

Achene micromorphology and its taxonomic significance in some species in *Taraxacum* sect. *Palustria* (Asteraceae)

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Abstract

The genus *Taraxacum* is one of the largest and taxonomically most complicated apomictic genera. Currently, it is considered to consist of over 2800 species placed within 60 sections. Due to the large number of species, and their uniform morphological design and plasticity of leaves, the identification of plants at the species level is challenging even for specialists. This problem significantly hinders the study of their properties and the rational use of these valuable medicinal and nutritional plants. This paper presents the results of research on the morphology and micromorphology of achenes of 28 *Taraxacum* species of sect. *Palustria* and for comparison one species per section of: *Erythrosperma*, *Naevosa*, *Piesis*, and *Taraxacum*. The achenes were measured with a stereoscopic microscope and a biometric program, and micromorphological studies were performed by scanning electron microscopy. It has been shown that traits associated with achene morphology and micromorphology have a high diagnostic value, allowing us to distinguish sections as well as species within the sect. *Palustria*. Based on the examined achene features, a dichotomous key for determining the studied species was constructed.

Keywords

achene, micromorphology, scanning electron microscopy (SEM), *Taraxacum*, taxonomy

Introduction

The family Asteraceae is a large family of flowering plants with over 25,000 species and 1620 genera (Stevens 2001). Asteraceae species can be found in all continental zones and they play a significant role in phytocenoses (Takhtajan 2009). *Taraxacum* is one of the largest and most taxonomically complex apomictic genera. Its wide variety of forms is reflected in over 2,800 species described so far, clustered in about 60 sections (Kirschner et al. 2015; Kirschner and Štěpánek 1997, 2004, 2008; Uhlemann et al. 2004). Among its main mechanisms, Kirschner and Štěpánek (1996) include multiple hybridization, polyploidization, and apomixis that fix hybrids with odd ploidy levels. At high latitudes of the Northern Hemisphere, where sexually reproducing species are scarce, the emergence of new forms (microevolution) is caused by autopolyploidization processes and somatic mutations perpetuated by apomixis (Kirschner and Štěpánek 1996; Mes et al. 2002; Majeský et al. 2012). The genetic variability is superimposed by the very high phenotypic plasticity of dandelions, which significantly increases the already serious problems with species identification (Kirschner et al. 2016). Phenotypic plasticity of the species is a form of adaptation of the plant to habitat conditions and an expression of its potential for colonizing areas that differ in many habitat features (Stace 1993; Sultan 1995, 2000, 2001). The features that are the least susceptible to environmental changes, and thus used in taxonomy, are the features of flower and seed, fruit, and leaf arrangement (Heywood 1967). On the other hand, the following features are the most susceptible to environmental changes: shoot height, leaf size and color, flower size and flowering time (Heywood 1967; Stace 1993; Sultan 1995).

The identification problem resulting from high variability, among others, also applies to the relatively thoroughly investigated *Taraxacum* sections, including one of the most vulnerable sections – *Palustria* – to which this study is devoted.

Taraxacum sect. *Palustria* has about 160 described and confirmed species (Hudziok 1969; Kirschner and Štěpánek 1998; Štěpánek and Kirschner 2001, 2017; Tikhomirov 2003; Aquaro et al. 2008; Carlesi and Peruzzi 2012; Marciniuk et al. 2012; Marciniuk et al. 2018). They are almost exclusively apomictic polyploids, from triploids ($2n = 24$) to hexaploids ($2n = 48$). Sexual diploids are represented only by the two southern European species *Taraxacum raii* and *T. tenuifolium*. In the *Palustria* section monograph of Kirschner and Štěpánek (1998), they developed a multi-access key for species identification which was based mainly on the morphology of flowers and inflorescences. In practice, this key allows for the determination of only very typical specimens with a set of well-developed diagnostic features for a species (or only a group of species). Such plants are rare in nature, and searching for them requires a great deal of knowledge and experience (Kirschner et al. 2016). Atypical specimens, challenging to identify, predominate in herbarium materials, which often leads to erroneous determinations. Such misidentifications have serious consequences, especially where *Taraxacum* is used for medical and cosmetic purposes. It is therefore essential to find new features and patterns to help identify dandelions.

One technique that allows for the determination of new diagnostic features is SEM (scanning electron microscopy). SEM had already been used in the first half of the 20th century (Zworykin et al. 1942). Since that time, SEM has been used for the identification of species in different groups of organisms such as bacteria, fungi, lichens, mosses, and vascular plants (Duckett and Soni 1972; Jamjoom 2007; Rewicz et al. 2017a, b; Fass 1973; Ullah et al. 2018). Nowadays, SEM is playing a useful role in taxonomic research of plants. It has been used to describe the ultrastructure of, e.g., fruits and seeds (Ullah et al. 2019a, b; Hadidchi et al. 2020). Many studies have shown that fruit or seed can very well serve in the identification, classification, and delimitation of species at various taxonomic levels (Clifford and Smith 1969; Bacchetta et al. 2011; Gamarra et al., 2008, 2010; Heneidak and Khalik 2015; Martín-Gómez et al. 2019a, b). Moreover, biometric seed and fruit sculpture analysis has proved to be a useful tool for phylogenetic inference (Saadaoui et al. 2013).

The application of SEM for micromorphologic evaluation in taxonomic research in the family Asteraceae seems to be promising (Kreitschitz and Vallès 2007; Bona 2015; Karaismailoglu 2015; Ozcan and Akinci 2019). Unfortunately, in the case of the genus *Taraxacum*, despite its size and taxonomic complexity, such research is scarce to date. The exceptions are the works of Savadkoohi et al. (2012) concerning 17 species from different sections; Dudáš et al. (2013) concerning four species from the section *Erythrosperma*; Marciniuk et al. (2009), in which achenes *T. scanicum* and *T. bellicum* (under the name *T. prunicolor*) were compared; Wu et al. (2011) concerning 10 species from North-East China; and a compilation of scanning microscopic images of achenes of selected species from *Taraxacum* sect. *Palustria* and *T.* sect. *Erythrocarpa* (Schmid 2002; Bednorz and Maciejewska-Rutkowska 2010; Marciniuk 2012), but without in-depth comparative studies.

It is important to develop a functional key for the genus *Taraxacum*, based on the largest possible number of features, including relatively stable fruit properties. Features associated with the morphology of leaves and inflorescences are highly variable (Kirschner et al. 2016), and usually poorly developed in the case of marsh dandelions not growing in optimal habitats. The determination of such plants is challenging and connected with a high risk of errors. Dandelions are essential medicinal and food plants as well as model organisms, among others, in research on apomixis. Thus, the high probability of erroneous determinations or the use of ambiguous collective names in publications reduces the credibility of the study and may even lead to undermining it (Kirschner et al. 2016). In our research, we focused primarily on the Central European section *Palustria*, whose representatives were compared with selected species from four sections (*Erythrosperma*, *Piesis*, *Taraxacum*, and *Naevosa*) with which *Taraxacum* sect. *Palustria* could have been crossed in the past.

The presented study aims to use micromorphological characters (based on scanning electron microscopy and biometrical traits) of achenes for the taxonomic identification and species delimitation in some species of the genus *Taraxacum*.

Materials and methods

Biometric analyses of achene body

We analyzed achenes from 28 *Taraxacum* species, 24 of which belong to sect. *Palustria* and 4 species to four other sections included for comparison: *Taraxacum bessarabicum* of sect. *Piesis*, *T. bellicum* (in the sense of the description of *T. prunicolor* by Schmid et al. 2004) of sect. *Erythrosperma*, *T. gelertii* of sect. *Naevosa*, and *T. linearisquameum* of sect. *Taraxacum*. Marsh dandelion species have been chosen to represent the majority of Central European species groups (according to Kirschner and Štěpánek 1998). Achenes were collected from properly developed plants from natural habitats (Table 1) for each species. From ten plants, at least 30 correctly developed and undamaged achenes were randomly selected for measurements. Herbarium sheets were deposited in the Herbarium of Siedlce University of Natural Sciences and Humanities (WSRP), Poland. Five achene traits were quantified: A) cone length, B) spinule length, C) achene width, D) achene length (without cone) (Fig. 1), and E) index – the ratio of achene length to cone length. The achene traits were measured automatically in the horizontal view using the biometric program OptaView-IS version 4.3.0.6001. The observations and measurements of the achene were performed with the use of OPTATECH optical stereomicroscope (Table 1). To analyze ornamentation on the achene body, we took about 50 measurements of spinules from the surface of achenes (three to five individuals from each species). Measurements were done based on SEM images.

The length of spinules was chosen as the criterion for dividing the analyzed species into three types:

- Type A) very short spinules with a free part length of 5 to 10 microns;
- Type B) medium spinules with a free part length from 11 to 19 microns;
- Type C) very long spinules with a free part length of 20 to 30 microns.

The terminology of ornamentation of achene body is based on Stearn (2004).

SEM analyses

Micromorphological data were obtained by SEM (Phenom Pro X) at the Department of Invertebrate Zoology and Hydrobiology, University of Lodz (Poland). The achenes were sputter-coated with a 4 nm layer of gold. The achene surface ultrastructure 3D models were made using 3D Roughness Reconstruction software from the Phenom Suite. The digital images obtained by SEM were trimmed and arranged in plates using Corel Draw 2018.

Statistical analyses

The following basic characteristic features were calculated: arithmetic average (\bar{x}), maximum and minimum values (max and min), standard deviation (SD), and coefficient of

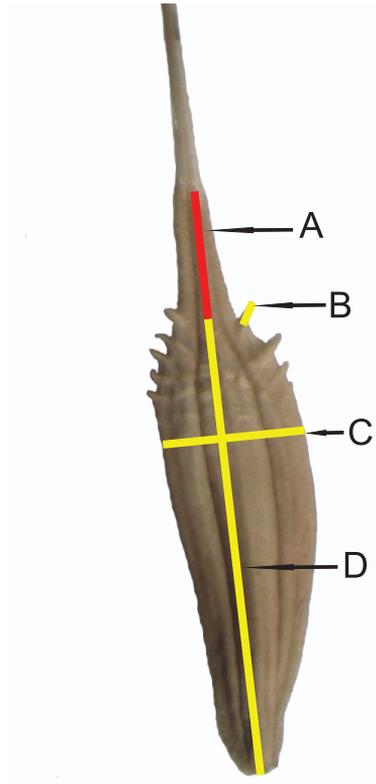


Figure 1. Measurement scheme of achenes: **A** cone length **B** spinule length **C** achene width **D** achene length.

variation (CV). A cluster analysis (CA) on the shortest Euclidean distances according to Ward's method was applied to determine the number of clusters between taxa. To differentiate between species, a K-means clustering analysis was conducted. The optimal number of K-groups was determined based on the results of agglomeration analysis.

The Shapiro-Wilk and Kolmogorov-Smirnov tests were conducted to check for a normal distribution of the data; both were not normal, and therefore, the Kruskal-Wallis test (for $P \leq 0.05$) was used, as a nonparametric alternative to ANOVA (Zar 1984).

The software packages STATISTICA PL. ver. 13.1 and MVSP 4.5 were used for all the mentioned numerical analyses (van Emden 2008).

Results

Biometrical studies of achene body

The analysis of achene traits revealed various informative features useful for the identification of species within this section. The longest achenes occur in *T. ancoriferum* (4.42

Table 1. List of studied species of *Taraxacum* included in this study. N – latitude, E – longitude; abbreviations: the first capital letter from the genus and the three first letters from the species name; bold: species from outgroup sections.

Species	Abbreviation	Number of analyzed achenes	Locality	N / E	Habitat
<i>T. ancoriferum</i> Hudziok in Feddes Repert. 80: 333. 1969	<i>T. anc</i>	43	Czuchów	52°17', 22°44'	wet meadow
<i>T. balricum</i> Dahlst. in Bot. Not. 1905: 162. 1905	<i>T. bal</i>	38	Pyzdry	52°09', 17°41'	salt meadow
<i>T. bavarium</i> Soest in Acta Bot. Neerl. 14: 21. 1965	<i>T. bav</i>	42	Czuchów	52°17', 22°44'	wet meadow
<i>T. bellicum</i> (sect. <i>Erythrosperma</i>) Sonck in Memoranda Soc. Fauna Fl. Fenn. 59: 1. 1983	<i>T. bel</i>	51	Nowogród	53°13', 21°52'	psammophilous grassland
<i>T. belorussicum</i> Val. N. Tikhom. in Novosti Sist. Vysš. Rast. 35: 207. 2003	<i>T. belo</i>	39	Mścichy	53°25', 22°30'	peat bogs in the Biebrza Valley
<i>T. bessarabicum</i> (sect. <i>Piesis</i>) (Hornem.) Hand.-Mazz. in Monogr. Taraxacum: 26. 1907	<i>T. bes</i>	42	Košice	48°45', 21°15'	city lawn
<i>T. brandenburgicum</i> Hudziok in Feddes Repert. 75: 131. 1967	<i>T. bra</i>	48	Pyzdry	52°09', 17°41'	salt meadow
<i>T. dentatum</i> Kirschner & Štěpánek in Thaiszia 4: 156. 1994	<i>T. den</i>	50	Czuchów	52°17', 22°44'	wet meadow
<i>T. fascians</i> Kirschner, Mikoláš & Štěpánek in Preslia 69: 45. 1997	<i>T. fas</i>	42	Bydgoszcz	53°06', 18°07'	wet meadow
<i>T. geleri</i> (sect. <i>Naevosa</i>) M. P. Christ. in Rosenvinge & Warming, Bot. Iceland 3: 303. 1942	<i>T. gel</i>	51	Władysławowo	54°47', 18°24'	wet meadow
<i>T. hollandicum</i> Soest in Ned. Kruidk. Arch. 52: 226. 1942	<i>T. hol</i>	47	Kozłówek	49°50', 21°40'	wet meadow
<i>T. linearisquameum</i> (set. <i>Taraxacum</i>) Soest in Proc. Kon. Ned. Akad. Wetensch., Ser. C, Biol. Med. Sci. 69: 471. 1966	<i>T. lin</i>	31	Lipnica Wielka	49°42', 20°43'	city lawn
<i>T. madidum</i> Kirschner & Štěpánek in Thaiszia 4: 149. 1994	<i>T. mad</i>	30	Krościenko	49°25', 20°25'	calcareous fen
<i>T. mariae</i> J. Marciniuk & P. Marciniuk in Phytotaxa 376 (5): 208. 2018	<i>T. mar</i>	33	Modliborzyce	50°45', 22°19'	wet meadow
<i>T. mendax</i> Kirschner & Štěpánek in Folia Geobot. Phytotax. 20: 413. 1985	<i>T. men</i>	56	Matulnik	49°52', 22°06'	wet meadow
<i>T. paucilobum</i> Hudziok in Feddes Repert. 72: 29. 1965	<i>T. pau</i>	41	Krześlin	52°13', 22°21'	wet meadow
<i>T. pauckertianum</i> Hudziok in Feddes Repert. 80: 328. 1969	<i>T. pauc</i>	38	Polanowo	52°24', 17°55'	wet meadow
<i>T. polonicum</i> Małecka & Soest in Acta Biol. Cracov., Ser. Bot. 15: 119. 1972	<i>T. pol</i>	48	Wislica	50°21', 20°40'	wet meadow
<i>T. portentosum</i> Kirschner & Štěpánek in Monogr. Taraxacum Sect. Palustris: 233. 1998	<i>T. por</i>	32	Krześlin	52°13', 22°21'	wet meadow
<i>T. skalinskanum</i> Małecka & Soest in Acta Biol. Cracov., Ser. Bot. 15: 120. 1972	<i>T. ska</i>	52	Modlniczka	50°07', 19°50'	wet meadow
<i>T. subalpinum</i> Hudziok in Feddes Repert. 72: 26. 1965	<i>T. sub</i>	38	Pyzdry	52°09', 17°41'	wet meadow
<i>T. subdolum</i> Kirschner & Štěpánek in Preslia 64: 28. 1992	<i>T. subd</i>	41	Czuchów	52°17', 22°44'	wet meadow
<i>T. subpolonicum</i> Kirschner & Štěpánek in Monogr. Taraxacum Sect. Palustris: 120. 1998	<i>T. subp</i>	34	Wilczonok	52°10', 22°02'	wet meadow
<i>T. telmatophilum</i> Kirschner & Štěpánek in Preslia 58: 104. 1986	<i>T. tel</i>	51	Gotówka	50°10', 23°32'	calcareous fen
<i>T. trilobifolium</i> Hudziok in Feddes Repert. 75: 134. 1967	<i>T. tri</i>	46	Krześlin	52°13', 22°21'	wet meadow
<i>T. udum</i> Jord. in Mém. Acad. Roy. Sci. Lyon, Sect. Lett., ser. 2 1: 325. 1851	<i>T. udu</i>	42	Pomiechówek	52°27', 20°43'	wet meadow
<i>T. vindobonense</i> Soest in Acta Bot. Neerl. 14: 50. 1965	<i>T. vin</i>	48	Krześlin	52°09', 17°41'	wet meadow
<i>T. zajacii</i> J. Marciniuk & P. Marciniuk in Ann. Bot. Fenn. 49: 388. 2012	<i>T. zaj</i>	53	Harta	49°51', 22°13'	wet meadow

mm) and *T. hollandicum* (4.30 mm), while the shortest achenes occur in *T. bellicum* (sect. *Erythrosperma*), *T. linearisquameum* (sect. *Taraxacum*), *T. subalpinum*, and *T. portentosum* (2.34 mm, 2.63 mm, 2.86 mm, and 2.93 mm, respectively). The widest achenes occur in *T. hollandicum* (1.14 mm), *T. ancoriferum* (1.11 mm), and *T. fascians* (1.11 mm). The narrowest achenes were recorded for the following species: *T. paucilobum* (0.62 mm), *T. bellicum* (0.68 mm), and *T. bavaricum* (0.69 mm). The species with the longest cones were *T. ancoriferum* (1.63 mm), *T. subdolum* (1.39 mm), and *T. madidum* (1.34 mm). The smallest cones were found in *T. gelertii* (sect. *Naevosa*) and *T. linearisquameum* (0.65 mm and 0.68 mm, respectively). The highest index occurs in *T. gelertii* (5.14), *T. udum* (4.46), and *T. hollandicum* (4.34), while the shortest index occurs in *T. ancoriferum* (2.70) and *T. bavaricum* (2.65). The longest spinule was found in *T. fascians* (0.35 mm), and the smallest spinule occurs in *T. mendax* (0.06 mm), *T. bavaricum* (0.05 mm), and *T. skalinskanum* (0.05 mm) (Table 1, Fig. 2, Suppl. material 29: Table S1).

The analysis of the coefficient of variation (CV) indicated that the most variable features were the spinules and the index of achenes. The variation of spinule traits ranged insignificantly from 13.84% (*T. subpolonicum*) to 97.33% (*T. skalinskanum*), and the index ranged from 7.73% (*T. subpolonicum*) to 18.66% (*T. fascians*). The lowest variation of the coefficient of variation was observed in the length of achenes: it ranged from 2.05% (*T. subpolonicum*) to 12.25% (*T. bellicum*).

The similarity analysis using Euclidean's distances showed three main clusters (Fig. 3). The first cluster comprises species with the longest index (*T. hollandicum*, *T. udum*, *T. gelertii*), and species with the widest achenes (*T. telmatophilum*, *T. zajacii*, and *T. mariae*). In the second cluster, most species are characterized by the shortest index and the longest cone (*T. balticum*, *T. skalinskanum*, *T. brandenburgicum*, *T. madidum*, *T. vindobonense*, and *T. subdolum*). In this cluster, the most distantly placed species is *T. ancoriferum* (the species was characterized by the longest and widest achenes and the longest cone). The last cluster is characterized by the shortest achenes and the shortest cone.

The elements of clusters received by K-means clustering analysis mostly correspond to clusters determined by similarity analysis. The first cluster contains mainly the species with the highest values for the length and the index. The second cluster encompasses species with the longest cone and the lowest index. The third cluster is a group of species with the shortest achenes (Fig. 4, Table 2).

Ordination diagrams of PCA of *Taraxacum* species based on five morphometric traits revealed that the first two principal components explained 80.66% of the total variance. The first component accounted for 36.41% of the total variance, and the second component accounted for 41.99% of the total variance (Fig. 5). Also, the distribution of species on the PCA diagram confirms the distinctiveness of *T. ancoriferum*. Other species are grouped closely together according to the division obtained on the similarity dendrogram.

Ornamentation on the achene body

The ultrastructure of the achene body as revealed by SEM showed a significant variation among species.

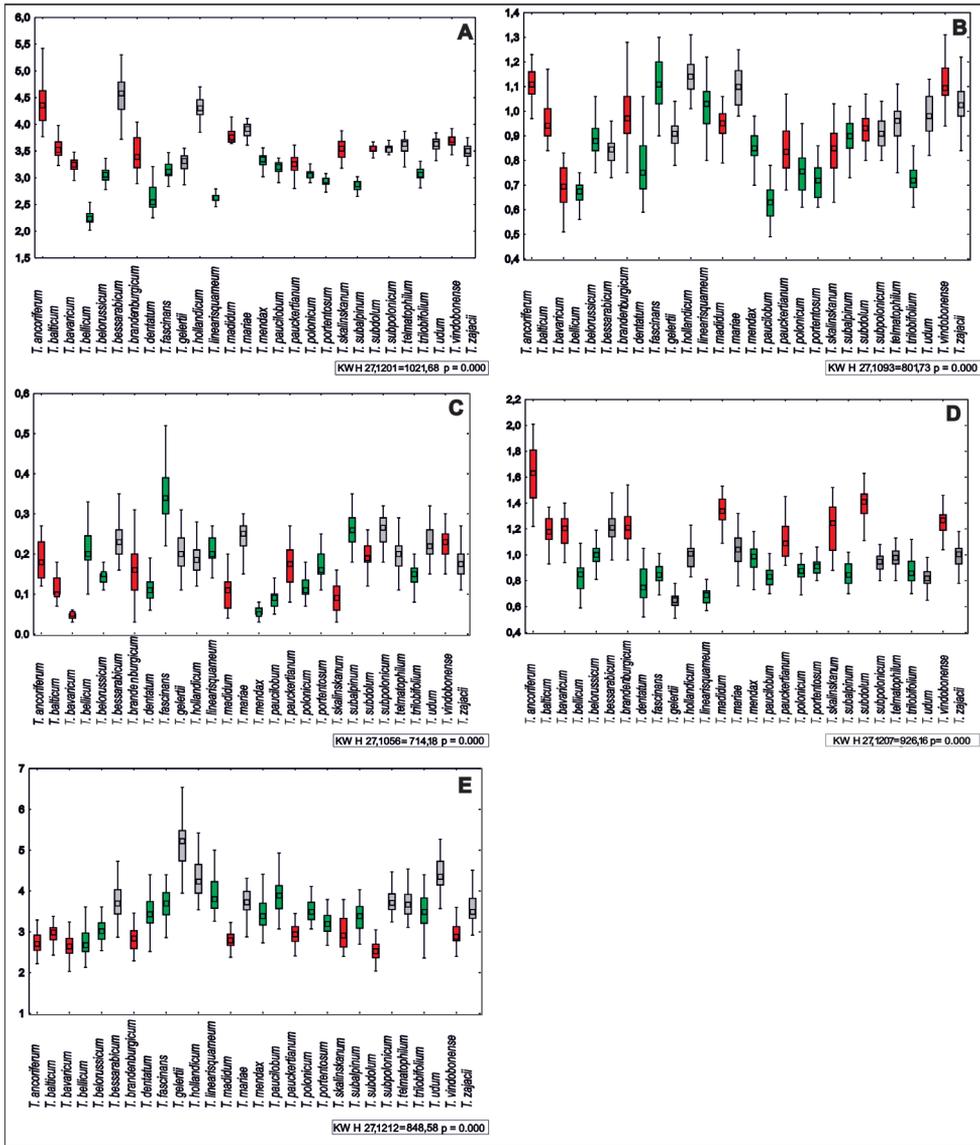


Figure 2. A–E Ranges of variation of traits of *Taraxacum* taxa: boxes represent the 25th–75th percentiles, the upper and lower whiskers extend the minimum and maximum data point, the square inside the box indicates median, while colors indicate K-groups 1: gray, 2: red, 3: green, **A** achene length **B** achene width **C** spinule length **D** cone length **E** index.

The criterion for the division of the analyzed species was the length of spinules. On this basis, three types are distinguished. The first type A) contains species whose surface is covered by very short adjacent spinules tapering towards the end; with a free part of the length measuring from 5 to 10 microns (Suppl. materials 1–9); the second type

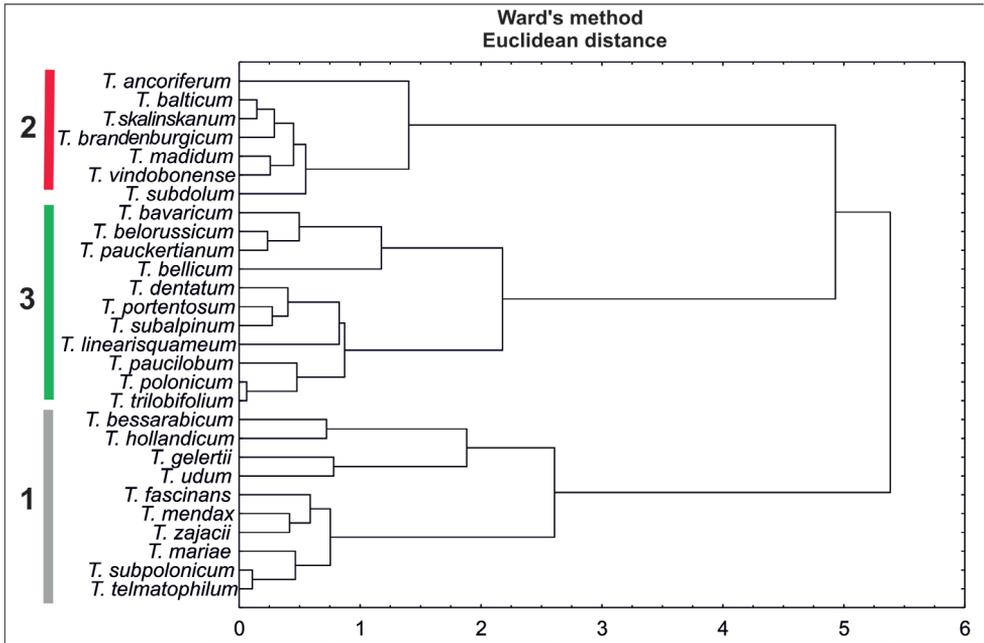


Figure 3. Dendrogram of similarities of *Taraxacum* taxa based on Euclidean distances.

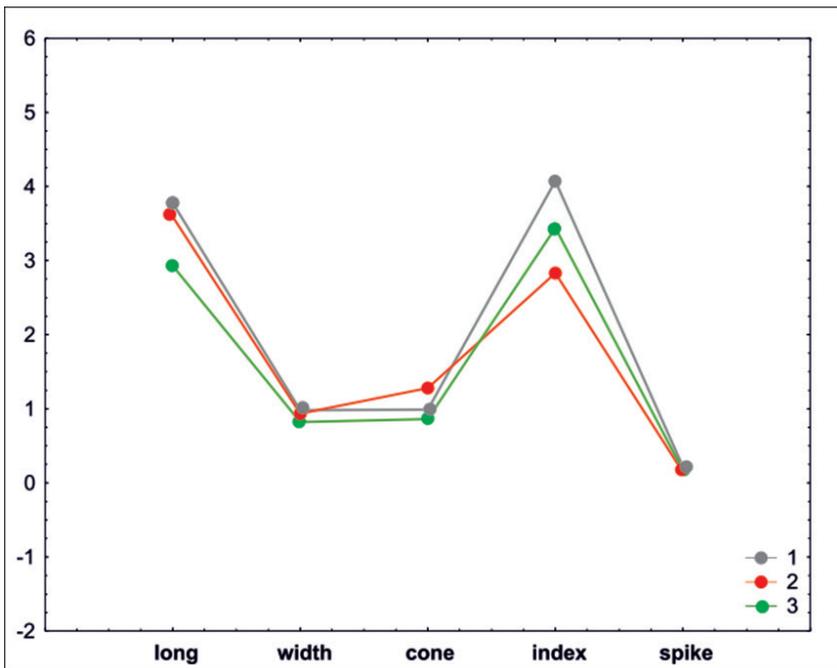


Figure 4. Graph of average clusters determined by K-means clustering analysis for species of *Taraxacum*. Number of K-groups: 1: gray, 2: red, 3: black.

spaced apart so as not to overlap; only in three species (*T. trilobifolium*, *T. udum*, *T. zajacii*) there was a clear adhesion and overlap of these structures. Here also two species are notable for spinules arranged evenly in rows in one line (*T. vindobonense*, *T. belorussicum*). In type C), spinules are irregular only in *T. bessarabicum* (sect. *Piesis*) and protrude from the surface, and in other species spinules clearly adhere to the surface and overlap.

Diagnostic keys for *Taraxacum* sect. *Palustria* fruit from Poland

- | | | |
|------|---|------------------------|
| 1 | Large achenes 3.75–5.55 mm with a long cone 1.2–2.0 mm ... | <i>T. ancoriferum</i> |
| 1* | Achenes smaller up to 3.75 mm or a shorter cone | 2 |
| 2 | Achenes with a large index, on average more than 4.35 mm | 3 |
| 2* | Achenes with a smaller index | 4 |
| 3 | Large achenes 3.85–4.7 mm, very short tight spinules | <i>T. hollandicum</i> |
| 3* | Small achenes 3.25–4.1 mm, medium tight spinules..... | <i>T. udum</i> |
| 4 | Long and numerous spinules, on average above 0.25 mm | 5 |
| 4* | Spinules shorter and not numerous..... | 8 |
| 5 | Broad achenes 0.9–1.3 mm..... | <i>T. fascians</i> |
| 6* | Narrower achenes | 7 |
| 7 | Large achenes 3.0–3.7 mm | <i>T. subpolonicum</i> |
| 7* | Small achenes..... | <i>T. subalpinum</i> |
| 8 | Few and very short spinules, below 0.1 mm | 9 |
| 8* | Longer and more numerous spinules | 12 |
| 9 | Narrow achenes, on average 0.62 mm, with a short cone (0.85 mm on average)..... | <i>T. paucilobum</i> |
| 9* | Wider achenes with a longer cone..... | 10 |
| 10 | Very short tight spinules | <i>T. bavaricum</i> |
| 10* | Medium tight spines..... | 11 |
| 11 | Cone on average 0.95 mm (0.73–1.18) | <i>T. mendax</i> |
| 11* | Cone on average 1.2 mm (0.88–1.52) | <i>T. skalinskanum</i> |
| 12 | Very short tight spinules | 13 |
| 12* | Medium spinules | 15 |
| 12** | Long tight spinules | 20 |
| 13 | Small achenes, on average 2.65 mm..... | <i>T. dentatum</i> |
| 13* | Achenes on average above 3.5 mm..... | 14 |
| 14 | Cone on average 1.4 mm, spinules on average 0.2 mm | <i>T. subdolum</i> |
| 14* | Cone on average 1.2 mm, spinules on average 0.11 mm | <i>T. balticum</i> |
| 15 | Spinules arranged in one line | 16 |
| 15* | Spinules irregularly arranged..... | 17 |
| 16 | Broad achenes, on average 1.1 mm | <i>T. vindobonense</i> |
| 16* | Achenes narrower, on average 0.85 mm | <i>T. belorussicum</i> |
| 17 | Cone on average 1.35 mm | <i>T. madidum</i> |
| 17* | Shorter cone, on average approx. 1.0 mm | 18 |

18	Broad achenes, on average 1.0 mm	<i>T. zajacii</i>
18*	Narrow achenes, on average less than 0.8 mm.....	19
19	Achenes on average 3.05 mm long with an index of 3.55.....	<i>T. trilobifolium</i>
19*	Achenes on average 2.9 mm long with an index of 3.2.....	<i>T. portentosum</i>
20	Index less than 3 mm.....	21
20*	Index more than 3.5 mm	22
21	Achenes 3.45 mm long, 0.1 mm wide.....	<i>T. brandenburgicum</i>
21*	Achenes on average 3.25 mm long, 0.85 mm wide	<i>T. pauckertianum</i>
22	Achenes on average 3.05 mm long, short spinules (on average 0.12 mm)	<i>T. polonicum</i>
22*	Achenes above 3.5 mm long, spinules above 0.2 mm.....	23
23	Achenes on average 3.85 mm long, 1.1 mm wide	<i>T. mariae</i>
23*	Achenes on average 3.6 mm long, 0.95 mm wide	<i>T. telmatophilum</i>

Discussion

Data provided in the literature on taxonomic studies of *Taraxacum* sect. *Palustria* concentrating on achene morphology has mainly provided accurate measurements as in the section monograph (Kirschner and Štěpánek 1998; van Soest 1965) and original species descriptions which are reproduced in subsequent publications (Table 3). None of the articles published so far has provided information on the width of achenes or spinule length. There are also no publications on the micromorphology of marsh dandelion achenes. Our results partly differ from the previous data.

Comparing our research with available literature data is very difficult because of different approaches used by other authors (Table 3). Because of different approaches to measurements, we recorded higher values (length with cone) in five tested species (*T. ancoriferum*, *T. hollandicum*, *T. madidum*, *T. subdolum*, and *T. subpolonicum*) and lower values of three species (*T. portentosum*, *T. bavaricum*, and partly *T. trilobifolium*). The achenes we measured for the other species of marsh dandelions do not differ from the published data, and this also applies to *T. belorussicum*, *T. zajacii*, and *T. mariae*, for which the only information about achene morphology was published in the original species descriptions (Tikhomirov 2003; Marciniuk et al. 2012; Marciniuk et al. 2018). A similar situation occurs with the average cone length; our results for seven analyzed species were higher than the ranges reported in the literature (Table 3). There is a lack of precise biometric data in the literature with which it would be possible to compare the achenes of the species we studied from other sections, i.e., *T. linearisquameum* (sect. *Taraxacum*), *T. bessarabicum* (sect. *Piesis*), and *T. gelertii* (sect. *Naevosa*). The exception is *T. bellicum* (sect. *Erythrosperma*), from which we obtained results indicating a larger range of achene variation – the achene length (without cone) being 2.02–3.61 mm, the cone length 0.59–1.09 (in our study); compared to research by Dudáš et al. (2013) – achenes 2.3–3.0 mm, cone length 0.8–1.1 mm and the original description of *Taraxacum prunicolor* (Schmid et al. 2004) – achenes 3.8–4.1 mm (with cone), cone length 0.7–1.0

Table 3. Comparison of previously published biometric data of achenes of the studied taxa with the outcomes of our research.

