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Research Article

Melanoseris penghuana (Lactucinae, Cichorieae, Asteraceae), a new species from North-central Yunnan, China

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Abstract

In this paper, we describe a new species, *Melanoseris penghuana*, from Mt. Jiaozi Xueshan located in North-central Yunnan, China. Despite its morphological similarities to *M. likiangensis*, *M. penghuana* exhibits distinct differences in leaf texture, shape of terminal lobes, indumentum of leaves, peduncles, and involucres, as well as the length of the achenes. Additionally, the conservation status of this species is classified as Vulnerable through data analysis from two field surveys.

Key words: *Melanoseris likiangensis*, morphology, Mt. Jiaozi Xueshan, new taxon, taxonomy

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Introduction

The genus *Melanoseris* Decne. was initially established with only two species (Decaisne 1843). Later, Edgeworth (1846) expanded the genus to include seven species. However, the genus name remained unused by subsequent taxonomists for more than 165 years until Kilian reinstated its usage during the compilation of the Flora of China (Shih and Kilian 2011). As a result, numerous species within this genus were reassigned to other genera, such as *Lactuca* L., *Cicerbita* Wallr., *Prenanthes* L., *Cephalorrhynchus* Boiss., *Mulgedium* Cass., *Chaetoseris* Shih, and *Stenoseris* Shih, during this period of absence (Shih 1991, 1997; Zhu 2004; Zhu et al. 2004, 2006; Bano 2009; Bano and Qaiser 2009, 2010; Deng et al. 2011), making the delineation of species within this genus a challenging task. With the continuous in-depth research by taxonomists in recent years (Zhu 2004; Zhu et al. 2004, 2006; Kilian et al. 2009, 2017; Wang et al. 2009; Deng et al. 2011; Shih and Kilian 2011; Zhang et al. 2011; Wang et al. 2013, 2015, 2020; Abid et al. 2017; Ghafoor et al. 2017; Yin et al. 2018; Zhong et al. 2023), the species range of this genus has been gradually clarified. Currently, *Melanoseris* is the largest genus in the subtribe Lactucinae occurring in China, with a total of 20 species mainly distributed in the Pan-Himalayan region (Wang et al. 2013, 2015, 2020; Yin et al. 2018; Zhong et al. 2023).

During a field survey of Mt. Jiaozi Xueshan in 2021, we discovered a species of *Melanoseris* growing on the steep slopes on both sides of the Jiulonggou valley. It had large leaves, and the terminal lobes of leaves were extremely elongated, which caught our attention. Subsequent in-depth research confirmed that it may be an unpublished species of *Melanoseris*. To test the stability of its elongated terminal lobes, we conducted another field investigation in 2022 to examine its plant's morphological variation and population size. The results of the investigation showed that the unique terminal lobes were a stable characteristic within the population. Further morphological studies and analysis revealed both similarities and distinct differences between this plant and *M. likiangensis* (Franchet) N.Kilian & Ze H.Wang. Based on these findings, the authors reached the conclusion that this plant represents a newly identified species, which is comprehensively described and illustrated in this study.

Material and methods

To conduct the morphological description of the new species, we observed and photographed live plants in the field. Additionally, we utilized herbarium collections (KUN, GTZM) from these occasions. For morphological comparative analysis, we referred to the keys of the genus and descriptions of the species in Flora Reipublicae Popularis Sinicae (Shih 1997) and Flora of China (Shih and Kilian 2011). To facilitate further comparisons, we examined the protologue of *M. likiangensis* (Franchet 1895), as well as the specimen photographs in the herbaria IBSC, E, K, KUN, P, and PE. The morphology of trichomes and pappus, as well as the length of ligules, anther tubes, and achenes, were observed or measured using an anatomy microscope (OD500H) or a light microscope (Olympus DP72) on fresh or dried specimens. The classification of trichomes in this study followed Ramayya's classic treatment of trichomes on Compositae (Ramayya, 1962). Photographs were taken using a Canon EOS 77D and a Dell E2014Hf camera. Figures were edited, arranged, and merged using Adobe Illustrator CS4. Additionally, a distribution map was generated with QGIS 3.32.2.

Results

Taxonomy

***Melanoseris penghuana* Ze H.Wang & H.J.Dong, sp. nov.**
urn:lsid:ipni.org:names:77335477-1
Figs 1, 2

Type. China, Yunnan Province, Kunming City, Dongchuan District, Mt. Jiaozi Xueshan, Jiulonggou, 26°09.95'N, 102°54.83'E, alt. 3269 m, 12 Oct 2022, *Tian Qin et al.* 20221001 (holotype: KUN1584358!, isotypes: KUN1584356, 1584357!, GTZM0220112, 0220113!).

Diagnosis. *Melanoseris penghuana* is most similar to *M. likiangensis*, but differs from the latter primarily in the following characteristics: leaves thick papery (vs. papery), clearly hairy (vs. glabrous or sparsely hairy), terminal lobes of basal and lower leaves elongated triangular (vs. broad triangular), the length 3–4 times (vs. 1–1.5 times) that of the width; peduncles covered with simple

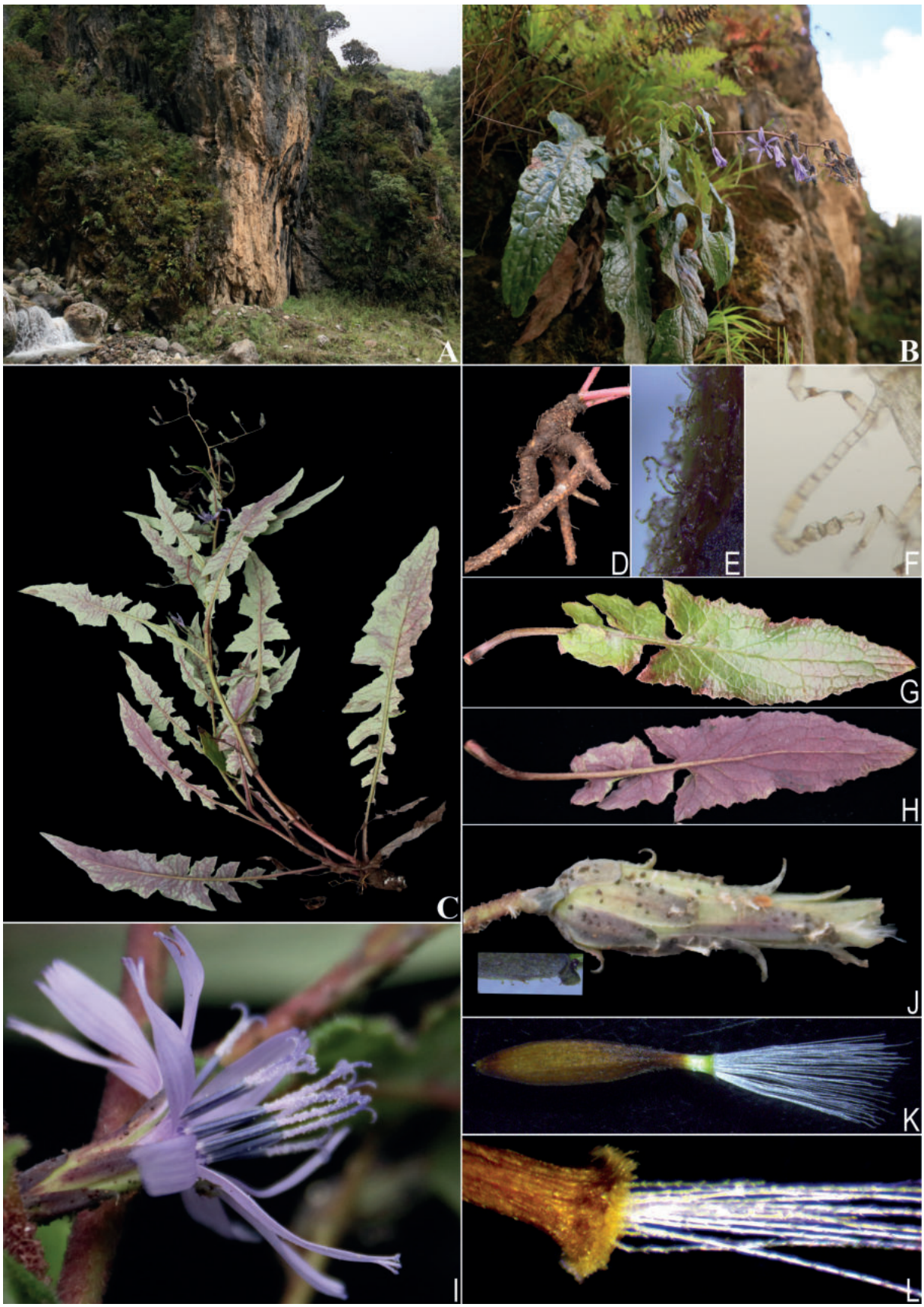

Figure 1. *Melanoseris penghuana* sp. nov. **A** habitat **B**, **C** plants **D** root **E** trichomes on the peduncle under an anatomy microscope **F** trichomes on the peduncle under a light microscope (simple filiform hairs) **G, H** basal leaves **I** capitulum **J** involucre **K** achene **L** pappus. Photographed by Qin Tian.

filiform hairs (vs. multiseriate capitate glandular hairs), involucres glabrous (vs. glandular hispid), achenes ca. 9.5 mm (vs. ca. 7 mm).

Description. Perennial herbs, 30–55 cm tall. Roots fleshy 0.5–1.5 cm in diameter, cylindrical, branched. Stems 1–2, emerging from the apex of a rhizome, erect, with a basal diameter of 3–4 mm, apically branched, covered with simple filiform hairs, especially at the apex. Basal leaves 24–40 × 4–9 cm, thick papery, elongated and narrowly elliptic, lyrately pinnatipartite; terminal lobes 10–18 × 4–8 cm, elongated triangular, apical acuminate to long acuminate; lateral lobes 2–5 pairs, 0.7–5 × 0.4–3 cm, inverted triangular, widest at base. Petioles 2–9 cm long, sparsely pubescent. Lower and middle stem leaves 11–23 × 3–5 cm, like basal leaves but smaller, lyrately pinnatipartite; terminal lobes 5–13 × 2–4 cm, elongated triangular, apex long acuminate; lateral lobes 3–4 pairs, 0.5–3 × 0.3–2 cm, inverted triangular. Petioles 1–2 cm long, narrowly winged, basally widened and clasping. Upper stem leaves like middle stem leaves but smaller, with a shorter petiole conspicuous winged and auriculately clasping. Uppermost leaves lanceolate, less divided or entire. All the leaves clearly covered with simple filiform hairs on both surfaces, especially on the veins; margins coarsely dentate, green adaxially, usually purplish-red abaxially. Capitulescence racemiform to narrowly paniculiform; peduncles clearly covered with simple filiform hairs, bracts few, inconspicuous, scale-like. Capitula few, pendulous, with 10–12 florets. Involucre 1.6–1.9 × 0.5 cm, cylindrical, dark purplish green, glabrous. Phyllaries imbricate, 4–5-seriate, with apex acute to acuminate, conspicuously reversed; outer phyllaries 2–3 × 1 mm, triangular ovate, margin occasionally with a few transparent protrusions; middle phyllaries 7–10 × 2–3 mm, long ovate; innermost phyllaries 8, 16–19 × 2 mm, narrowly lanceolate. Florets ligulate, tube ca. 4 mm long, light purple, ligules ca. 12 × 1.5 mm, 5-toothed at the apex, purple. Stamens synantherous, anther tube 5.0–5.2 mm long, dark purple. Ovary inferior, flattened, ellipsoid, style ca. 16 mm long, apically bifid, stigmatic braches ca. 1.2 mm long, long and acuminate, evenly coated with elongate collection hairs. Achenes 10 × 2 mm, fusiform, dark brown, each side with 3 raised longitudinal ribs, surface sparsely hairy, and apex contracted into a 3 mm beak, beak discolorous, with the top half being white. Pappus 2-seriate, white, outer seriate 0.1–0.2 mm, inner seriate ca. 7 mm long, finely serrated.

Distribution and habitat. *Melanoseris penghuana* is currently observed growing on steep grassy slopes along the valley edge of Jiulonggou, Mt. Jiaozi Xueshan, at an elevation of approximately 3200 m (Fig. 3). The companion plants mainly include *Youngia mairei* (H.Léveillé) Babcock et Stebbins (Asteraceae), *Saxifraga filicaulis* Wallich ex Seringe (Saxifragaceae), *Silene delavayi* Franchet (Caryophyllaceae), *Rubus delavayi* Franchet (Rosaceae), *Lilium sempervivoideum* H.Léveillé (Liliaceae), *Oreocharis mairei* H.Léveillé (Gesneriaceae) etc.

Phenology. Flowering and fruiting from September to October.

Etymology. The specific epithet "*penghuana*" is named in honor of Professor Hua Peng, a renowned expert in plant taxonomy in China, for his outstanding contributions to the protection of Mt. Jiaozi Xueshan.

Vernacular name. Simplified Chinese:彭氏毛鳞菊; Chinese Pinyin: Péngshì Máolínjú.

Conservation status. *Melanoseris penghuana* is found distributed along the steep grassy slopes on both sides of the Jiulonggou valley in Mt. Jiaozi Xueshan, Yunnan Province. In 2021 and 2022, the authors discovered three subpopula-

Figure 2. A morphological comparison between *Melanoseris penghuana* and *M. likiangensis* **A1–A6** *M. penghuana*: **A1** basal leaves **A2** trichomes on the peduncle under an anatomy microscope **A3** simple filiform hairs on the leaves under a light microscope **A4** capitulum **A5** involucre **A6** achene **B1–B6** *M. likiangensis*: **B1** basal leaves **B2** trichomes on the peduncle under an anatomy microscope **B3** multiseriate capitate glandular hairs on the leaves under a light microscope **B4** capitulum **B5** involucre **B6** achene. Scale bars: 2 mm. **A1–A2, A4, A5** were photographed by Qin Tian, others were photographed by Ze-Huan Wang.

tions; each of them had a considerable number of flowering plants and seedlings with only rosette leaves. Preliminary estimates suggest that there are more than 250 mature individuals. Although the current survey indicates that the distribution of *M. penghuana* is relatively concentrated, it is worth noting that its distribution areas are located within the Jiaozi Xueshan National Nature Reserve, where human disturbance is minimal. As a result, its habitat is relatively well protected. Thus, based on its very restricted population and the number of mature individuals estimated to be larger than 250 but fewer than 1000 (IUCN 2012, 2022), this new species should be classified as Vulnerable (VU; criteria D1).

Additional specimens examined. China, Yunnan Province, Kunming City, Dongchuan District, Mt. Jiaozi Xueshan, Jiulonggou, 26°9.97'N, 102°54.92'E, alt. 3279 m, 6 Oct 2021, Dong Hong-Jin et al. D634 (KUN1584359!, GTZM0220114!); ibid, 26°09.95'N, 102°54.87'E, alt. 3281 m, 12 Oct 2022, Tian Qin et al. 20221002 (KUN1584360!, GTZM0220115!).

Discussion

Melanoseris likiangensis is an endemic species found in Northwest Yunnan, China (Fig. 3). Most of its specimens were collected several decades ago. Currently, there are still unresolved issues regarding the classification of *M. likiangensis*. For example, among the specimens defined as *M. likiangensis*, there are two types of inner involucral bracts: some have 5 bracts while others have 8 bracts. Furthermore, there is no consensus yet on whether *M. bonatii* (Beauverd) Ze H.Wang, a species found in Northeastern Yunnan, is conspecific with *M. likiangensis*. Resolving these taxonomical issues necessitates more specimen studies and specialized field investigations. To accurately compare the morphological characteristics of *M. penghuana* and *M. likiangensis*, we consulted the original description of *M. likiangensis* in the protologue (Franchet 1895). The main morphological differences between these two species are detailed in Table 1.

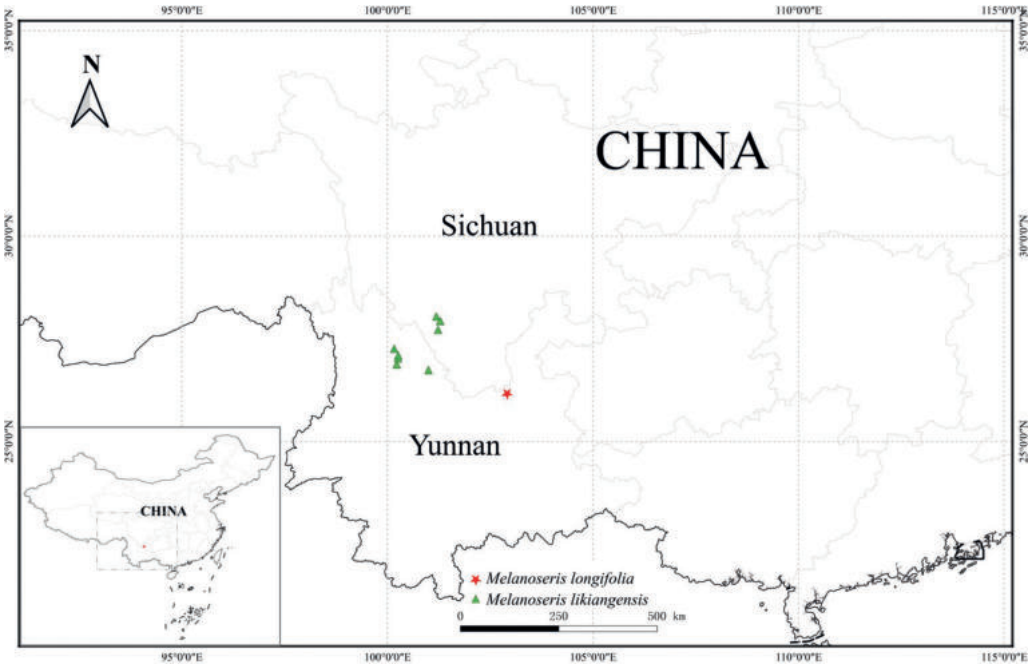

Figure 3. Distribution map of *Melanoseris penghuana* and *M. likiangensis*.

Table 1. Comparison of the morphological characteristics between *Melanoseris penghuana* and *M. likiangensis*.

Characteristics	***M. penghuana***	***M. likiangensis***
Leaf texture	thick papery	papery
Terminal lobes of basal and lower leaves	elongated triangular, ca. 7–19 cm, the length is 3–4 times that of the width, apical acuminate to long acuminate	broad triangular, ca. 7 cm, the length is 1–1.5 times that of the width, apical acuminate to acute
Leaves trichomes	all the leaves clearly covered with simple filiform hairs on both surfaces, especially on the abaxially veins	all the leaves typically glabrous on both surfaces, with the occasional presence of sparsely distributed multiseriate capitate glandular hairs adaxially
Peduncles trichomes	simple filiform hairs	multiseriate capitate glandular hairs
Involucres	glabrous, margin occasionally with a few transparent protrusions	the middle vein of outer and middle phyllaries has one row of multiseriate capitate glandular hairs outside
Achenes	ca. 9.5 mm	ca. 7 mm

The continuity of a new species' population often receives significant attention from taxonomists. In the case of *Melanoseris penghuana*, the expansion of its population is influenced by a combination of unfavorable and favorable factors. One of the unfavorable factors is the relatively low number of head inflorescences on each plant, and what's worse, there are only 10–12 florets per inflorescence. Furthermore, the author observed that the inflorescences of this species, similar to *Sinoseris muliensis* (Y.S.Chen, L.S.Xu & R.Ke) Ze H.Wang, N.Kilian & H.Peng (Wang et al. 2020) and *M. kangdingensis* Ze H.Wang (Zhong et al. 2023), are susceptible to parasitism by certain insects. These factors contribute to a lower quantity of seeds produced by *M. penghuana* plants.

On the other hand, there are several favorable factors contributing to the expansion of the *Melanoseris penghuana* population. Firstly, the species is distributed in the Jiaozi Xueshan National Nature Reserve, where the habitat is relatively well-protected. Secondly, the recent relocation of residents from Jiulonggou Village has reduced human disturbance in the area where *M. penghuana* grows. Thirdly, based on the field survey conducted by the authors in 2022, the population of *M. penghuana* is relatively large and not as endangered as many other recently discovered plants (Ma et al. 2019; Huang et al. 2020; Qiu et al. 2020; Nong et al. 2021). Lastly, compared with the recently published *M. kangdingensis* (Zhong et al. 2023), the growing environment of *M. penghuana* is also steep, but the soil layer of its habitat is relatively well-developed. Therefore, the probability of successful seed germination of *M. penghuana* after landing is much higher than that of *M. kangdingensis*.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

The collection of *Melanoseris penghuana* specimens mentioned in this article has been permitted by the management authority of the conservation area.

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Author contributions

Conceptualization: ZW. Data curation: JX, ZW. Formal analysis: JX. Funding acquisition: HD, ZW. Investigation: HD, QT. Methodology: LC, QZ. Project administration: ZW. Resources: QT. Software: LC, QZ. Supervision: ZW. Validation: ZW. Visualization: QZ. Writing – original draft: JX. Writing – review and editing: ZW, HD.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Research Article

Resurrection of *Perilimnastes* (Sonerileae, Melastomataceae) with description of a new species *P. nana*

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Abstract

Recent research has indicated that the *Phyllagathis* (raphides) clade (Sonerileae, Melastomataceae) is only distantly related to the type of *Phyllagathis* and should be separated as a distinct genus. Phylogeny of this clade is here reconstructed with expanded taxon sampling. Four strongly supported subclades have been identified. The possible affinities of taxa that were not sampled in the analysis are discussed, based on morphological data. *Perilimnastes* is resurrected as the generic name of the *Phyllagathis* (raphides) clade. A generic description, colour figures, map of distribution, a list of included species and a key are provided for *Perilimnastes*. Fifteen new combinations are made plus the description of a new species. As interpreted here, *Perilimnastes* consists of twenty species and two varieties.

Key words: Melastomataceae, *Perilimnastes*, *Phyllagathis*, taxonomy

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Introduction

The genus *Perilimnastes* Ridl. was initially established based on *P. fruticosa* (Ridl.) Ridl. (Ridley 1918, 1922). Nayar (1974) followed Ridley's concept of *Perilimnastes* and described a second species in the genus, namely *P. rupicola* M.P.Nayar. The two species show clear similarities in the morphology of leaves, calyx lobes, stamens, and capsules. However, subsequent authors did not recognise *Perilimnastes* (Maxwell 1982, 1989; Cellinese 2002, 2003). Both species are currently treated in a broadly defined *Phyllagathis* Blume. Previous molecular phylogenetic studies have revealed the polyphyletic nature of *Phyllagathis* (Zeng et al. 2016; Zhou et al. 2018; Zhou et al. 2019a, b, c; Liu et al. 2022; Zhou et al. 2022). The species currently treated under *Phyllagathis* were found to be nested within 17 lineages of Asian Sonerileae (Liu et al. 2022; Zhou et al. 2022). Although *P. fruticosa*, the generic type of *Perilimnastes*, was not sampled in these studies, species that are quite similar to it were identified as belonging to the *Phyllagathis* (raphides) clade. Members of this clade are often shrubs or shrublets with cuneate to rounded leaf bases, umbellate or cymose inflorescences (sometimes reduced to a single flower), isomorphic stamens, dorsally spurred connectives, crowned capsules, horned placental column and thready

placentas. Some of them (Fig. 1) are also characterised by the presence of raphide crystals in various parts of the plant. Based on these diagnostic features as well as strong resemblance between sampled and unsampled species, Zhou et al. (2022) estimated that the *Phyllagathis* (raphides) clade might contain 20 species in southernmost China, Vietnam, the Malay Peninsula and Borneo. This clade should be removed from *Phyllagathis* and treated as a distinct genus, since it is only remotely related to the type of *Phyllagathis*. As a result, *Perilimnastes* should be re-instated as the generic name (Zhou et al. 2022).

This work aims to formalize the taxonomic treatment of the *Phyllagathis* (raphides) clade. To this end, we reconstructed the phylogeny of this clade with expanded taxon sampling, using a nuclear genomic dataset assembled by mapping the genome resequencing reads to the draft genome of *Bredia hirsuta* Blume. We also discussed putative affinities based on morphological data for species that were not sampled in the phylogenetic analysis. *Perilimnastes* is resurrected as the generic name of the *Phyllagathis* (raphides) clade. A generic description, colour figures, map of distribution, a list of included species and a key are provided for *Perilimnastes*. Fifteen new combinations are made plus the description of a new species from southern China. *Perilimnastes*, as we here delimit it, now consists of twenty species and two varieties.

Methods

Phylogenetic reconstruction

For phylogenetic reconstruction of the *Phyllagathis* (raphides) clade, ingroups and outgroup were selected according to the genomic tree of Sonerileae (Zhou et al. 2022). We sampled 36 accessions from Sonerileae, including 16 species from the *Phyllagathis* (raphides) clade, as well as species of *Phyllagathis* [including the generic type *P. rotundifolia* (Jack) Blume], *Styrophyton* S.Y.Hu, *Bredia* Blume, *Fordiophyton* Stapf, *Blastus* Lour., *Kerriothyrsus* C.Hansen, *Cyphotheca* Diels, *Plagiopetalum* Rehder and *Sporoxeia* W.W.Sm. (Suppl. material 1: table S1).

For DNA extraction, library preparation, whole genome resequencing and quality control of the raw reads, methods employed in this study followed the protocols outlined in Zhou et al. (2022). The genomic single nucleotide polymorphism (SNP) dataset was assembled by mapping the genome resequencing data to the draft genome of *Bredia hirsuta*, which can be accessed at https://doi.org/10.17632/s85vv6yyjs.1. High-quality reads were mapped to the reference genome using BWA-MEM (Li and Durbin 2010). SNPs and short insertions/deletions (InDels) were identified using HaplotypeCaller in GATK v.4.1.8.1 (McKenna et al. 2010) under the GVCF mode for each sample separately. Next, we conducted hard filtering to minimise false positives by applying the following parameters: (1) QUAL < 30.0; (2) DP < 15.0; (3) QD < 2.0; (4) FS > 60.0; (5) MQ < 50.0; (6) SOR > 3.0; (7) MQRankSum < -12.5; (8) ReadPosRankSum < -8.0; (9) InbreedingCoeff < -0.5. VCFtools v.0.1.16 (Danecek et al. 2011) is used to exclude SNPs with a missing rate exceeding 15% and those with minor allele frequencies (MAF) below 0.05. The SNPs obtained were pruned, based on their linkage disequilibrium (LD) patterns using the –indep-pairwise option in PLINK (Purcell et al. 2007). Only one SNP was retained for each SNP pair with an r^2 value above 0.5 within a sliding window of 50-SNPs (advanced by 5 SNPs each).

Maximum Likelihood analysis of the genomic dataset was performed using a partitioned approach in IQ-TREE v.2.0.3 (Nguyen et al. 2015). *Phyllagathis rotundifolia* was designated as the outgroup taxon. The selection of best fitting substitution model was conducted using ModelFinder (Kalyaanamoorthy et al. 2017) based on the Bayesian Information Criterion (BIC). The genomic dataset was partitioned into bins of equal length, each containing 2,000 SNPs. TVMe+ASC+R2 was selected as the best fitting substitution model for all partitions. Node support was accessed using 1000 replicates of the UFBS and SH-aLRT test.

Morphological comparison

Morphological data were obtained through fieldwork, herbarium records, literature survey and observation of living plants in the facilities of Sun Yat-sen University. We examined specimens or their high-resolution photos of the relevant species from the following herbaria: A, BM, C, E, G, GXMI, IBSC, IBK, K, KUN, NY, P, PE, SYS and US. Species delimitation mainly followed Chen (1984a), Hansen (1992), Cellinese (2002, 2003) and Chen and Renner (2007).

Results and discussion

Phylogenetic relationships

After SNP filtering and pruning, the genomic dataset contained 2,412,522 SNPs, 1,667,363 of which were parsimony informative, with 26.46% of missing data (available at http://doi.org/10.17632/g9yjn97kns.2). The partitioned genomic ML tree was presented in Fig. 1. All nodes in the tree received full support (SH-aLRT test = 100%, UFBS = 100%), except for five nodes (Fig. 1).

Four well-supported lineages were identified within the *Phyllagathis* (raphides) clade, but relationships amongst them were only moderately supported (SH-aLRT test = 100%, UFBS = 92%; SH-aLRT test = 100%, UFBS = 92%). Subclade 1 contains *Perilimnastes multisepala* J.H.Dai, T.V.Do & Ying Liu from central Vietnam, *Phyllagathis setotheca* H.L.Li from southern China and a new species from Guangdong, China, namely *Perilimnastes nana* C.Y.Zou & Ying Liu. The three species are characterised by large flowers (> 20 mm in diameter), large anthers (> 8 mm long) and the presence of druses (instead of raphides). Subclade 2 consists of two species from Hainan Island, China [*Phyllagathis stenophylla* (Merr. & Chun) H.L.Li and *P. melastomatoides* (Merr. & Chun) W.C.Ko] and two from central Vietnam (*P. suberalata* C.Hansen and *P. sessilifolia* C.Hansen). Species in this subclade varied in the morphology of leaves and flowers, but they all have druses and yellow connectives that produced into a collar at the anther base. Subclade 3 comprises two species from Borneo [*Phyllagathis dispar* (Cogn.) C.Hansen and *P. elliptica* Stapf] and three newly-published species from central and southern Vietnam (*Perilimnastes setipetiola* J.H.Dai, T.V.Do & Ying Liu, *P. uniflora* J.H.Dai, T.V.Do & Ying Liu and *P. banaensis* J.H.Dai, T.V.Do & Ying Liu). These species are morphologically quite different, yet all of them have raphide crystals, somewhat elliptic leaf blade and at least some have terminal and axillary umbels with very short or no peduncles. Subclade 4 consists of five taxa mainly distributed in southern China, viz. *Phyllagathis deltoidea* C.Chen, *P. elegans* Hai L.Chen, Yan

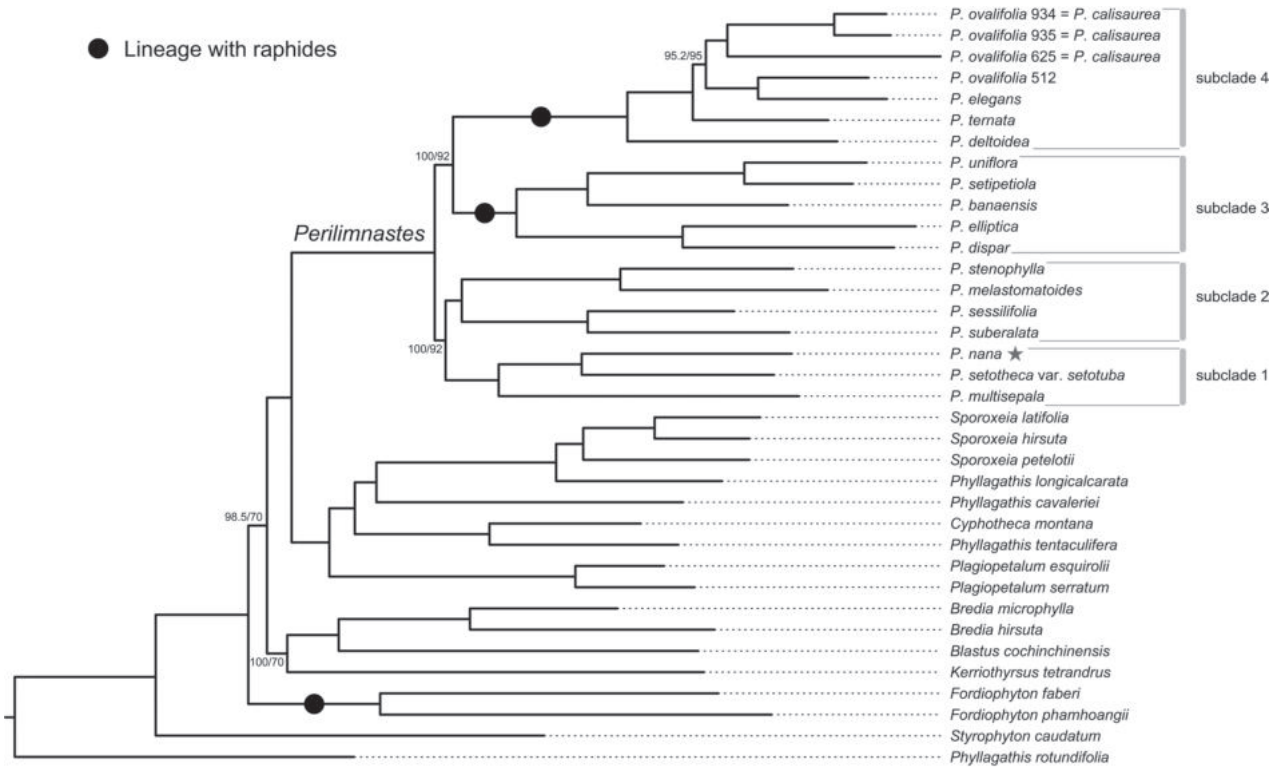

Figure 1. The partitioned Maximum Likelihood (ML) phylogenetic tree inferred from the genomic SNP dataset using IQ-TREE, showing the four subclades within *Perilimnastes* [*Phyllagathis* (raphide) clade]. For the nodes without full support, values from SH-aLRT test (left) and ultrafast bootstrap (right) are given at the nodes. The new species is indicated with a star. Lineages with raphides are noted with solid circles.

