free at base, fused towards tip. *Fruits* 1–1.1 × 1–1.1 cm, globular, sericeous, slightly angular.

**Distribution.** Northeastern India, Bangladesh, northern Myanmar, southern Yunnan and Guangxi provinces of China, Thailand, Vietnam, and Malaysia from 600 to 1800 m (Wu and Larsen 2000).

**Indian specimens examined.** **INDIA.** **Arunachal Pradesh:** Changlang Dt.: Wakka to Nagminu, 5 Jul 1961, *D.B. Deb* 26547 (ASSAM, CAL); Chenglang to Khela, 666.6 m, 12 Mar 1958, *G.K. Murthy* 12939 (ASSAM, CAL); Dibang Valley Dt.: Delei Valley, 28°21'N, 96°37'E, 14 Jul 1928, *F.K. Ward* 8448 (K); **EAST SIANG** Dt.: Rengging, Flora of Abor expedition, 24 Feb 1912, *J.H. Burkill* 36708 (CAL); Lohit Dt.: Dreyi above Denning, 28°10'N, 96°15'E, 2000–4000 ft, 5 Mar 1928, *F.K. Ward* 7916 (K); Forest around Hayuliang along Dalai River, 13 Jan 1970, *J. Joseph* 48932 (ASSAM); **Assam:** Kamrup Dt.: Golaghat Dt.: Jabocka, Naga Hills, 6000 ft, Mar 1899, *Prain's Collector* 99 (CAL); Lakhimpur Dt.: Kakopathar, 23 Feb 1947, *M.M. Srinivasan* 21955 (ASSAM); **Manipur:** s.loc., 22 Jan 1953, *D. Deb* 682 (CAL); Koupia N.W. range, 4–6000 ft, 10 Feb 1882, *G. Watt* 5844 (CAL, E, K); Imphal Dt.:



**Figure 3.** *Hedychium villosum* var. *tenuiflorum* (Wall. ex Voigt) Wall. ex Baker. **A** bract **B** bracteole **C** single flower **D** calyx **E** corolla tube with calyx and ovary **F** dorsal and lateral corolla lobes **G** labellum **H** lateral staminodes **I** stamen **J** anther, back view (left) and lateral view (right) **K** ovary with epigynous glands and base of style **L** cross section of ovary **M** stigma with a part of style. Line drawing by E. Sanoj; voucher *E. Sanoj 95619* (CALI).



Kauglatonghi, *s.coll.* 10815 (K), 3000 ft, Feb 1906, *A. Meebold* 10815 (CAL), 3500 ft, 5 Mar 1946, *J. Hake* 980 (K); **Meghalaya**: Khasia, 4000 ft, *J.D. Hooker & J. Thomson s.n.* (K), s.loc. 1845, *Griffith* 45 (K), s.loc. 5000 ft, 1878, *Geo. Gallatly* 108 (CAL), *Native collectors of Bot. Garden Calcutta s.n.* (E), 5–6000 ft, Feb 1906, *A. Meebold* 5179 (CAL), 8 Mar 1921, *U. Kanjilal* 7660 (ASSAM); East Khasi Hills Dt.: Baedon Falls, Shillong, 22 Mar 1892, *D. Prain* 43 (CAL); Pynursla forest, 18 Oct 1938, *R.N. De & D.C. Forests* 19615 (ASSAM); Mawrynklang, near Wattle Plantation, 27 Jan 1957, *G.K. Deka* 5232 (ASSAM, CAL); Mawswai, K&J Hills, 1200 m, 26 Mar 1960, *G. Panigrahi* 21338 (ASSAM); Woodlands, 11 Mar 1966, *D.M. Verma* 36862 (ASSAM); Barapani, 5000 ft, Geo Gallatly 108 (K); Jorain, 1580 m, 13 Aug 2004, *E. Sanoj* 95619 (CALI); Jaintia Hills Dt.: Lumsnong, 4 Jan 1958, *A. Sanyal* 9 (CAL); West Khasi Hills Dt.: Nongstoin village, 9 Mar 1972, *P.C. Pant* 51483 (ASSAM); **Mizoram**: Zopuitlang, 1332 m, N22°50'83.2", E092°48'80.5", 07 Sep 2002, *M.G. Prasanth Kumar & Jana Leong-Škorníčková* 86213 (CALI); Lunglei Dt.: Near Fort Lungleh, 3–4000 ft, Apr 1899, *A.T. Gage* 120 (CAL); Lushai Hills, Darzo, 5000 ft, Jan 1928, *N.E. Parry* 581 (K); **Nagaland**: Naga Hills, Pipluma, 1 Mar 1882, *s.coll.* 158 (CAL), Naga hills, Jun 1935, *N.L. Bor* 21217 (ASSAM), Jisi, 5000 ft, 6 Mar 1955, *N.L. Bor* 2871 (K); Kohima Dt.: Tseminyu forest-Wokha Road, 12 Apr 1975, *Chandra Bahadur* 61794 (ASSAM); Tuensang Dt.: 5 Km from Noklak, 20 May 2007, *V.P. Thomas & V.A. Muhammed Nissar* 103700 (CALI); **Locality unknown**. *Mack s.n.* (K); *C.B. Clarke s.n.* (K); *Hooker & Thomson* 6545 (K); *N.E. Parry s.n.* (CAL); *Griffith s.n.* (CAL).

### Nomenclatural confusion surrounding these names

In 1890, probably following Roscoe (1827), C.B. Clarke annotated two herbarium sheets at Kew, each of which is a single sheet with two specimens mounted on it. He determined the left hand specimens of both sheets (K000640488! and K000640489!) bearing long cylindrical inflorescences and rather small flowers and anthers as 'var. *tenuiflorum* Wall.', and the right hand specimens (K000640486! and K000640487!) bearing rather large flowers and anthers as *H. villosum*. It appears that subsequent authors (Baker 1892; Schumann 1904) treated *H. villosum* Wall. not as understood by Wallich (in Roxburgh 1820) but in the sense of Roscoe (1827) and Clarke's annotation of the Kew sheets in 1890. Further propagating this error, Baker (1892) attempted to provide a short description for Wallich's variety, var. *tenuiflorum*, for the first time and cited original Wallich material - *Wallich* 6545C (he incorrectly cited "6546 C", a correctable error). Unfortunately his description ("flowers much smaller than the type, corolla-segments staminodes and lip ½ in") is not applicable to var. *tenuiflorum* (*sensu Wallich* 6545C), but to the typical variety. Baker cited Roscoe's plate (Monandr. Pl. Scitam. t. 54. 1827) and considered the white and large-flowered plant as the typical *H. villosum* Wall., not the pale yellow and small flowered one as Wallich (in Roxburgh 1820) originally described the species.