Species	Literature data the achene length (with cone) mm			This study results			Literature data the cone length			This study results		
	Schmid 2002	Kirsch. & Štěp. 1998	Soest Hudziok 1969	Average	Min	Max	Schmid 2002	Kirsch. & Štěp. 1998	Soest Hudziok 1969	Average	Min	Max
<i>T. ancoriferum</i>	(4.5-)4.7-5.2(-5.5)	(4.5-)4.7-5.2(-5.5)	5.0-5.4	4.42/6.05	3.77	5.56	1.2-1.5	1.2-1.5	1.1-1.4	1.63	1.22	2.01
<i>T. bulbicum</i>		4.5-5.2(-6.0)		3.55/4.74	3.23	3.98	(0.9-)1.1-1.2(-1.5)			1.19	0.93	1.37
<i>T. buvaricum</i>	4.8-5.3	4.8-5.3	4.5	3.17/4.35	2.29	3.48	1.6-2.0		0.9	1.18	0.94	1.40
<i>T. belarusicum</i>				3.06/4.07	2.78	3.43				1.01	0.81	1.32
<i>T. brandenburgicum</i>		3.8-4.2(-5.0)		3.44/4.65	2.89	4.04	0.8-1.0			1.21	0.96	1.63
<i>T. dentatum</i>	(2.9-)3.3-3.8	(2.9-)3.3-3.8		2.65/3.42	2.25	3.21	0.5-0.7	0.5-0.7(-0.8)		0.77	0.52	1.05
<i>T. fascians</i>		3.5-4.2		3.12/3.97	2.84	3.47	0.7-1.0			0.85	0.69	1.01
<i>T. hollandicum</i>	(4.0-)4.3-4.6(-5.0)	4.3-4.6		4.30/5.31	3.85	4.70	0.5-0.7(-0.9)	0.5-0.7(-0.9)		1.01	0.83	1.35
<i>T. madidum</i>	4.0-4.4	4.0-4.4		3.78/5.12	3.64	4.14	(0.8-)0.9-1.0(-1.1)	(0.8-)0.9-1.0(-1.1)		1.34	1.09	1.53
<i>T. mariae</i>				3.87	3.18	4.36				1.03	0.76	1.32
<i>T. mendax</i>	(3.8-)4.0-4.2(-4.3)			3.34/4.32	3.02	3.56	(0.8-)0.9-1.1	(0.8-)0.9-1.1		0.98	0.73	1.18
<i>T. paucibulum</i>	4.0-4.5	4.0-4.5		3.19/4.03	2.91	3.37	(0.7-)0.8-0.9	(0.7-)0.8-0.9		0.84	0.70	1.01
<i>T. paucerriticum</i>	3.8-4.1	3.8-4.1	4.0-4.7	3.24/4.35	2.80	3.61	(0.8-)0.9-1.0	(0.8-)0.9-1.0	0.5-0.9	1.11	0.92	1.45
<i>T. polonicum</i>		3.6-4.5		3.05/3.92	2.80	3.30	0.7-0.9	0.7-0.9		0.87	0.69	1.01
<i>T. ponticosum</i>	4.1-4.5(-4.8)			2.93/3.82	2.71	3.18	0.9-1.2	0.9-1.2		0.91	0.80	1.06
<i>T. skadinskanum</i>	4.8-5.2			3.53/4.74	3.18	3.88	1.2-1.7	1.2-1.7		1.21	0.88	1.52
<i>T. subalpinum</i>	3.7-4.2	3.7-4.2		2.86/3.72	2.65	3.02	0.8-1.0	0.8-0.9		0.86	0.70	1.02
<i>T. subdolum</i>	4.2-4.4	4.2-4.4		3.53/4.92	3.15	3.97	1.0-1.4	1.0-1.4		1.39	1.11	1.63
<i>T. subpolonicum</i>		3.5-4.0		3.53/4.47	3.01	3.70	0.6-0.8	0.6-0.8		0.94	0.80	1.08
<i>T. tetraophyllum</i>	4.2-4.5	4.2-4.5		3.59/4.56	3.02	3.87	0.9-1.0	0.9-1.0		0.97	0.75	1.13
<i>T. trilobifolium</i>	(4.1-)4.2-4.9(-5.1)	(4.1-)4.2-4.9(-5.1)	3.8-4.3	3.07/3.94	2.81	3.43	(0.7-)0.8-1.1(-1.2)	(0.7-)0.8-1.1(-1.2)	0.7-1.0	0.87	0.70	1.24
<i>T. udum</i>	(4.0-)4.4-4.7(-5.0)	(4.1-)4.4-4.7(-5.1)		3.63/4.45	3.26	4.09	0.5-0.9	0.5-0.9		0.82	0.62	1.08
<i>T. vindobonense</i>	(3.8-)4.0-4.3(-5.0)	(3.8-)4.0-4.3(-5.0)		3.68/4.94	3.26	3.99	0.7-0.9(-1.0)	0.7-0.9(-1.0)		1.26	1.04	1.54
<i>T. zsigmondii</i>				3.50	3.00	3.88				1.0	0.78	1.18

mm. The demonstrated morphometric differences between the achenes studied by other authors and by us may be due to the high plasticity and geographical diversity of the species studied. Previous studies show that the phenotypic plasticity of some *Taraxacum* traits (like leaf size, inflorescence height, or reproductive phenology) is affected by quality and intensity of light (Brock et al. 2005). To answer whether these features are more plastic, detailed research is needed based on material from different locations.

The micromorphology analysis of achenes has allowed us to distinguish three main types that do not quite delimit *Taraxacum* sect. *Palustria* from other sections. *Taraxacum gelertii* (sect. *Naevosa*) and *T. bellicum* (sect. *Erythrosperma*) have the same type of ornamentation as some species from the section *Palustria*. Our finding is confirmed by previous studies (Savadkoochi et al. 2012; Wu et al. 2011), which showed the lack of proper diagnostic features allowing us to delimit *Taraxacum* sections based on achene micromorphology. In contrast, the features associated with ornamentation are helpful to mark even closely related species. Savadkoochi et al. (2012) presented the results of biometric and ultrastructural studies performed on 17 Asian species belonging to nine sections. Those species were assigned to six groups differing in terms of type of achene ornamentation.

Taraxacum sect. *Palustria* is a relatively large taxonomic unit with still unknown intra-group relationships. Section monographs (Kirschner and Štěpánek 1998) distinguished geographical and morphological groups of species. The division criteria used – morphological similarity (mainly cage-related features) and similar geographical ranges – are not sufficient to determine actual phylogenetic relationships. However, at least some species within individual groups are probably closely related. The division into groups of species in our research differed in quantitative features of achenes which contrasts to the division of Kirschner and Štěpánek (1998) and the proposals of other authors (Schmid 2002; Uhlemann 2003). In each group, aside from very similar taxa, there were species with clearly different characteristics of leaves and inflorescences. Such incongruence is due to the very complicated reticulate evolution of the genus responsible for the uneven, mosaic distribution of traits (Kirschner et al. 2016). In the first group, species with generally similar morphology are *T. udum* and *T. hollandicum*. Interestingly, the achenes of these species are similar to those of the achenes of taxa from other sections, such as *T. gelertii* (sect. *Naevosa*), with which they also share a similar leaf shape, and *T. bessarabicum* from the basal section *Piesis*. Other species of this group, apart from the achenes, differ significantly in the shape and staining of the outer cover leaves and are included in various morphological groups (Kirschner and Štěpánek 1998; Marciniuk et al. 2012, 2018). The second group includes species classified into separate morphological groups by Kirschner and Štěpánek (1998). Nevertheless, *T. ancoriferum*, *T. balticum*, and *T. brandenburgicum* are quite similar in terms of inflorescence morphology. Comparable relations of similarity exist between *T. subdolum* and *T. skalinskanum* as well as *T. vindobonense* and *T. madidum*. The third group includes pairs of species from three taxonomic groups as defined by Kirschner and Štěpánek (1998), namely: 1) *T. bavaricum* and *T. pauckertianum*, 2) *T. paucilobum* and *T. polonicum*, 3) *T. belorussicum* and *T. dentatum*. The other three species: *T. trilobifolium*, *T. portentosum*, and *T. subalpinum*, belong to different morphological groups. *T. subalpinum* is certainly assignable to the *Taraxacum* section; that is further

confirmed by the similarity of its achenes to those of *T. linearisquameum* (*Taraxacum* sect. *Taraxacum*). *Taraxacum bellicum* from the section *Erythrosperma* has an isolated position in the group taking into account the color of achenes among all the species tested.

Conclusion

Achene morphology and micromorphology of *Taraxacum* provide useful diagnostic features. The key presented here may be a useful auxiliary tool (in conjunction with the morphological features of leaves and inflorescences) for the determination of species of *Taraxacum* sect. *Palustria* occurring in Poland.

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Supplementary material 1

Figure S1

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. balticum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl1>

Supplementary material 2

Figure S2

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. bavaricum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl2>

Supplementary material 3

Figure S3

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. dentatum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl3>

Supplementary material 4

Figure S4

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. gelertii* **B–D** achene micromorphology **E, F** sculpture, **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl4>

Supplementary material 5

Figure S5

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. hollandicum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl5>

Supplementary material 6

Figure S6

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. linearisquameum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl6>

Supplementary material 7

Figure S7

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. paucilobum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl7>

Supplementary material 8

Figure S8

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. subdolum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl8>

Supplementary material 9

Figure S9

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. subpolonicum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl9>

Supplementary material 10

Figure S10

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. ancoriferum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl10>

Supplementary material 11

Figure S11

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. bellicum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl11>

Supplementary material 12

Figure S12

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. belorussicum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl12>

Supplementary material 13

Figure S13

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. fascians* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl13>

Supplementary material 14

Figure S14

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. madidum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl14>

Supplementary material 15

Figure S15

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. mendax* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl15>

Supplementary material 16

Figure S16

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. portentosum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl16>

Supplementary material 17

Figure S17

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. skalinskanum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Supplementary material 18

Figure S18

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. subalpinum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl18>

Supplementary material 19

Figure S19

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. trilobifolium* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Supplementary material 20

Figure S20

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. udum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl20>

Supplementary material 21

Figure S21

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. vindobonense* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl21>

Supplementary material 22

Figure S22

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. zajacii* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl22>

Supplementary material 23

Figure S23

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. bessarabicum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl23>

Supplementary material 24

Figure S24

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. brandenburgicum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl24>

Supplementary material 25

Figure S25

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. mariae* **B–D** achene micromorphology **E, F** sculpture, **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl25>

Supplementary material 26

Figure S26

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. pauckertianum* **B–D** achene micromorphology **E, F** sculpture **G** e surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl26>

Supplementary material 27

Figure S27

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. polonicum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl27>

Supplementary material 28

Figure S28

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A** general view of achene of *T. telmatophilum* **B–D** achene micromorphology **E, F** sculpture **G** surface 3D ultrastructure.

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Link: <https://doi.org/10.3897/phytokeys.166.54271.suppl28>

Supplementary material 29

Table S1

Authors: Agnieszka Rewicz, Jolanta Marciniuk, Paweł Marciniuk

Data type: image

Explanation note: **A–E** Biometric characteristics of Taraxacum species: x – arithmetic means, min. max – minimum, maximum, CV – variation coefficients, SD – standard deviation.

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Re-instatement of *Sorbus harrowiana* (Rosaceae), based on morphometric analysis

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Abstract

Sorbus harrowiana (\equiv *Pyrus harrowiana*), previously considered a synonym of *Sorbus insignis* (\equiv *Pyrus insignis*) in the *Flora of China*, is re-instated here and shown to be distinct from *S. insignis*, based on morphometric analysis, coupled with herbarium and field investigation. We also present for the first-time full descriptions, distributional records and notes for *S. harrowiana* and *S. insignis*.

Keywords

George Forrest, herbarium research, morphometric analysis, *Pyrus*, taxonomy

Introduction

Sorbus L. *sensu lato* (Rosaceae) contains approximately 260 species that widely occur in the temperate zone of the Northern Hemisphere (Yü and Lu 1974; Phipps et al. 1990; Aldasoro et al. 1998; Lu and Spongberg 2003). However, recent research using both molecular (Campbell et al. 2007; Lo and Donoghue 2012) and morphological evidence (Zheng and Zhang 2007) suggests that *Sorbus sensu lato* is polyphyletic. *Sorbus* has been separated into six distinct genera: *Aria* (Pers.) Host, *Chamaemespilus* Medikus, *Micromeles* Decaisne, *Torminalis* Medikus, *Sorbus sensu stricto* and *Cormus* Spach. *Sorbus* L. *sensu stricto* (Rosaceae) comprises ca. 80 species which are delimited from the

aforementioned genera by their pinnately compound-leaves and are mainly distributed in the Northern Hemisphere: one or two species in Europe, seven species in North America and ca. 70 species throughout Asia (Hooker 1878; Warburg and Kárpáti 1968; Phipps et al. 1990; Lu and Spongberg 2003; McAllister 2005; Zika and Bailleul 2015).

Many species within *Sorbus* are difficult to delimit, including *S. insignis* (Hook. f.) Hedl. (\equiv *Pyrus insignis* Hook. f.), which bears similarities with *S. harrowiana* (Balf. f. & W. W. Smith) Rehd. (\equiv *Pyrus harrowiana* Balf. f. & W.W. Smith) in fruits and strong branchlets.

Sorbus insignis was first published by J. D. Hooker and C B. Clarke (Hooker 1878) in the genus *Pyrus* (\equiv *Pyrus insignis* Hook. f.), based on the collections from the Sikkim Himalaya. In the protologue, Hooker (1878) described *S. insignis* as a small, very robust tree with 4–6 paired leaflets per compound leaf and leaflet blades 3–4 inches (ca. 7–10 cm) long. Then, Hedlund (1901) transferred it to the genus *Sorbus*, based on its pinnately compound-leaves.

Sorbus harrowiana was described on a single George Forrest collection from the Yunnan, south-western China. In the protologue, Rehder (1920) emphasised the large leaflets which often exceed 8 inches (ca. 20 cm) in length and stated that *S. harrowiana* is markedly different from *S. insignis*, although the exact differences were not mentioned. Most taxonomists followed his opinion and considered the two to be distinct species (Yü and Lu 1974; Long 1987; Phipps et al. 1990; Kress et al. 2003; McAllister 2005; Watson and Manandhar 2012).

Gabrielian (1978), however, treated *S. harrowiana* as a synonym of *S. insignis* in the taxonomic and nomenclatural works of the genus *Sorbus* in western Asia and the Himalayas, but gave no detailed explanation. This treatment was subsequently adopted in the *Flora of China* (Lu and Spongberg 2003) and Tropicos (<https://www.tropicos.org>). During our taxonomic research on *Sorbus*, we found that these two species are easily identified and distinguishable in terms of morphological characteristics and geographical distribution. Herein, we evaluate the morphological variation between *S. insignis* and *S. harrowiana* through a morphometric study of herbarium specimens to establish the delimitation and validity of the two species and to produce a taxonomic treatment including descriptions and distributional notes.

Materials and methods

Plant material and characters scored

Herbarium specimens were studied at A, CAS, CDBI, GH, E, IBSC, K, KATH, KUN, LBG, MO, P, PE, TI and WU (abbreviations according to Thiers 2019). Leaflet length, width and length/width ratio (l/w ratio) were chosen as the morphometric variables to be measured amongst 133 specimen sheets (17 of *Sorbus insignis* and 116 of *S. harrowiana*) in 56 collections from across the range of their geographic distribution (Suppl. material 1: Table S1). Two to four compound leaves were randomly

selected from each specimen. Two middle leaflets from each compound leaf were selected for measurement. A total of 1323 leaflets were measured (141 of *S. insignis* and 1128 of *S. harrowiana*).

Statistical analyses

Normality of the QN standardised variables was tested using the Shapiro and Wilk test (Mahibbur and Govindarajulu 1997), with statistically-significant differences set by the p value < 0.05 . Length and width data did not fit a normal distribution, even after \log_{10} - or square root- transformation, with only l/w data fitting a normal distribution after \log_{10} transformation. As such, we performed analyses using both non-parametric Wilcoxon signed-rank tests on untransformed data and parametric Welch Two Sample T-tests on \log_{10} transformed data as T-tests are considered robust to non-normality when large sample sizes are used. The analyses were performed in R version 4.0.2 (R Foundation for Statistical Computing, Vienna, AT). The data matrix for analysis was prepared in Microsoft Excel 2011 and is available on request.

Results

Morphometric analysis

Both the non-parametric Wilcoxon signed-rank tests on untransformed data and parametric Welch Two Sample T-tests on \log_{10} transformed data found highly significant ($p < 0.001$) differences between *S. harrowiana* and *S. insignis* in terms of middle leaflet length, width and l/w ratio (Fig. 1). Further detailed examination revealed other morphological characters, such as number and spacing of leaflets on the compound leaves and leaflet shape, venation and indumentum, that differentiate these two species: *Sorbus insignis* possesses pinnately compound leaves with 7–16 leaflets, leaflets at intervals of 1–2 cm, oblong or oblong-lanceolate, 5–8 × 1.5–2.0 cm, middle leaflets l/w ratio 3.3–4.0, lateral veins 24–30 pairs, both surfaces tomentose when young, glabrescent with age. *Sorbus harrowiana* has pinnately compound leaves with 5–7 leaflets, leaflets at intervals of 1–2.5 cm, oblong, 10–18 × 2.5–3.5 cm, middle leaflets l/w ratio 3.5–4.5, lateral veins 19–21 pairs, both surfaces glabrous. Our critical observations and morphometric analyses of herbarium specimens (including type pictures) demonstrate that *S. harrowiana* should be recognised as distinct from *S. insignis*.

Taxonomic treatment

***Sorbus insignis* (Hook. f.) Hedl., Kongl. Svenska Vetenskapsakad. Handl. 35(1): 32. 1901.**

≡ *Pyrus insignis* Hook. f., Fl. Brit. India 2(5): 377. 1878.

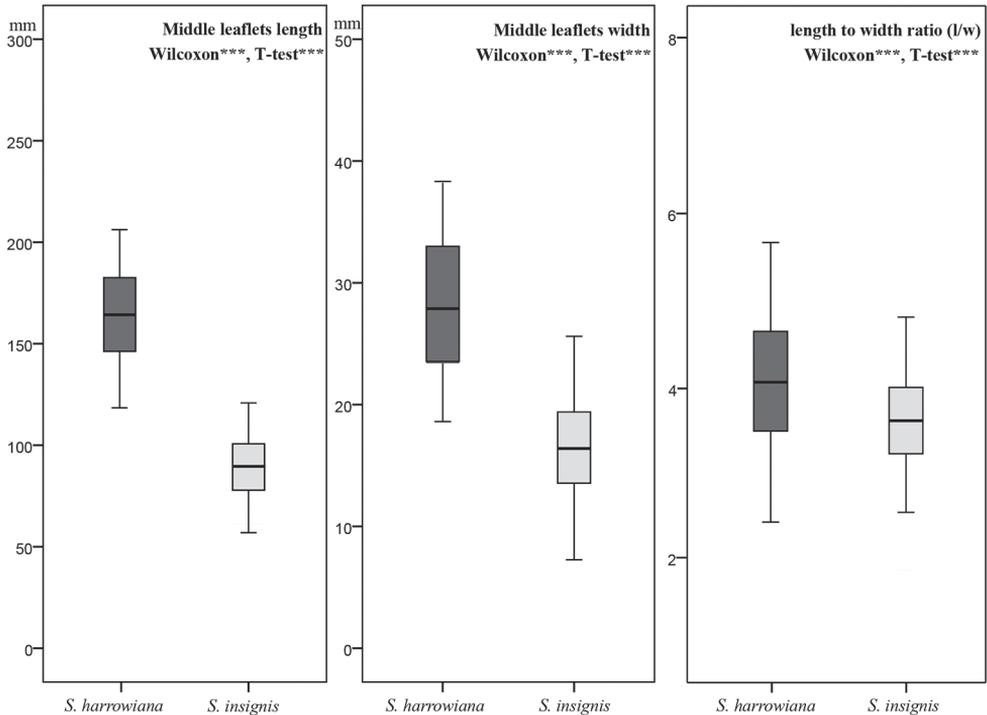


Figure 1. Box plot of comparisons between *S. harrowiana* and *S. insignis* in middle leaflet length, width and l/w ratio. Significant differences found upon analysis using non-parametric Wilcoxon rank sum test on untransformed data (Wilcoxon) and parametric Welch Two Sample T-test on \log_{10} transformed data (T-test) are noted within the figures (***) = $p < 0.001$).

Type. INDIA. **Sikkim:** 8000–11000 ft [2438–3353 m alt.], *J.D. Hooker & C.B. Clarke s.n.* (holotype: K (K000758177 [image!])). Fig. 2A.

Description. Trees or shrubs. Stems greyish-brown; bark grey; branchlets greyish-brown when old; rusty brown tomentose when young, glabrous when old; winter buds narrowly ovoid, 1.0–1.8 cm long, scales initially puberulent, glabrate later; apex shortly acuminate or acute, brownish. Leaves pinnately compound, 15–20 cm long; stipules persistent, suborbicular, sometimes lobed, 1–2 cm wide, margin entire or serrate with pointed teeth; petiole 1.7–4.0 cm long, glabrous; rachis sparsely tomentose, glabrous when old; leaflets 7–16, at intervals of 1–2 cm long, oblong or oblong-lanceolate, 5–8 × 1.5–2.0 cm, l/w ratio 3.2–4.2, middle leaflets l/w ratio 3.3–4.0, lateral veins 24–30 pairs, margin slightly revolute and shallowly crenate, base rounded or obliquely cordate, apex obtuse, both surfaces tomentose when young, glabrescent. Inflorescences compound corymbs, 30–80 flowered, 8–12 cm in diam., peduncles sparsely pubescent; pedicels 2–4 mm long, sparsely pubescent; flowers 6–8 mm in diam.; hypanthium abaxially pubescent; sepals triangular, ca. 1.5 mm long, glabrous or somewhat puberulous, apex acute, with reddish dentate glands along margin; petals creamy white, suborbicular, ca. 4 × 3 mm; stamens



Figure 2. Type pictures of *Sorbus insignis* (Hook. f.) Hedl. (**A** barcode K000758177) and *S. harrowiana* (Balf. f. & W. W. Smith) Rehd. (**B** barcode E00072735).

ca. 20; carpels 3–(4); styles 2 or 3, 2.5 mm. Infructescence sparsely pubescent or glabrous; pomes green when young, white or crimson when mature, globose or ovoid-globose, 5–8 mm in diam., sepals persistent erect; seeds brownish, reniform, 1.5–2.0 mm long; $2n = 34$.

Phenology. Flowering May–June; fruiting Sep–Oct.

Distribution and habitat. *Sorbus insignis* is distributed in India, Nepal and China (Xizang) (Fig. 3). It is also mentioned as occurring in ‘NW Yunnan’ China (Lu and Spongberg 2003), but we have not yet seen any convincing specimens from Yunnan. All specimens labelled as ‘*S. insignis*’ from Yunnan that we have examined were misidentified. It grows in broad-leaved forests on rocky slopes with an altitudinal range between 2500 and 3100 m.

Additional specimens examined. CHINA. **Xizang province:** Motuo, 2900 m alt., 25 Oct 2016, *B. Xu et al.* YLZB4493 (CDBI); Galung La, 2700 m, 18 Aug 1982, *S.Z. Cheng & B.S. Li* 0200 (PE).

INDIA. Manipur state: Sirohifurar, 2500 m alt., Jan. 1982, *G. Watt* 5965 (P); Ching Sow, 2400–2700 m alt., 16 April 1982, *G. Watt* 6539 (P); **Sikkim state:** *T. Thomson s.n.* (E).

NEPAL. Eastern Nepal: Sankhuwasabha, 29 Oct 1963, *H. Hara et al.* 6301809 (TI); Kuwa Pani, 2890 m alt., 23 Aug 1997, *S. Noshiro et al.* 9755184 (A, E); Kauma,

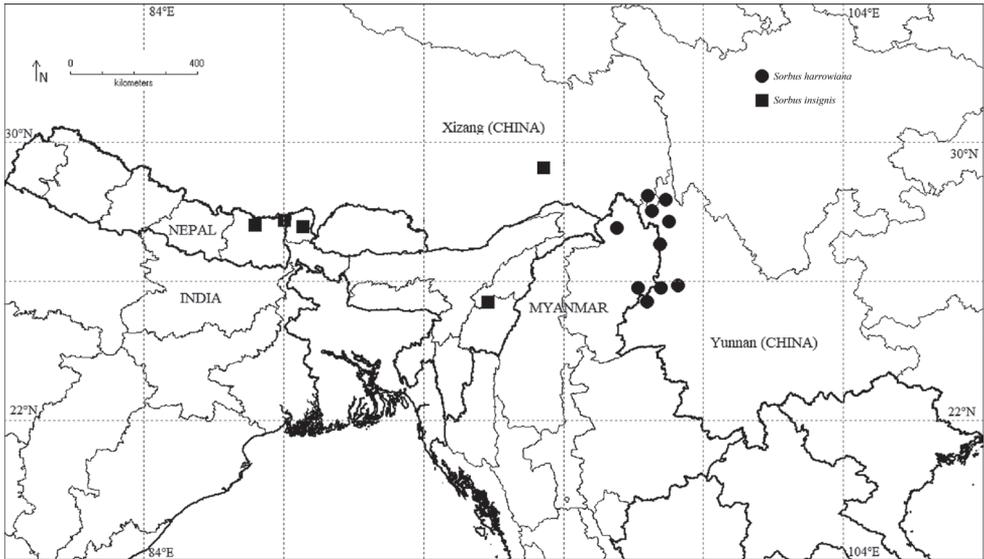


Figure 3. Distribution of *Sorbus insignis* and *S. harrowiana* at county level.

3130 m alt., 25 Sep 1991, *Edinburgh Makalu Expedition 259* (E, KATH); Koping, 3040 m alt., 24 Oct 1991, *Edinburgh Makalu Expedition 1019* (E); Jhakpu, 2750 m alt., 26 Sep 1971, *P.R. Shikyo & M. Ohsawa 1069* (KATH); Bhyaha, 2880 m alt., 31 Oct 1981, *P.R. Shakya 7296* (KATH); Taplejung, 2700 m alt., 30 Sep 1981, *P.R. Shakya 6777* (KATH).

***Sorbus harrowiana* (Balf. f. & W. W. Smith) Rehd., *J. Arnold Arbor.* 1(4): 263. 1920.**

≡ *Pyrus harrowiana* Balf. f. & W.W. Smith, *Notes Roy. Bot. Gard. Edinburgh* 10 (46): 61–62. 1917.

Type. CHINA. **Yunnan:** Western flanks of the Shweli-Salwin Divide (Tenchong County?), 2800 m alt., 15 Aug 1912, *George Forrest 9040* (holotype: E (E00072735 [image!]); isotypes: A (A00046014!), E (E00010858 [image!], E00072736 [image!]), K (K000758123 [image!])). Fig. 2B.

Description. Small trees or shrubs. Stems greyish-brown; bark grey to bronze; branchlets glabrous; winter buds conic, 1.5–2.0 cm long, scales glabrous; apex acute, reddish-brown. Leaves pinnately compound, 15–25 cm long; stipules persistent, sub-orbicular, 1–2 cm, margin toothed; petiole 2.0–4.0 cm long, glabrous; rachis sparsely tomentose, glabrous when old; leaflets 5–7, at intervals of 1–2.5 cm long, oblong,

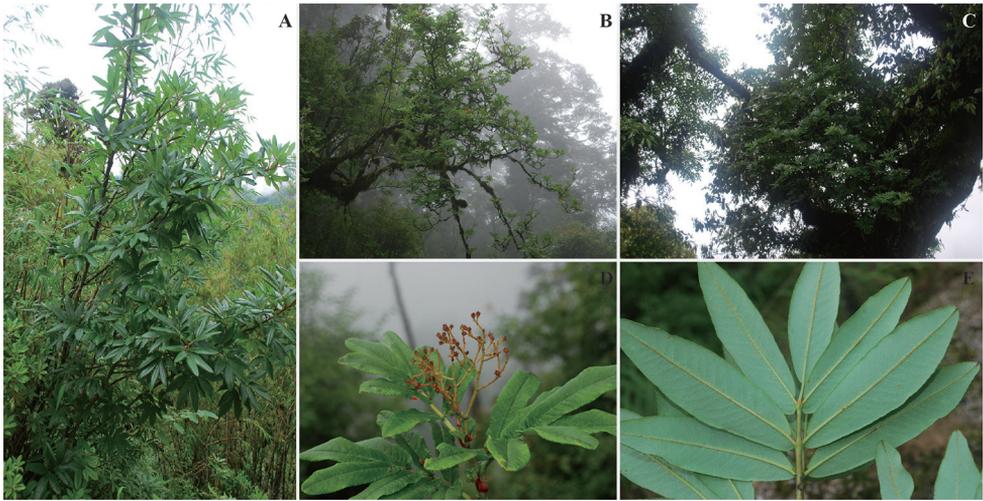


Figure 4. *Sorbus harrowiana* **A** growing near the road in mixed forest **B** growing on a steep forested slope above road **C** growing on *Lithorcarpus* like an epiphytic shrub **D** fruiting branch **E** pinnately compound-leaves.

10–18 × 2.5–3.5 cm, l/w ratio 3.2–4.6, middle leaflets l/w ratio 3.5–4.5, lateral veins 19–21 pairs, margin slightly revolute and shallowly crenate, base rounded or obliquely cordate, apex rounded, both surfaces glabrous. Inflorescences compound corymbs, 30–200 flowered, 12–20 cm in diam., peduncles sparsely pubescent or glabrous; pedicels 3–6 mm, sparsely pubescent or glabrous; flowers 6–9 mm in diam.; hypanthium abaxially pubescent; sepals triangular, ca. 2.0 mm long, glabrous or somewhat puberulous, apex acute, with serrate along margin; petals creamy white, suborbicular, ca. 4 × 4 mm; stamens ca. 15–25; carpels 3(–4); styles 2–4, 2–4 mm. Infructescences sparsely pubescent or glabrous; pomes creamy-white rarely pink, globose or ovoid-globose, 5–7 mm in diam., sepals persistent erect; seeds brownish, reniform, 1.5–2.0 mm long; $2n = 34$.

Phenology. Flowering May–July; fruiting Sep–Oct.

Distribution and habitat. *Sorbus harrowiana* is distributed in China and Myanmar (Fig. 3). It grows in broad-leaved forests with an altitudinal range between 2100 and 3300 m. (Fig. 4).

Additional specimens examined. CHINA. Yunnan province: Deqin, Cizhong, 2800 m alt., 8 Oct 1959, *K.M. Feng 23997* (KUN, PE); Fugong, Lumadeng Xiang, 3100 m alt., 13 Aug 2005, *Gaoligong Shan Biodiversity Survey (G.S.B.S.) 27252* (CAS, GH, KUN); Biluo Mountain, 2800 m alt., 28 May 1982, *Qinghai-Tibet Expedition 6939* (KUN, PE); Yaping pass, 2884 m alt., 2 May 2002, *G.S.B.S. 20209* (CAS, E, GH, KUN, MO); Yaduo Cun, 2700 m alt., 6 Aug 2005, *G.S.B.S. 26500* (CAS, GH, KUN); Shibali, 2700 m alt., 15 Aug 2005, *G.S.B.S. 28304* (CAS, GH,

KUN); *G.S.B.S. 28409* (CAS, GH, KUN); Gongshan, Bingzhongluo, 2530 m alt., 1 Sep 2006, *G.S.B.S. 31826* (CAS, E, GH, MO, KUN); 2700 m alt., 25 Jul 1982, *Qinghai-Tibet Expedition 7512* (KUN, PE); Zguziluo, 2800–3000 m alt., 25 Jun 1978, *Bijiang Expedition 1009* (KUN); Champutung, 3000 m alt., Oct 1935, *C.W. Wang 67581* (A, KUN, LBG, NAS, PE, PE, WUK); Dulongjiang, 2700 m alt., 21 May 1991, *Dulongjiang Expedition 7022* (KUN); Kongdang, 3030 m alt., 28 Sep 2002, *G.S.B.S. 16655* (CAS, E, GH, KUN); Labadi, 2970 m alt., 30 Sep 2002, *G.S.B.S. 16792* (CAS, E, GH, KUN); Pula river, 3100 m alt., 3 Oct 2002, *G.S.B.S. 16906* (CAS, E, GH, KUN); Fucai, 2780 m alt., 1 Sep 2006, *G.S.B.S. 31772* (CAS, E, GH, MO, KUN); Yidongwei, 2530 m alt., 1 Sep 2006, *G.S.B.S. 31826* (CAS, E, GH, MO, KUN); Mangzhou Wadi, 3010 m alt., 12 Aug 2006, *G.S.B.S. 33217* (CAS, E, G, KUN); Qi-Qi Nature Reserve Station, 3200 m alt., 16 Oct 1996, *G.S.B.S. (1996) 7803* (E); Dong Shao Fang, 3100 m alt., 21 Sep 1997, *G.S.B.S. (1997) 9495* (E, MO); Danzhu river, 2750 m alt., 1 Jul 2000, *H. Li et al. 11855* (CAS, E GH, KUN); Dulong Jiang valley, 2770–3050 m alt., 15 Jul 2000, *H. Li et al. 12614* (CAS, E, GH, MO, KUN); Su Ki Tung, 1923, *J. Rock 10161* (A); Mt. Kenyichunpo, 10000 ft [3048 m alt.], Jul 1923, *J. Rock 22068* (A, E); Cikai, 07 Oct 1940, *K.M. Feng 7946* (KUN, PE); East Check Point, 2700 m alt., 22 Jul 1982, *K.M. Feng 8226* (KUN, PE); Wangtzang, 2800 m alt., 13 Sep 1938, *T.T. Yü 20216* (A, E, KUN, PE); Swangchiang, 13 Jul 1938, *T.T. Yü 22088* (A, E, KUN, PE); Lushui, 2800 m alt., 6 Jul 2016, *Meng Li et al. GYD0058* (CDBI); Tenchong, Mingguang Xiang, 19 May 2006, 3000–3050 m alt., *G.S.B.S. 29157* (CAS, E, GH, KUN); Zizhi Cun, 2750–2850 m alt., 19 May 2006, *G.S.B.S. 29224* (CAS, E, GH, MO, KUN); Jiangao Shan, 3020 m alt., 23 May 2006, *G.S.B.S. 30546* (CAS, E, GH, MO, KUN); Weixi, 2900 m alt., 13 Oct 1934, *H.T. Tsai 59790* (A, IBSC, KUN, P, PE); 2800 m alt., 20 Oct 1934, *H.T. Tsai 59902* (A, IBSC, KUN, LBG, PE); Biluo Snow Mountain, 3250 m alt., 11 Jul 1981, *PE Hengduan Mountain Collection Team 01402* (PE); Cangjiang river, 3300 m alt., 18 May 1940, *K.M. Feng 3965* (KUN, PE); Baimaluo, 3200 m alt., 3 June 1940, *K.M. Feng 4429* (KUN, PE); Yanwa, 3600 m alt., 11 May 1960, *Kunming Workstation of Institute of Botany 8375* (KUN, PE); Kangpucheda, 3000 m alt., 8 Oct 1956, *P.I. Mao 385* (KUN, PE); Magelo, 23 Aug 1956, *P.I. Mao 401* (KUN, PE); Bading, 3500 m alt., 11 May 1982, *Qinghai-Tibet Expedition 6434* (PE); Yunlong, Nu Shan, 2 Nov. 1993, *K.D. Rushforth 2663* (E); **Xizang province:** Chayu, 10000–11000 ft [3048–3353 m alt.], June 1922, *G. Forrest 21806* (A, E, P); Oct. 1922, *G. Forrest 22870* (A, E).