Liu & Ying Liu, *P. ternata* C.Chen, *P. ovalifolia* H.L.Li and *P. calisaurea* C.Chen (currently synonymised under *P. ovalifolia*). These species have raphides and share obvious similarities in the inflorescences with 1–3.5 cm long peduncles and purple anthers with a short dorsal spur and without ventral appendages. Zhou et al. (2022) found that the crystal type exhibits the lowest level of homoplasy amongst 14 characters they tested. The shift from druses to raphides took place on only three occasions within Asian Sonerileae (Zhou et al. 2022), one in *Fordiophyton* and two in two subclades of the *Phyllagathis* (raphides) clade. The presence of raphides, therefore, is a useful diagnostic character for these lineages.

Species without molecular data

Perilimnastes fruticosa, *Phyllagathis guillauminii* H.L.Li, *Phyllagathis brookei* M.P.Nayar and *Perilimnastes rupicola* M.P.Nayar, four putative members of the *Phyllagathis* (raphides) clade, have never been included in phylogenetic studies. Nevertheless, they can be easily referred to specific lineages within this clade, based on compelling morphological evidence. *Perilimnastes fruticosa* from the Malay Peninsula closely resembles *P. multisepala* from subclade 1 and *P. stenophylla* and *P. suberalata* from subclade 2. The four species are shrubs characterised by somewhat oblong-lanceolate, 3-veined leaf blades, few-flowered inflorescences, narrow calyx lobes and the presence of druses. Moreover, they grow in similar habitats, specifically on rocks along streams in dense forests. *Perilimnastes fruticosa* is possibly a member of subclade 1 or subclade 2.

Raphides have been found in the tissues of *P. guillauminii* (southern Vietnam), *P. brookei* (Borneo) and *P. rupicola* (Borneo). The three species can be confidently referred to subclade 3 since all Vietnamese and Bornean species with raphides were consistently recovered as members of this subclade in phylogenetic analyses (Zhou et al. 2022; this study). *Phyllagathis guillauminii* resembles *P. uniflora* from subclade 3 in 3-veined leaves with cuneate base and somewhat acuminate apex and narrow calyx lobes. The close relationships amongst *P. dispar*, *P. elliptica*, *P. brookei* and *P. rupicola* had been proposed by Cellinese (2003). Their caulescent and erect stems, small leaves, few-flowered umbels, as well as crystal type make them a distinct group that is morphologically very different from other Bornean species treated under *Phyllagathis* (Cellinese 2003).

Another species, *P. marumiaetricha* (Guillaumin) C.Hansen, was listed as a putative member of the *Phyllagathis* (raphides) clade by Zhou et al. (2022). It resembles *P. setotheca* from subclade 1 in the inflorescences with large basal bracts, petals and flowers. However, the huge leaves, distinctive hypanthial emergences and the peculiar sepals of this species readily distinguish it from members of the *Phyllagathis* (raphides) clade. As its generic affiliation remains to be further tested, no taxonomic treatment is proposed here.

Conclusion

Molecular phylogenetic data and morphological evidence support the *Phyllagathis* (raphides) clade as a distinct lineage encompassing species distributed in southernmost China, Vietnam, the Malay Peninsula and Borneo. *Perilimnastes* is, therefore, resurrected below as the generic name for this clade. For a comparison of *Perilimnastes* [the *Phyllagathis* (raphides) clade] and other lineages of Asian Sonerileae, please see table S9 in Zhou et al. (2022).

Taxonomy

Perilimnastes Ridl., J. Straits Branch Roy. Asiat. Soc. 79: 70. 1918, emend. Ying Liu

Type. *Perilimnastes fruticosa* (Ridl.) Ridl., J. Straits Branch Roy. Asiat. Soc. 79: 70, in obs. 1918; Ridley, Fl. Mal. Penins. 1: 773. 1922.

Description. Erect shrubs, erect/ascending shrublets or caulescent herbs, sometimes with raphides in many parts. Stems terete, obtusely 4-sided or ribbed, with uniseriate or multiseriate, appressed or spreading hairs, rarely glabrous. Leaves opposite, equal, subequal or unequal in a pair, petiolate, rarely sessile (in *P. sessilifolia*); leaf blades elliptic, ovate, elliptic-lanceolate, obovate, oblanceolate or suborbicular, submembranous, papery or stiffly papery, 3–7-nerved, base cuneate, acute, rounded, subcordate to broadly cordate, margin entire or inconspicuously serrulate or denticulate. Inflorescences usually terminal (rarely axillary) umbels subtended by two or more bracts, many- to few-flowered, sometimes reduced to a single flower. Flowers 4-merous; hypanthia ± campanulate, cup-shaped or funnel-shaped; calyx lobes triangular, ± attenuate to ligulate or linear; petals white, pink or purplish, obovate, ovate, oblong, or elliptic, more or less oblique, apex acute or acuminate; stamens 8, equal or subequal; anthers isomorphic, yellow, pinkish or purplish, narrowly ovate to lanceolate,

curved to ventral side, connectives ventrally inappendiculate and dorsally spurred, or basally forming a collar with two ventral auricles/lobes/ridges and a dorsal spur; ovary half inferior, ovoid, 4-celled, crown of four partly or fully connate lobes; style filiform. Old capsule cup-shaped, campanulate, quadrangular, crown persistent and enlarged, enclosing an obpyramidal space; placental column 4-horned; placentas thready. Seeds numerous, minute, cuneate. (Figs 2–4)

Distribution. Twenty species and two varieties, eight species (seven endemic) and two varieties in southernmost China (Guangdong, Guangxi, Hainan, Yunnan), eight (seven endemic) in Vietnam, one on the Malay Peninsula and four in Borneo (Fig. 5).

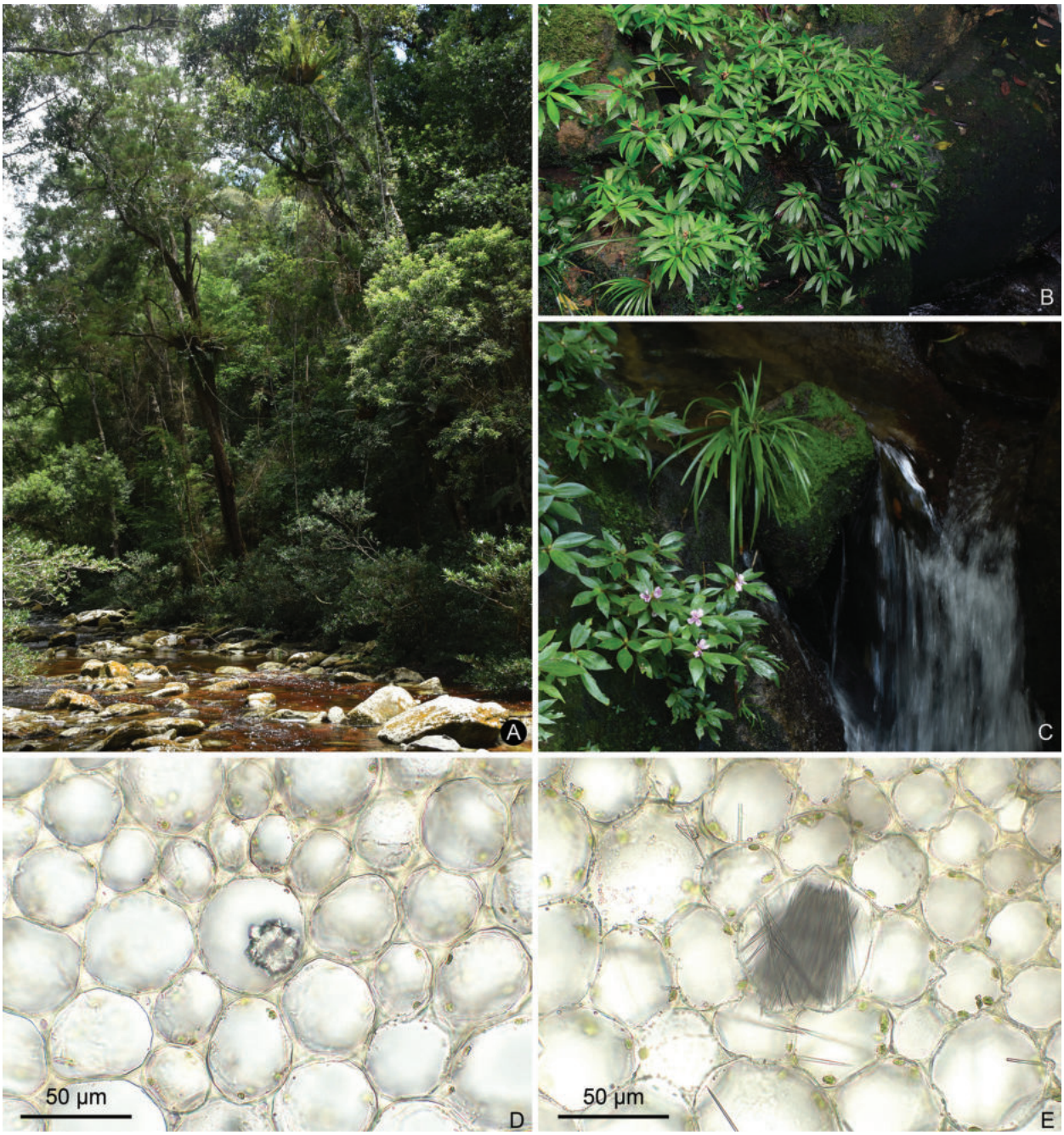

Figure 2. Habitat (**A–C**) and crystal type (**D, E**) of *Perilimnastes* **A** *P. stenophylla* **B** *P. elegans* **C** *P. melastomatoides* **D** druses of *P. multisepala* **E** raphides of *P. elegans*. Scale bars: 50 µm (**D, E**).

Figure 3. Flowering/fruiting branches of *Perilimnastes* **A** *P. deltoidea* **B** *P. elegans* **C** *P. elliptica* **D** *P. melastomatoides* **E** *P. stenophylla* **F** *P. suberalata*.

Species included in *Perilimnastes*

Perilimnastes banaensis **J.H.Dai, T.V.Do & Ying Liu, PhytoKeys 235: 14. 2023.**

Type. Vietnam. Đà Nẵng: Hòa Ninh, Ba Na Hills, 1,360 m elevation, in forests on damp slopes near steam, 22 Nov 2019, Jin-hong Dai and Ying Liu 813 (holotype: PE; isotypes: A, SYS, VNMN).

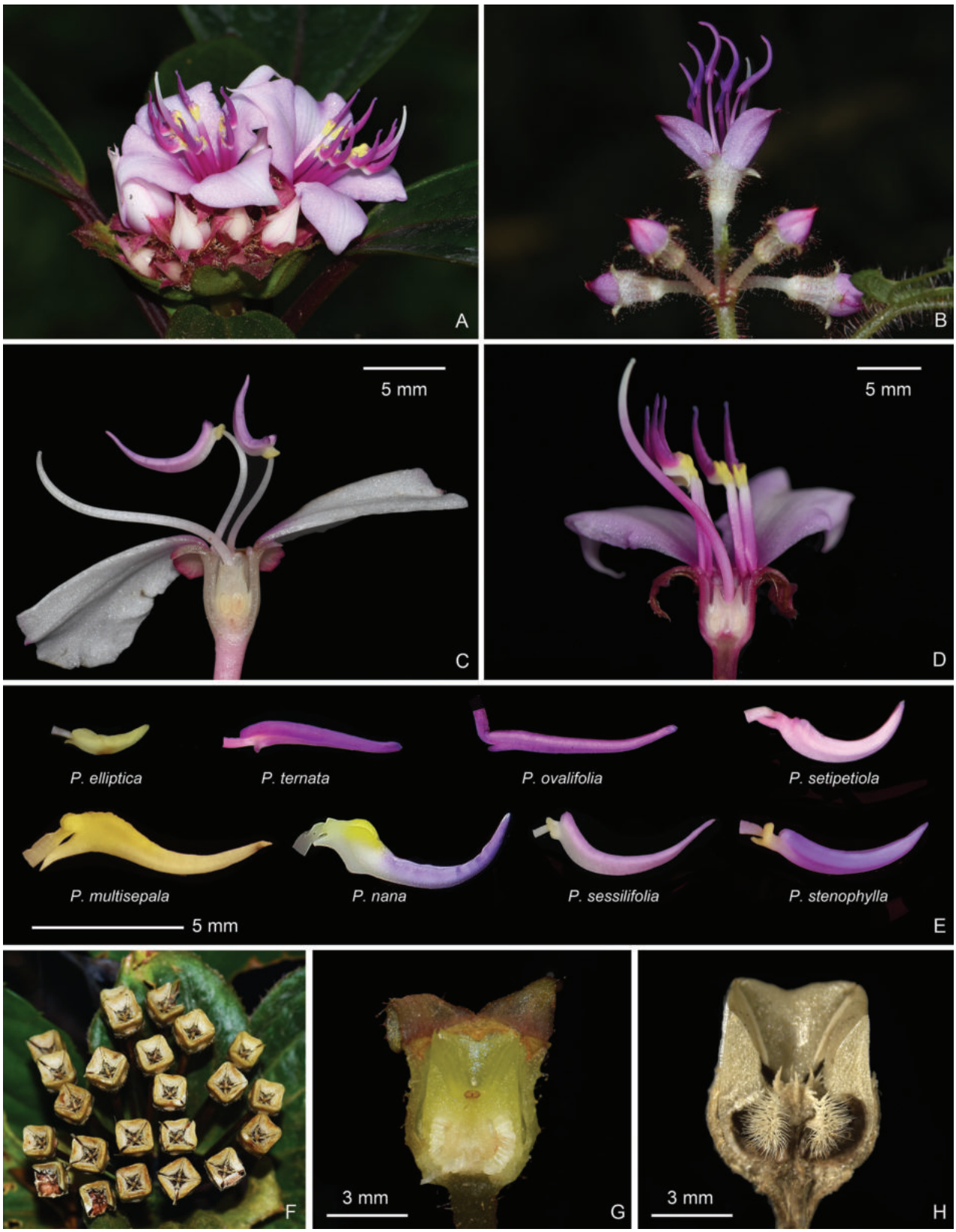

Figure 4. Inflorescence (**A, B**), longitudinal section of flower (**C, D**), anther morphology (**E**), infructescence (**F**), and longitudinal sections of young and old capsules (**G, H**) of *Perilimnastes* **A** *P. setotheca* **B** *P. ternata* **C** *P. sessilifolia* **D** *P. setotheca* **E** *P. elliptica*, *P. ternata*, *P. ovalifolia*, *P. setipetiola*, *P. multisepala*, *P. nana*, *P. sessilifolia* and *P. stenophylla* (from left to right and top to bottom) **F** *P. elliptica* **G** *P. ovalifolia* **H** *P. ovalifolia*. Scale bars: 5 mm (**C–E**); 3 mm (**G, H**).

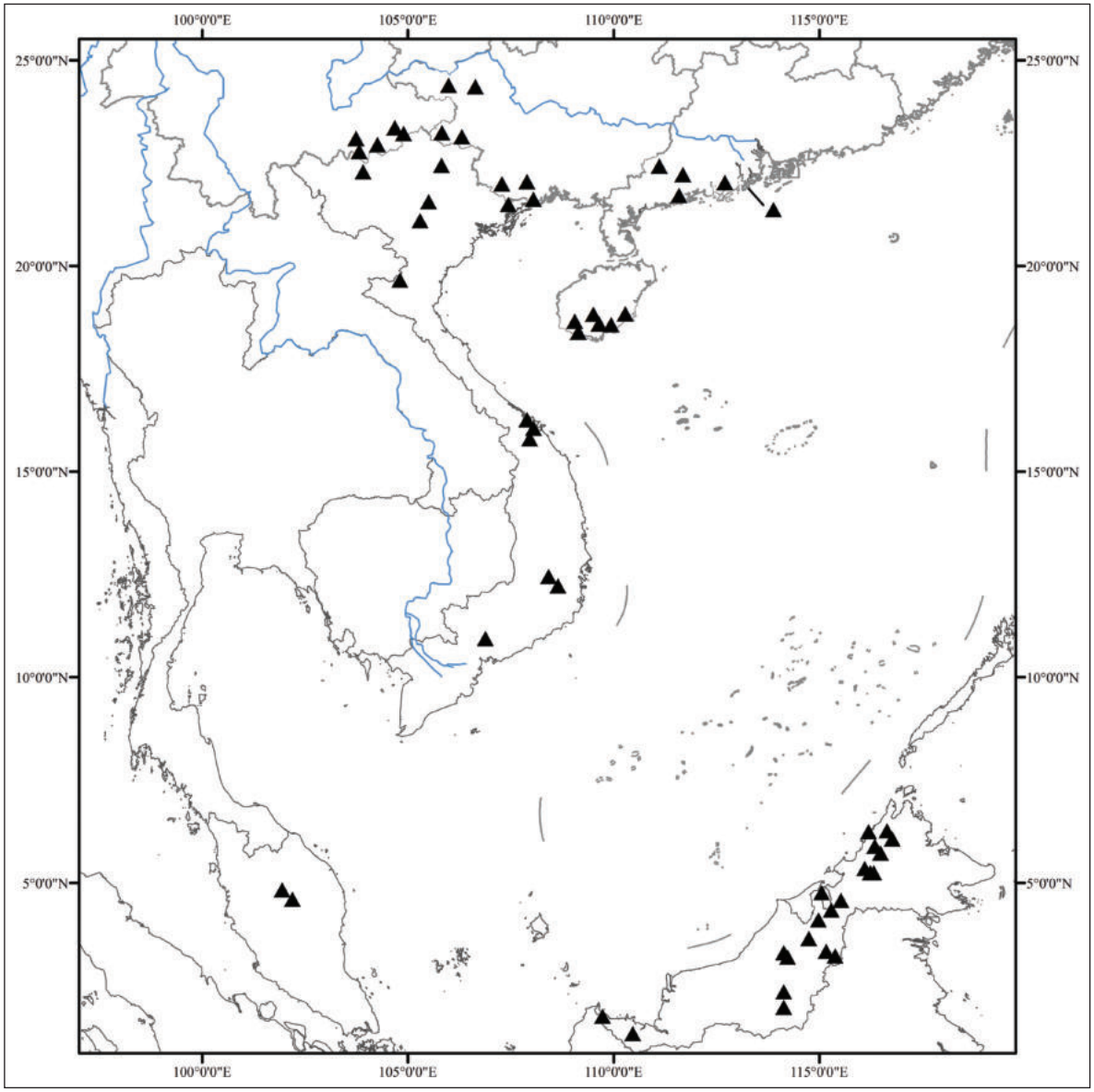

Figure 5. Distribution of *Perilimnastes*.

Perilimnastes brookei **(M.P.Nayar) Ying Liu, comb. nov.**
urn:lsid:ipni.org:names:77335505-1

Phyllagathis brookei M.P.Nayar, J. Jap. Bot. 51(8): 232. 1976 (Basionym). Type: Malaysia. Sarawak: Bilengki, Bakelalan, 16 Aug 1955, W.M.A Brooke 10416 (holotype: BM! [BM000019481]).

Perilimnastes deltoidea **(C.Chen) Ying Liu, comb. nov.**
urn:lsid:ipni.org:names:77335506-1

Phyllagathis deltoidea C.Chen, Bull. Bot. Res., Harbin 4(3): 48. 1984 [“deltoda”] (Basionym). Type: China. Guangxi: Ningming, Mingjiang, Aidian, Gongmushan, 4,000 feet elev., 16 Dec 1935, H.H.Soo 68119 (holotype: IBSC! [IBSC0003993]; isotypes: IBK! [IBK00190675, IBK00190676]).

***Perilimnastes dispar* (Cogn.) Ying Liu, comb. nov.**
urn:lsid:ipni.org:names:77335507-1

Anerincleistus dispar Cogn. ex Boerl., Handl. Fl. Ned. Ind. (Boerlage) i. 2: 531. 1890; et in DC. Monog. Phan. vii: 479. 1891 (Basionym). Type: Malaysia. Sarawak: O.Beccari 2400 (holotype: FI; isotypes: K! [K000867722], P! [P02274765]).
Phyllagathis dispar (Cogn.) C.Hansen, Nordic J. Bot. 2(6): 559. 1983.
Phyllagathis uniflora Stapf, Hooker's Icon. Pl. 23: t. 2280. 1894. Type: Malaysia. Sabah: Kinabalu, 1892, G.D.Haviland 1172 (holotype: K! [K000867723]; isotypes: K! [K000867724], SAR, SING).
Phyllagathis uniflora var. *longiloba* M.P.Nayar, J. Jap. Bot. 51(8): 233. 1976. Type: Malaysia. Sabah: Kinabalu, Ulu Langanani, Sungei Mamut, 4,500 feet elev., 8 Aug 1961 W.L.Chew, E.J.H.Corner, and A.Stainton 1262 (holotype: K! [K000867721]; isotypes: L, SAR, SING).

***Perilimnastes elegans* (Hai L.Chen, Yan Liu & Ying Liu) Ying Liu, comb. nov.**
urn:lsid:ipni.org:names:77335508-1

Phyllagathis elegans Hai L.Chen, Yan Liu & Ying Liu, Phytotaxa 509(2): 225. 2021 (Basionym). Type: China. Guangxi: Dongxing County, Ma-lu Town, Ping-feng Village, Yuan-ling, Shi-men Valley, on rocks and along grassy streamside in forests, 400–450 m elev., 9 Sept 2020, H.L.Chen, S.Y.Nong, and J.Q.Huang JHC343 (holotype: IBK!; isotypes: A!, IBSC!, PE!)

***Perilimnastes elliptica* (Stapf) Ying Liu, comb. nov.**
urn:lsid:ipni.org:names:77335509-1

Phyllagathis elliptica Stapf, Hooker's Icon. Pl. 23: t. 2279. 1894 (Basionym). Type: Malaysia. Sabah: Kinabalu, G.D.Haviland 1286 (lectotype, designated by Cellinese [2003]: K! [K000867720]).

***Perilimnastes fruticosa* (Ridl.) Ridl., J. Straits Branch Roy. Asiat. Soc. 79: 70, in obs. 1918; Ridley, Fl. Mal. Penins. 1: 773. 1922.**

Anerincleistus fruticosus Ridl., J. Linn. Soc., Bot. xxxviii. 309. 1908 (Basionym). Type: Malaysia. Pahang: Gunong Tahan, 2 Jul 1905, L.Wray and H.C.Robinson 5453 (lectotype, designated here: BM! [BM000565932]; isolectotypes: K! [K000867593, K000867594], CAL).
Phyllagathis fruticosa (Ridl.) C.Hansen ex Cellin., Blumea 47(3): 473. 2002.

Notes. When publishing *A. fruticosus*, Ridley (1908) designated L.Wray and H.C.Robinson 5453 as the type without citing a particular herbarium, only stating that the whole collection made by Robinson's expedition should be

sent to the British Museum (BM). Nayar revised *Perilimnastes* in 1974 and noted the specimen in BM as holotype of this species. This was probably only a speculation rather than deliberate lectotypification. In the revision of *Phyllagathis*, Cellinese (2002) chose a duplicate sheet in K as the lectotype, but did not include the phrase "designated here" in the typification statement, as required by Art. 7.11 of the Code (Turland et al. 2018). The specimen sheet in BM [BM000565932] is here designated as the lectotype to eliminate any uncertainty.

***Perilimnastes guillauminii* (H.L.Li) Ying Liu, comb. nov.**
urn:lsid:ipni.org:names:77335510-1

Phyllagathis guillauminii H.L.Li, J. Arnold Arbor. 25: 29, in obs. 1944 (Basionym). Type: Cochinchine. Bien Hoa, Bao Chiang, L.Pierre s.n. (lectotype, designated by Hansen [1992]: P! [P05200250], drawing, C! [C10014976]). Additional syntype: Vietnam. Annam: Hue, s.n. (P! [P05200249]).
Phyllagathis hirsuta Guillaumin, Notul. Syst. (Paris) 2: 325, 1913, non Cogn. (1894).

***Perilimnastes melastomatoides* (Merr. & Chun) Ying Liu, comb. nov.**
urn:lsid:ipni.org:names:77335511-1

Osbeckia melastomatoides Merr. & Chun, Sunyatsenia 2: 293. 1935 (Basionym). Type: China. Hainan: Mo San Leng, 21 Nov 1932, N.K.Chun and C.L.Tso 44310 (lectotype, designated by Li [1944]: A! [A00055333]; isolectotypes: NY! [NY00229583], US! [US00120468]).
Phyllagathis melastomatoides (Merr. & Chun) W.C.Ko, Acta Phytotax. Sin. 8(3): 267. 1963.

***Perilimnastes melastomatoides* var. *brevipes* (W.C.Ko) Ying Liu, comb. nov.**
urn:lsid:ipni.org:names:77335512-1

Phyllagathis melastomatoides var. *brevipes* W.C.Ko, Acta Phytotax. Sin. 8(3): 268. 1963 (Basionym). Type: China. Hainan: Ya Hsien, Yulinwan, 15 Nov 1933, C.Wang 35035 (holotype: HC; isotypes: IBK! [IBK00129997], IBSC! [IBSC0246912, IBSC0003951], NY! [NY00079855]).

***Perilimnastes multisepala* J.H.Dai, T.V.Do & Ying Liu, PhytoKeys 235: 4. 2023.**

Type. Vietnam. Quảng Nam Province: Đại Lộc, about 400 m south of Khu Du Lich Sinh Thai Khe Lim, along newly opened road, 574 m elevation, on rocks along a stream, 23 Nov 2019, Jin-hong Dai and Ying Liu 821 (holotype: PE; isotypes: A, SYS, VNMN).

***Perilimnastes ovalifolia* (H.L.Li) Ying Liu, comb. nov.**
urn:lsid:ipni.org:names:77335513-1

Phyllagathis ovalifolia H.L.Li, J. Arnold Arbor. 25: 31. 1944 (Basionym). Type: China. Yunnan: Ping-pien Hsien, 1,400 m, 7 Aug 1934, Tsai 61456 (holotype: A! [A00055329]; isotypes: PE! [PE00781713, PE00781714]).
Phyllagathis calisaurea C.Chen, Bull. Bot. Res., Harbin 4(3): 45. 1984. Type: China. Guangxi: Jingxi, Nanpo, Diding, 20 Jun 1978, T. Fang and X. H. Lu 23672 (holotype: GXMI! [GXMI050227]; isotype: GXMI! [GXMI050228]).
Phyllagathis ovalifolia var. *pauciflora* R.H.Miao, Acta Sci. Nat. Univ. Sunyatseni 32(4): 61. 1993. Type: China. Yunnan: Maguan County, Z.R.Xu and B.Li GL86-7974 (holotype: SYS! [SYS00103897]).

Notes. *Phyllagathis calisaurea* was described, based on specimens collected in western Guangxi, China (Chen 1984b). Subsequent authors did not recognise it as a distinct species and synonymised it within *P. ovalifolia* (Hansen 1992; Chen and Renner 2007). *Phyllagathis calisaurea* and *P. ovalifolia* have adjacent distribution ranges (Guangxi vs. Yunnan, China). They are morphologically quite similar, with the only differences being leaf size (6.5–11.5 × 2–3.7 cm vs. 9–18 × 3–8.5 cm), leaf shape (ovate lanceolate vs. ovate to elliptic) and indumentum of the stems and leaves. Nonetheless, they failed to form a monophyletic group in both the previous (Zhou et al. 2022) and current phylogenetic analyses (Fig. 1). As only one accession of *P. ovalifolia* was included in these analyses, the boundary between *P. ovalifolia* and *P. calisaurea* needs to be further investigated using multiple accessions from across the distribution range. For the time being, we adhere to the species delimitation proposed by Hansen (1992) and Chen and Renner (2007).

***Perilimnastes rupicola* M.P.Nayar, J. Bombay Nat. Hist. Soc. 71(1): 173. 1974.**

Anerincleistus rupicola (M.P.Nayar) J.F.Maxwell, Gard. Bull. Singapore 35(2): 215. 1983.
Phyllagathis rupicola (M.P.Nayar) C.Hansen ex Cellin., Blumea 48(1): 92. 2003.

Type. Malaysia. Sarawak: Mt Dulit, Ulu Koyan, alt. 800 m, 16 Sept 1932, S.Synge 503 (holotype: K! [K000867704]).

***Perilimnastes sessilifolia* (C.Hansen) Ying Liu, comb. nov.**
urn:lsid:ipni.org:names:77335514-1

Phyllagathis sessilifolia C.Hansen, Bull. Mus. Natl. Hist. Nat., B, Adansonia Sér. 4, 12(1): 39. 1990 (Basionym). Type: Indochine. Annam: Nui Bach Ma station d'altitude de Huê, 6 Sept 1938, E.Poilane 27614 (holotype: P! [P02274752]; isotypes: P! [P02274753, P02274754]).

***Perilimnastes setipetiola* J.H.Dai, T.V.Do & Ying Liu, PhytoKeys 235: 5. 2023.**

Type. Vietnam. Lâm Đồng Province: Đà Lạt, Bidoup Nui Ba National Park, 1,500–1,700 m elevation, at damp places under forest, 29 Nov 2019, Jin-hong Dai and Ying Liu 836 (holotype: PE; isotypes: A, SYS, VNMN).

***Perilimnastes setotheca* (H.L.Li) Ying Liu, comb. nov.**
urn:lsid:ipni.org:names:77335515-1

Phyllagathis setotheca H.L.Li, J. Arnold Arbor. 25: 32. 1944 (Basionym). Type: China. Guangxi: Shih Wan Tai Shan, 21 Jul 1937, H.Y.Liang 69817 (holotype: A! [A00055328]; isotypes: IBK! [IBK00127588], IBSC! [IBSC0003958], PE! [PE00781748]).