Schumann (1904) recognized *H. villosum* var. *tenuiflorum* as a distinct species under the name *H. tenuiflorum* (Baker) K. Schum. He differentiated his distinct spe-

cies by the nature of inflorescence, less than 1 mm long anthers, narrower leaves and smaller flowers. As with Baker (1892), Schumann's description of the taxon (except "*corolla prob. albae*") – "*Folia omnia summa ipsa sessilia stricte lanceolata longissime attenuato-acuminata et rostrata acutissima basi angustata utrinque glabra ....., Spica 25–30 cm longa anguste cylindrical ....., anther vix 1 mm longa*" perfectly agrees with what is currently understood as *H. villosum* Wall. Inspection of specimens cited, such as *Hooker & Thomson s.n.* (K!), *Griffith 5661* (K!) and *Prain 43* (CAL!) supports our contention that this is what Schumann did. Schumann (1904) also cited a specimen from Silhet, *Wallich 6545A* both for his *H. tenuiflorum* and *H. villosum*. Although he mentioned Robert Smith's introduced material in 1815 under *H. villosum*, his description does not agree perfectly with Wallich's protologue. There are two sheets in the microfiche of the Wallich Catalogue bearing catalogue number 6545A. Of the two sheets labelled as Wall. Cat. n. 6545A, the first sheet contains two specimens of *H. villosum* var. *tenuiflorum* and second one is a composite of two taxa, the top left material corresponding to *H. villosum* and the other two specimens matching what we currently recognize as *H. villosum* var. *tenuiflorum*. Judging from the description and materials cited by Schumann (1904), it appears that he treated *H. villosum* in the sense of Roscoe (1827), not in the sense of Wallich.

## Acknowledgements

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# ***Bergbambos* and *Oldeania*, new genera of African bamboos (Poaceae, Bambusoideae)**

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## **Abstract**

Two new monotypic genera, *Bergbambos* and *Oldeania* are described for African temperate bamboo species in the tribe *Arundinarieae*, after a comparison of their morphological characteristics with those of similar species from Asia. Morphological differences are supported by their isolated geographical distributions. Molecular evidence does not support the inclusion of these species in related Asian genera, recognising them instead as distinct lineages. New combinations *Bergbambos tessellata* and *Oldeania alpina* are made.

## **Keywords**

*Thamnocalamus*, *Yushania*, *Arundinarieae*, new genus, Africa

## **Introduction**

While Asian temperate bamboos have received critical attention over recent decades (Stapleton 1994, Wong 1995, Li et al. 2006), the generic placement of the temperate bamboos of Africa has not been properly addressed. There seem to be only two temperate bamboo species on the African mainland, currently enumerated most frequently as *Thamnocalamus tessellatus* (Nees) Soderstrom & R.P. Ellis and *Yushania alpina* (K. Schum.) W.C. Lin. These species are in tribe *Arundinarieae* Nees ex Asch. & Graebn., a group also known as the northern temperate clade, identified as a strongly supported monophyletic group from the first molecular analyses of bamboos onwards (Watanabe et al. 1994, Zhang 1996).

Tribe Arundinarieae contains woody bamboos with semelauctant synflorescences (lacking a capability for indeterminate growth from buds subtended by the basal spikelet bracts), ebracteate or partially bracteate synflorescence paraclades (reduced sheathing subtending inflorescence branches) and 3 stamens in each floret. They constitute ca. 800 of the ca. 1400 woody bamboos, and are found in Asia, Africa, and the USA, having a montane or subtropical to temperate distribution.

Molecular studies reviewed by Bamboo Phylogeny Group (2012) suggest that semelauctant inflorescences with 3 stamens and reduced branch sheathing have evolved from tropical bamboos at least twice, once to give the northern temperate clade *Arundinarieae* of Asia and Africa, spreading to N America, and on separate occasions in Central & South America within the *Bambuseae* Kunth ex Dumort., principally to give *Chusqueinae* Bews, with these characters also evolving on a smaller scale within the *Arthrostylidiinae* Bews and *Guaduinae* Soderstr. & R. P. Ellis as well.

Most of the older 3-stamened species were placed at some time in *Arundinaria* Michx., which has 529 combinations, but that genus is now widely recognised as containing only 3 species, all from the Southeast USA (Stapleton et al. 2004, Zeng et al. 2010, Bamboo Phylogeny Group 2012). Treatments of the other species of tribe Arundinarieae vary, according to the breadth of generic concept used, and which characters are given greatest weight. For example, the group of Asian species morphologically closest to *Arundinaria* could be placed (Zhang et al. 2012) either in a polyphyletic broad interpretation of *Arundinaria* (e.g. Li et al. 2006), in a polyphyletic broad interpretation of *Bashania* Keng f. & T.P. Yi (e.g. Keng and Yi 1996), or in the monophyletic *Sarocalamus* Stapleton (Stapleton et al. 2004, Bamboo Phylogeny Group 2012). The morphologically more distinct species are currently placed in other genera, 27 of which were recognised by Bamboo Phylogeny Group (2012), out of a total of 42 genera that have been described within the tribe.

There appears to have been a rapid and relatively recent diversification within bamboos with 3 stamens, including tribe Arundinarieae (Stapleton et al. 2009, Hodkinson et al. 2010, Zhang et al. 2011, Kelchner and BPG 2013), especially those found in montane and temperate areas such as the Andes, the Himalayas, and Northeast Asia. There have also been several reports of hybridisation, reviewed by Triplett et al. (2010) and Zhang et al. (2012). Hybridisation may well have been common in the bamboos, as mechanisms to avoid it have not been documented. Recent rapid diversification and hybridisation, combined with long generation times, appear to have limited the ability of DNA analyses to resolve phylogenetic patterns and define well supported groups for taxonomy, especially at the generic level (Stapleton et al. 2009, Hodkinson et al. 2010), despite reasonable or sometimes very substantial morphological variation.