MYANMAR. Kachin state: Myitkyina, 3050 m alt., 19 Oct 1919, *R. Farrer 1403* (E); *G. Forrest 24481* (E, PE); Chimili, *G. Forrest 26813* (A, E); *G. Forrest 27541* (A, E); *G. Forrest 29775* (E, PE); Putao, 2800 m alt., 16 May 1953, *F. Kingdon-Ward 20921* (E); Tata Bum, 3000 m alt., 19 June 1953, *F. Kingdon-Ward 21009* (A, E); Trails above Camp 3, 3000–3140 m alt., 22 Oct 2013, *Hponyin Mountains Expedition 206A* (E); Adung velly, *F. Kingdon-Ward 9568* (A).

Key to species in *Sorbus* Ser. *Insignes* Yü.

Note. George Forrest made seven major expeditions to western China and north-eastern Myanmar during 1917 and 1931, with over 30,000 collections being made. In these expeditions, G. Forrest collected at least 23 specimens of *Sorbus harrowiana*, of which 15 lacked locality information. However, from limited collection information, we are able to broadly georeference these 15 specimens to four different regions (as he mentioned in the collection record), i.e. (1) China: Yunnan: Shweli-Salwin divide, *G. Forrest 15888* (E, P), *G. Forrest 16101*(E), *G. Forrest 18506* (E), *G. Forrest 24373* (E, P, PE), *G. Forrest 26778* (A, E); (2) China: Yunnan: N'mai kha-Salwin divide, *G. Forrest 18527* (E, P), *G. Forrest 18753* (E); (3) China: Yunnan: Salwin-Kui Chiang divide, *G. Forrest 25687* (E, PE), *G. Forrest 25768* (E); (4) China: Yunnan, *G. Forrest 19874* (E), *G. Forrest 20849* (E), *G. Forrest 20869* (E, P), *G. Forrest 21806* (A, E, P), *G. Forrest 29015* (E, PE), *G. Forrest 30374* (E, PE). The specimens examined by us also covered those four regions.

- 1 Leaflets, Inflorescences and infructescence pubescent..... ***S. helenae* Koehne**
- Leaflets, inflorescences and infructescence glabrous.....**2**
- 2 Leaflets 7–16 per compound leaf, 5–8 × 1.5–2.0 cm, oblong or oblong-lanceolate, lateral veins 24–30 pairs, both surfaces tomentose when young, glabrescent with age***S. insignis***
- Leaflets 5–7 per compound leaf, 10–18 × 2.5–3.5 cm, oblong, lateral veins 19–21 pairs, both surfaces glabrous.....***S. harrowiana***

Acknowledgements

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Supplementary material I

Table S1. Accessions of herbarium specimen for measurements

Authors: Meng Li, Steven P. Sylvester, Zhang-Pei Wang, Yi-Da Pei, Xin-Fen Gao, Yuan Zhao, Wen-Qi Jiang

Data type: measurement

Explanation note: .

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Link: <https://doi.org/10.3897/phytokeys.166.57672.suppl1>

Calamagrostis hongii (Poaceae, Agrostidinae), a new species from southwestern China

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Abstract

Calamagrostis hongii, a new species of *Calamagrostis* (Poaceae) from southwestern China (S Chongqing, W Guizhou, Sichuan, SE Xizang, Yunnan), is here described and illustrated. It is similar to *C. arundinacea* and *C. effusiflora* in spikelet traits, but can be distinguished by its moderately or densely scabrous upper leaf surface with ribs covered by short, stiff, prickly hairs, and glabrous leaf sheaths, blades and collars. Nomenclature *Deyeuxia zhongdianensis* lacks Latin description or diagnosis and is an unavailable *nomen nudum* (naked name).

Keywords

Asia, *Deyeuxia*, distribution, endemism, Flora of China, Sino-Himalayan region, taxonomy

Introduction

Six species of *Calamagrostis* Adans. and thirty four species of *Deyeuxia* Beauv. were reported in the published taxonomic treatments for the “Flora of China” (Lu and Phillips 2006; Lu et al. 2006). Among them, 15 species of *Deyeuxia* and one species of *Calamagrostis* were considered to be endemic to China (Lu and Phillips 2006; Lu et al. 2006; Huang et al. 2011, 2017). Twelve of these endemics occur in the mountains of SW China, which are recognized as a global biodiversity hotspot (Boufford 2014; Cai et al. 2019) and this region continues to produce species of grass new to science. Re-

cent examples include one new species of *Achnatherum* Beauv., two new species of *Deyeuxia*, two new species of *Prilogrostis* Griseb. and two new species of *Stipa* L. (Paszko and Chen 2013; Paszko and Pendry 2013; Nobis et al. 2016; Zhang et al. 2016, 2017, 2018; Zhao and Guo 2017; Cai et al. 2019).

At present, a taxonomic revision of *Calamagrostis* (including Asian species of *Deyeuxia*) for China is being prepared by the second author (Paszko 2019). Following recent molecular studies, all Asian species of *Deyeuxia* have been placed in the genus *Calamagrostis* (Saarela et al. 2010, 2017; Paszko et al. 2017). To date, a great number of major changes have been made within the classification of the genus *Calamagrostis* in China since 2006. These changes cover new species, taxonomic novelties and range extensions of several species. There is a considerable increment in the number of species. Thus, the total number of species described and reported from China increased from 40 up to 47. The subsequent major changes are summarized in more detail herein. To date, two species (*C. sorengii* (Paszko & WL Chen) Paszko and *C. gaoligongensis* (Paszko) Paszko) new to science have been described (Paszko and Chen 2013; Paszko and Pendry 2013), a third one is described here (*C. hongii* Paszko & Bing Liu). *Calamagrostis altaica* Tzvelev, described from China and overlooked in the “Flora of China”, was shown to be a separate species (Paszko et al. 2016a). Two names, *Calamagrostis kengii* T. F. Wang and *Deyeuxia flavens* Keng, have been considered synonymous with taxa that occur beyond China (Paszko 2012; Paszko and Ma 2011).

In addition, several major range extensions to China and beyond turn up. Two new records for China (*C. filiformis* Hooker f., *C. garhwalensis* Hubbard & Bor) have been reported (Paszko 2012, 2014b) and Tzvelev’s (1968) records of *C. salina* Tzvelev, neglected in the “Flora of China”, have been confirmed from China (Paszko et al. 2016b). Three species, *Calamagrostis effusiflora* (Rendle) J.L. Yang, *C. diffusa* (Keng) Keng f. and *C. himalaica* (Liou ex W.L. Chen, emend. Paszko) Paszko, can no longer be recognized as endemic to China because they have been documented in at least one additional country (Paszko and Soreng 2013; Paszko 2014a, Paszko in Nobis et al. 2015).

Calamagrostis has its highest species diversity in SW China, particularly in Sichuan, SE Xizang and Yunnan, where the species number of *Calamagrostis* has increased recently. Several species have much wider distribution in China than previously thought. To date, 14 new provincial records have been reported from this region including seven from Yunnan (*C. debilis* Hook. f., *C. extremiorientalis* (Tzvelev) Prob., *C. filiformis* Griseb., *C. gaoligongensis* (Paszko) Paszko, *C. himalaica* (Liou ex W.L. Chen emend. Paszko) Paszko, *C. nyingchiensis* (Kuo & Lu) Paszko, *C. yanyuanensis* Yang), four from Xizang (*C. abnormis* (Hook. f.) Shukla, *C. gaoligongensis* (Paszko) Paszko, *C. sichuanensis* Yang, *C. sorengii* (Paszko & W.L. Chen) Paszko) and three from Sichuan (*C. abnormis*, *C. garhwalensis* C.E. Hubb. & Bor, *C. extremiorientalis* (Tzvelev) Prob.) (Paszko 2012, 2014a, 2015, 2016, 2019; Paszko and Chen 2013; Paszko and Pendry 2013; Paszko and Soreng 2013; Paszko et al. 2013; Paszko and Chen in Nobis et al. 2014a; Paszko in Nobis et al. 2014b; Paszko et al. 2017; Paszko and Liu 2018).

In the course of the review of specimens of *Deyeuxia* in three Chinese Herbaria (CDBI, KUN, PE), numerous specimens formerly undetermined or identified as *Deyeuxia pyramidalis* (Host) Veldk. caught the second author’s attention. Most of

these specimens were collected in Yunnan, Sichuan and SE Xizang, with a few in adjacent Chinese provinces. For comparison, *Calamagrostis effusiflora* and Eurasian *C. arundinacea* (L.) Roth (in the “Flora of China” as *Deyeuxia pyramidalis* (Host) Veldk.) that show similarity in habit and spikelet traits, were also examined. We concluded that these plants represent an undescribed species new to science and we describe it here as *Calamagrostis hongii* Paszko & Bing Liu.

Materials and methods

We employed standard techniques for morphological studies of herbarium specimens from the CDBI, KUN, PE, US and W (acronyms follow Thiers 2017). All measurements were taken from the best-developed spikelets and leaf characteristics were determined on the 2nd leaf from the top of the plants. The locality data in accounts below inferred from sources other than herbarium labels are placed in square brackets. The localities were sorted according to the county-level administrative division of the People’s Republic of China. The distribution map was created with SimpleMapp (Shorthouse 2010) (Fig. 1). Specimens with the barcode numbers are accessible online via the PE Herbarium (<http://pe.ibcas.ac.cn/en/>), the National Plant Specimen Resource Center (<http://www.cvh.ac.cn/>), or the Muséum National d’Histoire Naturelle (<https://science.mnhn.fr/institution/mnhn/collection/p/item/search>). The data underpinning the analyses reported in this paper are deposited at GBIF, the Global Biodiversity Information Facility, <https://www.gbif.org/dataset/c6dd8791-eaae-49f5-9c18-b4bc06a7357f>.

Taxonomic treatment

Calamagrostis hongii Paszko & Bing Liu, sp. nov.

urn:lsid:ipni.org:names:77212604-1

Figs 1–3

Deyeuxia zhongdianensis L. Liou (Liou 1994: 2235), nom. nud. (Art. 39.1 of the ICN, Turland et al. 2018; no Latin description and/or diagnosis). Cited material: “[CHINA. Yunnan] Zhongdian Co. [now Shangri-La] (K.M. Feng 3326), grassland under forest, riversides, 2700 m”.

Diagnosis. *Calamagrostis hongii* is similar in habit and spikelet morphology to *C. arundinacea* and *C. effusiflora*, but differs in color and hairiness of the upper (adaxial) leaf blade surface. The upper leaf surface of *Calamagrostis hongii* is characterized by the grey color (vs. green or grey-green in *C. arundinacea* and *C. effusiflora*), the presence of moderately impressed veins forming ribs (vs. leaf surface flat or veins only slightly impressed in *C. arundinacea* or veins moderately or distinctly impressed, forming ribs in *C. effusiflora*), the presence of numerous prickly hairs covering the ribs (vs. lack of prickly hairs on veins or ribs of *C. arundinacea* and *C. effusiflora*) and the absence of hairs (vs.

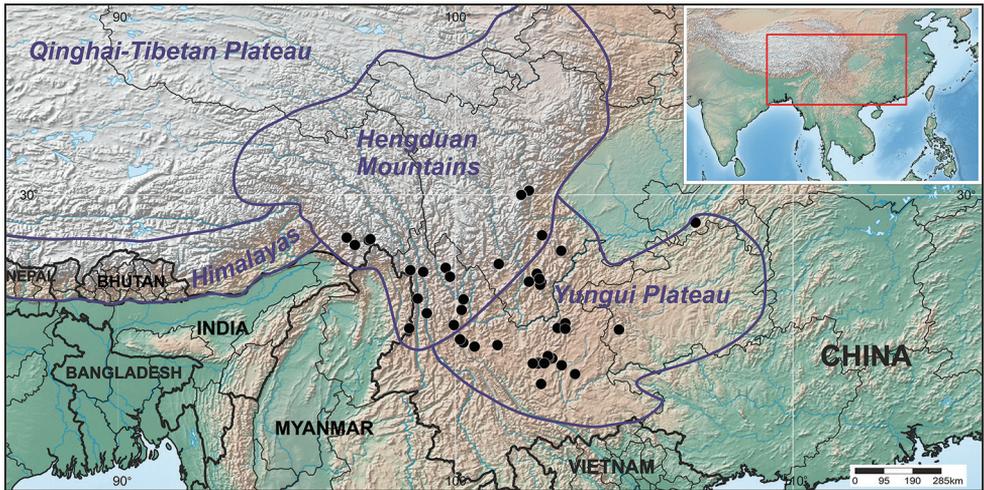


Figure 1. General distribution of *Calamagrostis hongii* Paszko & Bing Liu in southwestern China.

moderately or densely hairy in *C. effusiflora* and slightly or not hairy in *C. arundinacea*). *Calamagrostis hongii* is characterized by glabrous leaf sheaths, blades and collars.

Type. CHINA • **Yunnan:** Shilin Co., Guishan, Haiyi village to Yumeidu village; alt. 2095 m; 24.647N, 103.542E; 18 August 2006; Y.M. Shui et al. 64471 (Holotype PE! [herb. no. 2308966], Isotypes PE! [herb. no. 2058824, 2070270]).

Description. *Perennial grass*, cespitose, without rhizomes. **Culms** 55–140 cm tall, erect, unbranched above, 3–4.5 mm in diameter near the base, nodes 3–5, glabrous below the panicle. **Leaf sheaths** glabrous; **collar** glabrous; **ligules** 1.9–10 mm long, acute; **blades** 5–55 cm long, 4.3–9.5 mm wide, flat, slightly ribbed with glabrous furrows and scabrous ribs, upper (adaxial) surface scabrous owing to the presence of short stiff prickles on ribs, gray or gray-green, lower surface slightly scabrous, green, scabrous along margins. **Panicles** 13–25 cm long, erect, open, or loosely contracted at maturity; proximal internode 0.6–3.7(–4.5) cm long; rachis with 3–7 branches per node; **branches** 4–10 cm, slightly scabrous, spikelet-bearing only beyond mid-length. **Spikelets** 3.8–6.6 mm long, 1-flowered, with one fertile floret with rachilla extension, laterally compressed, disarticulation above the glumes; **glumes** subequal or equal, glabrous, very weakly scabrid on keel, apex acuminate; **lower glumes** 3.8–6.6 mm long and 0.9–1.4 mm wide, 1-veined; **upper glumes** 3.5–5.9 mm long and 1.1–1.6 mm wide, 3-veined, 0.8–1.1 times as long as the lower glume; **callus hairs** 1.0–2.9 mm long, 0.3–0.6 times as long as the lemmas; **lemmas** 3.5–4.8 mm long, 5-veined, 0.7–1.0 times as long as the lower glumes, apex 4-toothed; **lemmatal awn** 5.3–7.8 mm long, arising from near base (0.06–0.15 way up the back) of the lemmas, exserted, slender and easily distinguished from the callus hairs, geniculate, with twisted column; **paleas** 2.8–4.5 mm long, subequal or equal to the lemma, 0.8–1.0 times as long as the lemmas; **rachilla** extensions 1.0–2.8 mm long, densely bearded with hairs 2.4–4.2 mm; **stamens** 3, **anthers** 1.3–2.6 mm long. **Fl.** Jul–Aug. **Fr.** Aug–Sep.



Figure 2. Illustration (drawn by Jolanta Urbanik) of *Calamagrostis hongii* Paszko & Bing Liu based on Y.M. Shui et al. 64471 (PE, herb. no. 2308966) from Shilin County (Yunnan, China) **A** habit **B** glumes **C** floret **D** anthers **E** rachilla prolongation. Scale bars: 5 cm (**A**); 1 mm (**B–E**).

Taxonomic note. Although *Calamagrostis* and *Deyeuxia* were revised for China only fourteen years ago in the “Flora of China” (Lu and Phillips 2006, Lu et al. 2006) it is necessary to present a new taxonomic account of these species because of the changes in generic circumscription and the description of new species. *Calamagrostis hongii* is

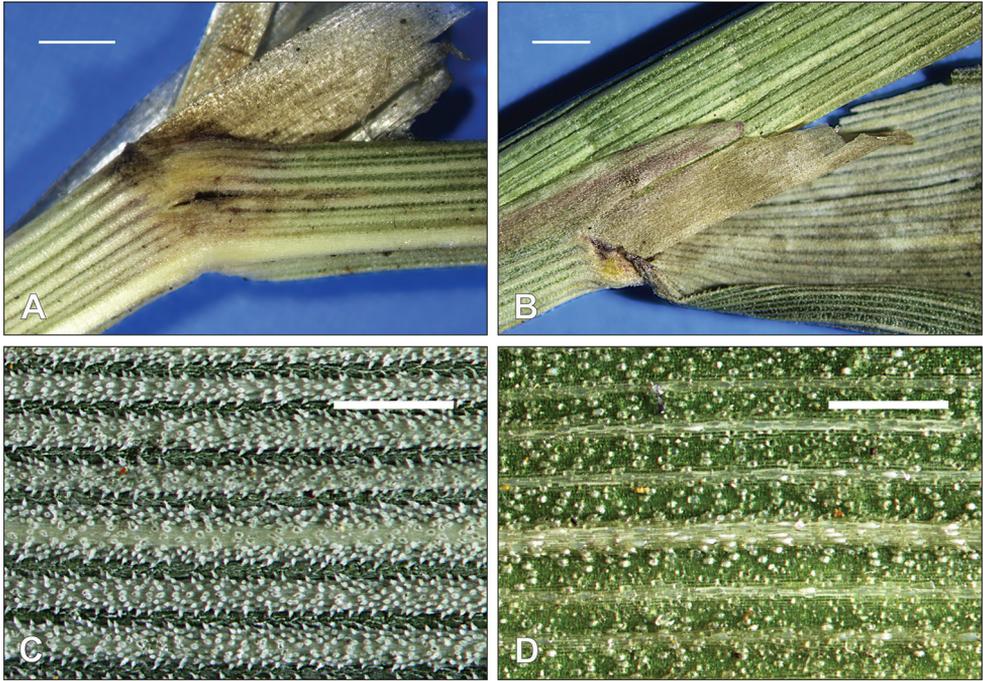


Figure 3. Leaf (2nd leaf from the top) characteristics of *Calamagrostis hongii* Paszko & Bing Liu **A** glabrous leaf collar **B** leaf ligule **C** upper (adaxial) leaf surface **D** lower (abaxial) leaf surface. **A–D** China, Yunnan: Shilin Co., Y.M. Shui et al. 64471 (PE, herb. no. 2308966). Scale bars: 1 mm (**A, B**); 0.5 mm (**C, D**). Photographs by B. Paszko.

the third new species of *Calamagrostis* reported from China since the publication of the “Flora of China”. This new species is probably a member of the *C. arundinacea* complex and it is similar to *C. arundinacea* and *C. effusiflora* in habit and spikelet traits, including size of glumes, lemmas and paleas, presence of well-developed rachilla prolongation and a geniculate lemma awn with a twisted basal column, lemma awn length and its insertion on the lemma back (near the base to the lower 1/3). However, they differ in several diagnostic characteristics. Prior to this study, most of the specimens currently identified as *C. hongii* had been identified as *Deyeuxia pyramidalis* [= *Calamagrostis arundinacea*]. The detailed revision of this group of species by the present authors showed that the upper surfaces of the leaves of *C. hongii* are unique. They are gray in color and moderately or densely scabrous and characterized by the presence of moderately impressed veins forming ribs that are slightly or densely covered by numerous prickle hairs (Fig. 3). Such prickle hairs are absent from the upper surfaces of the leaf blades of *C. arundinacea* and *C. effusiflora*. The upper surface of the leaf blade of *C. arundinacea* has veins that are only slightly impressed and the leaf blade surface is almost flat and hairless or covered by scattered macro hairs (Fig. 4), whereas *C. effusiflora* has veins slightly to distinctly impressed, forming ribs that are usually moderately to very densely hairy (Fig. 5). All three species have prickly leaf edges. The prickle hairs have thick walls that can be silicified. For additional diagnostic characteristics see Table 1.

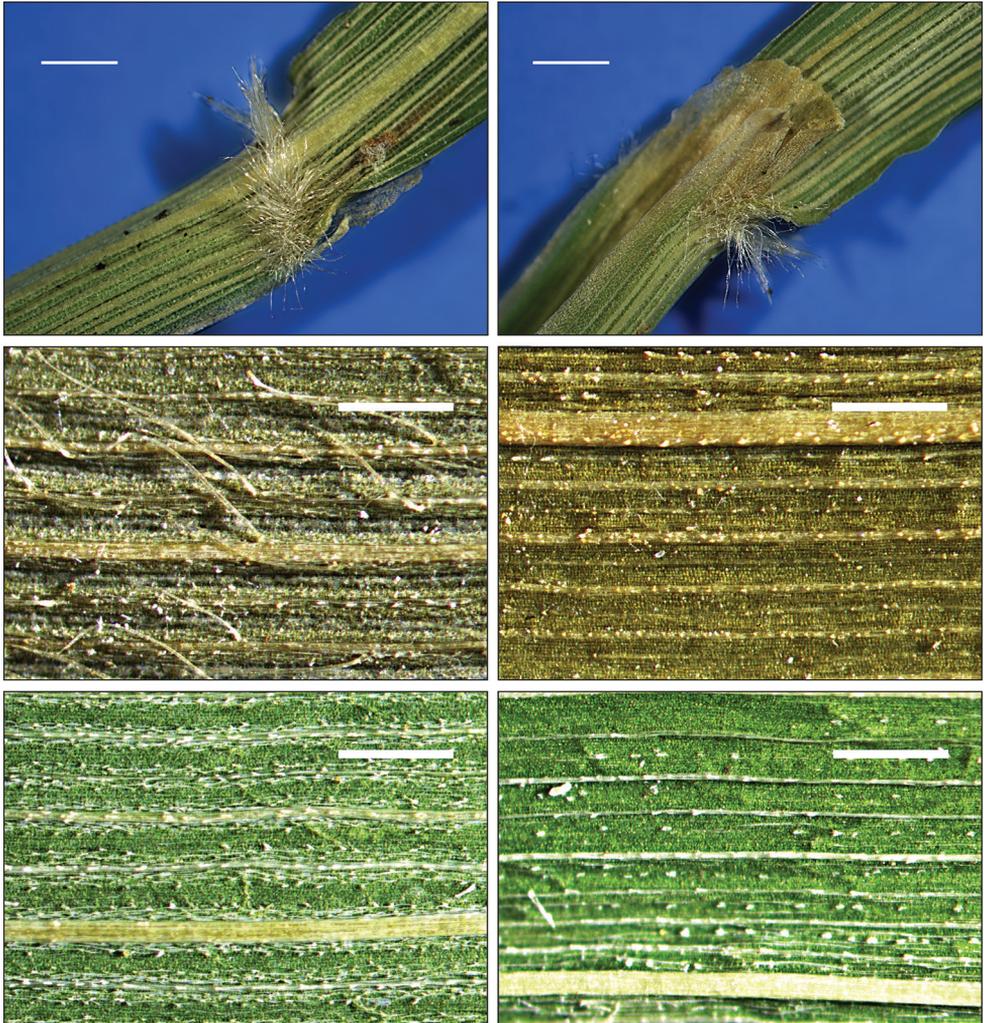


Figure 4. Leaf (2nd leaf from the top) characteristics of *Calamagrostis arundinacea* (L.) Roth. **A** hairy leaf collar **B** leaf ligule **C** upper (adaxial) surface **D** lower (abaxial) surface. **A–D** Slovakia, V. Mikoláš 8501 (W) **E, F** France, G. Gautier 63 (W). Scale bars: 1 mm (**A, B**); 0.5 mm (**C, D**). Photographs by B. Paszko.

The designation *Deyeuxia zhongdianensis* L. Liou (Liou 1994: 2235) was described without Latin description or diagnosis. From January 1, 1935, to December 31, 2011, one or both had to be in Latin, thus *Deyeuxia zhongdianensis* is nomenclaturally invalid and therefore unavailable under the Article 39.1 of the ICN (Turland et al. 2018). Liou (1994: 2235) cited Feng’s collection no. 3326 from Zhongdian County (now Shangri-La) in Yunnan Province, but the herbarium was not specified by the author. In PE we located three herbarium sheets (PE01854125, PE02108399, PE02108400) collected at Mt. Wuzhujun at Shangri-La City (former Zhongdian Co.) in Yunnan Province. We identified Feng’s collection as *C. hongii*. Lu et al. (2006) incorrectly synonymized *Calamagrostis zhongdianensis* with *Deyeuxia pyramidalis* (= *C. arundinacea*).

Table 1. Diagnostic morphological characters of *Calamagrostis hongii*, *C. arundinacea*, and *C. effusiflora*.

character	<i>C. hongii</i>	<i>C. arundinacea</i>	<i>C. effusiflora</i>
Panicle length (cm)	12–25	12–28	13–43
Rachilla length (mm)	1.0–2.75	0.75–1.75	0.25–2.0
Rachilla length with hairs (mm)	2.4–4.4	1.55–4.25	1.5–4.0
Anther length (mm)	1.35–2.6	2.15–3.3	1.2–2.75
Leaf ligule length (mm) at the 2 nd leaf from the top	1.9–10.3	0.9–5.5	0.8–18.0
Ratio: palea to lemma length	0.8–1.0	0.7–1.1	0.8–1.0
Colour of upper (adaxial) leaf blade surface	grey	green	grey-green, rarely green
Leaf veins on the upper (adaxial) leaf blade surface (in the middle of a leaf)	moderately impressed, forming ribs	only slightly impressed, leaf surface flat or almost flat	slightly to distinctly impressed, forming ribs
Upper (adaxial) leaf blade surface	moderately to densely scabrous, glabrous	smooth or covered with scattered macro hairs	slightly to densely hairy, macro hairs absent or present
Lower (abaxial) leaf blade surface	slightly scabrous	slightly scabrous	slightly scabrous
Presence of prickly hairs on leaf edges	present	present	present
Leaf collar (the junction of the leaf sheath and blade)	always glabrous	usually hairy, very rarely glabrous	usually glabrous, rarely hairy, the collar may also be found with a hairy margin
Altitude (m)	1800–3350	0–2300	600–2900(?)

Vernacular name. 洪氏野青茅 (Chinese), Hong's Bent-grass (English).

Etymology. The specific epithet honors Professor De-Yuan Hong, the Academician of Chinese Academy of Sciences (CAS) (State Key Laboratory of Systematic and Evolutionary Botany, Institute of Botany, CAS, Beijing, China) for his outstanding achievements in systematics, morphology, cytology, ecology and molecular evolution. The second author thanks Professor De-Yuan Hong for his continuous support during her multiple research visits to the Chinese herbaria as part of an exchange program between the Polish Academy of Sciences and the Chinese Academy of Sciences, in order to study the herbarium collections of *Calamagrostis* and *Deyeuxia* for the “Flora of Pan-Himalaya”.

General distribution. CHINA (S Chongqing, W Guizhou, Sichuan, SE Xizang, Yunnan).

Distribution and habitat. *Calamagrostis hongii* is endemic to south-western China. It is centered on the northern part of Yunnan and southern part of Sichuan and adjacent regions in south-western and central China, such as southern Chongqing, western Guizhou, central Sichuan and south-eastern Xizang. Its distribution covers the Southern Hengduan Mts and western and northern part of Yungui Plateau. A dot map provided here (Fig. 1) shows it to be common (or at least commonly collected) in northwestern Yunnan, with three dots along the Chinese border with Kachin State of Myanmar, where it may also occur. *Calamagrostis hongii* is restricted to the Sino-Himalayan subkingdom, primarily the Yunnan Plateau and Hengduan Mountains (Peng and Wu 2013, Tang 2015). The species occurs in the montane belt from circa

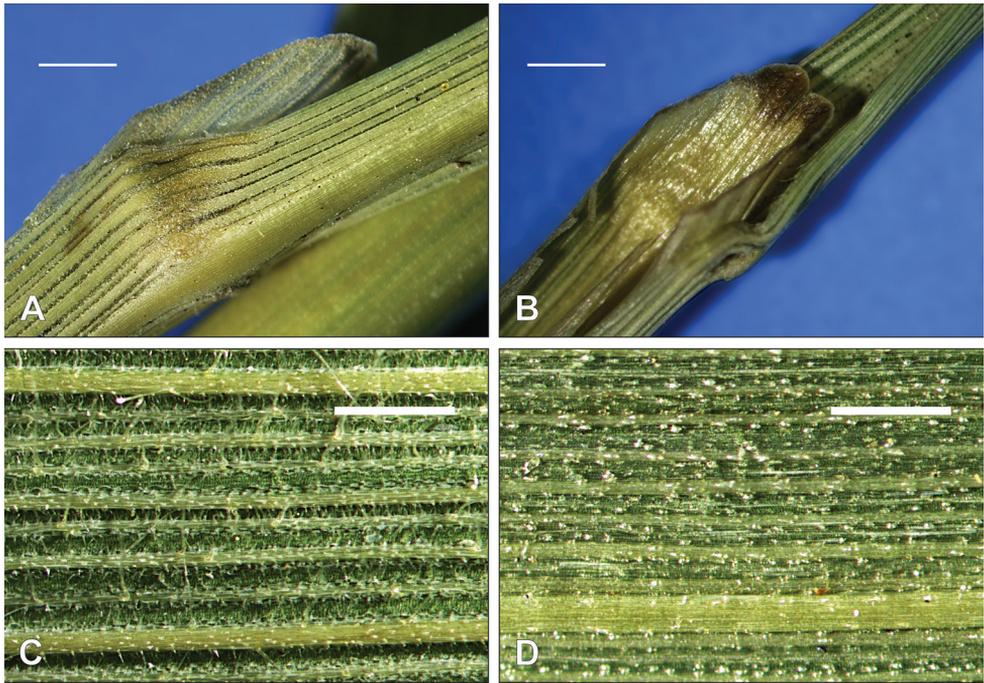


Figure 5. Leaf (2nd leaf from the top) characteristics of *Calamagrostis effusiflora* (Rendle) J.L.Yang **A** leaf collar **B** leaf ligule **C** upper (adaxial) surface **D** lower (abaxial) surface. **A–D** China, Sichuan, Wenchuan Co., Wolong Nature Reserve, 1500 m, 1 September 1982, K.Y. Lang et al. 1424 (PE01727049). Scale bars: 1 mm (**A, B**); 0.5 mm (**C, D**). Photographs by B. Paszko.

1800 m to 3350 m a.s.l., in grasslands, among bushes, forest edges and in mixed *Pinus yunnanensis* forests.

Phenology. *Calamagrostis hongii* flowers from July to August and is in fruit from August to November.