***Perilimnastes setotheca* var. *setotuba* (C.Chen) Ying Liu, comb. nov.**
urn:lsid:ipni.org:names:77335516-1

Phyllagathis setotheca var. *setotuba* C.Chen, Bull. Bot. Res., Harbin 4(3): 44. 1984 (Basionym). Type: China. Guangdong: Yangjiang, Longgaoshan, 29 May 1956, Wang 41508 (holotype: IBSC! [IBSC0003999]; isotype: IBK! [IBK00127590]).

***Perilimnastes stenophylla* (Merr. & Chun) Ying Liu, comb. nov.**
urn:lsid:ipni.org:names:77335517-1

Bredia stenophylla Merr. & Chun, Sunyatsenia 5: 146. 1940 (Basionym). Type: China. Hainan: Yaichow, 11 Aug 1933, Liang 62530 (lectotype, designated by Li [1944]: A! [A00055335]; isolectotypes: E! [E00090770], G! [G00353917], NY! [ny00221474]).
Phyllagathis stenophylla (Merr. & Chun) H.L.Li, J. Arnold Arbor. 25: 32. 1944.

***Perilimnastes suberalata* (C.Hansen) Ying Liu, comb. nov.**
urn:lsid:ipni.org:names:77335518-1

Phyllagathis suberalata C.Hansen, Bull. Mus. Natl. Hist. Nat., B, Adansonia Sér. 4, 12(1): 39. 1990 (Basionym). Type: Indochine. Annam: Nui Bach Ma station près de Huê Grande Cascade, 16 Apr 1939, E.Poilane 29758 (holotype: P! [P02274749]; isotypes: P! [P02274750, P02274751]).

***Perilimnastes ternata* (C.Chen) Ying Liu, comb. nov.**
urn:lsid:ipni.org:names:77335519-1

Phyllagathis ternata C.Chen, Bull. Bot. Res., Harbin 4(3): 49. 1984 (Basionym). Type: China. Guangdong: Xinyi, Dadufoshan, stream side, 10 Aug 1931, S.P.Ko 51772 (holotype: IBSC! [IBSC0004000]; isotype: IBSC! [IBSC0223824]).

Phyllagathis xinyiensis Z.J.Feng, J. South China Agr. Univ. 15(4): 75. 1994. Type: China. Guangdong: Xinyi, Dawuling, infra silvis, Z.J.Feng 53621 (holotype: CANT).

***Perilimnastes uniflora* J.H.Dai, T.V.Do & Ying Liu, PhytoKeys 235: 11. 2023.**

Type. Vietnam. Đà Nẵng: Hòa Ninh, Ba Na Hills, 1,360 m elevation, in forests on damp rocks along steam, 22 Nov 2019, Jin-hong Dai and Ying Liu 814 (holotype: PE; isotypes: A, SYS, VNMN).

***Perilimnastes nana* C.Y.Zou & Ying Liu, sp. nov.**
urn:lsid:ipni.org:names:77335520-1
Figs 6, 7

Type. China. Guangdong Province: Taishan County, Chixi Town, near Zhuxing Village, 200–300 m elevation, amongst rocks along a stream in forests, 15 Jun 2022, *Chun-yu Zou* 3608 (holotype: IBK; isotypes: IBK, PE).

Diagnosis. Resembles *P. stenophylla* in leaf morphology, but differs in height (to 0.15 m vs. 0.8 m tall), number of flowers per inflorescence (1 vs. 2–3-flowered), length of the peduncle (10–22 mm vs. 4 mm) and the shape of calyx lobes (broadly obovate vs. narrowly triangular). Resembles *P. setotheca* in having 4-sided branchlets, large and persistent bracts below flower and stamen morphology, but differs in plant size (to 0.15 m vs. 1 m tall), leaf shape and size (oblong-lanceolate or obovate-lanceolate, 1.7–7 × 0.73–2.2 cm vs. oblong-lanceolate, elliptic or obovate, 10–20 × 3–8 cm) and number of flowers per inflorescence (1-flowered vs. 3 to more than 20-flowered).

Description. Dwarf shrubs, much-branched, ascending, to 0.15 m tall, with druses in many parts. Stems and leaves sparsely puberulent with minute brown hairs (with few-celled stalk and a glandular head) when young, glabrous when mature. Stems obtusely 4-sided; branchlets 4-sided, with four ribs and two additional ridges extending from the base of the leaf petioles. Leaves opposite, equal to subequal in a pair, glabrous when mature; petiole 2–22 mm; leaf blade oblong-lanceolate or obovate-lanceolate, 1.7–7 × 0.73–2.2 cm, thick papery, 3-veined, green to dark green adaxially, pale green abaxially, base cuneate, apex acute, margin basally entire and remotely denticulate to repand above the base or the middle. Inflorescences terminal, peduncles 1–2.2 cm long; flower solitary, subtended by one or two pairs of leaf-like bracts, bracts 1–1.8 × 0.7–0.9 cm, persistent in fruit. Flowers 4-merous; pedicel 4-sided, ca. 4 mm long in flower and 4–10 mm in fruit; hypanthia funnel-shaped, glabrous, ca. 7 × 6 mm; calyx lobes 4, broadly obovate, glabrous, 4–5 × 5 mm; petals pinkish-purple, ca. 15 × 7 mm, obovate, oblique, apex acute or short acuminate, glabrous on both sides; stamens 8, isomorphic, filaments 8–10 mm long, white or pink, glabrous, anthers ovate-lanceolate, curved to ventral side, pinkish-purple with yellow base, ca. 9 mm long, connective dorsally forming a 0.7–1 mm long spur and ventrally forming two yellow ridges; ovary ca. 3 mm long, half as long as hypanthium (crown excluded), ovary crown wedge-like, 4-lobed; styles 20 mm long. Old (post-mature) capsules cup-shaped, 7–9 × 4–7 mm, 4-sided; hypanthium 8-ribbed; crown enlarged and enclosing an obpyramidal space; placental column unbeaked, 4-horned; placenta thready.

Figure 6. Holotype of *Perilimnastes nana*, Chun-yu Zou 3608 (IBK). The insets show details of leaf surface under stereoscope, branchlet and flower. Scale bars: 10 cm, 1 mm (upper right inset); 3 mm (lower insets).

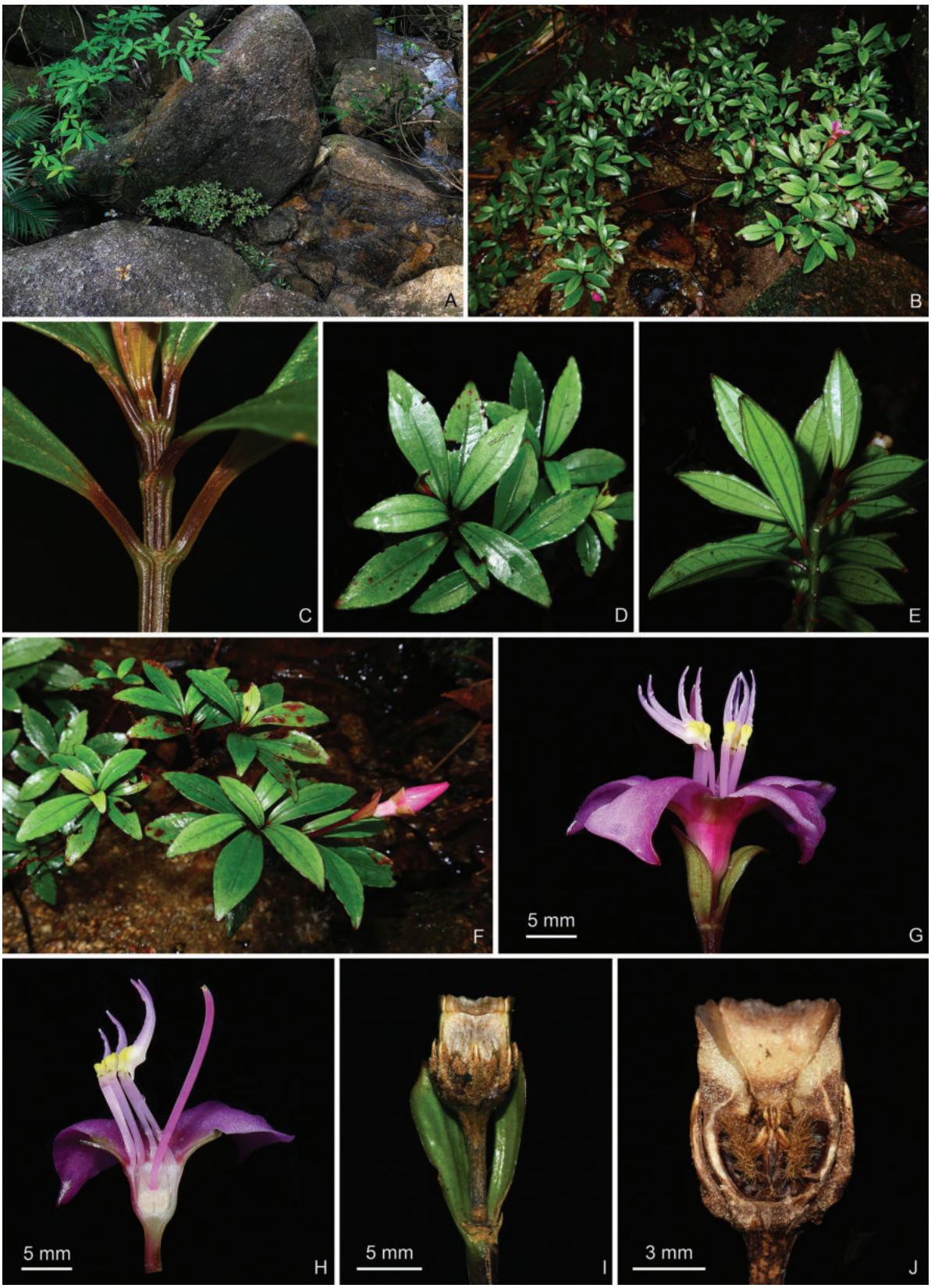

Figure 7. *Perilimnastes nana* **A** habitat **B** habit **C** close-up of a branchlet **D** adaxial leaf surfaces **E** abaxial leaf surfaces **F** a flowering branch showing an inflorescence with a single flower and two large bracts **G** lateral view of a flower **H** longitudinal section of a flower showing stamen morphology **I** lateral view of an old capsule with one persistent bract removed **J** longitudinal section of an old capsule showing enlarged ovary crown and morphology of the placental column and placentas. Scale bars: 5 mm (**G–I**); 3 mm (**J**). All from Chun-yu Zou 3608 (IBK, PE).

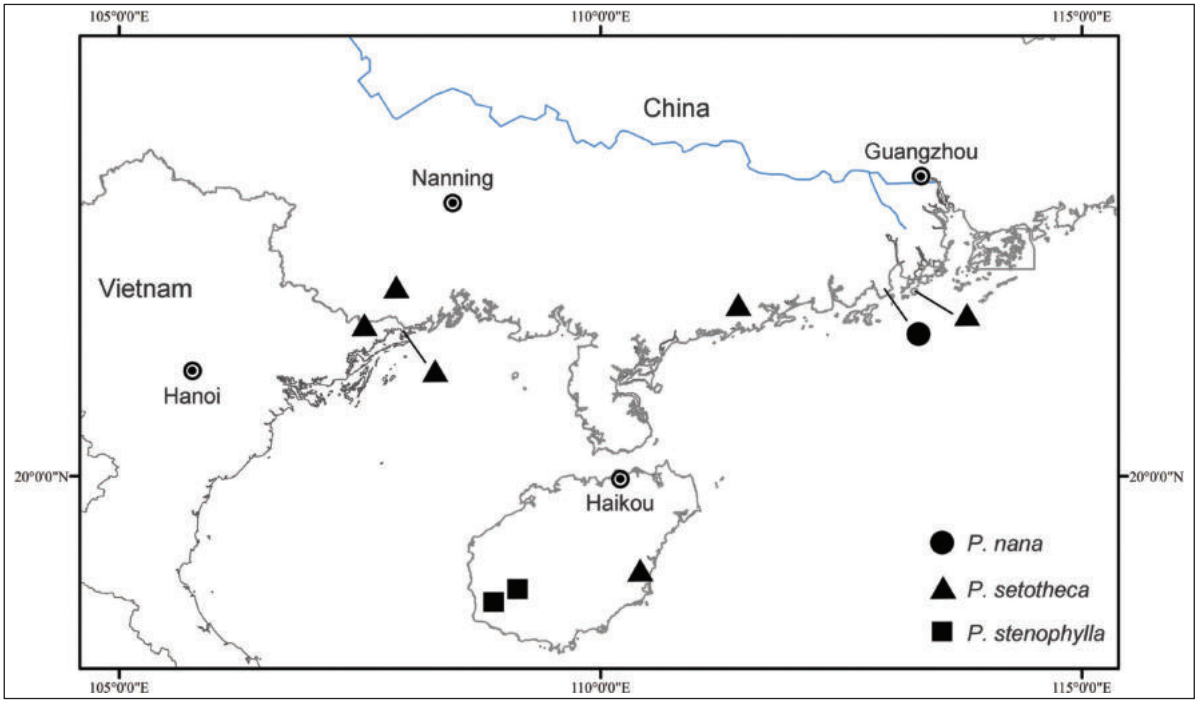

Figure 8. Distribution of *Perilimnastes nana* (solid circle), *P. setotheca* (triangle) and *P. stenophylla* (square).

Phenology. Flowers in May and June, old capsules in October.

Etymology. The specific epithet is based on the habit of this species, viz. dwarf shrubs to 15 cm tall.

Distribution. *Perilimnastes nana* is currently known from Taishan County, Guangdong Province, China (Fig. 8). It grows amongst rocks along streams in the forest, at 200–300 m elevation.

Notes. During a survey of herbarium specimens of *Phyllagathis* in IBSC, a collection (Ze-xian Li et al. 516) from Taishan, Guangdong, China caught our attention. This plant (*P. nana*) closely resembles *P. stenophylla* from Hainan Island in the oblong-lanceolate leaf blades and was misidentified as the latter species. Closer inspection reveals that it has strictly 1-flowered inflorescences and broadly obovate calyx lobes, which distinguishes it from *P. stenophylla*. Field trips in 2022 and 2023 revealed other differences between the two species, such as plant size and peduncle length. *Perilimnastes nana* is phylogenetically closest to *P. setotheca*, a species found in Guangdong, Guangxi and Hainan China (Fig. 8). However, they differ markedly in plant size, leaf shape and size and number of flowers per inflorescence. As a result, *P. nana* is quite distinct from its closest relatives, prompting us to describe it as a new species.

Additional specimen examined. China. Guangdong Province: Taishan County, Chixi Town, Zhuxing Village, 220 m elevation, 17 Oct 2023, Ying Liu 892 (SYS); Taishan County, Chixi Town, Liugushan, 8 May 1981, Ze-xian Li et al. 516 [IBSC (IBSC0223903)].

Key to the species of *Perilimnastes*

1 Raphides present, appearing on leaf surfaces as whitish oblong spots when dried **2**

– Raphides absent **13**

2 Flowers always solitary **3**
– Flowers often in few-flowered umbels, sometimes or rarely reduced to a solitary flower, rarely many-flowered **4**
3 With sparse minute brown glands on branchlets and leaves when young, glabrescent; leaf blade obovate to obovate-lanceolate, base cuneate to narrowly cuneate ..... ***P. uniflora***
– With uniseriate, pale brown hyaline hairs on branchlets and leaves; leaf blade elliptic, base acute to rounded ..... ***P. dispar***
4 Leaf blades broadly obovate to suborbicular, 2.5–3.5 cm long ..... ***P. brookei***
– Leaf blades ovate, elliptic, narrowly elliptic, or elliptic-lanceolate, often > 4 cm long **5**
5 Inflorescence sessile or nearly sessile **6**
– Inflorescence with 1–3.5 cm long peduncles **10**
6 Leaf blades narrowly elliptic **7**
– Leaf blades broadly elliptic or elliptic **8**
7 Hypanthia with sparse minute brown glands; anthers yellow ..... ***P. rupicola***
– Hypanthia with sparse minute brown glands and dense patent brown bristles; anthers purplish ..... ***P. guillauminii***
8 Petioles densely villous with appressed, brown hyaline hairs, without bristles ..... ***P. banaensis***
– Petioles with bristles **9**
9 Mature stem with curly retrorse bristles; leaf bases rounded to broadly rounded; anthers yellowish ..... ***P. elliptica***
– Mature stem glabrescent; leaf bases cuneate; anthers pinkish ..... ***P. setipetiola***
10 Stems hirsute with crooked, multiseriate hairs **11**
– Stems hirsute with straight, multiseriate hairs **12**
11 Leaf blade oblanceolate to elliptic-lanceolate, 4.8–14 × 1.1–2.7 cm; peduncle pubescent with minute, appressed hairs ..... ***P. elegans***
– Leaf blade elliptic to long elliptic, 5–13 × 1.5–4 cm; peduncle pubescent with spreading hairs ..... ***P. deltoidea***
12 Stems retrorse hirsute with multiseriate hairs or pubescent with hyaline uniseriate hairs; leaf blade 7–18 × (2–)3–8.5 cm ..... ***P. ovalifolia***
– Stems densely setose with multiseriate hairs; leaf blade 5–8 × 2.5–4 cm ..... ***P. ternata***
13 Leaf base broadly cordate ..... ***P. sessilifolia***
– Leaf base broadly cuneate, cuneate, or acuminate **14**
14 Mature stems and leaves with appressed or ascending bristles ..... ***P. melastomatoides***
– Mature stems and leaves glabrous **15**
15 Leaves unequal, rarely subequal, in a pair ..... ***P. suberalata***
– Leaves usually equal or subequal in a pair **16**
16 Leaf blades 10–20 × 3–8 cm; inflorescences subtended by an involucre of several bracts (often 4) ..... ***P. setotheca***
– Leaf blades 2.8–10(–14) × 0.6–2.4(–4.2) cm; inflorescences subtended by a pair of small leaves/bracts **17**
17 Calyx lobes 4–8 ..... ***P. multisepala***
– Calyx lobes 4 ..... **18**
18 Dwarf shrubs to 15 cm tall; inflorescence 1-flowered ..... ***P. nana***
– Shrubs to 80–100 cm tall; inflorescence 1–4-flowered **19**

19 Calyx lobes ca. 3 mm long, not keeled; anthers purplish..... ***P. stenophylla***
– Calyx lobes 4–7 mm long, keeled; anthers yellow ..... ***P. fruticosa***

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

Methodology: YL. Field work: YL, JHD, CYZ, KNM. Data analysis: YL, QYZ. Writing: YL, JHD, QYZ.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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Supplementary material 1

Source of materials studied

Authors: Ying Liu, Jin-Hong Dai, Qi-Yuan Zhuang, Chun-Yu Zou, Kai-Nan Ma

Data type: xlsx

Explanation note: The name of the new species is indicated in bold.

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Research Article

Taxonomic revision of the native *Magnolia* (Magnoliaceae) species of Brazil

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Abstract

The genus *Magnolia* (Magnoliaceae) has a wide and disjunct geographic distribution ranging from Eastern and South Asia to Malaysia, extending across the Neartics and reaching into the Neotropics. Regarding its infrageneric classification, the genus is divided into three subgenera: *Yulania*, *Gynopodium* and *Magnolia*, the latter including the section *Talauma* in which the native Brazilian taxa are classified. The species of *Magnolia* sect. *Talauma* can be recognized by two parallel longitudinal scars on the petiole formed by the shedding of the stipules, in addition to a woody syncarp that breaks into irregular plates at dehiscence. Currently, in Brazil, species recognition is not clear on national platforms that are widely used by the Brazilian botanical community (e.g. Flora do Brasil), with only two native *Magnolia* species being accepted: *M. amazonica* and *M. ovata*. The lack of knowledge about the species and their respective characteristics has resulted in many identification errors in Brazilian herbaria, which contributes to the lack of knowledge about their current conservation status. We conducted a complete taxonomic revision based on extensive fieldwork, a herbarium survey, along with literature study. Based on this, we propose to recognize three previously described species, supporting the acceptance of five native *Magnolias* occurring in Brazil, namely: *M. amazonica*, *M. brasiliensis*, *M. irwiniana*, *M. ovata* and *M. sellowiana*. However, we follow the Flora do Brasil in maintaining *M. paranaensis* as a synonym of *M. ovata*. Additionally, we designate a lectotype for *M. sellowiana*. We present morphological descriptions and the geographic distribution for each species, in addition to an identification key to all of these plus the two introduced ornamental species from Asia and North America, illustrations, photographs, ecological data, updated conservation status and taxonomic notes.

Key words: Brazilian Flora, conservation, distribution, Magnolioideae, Neotropics, Pinha-do-brejo, sect. *Talauma*, taxonomy

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Introduction

Magnolia L. is a genus of approximately 370 species distributed disjunctly ranging from Eastern and South Asia to Malaysia, extending across the Neartics (Canada and USA) and reaching into the Neotropics (Stevens 2001; Aldaba Núñez et al., unpublished data). *Magnolia* species have an important ornamental value due to their colorful and showy flowers (e.g., *Magnolia grandiflora* L., *M. liliiflora* Desr., *M.* × *soulangeana* Soul.-Bod., *M. virginiana* L., *M. ovata* (A.St.-Hil.) Spreng.), and some species have also been used in traditional medicine (e.g., *M. dealbata* Zucc., *M. liliiflora*, *M. mexicana* DC. and M. *officinalis* Rehder & E.H.Wilson) or as a timber species (e.g., *Magnolia dixonii* (Little) Govaerts, *M. grandiflora*, *M. striatifolia* Little) (Pérez-Castañeda 2015; Wang et al. 2020; Xie et al. 2022).

Despite its scientific and economic relevance, the taxonomy of *Magnolia* is incomplete, and so far, few in-depth studies have been conducted to understand all variation in its morphological characters, despite the recognition of moderate phenotypic plasticity in Magnoliaceae (Vázquez-García et al. 2014; Gutiérrez-Lozano et al. 2021). Among the studies conducted within the genus, those combining morphological and molecular data to compare individuals of widely distributed species stand out (e.g. Arteaga-Rios et al. 2020). Such studies highlight significant morphological variations and mostly conclude that different species may be confused as a single widely conceptualized species, with a large variation in occurrence and morphology (Arteaga-Rios et al. 2020). This shows the need for further research to clarify the taxonomy of this genus, especially regarding species delimitation.

Regarding its infrageneric classification, *Magnolia* is divided into three subgenera (Figlar and Nooteboom 2004) (subgen. *Magnolia*, subgen. *Yulania* (Spach) Rchb. and subgen. *Gynopodium* (Dandy) Figlar and Noot.) and 15 sections (Wang et al. 2020). *Magnolia* sect. *Talauma* belongs to the subgenus *Magnolia* and is the richest section in terms of species number, with nearly 130 taxa (Pérez-Castañeda 2015; Aldaba Núñez et al., unpublished data). All native *Magnolia* species occurring in Brazil belong to section *Talauma* subsection *Talauma.* Its species are characterized as perennial trees with stomata grouped in numbers of two, three, or five (Figlar and Nooteboom 2004; Wang et al. 2020). The stipules are fused to the petiole, leaving two parallel longitudinal scars after shedding (Fig. 1). The flowers are terminal, protected by one or two bracts, here referred to as 'perula' (Treseder 1978) (Fig. 2), with three sepals, six or seven petals, usually white or yellow, thick and fleshy. In a considerable number of species, the sepals and petals are not differentiated and are named tepals (Beentje 2010). The androecium has 20–220 stamens, and the carpels in the gynoecium can be few or numerous, free or, predominantly in South American species, fused, with each carpel having two ovules (Fig. 3). The fruit is apocarpous, multifollicular, or, in the South American species, a woody syncarp that splits into irregular plates upon dehiscence, exposing seeds with reddish or orange sarcotesta, which are individually pendulous by a funiculus (Fig. 4) (Law 1984; Lozano-Contreras 1990; Vázquez-García et al. 2016; Mello-Silva et al. 2023).

Eichler (1864) recognized two species of Magnoliaceae for Brazil: *Talauma ovata* A.St.-Hil. and *T. dubia* Eichler. Lozano-Contreras (1990), in a more comprehensive study on the family in Brazil, recognized four species for the country: *T. amazonica* Ducke, *T. irwiniana* Lozano, *T. ovata* (synonymizing *T. dubia*, due to

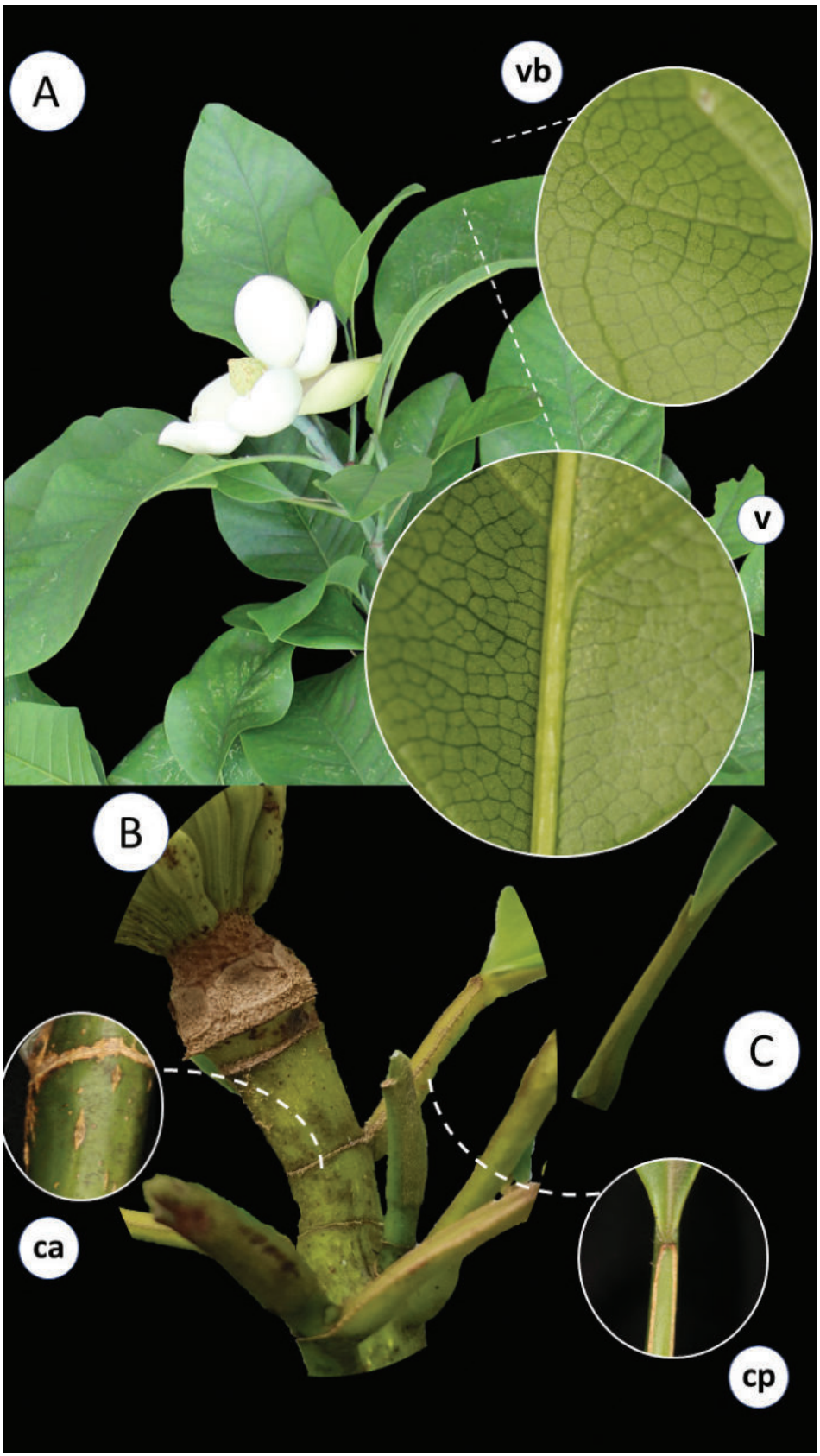

Figure 1. A branch with alternate leaves, present stipules, and terminal flower, **v.** detail of central vein, **vb.** detail of brochidodromous venation **B** detail of the branch showing scars **C** adnation of the stipule (which later falls) on the petiole, a characteristic of *Magnolia* section *Talauma*; **ca**. Annular scar; **cp.** Petiolar scar (resulting from stipule fall). Photos: A, v, vb, ca, cp: D.A. Zavatin; B-C: J. C. J. Barbosa.

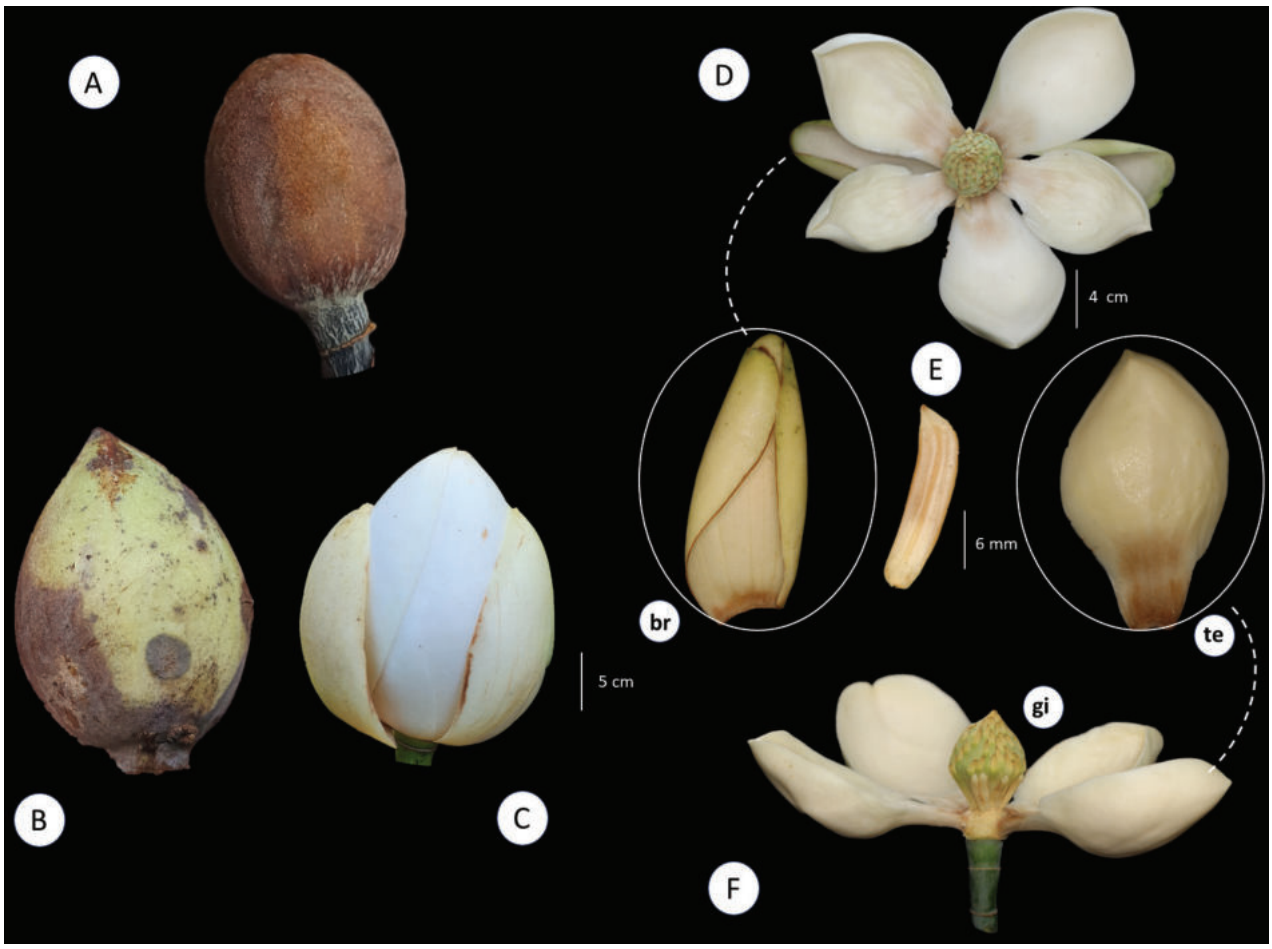

Figure 2. *Magnolia* flower stages **A** perule **B** immature floral bud **C** mature floral buds **D, F** flower at anthesis; **br.** Sepaloid tepal **te.** Petaloid tepal; **gi.** Flower with detail of the gynoecium **E** stamen. Photos: A: *U. Pastore & R.M. Klein 145* (MBM115080); B-C: J. C. J. Barbosa; D, bra, te: D. A. Zavatin.

their similarity in their leaf blade shape, number of carpels, syncarp morphology and because they do not present an indument on any of their structures), and *T. sellowiana* A.St.-Hil. Vázquez-García et. al (2013) described *Magnolia paranaensis* as a new species for Brazil, based on new records, restricted to the Serra do Mar (Paraná). de Azevedo et al. (2018) described *M. brasiliensis* C.O. Azevedo, A.F.P. Machado & A. Vázquez, based on material collected in the states of Bahia and Minas Gerais, which were the first records of Magnoliaceae for the Northeast region of Brazil up to that point. However, considering a broader concept of species, the authors of the Flora do Brasil 2023 treatment (Mello Silva et al. 2023) only accepted four species: *M. amazonica* (Ducke) Govaerts and *M. ovata*, as native to the country, and *M. champaca* L. and *M. grandiflora* L., both introduced and cultivated. They synonymized *M. brasiliensis* with *M. amazonica*, and *M. irwiniana*, *M. paranaensis*, and *M. sellowiana* with *M. ovata*, without further explications. In the "Magnoliaceae Red List" (Rivers et al. 2016), as well as on platforms where the accepted names of *Magnolia* for Brazil are found, such as SpeciesLink (2023), there are differences in species determinations, which evidences divergence in their delimitation among different authors, causing confusion in the identification of material collected throughout the country.