In the absence of reliable molecular analyses, for the purpose of descriptive treatments of bamboo species (Li et al. 2006, Wong 1995, Dransfield 2000, Widjaja 1997) a more traditional morpho-geographic approach has been maintained in the classification of Asian bamboos. It has only been possible to use molecular data for the elimination of blatantly polyphyletic groups, rather than the determination of monophyletic ones. Attempts to group the genera substantially (e.g. Clayton and Renvoize 1986,



Chao and Renvoize 1989) have resulted in polyphyletic and paraphyletic groups, or clades with weak support that are inconsistent in different analyses.

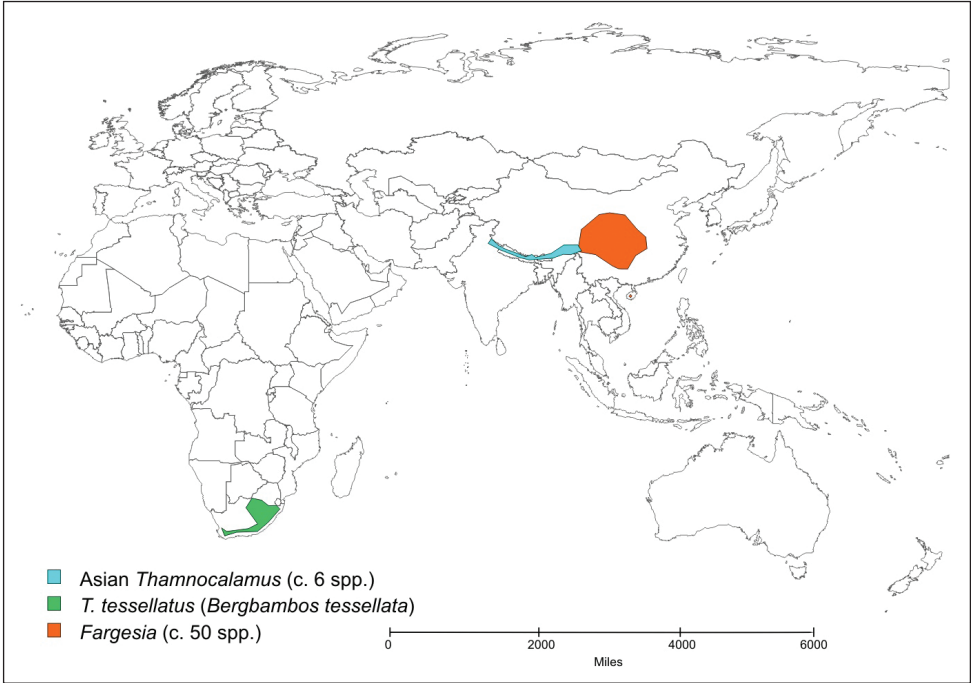
Rapid recent diversification seems to have spawned a host of small groups, often distinguished by relatively minor characters. Combining them together into a few large genera has not been possible without establishing excessively variable genera that are difficult to define and demonstrably polyphyletic. On the other hand recognising only half of the genera described would still lead to a generic concept that is unusually narrow in the grasses. The latter procedure has been followed (Bamboo Phylogeny Group 2012), largely because it has been found unavoidable if a functional binomial classification system is to be maintained. This is necessary in order to allow pragmatic field identification, and subsequently improve sustainable utilisation and conservation of these species, many of which have a limited range of distribution and are threatened by changes in land use and climate. A substantial proportion of the woody bamboos are yet to be described, and the lack of a functional and stable nomenclatural system for field identification has been a major factor preventing their recognition.

Only two species of temperate bamboo have been described from the African mainland. *Thamnocalamus tessellatus* (Nees) Soderstrom & R.P. Ellis is from mountains in southern Africa, while *Yushania alpina* (K. Schum.) W.C. Lin is from mountains in several countries across tropical Africa. *Y. alpina* was described initially in *Arundinaria*, and *T. tessellatus* was soon transferred into that genus from *Nastus* Juss. They were more recently moved into the morphologically closer Asian genera, *Thamnocalamus* Munro and *Yushania* Keng f., the geographically closest representatives of which are found in the Western Himalayas, Map 1 and Map 2.