Additional specimens examined. CHINA – **Chongqing** • **Nanchuan** Distr.; [29.168N, 107.105E]; 31 Oct. 1960; Nanshuibeidiao Exped. Team 4852 leg.; KUN (KUN0079536). – **Guizhou** • [**Panzhou** City (Panxian Co., Pan Co.)]; Mt. Bada; mountain top, bushy and sunny place; alt. 2620 m; [25.975N, 104.839E]; 22 Aug. 1959; Anshun Exped. Team 1119 leg.; KUN (KUN0081068), PE. – **Sichuan** • **Dechang** Co.; [27.405N, 102.173E]; 1 Sept. 1959; S.F. Zhu 20177 leg.; PE (PE01726895); • **Kangding** City, Guzan; alt. 2200 m; [30.12N, 102.177E]; 6 Aug. 1961; Nanshuibeidiao Exped. Team 9903 leg.; PE (PE01726896) • **Kangding** City, [Xinduqiao Township], (Thibet Orient.) Tongolo [东俄洛, Dong'eluo] (Principauté de Kiala); [30.079N, 101.48E]; Jun.–Jul. 1892; R.P. Soulié s.n. leg.; P (P02650457, P02650453), PE (PE00449806) • **Meigu** Co.; mixed forest; alt. 2220 m; [28.325N, 103.127E]; 3 Aug. 1959; Z.T. Guan 7448 leg.; PE (PE00449784) • **Muli** Co., Zhongmi; alt. 2700 m; [27.925N, 101.263E]; 18 Jul. 1978; K.H. Mou, Y.B. Yang 7390 leg.; CDBI (CDBI0154069) • **Muli** Co., alt. 2800–3350 m, [27.934N, 101.28E], 15 Sept. 1959, S.K. Wu 3261 leg.;

KUN (KUN0081354), PE (PE00449779) • **Puge** Co., Tuomugou; forest, slope; alt. 1800 m; [27.381N, 102.54E]; 28 Aug. 1959; s.c. 5589 leg.; KUN (KUN0079385), PE (PE00449783) • **Puge** Co., Li'an; sunny slope; [27.312N, 102.508E]; 18 Aug. 1959; s.c. 5427 leg.; KUN (KUN0079386), PE (PE01726900) • **Puge** Co., Qiaowo Farm; alt. 1600 m; [27.489N, 102.483E]; 7 Aug. 1976; s.c. 14197 leg.; CDBI (CDBI0154083); PE (PE01727010) • **Yuexi** Co., Bao'an; alt. 2000 m; [28.79N, 102.561E]; 12 Jul. 1959; s.c. 3863 leg.; CDBI (CDBI0154071), PE (PE01726894) • unknown locality; alt. 2700 m; 30 Oct. 1965; Xizang Exped. Team s.n. leg.; PE (PE01727001). – **Xizang**: • **Zayü** Co. [formerly known as Tsarung], Tsawarung, Nar-jou; *Pinus yunnanensis* forest; alt. 3300 m; [28.675N, 97.476E]; Sept. 1935; C.W. Wang 66441 leg.; KUN (KUN0081350) • **Zayü** Co., Xiachayu; alt. 2400–2600 m; [28.499N, 97.02E]; 30 Aug. 1983; B.S. Li et al. 7165 leg.; PE (PE01726905) • **Zayü** Co., Zhuwagen; alt. 2500 m; [28.64N, 97.425E]; 8 Aug. 1973; s.c. 652 leg.; PE • **Zayü** Co., Shangchayu; alt. 2000 m; [28.718N, 96.777E]; 20 Aug. 1979; T.P. Yi 79153 leg.; KUN • **Zayü** Co., Shangchayu; alt. 2200 m; [28.718N, 96.777E]; 24 Jul. 1980; Z.C. Ni et al. 0724 leg.; PE (PE00449813, PE00449814) • **Zayü** Co.; Hougou; alt. 2300–2600 m; 26 Aug. 1983; B.S. Li et al. 6827 leg.; PE (PE01727016)). – **Yunnan**: • **Anning** City, Mt. Bijia, bushes, limestone, alt. 2200 m, [24.993N, 102.459E]; 2 Sept. 1977; B.Y. Qiu 77844 leg.; CDBI (CDBI0154080), KUN (KUN0097423) • **Anning** City, Wenquan Town; pine forest; alt. 1880 m; [24.962N, 102.45E]; 14 Aug. 2006; E.D. Liu 1807 leg.; KUN (KUN0397297) • **Anning** City, Anfengying; [24.966N, 102.289E]; 22 Jul. 2007; Y.C. Liu, J. Xu 119 leg.; KUN (KUN1221260) • **Dali** City, Ta-li Hsien; pine forest; alt. 2400 m; [25.589N, 100.226E]; 28 Jul. 1933; H.T. Tsai 53898 leg.; KUN (KUN0081049), PE (PE00449810) • **Dali** City, Mt. Cangshan; grassland; [25.589N, 100.226E]; 3 Aug. 1963; Zhongdian Exped. Team 63-3845 leg.; KUN (KUN0081048) • **Dali** City, Mt. Cangshan; alt. 3000 m; [25.589N, 100.226E]; 1 Oct. 2002; H.Y. Ma 153 leg.; KUN (KUN0081035) • **Dali** City, Mt. Cangshan; [25.467N, 100.56E]; 20 Jul. 1906; F. Ducloux 4223 leg.; PE • **Dali** City, Mt. Cangshan, Zhonghe Temple; [25.68N, 100.132E]; 30 Nov. 1948; T.N. Liou 17405 leg.; PE (PE00449804) • **Dali** City; without precise locality; Sept. 1941; H.C. Wang 1386 leg.; PE (PE00449803) • **Dongchuan** Distr., Kunming, Fazhecun, Damufang; [26.023N, 103.021E]; 16 Aug. 1964; Diandongbei Exped. Team 811 leg.; KUN (KUN0081296) • **Eryuan** Co.; alt. 2600 m; [26.113N, 99.949E]; 31 Sept. 1963; W Yunnan-Jinsha River Exped. Team 63-6292 leg.; KUN • **Eryuan** Co., without precise locality; alt. 2600 m; [26.113N, 99.949E]; W Yunnan-Jinsha River Exp. Team 63-6292 leg.; KUN (KUN0081353), PE (PE01726887, PE01726893) • **Fugong** Co., Famufang, forest; alt. 2700 m; [26.901N, 98.88E]; 23 Jun. 1978; Bijiang Exped. Team 715 leg.; KUN (KUN0097433) • **Gongshan** Co., Suroula; alt. 3000 m; [27.748N, 98.662E]; Sept. 1935; C.W. Wang 66586 leg.; PE (PE00449807) • **Guandu** Distr., Kunming, Shuanglong; grassland; alt. 1900 m; [25.119N, 102.862E]; 1 Sept. 1977; B.Y. Qiu 77700 leg.; CDBI (CDBI0154079), KUN (KUN0079418, KUN0079425) • **Heqing** Co., Huangping, Junle, Shangdapingzi; alt. 2500 m; [26.559N, 100.179E]; 16 Aug. 1963; Jinshajiang Exped. Team 6555 leg.; KUN (KUN0081171), PE (PE01726857, PE01726891) • **Heqing** Co., Les patu-

rages au col de Koua-la-po, pres Hokin; alt. 3000 m; 1883–1885; M. Delavay 2465 leg.; P (P02650445), PE (PE01938085, PE01663486), W (1916-38022) • **Huize** Co., Liangwang Shan, ca. 15 km E of Dongchuan ca. 120 km NNE of Kunming, on new rd. to Zhoatong via Zhehai; shallow grassy valley in low, red clay hills, with limestone substrate surrounded by 2nd growth *Pinus yunnanensis*, *Alnus nepalensis*, *Quercus variabilis* and *Q. glaucooides* forest, *Capillipedium* abundant; alt. 2280 m; 26.167N, 103.25E; 14 Sept. 1997; R.J. Soreng et al. 5309 leg.; KUN (KUN0079581), PE (PE00487541), US (US00895217) • **Huize** Co., Liangwang Shan, ca. 20 km E of Dongchuan, ca. 110 km NNE of Kunming, on new rd. to Zhoatong via Zhehai; low, eroded, red clay hills, with limestone substrat, scrubby *Pinus yunnanensis*/*Alnus nepalensis* forest, shrubs and grasses, around corn and tobacco fields, among trees; 26N, 103.25E; 14 Sept. 1997; R.J. Soreng et al. 5293 leg.; KUN (KUN0079580), US (US00844386) • **Jiangchuan** Distr., Yuxi City, Cuifeng, Yongsheng; limestone; [24.355N, 102.533E]; 9 Aug. 1975; B.Y. Qiu 60633 leg.; KUN (KUN0081051) • **Lanping** Co., Yingpan, Luomuping; alt. 2300 m; [26.464N, 99.149E]; 21 Jun. 1981; PE Mt. Hengduan Exped. Team 683 leg.; PE (PE01663487) • **Lushui** City, Pianma Town; grassland of forest edge; alt. 2100 m; [26.012N, 98.63E]; 30 Jul. 1978; Bijiang Exped. Team 1542 leg.; KUN (KUN0081066) • **Panlong** Distr., Kunming, Heilongtan; [25.141N, 102.751E]; 1945; K.M. Feng 10636 leg.; KUN (KUN0081054) • **Panlong** Distr., Kunming, Heilongtan; shady slope among high herbs; [25.141N, 102.751E]; 26 Jul. 1941; F.T. Wang 2286 leg.; KUN (KUN0081089) • **Weishan** Co., Huangshucun; alt. 2370 m; 22 May 1965; CAS Integrated Exped. Team for SW China 449 leg.; PE • **Weixi** Co., Wei-si Hsien, Yeh-Chih [Yezhizhiang]; ravine; alt. 2400 m; [27.699N, 99.044E]; Jul. 1935; C.W. Wang 67940 leg.; KUN (KUN0081351) • **Wuhua** Distr., Kunming, Xiaoshao; 25.186N, 102.735E; 18 Jul. 2007; H. Peng et al. 68 leg.; KUN (KUN1221262) • Zhongdian Co. [now **Shangri-La** City], Mt. Wuzhujun; forest; alt. 2700 m; [27.817N, 99.707E]; 12 November 1939; Feng 3326 leg.; PE (PE02108400, PE02108399, PE01854125) • Zhongdian Co. [now **Shangri-La** City], Xiaozhongdian, East Mt.; alt. 3250 m; [27.55N, 99.835E]; 13 Aug. 1981; s.c. W16 leg.; PE (PE01726860) • Zhongdian Co. [now **Shangri-La** City]; alt. 2900 m; 9 Jul. 1962; Zhongdian Exped. Team 2106 leg.; PE (PE01726889) • **Xishan** Distr., Kunming, Hsi-Shan [Xishan], near San-Ching-Ke; grassland; alt. 2100 m; [24.97N, 102.627E]; 11 Aug. 1945; T.N. Liou 14085 leg.; PE (PE00449812) • **Xishan** Distr., Kunming, Western Hills; [24.974N, 102.628E]; 1941; T.N. Liou 19823 leg.; PE (PE00449802) • **Yao'an** Co., Daxingshan; alt. 2180 m; [25.514N, 101.242E]; 11 Jul. 1965; CAS Southwest Exped. Team 484 leg.; PE • **Yi-liang** Co., way to Yangzonghai; alt. 1800 m; [24.911N, 103.142E]; 6 Sept. 1977; B.Y. Qiu 771257 leg.; CDBI (CDBI0154088) • **Yulong** Co., Yangtze Watershed, Prefectural District of Lijiang, eastern slopes of Lijiang Snow Range; [26.877N, 100.234E]; May–Oct. 1922; J.F. Rock 5911 leg.; PE • same collection data as for preceding; J.F. Rock 5908 leg.; P (P02650461), W • **Yulong** Co., Lijiang (Likiang), Mt. Yulong-schan; Jun–Sept. 1914–1916; Handel-Mazzetti s.n. leg., Inter Sinense 1914–1918 no. 3790; W • **Yongsheng** Co., Boluo; edge of *Pinus yunnanensis* forest; alt. 2600 m; 16 Jul. 1960; Sino-Russia Exped. Team 6205 leg.; PE (PE01726892).

Acknowledgments

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Checklist of vascular plants of Klang Gates Quartz Ridge, Malaysia, a 14-km long quartz dyke

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Abstract

The Klang Gates Quartz Ridge (KGQR) is proposed for protection as National Heritage and as a UNESCO World Heritage Site because of its spectacular size, exceptional beauty and significant biodiversity. The checklist of vascular plants documents 314 species that comprise a unique combination that grows on lowland quartz and that is distinct from the surrounding lowland equatorial rain forest by the absence of orchids, palms, gingers and tree canopy families. The Rubiaceae, Gramineae, Moraceae, Apocynaceae, Melastomataceae and Polypodiaceae are the most speciose families. The summit vegetation at 200–400 m elevation is dominated by *Baeckea frutescens* (Myrtaceae) and *Rhodoleia championii* (Hamamelidaceae) and shows similarities to the plant community on rocky mountain peaks above 1500 m. About 11% of its species are endemic in Peninsular Malaysia and four are endemic to KGQR: *Aleisanthia rupestris* (Rubiaceae), *Codonoboea primulina* (Gesneriaceae), *Spermacoce pilulifera* (Rubiaceae), and *Ilex praetermissa* (Aquifoliaceae). All four are provisionally assessed as Critically Endangered. Two, *Eulalia milsumi* (Gramineae) and *Sonerila prostrata* (Melastomataceae), are endemic to KGQR and a few neighbouring smaller quartz dykes. They are assessed as Endangered. The KGQR is a fragile habitat and conservation management is urgently required to halt the spread of the aggressive alien grass, *Pennisetum polystachion* and to prevent further habitat degradation from visitors. Based on KGQR being a threatened habitat, its biodiverse flora, and endangered species, it qualifies as an Important Plant Area.

Keywords

Alien species, endangered species, endemic species, flora, Important Plant Area, quartz dyke, Selangor, UNESCO World Heritage Site

Introduction

The Klang Gates Quartz Ridge (KGQR), renamed Gombak Selangor Quartz Ridge (Mohd.-Zainuddin 2015), is a 14 km-long quartz dyke (3.12N, 101.42E to 3.15N, 101.48E) 12 km northeast of Kuala Lumpur in the state of Selangor, Malaysia. Rising to about 400 m, it dominates the skyline north of Kuala Lumpur and is believed to be the longest exposed quartz dyke in the world. Running from east to west, it is flanked to the north by the Hulu Gombak Forest Reserve Extensions and the Klang Gates Dam, a large reservoir covering 207 ha that supplies water to the capital, Kuala Lumpur. To the south, it is increasingly exposed to human disturbance.

Composed of pure quartz, the dyke was exposed as the surrounding granite material weathered away revealing sheer pale grey or white vertical cliffs rising above the surrounding vegetation. Though about 200 m wide at the base, in places the summit ridge is a knife edge only a metre or so wide with precipitous drops on either side. Jagged like a dragon's spine, it is dissected by vertical faults giving it the appearance of limestone karst, so it has been termed a pseudo-karst formation. It is pierced by three rivers that flow through narrow gullies. The pure quartz weathers to coarse sand that is very nutrient poor, has poor water retention, and has crumbled to form a steep base of colluvium with 30–35° and in places up to 60° slopes.

Adaptation to the extremely poor nutrient status and water retention has resulted in a distinctive flora with a unique assemblage of plants that includes several rare and/or endemic species restricted to the KGQR. It is markedly different from the surrounding tropical lowland rain forest not only in species composition, but also in physiognomy (with sparse stunted trees), complexity (not multi-layered and without the epiphyte flora) and lower species diversity (Saw 2010).

Its striking topography and unique flora have long attracted botanists. The first botanical collections were made by H.N. Ridley, who made three visits in 1908, 1916 and 1921 that mainly concentrated on the summit ridge flora. He wrote the first account of the flora (Ridley 1922a), describing ten new species. Henderson (1928) produced the first comprehensive listing of plants from the KGQR included in his checklist of the flowering plants of Kuala Lumpur. It was based on collections made by Forestry Department staff, in particular by Mohd Hashim in 1908, and by H.L. Hume, employed by the Federated Malay States Museum, in 1921, who discovered the new species, *Hydnocarpus humei*, that was named in his honour. Subsequently, the herbarium collection of the Federated Malay States Museum was loaned indefinitely to the Singapore Botanic Gardens Herbarium (Henderson 1928). Henderson's listing of 265 species provided the most complete inventory of the vegetation on the steep slopes that were still forested in those days. Unfortunately, Henderson did not cite specimens. Later significant collections were made by staff of the Forest Research Institute Malaysia, principally by E.J. Strugnell in 1927 and C.F. Symington in 1933, 1935 and 1939. After a long hiatus, Kiew (1978) described a new species, *Ilex praetermissa*, she had discovered and produced the third account of the flora (Kiew 1982) based on her collections made between 1977–1982 and included for the first time a checklist of ferns collected by B. Molesworth-Allen and A.G. Piggott, who recorded *Syngamma dayi*, a fern restricted to quartz habitats.

Effect of Human Activities on the Flora of KGQR

Being so close to the capital Kuala Lumpur, it has suffered disturbance from agricultural activities, urbanisation, visitor pressure, and the invasion of alien weeds. All these activities threaten the continued existence of its flora and species of conservation importance. On the Kuala Lumpur side, encroachment from housing and road building threatens. The north side is protected by the Hulu Gombak Forest Reserve Extensions and the Klang Gates Dam.

Agricultural activities were a particular problem in the 1970s and 1980s (Kiew 1982; Perumal 1992) when there was widespread clearing of sections of the steep base on the south side to plant bananas and pineapple. Clearing the land by burning the vegetation got out of control and the 5 m-tall *Baeckea frutescens* trees were burned to the ground together with thick festoons up to half a metre long of the old man's beard lichen, *Usnea* sp. Fortunately, *B. frutescens* regenerated from seed and suckers but after 30 years the old man's beard lichen has not re-established (Kiew pers. obs.). *Rhodoleia championii* (Figure 1) survived the fires with only its leaves being scorched, but in contrast the sappy *Fagraea auriculata* was totally destroyed. Due to the nutrient-poor soil, these agricultural activities failed and the area was quickly invaded by weeds of which the most damaging was the grass *Imperata cylindrica*, a fire hazard because it becomes tinder-dry in dry weather and fuelled fires on the lower slopes.

The impact of urbanisation began with the building of a bungalow in 1883 on the top of the ridge above the gully through which the Klang River flows. Between 1893 and 1895



Figure 1. *Rhodoleia championii*, one of the dominant tree species on the summit.

this gully was dammed to form a reservoir (Barlow 1995). By 1926, the bungalow had become derelict and today any sign of it has almost disappeared, although a few garden plants still persist with the patch of the native *Eriachne pallescens* grass indicating where the bungalow once stood (Kiew 1982). In the 1950s a quarry was established at the western end to utilise the quartz for glass making. It had only a very local impact and was discontinued due to lack of commercial viability. The expanding population of Kuala Lumpur required a greater water supply that resulted in enlargement of the Klang Gates Dam to its present size. This caused some local damage. Housing developments continue to creep ever closer to the KGQR. The major Kuala Lumpur-Karak Highway cuts through the western end. In 2016, a major highway development, the Eastern Klang Valley Expressway, threatened its integrity but due to public protest was re-routed away from the KGQR.

The KGQR's easy accessibility and proximity to Kuala Lumpur has long encouraged rock climbers and hikers who are rewarded by a panoramic view of the Kuala Lumpur skyline in one direction and the reservoir lake and virgin rain forest in the other (Figure 2). Unfortunately, increasing visitor pressure has its negative effects including cutting down trees for camp fires (Perumal 1992). In the 1980s it was still possible to see quartz crystals 7–10 cm long, but these have long since been taken by visitors. Notable too is the disappearance from easily accessible places of *Eurycoma longifolia*, formerly a striking plant on the summit (Kiew 1982). Local Malays believe it to be a powerful aphrodisiac. The spider orchid, *Renanthera* sp., reported by Adams (1953) is also long gone. Both are the prey of opportunistic collecting by visitors. However, they may persist on inaccessible peaks.



Figure 2. View of the eastern ridge of Klang Gates Quartz Ridge from summit of western ridge, the summit (foreground) dominated by 2–3 m tall *Baeckea frutescens*.

The natural open nature of the KGQR flora makes it vulnerable to invasion by weeds. Formally, it was an island surrounded by rain forest that acted as a buffer against weed dispersal. Now this has gone from the southern side, so the KGQR is open to invasion by any weed that can withstand harsh conditions for plant growth. The agricultural activities mentioned above led to a great increase in the number of weed species recorded from the KGQR (Kiew 1982). After the initial invasion by *Imperata cylindrica*, by the 1990s Wong et al. (2010) reported that the aggressive fern *Dicranopteris linearis* covered large areas, the composite *Chromolaena odorata*, the shrub *Clidemia birta*, the secondary forest tree *Cyrtophyllum fragrans* and a variety of grasses were already established.

Legal Protection

In 1936, 130 ha of the KGQR were gazetted as the Klang Gates Wildlife Reserve to protect all wildlife and in particular the serow, *Capricornis sumatraensis*, a totally protected animal in Malaysia (Perumal 1992). Over the years, KGQR has been proposed to be designated as a National Nature Monument (in 1974 by the Malaysian Nature Society in the Blueprint for Conservation in Peninsular Malaysia) and to be included in the Selangor Heritage Park (Wong et al. 2010). The Hulu Gombak Forest Reserve Extensions were given enhanced protection when upgraded to Permanent Reserved Forest Status and from 2007 the KGQR lies within the Selangor State Park. In June 2015, the Selangor Town and Country Planning Department (JPBD) renamed the KGQR the Gombak Selangor Quartz Ridge and committed to protect it as National Heritage and to get it declared a UNESCO World Heritage Site on the grounds that it is a world-class geological phenomenon being the longest exposed quartz dyke in the world, as well as for its spectacular size, exceptional beauty, and its importance as a significant natural habitat for *in situ* conservation of biodiversity. It is currently on the Tentative List of World Heritage Sites.

In anticipation of the KGQR becoming a UNESCO World Heritage Site, this account aims to make available essential baseline data on the unique assemblage of plants that make up its flora by providing:

- a complete checklist of vascular plant species
- details of the endemic and rare species of conservation importance
- a complete bibliography for the botany of the KGQR.

Materials and methods

Accessibility and proximity to Kuala Lumpur means that many botanists have from time to time collected plants there so its flora can be said to be well-collected. This has meant that it has been possible to build the checklist using herbarium specimen data from the herbaria at KEP, KLU and SING that hold the majority of KGQR collections.

Herbarium codes follow *Index Herbariorum* at <http://sweetgum.nybg.org/ih>. Herbarium specimens provide a permanent record and, should there be questions about a species' identity, they can be verified at any time in the future by reference to the specimen. An example of the importance of making herbarium specimens is illustrated by the case of *Hoya mappigera*, a species only described in 2011 but that had been collected from the KGQR in 1962 (*Sinclair 10730*) under the name *Hoya campanulata*.

The database software Botanical Research and Herbarium Management System (BRAHMS) in the National Herbarium of Malaysia (KEP) at the Forest Research Institute Malaysia, Selangor, Malaysia, enabled records to be extracted from its extensive holding. Not included are exotic weeds, invasive species or plants from the surrounding lowland rain forest.

For cases where species are recorded from KGQR in the literature but specimens were not cited, for instance Henderson (1928), Molesworth-Allen (1963) and Piggott (Kiew 1982), the literature source is cited in the checklist.

Results

The checklist compiled in this study contains 314 species of vascular plants in 233 genera and 105 families (Table 1, Appendix I). The most speciose families are Rubiaceae (32 species), Gramineae (15), Moraceae (14), Apocynaceae (11), Melastomataceae (10) and Polypodiaceae (10). Genera with five or more species include: *Ficus* (11 species), *Hedyotis* (5) and *Ixora* (5). About 11% (36 species) are endemic in Peninsular Malaysia. Percentage endemism is lower than the national average of about 25% for tree species (Saw 2010). Four species are endemic to KGQR and a further two endemic to KGQR and several neighbouring smaller quartz dykes.

In the checklist, four species proved to be endemic to KGQR, namely *Aleisanthia rupestris*, *Codonoboea primulina*, *Ilex praetermissa* and *Spermacoce pilulifera* (Figure 3). Following the IUCN criteria and categories (2001), these four species are all provisionally assessed as Critically Endangered under criteria CR B2ab(iii,iv) on the grounds that they are endemic in Peninsular Malaysia, where they are restricted to one locality that although it lies within the Selangor State Park is threatened by habitat degradation from visitor pressure and from invasive species. A further two species, *Eulalia milsumi* and *Sonerila prostrata*, endemic to KGQR and a few nearby smaller quartz dykes in the Gombak Valley, are provisionally assessed as Critically Endangered under criteria

Table 1. Families, genera and species of vascular plants of Klang Gates Quartz Ridge.

Group	Families	Genera	Species
Lycophytes	1	1	2
Ferns	16	24	36
Gymnosperms	1	1	1
Flowering plants	87	207	275
Total	105	233	314



Figure 3. Endemic species in Klang Gates Quartz Ridge: *Eulalia milsumi* (left) and *Aleisanthia rupestris*.

EN B2ab (iii, iv) on the grounds that they are endemic species, restricted to two to four quartz dykes that, although they lie within the Selangor State Park, are vulnerable to habitat degradation. Other species of conservation importance include *Syngramma dayi*, endemic in quartz habitats in Perak and Selangor, and a few species that are extremely rare: *Hydnocarpus humei* is known from one other collection from Larut, Perak; *Hoya mappigera* is known from one other collection from Lumut, Perak, and another from Thailand. Further, the specimen of *Galearia fulva* that Ridley described as *G. lancifolia* is strikingly different from the typical form in having extremely narrow leaves and may prove to be a distinct taxon.

Discussion

Habitats

Without a doubt, it is the summit flora that is of greatest botanical interest for its unique combination of species. *Baeckea frutescens* and *Rhodoleia championii* are the dominant tree species, while shrubs include *Austrobuxus nitidus* and *Vaccinium ban-canum* and several epiphytic species, for instance *Fagraea auriculata*, *Ficus deltoidea*

var. *angustifolia* and *Rhododendron longiflorum*, that here grow directly on the quartz rocks. The ground layer is sparse with mats of the white moss *Leucobryum aduncum* covering the thin peat layer. The endemic grass *Eulalia milsumi* forms sparse tussocks in soil-filled cracks and crannies. *Aleisanthia rupestris* as its name suggests grows in crevices on the sheer cliff faces in full sun. In contrast, *Ilex praetermissa* grows in forest on steep slopes in partial shade where there is an accumulation of peat. The gorges that pierce the ridge present a completely different cool, humid, shaded environment where lush herbs, for instance *Begonia sinuata*, *Codonoboea primulina* and ginger, can thrive.

Comparison with other plant communities

Notable in the checklist is the absence or poor representation of trees typical of the canopy of lowland equatorial rain forest (Saw 2010), such as the Anacardiaceae, Burseraceae, Dipterocarpaceae, Guttiferae, Leguminosae, Myristicaceae, and Myrtaceae, and families like Orchidaceae, Palmae and Zingiberaceae. While it is obvious that the harsh exposed conditions and scanty soil act as a filter that excludes the majority of trees, shrubs and herbs that are typical of equatorial rain forest, it is notable that this lowland quartzite flora at 200–400 m elevation has much in common with the plant community of upper montane forest that grows above 1500 m on mountain peaks with peat that develops on weathered granitic soils (Reid 1951). In fact, Ridley (1922b) first drew attention to this phenomenon noting that KGQR included a “small but quite peculiar flora consisting of several endemic species with several only known from much higher altitudes in our mountains”. Species that illustrate this striking disjunct altitudinal distribution include *Austrobuxus nitidus*, *Baeckea frutescens*, *Dipteris conjugata*, *Oleandra neriiformis*, *Rhodoleia championii* and *Vaccinium bancanum*. Further, Whitmore (1984) drew attention to a few of these species, *Austrobuxus nitidus* and *Baeckea frutescens*, that also grow in lowland heath forest that also has base-poor, often sandy soil topped by a peat layer.

It might be expected that the quartzite flora would share similarities with the limestone flora that also grows on a rocky, free-draining substrate with poor soil development. However, comparison with the flora of Batu Caves with 269 species (Kiew 2014), a karst hill just 7 km from the KGQR, shows that in fact they share very little in common with just five species that grow in both localities, namely, *Alstonia scholaris* (a secondary forest species), *Pogonanthera pulverulenta* (an epiphyte that grows on trees, not on the rock substrate), *Microsorium membranifolium* (a lithophyte), and the figs, *Ficus hispida* and *F. punctata*. Even at the family level, the differences are very pronounced. At Batu Caves, Orchidaceae is the most speciose family with 23 species contrasting with just two orchid species on KGQR; while speciose families on KGQR, Rubiaceae (32 species), Gramineae (15 species), Melastomaceae (10 species), Polypodiaceae (10 species) and are represented by 13, 0, 1 and 2 species, respectively, on Batu Caves.

Changes in the flora

The repeated burning of a large section of the southern face has resulted in long-term detrimental consequences. The steep slope is still covered by secondary vegetation among which the aggressive fern *Dicranopteris linearis* smothers competing vegetation. Many of the trees recorded by Henderson (1928) have not been recollected for more than 50 years, though they might still persist on the undisturbed northern side. *Sonerila prostrata* and *Spermacoce pilulifera* have not been re-collected for more than 35 years.

Among the site endemic species, *Ilex praetermissa* populations are now found only on the northern side suggesting that they are unable to disperse and become established in secondary vegetation on the southern side. This species is critically endangered having an extremely small population size and, in addition, it is a dioecious species (Kiew 1983). Wong et al. (2010) counted only 20 *Ilex* plants on a 250 m transect.

The endemic grass, *Eulalia milsumi*, is also seriously threatened by disturbance. Although reasonably common in less disturbed habitats, Wong et al. (2010) discovered that its population is highly sensitive to disturbance by aggressive smothering by weeds like *Dicranopteris linearis* and that it was significantly less frequent in disturbed areas. In addition, recently it is particularly threatened by the large, tussock forming alien grass, *Pennisetum polystachion*, first reported from KGQR by Yao (2007), but is now widespread (Kiew 2009; Lim and Yao 2010).

Fortunately, *Aleisanthia rupestris* appears to be less influenced by disturbance (Wong et al. 2010) probably because it grows in such exacting conditions in full sun on vertical rock faces rooted in tiny cracks and crevices where even weeds are unable to gain a toe-hold.

The very small population of *Codonoboea primulina* of less than 150 individuals that grows in an extremely small area measuring about 50 m² (Kiew 1983), is most at risk from botanical collectors, even though there is no need for repeated collecting because it is already represented in most major herbaria in the world.

Conclusion

The proposal by the Selangor Town and Country Planning Department to protect the KGQR under the National Heritage Act 2005 (Act 645) status is long overdue. Globally, it is indeed unique for a combination of its great size, the tall exposed quartz dyke with its pseudo-karst morphology, and its unique assemblage of plant species that includes endemic and rare plants. It meets all three criteria for being designated an Important Plant Area (Anderson 2002). The quartz dyke is a fragile, threatened habitat vulnerable to visitor pressure and invasive plant species, it harbours a unique biodiverse flora quite unlike that of either lowland forest or the limestone hill flora and of its 314 species 11% are endemic to Peninsular Malaysia, among which four are provisionally assessed as Critically Endangered and two as Endangered. Management of the dyke not only needs

to control visitor access (Mohd.-Zainuddin 2015) but also to manage the invasion of aggressive weed species, most notably the *Dicranopteris linearis* thickets and to weed out *Pennisetum polystachion* by hand before it irreversibly impacts on the native flora.

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Appendix I

Checklist of vascular plant species collected from the Klang Gates Quartz Ridge, Selangor, Malaysia.

(Endemism: E – endemic in Peninsular Malaysia, EE – endemic in KGQR, E? – possibly endemic in Peninsular Malaysia).

Family classification follows the Flora of Peninsular Malaysia for ferns (Parris 2010) and flowering plants (Kiew et al. 2010).

Where details of herbarium specimens are not available, the literature source is provided, namely Henderson (1928), Molesworth-Allen (1963) and Piggott in Kiew (1982).

LYCOPHYTES

SELAGINELLACEAE

^E*Selaginella strigosa* Bedd.

Sinclair SFN 40140

Selaginella stipulata (Blume) Spring

Molesworth-Allen

FERNS

ADIANTACEAE

Haplopteris ensiformis (Sw.) E.H.Crane

Piggott

Haplopteris scolopendrina (Bory) C.Presl

Piggott

ASPLENIACEAE

Asplenium affine Sw.

Syahida FRI 55109

Asplenium nitidum Sw.

Kiew RK 1090, Parris 10968, Sinclair

SFN 40142

Asplenium pellucidum Lam.

Molesworth-Allen, Piggott

BLECHNACEAE

Blechnopsis orientalis (L.) C.Presl

Piggott

CIBOTIACEAE*Cibotium barometz* (L.) J.Sm.

Anthonysamy SA 374, Molesworth-Allen, Piggott

DAVALLIACEAE*Davallia denticulata* (Burm.f.) Mett. ex Kuhn

Molesworth-Allen

Davallia heterophylla J.Sm.

Ng FRI 22112, Molesworth-Allen, Piggott

Davallia repens (L.f.) Kuhn

Piggott

Davallia solida (G.Forst.) Sw.

Molesworth-Allen, Piggott

DENNSTAEDTIACEAE*Microlepia speluncae* (L.) T.Moore var.*hancei* (Pantl) C.Chr. & Tardieu

Piggott

Pteridium esculentum (Forst.) Cockayne

Molesworth-Allen, Piggott

DIPTERIDACEAE*Dipteris conjugata* Reinw.

Piggott

GLEICHENIACEAE*Dicranopteris linearis* (Burm.f.) Underw.

Piggott

HYMENOPHYLLACEAE*Hymenophyllum blandum* Racib.

Molesworth-Allen, Piggott

NEPHROLEPIDACEAE*Nephrolepis biserrata* (Sw.) Schott

Anthonysamy SA 373

Nephrolepis falciformis J.Sm.

Piggott

OLEANDRACEAE*Oleandra neriiformis* Cav.

Kiew RK 1080, Piggott

POLYPODIACEAE*Drynaria rigidula* (Sw.) Bedd.

Piggott

Goniophlebium percussum (Cav.)

W.H.Wagner & Grether

Piggott

Lepisorus longifolius (Blume) Holttum

Strugnell FMS 14623

Leptochilus macrophyllus (Blume) Noot.

Piggott

Microsorium membranifolium (R.Br.) Ching

Ingram FMS 14605

Pyrrosia angustata (Sw.) Ching

Symington 39403, Piggott

Pyrrosia lanceolata (L.) Farw.

Anthonysamy SA 372, Piggott

Selliguea heterocarpa (Blume) Blume

Piggott

Selliguea lateritia (Baker) Hovenkamp

Kiew RK 1088

Selliguea stenophylla (Blume) Parris

Piggott

PTERIDACEAE*Pteris biaurita* L.

Strugnell FMS 14603

Pteris longipinnula Wall. ex J.Agardh

Molesworth-Allen, Piggott

^E*Syngamma dayi* (Bedd.) Bedd.

Parris 10967, Sinclair SFN 40139

SINOPTERIDACEAE*Cheilanthes tenuifolia* (Burm.f.) Sw.

Piggott

TECTARIACEAE*Tectaria fissa* (Kunze) Holttum

Kiew RK 1089, 1091, Parris 10969, Hume 7065

Tectaria singaporiana (Wall. ex. Hook. & Grev.) Copel.

Molesworth-Allen

WOODSIACEAE

Diplazium polyodioides Blume
Ingram FMS 14602

GYMNOSPERMS

GNETACEAE

Gnetum gnemon L. var. *brunonianum*
(Griff.) Markgr.
Henderson
Gnetum sp.
Kiew RK 991

FLOWERING PLANTS

ACANTHACEAE

Peristrophe acuminata Nees var. *acuminata*
Henderson
Pseuderanthemum graciliflorum Ridl.
Henderson
^E*Pseuderanthemum selangorensis* (C.B. Clarke)
Ridl.
Henderson
Staurogyne kingiana C.B. Clarke
Henderson

ACHARIACEAE

^E*Hydnocarpus humei* Ridl.
Hume 7256
^E*Ryparosa fasciculata* King
Henderson

ANACARDIACEAE

Buchanania sessilifolia Blume
Henderson
Semecarpus velutina King
Mohd. Hashim FMS 102
Swintonia schwenckii Teijsm. & Binn. ex
Hook.f.
Henderson

ANISOPHYLLEACEAE

Anisophyllea corneri Ding Hou
Watson 538, Kiew RK 992

ANNONACEAE

Alphonsea elliptica Hook.f. & Thomson
Syahida FRI 55106
Mitrella kentii (Blume) Miq.
Symington KEP 39393
Trivalvaria pumila (King) J.Sinclair
Sinclair SFN 40143, Kiew RK 1170

APOCYNACEAE

Alstonia scholaris (L.) R.Br.
Henderson
Chilocarpus costatus Miq.
Henderson
Dischidia bengalensis Colebr.
Kiew RK 211
Epigynum ridleyi King & Gamble
Henderson
^E*Hoya campanulata* Blume
Strugnell FMS 13033
Hoya mappigera Rodda & Simonsson
Sinclair SFN 10730
Hoya revoluta Wight
Kiew RK 1155, Strugnell FMS 55109
Kibatalia maingayi (Hook.f.) Woodson
Watson 533
Pottsia laxiflora (Blume) Kuntze
Henderson
Willughbeia edulis Roxb.
Mohd. Hashim FMS 402, Kiew FRI
65534, Symington KEP 39395

AQUIFOLIACEAE

^{EE}*Ilex praetermissa* Kiew
Kiew RK 215, RK 1255, Strugnell FMS
33213, Symington KEP 39398

ARACEAE

Aglanema nebulosum N.E.Br.
Henderson
Amydrium medium (Zoll. & Moritizi)
Nicolson
Henderson
Anadendrum microstachyum (de Vriese &
Miq.) Backer & Alderw.

Kiew RK 1150

Homalomena humilis (Jack) Hook.f.

Hay AH 2023, Kiew RK 1175, Saw FRI

34265

Homalomena pendula (Blume) Bakh.f.

Hay AH 2024

Rhaphidophora montana (Blume) Schott

Henderson

Schismatoglottis scortechinii Hook.f.

Henderson

ARALIACEAE*Arthrophyllum diversifolium* Blume

Henderson

Schefflera oxyphylla (Miq.) R.Vig.

Henderson

ARISTOLOCHIACEAE*Thottea piperiformis* (Griff.) Mabb.

Kiew RK 1139, Stone 15648

BEGONIACEAE^E*Begonia holttumii* Irmsch.