In 2018, Azevedo and colleagues realized that some paratypes of *M. brasiliensis*, initially identified as *M. ovata* by Pirani and De Mello-Silva (1996) in their

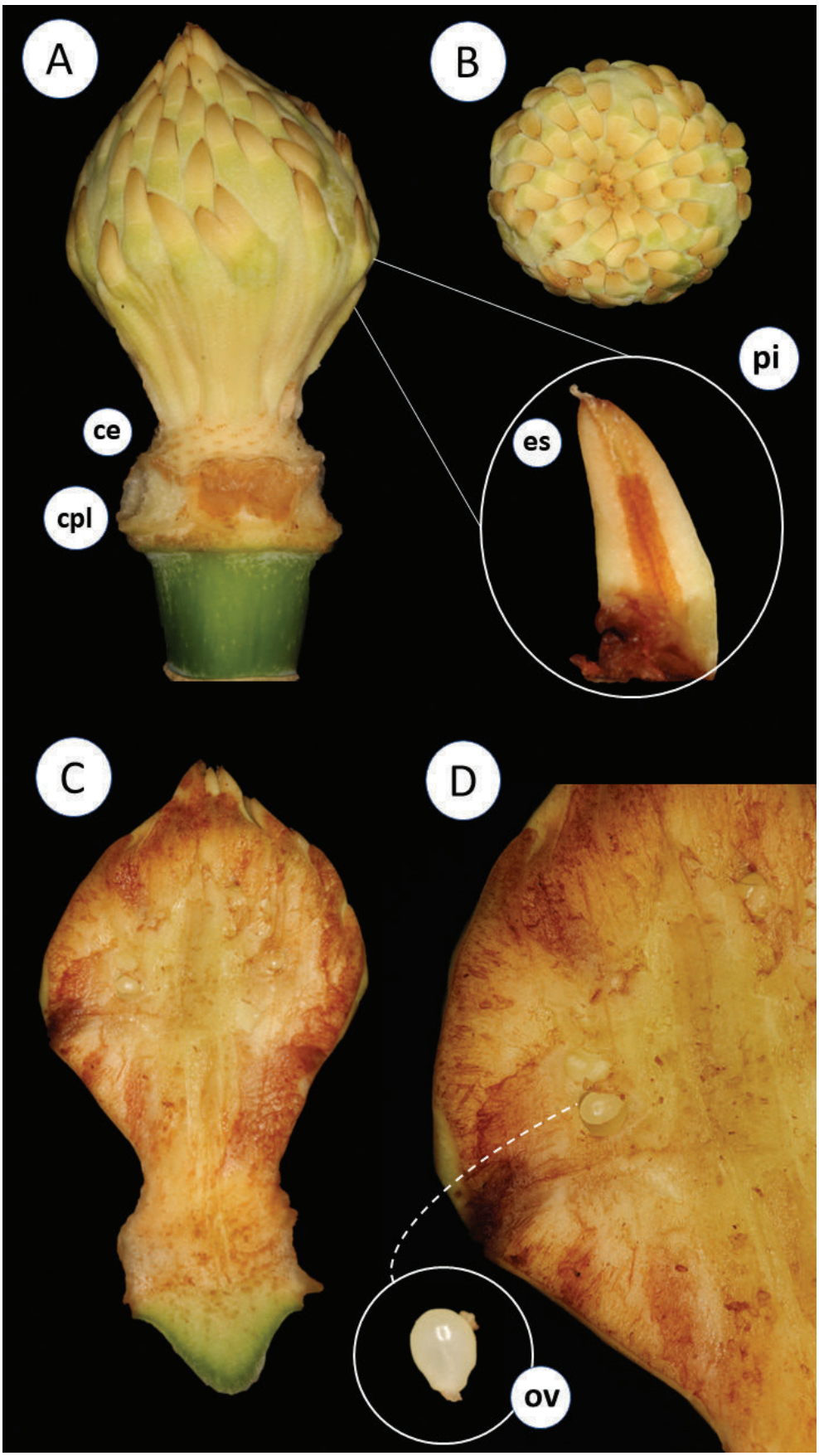

Figure 3. A gynoecium, vertical view **B** gynoecium, viewed from above **ce.** Staminal scar, **cpl.** petaloid scar, **pi.** Pistillum, **es.** Stigma **C** longitudinal section, receptacle and gynoecium **D** detail ovary, **ov.** ovule. Photos: D. A. Zavatin.

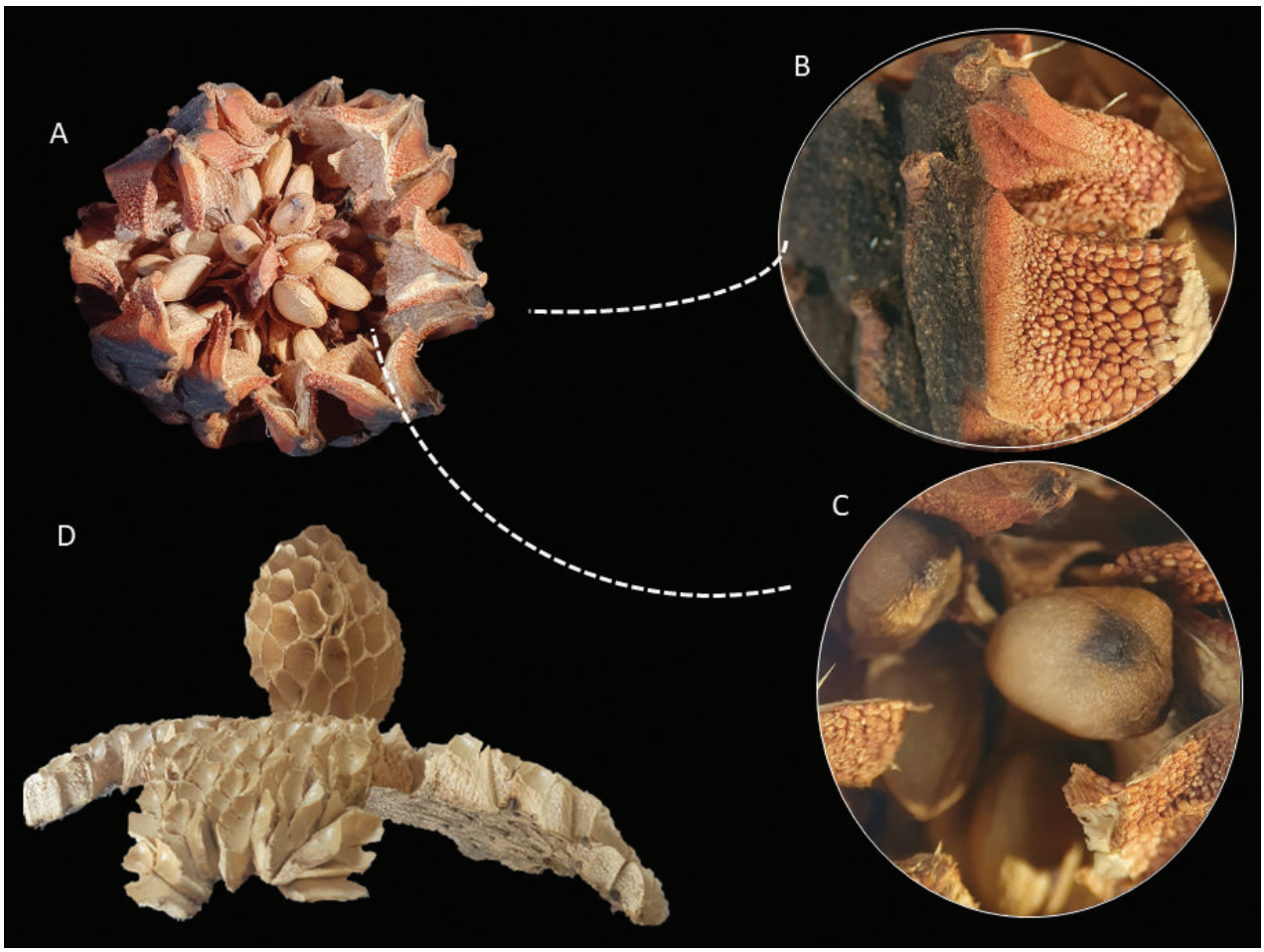

Figure 4. Fruit stages **A** partially open syncarpous fruit **B** detail of the inner woody part of the fruit **C** 1–2 seeds per carpel **D** mature fruit, with open woody masses (seeds already fallen from the fruit) Photos: J. C. J Barbosa.

revision of Magnoliaceae in Serra do Cipó, Minas Gerais, did not provide information on important characters that could help distinguish the species, such as the number of stamens and carpels. Although *M. ovata* is included as one of the species within the section *Talauma* in Wang et al. (2020), the specimen used for this phylogenetic analysis was *R. Mello-Silva et al. 50* (US), the same material used by de Azevedo et al. (2018) to describe *M. brasiliensis*. This is a good example of the widespread misidentification of distinct species as *M. ovata*.

The difficulties in delimiting the species that are addressed in this work not only affect the taxonomic scope, where identification errors are leading to wrong interpretations in broad studies, but also have consequences for the assessment of the conservation status of the taxa involved. With only two species without conservation problems, while the rest are Endangered or Data Deficient, conservation actions are urgently needed. The conservation status of the Brazilian *Magnolia* species, mentioned by Rivers et al. (2016), were assessed as follows: *M. amazonica*: Least Concern (LC); *M. irwiniana*: Endangered (EN); *M. ovata*: Least Concern (LC); *M. paranaensis*: Data Deficient (DD); and *M. sellowiana*: Data Deficient (DD). In 2021, Lamarche & Azevedo assessed *M. brasiliensis* as Endangered (EN) in the International Union for Conservation of Nature (IUCN) Red List (2022).

Taxonomic disagreements, such as the delimitation of species and the number of accepted names by different authors, have a significant impact on

our understanding of the actual distribution and current conservation status of *Magnolia* species, especially regarding the supposedly widely distributed *M. ovata*. This study aims to expand the taxonomic knowledge of *Magnolia* in Brazil, focusing on the native species, and contribute to the conservation of the genus' diversity in the Neotropical region.

Materials and methods

To perform the analysis of botanical material, protologues and images from type collections in virtual databases such as Tropicos (2023) and JSTOR (2023) were consulted, in addition to visits to seven herbaria (HEPH, HUFSP, RB, SP, VIC, SPSF, MBM, ESA) (Thiers continuously updated). A total of approximately 100 specimens were analyzed physically, supplemented by field observations of species' populations in their natural habitats, and approximately 180 specimens were studied in databases such as Flora e Funga do Brasil (2023) and SpeciesLink network (2023), provenant from 24 herbaria (CEN, ESA, F, FURB, G, HEPH, HJ, HUEFS, IAN, ICN, JOI, MBM, MO, NY, P, RB, S, SP, SPSF, UB, UEC, UPCB, US, VIC) (Thiers , continuously updated). All material collected during fieldwork was herborized following traditional techniques as described in Mori (1989), and samples were deposited in the HUFSP and SP herbaria. Measurements were obtained from the examined specimens, considering the smallest and largest structure analyzed, when available. In addition, tables with morphological characters (e.g., leaf shape, petiole scars, pubescence, fruits), protologue descriptions, the reference work by Lozano-Contreras (1990), and observations made, were used to complement the descriptions of each species and for further understanding the genus, such as the study of ecology and distribution. Definitions of botanical characters and terms were taken and adapted from Radford et al. (1974), Howard (1948) and Lozano-Contreras (1990).

A database of distribution records was constructed from specimens with confirmed identifications by the first author of this paper, with additional records extracted from the Flora e Funga do Brasil (2023) and SpeciesLink network (2023) databases, where the species identification was possible based on morphological and distributional information. Distribution maps were produced using QGIS software v. 3.28.3 (QGIS Development Team 2015). The Brazilian regions mentioned in the work follow those of the IBGE (2017) on the regional divisions and subdivisions of Brazil.

Geospatial analyses were conducted to determine the Area of Occupancy (AOO) and the Extent of Occurrence (EOO) using the online Geospatial Conservation Assessment Tool (GeoCAT) software (Bachman et al. 2011) (http://geocat.kew.org/editor). The IUCN categories and criteria (2022) were used to assess the preliminary conservation status for each of the species studied.

Results

Seventeen morphological characteristics were obtained for analysis and preparing the descriptions and the identification key. Ten locations were visited in the Southeast, South and Central-West regions of Brazil.

Five species of *Magnolia* native to Brazil are here recognized: *M. amazonica*, *M. brasiliensis*, *M. irwiniana*, *M. ovata* and *M. sellowiana*, whereas *M. pa-*

ranaensis is considered a synonym of *M. ovata*. Most species occur in riparian forests and rainforest, with the exception of *M. brasiliensis*, which is found in semi-deciduous seasonal forest (Rizzini 1979).

Taxonomic treatment

***Magnolia* L.**

Type. *Magnolia virginiana* L.

Description. Trees or shrubs, evergreen or deciduous, branches lenticulate with internodes marked by annular scars, stipules free or, in Neotropical species (*Magnolia* sects. *Talauma* and *Macrophylla*), attached to the petiole, leaving 2 parallel longitudinal scars after shedding. Flowers terminal, solitary, protected by 1–2 bracts (perula); sepals 3; petals 3–12(–15), fleshy, cream-colored; stamens 20–220; carpels few to numerous, free or, predominantly in South American species, coalescent; ovules 2–(5), pollen large, > 50 µm diameter, stamens deciduous during male phase (except sect. *Oyama*). Fruit apocarpic, multifollicular or, predominantly in South American species, syncarpous, woody, which breaks into irregular plates at dehiscence, exposing the seeds provided with reddish or orange sarcotesta, which are individually pendulous by a funiculus (Figs 1–4) (Lozano-Contreras 1990; Figlar and Nooteboom 2004; Vázquez-García et al. 2016; Mello-Silva et al. 2023).

Distribution and habitat. *Magnolias* tend to occur at higher altitudes, mostly in high and humid forests. Preference and resistance in environments with varying temperatures and precipitation depend on the species (Song et al. 2019; Aldaba Núñez et al., unpublished data). Its distribution ranges from Eastern and South Asia to Malaysia, extending across the Neartics (Canada and USA) and reaching into the Neotropics (Stevens 2001; Aldaba Núñez et al., unpublished data). In Brazil, it is found in North, Northeast, Central-West, Southeast and South regions, at elevations approximately ranging between 200 and 1400 m. It occurs in anthropized areas, riparian forest, 'terra firme' forest, 'várzea' forest, and rainforest (Rizzini 1979; Eiten 1983).

We here provide an identification key to distinguish all Brazilian *Magnolias*, including both native and cultivated species.

Key to sections of the genus *Magnolia* in Brazil

1 Flower terminal, anther dehiscence introrse **2**
– Flower pseudo-axillary, anther dehiscence latrorse ..... **sect. *Michelia***
2 Stipular scar covering the entire petiole, fruit globose to ellipsoidal .... **sect. *Talauma***
– Stipular scar covering a small area of the petiole, fruit ovoid ... **sect. *Magnolia***

Key to species of *Magnolia* in Brazil

1 Predominant branching pattern syllepsis, stamens during the male phase shedding **2**
– Predominant branching pattern prolepsis, stamens during the male phase persistent ..... ***M. champaca* (introduced and cultivated)**

2 Fruit ovoid, stamens pubescent.....***M. grandiflora* (introduced and cultivated)**
– Fruit globose to ellipsoidal, stamens glabrous.....**3**
3 Branches pubescent.....**4**
– Branches glabrous **5**
4 Leaf margins entire, symmetrical.....**6**
– Leaf margins sinuate, asymmetrical..... ***M. irwiniana***
5 Fruits strigose, leaves coriaceous..... ***M. brasiliensis***
– Fruits glabrous, leaves papyraceous..... ***M. ovata***
6 Leaves broadly elliptic, secondary veins 5–13 pairs, carpels ca. 100 .....
.....***M. sellowiana***
– Leaves elliptic, secondary veins 8–19 pairs, carpels ca. 46.... ***M. amazonica***

***Magnolia amazonica* (Ducke) Govaerts, World Checkl. Bibliogr. Magnoliaceae, 70. 1996.**
Figs 5, 6, 11

≡ *Talauma amazonica* Ducke, Arch. Jard. Bot. Rio de Janeiro 4: 11. 1925.

Type. Brasil. "Prope medium flumen Tapajoz civitatis Pará loco Francez", fl, 10 January 1922, *A. Ducke 12487* (holotype: RB! [RB00540679]; isotypes: B! [B10 0248229],BM! [BM000551380, BM000551379], G! [G00352605], K! [K000470024, K000470025], P! [P00734783], R! [R000024142], RB! [RB00556527, RB00556528], S! [SR6051]).

Description. ***Trees*** 15–20 m tall; ***branches*** cylindrical, yellowish-brown, lenticulate, tomentose at annular scars closest to the flower bud, trichomes yellowish. ***Stipules*** adnate to petiole, green, oblong to conical, apex obtuse, base truncate, deciduous, tomentose. ***Petioles*** 1.8–5 cm long, stipular scar ranging from 90% to 100% of its length, tomentose when young and short, trichomes glabrescent. ***Leaf blades*** 11–28 cm × 4–12.4 cm, elliptic, base cuneate to acute, apex acute, margin entire; slightly coriaceous; venation pinnate, brochidodromous, 8–19 pairs of secondary veins irregularly spaced apart; when young tomentose abaxially, adaxially glabrous, yellowish-green. ***Peduncle*** cylindrical, tomentose at the annular scars, yellow trichomes, annular scars present. ***Flowers*** terminal, solitary; ***flower bud*** 3.95–6.34 cm × 3.25–4.70 cm, ovoid, yellowish-white, glabrous, protected by perula enveloping and protecting the flower bud, perula concave, brownish when dried; ***outer sepalloid tepals*** 3, 5–7 × 3–4 cm, asymmetrical, base cuneate, apex rounded, yellowish when dry; ***inner petaloid tepals*** 6, 6–7 cm × 3–5 cm, oblong, base attenuate, apex rounded, brown when dry; ***stamens*** ca. 100, laminar, slightly falcate, spirally arranged in 4–5 series, apex obtuse, whitish to yellowish, thecae 2, anthers introrse, dehiscence longitudinal; **gynoecium** 1.97 cm × 1.78 cm, conical, yellowish, carpels ca. 46. ***Immature* fruits** 4.4–5.5 cm long, 5 cm in diameter, globose, with puberulent pubescence, dehiscence circumscissile, in irregular syncarpous masses; ***seeds*** 1–2 per carpel, sarcotesta red.

Distribution and habitat. *Magnolia amazonica* is the only Brazilian *Magnolia* known from the Amazon region. In Brazil, it is found in the North (Amazonas and Pará) and Southeast (Rio de Janeiro) regions, and it is also known from the tropical forests of Peru and Bolivia (Lozano-Contreras 1990), although other species have been recently described there, being segregated from this spe-

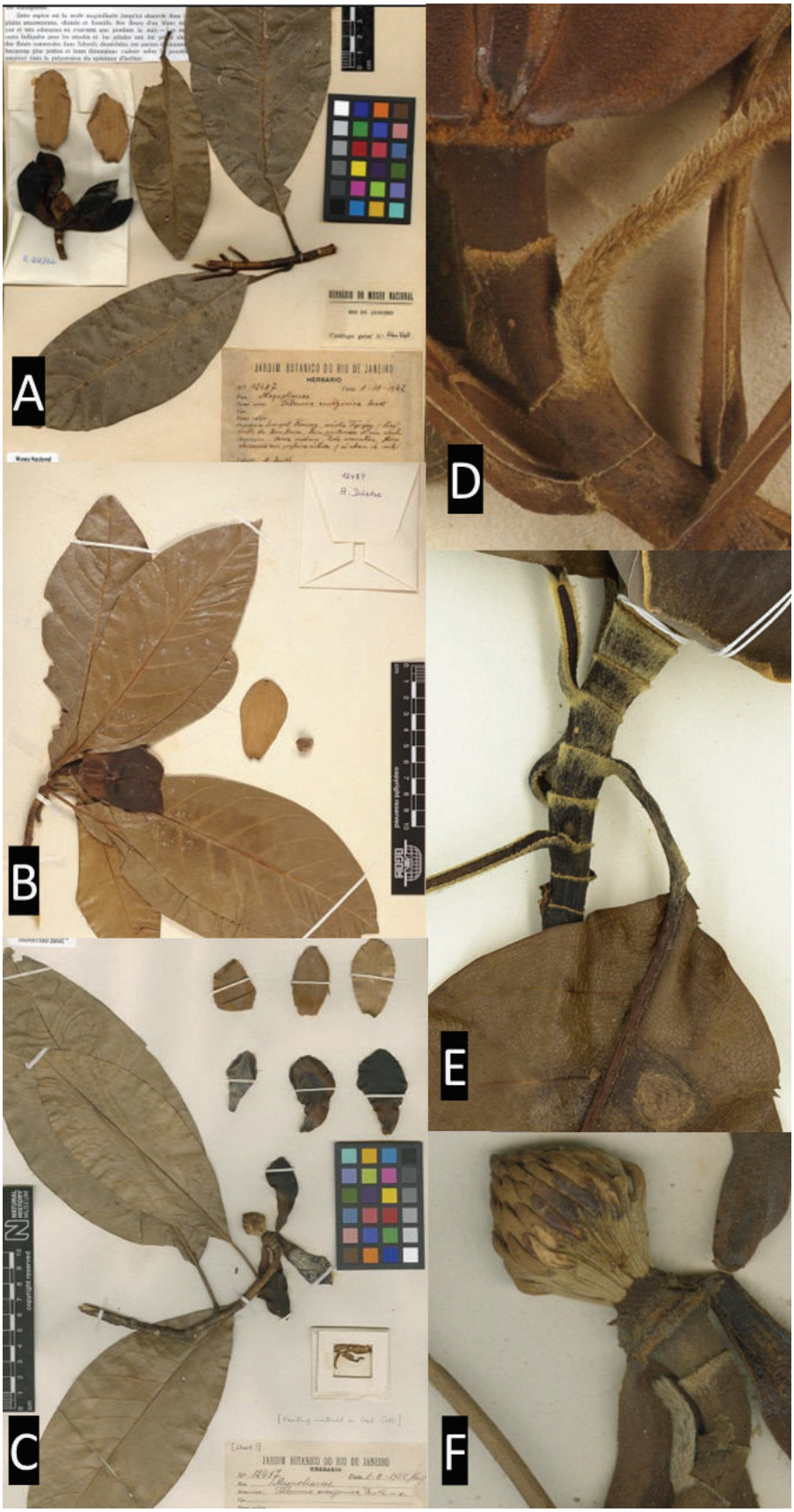

Figure 5. *Magnolia amazonica* **A–C** specimen deposited in herbarium **D–E** detail petiole and peduncle (in the region of the annular scars) showing trichomes in the youngest structures **F** gynoecium. Photos: **A–C** *W.A. Ducke 12487* (R000024142; BM000551380); **B–D**: (B100248229); **C–F**: BM551380; **F**: *I. M. Silva 471* NY 03097880.

cies, e.g. *M. peruviana* A. Vázquez. As a consequence, the presence and distribution of *M. amazonica* in that country needs further investigation. *Magnolia amazonica* is a perennial tree that grows up to 20 m tall in Amazon rainforest.

Phenology. Its creamy-white flowers open at night and were collected in mid-January. Its fruits were observed in mid-July (Ducke 1925).

Preliminary conservation status. This species has previously been assessed as Least Concern (LC) (Khela 2014). However, in this analysis (Brazilian specimens) its area of occupancy (AOO) is about 44.000 km^2 and it is considered to be Endangered (EN) B2b (i,ii) (IUCN 2022). It is likely that this species is declining due to deforestation and land use changes, especially in the northern region of the country, where unfortunately there are flawed laws regarding preservation (Gonçalves et al. 2010). In addition, with the recent description of a *Magnolia* species in its distribution area in Peru (*M. peruviana*), the delimitation of *M. amazonica* may be narrowed in the future, with further studies. Therefore, the conservation status will also likely need to be updated.

Specimens examined. Brasil. Pará: Novo Progresso, Serra do Cachimbo, Área da Aeronáutica torre 2 do Stand de tiro, mata de transição com campinarana, solo areno-argiloso, 9°19'16"S a 9°16'196"S, 54°59'42"W a 54°56'222"W, 20 Aug 2003, *A.S.L. Silva 3967* (RB787799); **Rio de Janeiro:** Município Silva Jardim, Reserva Biológica de Poço das Antas, Trilha do Morro do Calcário, 22°30'/22°33'S, 42°15'/42°19'W, 5 Mar 1993, *S.M. Barreto 30* (RB300133); Nova Iguaçu, Margem do Brejo do Macuco, 12 Dec 2001, *S.J. Silva Neto & M.V. Pereira-Moura 1573* (RB364320); Nova Iguaçu, Região SE, Rebio, Tinguá, Estrada do Ouro, Ponto 154, Planalto próximo a entrada para Igrejinha de Santana, 600 msm, 22°33'56.9"S, 43°28'11.2"W), 25 Jan 2006, *R.D. Ribeiro 569* (RB419738).

Notes. *Magnolia amazonica* is recognized by its puberulent-tomentose pubescence (on several of its structures, e.g., branches, stipules, petioles (Table 1), and can be found in the Amazon region of the country.

The specimen *A.S.L. Silva 3967* in the herbarium of the Botanical Garden of Rio de Janeiro (RB787799) had been erroneously identified as *M. ovata*, likely because of the similarity in the leaf shape between both species. However, they can be differentiated by the absence of trichomes in *M. ovata* (vs. trichomes present on petiole and branches in *M. amazonica*) and the number of carpels: 144–150 in *M. ovata* vs. 98–102 in *M. amazonica*.

***Magnolia brasiliensis* C. O. Azevedo, A. F. P. Machado & A. Vázquez, Brittonia 70(3): 307. 2018.**
Figs 6, 7

≡ *Talauma brasiliensis* (C.O.Azevedo, A.F.P.Machado & A.Vázquez) Sima & Hong Yu, J. W. China Forest. Sci 49(4): 34 2020.

Type. Brasil. Bahia: Vitória da Conquista, Poço Escuro, 14°52'S, 41°0'W, 900–1300 m, fl., 10 November 2008, *C. O. Azevedo et al. 354* (holotype: HUEFS! [HUEFS000037437]).

Description. ***Trees*** 10–20 m tall; ***branches*** cylindrical, blackish when dried, with sparse lenticels, glabrous. ***Stipules*** adnate to petiole, 4–5 mm long, green, oblong to conical, apex obtuse, base truncate, deciduous, glabrous.

Petioles 1.8–3.8 cm long, stipular scar along their entire length (100%), glabrous. ***Leaf blades*** 7.5–15.2 cm × 3.5–7.1 cm, elliptic to oval, base acute, apex acute to obtuse, margin entire, strongly coriaceous when dried, venation pinnate, brochidodromous, 8–12 pairs of secondary veins, glabrous, prominent on both faces. ***Peduncle*** cylindrical, glabrous, annular scars present. ***Flowers*** terminal, solitary, ***flower bud*** ellipsoid, 3–4 × 2–2.5 cm; protected by perula enveloping and protecting the flower bud, perula concave, green to yellowish when mature, brownish when dried; ***outer sepaloid tepals*** 3, 3–3.2 cm × 2.4–3.2 cm, navicular, obovate, base truncate, apex rounded, greenish; ***inner petaloid tepals*** 6 (7), 3–3.5 cm × 1.3–1.7 cm, navicular, spathulate, apex obtuse, base attenuate to truncate, cream-colored; ***stamens*** 75–93, 8–9 mm, laminar, slightly falcate, arranged spirally in 4–5 series, apex obtuse, whitish to yellowish, thecae 2, anthers introrse, dehiscence longitudinal; ***gynoecium*** 1.8–2 cm × 1–1.3 cm, conical to ellipsoid, cream-colored, slightly suberous, carpels 40–57. ***Immature fruits*** 4.4–6.7 cm long, 5 cm in diameter, obovoid to broadly ovoid, occasionally subspherical, cream-green basally, dark green distally, lenticellate, with short yellowish strigose trichomes; ***mature fruits*** 7–8 cm × 6–7 cm subspherical, dehiscence circumscissile, in irregular, blackish syncarpous masses; ***carpels*** slightly prominent, blackish on dorsal wall; ***seeds*** 1–2 per carpel, angular, obovoid, 8–12 mm long, 5 mm thick (broadest side), sarcotesta dark red, scented.

Distribution and habitat. *Magnolia brasiliensis* is an endemic species that has been found in the states of Bahia and Minas Gerais, typically at 900–1300 m elevation (de Azevedo et al. 2018). In Bahia, it occurs in Mata de Cipó, in semi-deciduous seasonal forest, in the transition between Caatinga and Atlantic Forest. In Serra do Espinhaço, in Minas Gerais, *M. brasiliensis* is always associated with watercourses and riparian forests (de Azevedo et al. 2018).

Phenology. The species was observed flowering between October and December and fruiting between January and March.