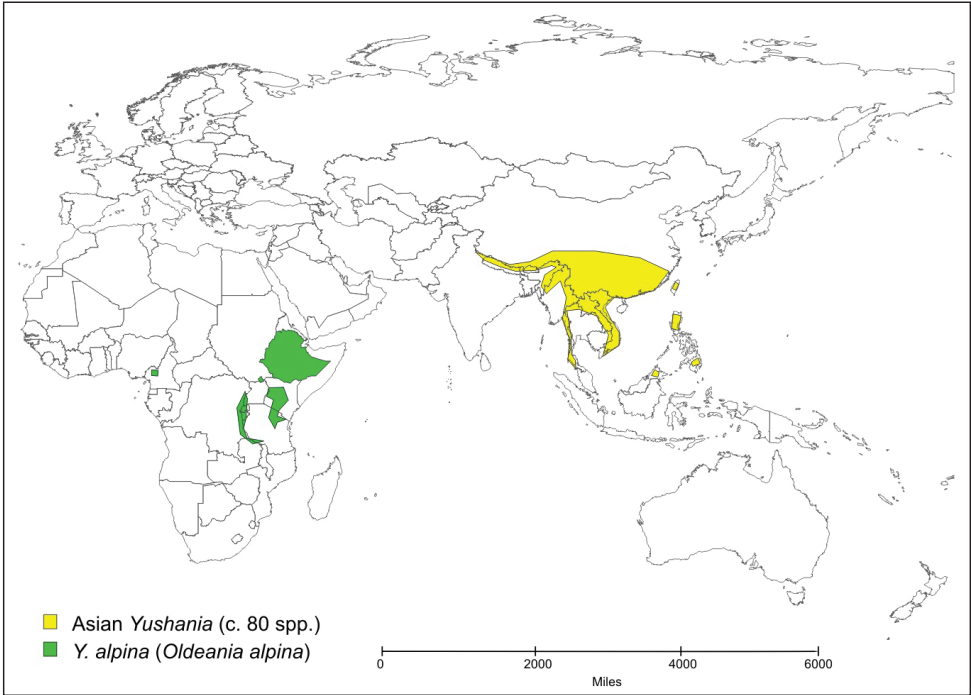
Three further, less well known species, *Thamnocalamus ibityensis* (A. Camus) Ohrnb., *Yushania madagascariensis* (A. Camus) Ohrnb. and *Yushania humbertii* (A. Camus) Ohrnb. (including *Yushania ambositrensis* (A. Camus) Ohrnb.) were described from Madagascar. *Thamnocalamus ibityensis* has been considered conspecific with *T. tessellatus* (Chao & Renvoize, 1989), but it would appear to have substantially different branch sheathing. The two *Yushania* species would appear to share characteristics with *Y. alpina*, but their culms, branching and culm sheaths are not known. *Y. ambositrensis* resolved in a clade with *Y. alpina* (Triplett, 2008), but it is not clear how closely related they really are to *Y. alpina*, or to each other, and which species names should be recognised. Further field work on temperate species of Madagascar is required, as existing collections are incomplete, although any such species may have already become extinct.

## Comparison of morphological characters

Systematics within the grass family has traditionally given greater weight to floral than to vegetative characters. This has often led to polyphyletic genera in the bamboos, the superficiality of their similarities and their separate origins only being revealed by in-depth morphological investigations and/or molecular studies. In order to allow deeper, more objective morphological comparisons and to allow inclusion of consist-



**Map 1.** Distribution of *Thamnocalamus tessellatus*, *Thamnocalamus* in Asia, and *Fargesia*.



**Map 2.** Distribution of *Yushania alpina* and Asian *Yushania* species.

ent and accurate vegetative as well as floral characters in descriptions, the morphology of woody bamboos has been reviewed in depth (Stapleton 1997, available online). Recent bamboo treatments (Judziewicz et al. 1999, Li et al. 2006, Triplett et al. 2006, BPG 2012) have employed these revised concepts and terminologies, and they are followed here.

The characters and character states considered important at the generic level for distinguishing the two African species from similar Asian genera are given in Table 1.

### *Thamnocalamus tessellatus*

Previous generic placements of *Thamnocalamus tessellatus* were based upon an incomplete knowledge of its morphology. *Nastus tessellatus* Nees was described before its flowers were known, and transferred into *Arundinaria* (Munro 1868) simply as it bore “very great resemblance” to that genus. Later discovery of its flowers has shown that it indeed has 3 stamens, rather than the 6 of *Nastus*, but it has pachymorph rhizomes (see Stapleton 1997: fig.1) rather than the leptomorph rhizomes of *Arundinaria*.

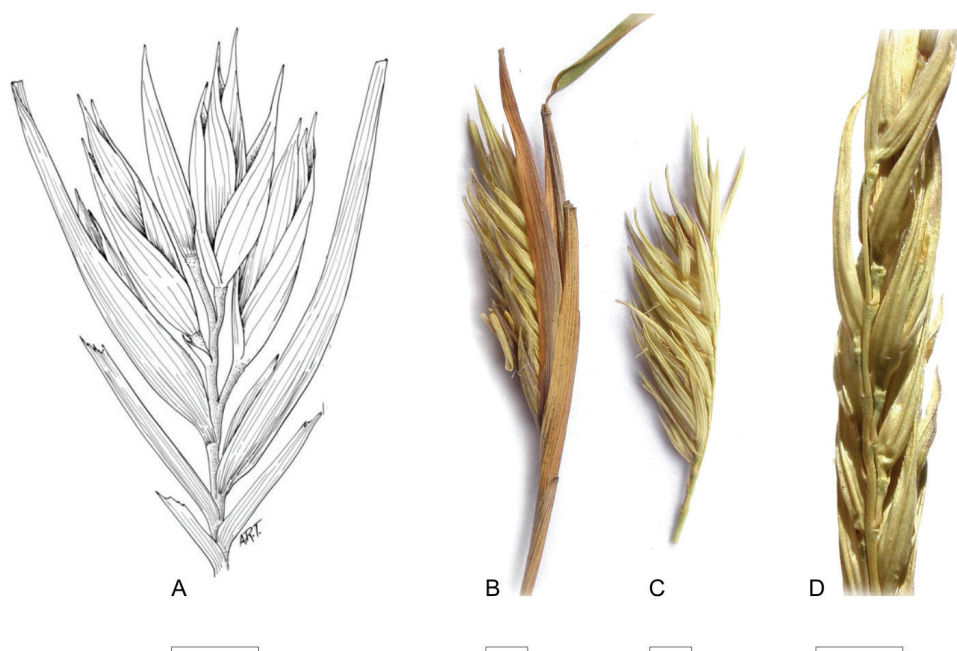
It was transferred into *Thamnocalamus* largely on the basis of leaf anatomical characters by Soderstrom and Ellis (1982), who found that *A. tessellata* shared 10 characters out of 11 with *Thamnocalamus spathiflorus* (Trin) Munro, while it only shared 7 characters with *Fargesia nitida* (Mitford) Keng f. However, *A. tessellata* also shared only 5 characters with *Thamnocalamus aristatus* E.G. Camus, while the possibly conspecific *T. spathiflorus* and *T. aristatus* themselves only shared 6 out of 11 characters. When morphological characters other than those of leaf anatomy, along with more recent molecular results are taken into account, it would appear that the anatomical characters used by Soderstrom and Ellis (1982) are more informative at the level of species or below rather than at generic level.