Henderson 7291

Begonia wrayi Hemsl.

Ridley 13430

Begonia sinuata Wall. ex Meisn.

Kiew RK 1084, Sinclair SFN 40132, Saw

FRI 34264

CAMPANULACEAE*Lobelia zeylanica* L.

Henderson

CAPPARACEAE*Capparis versicolor* Griff.

Ridley s.n., Henderson

COMMELINACEAE*Amischotolype gracilis* (Ridl.) I.M.Turner

Ridley s.n. (1908), Kiew RK 1180

COMPOSITAE*Blumea balsamifera* (L.) DC.

Henderson

Vernonia arborea Buch.-Ham.

Henderson

CONNARACEAE^E*Rourea rugosa* Planch.

Henderson

CONVOLVULACEAE*Argyreia capitiformis* (Poir.) Ooststr.

Henderson

Neuropeltis maingayi Peter ex Ooststr. var.*maingayi*

Henderson

COSTACEAE*Cheilocostus speciosus* (J.Koenig)

C.D.Specht.

Henderson

CYPERACEAE*Cyperus compressus* L.

Henderson

Cyperus cyperoides (L.) Kuntze

Kiew RK 1142

Cyperus laxus Lam.

Kiew RK 1147A

Fimbristylis thouarsii (Kunth) Merr.

Symington KEP 33210, KEP 39410

Mapania palustris (Hassk. ex Steud.)

Fern-Vill.

Kiew RK 1144

DICHAPETALACEAE^E*Dichapetalum griffithii* (Hook.f.) Engl.

Henderson

DILLENACEAE*Tetracera asiatica* (Lour.) Hoogl.

Julius FRI 54873

DIOSCOREACEAE*Dioscorea pyrifolia* Kunth

Anthonysamy SA 195

DIPTEROCARPACEAE

Shorea bracteolata Dyer
Watson 741
Shorea parvifolia Dyer subsp. *parvifolia*
Watson 739

DRACAENACEAE

Dracaena elliptica Thunb.
Kiew RK 224
^{EE}*Dracaena maingayi* Hook.f.
Kiew RK 1124, RK 1140
Dracaena umbratica Ridl.
Kiew RK 1194

EBENACEAE

Diospyros sumatrana Miq.
Henderson

ELAEOCARPACEAE

Elaeocarpus mastersii King
Kiew RK 77, Symington 33207, Burkill
SFN 10028
Elaeocarpus nitidus Jack var. *nitidus*
Phoon 108, 110
Elaeocarpus stipularis Blume var. *stipularis*
Phoon 107

ERICACEAE

Rhododendron longiflorum Lindl.
Ridley s.n., Symington KEP 33215
Vaccinium bancanum Miq. var. *tenuinervium* J.J.Sm.
Symington KEP 33206, 39404

EUPHORBIACEAE

Croton oblongus Burm.f.
Henderson
Epiprinus malayanus Griff.
Henderson
Euphorbia ridlei Croizat.
Wong FRI 35270
Macaranga gigantea (Rchb.f. & Zoll.)
Müll.Arg.
Henderson

Macaranga bullettii King ex Hook.
Henderson
Macaranga hypoleuca (Rchb.f. & Zoll.)
Müll.Arg.
Henderson.
Mallotus macrostachyus (Miq.) Müll.Arg.
Henderson
Pimelodendron griffithianum (Müll.Arg.)
Benth.
Henderson

FAGACEAE

Castanopsis inermis (Lindl. ex Wall.) Benth.
& Hook.f.
Mohd Hashim FMS 305
Castanopsis megacarpa Gamble
Henderson
Lithocarpus ewyckkii (Korth.) Rehder
Henderson
Lithocarpus sundaicus (Blume) Rehder
Mohd Hashim FMS 29

GENTIANACEAE

Fagraea auriculata Jack
Henderson

GESNERIACEAE

Aeschynanthus pulcher (Blume) G.Don
Kiew RK 1081, Syahida FRI 55108
^{EE}*Codonoboea primulina* (Ridl.) Kiew
Ridley s.n., Kiew RK 1182, Soh FRI
471218, Syahida FRI 55105
Codonoboea quinquevulnera (Ridl.)
C.L.Lim
Kiew RK 1077, Symington KEP 39407,
Syahida FRI 55107

GRAMINEAE

Acroceras tonkinense (Balansa) C.E.Hubb.
Chew FRI 51872
Axonopus compressus (Sw.) P.Beauv.
Chew FRI 51866
Centotheca lappacea (L.) Desv.
Chew FRI 51873

Chrysopogon aciculatus (Retz.) Trin.

Chew FRI 51868

Cyrtococcum patens (L.) A. Camus

Chew FRI 51875

Digitaria fuscescens (J. Presl) Henrard

Chew FRI 51864

Eragrostis brownii (Kunth) Nees

Chew FRI 51863

Eriachne pallescens R. Br.

Chew FRI 51862, Kiew RK 1126, Symington KEP 47125

^{EE}*Eulalia milsumi* Ridl.

Symington KEP 39405, Chew FRI 51879

Lophatherum gracile Brongn.

Chew FRI 51871

Melinis repens (Willd.) Zizka

Chew FRI 51867

Ottochloa nodosa (Kunth) Dandy

Chew FRI 51874

Panicum brevifolium L.

Chew FRI 51876

Paspalum conjugatum P.J. Bergius

Chew FRI 51880

Pennisetum polystachion (L.) Schult.

Chew FRI 51865

GUTTIFERAE

^E*Calophyllum ferrugineum* Ridl. var. *oblongifolium* (T. Anderson) P.F. Stevens
Wyatt-Smith 66609

^E*Mesua elegans* (King) Kosterm.

Ridley 13527

^E*Mesua kunstleri* (King) Kosterm. var. *kunstleri*

Symington KEP 47132

HAMAMELIDACEAE

Rhodoleia championii Hook. f.

Foxworthy KEP 10031, Strugnell KEP 10991, Kiew RK 210

HUGONIACEAE

Indorouchera griffithiana Planch. Hallier f.
Henderson

ICACINACEAE

Gomphandra quadrifida (Blume) Sleumer
Henderson

IXONANTHACEAE

Ixonanthes icosandra Jack

Henderson

Ixonanthes reticulata Jack

Symington KEP 33220, 37450

LABIATAE

Callicarpa longifolia Lam.

Henderson

Callicarpa pentandra Roxb.

Henderson

Clerodendrum deflexum Wall.

Henderson

Rothea serrata (L.) Steane & Mabb.

Kiew RK 209, Anthonsamy SA 163

^E*Vitex longisepala* King & Gamble

Henderson

LAURACEAE

Alseodaphne nigrescens (Gamble) Kosterm.

Henderson

Litsea umbellata (Lour.) Merr.

Mohd Hashim FMS 198

Litsea costalis (Nees) Kosterm.

Mohd Hashim FMS 277

LECYTHIDACEAE

Barringtonia macrostachya (Jack) Kurz

Kiew RK 1107

Barringtonia scortechinii King

Kiew RK 1179

LEGUMINOSAE

Archidendron contortum (Mart.)

I.C. Nielsen

Henderson

Archidendron jiringa (Jack) I.C. Nielsen

Henderson

Derris elegans Grah. ex Benth.

Strugnell FMS13389

Bauhinia bidentata Jack
Mead FMS 30765
Flemingia strobilifera (L.) W.T.Aiton
Strugnell FMS 13387
^E*Fordia albiflora* (Prain) Dasuki & Schot
Henderson

LOGANIACEAE

Norrisia malaccensis Gardner
Symington KEP 37448

LORANTHACEAE

Macrosolen cochinchinensis (Lour.) Tiegh.
Symington KEP 37446, Stone 15641
Scurrula ferruginea (Jack) Danser
Kiew RK 1125

LOWIACEAE

^E*Orchidantha longiflora* (Scort.) Ridl.
Henderson

MALVACEAE

Durio griffithii (Mast.) Bakh.
Symington KEP 47126
Grewia laevigata Vahl
Henderson
Microcos tomentosa Sm.
Henderson
Pterospermum javanicum Jungh.
Watson 531

MARANTACEAE

Donax canniformis (G.Forst.) K.Schum.
Henderson

MELASTOMATACEAE

^E*Anerincleistus pauciflorus* Ridl.
Sinclair SFN 40137
Diplectria divaricata Kuntze
Henderson
Medinilla crassifolia (Reinw. ex Blume)
Blume
Poore 1086
Melastoma malabathricum L.

Omar FMS 9936
Oxyspora bullata (Griff.) J.F.Maxwell
Kiew RK 1178
Oxyspora exigua (Jack) J.F.Maxwell
Henderson
Pogonanthera pulverulenta (Jack) Blume
Kiew RK 993, Putz FRI 21901, Wyatt-
Smith KEP 66610
Pternandra echinata Jack
Henderson
Sonerila obliqua Korth.
Kiew RK 1086, Sinclair SFN 40133
^E*Sonerila prostrata* Ridl.
Ridley s.n., Foxworthy KEP 10039, Sym-
ington KEP 47134

MELIACEAE

Chisocheton pentandrus (Blanco) Merr.
subsp. *paucijugus* (Miq.) Mabb.
Henderson
Dysoxylum arborescens (Blume) Miq.
Mohd Hashim FMS 1310

MELIOSMACEAE

Meliosma sumatrana (Jack) Walp.
Henderson

MEMECYLACEAE

Memecylon dichotomum (C.B.Clarke) King
var. *dichotomum*
Henderson

MENISPERMACEAE

Pericampylus glaucus (Lam.) Merr.
Henderson

MORACEAE

Artocarpus gomezianus Wall. ex Trécul
Henderson
Ficus chartacea (Wall. ex Kurz) King
Henderson
Ficus deltoidea Jack var. *angustifolia* (Miq.)
Corner

Mohd Hashim FMS 1103, Kiew RK 214, *Knema malayana* Warb.
 Strugnell FMS 13029
Ficus deltoidea Jack var. *kunstleri* (King) ^E*Knema plumulosa* J.Sinclair
 Corner
 Kiew RK 93, Mead FMS 30761, Symington
 ton KEP 39390
Myristica cinnamomea King
 Kiew RK 222

Ficus fulva Reinw. ex Blume
 Henderson

Ficus hispida L.f.
 Anthonysamy SA 167

Ficus obscura Blume var. *borneensis* (Miq.)
 Corner
 Henderson

Ficus pellucidopunctata Griff.
 Henderson

Ficus punctata Thunb.
 Davies 2837

Ficus sagittata Vahl
 Henderson

Ficus sumatrana Miq.
 Symington KEP 39394

Ficus trichocarpa Blume
 Henderson

Ficus villosa Blume var. *villosa*
 Henderson

Hullettia dumosa King
 Kiew RK 1171

MYRISTICACEAE

Gymnacranthera forbesii (King) Warb.
 Henderson

Horsfieldia majuscula (King) Warb.
 Henderson

Horsfieldia polyspherula (Hook.f. ex King)
 J.Sinclair var. *sumatrana* (Miq.) W.J.de
 Wilde
 Watson FMS 537

Knema furfuracea (Hook.f. & Thomson)
 Warb.
 Henderson

Knema hookeriana (Wall. ex Hook.f. &
 Thomson) Warb.
 Henderson

MYRSINACEAE

^E*Antistrophe caudata* King & Gamble
 Kiew RK 1181, Sinclair SFN 40132

Ardisia colorata Roxb.
 Henderson

Ardisia lanceolata Roxb.
 Henderson

Ardisia villosa Roxb.
 Henderson

Grenacheria amentacea Mez
 Henderson

Grenacheria lampani Mez
 Henderson

Labisia pumila (Blume) Fern.-Vill.
 Kiew RK 1148

MYRTACEAE

Baeckea frutescens L.
 Symington KEP 37441

Syzygium attenuatum (Miq.) Merr. &
 L.M.Perry

Strugnell FMS 13036, Symington KEP
 33202

Syzygium chloranthum (Duthie) Merr. &
 L.M.Perry

Mead FMS 30764

Syzygium gratum (Wight) S.N.Mitra
 Kiew RK 850

Syzygium subdecussatum (Wall. ex Duthie)
 I.M.Turner var. *subdecussatum*

Kiew RK 213, Symington KEP 47123

OCHNACEAE

Campylospermum serratum (Gaertn.)
 Bittrich & M.C.E.Amaral
 Henderson

OLEACEAE

Jasminum elongatum (P.J.Bergius) Willd.
Kiew RK 1154

OPILIACEAE

Champereia manillana (Blume) Merr.
Henderson
Lepionurus sylvestris Blume
Henderson

ORCHIDACEAE

Renanthera sp. (Spider orchid)
Adam obs.
Dendrobium acerosum Lindl.
Strugnell FMS 13398

PALMAE

Calamus javensis Blume
Henderson
Eugeissona tristis Griff.
Adams obs, Kiew obs.
Licuala triphylla Griff.
Kiew RK 1079, RK 1172
Pinanga disticha (Roxb.) Blume ex
H.Wendl.
Kiew RK 1173

PANDACEAE

Galearia fulva (Tul.) Miq.
Hume 7146

PANDANACEAE

Benstonea ornata (Solms.) Callm. & Buerki
Kiew RK 1145, Rk 1810

PENTAPHRAGMATAACEAE

Pentaphragma horsfieldii (Miq.) Airy Shaw
Henderson

PENTAPHYLACACEAE

Eurya acuminata DC.
Henderson

PHRYMACEAE

Cyrtandromoea grandis Ridl.
Kiew RK 1146

PHYLLANTHACEAE

Antidesma salicinum Ridl.
Henderson
Aporosa benthamiana Hook.f.
Henderson
Baccaurea brevipes Hook.f.
Henderson
Breynia discigera Müll.Arg.
Henderson
Bridelia tomentosa Blume
Burkill SFN 10033, Julius FRI 54866
Glochidion superbum Baill.
Henderson
Phyllanthus pulcher Wall.
Henderson
Sauropus androgynus (L.) Merr.
Henderson

PICRODENDRACEAE

Austrobuxus nitidus Miq.
Kiew RK 848, Symington KEP 37444,
Wyatt-Smith KEP 6612

PIPERACEAE

²*Piper porphyrophyllum* N.E.Br.
Henderson
Piper stylosum Miq.
Kiew RK 1176

POLYGALACEAE

Salomonina cantoniensis Lour.
Kiew RK 208
Xanthophyllum griffithii Hook.f. ex
A.W.Benn.
Watson 529
Xanthophyllum wrayi King
Henderson

PRIMULACEAE

Maesa ramentacea (Roxb.) A.DC.
Henderson

PROTEACEAE

Helicia attenuata (Jack) Blume
Hume FMS 7251

RHIZOPHORACEAE

Carallia eugenoidea King
Ridley s.n. (1921), Strugnell FMS 33208,
Symington KEP 39396
Carallia suffruticosa Ridl.
Sinclair SFN 40136

ROSACEAE

Prunus grisea (Blume) Kalkman var.
tomentosa
Henderson

RUBIACEAE

^{EE}*Aleisanthia rupestris* (Ridl.) Ridl.
Ridley s.n., Symington KEP 33201, Kiew
RK 216
Argostemma pictum Wall.
Kiew RK 1185
Chassalia curviflora (Wall.) Thwaites
Henderson
Greenea corymbosa (Jack) K.Schum.
Kiew RK 1153
Hedyotis auricularia L.
Henderson
Hedyotis capitellata Wall. ex G.Don
Henderson
Hedyotis corymbosa (L.) Lam.
Henderson
Hedyotis dichotoma J.Koenig ex Roth
Kiew RK 207
Hedyotis vestita R.Br. ex G.Don
Henderson
Ixora concinna R.Br. ex Hook.f.
Kiew RK 1143
Ixora congesta Roxb.
Kiew RK 1152

Ixora javanica (Blume) DC. var. *javanica*
Henderson
Ixora lobbii Loudon
Henderson
Ixora pendula Jack var. *pendula*
Kiew RK 1151
Lasianthus densifolius Miq.
Henderson
Lasianthus maingayi Hook.f.
Henderson
^{EE}*Lasianthus oblongus* King & Gamble
Henderson
Mitragyna speciosa (Korth.) Havil.
Henderson
Mussaenda villosa Wall. ex G.Don
Henderson
Nauclea subdita (Korth.) Steud.
Henderson
Neonauclea pallida (Reinwa. ex Havil.)
Bakh.f.
Henderson
Ophiorrhiza communis Ridl.
Henderson
Ophiorrhiza discolor R.Br.
Henderson
Pavetta graciliflora Wall. ex Ridl.
Henderson
Porterandia anisophylla (Jack ex Roxb.)
Ridl.
Henderson
^{Ez}*Psychotria maingayi* Hook.f.
Henderson
Psydrax sp.
Kiew RK 213
Rothmannia macrophylla (R.Br.) Bremek.
Kiew RK 1149
^{EE}*Spermacoce pilulifera* (Ridl.) I.M.Turner
Henderson
Timonius wallichianus (Korth.) Valetton
Kiew RK 989
Uncaria lanosa Wall. var. *glabra* (Blume)
Ridsdale
Henderson
Urophyllum hirstum (Wight) Hook.f.

Henderson

RUTACEAE*Glycosmis chlorosperma* Spreng. var. *chlorosperma*

Henderson

SALICACEAE*Homalium caryophyllaceum* Benth.

Henderson

Osmelia maingayi King

Henderson

SAPINDACEAE*Guioa diplopetala* (Hassk.) Radlk.

Symington KEP 37447

Lepisanthes tetraphylla Radlk.

Kiew RK 1141, Symington Keo 37449

Pometia pinnata J.Forst. & G.Forst.

Henderson

SAPOTACEAE*Payena lucida* DC.

Henderson, Mohd Hashim FMS 37449

SIMAROUBACEAE*Eurycoma longifolia* Jack

Kiew RK 990, RK 1073

SMILACACEAE*Smilax myosotiflora* A.DC.

Kiew RK 1147B

STYRACACEAE*Styrax benzoin* Dryand.

Henderson

THYMELAEACEAE*Gonystylus maingayi* Hook.f.

Henderson

TORRICELLIACEAE*Aralidium pinnatifidum* (Jungh. & de Vre-ise) Miq.

Henderson

URTICACEAE*Nothocnide mollissima* (Blume) Chew

Henderson

Poikilospermum suaveolens (Blume) Merr.

Henderson

VIOLACEAE*Rinorea anguifera* (Lour.) Kuntze

Henderson

Rinorea horneri (Korth.) Kuntze

Henderson

VITACEAE*Ampelocissus cinnamomea* (Wall.) Planch.

Henderson

Cayratia mollissima (Wall.) Gagnep.

Henderson

Cayratia japonica (Thunb.) Gagnep.

Kiew RK 223

Cissus hastata Miq.

Henderson

Leea indica (Burm.f.) Merr.

Henderson

ZINGIBERACEAE*Camptandra parvula* (King ex Baker) Ridl.

Kiew RK 1177, Saw FRI 34267

Etilingera littoralis (J.Koenig) Giseke

Henderson

Globba patens Miq. var. *costulata* S.N.Lim

Kiew RK 1082

Globba pendula Roxb. var. *pendula*

Henderson

[†]*Globba variabilis* Ridl. var. *variabilis*

Henderson

Zingiber gracile Jack

Kiew RK 1174

Synotis panzhouensis (Asteraceae, Senecioneae), a distinct new species with red-purple pappus from southwestern Guizhou, China

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Abstract

A new species of Asteraceae, *Synotis panzhouensis*, is described and illustrated from Guizhou Province in China. Compared with other species of the genus, it is distinguishable by having red-purple pappus; additionally, it differs from its closest ally *S. nayongensis* by the larger involucre and phyllaries, and higher number of phyllaries and disk florets. In addition, detailed discussion of morphological differences, the provisional IUCN status and a distribution map are provided.

Keywords

Asteraceae, new species, Senecioneae, taxonomy, *Synotis nayongensis*

Introduction

Synotis (Clarke) C. Jeffrey & Y.L. Chen (Asteraceae, Senecioneae) includes 60 annual and sub-shrubby species predominantly distributed in northern India, Nepal, Bhutan, northern Myanmar, Thailand, Vietnam and southern China (Jeffrey and Chen 1984; Chen 1999; Chen et al. 2011; Tang 2014; Joshi et al. 2013). The genus was separated from *Senecio* L. mainly due to the anther bases having sterile tailed auricles

(vs. without sterile tailed auricles) (Jeffrey and Chen 1984). For China, many taxonomic and nomenclatural novelties within the genus have been reported in recent years (Tang et al. 2013a, b, c, 2014, 2017; Tong et al. 2017; Li et al. 2018), and at the present time, approximately 50 species are recorded in China, of which 24 are endemic (Tang 2014, Tang unpublished data).

During an expedition to Panzhou, Guizhou Province, China in 2020, we found an unusual population of *Synotis* at pre-anthesis. Initially, the plants seemed to be similar to *S. nayongensis* C. Jeffrey & Y.L. Chen, but further examination revealed several diagnostic differences between the Guizhou population and *S. nayongensis*; therefore, we describe the Guizhou plants as a new species to science here.

Material and methods

Herbarium studies were conducted in GZAC, IBSC, JXAU, KUN, and PE. Field observations were made in Panzhou, Guizhou, China in August and September 2020.

Results and discussion

Synotis panzhouensis M. Tang & H.L. Zheng, sp. nov.

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Figs 1, 2

Type. CHINA. Guizhou Province, Panzhou, Dazhai village, west of Luotuo valley, limestone mountains, 1803 m a.s.l., herbaceous tier in mixed forest, 26°04'37.59"N, 104°51'47.40"E, 1 September 2020, *Z. Li & M. Tang 2020-0901* (holotype JXAU! isotypes GZAC! JXAU!).

Diagnosis. *Synotis panzhouensis* is similar to *S. nayongensis* but differs from the latter species by its larger involucre bracts (7–8 × 3–4 mm vs. 5–6 × 2–2.5 mm) and phyllaries (7–8 × 2–3 mm vs. 5–6 × 1–1.5 mm), higher number of phyllaries ((7) 8 vs. 5) and disk florets (8–11 vs. 4–5), different colour of phyllaries (green vs. white with green apex) and pappus (red-purple vs. white).

Description. Perennial herbs, erect, rhizomatous. Rhizome thick, horizontal. Vegetative stem solitary, erect, 20–35 cm, densely white or ferruginous setulose. Flowering stem solitary, erect, scapiform, 30–60 cm tall, shortly branching, fulvous tomentose. Leaves rosulate at the base of fertile shoot; petioles 1–1.5 cm long, not winged, slightly expanded at base; blades oblanceolate or obovate, 10–18 × 2.5–5 cm, papyraceous, abaxially sparsely arachnoid, glabrescent or subglabrous, adaxially scattered setulose, pinnately veined, lateral veins 12–16, arcuate-ascending, base cuneate, margin shallowly sinuate-apiculate or repand-apiculate, apex subacute-acuminate. Stem leaves on reproductive shoots few, narrowly lanceolate, remote, much smaller. Capitula discoid, numerous, arranged in an attenuate narrowly paniculoid thyrse; pedicels 3–5 mm, fulvous tomentose, 1- or 2- bracteate; bracts below capitula linear, 5–10 mm long.



Figure 1. Holotype of *Synotis panzhouensis* (Panzhou, Guizhou, China, Z. Li & M. Tang 2020-0901 (JXAU)).

Involucres narrowly campanulate, 7–8 × 3–4 mm, calyculate; bracts of calyculus 3–5, ovate-oblong or lanceolate, 1/4–1/3 as long as phyllaries; phyllaries (7) 8, narrowly oblong, 2–3 mm wide, herbaceous, green, margin narrowly scarios, glabrous, not

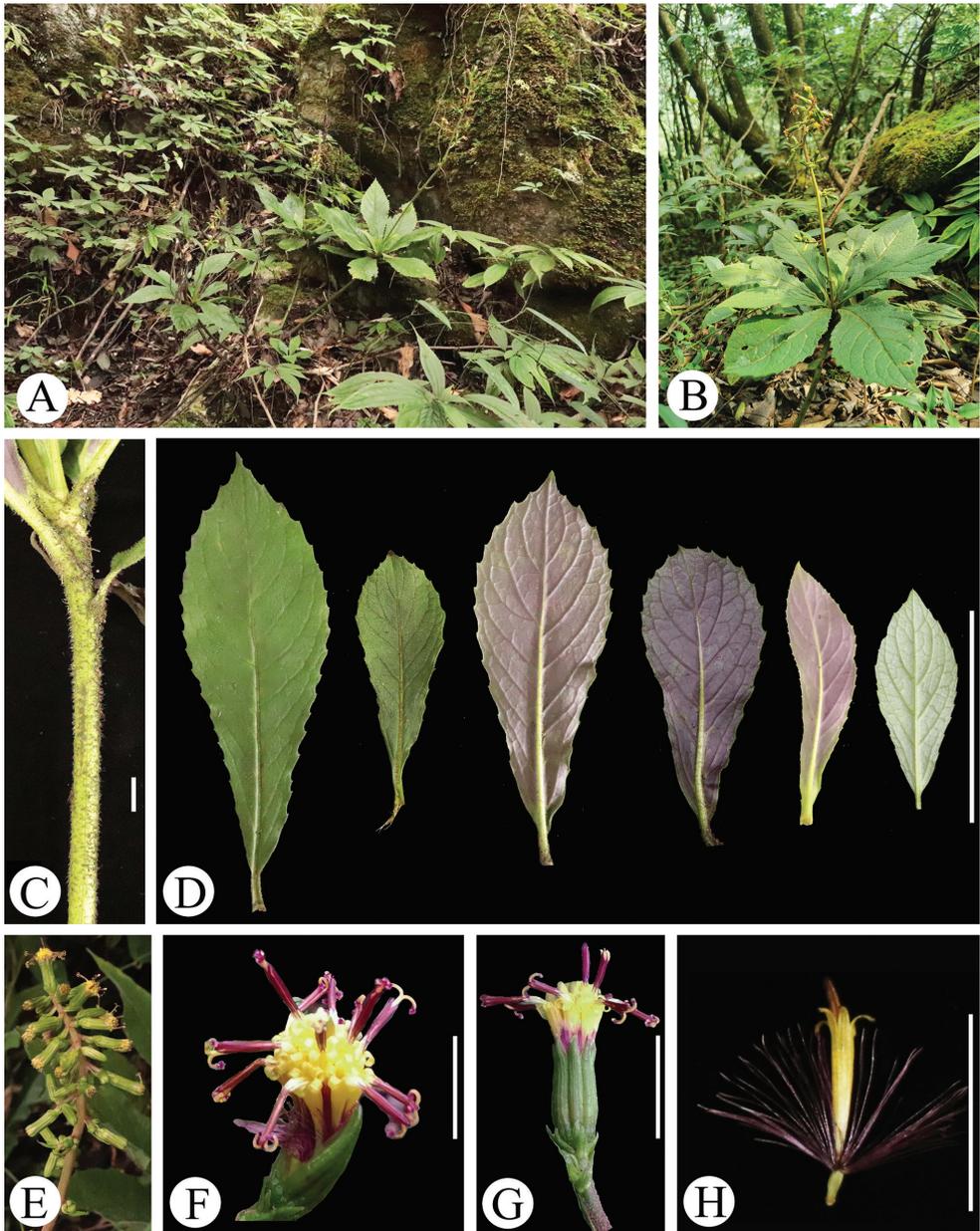


Figure 2. *Synotis panzhouensis* in the wild (Dazhai village, Panzhou, Guizhou, China). **A** habitat **B** general habit **C** portion of vegetative stem **D** leaf blades (left two: adaxial surface; right four: abaxial surface) **E** synflorescence **F** capitulum (top view) **G** capitulum (side view) **H** a disk floret with red-purple pappus. Scale bars: 5 mm (**C**); 10 cm (**D**); 4 mm (**F**); 1 cm (**G, H**).

veined, apically triangular, obtuse. Ray florets absent. Disk florets 8–11; corolla yellow, 8–10 mm, with tube 7–8 mm long, limb narrowly funnellform, somewhat exerted from involucre; lobes oblong-lanceolate, 1–2 mm long, apically acute. Anthers 3.5–4 mm long, anther tails equaling anther-collars; appendages lanceolate; anther-

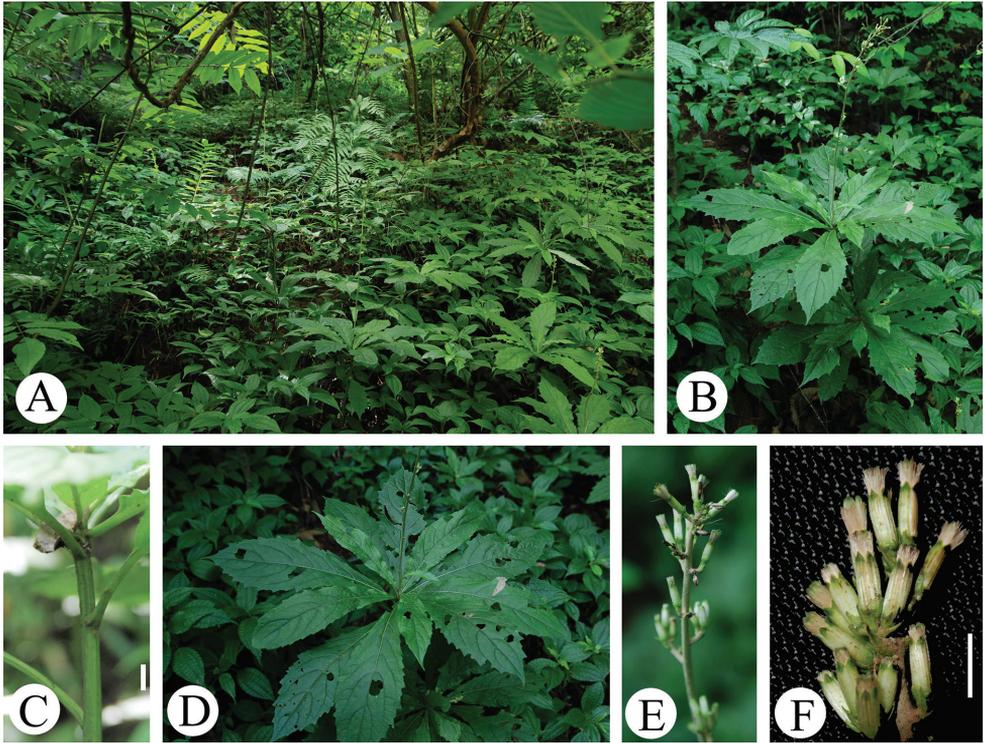


Figure 3. *Synotis nayongensis* in the wild (Luzui village, Nayong, Guizhou, China). **A** habitat **B** habit **C** portion of vegetative stem **D** leaf blades from the adaxial view **E** synflorescence **F** portion of synflorescence (side view, note the white phyllaries with green apex, and also note the white pappus). Scale bars: 5 mm (**C**); 6 mm (**F**).

collars balusterform, basally dilated. Style branches 1.8–2 mm long, covered with long marginal papillae and often with a central tuft not conspicuously longer. Achenes ca. 2 mm, glabrous. Pappus 8–10 mm long, red-purple.

Distribution. *Synotis panzhouensis* is endemic to southwestern Guizhou, China (Fig. 4); to date, only known from the type population.

Habitat. Growing in mixed forest with other herbs in limestone mountains at an elevation of ~1800 m.

Phenology. Flowering from late August to September; fruiting October.

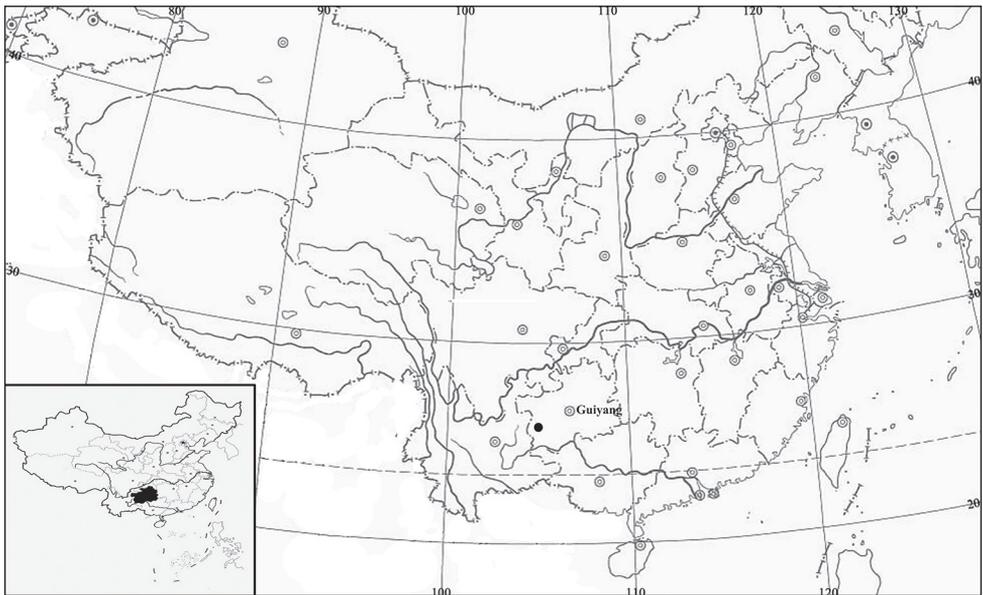
Etymology. The specific epithet is derived from Panzhou, the type locality of the species. The Chinese name is ‘盘州合耳菊 (Pan zhou he er ju)’.

Discussion. As shown in Figs 1–3, *Synotis panzhouensis* is similar to *S. nayongensis* in the oblanceolate or obovate rosulate leaves at the base of synflorescence, the narrow paniculoid thyrse and absence of ray florets. However, we detected significant differences between the two species as listed in Table 1.

Synotis panzhouensis is only distributed in Panzhou, southwestern Guizhou, China, while *S. nayongensis* is mainly distributed around northwestern Guizhou (Ruan et al. 2020), with its type locality in Nayong, a county located 200 km NE from Panzhou.

Table 1. Comparison of *Synotis panzhouensis* and *S. nayongensis*.