Preliminary conservation status. This species has been assessed as Endangered (EN) (Lamarche and de Azevedo, 2021), which is confirmed in this analysis, despite a few additional records. The area of occupancy (AOO) is about 24.000 km^2 and it is thus considered to be Endangered (EN) B2b (i,ii) (IUCN 2022), mainly taking into account its low occurrence number in current localities, and the possible risk of degradation of its natural habitat in the state of Bahia.

Specimens examined. Brasil. Bahia: Morro do Chapéu, Rio Ferro Doido, 22 km L de Morro do Chapéu, 01 May 1999, *F. França 2780* (HUEFS37437); Vitória da Conquista, Chapada dos Cactos, Poço Escuro, 10 Nov 2008, *C. Acevedo 354* (HUEFS145909); **Minas Gerais:** Conceição do Mato Dentro, Serra do Cipó, 13 Nov 2004, *A.E.H. Salles 3322* (HEPH12162); Ca. 7 km N.E of Diamantina, road to Mendanha, 29 Jan 1969, *H.S. Irwin 22808* (V0218886F); Morro do Coco, próximo ao trevo para Diamantina, ca. 1300 m, 18°26'S, 43°41'W, 21 Mar 1989, *R. Mello Silva 49* (MBM138963, V0218885F); Diamantina, km 685 da BR 367 na direção de Couto de Magalhães, lado esquerdo da rodovia, 18°13'04"S, 43°35'36"W, afloramentos rochosos, campo rupestre e brejo estaciona, 6 Jan 2009, *L.M. Borges 393* (CEN92706, HUEFS224097, RB664467); Mun. de Jaboticatubas, km 140 ao longo da rodovia Lagoa Santa-Conceição do Mato Dentro, 29 Feb 1980, *J.R. Pirani 5949* (SP168043); Santana do Riacho, Serra do Cipó,

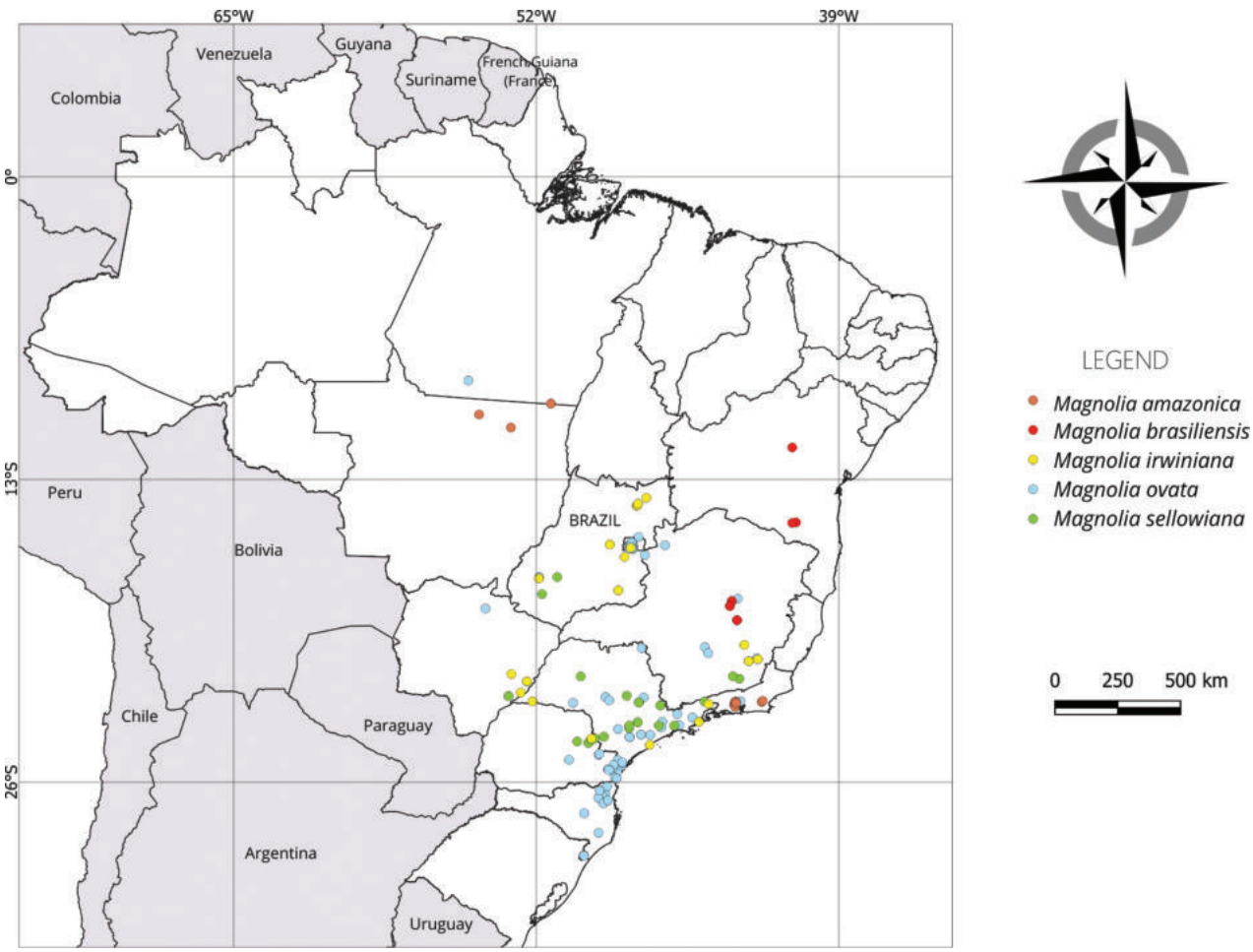

Figure 6. Geographical distribution of *Magnolia* species in Brazil.

córrego 2 pontinhas, 24 March 1989, *R. Mello Silva 15953* (US 1483304); Serra do Cipó, córrego 2 pontinhas, ca. 1220 m, 19°85'S, 43°34'W, 24 Mar 1989, *R. Mello Silva 50* (MBM138964, RB409806, V0218888F); Serra do Espinhaço. Serra do Cipó, 18 Feb 1972 *W.R. Anderson 8935* (US1996644); Serra do Cipó, Mun. Santana do Riacho, rodovia Belo Horizonte, Conceição do Mato Dentro km 112, córrego 2 pontinhas, 1250 m, *A.A. Grillo & M. Sztutman s.n.* (SP13861).

Notes. *Magnolia brasiliensis* is easily distinguished from other species of the genus occurring in Brazil due to its vegetative characteristics (Table 1). The species has elliptic leaves with entire margins, glabrous, coriaceous and smaller (7.5–15.2 cm × 3.5–7.1 cm) (vs. differently shaped, undented, membranous and larger leaves) when compared to other *Magnolia* species from Brazil. Another interesting character is the short strigose pubescence on its fruit, with linear distribution along its furrows, different from other species where the pubescence is broader and denser (e.g. in *M. amazonica*) (Figs 7, 11). Moreover, *M. brasiliensis* is the only representative of the genus known from Bahia.

The region where *M. brasiliensis* occurs is drier than that from the other species, in a transition area between Caatinga and Atlantic Forest of Brazil, a region that despite being humid, has a lower intensity of rainfall than other areas of the same domain, which may be a determining factor for the size and texture of the leaves and also for petiole size (Gutiérrez-Lozano et al. 2021).

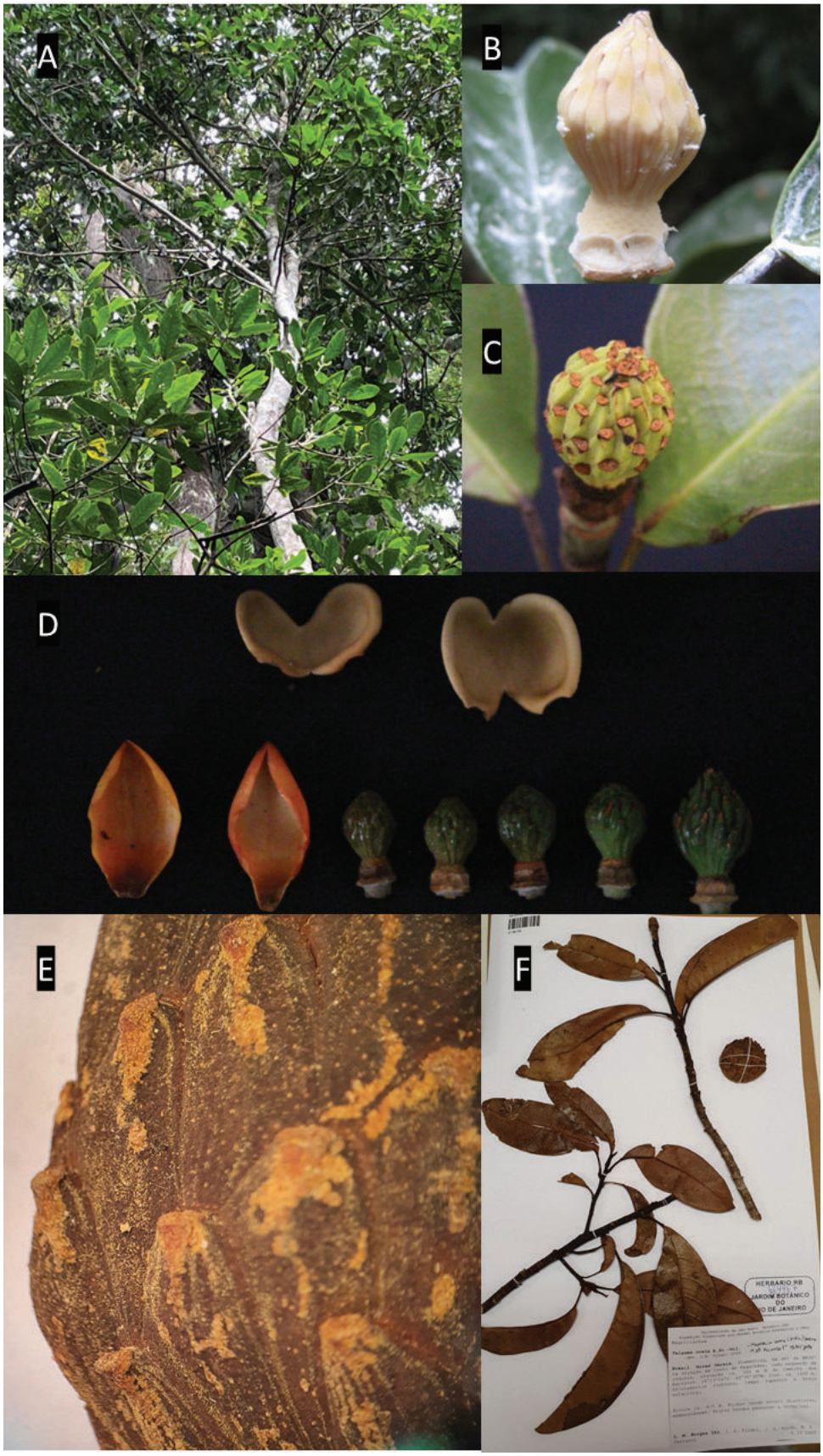

Figure 7. *Magnolia brasiliensis* **A** habit **B** immature gynoecium **C** immature fruit **D** bracts (perule) and gynoecium **E** details of trichomes on the fruit **F** specimen deposited in the RB herbarium showing coriaceous leaves. Photos: **A–D**: C. O. Azevedo; **E**: *R. Mello-Silva 50* (RB409806); **F**: *L.M. Borges 393* (RB664467).

Table 1. Morphological, geographic, vegetation and phenology comparison table between native *Magnolia* species occurring in Brazil. (*from Lozano (1990); **from Azevedo et al. (2018).

	M. amazonica	***M. brasiliensis***	***M. irwiniana***	***M. ovata***	***M. sellowiana***
Pubescence of the peduncle	Tomentose	Glabrous	Glabrescent	Glabrous	Glabrescent
Presence of lenticels	Lenticulate	Densely lenticulate	Sparse lenticels	Lenticulate	Sparse lenticels
Petiole size (cm)	1,8–5	1,8–3,8	2,3–6	2,5–5 cm	2–5,6
Pubescence of the petiole	Tomentose	Glabrous	Glabrescent	Glabrous	Glabrescent
Leaf size (cm)	11 – 28 × 4 – 12	7,5–15,2 × 3,5–7,1	9-19 × 5-9,2	12,7–29,07 × 7,8 – 16,5	10-15,1 × 4,7-10
Leaf shape	Elliptic	Elliptic to oval	Oval-elliptic	Ovate-elliptic	Broadly elliptic
Leaf margin	Entire	Entire	Undulate	Entire	entire-irregular
Pairs of secondary veins	8–19	8–12	6–11	8–13	5–13
Leaf texture	Slightly coriaceous	Strongly coriaceous	Slightly coriaceous	Papyraceous	Papyraceous-membranous
Pubescence of the leaf	Sericeous-tomentose	Glabrous	Glabrescent	Glabrous	Glabrescent
Petaloid tepal size	Petaloid 6, 6–7 cm × 3–5 cm	Petaloid 6(7), 3–3,5 cm × 1,3–1,7 cm	Petaloid 6, 3.0–3.8 cm × 2.4–3.2 cm	Petaloid 6, 3,0–3,8 cm × 2,4–3,2 cm	Petaloid 6, 2,7–3,1 cm × 1,5–2,9 cm
Sepaloid tepals size	Sepaloid 3, 5–7 cm × 3–4 cm	Sepaloid 3, 3–3,2 × 2,4–3,2 cm **	Sepaloid 3, 4.5–4.8 cm × 3.5–3.8 cm	Sepaloid 3, 4,5–4,8 cm × 3,5 – 3,8 cm	Sepaloid 3, 3,4–4,0 cm × 2,7–3,2 cm
Number of stamens	98–102**	75–93**	ca. 114*	144–150*	ca. 180*
Pubescence of the fruit	Puberulent	Strigose short	Puberulent	Glabrous	Glabrous
Number of carpels	44–48	40–57**	111*	68–71*	102*
Distribution	Amazon region (Brazil, Bolivia and Peru), Southeast Region (Rio de Janeiro)	Endemic Northeast Region (Bahia) Southeast Region (Minas Gerais)	Endemic Southeast (São Paulo, Minas Gerais), and Central-West (Distrito Federal,Goiás, Mato Grosso do Sul) regions	Endemic North, South, Southeast, Midwest	Endemic Southeast (São Paulo, Minas Gerais), and Center-West (Goiás, Mato Grosso do Sul)
Vegetation	Tropical forest	Bahia: Semi-deciduous seasonal forest; Minas Gerais: Associated with watercourses and riparian forests	Tropical deciduous and riparian forests (next to watercourses)	Riparian forest and montane rain forest	Riparian forest
Phenology	Flowers: Mid-January	Flowers: October and December	Flowers: October to January	Flowers: September to December	Flowers: March to December
	Fruits: Mid-July	Fruits: January to March	Immature fruits: mid-October to March	Immature fruits: March to October	Immature fruits: January to July
				Mature fruits: June to September	

***Magnolia irwiniana* (Lozano) Govaerts, World Checkl. and Bibliogr. Magnoliaceae: 71. 1996.**
Figs 6, 8

≡*Talauma irwiniana* Lozano, Rev. Acad. Colomb. Ci. Exact. 66: 580. 1990.

Type. Brasil. Goiás: Chapada dos Veadeiros, "ca. 15 km W of Veadeiros", 1000 m, 12 February 1966, fr., *H.S. Irwin et al. 12681* (holotype: RB! [RB00540686]; isotypes: COL!, MO! [MO216832], NY! [NY00320735, NY00320738], US! [US00433287, US00433288]).

Description. ***Trees*** ca. 15 m tall; ***branches*** cylindrical, with sparse lenticels, with cream-colored, tomentose and glabrescent trichomes, ***Stipules*** adnate to petiole, 0.5–1 cm long, green, oblong to conical, obtuse apex, truncate base, deciduous, tomentose when young. ***Petioles*** 2.3–6 cm long, stipule scar over its entire length (100%), yellowish-villous-tomentose trichomes when young. ***Leaf blades*** 9–19 cm × 5–9.2 cm, oval-elliptic, asymmetrical, apex obtuse-rounded, base cuneate-cordate, margin undulate, when young tomentose on abaxial side, glabrescent or

trichomes persistent in herbarium material; venation pinnate, brochidodromous, abaxially slightly tomentose when young, adaxially glabrous, brown or yellowish; 6–11 pairs of secondary veins, glabrous, brown or yellowish. ***Peduncle*** cylindrical, tomentose at the annular scars, yellow trichomes or glabrescent, annular scars present. ***Flowers*** terminal, solitary, ***flower bud*** ovoid, 4.1 × 3.5 cm, white, glabrous, protected by the perula which is enclosing and protecting the flower bud, perula concave, brownish when dried; ***outer sepaloid tepals*** 3, 4,8–5 cm × 2,1–4 cm, cream-colored, navicular, spathulate, apex obtuse, base attenuate to truncate, glabrescent; ***inner petaloid tepals*** 6, 4,5–4,6 cm ×1,8–2,3 cm, navicular, spathulate, apex obtuse, base attenuate to truncate; ***stamens*** ca. 114, 1.2–1.4 cm × 0.1–0.2 mm, laminar, slightly falcate, arranged spirally in 4 series, apex obtuse, whitish to yellowish, thecae 2, introrse, dehiscence longitudinal; ***gynoecium*** conical to ellipsoid, slightly suberous, cream-colored, carpels ca. 111. ***Immature fruits*** 3–4 cm × 4.2–4.5 cm, obovoid to irregular shape, dehiscence circumscissile, in irregular syncarpous masses, yellow puberulent trichomes, ***seeds*** 1–2 per carpel.

Distribution and habitat. *Magnolia irwiniana* occurs in tropical deciduous and riparian forests (next to watercourses). During collecting expeditions, it was found exactly in a saturation area, on waterlogged soil. It occurs in the Southeast (São Paulo, Minas Gerais) and Central-West (Goiás) regions.

Phenology. The species was found with flowers between October and January and immature fruit was observed in mid-October and March.

Preliminary conservation status. This species has been assessed as Endangered (EN) (Global Tree Specialist Group, 2014), which is here confirmed. The area of occupancy (AOO) is about 96.000 km^2 and it is thus considered to be Endangered (EN) B2b (i,ii) (IUCN 2022). Despite having a reasonable number of locations, it was observed during expeditions that the sites where the species was found were degraded or extremely fragmented (in one case having only one adult individual in an area), which exemplifies the serious decline in habitat.

Specimens examined. Brasil. Distrito Federal: Brasília, Reserva ecológica do IBGE, proximidade do córrego Taquara, na divisa com Jardim Botânico de Brasília (Cristo) e Fazenda Água limpa-FAL-Unb, 13 Feb 2014, *M. Aparecida da Silva 8015* (RB1140562); **Goiás:** Alto Paraíso de Goiás, Camping Portal da Chapada, Centro Oeste, Mata de galeria, 1164 m, 11 Jan 2002 *L.H. Soares 1208* (RB534341); Chapada dos Veadeiros, gallery forest and adjacent campo. ca. 15 km. W. of Veadeiros, Goiás, 12 Fev 1966, *H.C. Irwin 12681* (MO216832, NY320735, IAN137999); Margem esquerda do lago, cerca de 1,5 km após a Barragem (montante), 30 Marc 2005, *A.A Santos 2576* (CEN66134); Near Pico dos Pirineus, 26 Jan 1968, *H. S. Irwin et al. 3734* (US2221273); Teresina de Goiás, Estrada Alto Paraíso Teresina, 10 Out 1979, *E. P. Heringer et al. 1658* (US3319311); **Mato Grosso do Sul:** Bataguassu, estrada para Anaurilândia, 19 Nov 1992, *I. Cordeiro et al. 922* (SP268180); Estrada Bataguassu-Brasilândia, próximo a Bataguassu, 22 Nov 1991, *I. Cordeiro 1030* (SP268194); **Minas Gerais:** Fazenda do Toninho, Alvinopolis, 15 Jun 1997, *C.C Paula 1393* (VIC17332); Araponga, Pq Estadual, perto de um centro de pesquisa, 05 Jan 2008, *B.S. Leoni 7072* (RB739528); Santos Drummont, Posses, Sítio Aracá, nascentes do córrego Araçá, 1000 m, 21°28'03"S, 43°39'26"W, 15 Oct 2003, *R. Mello Silva 2168* (RB 394934); Córrego Do Bárbaro, Parque Nacional da Serra da Canastra, São Roque de Minas, 19 Oct 1997, *J.N. Nakajima 2990* (ESA102608); Conceição do Mato Dentro, 10 Jan 2022, *J.C.J. Barbosa et al. 14* (SP540865); Viçosa, 2 Nov 1935, *C. Baez 1662* (RB210355); Viçosa, Estação de Pesquisa,

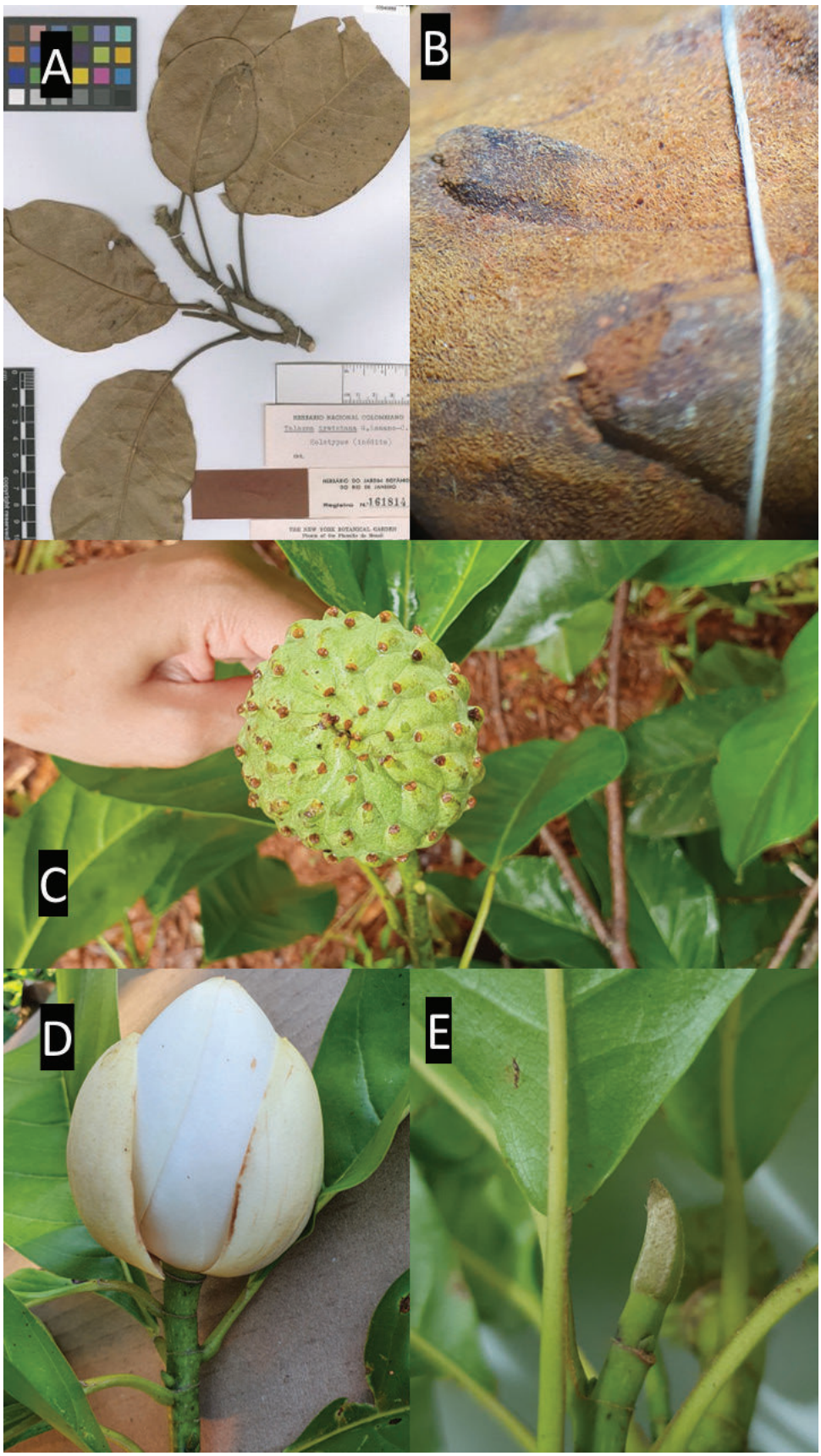

Figure 8. *Magnolia irwiniana* **A** herbarium specimen, asymmetrical leaves **B** detail of trichomes on the carpels **C** immature fruit **D** floral bud **E** detail of stipule and petiole scar. Photos: **A**: *H.S Irwin 12681* (RB 540686); **B**: *H.S Irwin 12681* (MO 216832) **C–E**: *J. C. J. Barbosa*.

Treinamento e Educação Ambiental, Mata do Paraíso, 13 Jun 2013, *M.V.R.C Simão 326* (VIC40472); Sítio Bom Sucesso, fragmento de mata próximo de nascente de rio,24 Nov 2021, *J.C.J Barbosa & J.D.B. Miranda 11* (SP540864); **São Paulo:** Estação Ecológica Juréia-Itatins, Margens do Rio Verde, proximidades do Pocinho, 12 Marc 1992 *S. Aragaki 13* (SP253046); São José do Barreiro, Fazendo Atibaia, Acesso pelo km 258 da Rodovia dos Tropeiro, Interior da Mata do Mascote, 4 Jul 2007, *H. Serafim 276* (RB719859); Reserva Estadual do Morro do Diabo, Mun. Teodoro Sampaio (à direita do Angelim), 28 Nov 1985, *O.T Aguiar 152* (SPSF9544); Ubatuba, Praia de Itamambuca, 05 Feb 1996 *H.F Leitão Filho et al. 34821* (SP295573).

Notes. *Magnolia irwiniana* has been extensively confused with *Magnolia ovata*, but it can be easily distinguished by the asymmetrical leaf with undulate margin, and the presence of trichomes on its structures (vs. symmetrical leaf with entire margin and glabrous structures) and the high number of carpels, ca. 111 (vs. 68–71) (Figs 11, 12).

***Magnolia ovata* (A.St.-Hil.) Spreng, Syst. Veg. 4(2): 217. 1827.**
Figs 6, 9

≡ *Talauma ovata* A.St.-Hil., Fl. Bras. Merid. 1: 26, t. 4, f. A. 1824.
= *Talauma dubia* Eichler, Fl. Bras. 13 (1): 126, 1864. Type. BRAZIL (W). S.l., s.d., *Pohl s.n.* (lectotype designated here: BR! [BR5429745], isolectotype; BR5430390]).
≡ *Talauma paranaensis* (A.Vázquez) Sima & Hong Yu, J. W. China Forest. Sci 49(4): 36 2020.
= *Magnolia paranaensis* A.Vázquez, Recursos Forest. Occid. México 4(2): 473 2013. Type. BRASIL. Paraná: Município de Cerro Azul, estrada antiga, Cerro Azul-Jaguariavia, 12 km depois da ponte sobre o Río Ribeira, 24°45'S, 48°45'W, 7 December 1983, *R. Callejas et al. 1871* (holotype: MO! [MO1942518]; isotypes: COL, MB, NY! [NY 413243]).
non Magnolia ovata P.Parm., Bull. Sci. France Belgique 27: 193, 250 1896 ≡ *Magnolia dodecapetala* (Lam.) Govaerts, World Checkl. & Bibliogr. Magnoliaceae [D.G. Frodin & R. Govaerts] 70 1996.

Type. Brasil. Minas Gerais: "In paludosis prope Olho d'Água, parte occidentali provinciae Minas Gerais quam vocant Certão", fl., *St. Hilaire s.n.* (holotype: P! [P00734790], isotypes: MPU! [MPU027385], P! [P00734791, P00734792]).

Description. ***Trees*** ca. 20 m tall; ***branches*** cylindrical, with sparse lenticels, glabrous. ***Stipules*** adnate to petiole, 0.5–4 cm long, green, oblong to conical, apex obtuse, base truncate, deciduous, glabrous. ***Petioles*** 2.5–5 cm long, stipular scar along their entire length (100%), glabrous. ***Leaf blades*** 12.7–29.07 cm × 7.8–16.5 cm; ovate-elliptic, apex and base rounded or obtuse, margin entire, papyraceous, venation pinnate, brochidodromous, 8–13 pairs of secondary veins, glabrous. ***Peduncle*** cylindrical, glabrous, annular scars present. ***Flowers*** terminal, solitary, ***flower bud*** ovoid, 3.1 × 3.7 cm, white, glabrous, protected by the perula which is enclosing and protecting the flower bud, perula concave, brownish when dried ; ***outer sepaloid tepals*** 3, 4.5–4.8 cm × 3.5–3.8 cm, broadly elliptic, base truncate, apex apiculate, glabrous, cream-colored; ***inner petaloid tepals*** 6, 3.0–3.8 cm × 2.4–3.2 cm, navicular to obovate, fleshy, base truncate, apex apiculate, cream-colored; ***stamens*** 144–150, 1.2 cm × 0.2–0.3 mm,

Figure 9. *Magnolia ovata* **A** specimen deposited in herbarium P **B** mature gynoecium **C** specimen deposited in herbarium SPSF **D** longitudinal section of flower bud (gynoecium and stamens) **E** immature fruit **F** annular and petiolar scars. Photos: **A**: *Saint-Hilaire s.n* (P00734792); **B**: *Irwin s.n* (RB161815); **C**: *O.C. Pavão et al.* (SPSF28228); **D**: *R. Marquete 2596* (RB398212); **E–F**: J. C. J. Barbosa.

obovate, spiral arranged in 4 series, thecae 2, introrse, dehiscence longitudinal; ***gynoecium*** 2–3 cm × 2–2.5 cm, hemispherical, cream-colored, carpels 68–71. ***Immature fruits*** 4–8.2 cm × 4.3–8.7 cm, ovoid, brown-green, ***mature fruits*** ca. 17 cm diameter, globose, dehiscence circumscissile, in irregular syncarpous masses, glabrous; ***seeds*** 1–2 per carpel, sarcotesta red.

Distribution and habitat. *Magnolia ovata* is endemic and found in all regions of the country, except the Northeast. It occurs in riparian forest and montane rain forest.

Common names. 'Pinha-do-brejo': 'pinha' means the best-known pine shape like in *Annona*, and 'brejo' (swamp) means the habitat where specimens are normally found; Baguaçu.

Phenology. This species was found flowering from September to December, with immature fruits between March and October, and mature fruits between June and September.

Preliminary conservation status. This species has previously been assessed as Least Concern (LC) (CNCFlora 2016). In contrast, in this analysis the area of occupancy (AOO) is about 288.000 km^2 and it is considered to be Endangered (EN) B2b (i,ii) (IUCN 2022). We need to consider that the knowledge about the genus was scarce at that time. The fact that other authors accepted a broader delimitation of the species and, consequently, a broader distribution for it, impacted their conservation status assessment, which differs from the one recorded in this paper. Despite its wide distribution, the habitat quality of *M.ovata* is not ideal, mainly because there are records in urban areas and without conservation actions.