The synflorescence of *T. tessellatus* has been well illustrated in Hooker’s *Icones Plantarum* (Prain 1913: Tab 2930 <http://www.botanicus.org/page/1349516>), and by Soderstrom and Ellis (1982). When examined closely, it can be seen that the synflorescence of *T. tessellatus* has similarities to those of both *Thamnocalamus* and *Fargesia* Franchet, see Table 1, as they are compressed, and are associated with several supporting sheaths. However, while *Thamnocalamus* has loose racemose panicles, *T. tessellatus*, like *Fargesia*, consistently bears short racemes. These are structurally very similar to those of *Fargesia*, but differences arise in the arrangement of the florets. In *Fargesia* the racemes are held tightly within imbricating sheaths, which can extend well beyond the spikelets. Development within the sheaths forces them to emerge to one side and appear unilateral, with the pedicels tightly pressed against the rachis. Those of *T. tessellatus* are more cylindrical, the spikelets not so constricted by the sheaths, and the pedicels are free to develop in a normal distichous fashion, Figure 1.

In addition, in *T. tessellatus* the pedicels are scabrous, the glumes of each spikelet are basally tight and contain no vestigial bud remnants, and the racemes are usually largely ebracteate. The usually single fertile florets also distinguish *T. tessellatus* from

**Table 1.** Principal morphological characters of *Bergbambos*, *Oldenania*, and Asian members of 5 similar genera.

	<i>Bergbambos</i> ( <i>Thamnocalamus</i> <i>tessellatus</i> )	<i>Thamnocalamus</i>	<i>Fargesia</i>	<i>Oldenania</i> ( <i>Yushania alpina</i> )	<i>Yushania</i>	<i>Borinda</i>	<i>Chimonocalamus</i>
synflorescence	raceme, not unilateral	raceme to panicle, not unilateral	raceme, unilateral	panicle, not unilateral	panicle, not unilateral	panicle, not unilateral	panicle, not unilateral
paraclaides	largely ebracteate	substantially bracteate	variably bracteate	largely ebracteate	largely ebracteate	largely ebracteate	largely ebracteate
pedicel	scabrous	glabrous	glabrous	glabrous	glabrous	glabrous	glabrous
fertile florets	1	2–several	2–several	2–several	2–several	2–several	2–several
glume bud remnants	absent	variable	present	absent	variable	variable	absent
rhizomes	short-necked	short-necked	short-necked	long-necked	long-necked	short-necked	short-necked
clump form	unicaespitose	unicaespitose	unicaespitose	culms solitary	pluricaespitose	unicaespitose	unicaespitose
nodes	without roots	without roots	without roots	with short roots	without roots	without roots	with root thorns
supranodal ridge	obscure	obscure	obscure	well developed	obscure	obscure	well developed
culm internodes	terete	terete	terete	sulcate	terete	terete	terete
branch sheathing	reduced	complete	reduced	reduced	reduced	reduced	complete
branch orientation	erect	erect	erect	spreading	erect to spreading	erect	spreading
mid-culm branches	5–7	3–8	5–7	3–7	5–11	5–7	3
culm sheath blades	erect or reflexed	usually erect	erect or reflexed	usually reflexed	erect or reflexed	erect or reflexed	usually reflexed



**Figure 1.** Raceme of *Thamnocalamus tessellatus* (A), compared to: B *Fargesia nitida*, lateral view with enclosing sheaths; C *Fargesia nitida* with enclosing sheaths removed D *Fargesia nitida*, dorsal view, sheaths removed. A from Soderstrom and Ellis (1982), drawn by A. R. Tangerini, © Smithsonian Institution. B, C, D from Stapleton 1061b. Scale bars 2 mm.

other *Thamnocalamus* and *Fargesia* species, but this character should be treated with caution as it can be a specific as well as a generic character.

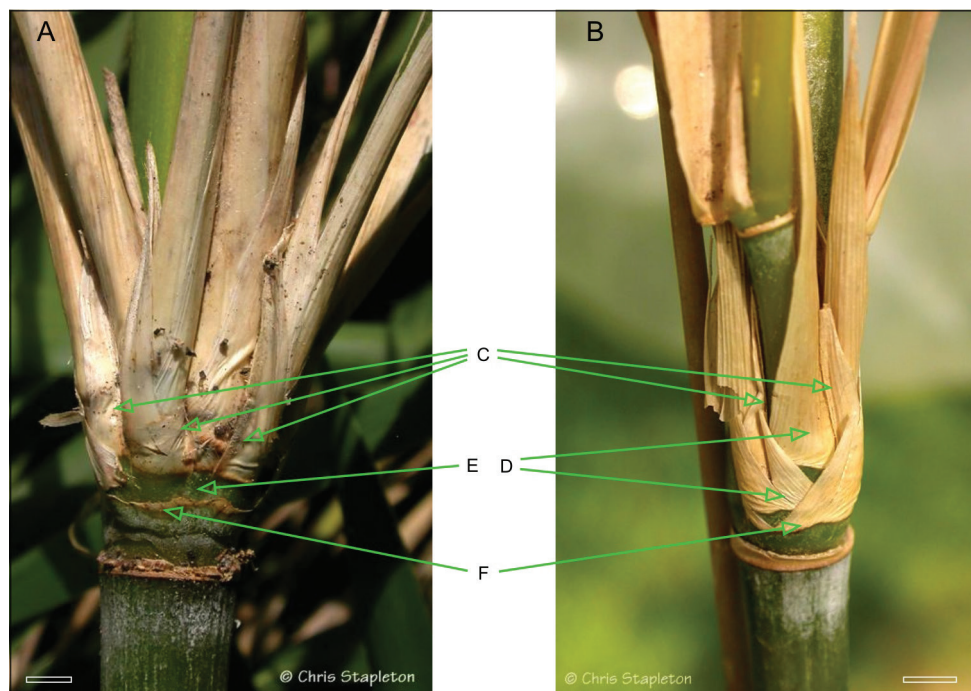
*Thamnocalamus tessellatus* also has vegetative characteristics that distinguish it, notably from Asian members of *Thamnocalamus*, (see Table 1). A close inspection of the branching reveals not the pattern seen in species such as *Thamnocalamus crassinodus* (T.P. Yi) Demoly, but instead the substantial reduction in sheathing seen in *Fargesia*, *Yushania*, and *Borinda* Stapleton, Figure 2.