Characters	<i>Synotis panzhouensis</i>	<i>S. nayongensis</i>
Indumentum of vegetative stem	densely white to ferruginous setulose	sparsely pubescent, glabrescent to glabrous
Petioles	1–1.5 cm	petiole 1–2.5 cm
Leaf blades	adaxially green or purple	adaxially green
Flowering stem	fulvous tomentose, not glabrescent	thinly tomentose, glabrescent
Involucres	7–8 × 3–4 mm	5–6 × 2–2.5 mm
Phyllaries	(7) 8, 7–8 × 2–3 mm, green, not veined	5, 5–6 × 1–1.5 mm, white, apex green, conspicuously 3–5-veined
Disk florets	8–11, deep yellow, lamina yellow	4–5, yellowish, lamina yellow-whitish, apex green when young
Anthers	red-purple	yellow-whitish
Achens	ca. 2 mm long	ca. 4 mm long
Pappus	red-purple	white

**Figure 4.** Record of *Synotis panzhouensis*.

From all other species of *Synotis*, *S. panzhouensis* is very distinct in the red-purple pappus. According to our observation of the plants *in vivo*, as well as a critical examination of taxa throughout the genus, most species (~50 spp.) have white pappus. Five species in sect. *S. ser. Fulvipapposae* C.Jeffrey & Y.L.Chen often have white or stramineous pappus, which is consistent with the descriptions reported by Jeffrey and Chen (1984), Chen (1999) and Chen et al. (2011). The pappus colour of *S. vaniotii* (Lévl.) C.Jeffrey & Y.L.Chen and *S. palmatisecta* Y.L.Chen & D.J.Liu were described as rubescent, but this might be the result of inattentive observation, for both of the species were found with white, or rarely pale brown pappus during our field and herbarium observations. It is noteworthy to mention that *S. chenopodiifolia* (DC.) M.Tang, C.Ren & Q.E.Yang, a species always reported with brown or yellow pappus, has been reported with a dark purple pappus in a population in Gyirong County (Tang et al.

2014), but such variation is rather atypical in the species. *Synotis chenopodiifolia* is a plant to 80–180 cm with triangular-ovate or triangular-hastate leaves and a capitulum with 5 phyllaries, 2 or 3(–4) disk florets, and it obviously differs from the leaf characters and capitulum characters as seen in *S. panzhouensis*.

Morphologically, following the characters and delimitation of Jeffrey and Chen (1984) and Tang (2014), *S. panzhouensis* is best referred to *Synotis* sect. *Synotis* ser. *Synotis* due to the leaves gathered at the apex of the vegetative stem and its terminal inflorescence.

IUCN Red List Category. *Synotis panzhouensis* was found in a single location with an extremely small population in Panzhou, southwestern Guizhou, China. Due to the remote distance and difficult and dangerous accessibility to the type locality, the population was not disturbed by human activity and currently appears to be growing very well. However, according to our observation, the population comprises no more than 100 plants, and with a small geographical range of no more than 1000 m², we recommend that *S. panzhouensis* be categorized as Critically Endangered (CR) using criteria B and C following the IUCN Red List categories (IUCN 2019).

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Helicteres binhthuanensis V.S.Dang (Malvaceae, Helicteroideae), a new species from southern Vietnam

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Abstract

Helicteres binhthuanensis V.S.Dang, **sp. nov.** from Ham Thuan Bac District, Binh Thuan Province, Vietnam is described and illustrated. It is morphologically similar to *H. angustifolia*, which is a common species in mainland southeast Asia, and *H. sphaerotherca*, which is endemic to the Northern Territory, Australia, but differs from both by several salient characters such as leaf and calyx size, androgynophore length, petal color, and fruit shape. Photographs, a vernacular name, a preliminary conservation assessment, and a table of morphological characters comparing this new species to two closely related species also are provided.

Keywords

Helicteres, Helicteroideae, Malvaceae, Vietnam

Introduction

Helicteres L. comprises about 60 species in the tropics of Asia and America (Cowie 2011). The genus was included in a broadly-defined Sterculiaceae by Cronquist (1981), but more recently is included in Malvaceae *sensu lato* based on morphological and molecular evidence (Mabberley 2008; APG IV 2016). The genus is characterized by the sta-

mens and pistil forming an androgynophore, sepals united, petals unguiculate, capsules cylindrical, fusiform or ovoid, spiral or rarely straight, pubescent, and seeds wingless due to parenchymal expansion (Cristóbal 2001; Chantaranothai and Poompo 2019). Currently, nine species and one variety of the genus have been recorded in Vietnam: *H. angustifolia* L., *H. angustifolia* var. *glaucoides* Pierre, *H. daknongensis* V.S.Dang & D.T.Bui, *H. elongata* Wall. ex Mast., *H. hirsuta* Lour., *H. isora* L., *H. lanata* (Teijsm. & Binn.) Kurz, *H. lanceolata* DC., *H. poilanei* Tardieu, and *H. viscida* Blume (Hoang et al. 2020).

During fieldwork in July 2019, we collected several specimens of *Helicteres* in Ham Thuan Bac District, Binh Thuan Province, southern Vietnam (Figure 1). After morphological study and reviewing the relevant literature from Vietnam and neighboring countries (Tardieu-Blot 1945; Pham 1999; Cristóbal 2001; Phengkhai 2001; Nguyen 2003; Tang et al. 2007; Cowie 2011), as well as comparing our material with specimens in several Vietnamese herbaria (HN, VNM, and VNMN) and images available via JSTOR Global Plants, K, and P (all acronyms follow Thiers 2020, continuously updated), we confirm that this material is distinct from previously known taxa. Here, we describe it as a new species, *H. binhthuanensis* V.S.Dang.

Materials and methods

Our description of the new species is based on observations from living and dried specimens; measurements were made using a ruler accurate to 0.5 mm. Voucher specimens were deposited in HN, VNM, and VNMN. The photographs were taken with a Canon 1000D camera fitted with an EF 100 mm *f*/2.8 Macro USM lens. The conservation status of the new species was assessed according to the International Union for Conservation of Nature (IUCN 2019).

Taxonomic treatment

Helicteres binhthuanensis V.S.Dang, sp. nov.

urn:lsid:ipni.org:names:77212606-1

Figures 2, 3

Diagnosis. Similar to *Helicteres angustifolia* L. (Figure 4) in its shrubby habit (to 2 m tall) and axillary inflorescences but distinguished by the size of its leaf blades (10–13 × 0.8–1.2 cm vs. 3–15 × 1–4 cm), larger petals (12–16 mm long vs. 5–10 mm long), longer androgynophores (10–15 mm long vs. 3–7.5 mm long), and stamen number (10 vs. 15). Also similar to *H. sphaerotherca* Cowie, but differs from the latter by having larger leaf blades (10–13 × 0.8–1.2 cm vs. 1.5–3.5 × 0.2–0.7 cm), longer stipules (3–4 mm long vs. 1–2 mm long) and bracts (1–2 mm long vs. 1 mm long), larger calyx (tube 6–8 mm long, lobes 4–5 mm long vs. tube 3.5–4.5 mm long, lobes ca. 0.5



Figure 1. Type locality of *Helicteres binhthuanensis*.



Figure 2. Habitat and habit of *Helicteres binhthuanensis* **A** habitat **B** habit. Photos by Van-Son Dang.

mm long) and petals (12–16 mm long vs. 7–9.5 mm long), and fruit shape (ovoid to ellipsoid vs. globular).

Type. VIETNAM. Binh Thuan Province, Ham Thuan Bac District, 40 km north of Phan Thiet City, in secondary forests, 11°07'02.30"N, 108°14'92.07"E, 80 m alt., 20 July 2019, *Van-Son Dang & Nghia-Son Hoang, Dang 386* (holotype: VNM; isotypes: HN, VNM, VNMMN).

Description. Shrubs, 1–2 m tall; branches slender, 2–3 mm in diam., densely yellow-brown stellate puberulent. Leaves alternate, blades narrowly lanceolate to narrowly oblanceolate, 10–13 × 0.8–1.2 cm, coriaceous, yellowish brown when dry, adaxially sparsely puberulent, abaxially densely yellow-brown puberulent, apex acute or acuminate, base rounded, symmetric, margin entire; midrib flat or slightly depressed adaxially, distinct and prominent abaxially; secondary veins 3–7 pairs, obscure adaxially, prominent abaxially; petioles 5–8 mm long, densely yellow-brown puberulent. Stipules persistent, 3–4 mm long, filiform or linear, densely pubescent. Inflorescences axillary or terminal, cymose, 8–14 mm long, 2–5-flowered; bracts 1–2 mm long; pedicels 1–5 mm long. Flowers with short pedicel; calyx tubular to campanulate, 10–13 mm long, whitish green, densely villous to hirsute, calyx tube 6–8 mm long, calyx lobes 5, unequal, lanceolate to triangular, 4–5 mm long, tips acute; petals 5, unequal in length, 12–16 mm long, whitish pink or purplish, darker at base of limb, reflexed at anthesis, limb cuneate, densely hirsute, callused near base, apex truncate, lower 3 petals slightly longer than upper pair, claw with 2 or 1 auriculate appendices, upper pair with 2 prominent appendages on the claw; androgynophore 10–15 mm long, straight, villous at base; stamens 10, shortly connate at base; staminodes 5, broadly lanceolate; filaments coalescent, surrounding ovary; anthers transverse, oblong; ovary ovoid or globose, 5-locular, densely villous; style 1.3–1.5 mm long; stigma 5-toothed, terete. Fruit a capsule, ovoid to ellipsoid, 1.5–2 × 0.8–1 cm, with 5 longitudinal lobes, densely villous, apex short-beaked, black when mature; seeds many, small, 2.5–4 × 1.5–2 mm, irregularly rugose, dark brown, angled when dry.

Other specimen examined. VIETNAM. Binh Thuan Province, Ham Thuan Bac District, 40 km north of Phan Thiet City, in secondary forests, 11°07'02.33"N, 108°14'92.27"E, 86 m elevation, 21 July 2019, *Van-Son Dang & Nghia-Son Hoang, Dang 383* (VNM).

Phenology. Flowering and fruiting specimens were collected in July.

Distribution and habitat. *Helicteres binhthuanensis* is known only from Ham Thuan Bac District, Binh Thuan Province, southern Vietnam. It grows along roadsides and edges of secondary forests at ca. 80–95 m elevation.

Etymology. The species epithet is derived from the name of the province (Binh Thuan) where the species was discovered.

Vernacular names. Tở kén bình thuận, An xoa bình thuận.

Preliminary conservation assessment. *Helicteres binhthuanensis* was collected from a small population in a habitat that was logged and disturbed. Therefore, we suggest its placement in the Data Deficient (DD) category based on the IUCN Red List Categories (IUCN 2019).

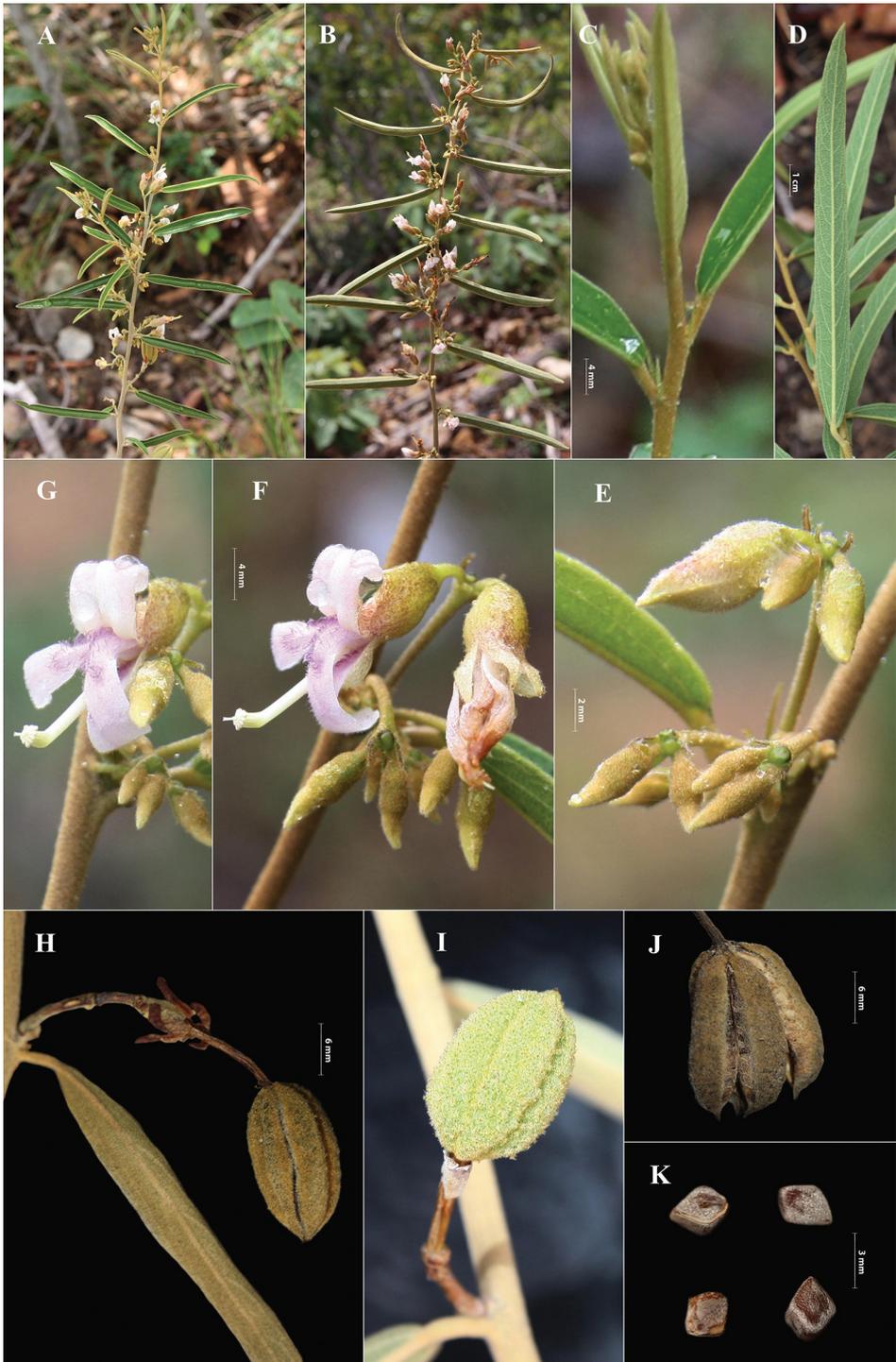


Figure 3. *Helicteres binhthuanensis* **A, B** flowering and fruiting branches **C** close-up of young leaves and stipules **D** abaxial leaf surface **E–G** close-up of axillary inflorescence and flowers **H–J** close-up of fruits **K** Seeds. Photos by Van-Son Dang.



Figure 4. *Helicteres angustifolia* **A** flowering branches **B** abaxial leaf surfaces **C** close-up of axillary inflorescence and flowers **D, E** close-up of fruits. Photos by Van-Son Dang.

Table 1. Comparison of *Helicteres binhthuanensis* with its morphologically closest allies (modified from Pham 1999; Phengkklai 2001; Tang et al. 2007; Cowie 2011).

Character	<i>H. binhthuanensis</i>	<i>H. angustifolia</i>	<i>H. sphaerotheca</i>
Branch indumentum	densely yellow-brown stellate puberulent	gray greenish puberulent	sparsely stellate hairy, hairs sessile
Petiole length	5–8 mm long	3–15 mm long	0.5–1 mm long
Leaf blade size	10–13 × 0.8–1.2 cm	3–15 × 1–4 cm	1.5–3.5 × 0.2–0.7 cm
Stipule length	3–4 mm long	3.5–6 mm long	1–2 mm long
Bract length	1–2 mm long	1.5–2 mm long	ca. 1 mm long
Calyx tube length	6–8 mm long	ca. 6 mm long	3.5–4.5 mm long
Calyx lobe length	4–5 mm long	3–4 mm long	ca. 0.5 mm long
Petal color at anthesis	whitish pink or purplish	bluish or pink	mauve-pink
Petal length	12–16 mm long	5–10 mm long	7–9.5 mm long
Androgynophore length	10–15 mm long	3–7.5 mm long	4.5–5 mm long
Number of stamens	10	15	10
Number of staminodes	5	0	5
Fruit shape	ovoid to ellipsoid	ovate to oblong	globular
Seed length	2.5–4 mm long	2–3.5 mm long	ca. 2.5 mm long

Notes. Morphologically, *Helicteres binhthuanensis* is most similar to *H. angustifolia*, which is a common species in mainland southeast Asia, and *H. sphaerotheca*, which is endemic to the Northern Territory of Australia, between the Mary River and the South Alligator River. It differs from those species in several characters that are summarised in Table 1.

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Pternopetalum paucifoliolatum (Apiaceae), a new Critically Endangered species from Sichuan, China

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Abstract

Pternopetalum paucifoliolatum, a new species from Sixigou Scenic Area, Emeishan City, Sichuan Province, is proposed and described. Diagnostic morphological characters, full description, detailed illustrations, and a distribution map are provided. The new species is similar to *P. porphyronotum* in possessing the 1-pinnate leaves and the abaxially purple-red leaflets, but differs from the latter by shorter stature, fewer leaflets ((1–) 3–7) and rays (5–8), the leaflet margin white-ciliate. The new species, which is assessed as Critically Endangered (CR), was only found on limestone cliffs. We also provide a new key to the species of *Pternopetalum*.

Keywords

Conservation, limestone, rare species, Umbelliferae

Introduction

Pternopetalum Franch. (Apiaceae), including ca. 20 species, is endemic to east Asia and one of the largest genera of Apiaceae in Asia (Pimenov et al. 2004; Wang 2012). It is distributed in South Korea, Japan, China, and the adjacent eastern Himalayan regions (Pu 1985; Pimenov and Leonov 1993; Pu and Phillippe 2005), with a diversity center

* Contributed equally as the first author.

in the East Himalaya-Hengduan Mountains region (Su and Sheh 2001). This genus is characterized by petals saccate at base, umbellules with only 2–4 (–5) flowers, and styles and rays reflexed in fructescence (Pu 1985; Pu and Phillippe 2005; Wang 2012). After Wang’s (2012) revision of *Pternopetalum*, four new species of this genus were described (Bhaumik and Satyanarayana 2014; Tan et al. 2014, 2015; Zhong et al. 2018).

During a field investigation in Sixigou Scenic Area, Emeishan City, Sichuan Province, China, in March 2019, we found an unusual *Pternopetalum* population with flowers. We noticed that they not only have dwarf plants, lobe margin white-ciliate, but also have 1-pinnate leaves with few leaflets, differing from all other known species of the genus. We revisited the same locality and collected several specimens with fruit in May 2020. Thus, this dwarf species with (1–) 3–7 leaflets is described here as new to science.

Key to the species of *Pternopetalum*

- 1 Stout perennial, usually more than 30 cm high; stylopodium conic; styles erect, twice as long as the stylopodium; calyx evident, triangular or subulate..... 2
- Slim perennial or annual, usually not more than 30 cm high; stylopodium lower conic; styles reflexed at upper part, shorter or equal than stylopodium at length; calyx minute or obsolete..... **10**
- 2 Stem well developed; umbels terminal and lateral **1. *P. delavayi***
- Stem dwarf; umbels terminal, occasionally with one or two lateral umbels **3**
- 3 Leaves only basal **4**
- Leaves basal and cauline, occasionally cauline leaves absent **6**
- 4 Leaves ternate; leaflets 3, ovate, margins crenate **2. *P. nudicaule***
- Leaves ternate, 2–4-pinnate or finely dissected **5**
- 5 Leaves finely dissected; ultimate segments linear **3. *P. trichomanifolium***
- Leaves bipinnate; ultimate segments ovate **4. *P. bipinnatum***
- 6 Leaves 2-ternate or ternate-2-pinnate; ultimate segments acute at apex **7**
- Leaves 2-ternate or ternate-1-pinnate; ultimate segments caudate at apex..... **5. *P. rosthornii***
- 7 Leaves ternate; leaflets 3, ultimate leaflets usually 2–3(–5)-lobed **6. *P. vulgare***
- Leaves 2-ternate or ternate-2-pinnate; ultimate segments margins incised-serrate or without lobed **8**
- 8 Leaves ternate-2-pinnate; ultimate segments margins incised-serrate **7. *P. latipinnulatum***
- Leaves 2-ternate; ultimate segments without lobed..... **9**
- 9 Leaf blades subleathery; ultimate segments broad-ovate, 2–3 × 1–3 cm; margins cartilaginous, veins sparsely setose **8. *P. cuneifolium***
- Leaf blades papery; ultimate segments ovate or rhomboidal, 2–7 × 1–3.5 cm; strigose on the veins **9. *P. davidii***
- 10 Plant has white lactate..... **10. *P. leptophyllum***
- Plant without white lactate..... **11**

- 11 Stem dwarf; leaves mainly basal, occasionally with 1–2 (–3) heteromorphic cauline leaves; umbels terminal..... **12**
 – Stem well developed; leaves basal and cauline, occasionally basal leaves absent; umbels terminal and lateral, occasionally terminal **17**
- 12 Leaves heteromorphic; basal ultimate segments flabelliform or lanceolate, cauline ultimate segments lanceolate or elongate-linear..... **11. *P. tanakae***
 – Leaves homogeneous, ultimate segments ovate-triangular or linear..... **13**
- 13 Leaves pinnate; ultimate segments ovate-triangular **14**
 – Leaves ternate 2–4-pinnate or ternate 3–4-pinnate; ultimate segments linear or linear-oblong..... **15**
- 14 Leaves ternate-pinnate; cauline leaf usually absent..... **12. *P. subalpinum***
 – Leaves 1-pinnate; cauline leaf 1 or occasionally absent **16**
- 15 Leaves ternate 2–4-pinnate; ultimate segments linear **13. *P. gracillimum***
 – Leaves ternate 3–4-pinnate; ultimate segments linear or linear-oblong, finely dissected..... **14. *P. arunachalense***
- 16 Leaflets (1–) 3–7; umbels 5–8 **15. *P. paucifoliolatum***
 – Leaflets 5–17; umbels 8–20..... **16. *P. porphyronotum***
- 17 Leaves cauline **17. *P. monophyllum***
 – Leaves basal and cauline **18**
- 18 Root tuberous, fusiform **18. *P. molle***
 – Rhizome distinct..... **19**
- 19 Ultimate leaf segments long-linear, margins entire **19. *P. caespitosum***
 – Ultimate leaf segments ovate or rhomboidal, margins serrate **20. *P. botrychioides***

Taxonomic treatment

Pternopetalum paucifoliolatum J.F. Ye, X.Jie Li & Ce H.Li, sp. nov.

urn:lsid:ipni.org:names:77212875-1

Figs 1–3

Type. CHINA. Sichuan, Emeishan County, Sixigou Scenic Area (29.40°N, 103.38°E), on moist limestone cliff, at an altitude of ca 850 m a.s.l., 02 May 2020, in fruit, X. J. Li CPG41074 (holotype: PE!).

Etymology. The specific epithet refers to the 3–7 (rare simple) leaflets of this species which differentiate it from all other species of *Pternopetalum*.

Diagnosis. *Pternopetalum paucifoliolatum* differs from *P. porphyronotum* J.B. Tan (2018: e01549) by shorter plants (5–7 cm), 3–7 leaflets (vs. 5–17), leaflet margin white-ciliate, rays 5–8 (Table 1).

Plants 5–7 cm tall. Taproot slender, ca. 3 cm long. Stem 1, unbranched, glabrous. Basal leaves petiolate; petioles 0.7–4 cm; ultimate segments ovate-triangular, 1.5–6 × 0.6–1.4 cm, 1-pinnate, occasionally simple; pinnae 1–3 pairs, broadly ovate, 3–6 ×

Table 1. Comparison of *Pternopetalum paucifoliolatum* sp. nov. and morphologically similar species. Morphological characters obtained from Zhong et al. (2018) and our field observations.

Character	<i>P. paucifoliolatum</i>	<i>P. porphyronotum</i>
Plant height (cm)	5–7	8–15
Stem	1	1, occasionally 2
Basal leaves	1–7, 1-pinnate or simple	5–12, 1-pinnate
Pinnae	ovate-triangular, margin white-ciliate, lobed	ovate-triangular, margins serrate, lacerate-incised or pinnatifid
Adaxial surface	Glabrous	Pubescent
Abaxial surface	purple-red	purple-red (paler on the edge)
Cauline leaf	1, occasionally 0	1, occasionally 0 or 2
Rays	5–8	8–20
Style	about two to three times as long as the stylopodium	approximately twice the length of the stylopodium
Altitude (m)	800–900	1200–1500

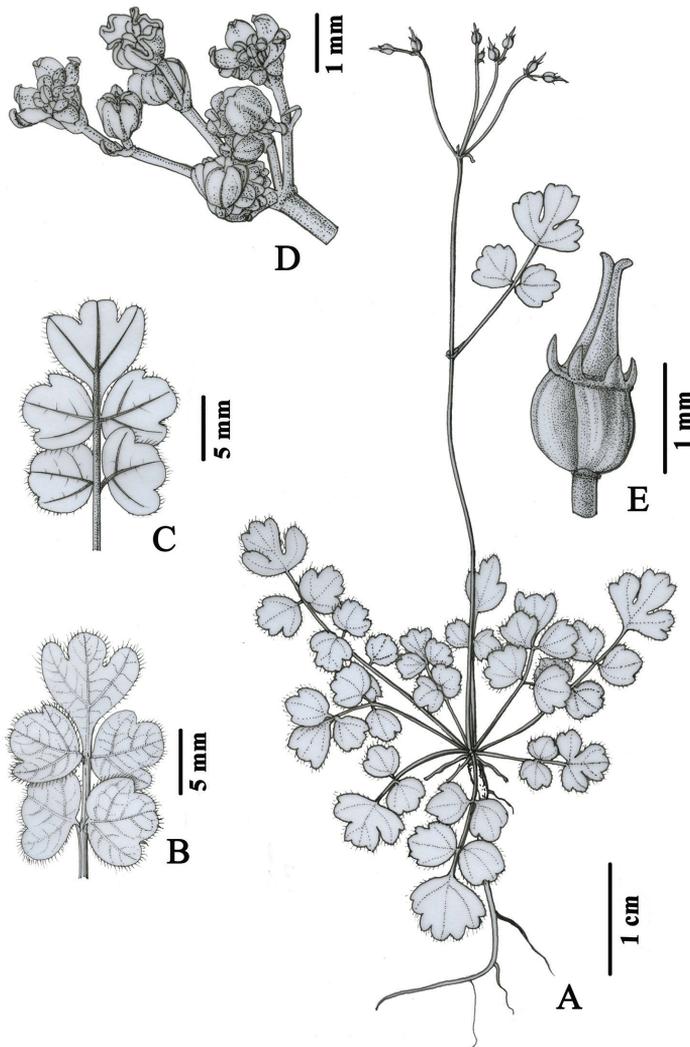


Figure 1. *Pternopetalum paucifoliolatum* J.F. Ye, Xiao-Jie Li & Ce-Hong Li **A** habit **B** adaxial surface of basal leaf **C** abaxial surface of basal leaf **D** umbel **E** mericarp. (Drawn by Y. B. Sun).

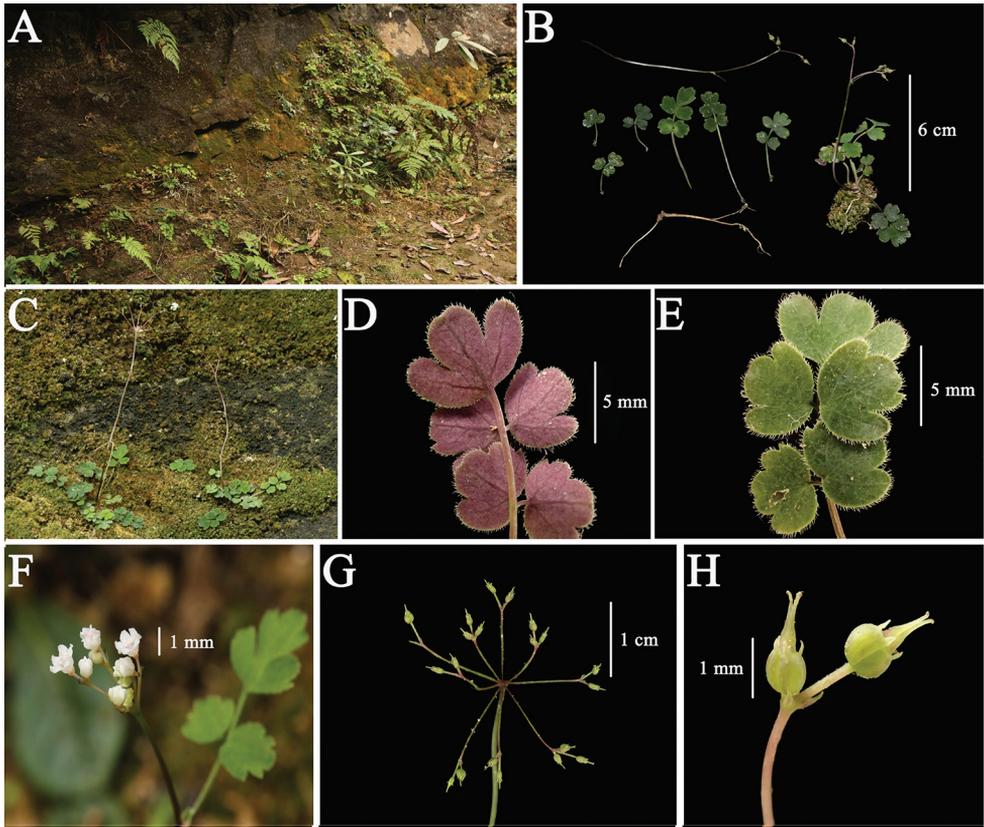


Figure 2. *Pternopetalum paucifoliolatum* J.F. Ye, Xiao-Jie Li & Ce-Hong Li **A** microhabitat **B, C** habit **D** basal leaf blade abaxially **E** basal leaf blade adaxially **F** umbel **G** infructescence **H** umbellule and fruits.

3–5 mm, lobed, margin white-ciliate, both surfaces glabrous, adaxially green, abaxially purple-red. Cauline leaves 1 or occasionally absent, similar to basal, occasionally linear-lanceolate, 8–12 × 5–6 mm. Umbels terminal, bracts absent, rays 5–8, 10–12 mm, subequal; bracteole 1, linear-lanceolate, 0.5–1 mm; umbellules 2(–3)-flowered; pedicels 0.2–2 mm. Calyx teeth distinct, triangular, ca. 0.3 mm. Petals white, oblong-obovate. Stylopodium conic; style ca. 1 mm, reflexed in the top half, about two to three times as long as the stylopodium. Fruit ovoid, 0.7–1.2 × 0.8–1 mm.

Phenology. *Pternopetalum paucifoliolatum* is flowering from March to April, and fruiting from May to June.

Distribution and habitat. *Pternopetalum paucifoliolatum* is only known from its type locality, Sixigou Scenic Area, Emeishan City, Sichuan Province, China. It grows together with grass or mosses on a moist limestone cliff, at 850 m a.s.l. Associated species include *Adiantum* sp., *Begonia wilsonii* Gagnep., *Dryopteris* sp., *Mitreola pedicellata* Benth., *Pteris gallinopes* Ching ex Ching & S. H. Wu., *Pteris* sp., *Selaginella* sp., *Cleistoblechnum eburneum* (Christ) Gasper & Salino, *Viola davidii* Franch.

Vernacular name. 少羽囊瓣芹 [shǎo yǔ náng bàn qín].

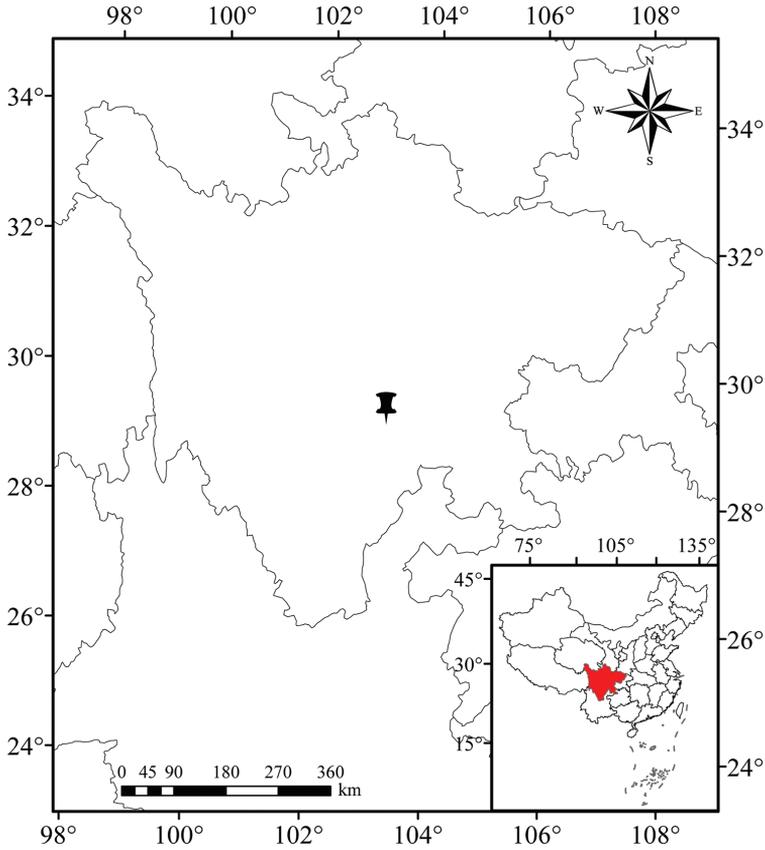


Figure 3. Distribution of *Pternopetalum paucifoliolatum* J.F. Ye, Xiao-Jie Li & Ce-Hong Li in Sichuan Province, China.

Conservation status. *Pternopetalum paucifoliolatum* is only distributed in Sixigou Scenic Area. We have gone all out to estimate the population size in this area, but found it only growing on one limestone cliff ca 850 m a.s.l., with no more than 200 individuals totally. Sadly, a new built highway will pass by the locality and serves as an entrance to the highway, which will destroy the habitat. Based on this current information and according to IUCN red list criteria (IUCN 2017), *P. paucifoliolatum* should be ranked as ‘Critically Endangered’ (CR C2a (ii)).

Discussion. *Pternopetalum paucifoliolatum* differs markedly from the other known species of this genus by the following characters: basal leaves 1-pinnate, occasionally simple; pinnae 1–3 pairs. It is somewhat similar to *P. porphyronotum* J.B. Tan by 1-pinnate leaves and the abaxially purple-red leaflets, solitary stem and terminal umbel, but differs from it by being 5–7 cm tall (vs. 8–15 cm), stem 1 (vs. 1, occasionally 2), abaxial surface of basal leaves purple-red (vs. purple-red, paler along the edge), rays 5–8, subequal (vs. 8–20, unequal) (Table 1).

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Leptomischus hiepii, a new species of Rubiaceae from Vietnam

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Abstract

Leptomischus hiepii, a new species of the tribe Argostemmatae from Son La province, northwestern Vietnam, is described and illustrated. Morphologically it allies to *L. wallichii*, *L. erianthus* and *L. funingensis* by sharing a similar habit, large stipules and similar corolla shape, but it differs by its anisophyllous leaves, 1-flowered inflorescences, homostylous flowers and tubular-campanulate corollas.