Specimens examined. Brasil. Distrito Federal. Área próxima à Reserva ecológica do IBGE, Cachoeira do Tororó, a ca. de 10 km entrando à esquerda na placa da Fazenda Santa Prisca, 15 Oct 1996, *R. Marquete 2596* (RB398212); Torto, Fundação Zoobotânica, 10 Oct 1961, *E. P. Heringer 6864* (US1691190); Fundação Zoobotânica, 20 Oct 1991, *E.P. Heringer*, *8726* (SP79747) Fazenda água limpa/UnB, mata de galeria do córrego da Onça, coletas efetuadas no final da mata, 7 Jul 1994, *B.M.T Walter 2166* (CEN18475, MBM225747); Estação Ecológica do Jardim Botânico de Brasília, 27 Oct 1964, *I.N.C. Azevedo 204* (HEPH12165; RB210306); Estação Ecológica do Jardim Botânico de Brasília, 7 Nov 2002, *F.P.R Jesus 207* (HEPH121750); Estação Ecológica do Jardim Botânico de Brasília área na borda do projeto Águas do cerrado, 3 Aug 1995, *F. Silva 15* (HEPH12171); Jardim Botânico de Brasília, 23 Sep 2008, *R.C. Martins 100* (HEPH12168); Jardim Botânico de Brasília, 8 Oct 1993, *M. Boaventura 49* (HEPH12159, HEPH8469); Jardim Botânico de Brasília, 29 Apr 1985, *Equipe do Jardim Botânico de Brasília 393* (HEPH12172); Jardim Botânico de Brasília, 20 km de Brasília, 24 Nov 1993, *I.V. Lima 304* (HEPH12169); Mata do Riacho Fundo, Fazenda Sucupira (CENARGEN/EMBRAPA), 18 Aug 1997, *A.B Sampaio 127* (CEN33404); Fazenda Sucupira, mata de Galeria do Riacho Fundo, atrás da churrasqueira, a aproximadamente 5 m da margem direita do Riacho Fundo, 28 Jun 2000, *E.S.G Guarino 250* (CEN39351); Rio Torto, ca. 10 km N of Brasília, 8 Jul 1966 *H.S. Irwin et al. 18092* (SP140657; SP1443714); Reserva Ecológica do IBGE, mata ciliar do córrego Roncador, 5 Jun 1989, *D. Alvarenga & F. C. A. Oliveira 1609* (US3255147); Road Brasília to Taguatinga, forest on marshy ground, 12 Nov 1964, *G.T. Prance s.n.* (P01753310); Mata do Bananal, atrás da EMBRAPA/CENARGEN, na margem esquerda do Córrego Bananal, 2 Aug 2000, *S. Ernestino et al. 335* (CEN39434); Vicinity of Planaltina, 3 Oct 1965, *H.S. Irwin 8905* (RB210326); **Goiás:** 42 km south of Caiapônia, riverine

forest of Rio Claro, 27 Oct 1965, *G.T Prance s.n* (P01753311); cerca de 2 km após a ponte sobre o rio Preto, sentido Palmital-Cristalina, à esquerda, em frente a entrada da faz. do Sr. Edileno, 11 Sep 2002, *A.A. Santos 1478* (CEN47791); **Mato Grosso do Sul:** Fazenda Panambi, Córrego São Bernardo, 28 Oct 1981, *P.P. Furtado 66* (RB210335); Coxim, Conglomerado, MS-141, Subunidade 01, subparcela 02, indivíduo 18, 12 Apr 2018, *G.H.L Silva 445* (CEN109241); **Minas Gerais:** Serra da Araponga, Fazenda Neblina, 23 Oct 2001, *L.S. Leoni 4755* (RB1341962); Carmópolis de Minas, Estação Ecológica da Mata do Cedro, 11 Dec 2004, *L. Echternacht 778* (HUEFS118654); Serra dos Órgãos, 1 Jan 1839, *Guillermin s.n* (P01753313); Viçosa, ESAV, *Y. Mexia s.n.* (VIC232); **Paraná:** Antonina Figueira de Braça, 30 Oct 1973, *G. Hatschbach 32972* (MBM31012); Antonina, Rio Pequeno, 18 Aug 1978, *G. Hatschbach 41553* (MBM59973); Antonina, Rio Capivari, 23 Jun 1972, *G. Hatschbach 29731* (MBM37889); Perto da Casa Branca, 10 km W de Cerro Azul, 12 Aug 1966, *J.C. Lindeman 2271* (MBM11594); Cerro Azul, Rib. Do Tigre, 7 Dec 1983, *G.Hatschbach 47636* (MBM88597); Guaraqueçaba, RPPN Salto Morato, trilha do pico, 18 Jul 2013,*M.L. Brotto 1324* (ICN193487; MBM429910); Rio Bananal, 9 Dec 1970, *G.Hatschbach 25776* (MBM22913); Rio do Cedro, encosta de morro, 13 Sep 1967, *G.Hatschbach 17193* (MBM6008); Reserva Natural Salto Morato, Área do Projeto Sucessão, 1 Oct 2001, *F. Putini 2855* (MBM279318); Serrinha, 6 Jul 1967, *G. Hatschbach 16696* (MBM3379); Rio Vermelho, 06 Dec 1972, *G.Hatschbach 30925* (MBM37887); Colônia Parati, 20 Mar 2002, *J.M Silva 3591* (RB210299); Monte Alegre, Embaú, 23 Mar 1954, *J.G. Khulmann s.n* (RB210320); Jaguariaíva, Rio do Sabia, 28 Nov 1968, *G. Hatschbach 20457* (MBM11348); Morretes, Serra do Marumbi, encosta voltada para América de Cima, 25°28'40"S, 48°53'04"W, 240 m, 11 Jul 2020, *M.L. Brotto 3885* (MBM429910); Porto de Cima, encosta de morro, 4 Jun 1974, *G. Hatschbach 34473* (MBM31011); Marumbi, 16 Nov 1978, *G. Hatschbach 41719* (MBM59972); Porto de Cima, margem do rio, 28 Nov 1973, *G.Hatschbach 33397* (MBM31014); PARNA Saint-Hilaire/Lange, 11 Dec 2017, *R.R. Völtz 1469* (UPCB3822); São João da Graciosa, 07 Nov 1961, *G.Hatschbach 8624* (MBM74971); Paranaguá, Rio Cambará, 24 Oct 1968, *G.Hatschbach 20121* (MBM12255); **Rio de Janeiro:** Petrópolis, Quitandinha, 20 Feb 1948, *O.C. Góes 29* (RB210304): **Santa Catarina:** Barra do Rio do Meio, 14 Mar 2010, *M. Verdi el al. 4475* (FURB23555, JOI6861); Blumenau, Associação Desportiva Hering, Parque da Hering, 31 Jan 2011, *E. Torres s.n*. (FURB33876); Ilhota, Morro do Baú, 22 Nov 2002, *D.B. Falkenberg 10449* (FURB41585); Jaraguá do Sul, Margem do rio Cerro, 21 Oct 2008, *A. Stival-Santos 148* (FURB8683); Joinville, Piraberaba-Rio da Prata, 17 Oct 2009, *S. Dreveck et al. 1194* (FURB15935); Fortaleza, Praia Grande, 9 Jan 2015, *A.A Oliveira 917* (FURB45398, FURB28181); Praia Grande, 23 Nov 1984, *G.Hatschbach 61236* (HUEFS21717); Pouso Redondo, 11 Nov 2008, *M. Verdi 939* (FURB9484); Rio Esperança, Rio dos Cedros, 8 Dec 2010, *M. Verdi 5949* (FURB32892, FURB28189, JOI15501); Rio Natal, Divisa entre São Bento e Corupá, 25 Nov 2013, *P. Schwirkowski 92* (MBM391903); **São Paulo:** Eldorado, 9 March 1995, *R.R. Rodrigues et al. 161* (ESA026072) Mun. Agudos, Faz. São João do Barreiro, mata de brejo ao lado da represa, 15 May 2012, *G.D. Colletta 653* (ESA118868); Loreto, Araras, 1 Dec 1917, *O. Vecchi s.n.* (SP1194); Assis, Estação Experimental do Inst. de Agronomia, região alagada, 19 Sept 1989, *J.A Pastore 261* (SPSF13111); Bauru, 27 Oct 2005, *M. Carboni 268* (ESA100050); Bauru, 14 Oct 2005, *M. Carboni 278* (ESA100047); Mun. Buri Estação Experimental de Buri, Floresta paludosa, degradada, 25 Nov 2014, *N.M Ivamauskas 6656* (SPSF49578); Juquitiba, chácara vizinha no Recanto

da Paz, 23°58'0"S, 47°6'0"W, 7 Sept 2006, *R.J Polisel 404* (SPSF39085); Piracicaba, 29 Jul 1993, *K.D Barreto et al. 797* (ESA10807); Mun. Pedregulho, Parque Estadual das Furnas do Bom Jesus, em capoeirinha, prox. Casa de Sta. Suzia, 23 Jan 1993, *J.R Guillaumon s.n.* (SPSF16065); Salesópolis, Bacia de acumulação do Rio Paraitinga, 4 Feb 2001, *S.A. Nicolau 2748* (SP352569); São José dos Campos, 23°04'30"S, 45°56'15"W, mata do Horto, 24 Oct 1985, *A.F. Silva 1327* (VIC10970); São Luiz do Paraitinga, Parque Estadual da Serra do Mar, 2 Dec 2009, *L.S. Silva et al. 1627* (UEC200460); São Miguel Arcanjo, Parque Estadual Carlos Botelho, Área do projeto Parcelas Permanentes, *V.C. Souza el al. 29220* (ESA109549); São Miguel Arcanjo, 13 Mar 2002, *O.T. Aguiar 1105* (ESA104291); São Miguel Arcanjo, Parque Estadual Carlos Botelho, 06 Jan 2015, *B.G. Silva et al. 183* (UEC188962); Serra da Cantareira, 4 Dec 1987, *O.T. Aguiar 221* (SPSF11587); Parque Estadual das Fontes do Ipiranga, Vila Fachini, 13 Aug 1987, *R. Mello-Silva et al. 20* (SP253208); Área da Companhia Votorantim. Estrada entre o alojamento da Barra e a portaria para Tapiraí, 30 Apr 2013, *V.C. Souza 34973* (ESA123872, RB854665, RB854669).

Notes. Several Brazilian *Magnolia* species have been synonymized under *M. ovata*, but one of the main characteristics that differentiate it from the majority of the other taxa is the absence of trichomes in its structures, being the only species native to Brazil without this feature (Table 1). *Magnolia paranaensis*, previously described as a new species to Paraná, and synonymized with *M. ovata* in the Flora do Brasil (Mello-Silva et al. 2023), does not contain distinguishing features to separate it from *M. ovata*; both have glabrous structures and similar leaf shapes and sizes. The type of *M. paranaensis* was originally identified as *Talauma amazonica*, but as stated in the abovementioned description of *M. amazonica*, the species can be differentiated by the absence of trichomes in *M. ovata* (vs. trichomes present on the petiole and branches in *M. amazonica*) and the number of carpels: 144–150 in *M. ovata* vs. 98–102 in *M. amazonica*.

One of the morphological characters that most impacts the distinction of *M. sellowiana* and *M. irwiniana* from *M. ovata* is the pubescence of the vegetative and reproductive organs, a characteristic not found in *M. ovata*, which is totally glabrous. Characteristics that can also help when distinguishing these species are the shape and texture of the leaves, in addition to the number of carpels and geographic distribution.

***Magnolia sellowiana* (A.St.-Hil.) Govaerts, World Checklist and Bibliography of Magnoliaceae 72. 1996.**
Figs 6, 10,12

≡ *Talauma sellowiana* A.St.-Hil., Fl. Bras. Merid. 1:26, pl. 4B. 1824.
≡ *Magnolia selloi* Spreng., Syst. Veg., ed. 16 [Sprengel] 4(2, Cur. Post.): 216. 1827.
= *Talauma fragrantissima* Hook., Ic. Pl. t. 208–212. 1840. Type. BRASIL. Swampy grounds in the Organ mountains, 3000 feet, January 1837, *Gardner 305* (holotype: BM! [BM000574769]).

Type. Brasil. São Paulo: "in sylvis, prope Ipanema, haud longe ab urbe Sorocaba", fl, *Sellow 2* (lectotype designated here: P! [P00734795]; isolectotypes: F! [F0077437F], P! [P00734796, P00734797], MPU! [MPU027383].

Description. ***Tree*** ca. 15 m tall, ***branches*** cylindrical, with sparse lenticels, with few sericeous trichomes on annular scars, glabrescent. ***Stipules*** adnate to petiole, 0.5–2 cm long, green, oblong to conical, apex obtuse, base truncate, deciduous, tomentose when young. ***Petioles*** 3.7–5,5 cm long, stipular scar along their entire length (100%), tomentose. ***Leaf blades*** 10–17.5 cm × 4.5–10.5 cm, broadly elliptic, base cuneiform, apex rounded or emarginate, entire-irregular margin, papyrus-membranous, young leaves with few trichomes on midvein, glabrescent or trichomes persistent on herbarium material, venation pinnate, brochidodromous, abaxially slightly tomentose when young, adaxially glabrous, 5–13 pairs of secondary veins, glabrous. ***Peduncle*** cylindrical, tomentose at the annular scars, yellow trichomes or glabrescent, annular scars present. ***Flowers*** terminal, solitary, ***flower bud*** not seen; ***outer sepaloid tepals*** 3, 3.4–4.0 cm × 2.7–3.2 cm, navicular to oblong, cream-green, base truncate, apex rounded, fleshy, cream-colored; ***inner petaloid tepals*** 6, 2.7–3.1 cm × 1.5–2.9 cm, cream-colored, obovate to navicular, base rounded, apex rounded, cream-colored, ***Stamens*** ca. 180, 1–1.4 cm × 0.1–0.4 mm, linear, arranged in 8 spiral series, base truncate, apex acute; ***gynoecium*** 1.6–2.5 cm × 1.3–2 cm, hemispherical, carpels ca. 102. Mature ***fruits*** globose, dehiscence circumscissile, in irregular syncarpous masses; ***seeds*** 1–2 per locule.

Distribution and habitat. An endemic species growing in the Southeast (São Paulo, Minas Gerais), and Central-West (Goiás, Mato Grosso do Sul). Found, as most species of the genus in Brazil, in riparian forest.

Phenology. The species was found flowering between March and December and with immature fruits between January and July.

Preliminary conservation status. The species has previously been assessed as Data Deficient (DD) (Khela 2014a). In this analysis, the area of occupancy (AOO) is about 92.000 km^2 and is thus considered to be Endangered (EN) B2b (i,ii) (IUCN 2022). As a species that occurs in regions like Goiás, which has high rates of forest fires and in regions like São Paulo that suffers from high real estate pressure, *M. sellowiana* needs urgent conservation attention, reforestation in protected areas is suggested.

Specimens examined. Brasil. Goiás: Jataí, Sudoeste de Goiás, 11 May 2004, *Souza*, *et al. 3622* (ESA108690); Estrada de acesso à fazenda das Pedras, em frente à sede da fazenda, 16 Jul 1997, *S.P.C. Silva 649* (CEN28390); Ipameri, Fazenda das Pedras, 7 Nov 1996, *S. P. C Silva 500* (CEN30626); **Mato Grosso do Sul:** Botaiporã, Várzea do Rio Samambaia, 7 km L da cidade, 27 Oct 1986, *U. Pastore 145* (MBM115080); Paraná, Município de Sengés, Fazenda Pisa-Papel e Celulose, Poço do Encanto, interior da mata, 18 Dec 1997, *S.I. Elias 306* (ESA377759); Sengés, PCH Fazenda Entre Rios, 26 Mar 2016, *J.M. Silva 9278* (MBM406513); Brasilândia. Estrada Brasilândia- Bataguassu, Córrego Boa Esperança, *A.* 14 Oct 1998, *Amaral Jr. 167* (RB210273, SP334514); Jaguariaiva, Rio Cilada, 18 Feb 1987, G.Hatschbach 50901 (MBM115251); Parque Estadual do Cerrado Jaguariaíva Pr., 10 Oct 2000, *L. von Linsigen 64* (MBM266020); Ventania, Campo de fora, 23 Jul 2004, *D.A Estevan 407* (IAN186917); **Minas Gerais:** Fazenda Neblina-Pq Estadual do Brigadeiro, ao lado da estrada, 2 Apr 1994, *B.S. Leoni 2689* (RB739505); Estação experimental de Café Coronel Pacheco, 5 Sep 1940, *E.P. Heringer 9* (RB44816); Santos Dumont, Posses. Sítio Araçá, Nascentes do córrego Araçá, 27 Mar 2005, *A.P. Fontana 1240* (RB2102370); Viçosa, 12 Nov 1979, *R.S. Ramalho 1659* (RB256157); **São Paulo:** Estrada da Granja TOK, mata

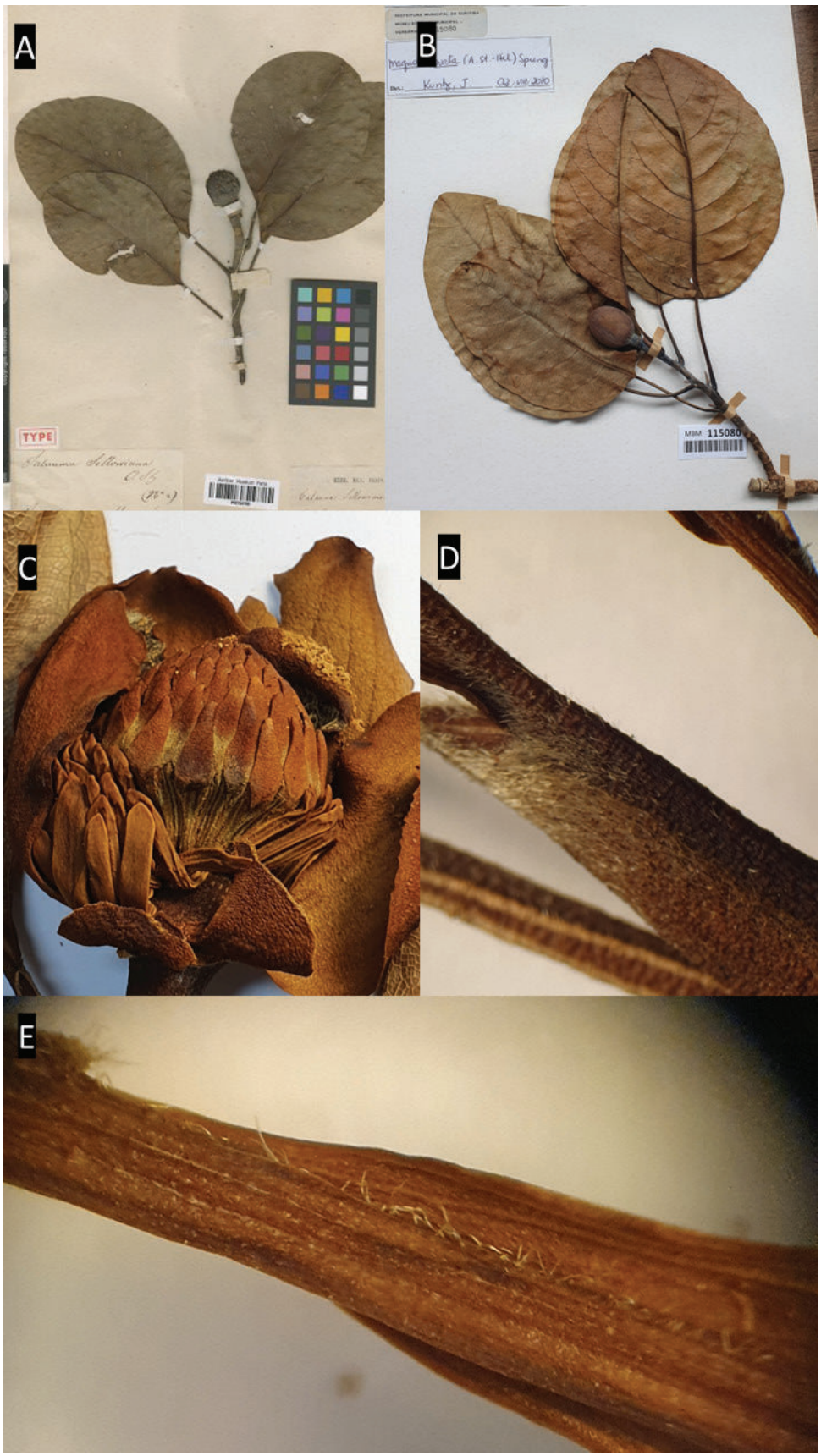

Figure 10. *Magnolia sellowiana* **A** specimen deposited in herbarium P showing broadly elliptic leaf **B** specimen deposited in herbarium MBM **C** flower, detail of gynoecium and stamens **D** stipule with trichomes **E** midvein with trichomes. Photos: **A**: *A. Saint-Hilaire s.n.* (P00734795); **B**: *U. Pastore & R.M Klein 145* (MBM 115080); **C–E**: *L.S. Leoni 2689* (RB739505).

na área da bacia de acumulação do Rio Biritiba Mirim, 20 Jan 2001, *S.A. Nicolau et al. 2591* (SP352454); Espraiado, Faz. N. Senhora da Glória, 2 Dec 1935, *J. Mello s.n* (SP35090); Piracicaba, Rio Claro, Trevo Iracemópolis, 3 Mar 2009, *J. Kuntz 3* (ESA113983); Piracicaba, 3 Mar 2009, *J. Kuntz 2* (ESA113984); Rodovia Piracicaba-Rio Claro-Trevo Iracemápolis, mata de brejo, 9 Oct 2009, *J. Kuntz 4* (RB646302); Rodovia Piracicaba-Rio Claro, Trevo Iracemápolis, 3 Mar 2009, *G.T. Prance 59697* (RB1110753); Mun. de Itapetininga, estação experimental, 29 Nov 1997, *L.C Souza 194* (SP335063, SPSF23732); Itapeva, Estação Experimental de Itapeva, *R.*, 24 Feb 2010, *Cielo Filho 1085* (SPSF43414); Monte Alegre do Sul, 20 Ago 1949, *J.A. Cunha 65* (ESA118919); Monte Alegre do Sul, Bairro do Bugrinho, 20 Jul 1949, *M. Kuhlmann 1809* (SP76739); Penápolis, 20 Ago 1917, *s.c s.n* (SP439); Queluz, 2 Jul 1899, *s.c 104* (SP23811); Butantã, 4 July 1917, *F.C. Hoehne s.n* (SP29959); Bois près Hypanema aux environs de Sorocaba Floresta nacional do Ipanema, s.d., *A. Saint-Hilaire s.n* (MO3411335, P00734797).

Notes. *Magnolia sellowiana* is distinguished from *M. ovata* by its broadly elliptic leaf shape, the greater number of carpels (ca. 102), and the presence of trichomes (vs. oval-elliptic leaves, carpels 68–71, and absence of trichomes in *M. ovata*) (Figs 11, 12).

Lozano-Contreras (1990) indicated that one of the P specimens is the holotype, and the remainder the isotype. However, as no details of each specimen are indicated, it is not clear to us which sheet he selected as holotype. Although P00734795 is indicated in the P herbarium database and JSTOR as holotype, we have not found information in the literature that formally proposes this particular sheet as the holotype. Therefore, we have proposed a lectotypification to formally address this issue.

Lozano-Contreras (1990) also mentioned that he had realized that a specimen deposited at P, originally from B, labeled as *Sellow 1*, was identified as *T. ovata*. However, this material is almost identical to the type of *T. sellowiana* and does clearly belong to this species and not to *T. ovata*. The misidentification of *Sellow 1* as *T. ovata* could be what has led authors to consider the two species as identical, and therefore, synonyms.

Discussion

The main objective of this study was to present the taxonomic revision of the genus *Magnolia* in Brazil, which had been scarcely documented. For the first time, a thorough taxonomic evaluation has been carried out of the majority of herbarium specimens of native *Magnolias*, collected in Brazil, including type material of all species. Furthermore, targeted fieldwork was conducted, leading to an updated delimitation of the previously accepted taxa for the country and thus changing the number of accepted species for the region. In the context of conservation, these updated species delimitations, based on the morphological study of an extensive number of specimens, are highly significant.

The protologues of most species are short and without much information about the morphological characters. Similar to the descriptions by Lozano-Contreras (1990), we prioritized that the descriptions made here integrated not only the reproductive characteristics but also the vegetative ones, taking into account that the flowers and ripe fruits are difficult to see in herbarium records of *Magnolia* species. Pubescence was a character used, together with

Figure 11. A leaf blade *Magnolia amazonica* **B** trichomes from the petiole of *M. amazonica* **C** *Magnolia brasiliensis* **D** fruit with trichomes in *M. brasiliensis* **E** leaf blade *M. brasiliensis* **F** *Magnolia ovata* showing perule **G** floral bud of *M. ovata* **H** leaf blade of *M. ovata* **I** *M. ovata* mature fruit. (**A–B**: *A.M Barreto 30*; **C–E**: *A.A. Grillo & M. Sztutman s.n.*; **F–G**: *E.P. Heringer, 8726*; **H**: *R.R. Rodrigues et al. 161*; **I**: based on photographs of J. C. J Barbosa.) Drawing prepared by Klei Souza.

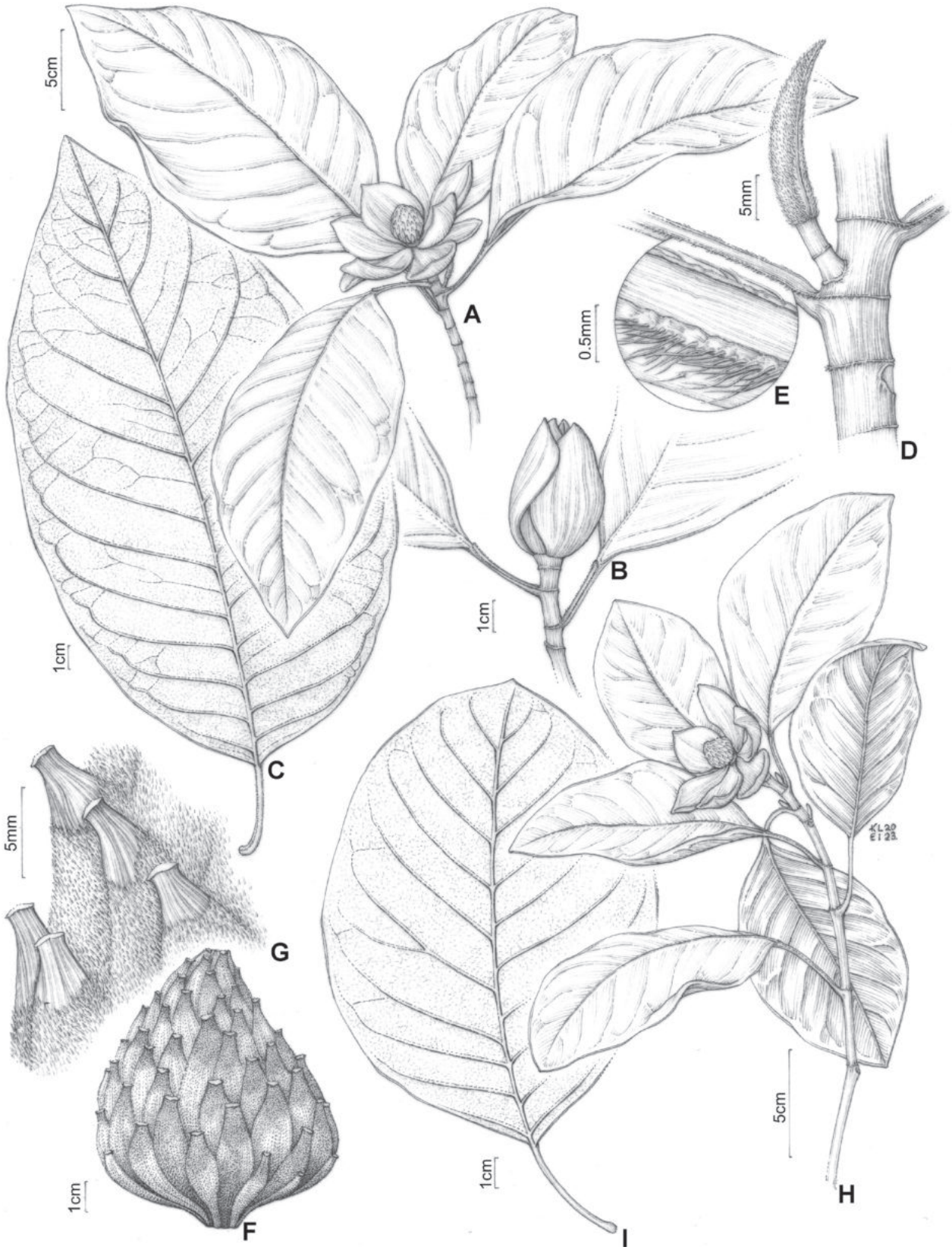

Figure 12. A *Magnolia irwiniana* **B** presence of flower bud in *M. irwiniana* **C** leaf blade of *M. irwiniana* **D** detail of branch and stipule with trichomes in *M. irwiniana* **E** detail of the trichomes on the petiolar scars **F** immature fruit of *M. irwiniana* **G** detail of the puberulent trichomes on the fruit **H** *Magnolia sellowiana* **I** leaf blade *M. sellowiana.* (**A**: based on photographs of D. A. Zavatin; **B**: based on photographs of J.C.J. Barbosa **C–G**: *H.F Leitão Filho et al. 34821*; **H**: based on photographs of D. A. Zavatin; **I**: *M. Kuhlmann 1809*) Drawing prepared by Klei Souza.

reproductive and distribution characteristics, to aid in the separation of species, with trichomes on the fruit being a novel character recognized for M. *brasiliensis*, and that was here described for the first time.

Regarding the synonimization of *M. paranaensis* with *M. ovata*, analysis of specimens in the herbarium and field observations in Paraná supported this decision. The herbarium of the state of Paraná, where the species occurs, was visited, 19 specimens that occur in the region were analyzed, in addition to field work carried out to search for the species. This species was described based on one specimen only, because of the lower carpel number. However, our ongoing research into Neotropical *Magnolias* shows the importance of taking into account a wide range of characters to distinguish between species, in which the carpel number is important but not defining, as it generally concerns a broad range for each species. Hence, it is important to count the number of carpels on many specimens, to be able to include a range rather than a single number. The currently available material for *M. paranaensis* does not allow for that, and therefore, further research is needed to confirm that it is indeed a separate species.

The counting of the number of structures as well as the observation of particular characters need to be carried out during particular developmental phases for both male and female parts. Several chemical studies on the stamens of *Magnolia* species show their importance both in releasing the aroma (Wang et al. 2011) and in understanding stamen development (Nie et al. 2022). It is important to highlight that the stamens of *Magnolia* section *Talauma* are deciduous in the male phase and shed easily, a known characteristic of the genus that aims to better disperse pollen, being a highly specialized evolution (Figlar and Nooteboom 2004; Canright 1952). The presence or absence of dehiscence of this structure is a taxonomic factor that can separate sections (Kim et al. 2002; Wang et al. 2020). However, quickly shedding structures make accurate counting difficult and, therefore, it is recommended to count the stamens while still in the flower bud.

In fruits, it was not possible in some cases to obtain exsiccates with mature fruit for analysis. Although we can achieve a delimitation using vegetative characters and immature material, it is extremely important to have mature material so that we can analyze the shape of the carpels and characteristics that can change during maturation (e.g., presence of trichomes). It is suggested that a sampling be carried out focused on looking for these characteristics.

Unfortunately, about 190 digital records of Brazilian *Magnolias* did not contain photos of the specimens, and more than about 42,1% (80 specimens) of these could not be identified, mainly for the following reasons: herbarium specimens lack reproductive parts, leaves were crumpled or broken, or reproductive parts were poorly mounted on the specimens, making it impossible to visualize trichomes and carpels. Moreover, about 10 specimens could not be identified, because their characters did not coincide with any of the described native Brazilian *Magnolia*, evidencing that new species may be discovered based on herbarium specimens, and that further exploration in the field is required. These are currently being analyzed for future descriptions. Nevertheless, ca. 300 specimens that could be studied in detail allowed us to present a representative study of the genus in Brazil.