The branches of *Thamnocalamus tessellatus* are subequal, arranged side by side through strong compression of the basal internodes of the central branch, accompanied by loss of some of the sheaths at the nodes, Fig. 2A, cf *Thamnocalamus crassinodus*, Fig. 2B. This allows lateral branch prophylls to be seen side by side without any intervening sheaths. These patterns were contrasted by Stapleton (1991; 1994: fig. 1; 1997: fig. 2), and also illustrated for *T. tessellatus* by Soderstrom and Ellis (1982: fig.1, fig. 4).

In addition to the synflorescence and branching, *T. tessellatus* also differs in minor details that are harder to quantify, including the more varied orientation of the foliage leaves, and the delicate appearance of its oral setae and their more varied orientation, Figure 3.

Thus in terms of vegetative macro-morphological characteristics important at the generic level, *T. tessellatus* is closer to *Fargesia* than to *Thamnocalamus*, but can be distinguished from both. In general appearance it resembles a coastal species of



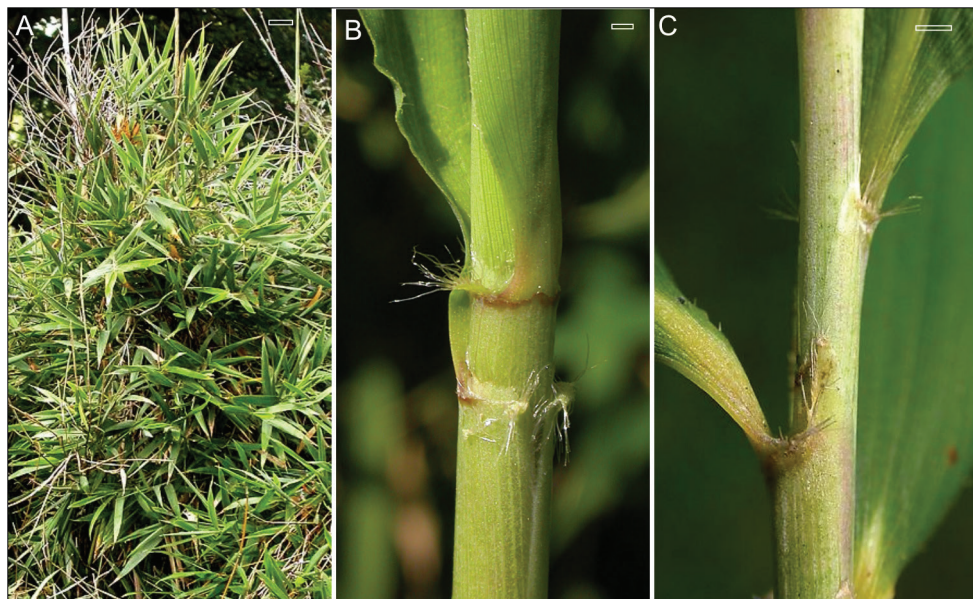


**Figure 2.** Comparison of branch complement sheathing from mid-culm nodes of *Thamnocalamus tessellatus* (A) and *Thamnocalamus crassinodus* (B) C Lateral branch prophylls D Sheaths obscuring prophyll bases in *T. crassinodus* E Equivalent sheaths completely absent in *T. tessellatus*, prophylls visible F Branch bud prophyll, removed in A, still present in B. Scale bars 1 cm. From <http://www.bamboo-identification.co.uk>

*Pleioblastus* Nakai from Japan, with rather loose clumps, erect culms with short branches bearing coarse, irregularly arranged foliage with persistent sheaths. This contrasts with the delicate foliage leaves, all oriented towards the light on pendulous branches seen in Himalayan species of *Thamnocalamus* and in *Fargesia*. This is likely to be associated with the more open ecological habitat in which *T. tessellatus* is found, rather than the darker forest understorey habitats of Asian *Thamnocalamus* and *Fargesia* species.

### *Yushania alpina*

The synflorescence of *Y. alpina* is practically indistinguishable from those of several Asian and American bamboos, including species of *Arundinaria*, *Sarocalamus*, and *Yushania*—an open panicle with nearly complete reduction in sheathing at points of branching so that it is essentially ebracteate. However, the sheaths are often reduced to small tough bracts, as well as the more delicate sheath remnants or tufts of hairs seen in



**Figure 3.** *Thamnocalamus tessellatus*. **A** Random orientation of leaf blade; **B** and **C** Irregular orientation of delicate oral setae. Scale bars **A** 10 cm, **B** and **C** 2 mm. From <http://www.bamboo-identification.co.uk/html/tessellatus.html>

similar genera. In addition the lateral spikelets are more often sessile or subsessile, without a long pedicel. However, these characters are relatively minor and quite variable.

*Yushania alpina* is more distinct vegetatively. Reaching heights of up to 20m in its natural habitat, the tall, very erect culms are potentially much larger than those of any Asian species of *Yushania*, which only reach a maximum height of about 7m. Culm nodes and branching also differ substantially from those of Asian species of *Yushania*, Figure 4.

Branches vary in size more than those of Asian *Yushania* species. The central branch is strongly dominant, and the first two lateral branches are also strong. The orientation of the branches is less erect than those of most species of *Yushania*, becoming nearly horizontal. Above the branches the internode is distinctly sulcate, much more prominently than is seen in Asian *Yushania* species, as a result of the development of strong branches. Moreover there is often a dense ring of short, partially developed aerial roots at nodes in the lower part of the culm, often extending into the mid-culm region as well. This character is only known in species of *Chimonocalamus* Hsueh & T.P. Yi, and the leptomorph-rhizomed *Chimonobambusa* Makino among the Asian temperate bamboos. The roots are not as sharp and thorn-like as those seen in *Chimonocalamus* and *Chimonobambusa*, but they can be very distinct and prominent. Nodes have a distinct infranode between the culm sheath attachment and the supranodal ridge, which is well developed, Figure 5.