Keywords

Argostemmatae, endemism, plant diversity, plant taxonomy

Introduction

Leptomischus Drake (Drake 1895) is a poorly known genus of Rubiaceae. It was first described as a monotypic genus with one species, *L. primuloides* Drake (Drake 1895), occurring in northern Vietnam. Nearly a century later, Lo (1986) published the second species found in southern and southwestern China and northern Vietnam, i.e. *L. parviflorus* H.S.Lo. Later, in his revision of *Leptomischus*, Lo (1993) included *Indopolysolenia* Bennet (Raizada and Bennet 1981) as a synonym of *Leptomischus*

and accommodated a new combination, *L. wallichii* (Hook.f.) H.S.Lo for *Polysolenia wallichii* Hook.f. (Bentham and Hooker 1873) from India. He also proposed a new synonym of *L. primuloides*, i.e. *Indopolysolenia burmanica* Deb & Rout (Deb and Rout 1990) reported from northern Myanmar. Subsequently, Lo (1998) reported three more new species of *Leptomischus* endemic to southwestern China; *L. erianthus* H.S.Lo, *L. funingensis* H.S.Lo, and *L. guangxiensis* H.S.Lo. Recently, *L. flaviflorus* Hareesh, L.Wu & M.Sabu, a new species from southern Tibet and northeastern India was published (Hareesh et al. 2017). To summarize, *Leptomischus* presently includes seven species distributed in tropical mainland Asia, including northeastern India (2 species), Myanmar (1 species), southern and southwestern China (5 species), and northern Vietnam (2 species).

Despite the fact that the genus *Leptomischus* is insufficiently known and has previously been studied by few researchers (Lo 1986, 1993, 1998; Chen and Taylor 2011; Hareesh et al. 2017), this group of plants can be readily distinguished from other genera of Rubiaceae by a combination of the following characters: perennial herbs or shrubs, heterostylous flowers, numerous ovules which are borne on a stipitate placenta near the base of the septum, dry capsular fruits dehiscent through the apical portion or through an operculum, small and numerous seeds with reticulate testa (Lo 1993; Chen and Taylor 2011; Razafimandimbison and Rydin 2019). *Leptomischus* is considered to belong to the Asian tribe Argostemmataeae in subfamily Rubioideae and was found to be sister to all other genera of the tribe (Razafimandimbison and Rydin 2019).

Among the characteristic features mentioned above, the mode of dehiscence of the capsule is the most important, as only two genera of the tribe share such a character (Lo 1993), i.e. *Leptomischus* and *Mouretia* Pitard (Pitard 1922). It is said that placenta insertion (near the base of the septum in *Leptomischus* and near the middle of the septum in *Mouretia*) is a key character to distinguish *Leptomischus* from *Mouretia* (Chen and Taylor 2011; Hareesh et al. 2017). However, the insertion of the placenta is difficult to observe since the ovary is quite small and the placentas are large in comparison with the septum. As a result, this characteristic was not illustrated for any species described (Bentham and Hooker 1873; Drake 1895; Raizada and Bennet 1981; Deb and Rout 1990; Lo 1986, 1993, 1998; Chen and Taylor 2011; Hareesh et al. 2017). Moreover, while describing *Leptomischus* in China, Chen and Taylor (2011) stated that the placentas were “inserted apparently near the middle of septum”, and we also found that the placenta of *L. funingensis* is inserted at the middle of septum (Fig. 4I). To our knowledge, all representatives of *Leptomischus* have corolla tubes longer than 14 mm (except for 6–6.5 mm long in *L. parviflora*), anthers 2–3.5 mm long and stigmas 2–5 mm long (Deb and Rout 1990; Lo 1998; Chen and Taylor 2011; Barbhuiya et al. 2014; Hareesh et al. 2017), whereas species of *Mouretia* have corolla tubes shorter than 4 mm, anthers 0.9–1.4 mm long and stigmas 0.7–2 mm long (Tange 1997; Chen and Taylor 2011).

During an expedition to Muong La Nature Reserve in Son La Province of northern Vietnam, an unusual species of the family Rubiaceae was discovered. It is a perennial herb, mostly glabrous, with anisophyllous leaves, usually 2-lobed stipules, terminal

1-flowered inflorescences, actinomorphic, 5–6-merous, hermaphroditic homostylous flowers, numerous ovules on a stipitate placenta attached to the middle of the septum, fleshy capsular fruits dehiscing through apical portion, small and numerous seeds with reticulate or verrucose testa. It clearly belongs to the tribe Argostemmatae, in which all genera are characterized by hermaphroditic flowers, bilocular ovaries (sometimes 3–5-celled in *Mycetia* Reinw., capsular fruits, and many small seeds (Rydin et al. 2009; Ginter et al. 2015; Razafimandimbison and Rydin 2019). Because of the corolla tube (3.2–)3.4–3.8(–4) cm long and (1.2–)1.3–1.5(–1.7) cm in diameter at the throat, the anthers 2.2–2.5 mm long, the stigmas 2.5–3 mm in length and the capsular fruits dehiscing through the apical portion, we tentatively place it in the genus *Leptomischus*.

After consulting the relevant literature (Bentham and Hooker 1873; Deb and Rout 1990; Lo 1986, 1993, 1998; Pham 2003; Barbhuiya et al. 2014; Chen and Taylor 2011; Hareesh et al. 2017) and available herbarium specimens (including types) housed in Vietnam (HN, VNMN) and China (BNU, CSFI, GXMI, HITBC, IBK, IBSC, KUN, PE), and digital images of specimens at K (<https://apps.kew.org/herbcat/navigator.do>) and P (<https://science.mnhn.fr/all/search>), the discovered plants were found to represent an undescribed species. The description and illustration of this new species is provided below.

Material and methods

The specimens of the newly described species are deposited at the following herbaria: Central South University of Forestry and Technology (CSFI), Institute of Ecology and Biological Resource of the Vietnam Academy of Science and Technology (HN), and Komarov Botanical Institute of Russia (LE). Herbarium acronyms follow Thiers (2020). Morphological observations and measurements of the new species are based on living material in the field as well as on dry specimens. The conservation status of the new species is evaluated based on field observations in accordance with IUCN guidelines (2017).

Taxonomic treatment

Leptomischus hiepii L.Wu, K.S. Nguyen & Aver., sp. nov.

urn:lsid:ipni.org:names:77212876-1

Figs 1–3, Table 1

Diagnosis. Similar to *L. wallichii*, *L. erianthus* and *L. funingensis*, but differs mainly by its anisophyllous leaves (vs. isophyllous), stipules usually 2-lobed (vs. entire or 3-lobed), 1-flowered inflorescence (vs. several-flowered), homostylous flowers (vs. heterostylous), and corolla tubular-campanulate, 3.2–4 cm long (vs. tubular, tubular-infundibulariform or tubular-salverform, 1.4–1.6(–3) cm).

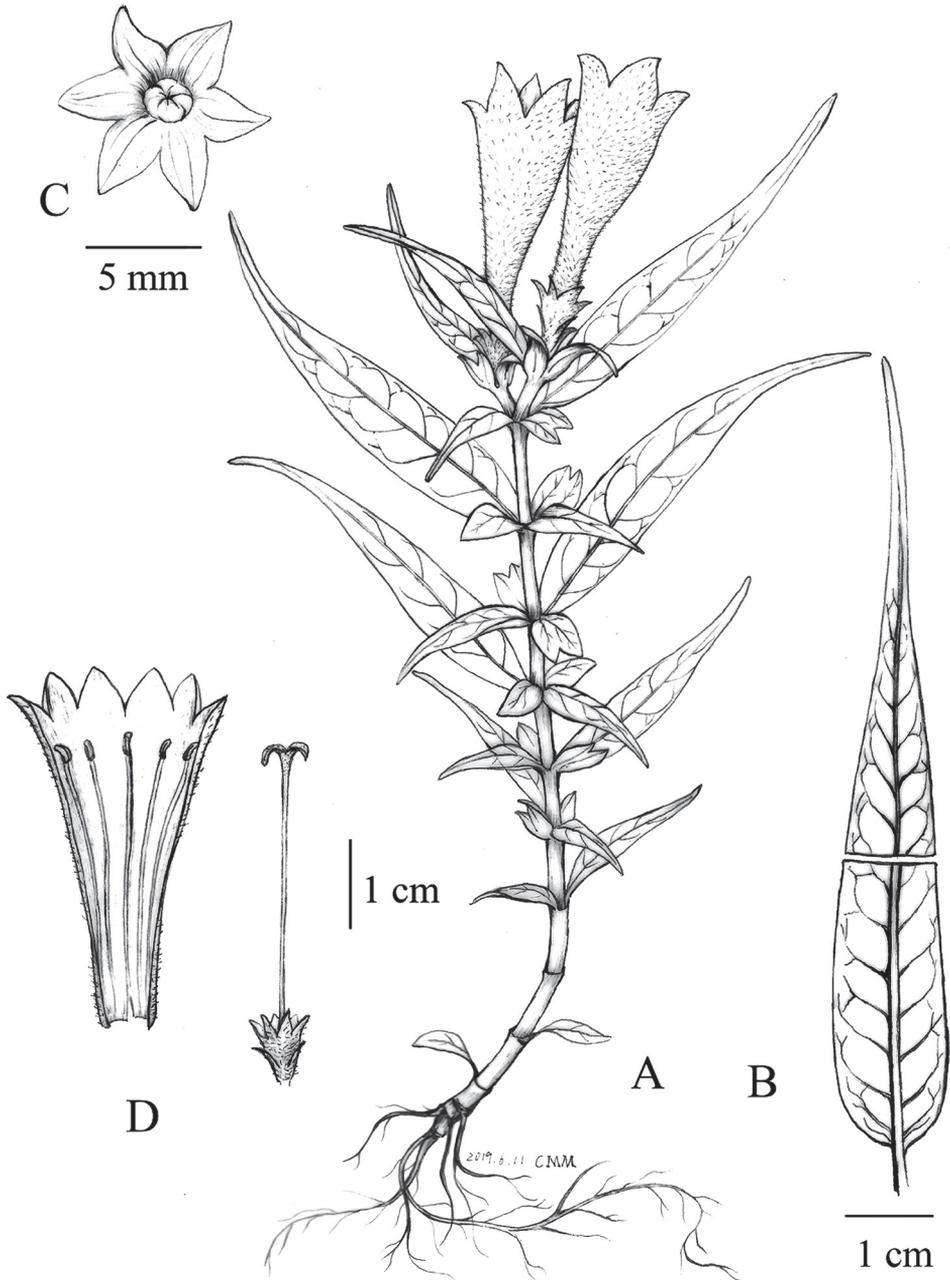


Figure 1. *Leptomischus hiepii* **A** habit **B** leaf, upper portion, adaxial surface **C** capsule, view from above **D** dissected flower showing stamens and pistil. Drawn by Bi-Shan Li from the holotype in CFSI.

Type. VIETNAM. Son La province: Muong La district, Ngoc Chien commune, Muong La Nature Reserve, around point 21.61032°N, 104.10576°E, elevation 1320–1350 m a.s.l., remnants of primary evergreen broad-leaved forest along streams at base

and on steep slope of sandstone mountain, lithophytic perennial herb 30–45 cm tall, in wet places, locally common, 2 March 2019, *Nguyen Sinh Khang, Mai Van Duc and Lo Van Chieu, NSK 1153* (holotype CSFI [CSFI069614]; isotypes CSFI, HN, LE [LE01058686, LE01058688, photo: LE01061374]).

Description. Perennial herb, lithophytic and occasionally terrestrial, 30–45 cm tall. Stem ascending or drooping, somewhat straight, simple or branched, terete, glabrous, green, with internodes of 6–30 mm long, 2–3 mm in diameter. Stipules persistent, glabrous, green, slightly equal to unequal, broadly to narrowly ovate, (4–)8–10(–16) × (3–)4–8(–10) mm, distally often divided up to 2/3th of their length into 2 narrowly ovate to broadly lanceolate, 3–5(–9) mm long obtuse lobes, usually bearing 2–3 longitudinal veins united at base and 3–5 lateral veins on each side. Leaves anisophyllous, glabrous on both surfaces, dark green above, paler green below, subsessile to shortly petiolate; petioles terete, 0.5–2.5 mm long, glabrous; leaf blades lanceolate to narrowly lanceolate, cuneate at base, gradually attenuate to caudate at apex, margin entire, often irregularly wavy; veins prominent on both surfaces; of a pair of leaves, the smaller one (8–)10–20(–30) × (2.5–)3–5(–8) mm, with (3–)5–7(–9) secondary veins on each side of midrib, the larger one (3–)5–9(–11) × (0.4–)0.8–1.2(–1.5) cm, with (9–)11–15(–17) secondary veins on each side of midrib. Inflorescence terminal, single-flowered; peduncle ca. 1 mm long, densely puberulent; bracts 2, subulate, 5–6 mm long, ca. 1 mm wide at base, acute, puberulent outside, glabrous inside. Flowers solitary, sessile, 6-merous, sometimes 5-merous, bisexual, homostylous. Calyx campanulate, densely puberulent outside; hypanthium obconic, 2.5–3.2 mm long, lobes triangular, acute, 2.2–4 × 1.6–2.5 mm, almost glabrous inside, ciliate along margin, somewhat recurved at anthesis. Corolla tubular-campanulate, (3.2–)3.4–3.8(–4) cm long, (1.2–)1.3–1.5(–1.7) cm in diameter at the throat, pure white, shortly densely villous outside, almost glabrous inside; corolla lobes (5–)6, triangular ovate, straight spreading or slightly recurved at anthesis, 5–8 mm × 4–7 mm, tips acute. Stamens (5–)6, filaments white, glabrous, connate with corolla tube from base to 5–6 mm below the throat, free parts terete, 1.8–2.6 mm, slightly incurved; anthers pale yellowish, oblong elliptic, 2.2–2.5 × 0.6–0.8 mm, dorsifixed, introrse. Ovary inferior, bilocular; disk glabrous, marginally convex and concave at the center; style erect, filiform, 2.5–3.2 cm long, white, glabrous; stigma dull brownish, finely papillose, 2-lobed; lobes narrowly oblong or linear, 2.5–3.5 mm long, recurved at a straight angle from the style axis, positioned 1.4–1.8 mm below the throat, slightly above anther apices. Fruit capsular, subglobose, ca. 3–4 mm in diameter, crowned by persistent calyx lobes, dehiscent through apical portion, pericarp and septum membranous, brown; placenta fleshy, brown, mushroom-shaped during anthesis then turning dark brown, woody, and broadly conoid (when dried), attached to middle of septum, distally bearing numerous seeds; seeds angled, 0.3–0.5 mm; testa reticulate or verrucous, black.

Etymology. The specific epithet honors Dr. Nguyen Tien Hiep, a famous botanist who made significant contributions to the plant taxonomy and nature conservation in Vietnam.

Additional specimens examined (paratypes). VIETNAM. Son La province: Muong La district, Ngoc Chien commune, Muong La Nature Reserve, same location as type specimen, lithophytic perennial herbs bearing fleshy capsules, fruit opened by an apical operculum, 22 August 2020, *Nguyen Sinh Khang & Lo Van Chieu, NSK 1347* (HN).

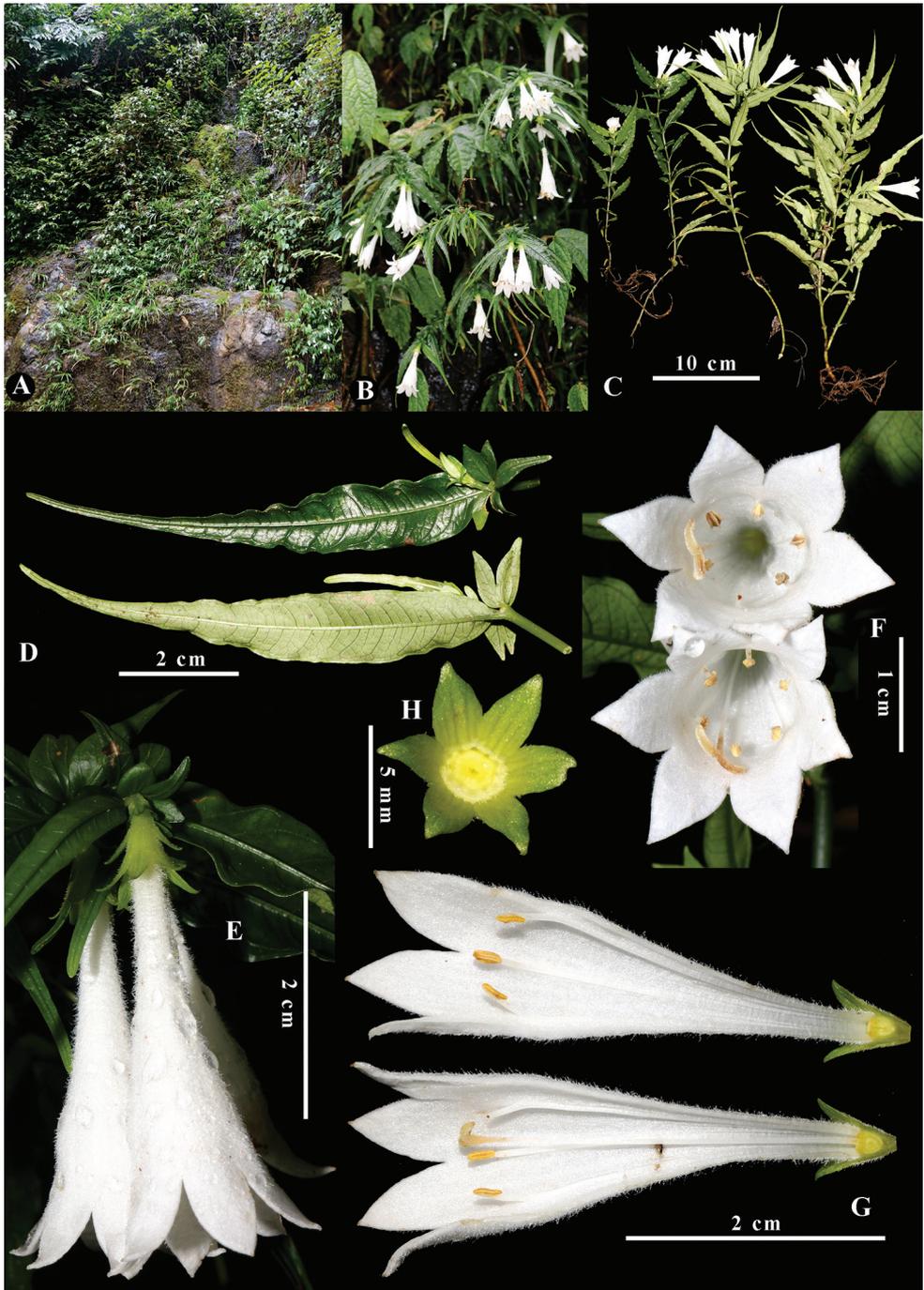


Figure 2. *Leptomischus hiepii* **A** typical habitat **B, C** habit **D** unequal leaf pair and stipules **E** inflorescence **F** flowers, view of the throat **G** dissected flower **H** calyx lobes and disc, seen from above. Photos and design by K.S. Nguyen and L. Wu.

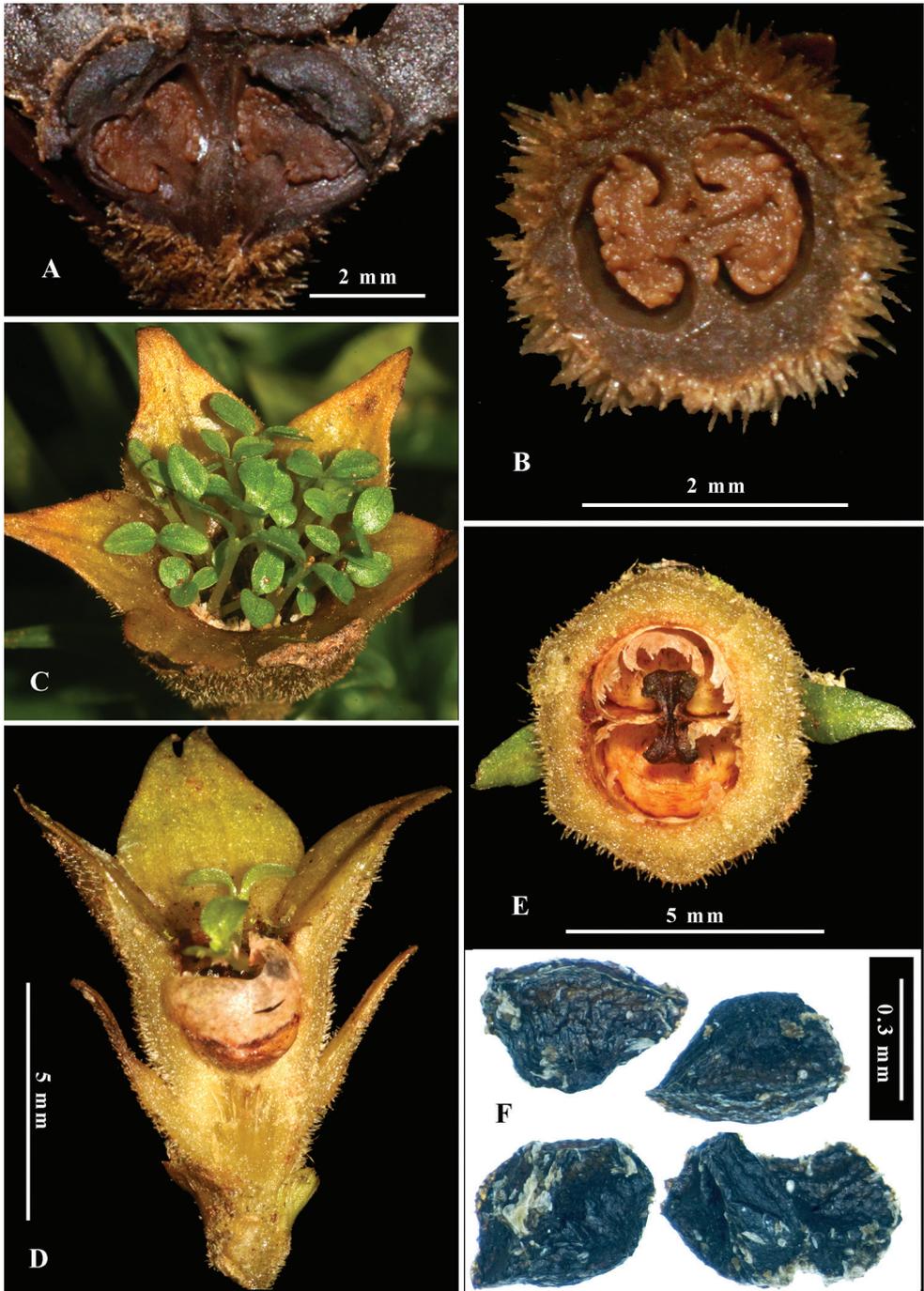


Figure 3. *Leptomischus hiepii* **A** longitudinally dissected ovary **B** transversely dissected ovary **C** mature fruits and viviparous seeds **D** longitudinally dissected capsule **E** Transversely dissected capsule **F** seeds. Photos and design by K.S. Nguyen.

Table 1. Morphological comparison of *Leptomischus hiepii*, *L. wallichii*, *L. erianthus* and *L. funingensis* (Lo 1993; Chen and Taylor 2011; Hareesh et al. 2017).

Characters	<i>L. hiepii</i>	<i>L. wallichii</i>	<i>L. erianthus</i>	<i>L. funingensis</i>
Stem	glabrous	Glabrous	densely hirsute	Pilose
Stipule	narrowly ovate to broadly ovate, 8–14 mm long, entire to 2-lobed	ovate to lanceolate, 7–13 mm long, 3-lobed	ovate or lanceolate, 8–9 mm long, entire	suborbicular, 4–5 mm long, entire
Leaves	anisophyllous, lanceolate to narrowly lanceolate, glabrous, 0.8–11 × 0.25–1.5 cm	isophyllous, oblanceolate to elliptic, glabrous, 4–12 × 0.7–1.8 cm	isophyllous, narrowly elliptic to lanceolate-elliptic, strigose to glabrescent, 4–12 × 1.5–4 cm	isophyllous, ovate, narrowly elliptic, or rarely obovate, adaxially glabrescent to pilose, abaxially villose, 8–15 × 2.5–4.5 cm
Inflorescence	1-flowered	capitate, several-flowered	subcapitate, several-flowered	cymose, several-flowered
Flower	homostylous, (5–)6-merous	unknown, 5-merous	distylous, (4–)5(–7)-merous	distylous, (4–)5(–6)-merous
Corolla shape	tubular-campanulate	Tubular	tubular-infundibulariform	tubular-salverform
Corolla tube length	3.2–4 cm	ca. 1.5–3.0 cm	1.5–1.6 cm	1.4–1.6 cm
Anther length	2.2–2.5 mm	ca. 2 mm	2–2.5 mm	2–2.2 mm
Stigma length	2.5–3.5 mm	ca. 1.3–1.5 mm	3–3.5 mm	3.5–4.5 mm

Habitat, phenology and conservation status. Lithophytic or terrestrial herb growing on rocks in streams and on moist cliffs under primary and secondary evergreen broad-leaved submontane forest on sandstone at elevations of 1300–1400 m a.s.l.. The plants flower in February–March, and bear fruits in July–August. The species was observed as being very common on waterfall cliffs and in humid places; around 300–500 mature individuals occur in Muong La Nature Reserve, spread over a very limited area of approximately 2500 m². In Muong La Nature Reserve, agricultural activities and exploitation for timber and non-timber forest products are prohibited. According to indigenous people, this species is not used as medicinal or ornamental plant, and disturbances to its existence so far have not been recorded. Numerous localities in the mountainous areas of the Hoang Lien Son range, spreading over the provinces of Lai Chau (Phong Tho, Tam Duong and Than Uyen districts) and Lao Cai (Bat Xat, Sa Pa and Van Ban districts) to Yen Bai (Tram Tau, Nghia Lo, Van Yen and Mu Cang Chai districts) and Son La (Muong La and Bac Yen districts), in north-western Vietnam and the south-western parts of Yunnan province in south-western China, fit the habitat characteristics of this new species. It is therefore expected that more populations of the species will be discovered soon if extensive field surveys are carried out in this region. At present, however, *L. hiepii* can be considered as an endemic species to Son La province, and is tentatively assessed as “data deficient” (DD) in accordance with the IUCN Red list categories and criteria (2017).

Distribution. Endemic to north-western Vietnam (Son La province, Muong La district, Muong La Nature Reserve).

Discussion. *Leptomischus hiepii* is a very special member of the genus in several ways, and is inconsistent with most of its congeners. Typical characters of *L. hiepii*

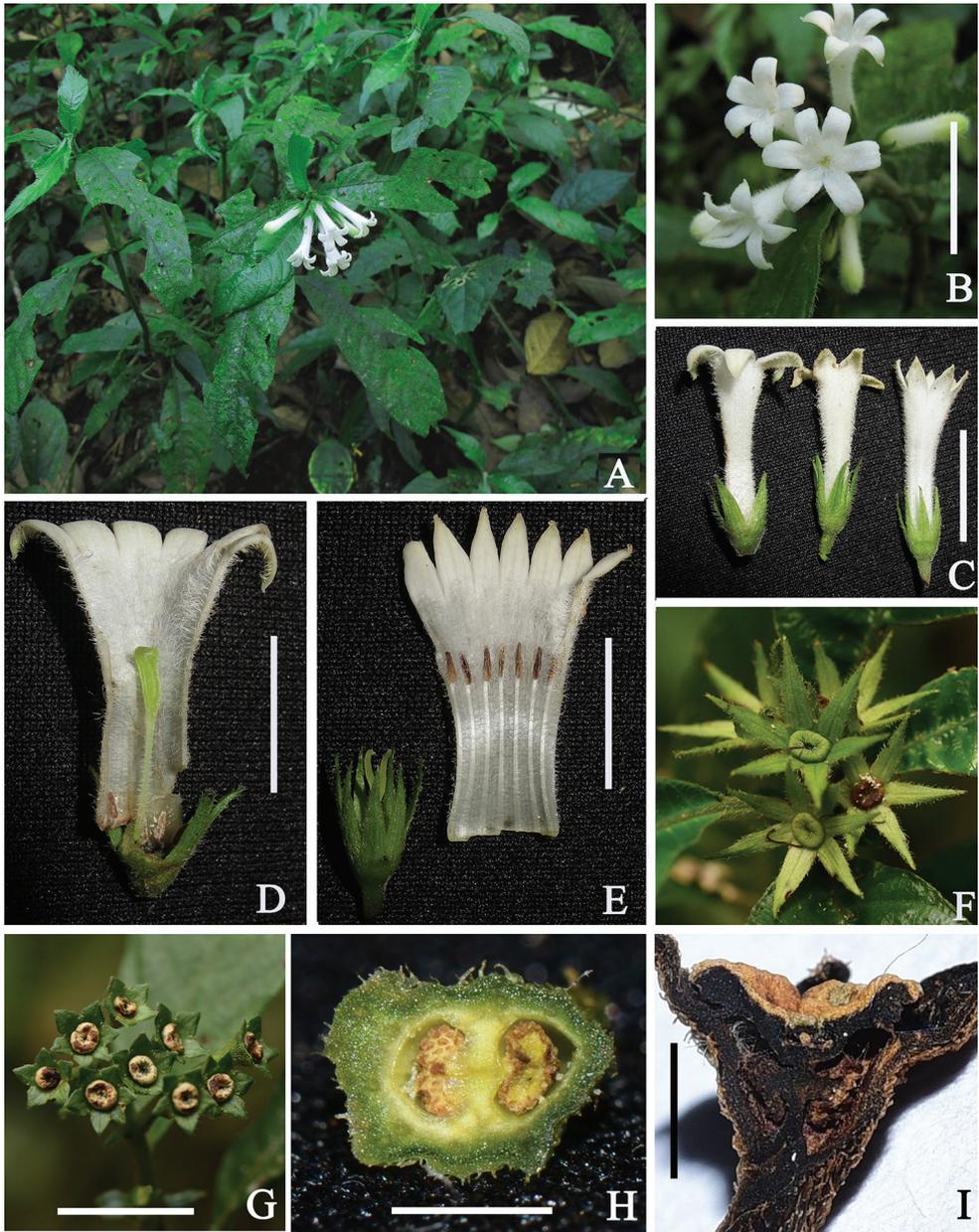


Figure 4. *Leptomischus erianthus* **A** habit **B** inflorescence **C** flowers **D** Dissected longistylous flower **E** dissected brevistylous flower **F** capsules, seen from above. *L. funingensis*. **G** infructescence, seen from above **H** transversely dissected ovary **I** Longitudinally dissected ovary. Scale bars: 1 cm (**A–G**); 2 mm (**H, I**). Photos and design by L. Wu.

are anisophyllous leaves, 1-flowered inflorescences, homostylous (5–)6-merous flowers and anthers and stigma positioned at the level of the throat of the corolla tube, while all currently known species of the genus are reported as having isophyllous leaves, sev-

eral-flowered inflorescences, heterostylous 5-merous flowers, and anthers positioned much lower than the stigma or vice versa. Anisophyllous and isophyllous leaves are commonly seen in *Mouretia*, *Mycetia* and *Argostemma* Wall. within the tribe Argostemmateae (Chen and Taylor 2011). The 1-flowered inflorescence has not been recorded in *Leptomischus* but is reported in *Argostemma*, e.g. in *A. bachmaense* T.V.Do (Do et al. 2020). Homostylous flowers have hitherto not been recorded in the tribe Argostemmateae but the rare presence of homostylous flowers in otherwise heterostylous genera is not rare in Rubiaceae (Chen and Taylor 2011), e.g., homostylous flowers are reported in *Mussaenda campanulata* T.T.Duan & D.X.Zhang (Duan et al. 2016) and *Ophiorrhiza longifloriformis* Schanzer (Schanzer 2005). Flower merosity is variable in the genera *Mycetia*, *Argostemma* (Chen and Taylor 2011) and *Leptomischus* as well, or even within the same inflorescence of a species such as *L. erianthus* bearing 4–7-merous flowers (Fig. 4B, E). Anthers and stigma positioned at the level of the throat of the corolla tube are a common feature in homostylous flowers of Rubiaceae and also occurs in *Neohymenopogon* Bennet of the tribe Argostemmateae (Chen and Taylor 2011).

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Strobilanthes sunhangii (Acanthaceae), a new species from Tibet, China

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Abstract

A new species of Acanthaceae, *Strobilanthes sunhangii*, is described from Mêdog County, Tibet, China. Morphologically, the new species is closely similar to *S. medogensis* and *S. divaricata*, but *S. sunhangii* differs in having glabrous stems, longer spikes, glabrous rachis, double curved corolla and glabrous calyx, different stamens and style.

Keywords

Mêdog, morphological evidence, new species, *Strobilanthes sunhangii*

Introduction

Strobilanthes Blume (1826: 781) is one of the most diverse genera in the family Acanthaceae (Ruellieae: Strobilanthinae) and comprises approximately 450 species mainly distributed in tropical and subtropical regions of Asia with some species extending to Pacific Islands (Hu and Tsui 2002; Hu et al. 2011; Tripp et al. 2013; Chen et al. 2019; Deng 2019). Historically, there has long been disagreement about whether the genus might be adopted on a broad or narrow circumscription (von Esenbeck 1847; Anderson 1867; Clarke 1885; Terao 1983). Beremekap (1944) divided Strobilanthinae into many small genera. However, molecular studies (Moylean et al. 2004) have shown that these segregate genera are nested within *Strobilanthes* and the broad concept of *Strobilanthes* has been generally accepted (Deng et al. 2006; Wood and Scotland 2009; Hu et al. 2011; Wood 2014; Deng 2019). In China, Hu et al. (2011) recorded 128 species mainly distributed in SE to SW China.

China has a vast territory with a wide range of complex and diverse topographies and soils and covering several climate types, which contribute to the wealth of Chinese botanical diversity (Sun et al. 2017; Chen et al. 2018a, b, 2020). Mêdog County, in which the highest peak is Mt. Namjagbarwa (7,782 m) in the north and the lowest point is Pasighat (154 m), has a rich biodiversity, including 1,805 species of seed plants (Sun and Zhou 1996, 2002; Yang and Zhou 2015; Chen et al. 2018b) and some new species have recently been reported from this region, such as *Cornus sunhangii* (Lv et al. 2019).

During a recent expedition in Mêdog, we discovered a species of *Strobilanthes* with very unusual morphological characters. After observations of wild living plants, herbarium specimens, laboratory studies and consultation of relevant literature (Blume 1826; Anderson 1867; Clarke 1885; Li 1985; Wood 1994, 2001, 2014; Carine and Scotland 2002; Hu and Tsui 2002; Deng et al. 2006; Hu et al. 2011; Adhikari 2018; Chen et al. 2019; Thomas et al. 2019), it is concluded that it does not match any other known species of *Strobilanthes* and represents an undescribed species. Therefore, it is described below as *Strobilanthes sunhangii* T. Deng, J.T. Chen & Y.F. Deng.

Materials and methods

The specimens of *Strobilanthes sunhangii* were collected from Mêdog County in Tibet and studied at the herbarium of Kunming Institute of Botany (KUN). Morphological characters, recorded for the new species, were based on fresh plants and dried specimens. Pollen grains were collected from dry specimens and the operation method for pollen measurement followed Chen et al. (2019). Morphological comparisons of *S. sunhangii*, with the related taxa *S. medogensis* (H.W. Li) J.R.I. Wood & Y.F. Deng and *S. divaricata* (Nees) T. Anderson are provided in Table 1.