As a consequence of our taxonomic study, five native Brazilian species of *Magnolia* are recognized here and their known distribution areas are updated (Table 1). Prior to this study, two widely distributed native *Magnolia* species were recognized in Brazil, *M. amazonica* and *M. ovata*, both species of Least Concern (Khela

2014; CNCFlora 2016), and are here proposed to be Endangered. The recognition of *M. brasiliensis*, *M. irwiniana* and *M. sellowiana* directly affects knowledge about the distribution and conservation status of *M. ovata*, up to now considered widely distributed. This widespread perception is due to the many herbarium specimens that were misidentified. Many of the previously known locations for *M. ovata* are, in fact, areas where we know instead that *M. brasiliensis*, *M. irwiniana* and *M. sellowiana* occur. Therefore, despite some species having their conservation status published on the IUCN Red List, these assessments did not take into account the number of records that were being collected and recognized as *M. ovata*.

There is currently only a good overview of the population health and threats (e.g. current population trend and continuing decline of mature individuals) of the recently described *M. brasiliensis*. None of the other native Brazilian *Magnolia* species has precise population data, although preliminary fieldwork in (type) localities or areas by the first author of this paper shows that the number of individuals is apparently very low. For instance, in Conceição do Mato Dentro, state of Minas Gerais, only one adult individual of *M. irwiniana* was identified despite the apparent suitability of the habitat. In contrast, in regions like Chapada dos Veadeiros, state of Goiás, and Viçosa, Minas Gerais, several young and adult individuals of *M. irwiniana* and *M. sellowiana* were found in small areas. It is important to note that the presence of a nearby mining company and pipeline may exert ecological pressure on the forest and dispersers.

Studies like this are of utmost importance for the understanding of poorly studied and highly relevant genera such as *Magnolia*. We conclude that not only *M. amazonica* and *M. ovata* do occur in Brazil, but that *M. brasiliensis*, *M. irwiniana*, and *M. sellowiana* are distinct and valid species that should be recognized in this country. This knowledge assisted in assessing the conservation status of each species and understanding the distribution of *M. ovata* throughout the country.

To advance the understanding of the ecology and distribution of species, especially *M. irwiniana* and *M. sellowiana*, which sometimes overlap (in terms of distribution and morphological characteristics), molecular studies are suggested, particularly in population genetics (Aldaba Núñez et al. 2021). The main difficulty in collecting species and attempting to conserve *Magnolia* is the fact that its species are part of threatened, small, fragmented and declining tropical ecosystems. More in-depth molecular studies on genetic differentiation that would help in the analysis of gene flow and possibilities of inbreeding, can help us carry out guided reforestation and the implementation of conservation actions.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

Conceptualization: MSS. Funding acquisition: MBRC and JCJB. Investigation: JCJB. Project administration: MBRC. Supervision: MBRC. Writing - original draft: JCJB. Writing - review and editing: MSS, ARGS.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Research Article

Hydrangea xinfeniae (Hydrangeaceae), a new species from Sichuan, China

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Abstract

Hydrangea xinfeniae W.B.Ju & J.Ru, a new species of Hydrangeaceae from Sichuan Province, China, is described and illustrated. The new species belongs to *Hydrangea* sect. *Dichroa* (Lour.) Y.De Smet & Samain, with its distinctive characteristic being the nearly superior ovary. It shares morphological similarities with *H. yaoshanensis* (Y.C.Wu) Y.De Smet & C.Granados, but can be distinguished by its hirsute trichomes densely covered on the branchlets, leaves, peduncles and pedicels, broadly elliptic to rectangular-elliptic leaf blade with nearly rounded base, coarse teeth leaf margins, 3–4 pairs of lateral veins, corymbose cyme with few and loose branches, lanceolate bract, the calyx tube and lobes margin with sparsely hirsute trichomes, adaxially glabrous and abaxially sparsely hirsute petal, outer whorl filaments are linear, inner ones are awl-shaped, glabrous styles, and the nearly superior ovary. *H. xinfeniae* **sp. nov.** currently known from only three relatively small populations of the type locality, and its conservation status is assessed as Data Deficient (DD).

Key words: *Hydrangea* sect. *Dichroa*, morphology, taxonomy

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Introduction

Hydrangea L. (Linnaeus 1753) had been treated to be a member of the tribe Hydrangeeae in Hydrangeaceae, comprising approximately 73 species distributed from Eastern to Southeastern Asia, as well as from Southeastern North America to Central America and Western South America (Huang et al. 1995; Wei and Bartholomew 2001). However, morphological and phylogenetic studies have indicated that *Hydrangea* is not monophyletic (Hufford 1995, 1997; Soltis et al. 1995; Ge 2003; Jacobs 2010; Samain et al. 2010; Zhang et al. 2021). Based on molecular phylogenetic analyses, De Smet et al. (2015) proposed the broad concept of *Hydrangea*, which encompasses *Hydrangea s. str.* and the remaining eight satellite genera within Hydrangeeae, including *Broussaisia* Gaudich., *Cardiandra* Siebold & Zucc., *Decumaria* L., *Deinanthe* Maxim., *Dichroa*

Lour., *Pileostegia* Hook.f. & Thomson, *Platycrater* Siebold & Zucc., *Schizophragma* Siebold & Zucc., grouped as a section within *Hydrangea s. l.* Furthermore, *Platycrater* is merged into *Hydrangea* sect. *Asperae* (Rehder) Y.De Smet & Samain. The broad concept of *Hydrangea* has been supported by Yang (2022). In this study, we also adopt the broad concept of *Hydrangea*.

Hydrangea sect. *Dichroa* (De Smet et al. 2015) comprises 12 species, widely distributed in the tropical and subtropical regions of Southeast Asia, with only a few species extending to Pacific islands. In China, there are six species of this section, distributed from the southwestern to eastern regions (Huang 1987; Huang et al. 1995; Wei and Bartholomew 2001). In recent years, new species from this section have been discovered in China (Huang et al. 2018; Deshmukh and Shende 2021).

During field investigations in Huagaoxi National Nature Reserve of Shuwei Town, Xuyong County, Sichuan Province, an unknown population of *Hydrangea* was discovered. After conducting a comprehensive review of relevant taxonomic literature (Chun 1954; Huang 1987; Huang et al. 1995; Wei and Bartholomew 2001; Jacobs 2010; Huang et al. 2018) and meticulously examining voucher specimens from various herbaria (A, B, C, CAS, CDBI, E, IBK, IBSC, P, PE, K, KUN, L, NYBG, US), we have identified that it represents a new species within *Hydrangea* sect. *Dichroa*, exhibiting morphological similarity with *H. yaoshanensis* (De Smet et al. 2015). In this study, we provide a detailed morphological characterization of this species based on our field observations and a thorough examination of the holotype specimen, and describe it as a new species.

Material and methods

The voucher specimens of the new species in this study were collected from the type locality, Huagaoxi National Nature Reserve, and are deposited in CDBI and KUN. The morphological description of characteristics of the new species was conducted through both living plants in the field and voucher specimens. The morphological measurements of the new species were based on living plants. We examined available online specimen images of *Hydrangea* sect. *Dichroa* species stored in A, B, C, CAS, CDBI, E, IBK, IBSC, P, PE, K, KUN, L, NYBG, and the US through the Chinese Virtual Herbarium (https://www.cvh.ac.cn/) and JSTOR Global Plants (https://plants.jstor.org/). Additionally, we compared the morphological characteristics of the new species with those of similar species, relying on online voucher specimen images and published literature (Huang 1987; Huang et al. 1995; Huang et al. 2018; Deshmukh and Shende 2021).

Taxonomic treatment

***Hydrangea xinfeniae* W.B.Ju & J.Ru, sp. nov.**
urn:lsid:ipni.org:names:77335528-1
Figs 1–3

Diagnosis. *Hydrangea xinfeniae* can be distinguished from the morphologically similar species *H. yaoshanensis* by the presence of densely hirsute trichomes on branchlets, leaves, peduncles and pedicels; leaf blades that are broadly elliptic to rectangular-elliptic with a nearly rounded base and coarse teeth along the

leaf margin, lateral veins 3–4 on each side of the midvein; a corymbose cyme with few, loosely arranged branches and lanceolate bract; calyx tube sparsely covered with hirsute trichomes, with only the edges of the lobes bearing such hairs; a glabrous adaxial surface of the petals, while the abaxial surface is adorned with scattered hirsute trichomes; outer whorl filaments are linear, inner ones are awl-shaped; styles are glabrous, and a nearly superior ovary.

Type. China. Sichuan Province: Xuyong County, Shuiwei Town,Huagaoxi National Nature Reserve, growing on the moist soil under the broadleaved forest, 28°13'29.97"N, 105°36'40.39"E, alt. 1368 m, 22 Jul. 2023, *W.B.Ju & R.Jiang J–1290* (holotype: CDBI!; isotype: KUN!).

Description. Shrub, 55–80 cm tall, slightly curved in the upper part, usually prostrate in the lower part. Branchlets densely covered with hirsute trichomes. Leaves papery, opposite; petioles 2–4.5 cm long, densely covered with hirsute trichomes; blades broadly elliptic to rectangular-elliptic, 6–8 cm long, 4–6 cm wide, covered with hirsute trichomes on both surfaces, denser on the abaxial surface, apex acute or shortly acuminate, base entire and nearly rounded, non-decurrent, margin with coarse teeth, midrib and lateral veins conspicuous, raised on the abaxial surface, 3–4 lateral veins on each side of the midvein, not reaching the leaf margin, extending obliquely. Inflorescence corymbose cymose, loosely few branches; bracts lanceolate, 3.5–4.5 cm long, 1.5–1.8 cm wide, covered with hirsute trichomes on both surfaces; peduncle 0.4–1.2 cm long, densely covered with hirsute trichomes. Flower buds ovate; pedicels ca. 2 cm long, covered with densely hirsute trichomes; calyx tube inverted conical, ca. 2 mm long, sparsely covered with hirsute trichomes, lobes 5–6, lanceolate, ca. 2 mm long, with sparse hirsute trichomes only on the margin; corolla blue, lobes 5–6, free, narrowly ovate-triangular, base flat, gradually narrowing towards the apex, ca. 6 mm long, ca. 2 mm wide, slightly inwardly curved at the apex to form a hook, glabrous adaxially, covered with scattered hirsute trichomes abaxially; stamens 10–12 in two whorls, the outer stamens alternate the petals, and the inner stamens opposite the petals; anthers ovoid, longitudinally split; outer whorl filaments are linear, the base sometimes slightly widens, 2.8–3 mm long, inner ones awl-shaped, slightly wider at the base, gradually narrowing upwards, 2.2–2.3 mm long; styles 3–6, ca. 3 mm long, glabrous, ovary nearly superior, with numerous ovules. Berry nearly spherical, 5.5–6 mm in diameter, sparsely covered with hirsute trichomes. Mature seeds not observed.

Phenology. Flowering from May to June; Fruiting from July to October.

Distribution and habitat. *Hydrangea xinfeniae* sp. nov. is found in its type locality, the Huagaoxi National Nature Reserve in Shuiwei Town, Xuyong County, Sichuan Province, China. It grows on moist soils under the broadleaved forest at an elevation of 1200–1300 meters.

Etymology. The species epithet *xinfeniae* is in honor of Prof. Xinfen Gao, a distinguished female botanist who made significant contributions to the plant diversity survey of Huagaoxi National Nature Reserve.

Vernacular name. Simplified Chinese: 信芬常山; Chinese pinyin: Xìnfēn cháng shān.

Additional specimens examined (paratypes). China. Sichuan Province: Xuyong County, Shuiwei Town, Huagaoxi National Nature Reserve, 28°15'26.33"N, 105°28'58.89"E, alt. 1220 m, 5 Jun. 2015, *W.B.Ju J–441* (CDBI); ibid., 28°13'51.04"N, 105°37'3.80"E, alt. 1272 m, 10 Sep. 2023, *W.B.Ju & J.Ru J–1374* (CDBI).

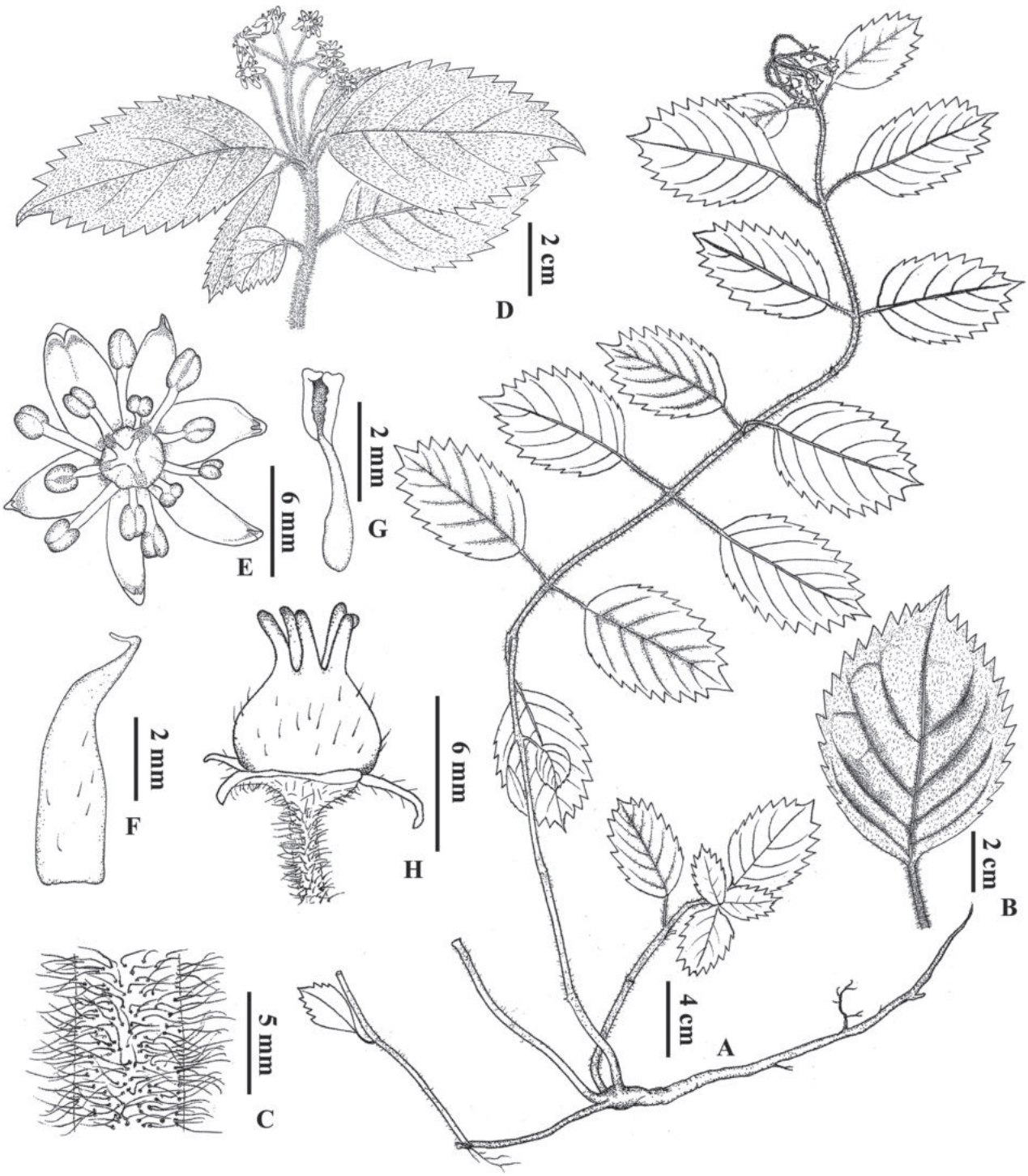

Figure 1. *Hydrangea xinfeniae* W.B.Ju & J.Ru, sp. nov. **A** plant **B** leaf adaxial **C** twig **D** a branch with inflorescence **E** flower **F** petal **G** stamen **H** berry. Illustration drawn based on living plants (flower and berry) combined with specimens from the holotype by Zhenlong Liang.

Preliminary conservation assessment. Based on the currently available survey data, only three relatively small populations have been discovered in Huagaoxi National Nature Reserve. Our knowledge regarding the status and distribution range of populations outside this area is limited. According to IUCN red list categories and criteria (IUCN 2022), the conservation status of the new species is temporarily assessed as Data Deficient (DD) due to insufficient avail-

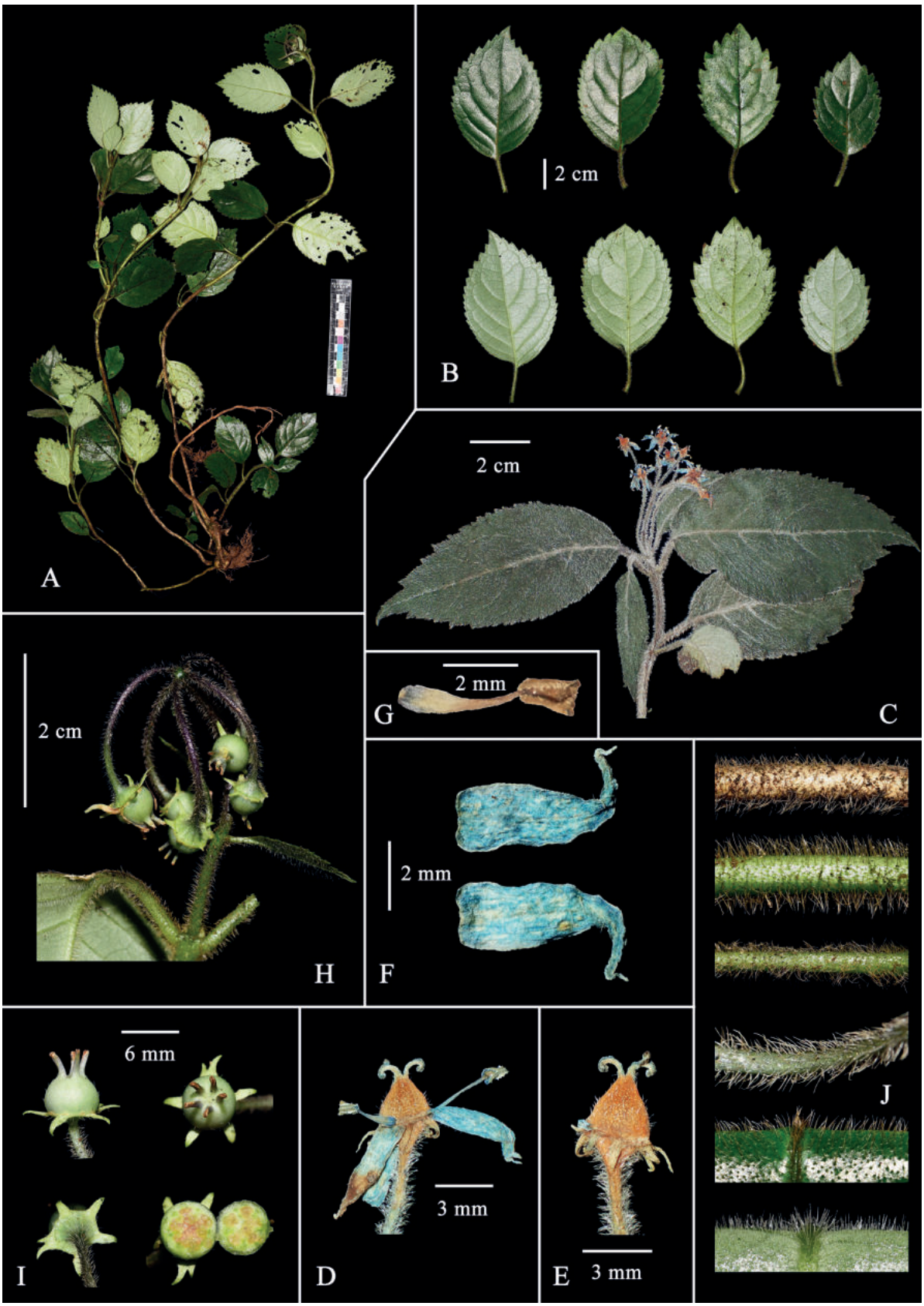

Figure 2. *Hydrangea xinfeniae* W.B.Ju & J.Ru, sp. nov. **A** plant **B** leaves (upper: adaxial, lower: abaxial) **C** a branch with inflorescence **D, E** flower **F** petal (upper: adaxial, lower: abaxial) **G** stamen **H** infructescence **I** young berry **J** indumentum on different organs, from upper to lower, including old branchlet, young branchlet, petiole, carpopodium, leaf adaxial, and leaf abaxial.

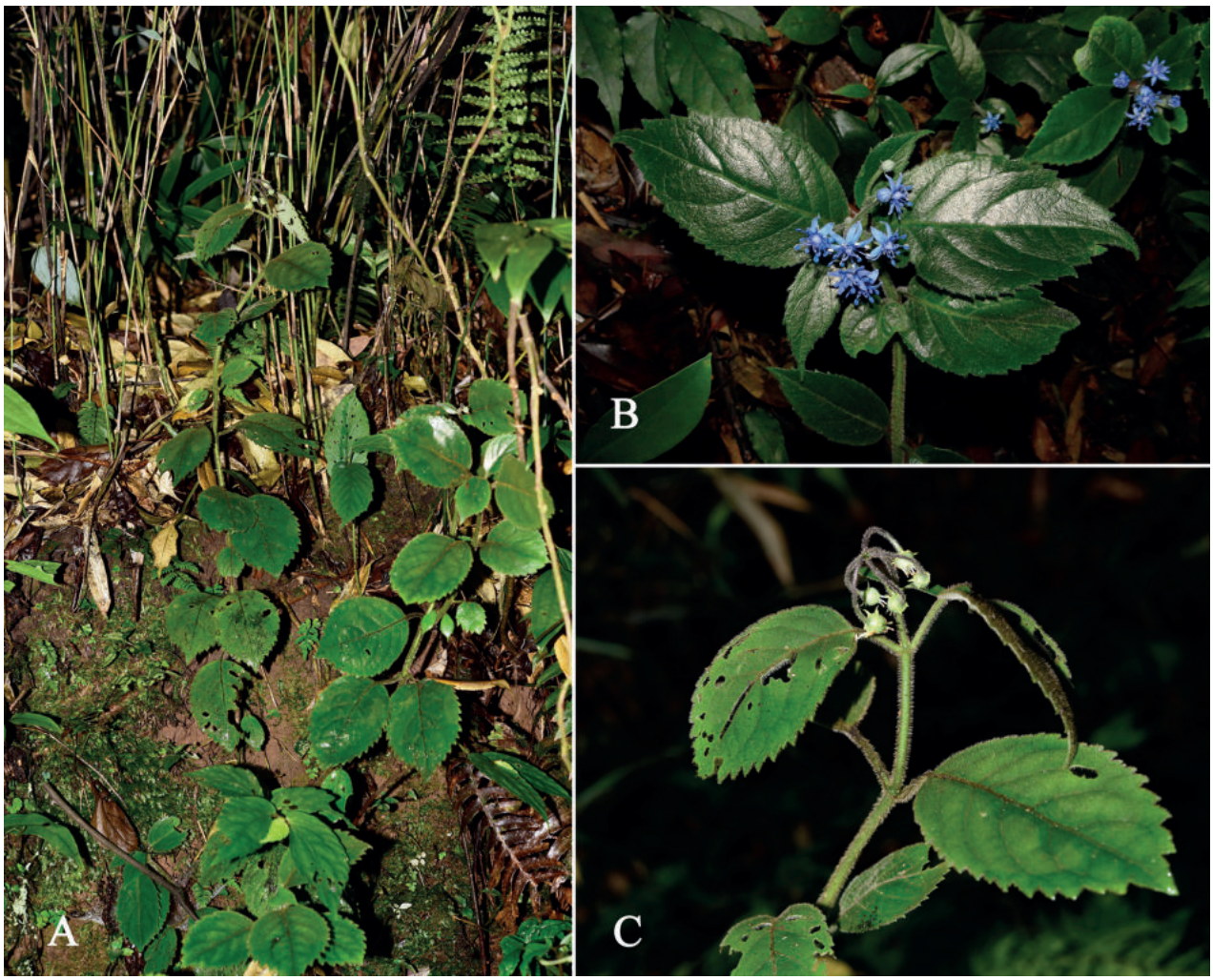

Figure 3. *Hydrangea xinfeniae* W.B.Ju & J.Ru, sp. nov. in the wild **A** habit **B** a branch with inflorescence **C** fruiting branch.

able data. Further comprehensive surveys in similar environments and neighboring regions are necessary to provide a better assessment of the distribution and abundance of this species.

Discussion

Hydrangea sect. *Dichroa* is distinguished from related sections within *Hydrangea* by characteristics such as being an erect shrub, inflorescences with all fertile flowers, calyx lobes never petaloid, and fruit as berry. Based on a series of morphological characteristics, including shrub, opposite leaves, bisexual and isomorphic flowers, an inverted conical calyx tube attached to the ovary, petals with slightly inwardly curled tips forming hooks, outer whorl filaments are linear, inner whorl filaments awl-shaped, and separated styles, *Hydrangea xinfeniae* sp. nov. is classified within the *Hydrangea* sect. *Dichroa* (Huang 1987; Huang et al. 1995; Wei and Bartholomew 2001; De Smet et al. 2015). Species within *Hydrangea* sect. *Dichroa* were previously treated as members of the genus *Dichroa* Lour. (Loureiro 1790) in Hydrangeeae.

In China, *Hydrangea* sect. *Dichroa* comprises six known species, including *H. daimingshanensis* (Y.C.Wu) Y.De Smet & C.Granados, *H. febrifuga* (Lour.) Y.De Smet & C.Granados, *H. hirsuta* (Gagnep.) Y.De Smet & C.Granados, *H. mollissima* (Merr.) Y.De Smet & C.Granados, *H. yaoshanensis*, *H. yunnanensis* (S.M.Hwang) Y.De Smet & C.Granados, as well as one new species, *H. fistulosa* (G.H.Huang & G.Hao) U.B.Deshmukh & M.B.Shende (Huang et al. 1995; Huang et al. 2018; Deshmukh and Shende 2021). Among the aforementioned species distributed in China, *H. xinfeniae* sp. nov. exhibits morphological resemblances to *H. yaoshanensis* in having the shape of leaf blade, corymbose cymose, inverted conical calyx tube and spherical-shaped berry. However, *H. xinfeniae* sp. nov. can be distinguished by its dense hirsute trichomes on branchlets, leaves, peduncles, and pedicels, as well as its broadly elliptic to rectangular-elliptic leaf blades, nearly entire circular leaf basis, coarse teeth on the leaf margin, 3–4 lateral veins on each side, corymbose cyme with sparsely and loosely branched, calyx tube with sparse hirsute trichomes, lobes with sparse hirsute trichomes only on the margins, glabrous on the inner surface of the petals, scattered hirsute trichomes on the outer surface, outer whorl filaments are linear, inner ones are awl-shaped, styles are glabrous, and nearly superior ovary. Notably, the nearly superior ovary is a unique characteristic of *H. xinfeniae* sp. nov. compared to other species within *Hydrangea* sect. *Dichroa*. For a detailed comparison of features, please refer to Table 1.

Table 1. The comparison of morphological characters of *Hydrangea xinfeniae* sp. nov. and *H. yaoshanensis*.

Characters	***H. xinfeniae* sp. nov.**	***H. yaoshanensis* (Huang et al. 1995; Wei and Bartholomew 2001)**
Habit	shrub, 55–80 cm tall	subshrub, up to 30 cm tall
Indumentum	branchlets, leaves, peduncles and pedicels densely covered with hirsute trichomes	branchlets, petioles, veins, and inflorescences covered with crisped pubescence and slightly pellucid hirsute trichomes
Leaf blade	broadly elliptic or rectangular-elliptic	elliptic or ovate-elliptic
	leaf base with nearly rounded, entire margins	leaf base cuneate or gradually narrowing, entire margins
	leaf margin with sparse coarse teeth	leaf margin serrate
	3–4 lateral veins on each side of midvein	5–11 lateral veins on each side of midvein
Inflorescence	corymbose cyme, loose, bract lanceolate	corymbose cyme, aggregate
	peduncle 0.4–1.2 cm	peduncle 0.5–1 cm
Pedicel	ca. 2 cm	ca. 5 mm
Calyx	calyx tube sparsely covered with hirsute trichomes	calyx tube densely covered with crisped pubescence and hirsute trichomes
	lobes ca. 2 mm long, with sparse hirsute trichomes only on the margins	lobes ca. 2.5–4 mm long, densely covered with hirsute trichomes on the outer and upper inner surfaces
Petal	glabrous on the inner surface, scattered hirsute trichomes on the outer surface	both surfaces densely covered with hirsute trichomes or without hairs on the inner surface
Stamen	outer whorl filaments are linear, inner ones are awl-shaped	filaments filiform
Pistil	styles glabrous	styles sparsely covered with hirsute trichomes at the lower part
	ovary nearly superior	ovary subinferior

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Additional information

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The authors have declared that no competing interests exist.

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Author contributions

Conceptualization: BX. Investigation: WH, HND, XZ, CJL. Methodology: WBJ. Writing – original draft: JR.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Research Article

Ligularia lushuiensis (Asteraceae, Senecioneae), a new species from northwestern Yunnan, China

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Abstract

Ligularia lushuiensis, a new species from northwestern Yunnan, China, is described and illustrated. It was tentatively placed in *L.* sect. *Ligularia* ser. *Ligularia* on the basis of the pinnate-palmate leaf venation, racemose synflorescence and pappus which is as long as tubular corolla. Within the series, it appeared somewhat close to both *L. lamarum* and *L. pseudolamarum*. However, *L. lushuiensis* can be easily distinguished from the latter two species by, among other characters, the leaf margin, bract size, involucre shape and size, and number and width of ray florets. Morphologically, *L. lushuiensis* is also superficially similar to *L. secunda* but differs readily by having distally shortly yellowish and brownish puberulent stems, palmately-pinnately veined leaves regularly dentate at margin, scarious, brown and larger bracts, and larger ray laminae. In addition, a distribution map and a diagnostic key to Chinese species of *L.* ser. *Ligularia* are also provided.

Key words: Compositae, Sino-Himalayan flora, taxonomy, Yunnan

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Introduction

Ligularia Cass. (Asteraceae, Senecioneae), with approximately 130 species recognized, is mainly distributed in eastern Asia (Liu 1989; Liu et al. 1994; Liu and Illarionova 2011; Ren et al. 2020). The center of species diversity of the genus lies in the eastern Himalayas and the Hengduan Mountains region in southwestern China (Liu et al. 1994, 2006; Liu and Illarionova 2011). In the last decade, many taxonomic revisions at specific level have been continuously carried out in the genus (see Fei et al. 2019; Lazkov and Sennikov 2019; Guo and Wang 2022; and literature cited therein).

During a botanical expedition to northwestern Yunnan, China in 2017, we discovered an unusual population of *Ligularia* in a less-botanized area in Lushui city (Fig. 1). It appeared to be similar to both *L. pseudolamarum* Long Wang & X.Q.Guo and *L. secunda* Y.S.Chen in the general habit, especially in the capitula that are oriented to one side of the synflorescence axis. However, they showed great differences in an array of characters. The plants also displayed a slight resemblance to *L. lamarum* (Diels) C.C.Chang, but

can also be easily distinguished from that species. We therefore determine that the plants in question represent a hitherto undescribed species, which we describe below.