In its natural habitat, the open stands have a widely spaced appearance closer to that of a species of *Phyllostachys* Siebold & Zucc., rather than the denser thickets of





**Figure 4.** *Yushania alpina*. **A** culm sheath **B** leaf sheaths, culm node with ring of thorn-like aerial roots and distinct supra-nodal ridge, sulcate internode, and dominant central branch. Scale bars top right, 2 cm.



**Figure 5.** *Yushania alpina* **A** tall culms arising separately with prominent supra-nodal ridges (arrowed), Rwenzori, Uganda **B** culm node with ring of thorn-like aerial roots (arrowed), Mt. Kenya. Scale bars **A** 25 cm, **B** 5 cm. Photos courtesy of: (A) Peter Gill, (B) Harry Jans, [www.jansalpines.com](http://www.jansalpines.com)

Asian *Yushania* species, because the rhizomes have consistently long necks, giving solitary culms rather than the denser clusters of pluricaespitose culms seen in Asian species of *Yushania*.

Branch structure and sheathing is difficult to distinguish from that of *Yushania* or *Fargesia*. Although the prophyll is usually 2-keeled, there is replication side by side of lateral branch initials without intervening sheaths. In this way it differs fundamentally from *Chimonocalamus*, which has only 3 branches and full sheathing.

## Discussion

The morphological differences between *Thamnocalamus tessellatus*, *Yushania alpina* and other representatives of these and similar Asian genera suggest that although the two African bamboos share several characters and presumably common ancestors with Asian bamboos, they are not as closely related to their Asian relatives as previously thought.

The morphological distinctions are supported by geographical isolation, (see Maps 1 and 2). Long-distance dispersal of temperate bamboos is highly unlikely because of a lack of any specialized seed dispersal mechanism or dormancy, brief viability of seed, exacting habitat requirements, and extremely infrequent flowering (Stapleton et al. 2004).

Together the morphological distinctions and geographical isolation justify the recognition of two new genera, following the existing relatively narrow generic concepts applied in the northern temperate clade, tribe *Arundinarieae*.

The new genera are keyed out below along with their 6 morphologically closest relatives in the tribe including the two Asian genera with distinct nodal thorns, as well as the North American type genus of the tribe, *Arundinaria*, and its Asian analogue, *Sarocalamus*.

## Key to *Bergbambos*, *Oldeania* and related genera

- 1 Rhizome leptomorph..... 2
- Rhizome pachymorph..... 4
- 2 Basal culm nodes with thorns, branches spreading ..... *Chimonobambusa*
- Basal culm nodes without thorns, branches erect ..... 3
- 3 Pedicels glabrous, leaf blades thick, SE USA ..... *Arundinaria*
- Pedicels not glabrous, leaf blades thin, Himalayas & W China ... *Sarocalamus*
- 4 Branches 3, all sheaths developed, basal nodes with thorns ... *Chimonocalamus*
- Branches 3-15, sheathing reduced, basal culm nodes with or without thorns ... 5
- 5 Rhizomes long or variable in length, clumps open or spreading ..... 6
- Rhizomes consistently short, culms in single clumps..... 7
- 6 Nodes raised, basal culm nodes usually with thorns, Africa ..... *Oldeania*
- Nodes not raised, basal culm nodes without thorns, Asia ..... *Yushania*
- 7 Branch sheathing complete ..... *Thamnocalamus*
- Branch sheathing reduced ..... 8
- 8 Synflorescence branching paniculate ..... *Borinda*

–	Synflorescence branching racemose.....	9
9	Racemes unilateral, W China.....	<i>Fargesia</i>
–	Racemes not unilateral, Africa.....	<i>Bergbambos</i>

Sufficient data is now available to test whether this classification would gain support from molecular phylogenetic evidence. These two African species were not clearly resolved with Asian representatives of any genera in any molecular studies. For example, in a comparison of ITS sequences (Guo et al. 2002), *Thamnocalamus tessellatus* did not resolve with the type species of *Thamnocalamus*, *T. spathiflorus*, and its position varied between topologies. In the nuclear ribosomal ITS analysis of Hodkinson et al. (2010), *Yushania alpina* did not group with other *Yushania* species or closely with any other taxon. Weak associations between *Yushania alpina* and *Chimonocalamus* species were found by Guo and Li (2004) and Triplett (2008), which is interesting as they share possession of aerial roots developed into thorn-like structures, although they differ in other ways. However, neither *Yushania alpina* nor *Thamnocalamus tessellatus* resolved with putative relatives in these or similar genera of temperate bamboos in the most comprehensive studies undertaken so far, using sequences from 8 regions of cpDNA in 146 species and 26 genera (Zeng et al. 2010), and 108 bamboos from 25 genera using plastid DNA and nuclear GBSSI gene sequences (Zhang et al. 2012).

The molecular data would suggest that their inclusion in Asian genera would render those genera polyphyletic. Because their monotypic status is considered likely they could not be supported as monophyletic groups themselves in a classification based solely on molecular phylogeny. However, Zeng et al. (2010) and Zhang et al. (2012) considered them both to represent distinct lineages, and it is not possible to place them in well supported meaningful monophyletic groups except the tribe *Arundinarieae*. Therefore while the molecular data would not allow the diagnosis of monophyletic genera for the African bamboos following a strict Hennigian cladistic analysis, neither their current placement in *Thamnocalamus* and *Yushania*, nor placement in any other existing genus receives any support either. Continuing to include these bamboos in Asian genera causes serious problems when describing or distinguishing between those genera.

Although woody bamboos are considered to have evolved originally in Gondwanaland rather than Eastern Asia (Hodkinson et al. 2010), these African representatives are nested within the northern temperate clade, the tribe *Arundinarieae*, with a largely Asian distribution. This is estimated to have diverged from other woody bamboos around 23 mya (Hodkinson et al. 2010), 29 mya (Bouchenak-Khelladi et al. 2010) or 37.5 mya (Christin et al. 2008), but to have radiated only ca. 9 mya (Bouchenak-Khelladi et al. 2010) 10 mya (Hodkinson et al. 2010), or 19 mya (Christin et al. 2008). Peng et al. (2013) after sequencing 95% of the *Phyllostachys edulis* genome found evidence of whole genome duplication 7–12 mya, supporting the more recent dates.