Results

Taxonomic treatment

***Strobilanthes sunhangii* T. Deng, J.T. Chen & Y.F. Deng, sp. nov.**

urn:lsid:ipni.org:names:77212877-1

Figs 1–4

Type. CHINA. Tibet: Mêdog County, Beibeng Town, 29.23319N, 95.17693E, elev. ca. 1,470 m, 5 Oct 2018, *H. Sun, T. Deng & Z.M. Li Sunhang19964* (**holotype**: KUN1345286!; **isotypes**: IBSC!, KUN1345287!, KUN1345288!)

Diagnosis. *Strobilanthes sunhangii* resembles *S. medogensis*, but differs by its stems subterete, glabrous (vs. slightly sulcate, bifariously puberulent); spikes (7–)11–22 cm long (vs. 3–6 cm long), rachis glabrous (vs. bifariously pubescent); corolla outside and lobes pinkish-white, inside purplish-pink (vs. corolla yellowish-white, but dull purple on lobes), the tube bent to ca. 90° twice (vs. straight), lobes apices emarginate (vs. rounded); calyx 7–8 mm long, glabrous, 5-lobed to middle (vs. ca. 12 mm long, gland-tipped pubescent, 5-lobed to base), lobes ovate, equal (vs. narrowly oblong-elliptic, subequal); stamens included (vs. exerted), filaments of shorter pair ca. 2 mm long (vs. 7–8 mm long), longer pair ca. 4 mm long (vs. 9–10 mm long), anther thecae ca. 4 mm (vs. ca. 1 mm); style with sparse gland-tipped trichomes (vs. glabrous).

Description. Undershrubs 1–2 m high, gregarious. Stems subterete, glabrous, slightly swollen at node. Leaves slightly anisophyllous, smaller one ca. 2/3 of the larger one in size; petiole 3–7 mm long or petiole of smaller leaf in each pair shorter, sulcate, glabrous; blades ovate to lanceolate-ovate, smaller ones 4.2–6.9 × 1.2–2.0 cm, larger ones 8.2–10.1 × 2.2–3.2 cm, both surfaces glabrous, densely covered with numerous linear cystoliths, secondary veins 3–5 on each side of midvein and prominent on both surfaces, base rounded to broadly cuneate, slightly oblique, margin serrulate, apex acuminate and narrowly caudate. Inflorescences of axillary spikes, simple or rarely 2-furcate, slender, (7–) 11–22 cm long; rachis glabrous; bracts and bracteoles not seen, caducous. Flowers (0.6–) 1.0–2.5 (–3.0) cm apart on rachis. Calyx 7–8 mm long, glabrous, 5-lobed to middle; lobes ovate, equal, margins narrowly scarious, 1-nerved abaxially, conspicuous after drying, apices acuminate. Corolla 2.8–3.3 cm long, campanulate, outside and lobes pinkish-white, inside purplish-pink, outside glabrous, inside glabrous except for bifarious hirsute retaining the style (Fig. 3E); tube basally cylindrical, ca. 3 mm wide and ca. 6 mm long, then bent to ca. 90° and gradually widened to 9–12 mm wide at middle and 1.6–1.8 cm long, then secondly bent to ca. 90° and tube upper cylindrical 9–12 mm wide and 1.6–1.8 cm long; lobes broadly elliptic, 8–9 × 7–8 mm, apices emarginate (Fig. 3A, B). Stamens 4, didynamous, included; the united part of filaments glabrous at base, with dense villous on middle and margin, with slightly sparse villous on upper (Fig. 3E), shorter pair ca. 2 mm long, longer pair ca. 4 mm long; anther thecae oblong, ca. 4 mm long. Pollen grains prolate in outline,



Figure 1. Photograph of the holotype of *Strobilanthes sunhangii* T. Deng, J.T. Chen & Y.F. Deng (KUN barcode 1345286!).

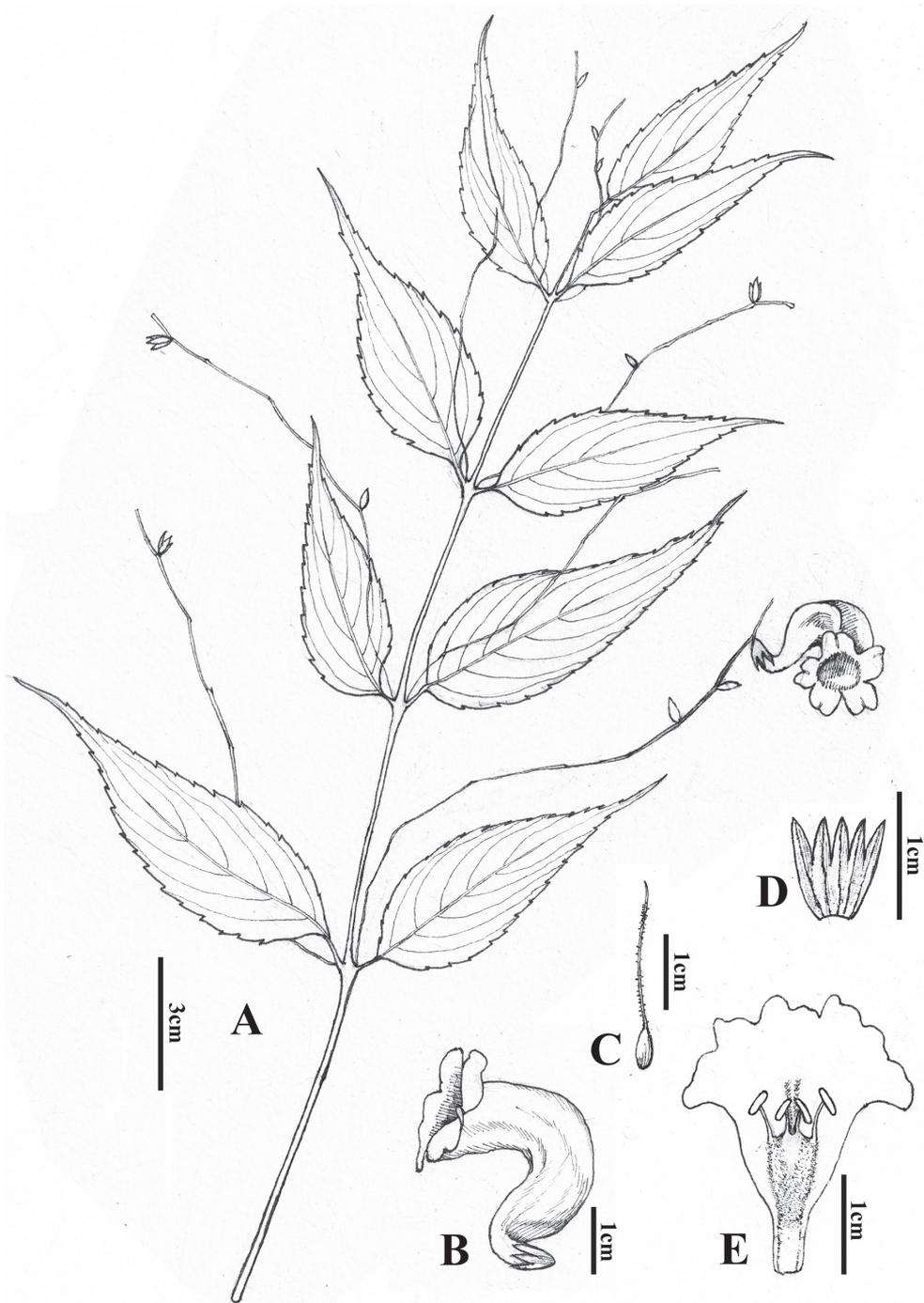


Figure 2. *Strobilanthes sunhangii* T. Deng, J.T. Chen & Y.F. Deng **A** plant showing flowering branch and leaves **B** flower (view from side) **C** pistil, ovary and style **D** calyx **E** opened corolla showing androecium (Drawn by Xiaoshuang Zhang based on the holotype of Sunhang19964).

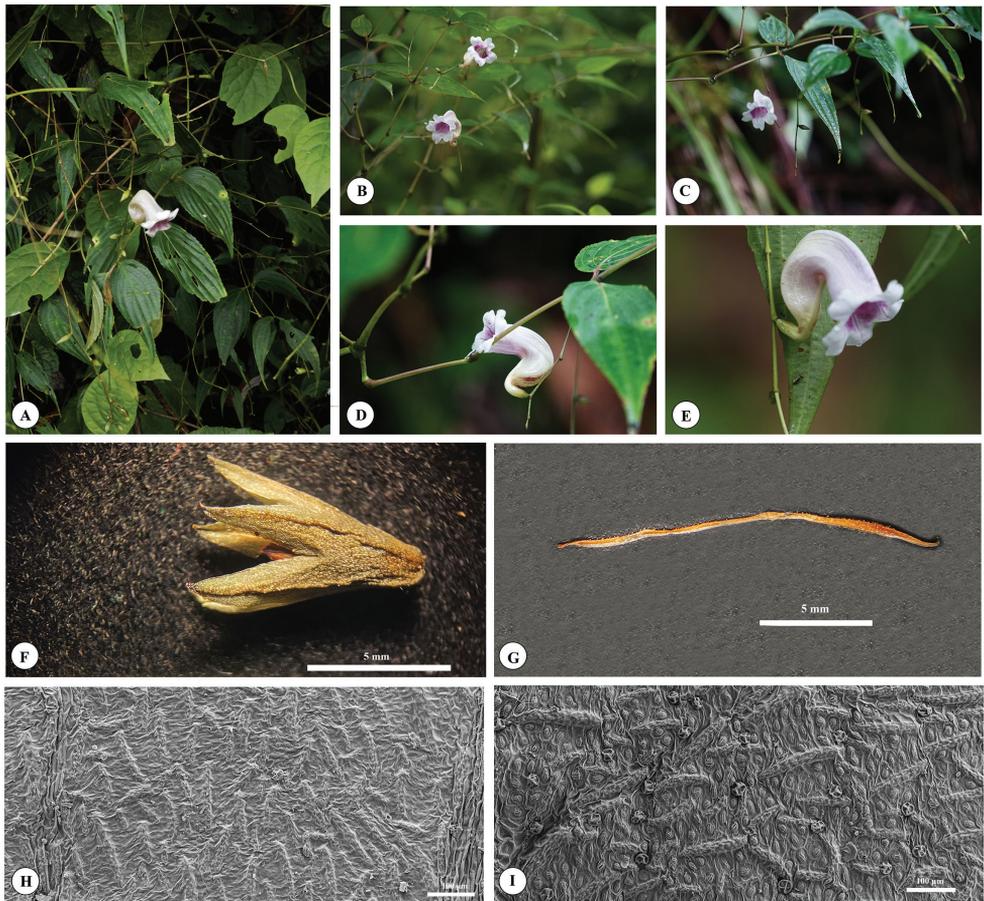


Figure 3. *Strobilanthes sunhangii* T. Deng, J.T. Chen & Y.F. Deng **A** habitat and flowering branch **B, C** flowering branch and flower (view from front) **D, E** flower (view from side) **F** calyx **G** style **H** leaf adaxial surfaces **I** leaf abaxial surfaces.

74.1 (72.2–76.1) × 49.7 (48.1–50.4) μm, P/E = 1.49, tricolporate, ribbed pseudocolpi 12, exine reticulate (Fig. 4). Ovary ca. 5 mm long, glabrous; style ca. 1.8 cm long, with sparse gland-tipped trichomes. Capsule not seen.

Phenology. Flowering from June–October.

Etymology. *Strobilanthes sunhangii* is named after Prof. Hang Sun (1963–) for his outstanding contributions to the flora of Himalayan regions and collecting this new species for the first time. Verucular name: The Chinese name is given as “双曲马蓝” (shuāng qū mǎ lán), referring to the double-curved corolla of the new species.

Distribution and habitat. The new species is currently known only from Mêdog County, Tibet, China. It grows in the moist evergreen forest at an elevation of 1,200–1,800 m. The associations include *Exbucklandia populnea* (R. Br.) R. W. Brown (Hamamelidaceae), *Viburnum* sp. (Viburnaceae), *Rubus* sp. (Rosaceae), *Campanumoea inflata* (Hook. f. & Thomson) C.B. Clarke (Campanulaceae), *Tripterosperrum volubile* (D. Don) H. Hara (Gentianaceae) and *Impatiens* sp. (Balsaminaceae), amongst others.

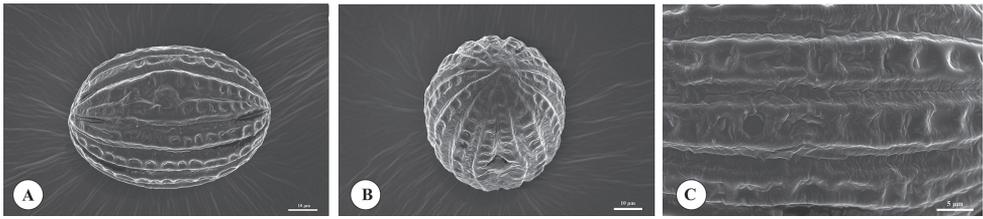


Figure 4. Pollen grains of *Strobilanthes sunhangii* T. Deng, J.T. Chen & Y.F. Deng **A** equatorial view **B** polar view **C** ornamentation.

Conservation status. The new species was only discovered in Beibeng Town, Mêdog County. About 1,000 individuals were observed and the extent of occurrence was ca. 5 km². Further explorations to obtain the precise population status are needed to assess its conservation status. Based on available data, the new species is assigned to the category ‘Data Deficient’ (DD) of the International Union for Conservation of Nature (IUCN 2019).

Specimens of *S. medogensis* examined. – CHINA. **Tibet:** Mêdog County, Gedang Town, elev. ca. 2,400 m, 27 Aug 1974, *QTP Expedition 74-4911* (holotype: KUN barcode 1219209!); Mêdog County, Gedang Town, 2,450 m elev., 11 Sept 1982, *B.S. Li & S.Z. Cheng 814* (PE); Mêdog County, Gedang Town, 1,940 m elev., 13 Oct 1982, *S.Z. Cheng & B.S. Li 1457* (PE); Mêdog County, 1,100 m elev., 1 Dec 1982, *S.Z. Cheng & B.S. Li 3238* (PE); Nyingchi County, Pailong Town, 2,175 m elev., 8 Sept 2006, *Tiber-MacArthur 261* (A); Lung County, Chayne chu, 2,750 m elev., 10 Jul 1936, *Ludlow & Sherriff 2336* (BM, E).

Specimens of *S. divaricata* examined. – INDIA. **Meghalaya:** Khasia, 1,524 m elev., 5 Oct 1886, *C. B. Clarke 45219* (BM, CAL, LE); Khasia, 1,219 m elev., 12 Nov 1871, *C. B. Clarke 15479* (CAL, K, LE); Khasia, Oct 1850, Simons 482 (CAL). **Sikkim:** Khuping, 1,676 m elev., 26 Sept 1884, *C. B. Clarke 35904* (LE); Khuping, 1,676 m elev., 26 Sept 1884, *C. B. Clarke 35920* (LE). – NEPAL. Koshi Zone, Sankhuwasabha District, 2,020 m elev., 16 Aug 1998, *S. Noshiro et al. 9840046* (A); Dhawalagiri Zone, Myagdi District, 1,820–2,360 m elev., 10 Sept 1996, *M. Mikage et al. 9681329* (A).

Discussion

Morphologically, the new species is closely related to *Strobilanthes medogensis* in having similar leaves and slender spikes, but differs in having glabrous stems, longer spikes, glabrous rachis, double curved corolla and glabrous calyx, different stamens and style (Li 1985; Wood 1994; Hu and Tsui 2002; Deng et al. 2006; Hu et al. 2011). In addition, the new species is also related to *S. divaricata* in the glabrous stems and calyx, slender spikes, but differs in having longer spikes, double curved corolla, different stamens and style (Wood 2001; Adhikari 2018). The new species is quite different from all other known species in its unique corolla shape. The corolla of *S. sunhangii* are bent twice, at the base and middle of throat, respectively, while that of other species is

Table 1. Morphological comparisons of *Strobilanthes sunhangii* with related species.

Characters	<i>S. sunhangii</i>	<i>S. medogensis</i>	<i>S. divaricata</i>
Stems	Stems subterete, glabrous.	Stems slightly sulcate, bifariouly puberulent.	Stems often zigzag above, angular, glabrous.
Leaves	Leaves slightly anisophyllous, leaf blade ovate to lance-ovate, smaller of pair ca. 2/3 size of larger one, 4.2–6.9 × 1.2–2.0 cm and larger ones 8.2–10.1 × 2.2–3.2 cm, base rounded to broadly cuneate, both surfaces glabrous and with numerous linear cystoliths.	Leaves anisophyllous, leaf blade ovate, smaller of pair ca. 2/3 size of larger one, (1.9–)4.0–6.0 × (0.5–)1.8–2.1 cm and larger ones 5.8–9.0 × 2.1–3.7 cm, base rounded to subcordate, both surfaces glabrous, adaxially with numerous cystoliths.	Leaves strongly anisophyllous, smaller leaves ca. 1/3 length of larger leaves, ovate, 1.5–6 × 0.5–2 cm, base rounded, larger ones lanceolate to elliptic, 8–18 × 2–5 cm, base cuneate or attenuate to a short petiole, both surfaces glabrous.
Inflorescences	Spikes slender, (7–)11–22 cm; rachis glabrous.	Spikes 3–6 cm; rachis bifariouly pubescent.	Spikes 1–6 cm, rachis glabrous to sparsely pilose.
Corolla colour	Corolla outside and lobes pinkish-white, inside purplish-pink.	Corolla yellowish-white but dull purple on lobes.	Corolla purple.
Corolla	Corolla 2.8–3.3 cm long, tube basally cylindrical and ca. 3 mm wide by ca. 6 mm long, then bent to ca. 90° and gradually widened to 9–12 mm wide at middle by 16–18 mm long, then second bent to ca. 90° and tube upper cylindrical and 9–12 mm wide by 16–18 mm long.	Corolla ca. 2.5 cm long, straight, tube basally cylindrical and ca. 2 mm wide by ca. 1 cm long, then gradually widened to 1–1.5 cm at mouth.	Corolla 3–3.5 cm long, tube cylindrical at base for 1 cm, then gradually widened up to 0.8 cm at mouth, straight or slightly bent towards mouth.
Corolla lobes	Corolla lobes widely elliptic, ca. 8–9 × 7–8 mm, apices emarginate.	Corolla lobes broadly ovate, ca. 3 × 8 mm, apices rounded.	Corolla lobes 5–5.5 × 6 mm, apices obtuse or rounded.
Calyx	Calyx 7–8 mm, glabrous, 5-lobed to middle; lobes ovate, equal, margins narrowly scarious.	Calyx ca. 12 mm, gland-tipped pubescent, 5-lobed to base; lobes narrowly oblong-elliptic, subequal.	Calyx 8–15 mm, glabrous rarely pilose at tips, lobes linear-lanceolate, acuminate, subequal.
Stamens	Stamens included; filaments of shorter pair ca. 2 mm, longer pair ca. 4 mm; anther thecae oblong, ca. 4 mm.	Stamens exerted; filaments of shorter pair 7–8 mm, longer pair 9–10 mm; anther thecae ca. 1 mm, incurved.	Stamens included, filaments of shorter pair incurved, 1 mm, longer pair unequal, longer one 5–5.5 mm, shorter one 4–4.5 mm; anther thecae ca. 1 mm.
Style	Style ca. 1.8 cm, with sparse gland-tipped trichomes.	Style 2.7–2.8 cm, glabrous.	Style 2–3 cm, sparsely glandular trichomes at base.
Distribution	Tibet (Médog), China.	Tibet (Médog), China.	India (NE-India, Darjeeling, Sikkim); Bhutan; Nepal.

straight or curved at the middle of the throat. The detailed morphological comparisons amongst *S. sunhangii*, *S. medogensis* and *S. divaricata* are shown in Table 1.

Till now, no infrageneric classification has been established. Bremekamp (1944) divided the subtribe Strobilanthinae into 54 genera and 27 informal groups. However, his classification is not supported by the studies of the only molecular phylogeny of *Strobilanthes* (Moylan et al. 2004) and morphological analysis (Carine and Scotland 2002). In this study, *S. divaricata* and *S. medogensis*, two species closest to the new species, were not included. Bremekamp placed *S. divaricata* into his new genus *Diffugossa* Bremek., which is characterised by the single flowers on each node on rachis, arranged in an open panicle, bracts small, deciduous and corolla straight. However, *S. divaricata* is quite different from other species of *Diffugossa*, which was informally placed in Panicle groups by Wood and Scotland (2003), in its paired flower on the rachis, arranged in spikes. *S. medogensis* was placed in *Goldfussia* Nees, which is characterised by the flowers arranged in congested head-like spikes and then compounded into small panicles, stamens 2-paired, the shorter pair unequal, nodding, anthers spherical (Li 1985). Obviously,

these three species form a species complex and further studies on the placement in the genus are necessary, depending on the establishment the infrageneric classification.

Pollen morphology has been widely used in species delimitation of *Strobilanthes* (Chen et al. 2019), so we observed and measured the pollen grains of this new species. Pollens grains of the new species are prolate, $74.1 (72.2-76.1) \times 49.7 (48.1-50.4) \mu\text{m}$, P/E = 1.49, 3-colporate, 12-pseudocolpate, with reticulate exine. The detailed pollen grains morphology is provided in Fig. 4. The pollen grains of *S. medogensis* (as *S. campaniformis*) were observed by Wood (1994) and those of *S. divaricata* have not yet been observed. Both *S. sunhangii* and *S. medogensis* belong to type 3 recognised by Hu et al. (2011). Therefore, the close relationship between *S. sunhangii* and *S. medogensis* is also supported by the pollen morphology.

This species was observed by the authors during the Mêdog expedition in 2018. To date, we only collected flowering specimens and whether this new species has a plietesial life history requires further explorations.

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Re-lectotypification of *Shivparvatia glanduligera*, the type of the genus *Shivparvatia* (Alsineae, Caryophyllaceae)

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Abstract

The genus *Shivparvatia* Pusalkar & D.K. Singh was described in 2015 and the specimen *J.D. Hooker 11* deposited in K (K000742193) was designated as the lectotype of its type species *S. glanduligera* (Edgew.) Pusalkar & D.K. Singh (\equiv *Arenaria glanduligera* Edgew.). Nevertheless, *J.D. Hooker 11* (K000742193) is actually the type of *S. ciliolata* (Edgew.) Pusalkar & D.K. Singh (\equiv *Arenaria ciliolata* Edgew.). Thus the lectotypification of *S. glanduligera* was problematic and a re-lectotypification for this species is needed. One of the syntypes of *S. glanduligera* collected from Kashmir (*H. Falconer s.n.*, K000742189) is selected here as its lectotype. Morphologically, *S. ciliolata* and *S. glanduligera* can be easily distinguished from each other by their different morphology of indumentum, disc gland and sepals, as well as the color of petals.

Keywords

Arenaria, nomenclature, taxonomy

The genus *Arenaria* L. s.l. includes over 300 species of herbs widely distributed from Northern Temperate to arctic regions (McNeill 1962; Wu et al. 2001). It was divided into ten subgenera traditionally based on the morphology of sepals and petals, as well as the number of styles and lobes at the top of capsules (McNeill 1962). A series of recent molecular phylogenetic studies have made great progress in clarifying the circumscription of *Arenaria* s.l. (Harbaugh et al. 2010; Greenberg and Donoghue 2011; Sadeghian et al. 2015), and resulted in the disintegration of this large genus and some of its subgenera or sections were elevated as independent genera (Pusalkar and Singh 2015; Sadeghian et al. 2015).

Based on phylogenetic results, Sadeghian et al. (2015) raised the subgenus *Solitaria* McNeill of *Arenaria* s.l. to generic rank and described it as a new genus *Solitaria* (McNeill) Sadeghian & Zarre, with three species of subgenus *Solitaria* sampled in their study transferred to this new genus, viz. *Solitaria ciliolata* (Edgew.) Sadeghian & Zarre, *S. glanduligera* (Edgew.) Sadeghian & Zarre, and *S. stracheyi* (Edgew.) Sadeghian & Zarre. They also lectotypified these species except *S. glanduligera*, but three syntypes of its basionym, viz. *Arenaria glanduligera* Edgew., were cited.

On the other hand, Pusalkar and Singh (2015) elevated the subgenus *Solitaria* to be a new genus and described it as *Shivparvatia* Pusalkar & D.K. Singh three months earlier than Sadeghian et al. (2015). Thus the generic name *Shivparvatia* has priority in taxonomy. Pusalkar and Singh (2015) also transferred the three species of the subgenus *Solitaria* to their new genus, viz. *Shivparvatia ciliolata* (Edgew.) Pusalkar & D.K. Singh, *S. glanduligera* (Edgew.) Pusalkar & D.K. Singh, *S. stracheyi* (Edgew.) Pusalkar & D.K. Singh. They further designated the species *S. glanduligera* as the type of *Shivparvatia* and lectotypified *S. glanduligera*. However, they didn't lectotypify the other two species.

In Pusalkar and Singh (2015), the Indian specimen *J.D. Hooker 11* deposited in K (K000742193, Fig. 1A) was designated as the lectotype of *Shivparvatia glanduligera*, and the other three specimens labeled as GH00353887, K000742194 (Fig. 1C) and K000742195 (Fig. 1B) were cited as isolectotypes of the species. After careful examination of the above mentioned specimens and relevant literature, we found that the four specimens cited in Pusalkar and Singh (2015) all represented *S. ciliolata* rather than *S. glanduligera*. The collection *J.D. Hooker 11* was actually the type of *S. ciliolata* (Edgeworth & Hooker, 1874), and the two specimens K000742194 and GH00353887 had been designated as the lectotype and isolectotype of *S. ciliolata*, respectively, by Sadeghian et al. (2015). The last specimen K000742195 (*J.F. Duthie 2760*, Fig. 1B) collected from Kumaun actually doesn't share the same collector, collection number and locality with the other three specimens cited in Pusalkar and Singh (2015).

It is therefore obvious that the lectotypification of *Shivparvatia glanduligera* by Pusalkar and Singh (2015) is problematic, thus a re-lectotypification of this species should be conducted. The basionym of *S. glanduligera*, viz. *Arenaria glanduligera*, was published based on three specimens: *H. Falconer s.n.* (K000742189, Fig. 2); *J.D. Hooker s.n.* (K, Fig. 3); *R. Strachey & J.E. Winterbottom s.n.* (K, Fig. 4) (Edgeworth and Hooker 1874). We therefore reselected one specimen from the syntypes of *S. glanduligera* as its lectotype. As only the specimen *H. Falconer s.n.* has been assigned a barcode number (K000742189), it is therefore selected.

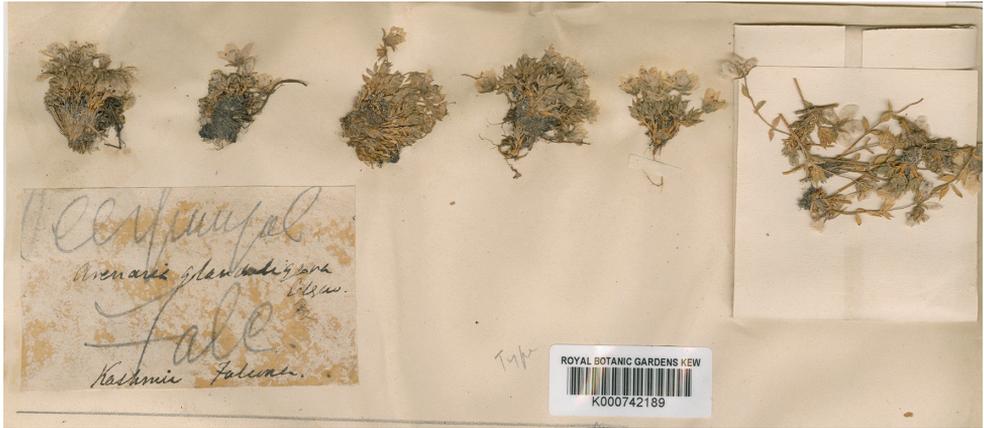


Figure 2. Lectotype of *Shiwparvatia glanduligera* (Edgew.) Pusalkar & D.K. Singh from Kashmir (*H. Falconer s.n.*, K000742189).

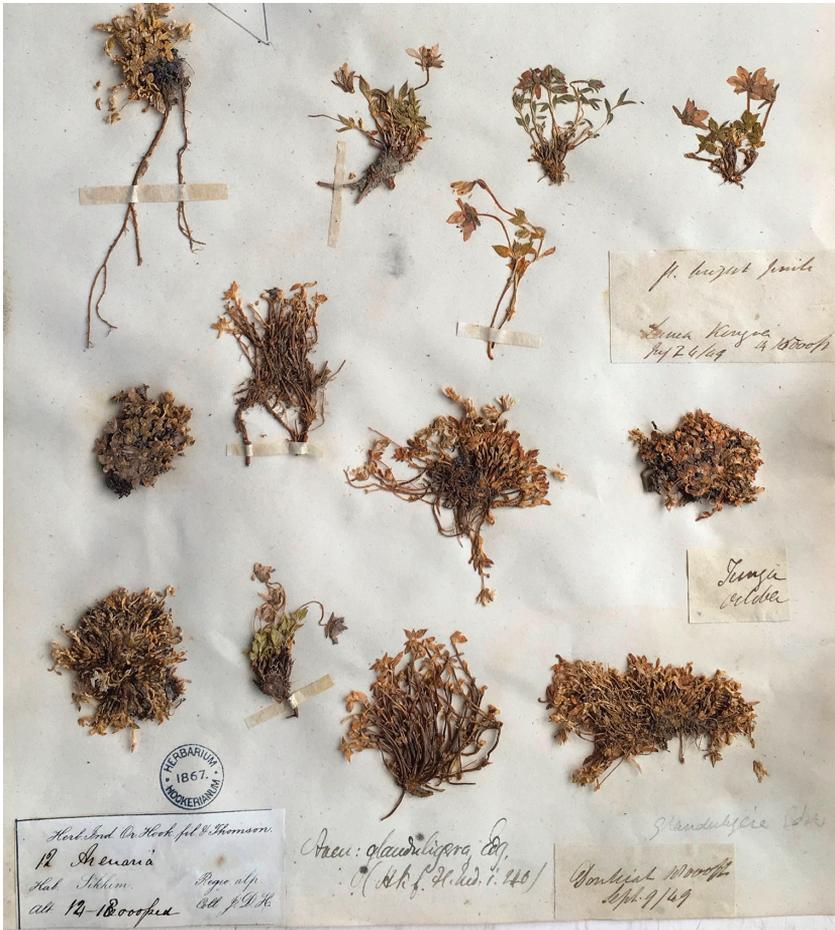


Figure 3. Syntype of *Shiwparvatia glanduligera* (Edgew.) Pusalkar & D.K. Singh from Sikkim (*J.D. Hooker s.n.*, K).

Typification

Shivparvatia glanduligera (Edgew.) Pusalkar & D.K. Singh, *Jpn. Bot.* 90: 84. 2015
Figs 2–4

≡ *Arenaria glanduligera* Edgew. in Edgew. & Hook. f., *Fl. Brit. India* 1: 240. 1874.

Type. Lectotype (designated here): Kashmir, *H. Falconer s.n.* (K000742189, Fig. 2); Remaining syntypes: INDIA. Interior of Sikkim, 14,000–18,000 ft, *J.D. Hooker s.n.* (K, Fig. 3); Kumaon, Barji Kang pass, 14,500 ft, *R. Strachey & J.E. Winterbottom s.n.* (K, Fig. 4).

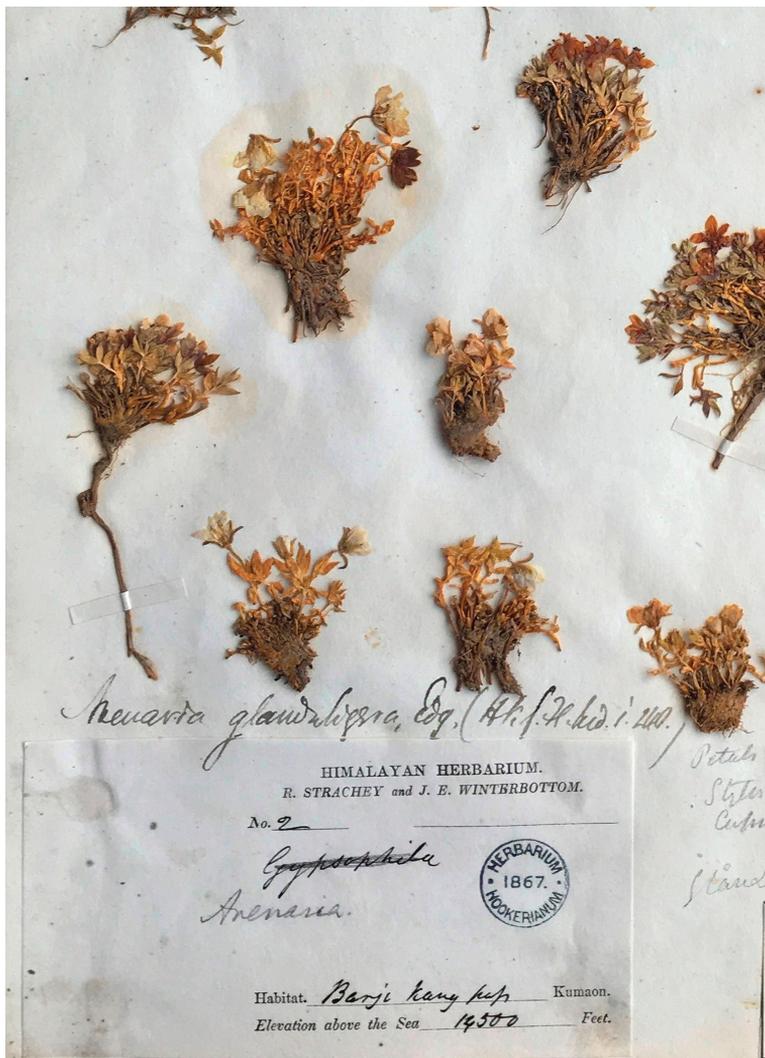


Figure 4. Syntype of *Shivparvatia glanduligera* (Edgew.) Pusalkar & D.K. Singh from Kumaon (*R. Strachey & J.E. Winterbottom s.n.*, K).

Note. Morphologically, *S. glanduligera* can be easily distinguished from *S. ciliolata* by its glandular pubescence, prominent disc gland, not pure white and usually violet petals, and scarious sepal margin. In contrast, the latter is characterized by its ciliate pubescence, small disc gland, entirely pure white petals, and thickened sepal margin (Wu et al. 2001; Pusalkar and Singh 2015).

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