Collision of tectonic plates has been suggested as a likely cause of this rapid radiation (Stapleton et al. 2009, Hodkinson et al. 2010). African and Indian plates met

the Eurasian plate around that time, allowing a biotic interchange and subsequent radiation and diversification of Gondwanan elements into a wealth of new habitats. However, the temperate ancestors of these two African bamboo genera seem to have diverged around the same time that temperate bamboos arrived in Eastern Asia. Inclusion of endemic temperate bamboos from S India, Sri Lanka and Madagascar in a molecular phylogeny is required before any conclusions can be drawn as to where bamboos from the northern temperate clade first evolved, but there seems no evidence for an African origin, and it seems more likely that temperate bamboos radiated from India to Asia, Africa, and N America.

## Nomenclature

### *Bergbambos* Stapleton, gen. nov.

urn:lsid:ipni.org:names:77131102-1

<http://species-id.net/wiki/Bergbambos>

**Remarks.** Differing from *Arundinaria* and *Sarocalamus* and similar to *Thamnocalamus* and *Fargesia* in its short-necked pachymorph rather than leptomorph rhizomes, and its compressed synflorescences. Differing from *Borinda* and *Thamnocalamus* in its racemose rather than paniculate synflorescence branching. Differing from *Fargesia* in the distichous rather than unilateral arrangement of spikelets in the racemes, the spikelets usually having only one fertile floret, and the scabrous pedicels. Differing from *Thamnocalamus* in the branch complement with reduced sheathing, and from *Fargesia* in the more varied orientation of the leaf blades.

**Type.** *Bergbambos tessellata* (Nees) Stapleton comb. nov. urn:lsid:ipni.org:names:77131104-1 Basionym: *Nastus tessellatus* Nees, Fl. Afr. Austr. 1: 463. 1841. *Arundinaria tessellata* (Nees) Munro; *Thamnocalamus tessellatus* (Nees) Soderstrom & R.P. Ellis. Type: S Africa, Katberg, 4000–5000ft, J.F. Drège s.n. (lectotype, designated in Soderstrom & Ellis 1982, pg. 54: K!, <http://apps.kew.org/herbcat/getImage.do?imageBarcode=K000345516>

Rhizome pachymorph, short-necked, giving dense clumps. Culms to 7 m tall, diam. to 2 cm, nodding to pendulous, terete, smooth, nodes not raised and unarmed. Mid-culm branch complement initially with 5–7 main branches, erect, sheathing reduced. Culm sheaths persistent, tough. Leaf sheaths several to many, persistent, blades thick with random orientation. Synflorescence semelauquant, racemose, branch sheathing occasionally a soft sheath remnant, usually absent. Racemes not unilateral. Spikelets shortly pedicellate with 1(–2) fertile florets, pedicel scabrous. Empty glumes 2, no bud remnants. Lemma and palea similar in length. Stamens 3, filaments free. Stigmas 3. Lodicules 3.

Name *Bergbambos* from the Afrikaans name (Bergbamboes) in South Africa.

This genus would appear to be monotypic, confined to the mountains of South Africa, Lesotho and Swaziland.



***Oldeania* Stapleton, gen. nov.**

urn:lsid:ipni.org:names:77131103-1

<http://species-id.net/wiki/Oldeania>

**Remarks.** Differing from *Arundinaria* and *Sarocalamus* and similar to *Yushania* in its long-necked pachymorph rather than leptomorph rhizomes, though similar to all in its open panicles. Differing from *Yushania* in its sulcate culm internodes, fewer, more horizontal branches, culm nodes with well developed supra-nodal ridge and often thorn-like aerial roots. Similar to *Chimonocalamus* in its panicles and thorn-like roots at culm nodes, but differing in its multiple branches with reduced sheathing and sulcate culm internodes.

**Type.** *Oldeania alpina* (K. Schum.) Stapleton comb. nov. urn:lsid:ipni.org:names:77131105-1 Basionym *Arundinaria alpina* K. Schum. in Engler, Pflanzenwelt Ost-Afrikas 5: 117. 1895. *Sinarundinaria alpina* (K. Schum.) C.S. Chao & Renvoize; *Yushania alpina* (K. Schum.) W.C. Lin. Type: Kenya, Kikiju, G.A. Fischer 672 (holotype: B n.v., destroyed).

Rhizome pachymorph, long-necked, giving open stands and solitary culms. Culms to 15(–20) m tall, diam. to 6(–10) cm, erect to nodding, terete with shallow sulcus above branches, smooth, nodes with prominent supranodal ridge, in lower to mid culm a nodal ring of dense, short, hard, and thorn-like aerial roots often well developed. Mid-culm branch complement initially with 3–5 main branches, spreading, sheathing reduced. Culm sheaths deciduous, tough. Leaf sheaths several to very many, blades thick. Synflorescence semelauctant, paniculate, branch sheathing reduced to hard bracts, soft sheath remnants or hairs. Spikelets pedicellate with several fertile florets, pedicel scabrous. Empty glumes 2, bud remnants present or absent, fertile glumes 4–8. Lemma and palea similar in length. Stamens 3, filaments free. Stigmas 2. Lodicules 3.

Name *Oldeania* from the Maasai common name (Oldeani) in Tanzania.

Currently only the type species can be reliably placed in the genus, which thus has a distribution across tropical Africa from Cameroon in the west to E Africa, where it occurs from Ethiopia south to Tanzania. There is a possibility that species from Madagascar will be placed in this genus when they are better known, but they may be conspecific or even introduced. It provides important montane wildlife habitats and food, notably for the critically endangered Mountain Gorilla, *Gorilla beringei beringei*.

The holotype, G.A. Fischer 672, was destroyed by fire during the 1939–1945 World War. No trace of the type collection or any duplicate has been found in surviving components of the Berlin collections, nor in other herbaria, including the Hamburg collections taken to Russia and recently repatriated (Poppendieck pers. comm.). The likelihood of substantial infraspecific variation, the possibility of further species, and the lack of other collections from the type locality together make it inadvisable to select a neotype or epitype until new collections have been made.

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