Material and methods

For morphological comparison, we critically examined physical or digitalized herbarium specimens deposited at several major herbaria in China, including CDBI, HNWP, IBSC, KUN, NAS, PE, SZ, and WUK (acronyms follow Thiers (2023)). Specimens of *L. lushuiensis* were collected and photographed during our field investigation to Yunnan province in 2017. Morphological observations and measurements were based on fresh material as well as herbarium specimens deposited at IBSC.

Taxonomic treatment

***Ligularia lushuiensis* Long Wang, sp. nov.**
urn:lsid:ipni.org:names:77335783-1
Figs 1, 2

Diagnosis. *Ligularia lushuiensis* should be placed within *L.* ser. *Ligularia* owing to character combination of palmate-pinnate leaf venation, scarious and brown bracts, single-oriented capitula, and broadly cylindrical involucres 1–1.1 cm high and 1.1–2 cm in diam. Morphologically, it is somewhat similar to *L. lamarum*, *L. pseudolamarum*, and *L. secunda*. From *L. lamarum*, it differs in the leaf margin, bract texture, color, and size, involucre shape and size, and ray floret number and width; from *L. pseudolamarum*, it differs in the leaf shape and margin, bract size, involucre shape and size, and ray floret number and size; and from *L. secunda*, it differs in the stem indumentum, leaf venation and margin, bract texture, color and size, and ray floret size.

Type. China. Yunnan: Lushui, Daxingdi, Lamaku Shan, 26°06'10.18"N, 98°59'34.68"E, alpine meadows, 3322 m a.s.l., 6 August 2017 (fl.), *Long Wang & Yun-yun Shao 1610* (holotype: IBSC; isotypes: IBSC). Fig. 2.

Description. Perennial herb. Stems solitary or 2, erect, 30–70 cm tall, 4–5 mm in diam. at base, proximal to middle part yellowish puberulent, distal part shortly yellowish and brownish puberulent. Basal leaves petiolate; petiole 5–12 cm long, not winged throughout; leaf blade ovate-cordate, 5–8(–10) cm long, 4.5–8(–11) cm wide, herbaceous, adaxially dark green, glabrous, abaxially greenish, slightly brownish puberulent only on veins, palmately-pinnately veined, base cordate, margin regularly dentate, apex obtuse; sinus narrow, basal lobes suborbicular, divergent. Stem leaves 3–6. Proximal stem leaves 1–2, similar to but smaller than basal leaves. Median stem leaves 1–2, shortly petiolate or sessile, base tubular-amplexicaul. Distal stem leaves 1–2, bracteal, scarious. Capitula (2–)5–9, in a lax raceme, oriented to one side of the synflorescence axis; peduncles short, ca. 1 cm long; bract 1, ovate-lanceolate, ca. 1 cm long, 6–7 mm wide, scarious, brown; bracteoles 2 or 3, oblong-lanceolate, ca. 1.1 cm long, 3 mm wide, scarious, brown. Involucres broadly cylindrical, 1–1.1 cm high, 1.1–2 cm in diam., outside more or less whitish arachnoid; receptacle whitish arachnoid outside; phyllaries 12–15, in 2 rows; outer phyllaries narrowly oblong,

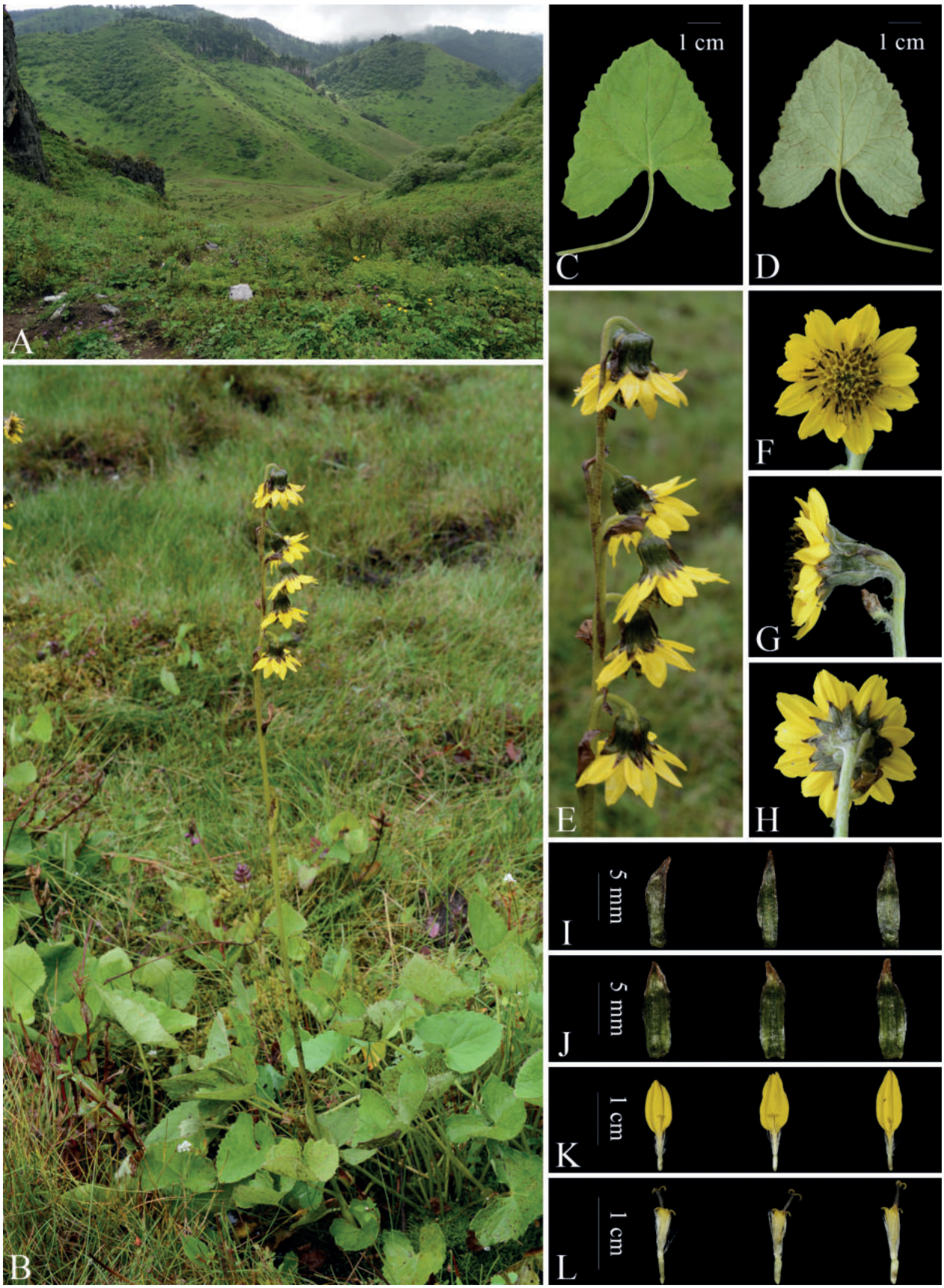

Figure 1. *Ligularia lushuiensis* sp. nov. **A** habitat **B** habit **C** basal leaf (adaxial surface) **D** basal leaf (abaxial surface) **E** synflorescence **F** capitulum (top view) **G** capitulum (side view) **H** capitulum (back view) **I** outer phyllaries (abaxial surface) **J** inner phyllaries (abaxial surface) **K** ray florets **L** tubular florets. Photographs by Long Wang.

Figure 2. Holotype sheet of *Ligularia lushuiensis* sp. nov.

2–2.5 mm wide, apex acute; inner phyllaries oblong, ca. 3 mm wide, margin membranous, apex acute to obtuse. Ray florets 10–13, yellow; lamina ovate-oblong, 1.5–1.6 cm long, 5–6 mm wide, apex obtuse, 2- or 3-denticulate; tube ca. 4 mm long. Tubular florets numerous, yellow, ca. 1 cm long; tube 2–3 mm long; limb campanulate, 4–5 mm long; style 6–7 mm long, branches dark yellow. Achenes (immature) narrowly oblong, 3.5–4 mm long, glabrous. Pappi white, ca. 7 mm long, as long as or slightly shorter than tubular corolla.

Distribution and habitat. *Ligularia lushuiensis* is currently known only from its type locality, i.e. Lushui, northwestern Yunnan, China (Fig. 3). It grows in alpine meadows at an elevation of ~3322 m above sea level.

Etymology. The specific epithet '*lushuiensis*' refers to the type locality of this new species, i.e. Lushui City.

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

Vernacular name. 泸水橐吾 (Chinese pinyin: lú shuǐ tuó wú).

Conservation status. *Ligularia lushuiensis* is currently known only from a small population at its type locality, i.e. Lamaku Shan. The single population we discovered consists of no more than 200 mature individuals. Overgrazing might be the major threat to the habitat of this species. According to the IUCN Red List Categories and Criteria (IUCN 2019), this species should be categorized as Critically Endangered (CR): B1ab(iii)+2ab(iii).

Notes. Morphologically, *Ligularia lushuiensis* resembles both *L. pseudolamarum* and *L. secunda*, especially in the single-oriented capitula and racemose synflorescences. It is also superficially similar to *L. lamarum*, especially in the general habit and in the leaf shape and synflorescence type. Table 1 provides detailed morphological comparisons among these four species.

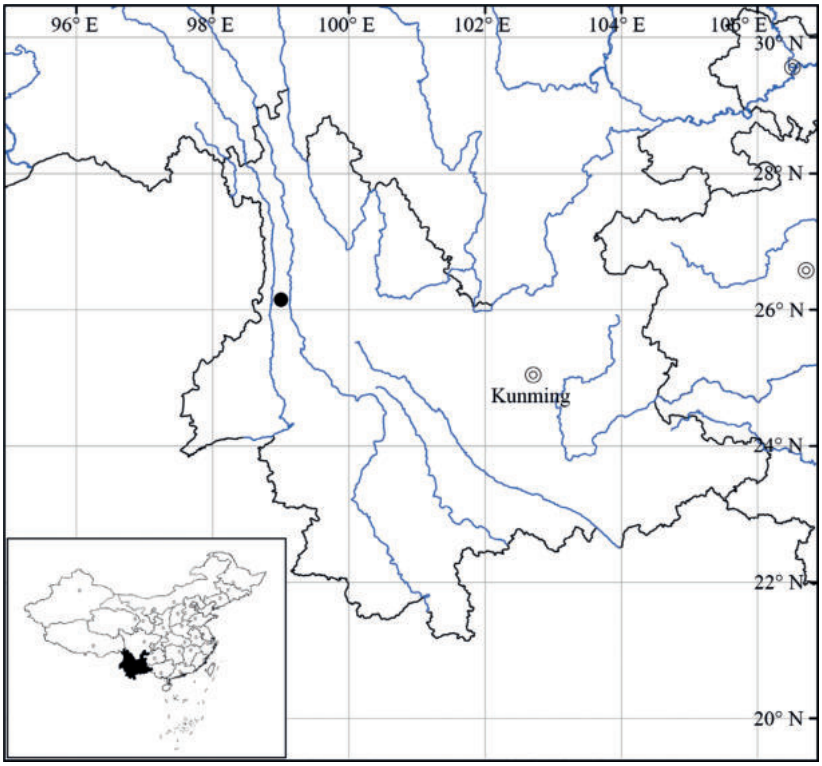

Figure 3. Distribution of *Ligularia lushuiensis* sp. nov. (black dot).

Table 1. Morphological differences among *Ligularia lamarum*, *L. lushuiensis* sp. nov., *L. pseudolamarum*, and *L. secunda*.

	L. lamarum	***L. lushuiensis***	***L. pseudolamarum***	***L. secunda***
Stems	distally white arachnoid or brown puberulent, 2–4 mm in diam. at base	distally shortly yellowish and brownish puberulent, 4–5 mm in diam. at base	distally shortly yellowish and brownish puberulent, 5–6 mm in diam. at base	distally shortly and sparsely white arachnoid-puberulent, 5–6 mm in diam. at base
Basal leaves	triangular-sagittate or ovate-cordate, 3–9 cm long, 2.2–12.5 cm wide, adaxially and abaxially glabrous, palmately veined, base cordate, margin regularly denticulate, apex acute	ovate-cordate, 5–8 (–10) cm long, 4.5–8 (–11) cm wide, adaxially glabrous, abaxially slightly brownish puberulent only on veins, palmately-pinnately veined, base cordate, margin regularly dentate, apex obtuse	triangular-sagittate, 3–8 cm long, 3–8 (–10) cm wide, adaxially slightly whitish puberulent to glabrescent, abaxially slightly whitish puberulent to glabrescent, palmately-pinnately veined, base cordate, margin coarsely dentate, apex sharply acute	ovate, 4.5–10 cm long, 3–7 cm wide, adaxially shortly puberulent, abaxially glabrous, pinnately veined, base truncate or shallowly cordate, margin denticulate, apex acute
Stem leaves	petiolar base tubular-amplexicaul	petiolar base tubular-amplexicaul	petiolar base tubular-amplexicaul	petiolar base semi-amplexicaul
Synflorescence	usually many-flowered, oriented to one side of the synflorescence axis	(2–) 5–9, oriented to one side of the synflorescence axis	(1–) 2–6 (–10)-flowered, oriented to one side of the synflorescence axis	5–10-flowered, turning to one side of the synflorescence axis
Bracts	subulate, leaflike, green, 1–1.5 cm long, 1–2 mm wide	ovate-lanceolate, scarious, brown, ca. 1 cm long, 6–7 mm wide	ovate-lanceolate, scarious, brown, ca. 3 cm long, 6–7 mm wide	boat-shaped to linear, leaflike, green, 2.5–4.5 cm long, ca. 1 cm wide
Involucres	campanulate-turbinate, 6–9 mm high, 3–5 mm in diam., outside glabrous	broadly cylindrical, 1–1.1 cm high, 1.1–2 cm in diam., outside more or less whitish arachnoid	narrowly cylindrical, 9–11 mm high, 3–4 mm in diam., outside slightly shortly yellowish puberulent to glabrescent	broadly cylindrical, 1.2–1.5 cm high, 1.5–2 cm in diameter, outside sparsely arachnoid-puberulent
Ray florets	5–8; lamina 7–10 mm long, ca. 1.5 mm wide	10–13; lamina ovate-oblong, 1–1.2 cm long, 5–6 mm wide	3–5; lamina oblong to elliptic, 7–8 mm long, 2.5–3 mm wide	8–9; lamina oblong, 1.1–1.3 cm long, 3–4 mm wide
Pappus	yellowish or brownish, 6–7 mm long	white, ca. 7 mm long	white, 7–8 mm long	white, 8 mm long

In the genus *Ligularia*, *L. confertiflora* C.C.Chang is also recorded to have capitula that are oriented to one side of the synflorescence axis except for *L. lushuiensis*, *L. pseudolamarum*, and *L. secunda*. However, this species is characterized by having palmate leaf venation and short pappus which is as long as the tube of tubular corolla and is readily placed in *L.* ser. *Speciosae* Pojark. It is easily distinguishable from *L. lushuiensis* in having discoid capitula and leaflike bracts.

According to the infrageneric classification proposed by Liu (1985), *Ligularia lushuiensis* is tentatively assigned to *L.* sect. *Ligularia* ser. *Ligularia* because of the character combination of pinnate-palmate leaf venation, racemose synflorescence and pappus which is as long as tubular corolla. It is noteworthy that the pinnate-palmate leaf venation appears frequently in several species within this series. With the addition of this new species, 14 species are currently recognized in the series in China (Liu 1988; Grierson and Springate 2000; Guo and Wang 2022). We herein provide a diagnostic key to the Chinese species of *L.* ser. *Ligularia* to facilitate identification of this group of plants.

Key to Chinese species of *L.* ser. *Ligularia*

1 Bracts ovate, ovate-oblong to ovate-lanceolate, 6–10 (–20) mm wide.....**2**

– Bracts linear-lanceolate to linear, usually less than 5 mm wide.....**5**

2 Leaf blades triangular-sagittate; basal lobes of sinuses sagittate; involucres narrowly cylindrical, 3–4 mm in diam., outside slightly shortly yellowish puberulent to glabrescent.....***L. pseudolamarum***

– Leaf blades ovate-cordate, triangular-cordate, reniform-cordate, broadly cordate, or reniform; basal lobes of sinuses oblong or suborbicular; involucre broadly cylindrical, campanulate, campanulate-turbinate, or cupular,

6–20 mm in diam., outside glabrous, more or less whitish arachnoid, or sparsely shortly puberulent **3**

3 Leaves palmately-pinnately veined; capitula (2–) 5–9, oriented to one side of the synflorescence axis ..... ***L. lushuiensis***

– Leaves pinnately veined; capitula numerous, not specifically oriented **4**

4 Leaf blades abaxially glabrous; bracts herbaceous, green; involucres broadly campanulate, campanulate, campanulate-turbinate, outside glabrous ..... ***L. sibirica***

– Leaf blades abaxially slightly yellow pilose; bracts membranous, purplish red; involucres cupular, outside sparsely shortly pilose ..... ***L. cyathiceps***

5 Capitula in racemes or solitary, with ray florets, rarely without florets (in *L. subspicata*) **6**

– Capitula usually in paniculate racemes, without ray florets **13**

6 Leaf blades ovate-cordate, triangular-cordate to triangular, hastate or sagittate, apically usually acute or obtuse, rarely rounded **7**

– Leaf blades reniform or cordate-reniform, apically usually rounded **9**

7 Leaf bases truncate, rarely cuneate or cordate; pappi purplish red ..... ***L. parvifolia***

– Leaf bases cordate; pappi usually whitish or yellowish **8**

8 Ray florets present ..... ***L. lamarum***

– Ray florets absent, or limbs of outer tubular florets divided, labiate ..... ***L. subspicata***

9 Stems robust, to 1 cm in diam. at base; involucres broadly campanulate to turbinate ..... ***L. wilsoniana***

– Stems slender, 1.5–4 (–6) mm in diam. at base; involucres usually campanulate to narrowly campanulate, rarely hemispheric (in *L. latiligulatum*) **10**

10 Ray laminae short, small, inconspicuous ..... ***L. atkinsonii***

– Ray laminae normal, conspicuous **11**

11 Abaxial surfaces of leaves densely shortly white pilose ..... ***L. pubifolia***

– Abaxial surfaces of leaves glabrous or slightly shortly pilose between teeth of leaf margins **12**

12 Involucres narrowly cylindrical; ray laminae linear, apically acuminate ..... ***L. hookeri***

– Involucres hemispheric; ray laminae broadly oblanceolate, apically truncate ..... ***L. latiligulata***

13 Distal stems, synflorescences and abaxial sides of involucres shortly brown pilose; leaves 5–11 cm wide, adaxially glabrous; pappus yellow ..... ***L. leveillei***

– Distal stems and synflorescences densely yellow pilose, and involucres glabrous; leaves ca. 5 cm wide, adaxially shortly yellow pilose; pappus brown ..... ***L. nanchuanica***

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

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Data availability

All of the data that support the findings of this study are available in the main text.

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Research Article

Piper motuoense, a new species of Piperaceae from Xizang, China

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Abstract

Piper motuoense X.W.Qin, F.Su & C.Y.Hao, a new species of Piperaceae from Xizang, China, is described and illustrated in this paper. The new species resembles *P. yinkiangense* and *P. anisotis*, but it can be readily distinguished from the compared species by several characteristics. Gonophyll leaves are chartaceous and the leaf secondary vein count is 7–9, with the outermost pair being very weak when there are nine veins. Additionally, the apical pair arises 2–4 cm above the base and the leaf base is asymmetrical, with bilateral petioles that cling and heal together. Pistillate floral bracts are sessile, with 3, 4 or 5 stigmas. The description of the new species includes photographs, detailed descriptions, notes on etymology, distribution and habitat, as well as comparisons with morphologically similar species.

Key words: Asia, Paleotropical flora, Piperales, Sino-Himalaya, taxonomy

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Introduction

Piper L. is the nominate genus of Piperaceae and one of the most diverse lineages amongst basal angiosperms (Tebbs 1993; Soltis et al. 1999). This genus was established, based on the species *P. nigrum* L. from India (Sen and Rengaian 2022). The genus is considered to comprise approximately 2,000 species, mainly distributed in the Tropics (Gentry 1982; Kubitzki et al. 1993; Marquis 2004; Quijano-Abril et al. 2014; Jaramillo et al. 2023; Suwanphakdee et al. 2023). Distinctive characteristics of *Piper* include swollen stem nodes and minute, usually unisexual flowers compacted together on a fleshy rachis in Asian *Piper* species. Its flowers lack perianth and consist only of the staminate and pistillate reproductive parts, which are subtended by 1–3 floral bracts. The number of stamens varies from 3–12 (Suwanphakdee and Chantaranothai 2014). The anther is distinguished by 2–4 thecae, with longitudinal or transverse dehiscence. Asian taxa of *Piper* have been studied in numerous publications and are currently estimated to consist of over 600 species (Wallich 1824–1849; Blume 1826; Hooker 1886; De Candolle 1910, 1912, 1923; Ridley 1924; Backer and Bakhuizen van den Brink 1963; Long 1984; Huber 1987; Gardner 2006; Suwanphakdee et al. 2006, 2008, 2011, 2012, 2014; Asmarayani 2018).

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Up to the present, more than 60 species have been recorded in China, half of which are endemic (Gilbert and Xia 1999; Cheng et al. 1999; Gajurel et al. 2001; Hao et al. 2012, 2015, 2017, 2020; Yang et al. 2017; Su et al. 2022). Some species are economically important. A typical example is *P. nigrum* L. (Linnaeus 1753), which is the source of black pepper, the world's most widely used spice (Takooree et al. 2019). A few other species, such *P. betle* L., *P. cubeba* L.f., *P. longum* L., *P. magen* B.Q.Cheng ex C.L.Long & Jun Yang bis and *P. pedicellatum* C.DC., are used locally as condiments or medicine (Yang et al. 2017; Salehi et al. 2019).

Through two field investigations over an interval of three years in Motuo County, Xizang, China, specimens of a dioecious plant were found and collected. Based on a detailed examination of the morphological characteristics of this plant and its possible relatives (Tseng 1979; Cheng et al. 1999; Gilbert and Xia 1999; Suwanphakdee and Chantaranothai 2011; Suwanphakdee and Chantaranothai 2014; Su et al. 2022; Hao et al. 2012, 2015, 2017, 2020; Junior and Guimaraes 2015; Mathew et al. 2016; Mukherjee 2016, 2018, 2020), we concluded that it did not match morphologically with any of the existing species. It exhibits trophophyll blades with an auriculate-cordate and asymmetrical base, with base bilaterally clung to the petiole and overlap together, leaf-blades abaxially densely villous, especially along the mid-vein and flowers with a single stamen. Due to these distinctive morphological features, we confirm that it is a new species, which we describe and illustrate here as *Piper motuoense* X.W.Qin, F.Su & C.Y.Hao.

Material and methods

Morphological studies of the new species were conducted, based on the type specimens deposited in the Herbarium IBSC and the living plants cultivated in the Spice and Beverage Research Institute, CATAS. All available specimens of *Piper* stored in the Herbaria of AU, BM, E, G, HITBC, IBK, IBSC, K, KUN, PE and WU were examined using online specimen images via the Chinese Virtual Herbarium (CVH, https://www.cvh.ac.cn/index.php) and JSTOR (https://plants.jstor.org). Measurements of morphological characters were taken from living plants and photographs were captured using a Nikon Z7 digital camera (Tokyo, Japan) and Dino-Lite digital microscope (Taiwan, China). Morphological comparison with closely-related species was made by consulting published literature.

Taxonomy

***Piper motuoense* X.W.Qin, F.Su & C.Y.Hao, sp. nov.**
urn:lsid:ipni.org:names:77335908-1
Figs 1, 2

Diagnosis. The new species is morphologically similar to *P. yinkiangense*, but can be easily distinguished from the latter in several aspects. The leaf-blades 12.5–18 × 3.5–6.5 cm, elliptic or ovate to lanceolate (vs. 11–14 × 6.5–8.5 cm, oblique-ovate), chartaceous (vs. membranous), abaxially sparsely villous along the mid-vein (vs. abaxially sparsely hispidulous), gonophyll leaves 7–9 secondary vein pairs, the outer pair arising 2–4 cm above base (vs. 8–9, outer pair

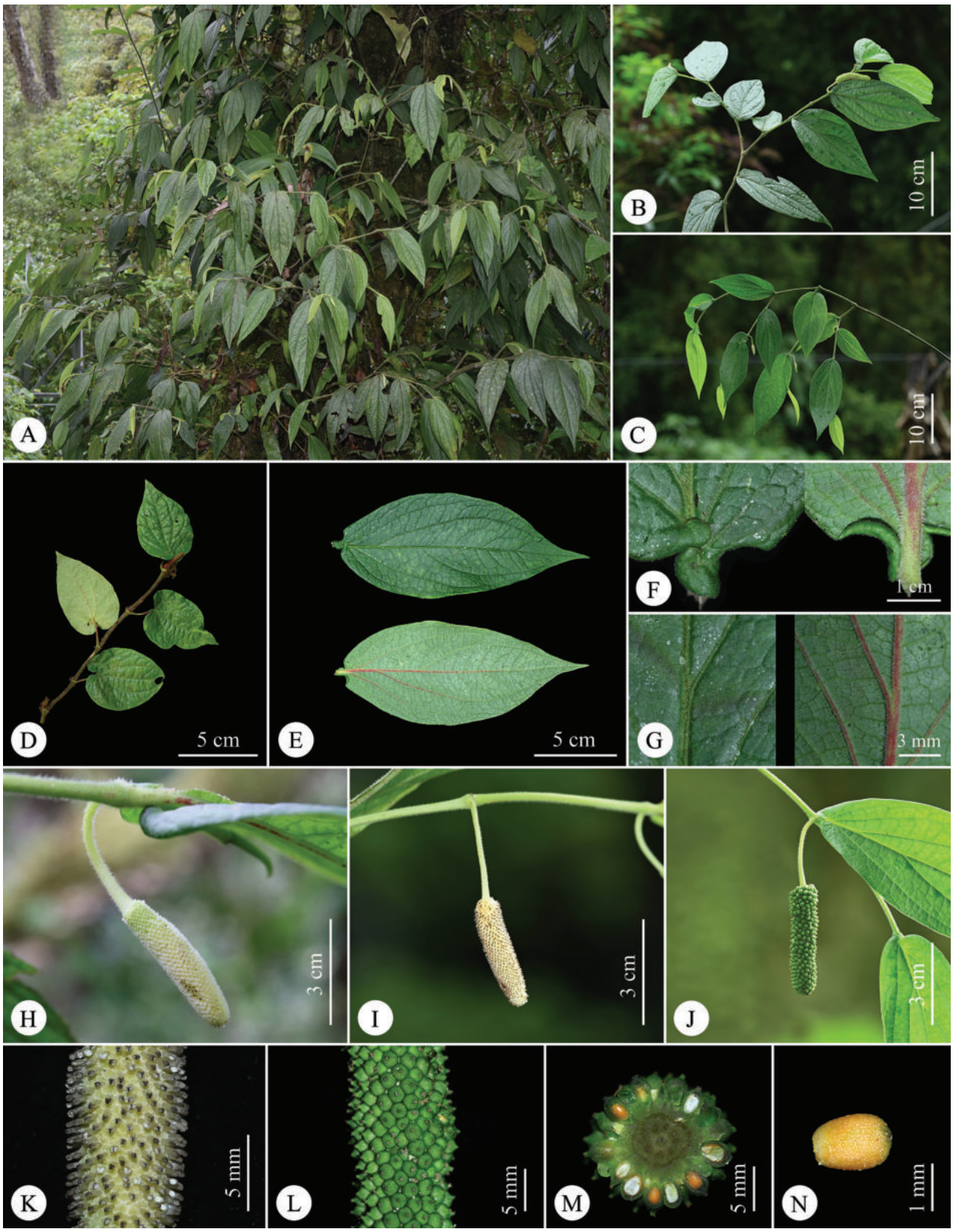

Figure 1. *Piper motuoense* X.W.Qin, F.Su & C.Y.Hao, sp. nov. **A** habit **B** branch with infructescence **C** branch with staminate spike **D** branch with trophophyll leaf **E** adaxial and abaxial surface of gonophyll leaf **F** adaxial and abaxial surface of gonophyll leaf base **G** detail of the indument along the mid-vein of the gonophyll leaf adaxial and abaxial surface **H** pistillate spike **I** staminate spike **J** infructescence **K** close-up of portion of the staminate spike **L** close-up of portion of the infructescence **M** cross-section of infructescence **N** seed (side view). Photographs by Fan Su.

Table 1. Morphological comparison of key characteristics in *P. motuoense*, *P. yinkiangense* and *P. anisotis*.

Characters		*P. motuoense*	*P. yinkiangense*	*P. anisotis*
Stem		Densely villous when young, glabrous when mature	Densely villous	Densely short tomentose
Gonophyll leaves	petiole	2.5–3 cm long	Ca. 2 mm long	Ca. 3 mm long
	blade	12.5–18 × 3.5–6.5 cm, elliptic or ovate to lanceolate, chartaceous, abaxially densely villous, especially along the veins, adaxially sparsely villous along the mid-vein	11–14 × 6.5–8.5 cm, oblique–ovate, membranous, abaxially densely pubescent, usually along veins, adaxial sparsely hispidulous	7.5–13 × 2.5–5 cm, oblique-oblong, membranaceous, abaxially densely villous, especially along the veins, adaxially densely hispidulous
	base	Auriculate-cordate, bilaterally clinging to leaves petiole and overlap together	Obliquely auriculate-cordate, basal sinus 1–2 mm wide on side of longer and wider lobe, 4–5 mm wide on other side, bilateral difference to 2–3 mm	Unequal-sided and more cordate, basal sinus 1–2 mm wide on side of longer and wider lobe, 3–4 mm wide on other side, bilateral difference to 1–2 mm
	secondaryveins	7–9, when 9 veins, the outermost pair is very weak, apical pair arising 2–4 cm above base	8–9, apical pair arising 1–2 cm above base	5–7, apical pair arising 1.3–2.5 cm above base
Pistillate spikes	spikes	4–5 × 0.5–0.7 cm	3 × 0.4 cm	1.5–3 × 0.4–0.6 cm
	peduncles	2–3 cm long, slightly shorter than spike	2.5 cm long, equal to or longer than spike	2 cm long, equal to or longer than spike
	floral bracts	suborbicular, sessile	suborbicular, short-pedicellate	suborbicular, short-pedicellate
	stigmas	3–4–5, 0.8–1 mm long	4, ca. 1 mm or longer	4, ca. 1 mm or longer
Fruit		3–3.5 × 2.5–3 mm	Ca. 3 mm in diam.	Ca. 3 mm in diam.

arising 1–2 cm above base), base bilaterally clinging to the petiole and overlap together (vs. basal sinus 1–2 mm wide on side of longer and wider lobe, 4–5 mm wide on other side, bilaterally free for 2–3 mm), floral bracts sessile (vs. petiolate) and stigmas 3, 4 or 5 (vs. 4). *P. motuoense* also resembles *P. anisotis* in the shape of leaves and fruit, but differs from the latter in the leaves vein 7–9 (vs. 5–7), leave base bilateral clinging to petiole and overlap together (vs. bilateral free for 1–2 mm) (Table 1).

Type. China. (Xizang): Linzhi, Motuo City, Beibeng, climbing on the taller trees in tropical rainforest, 29°10'48"N, 95°00'06"E, elevation ca. 490 m, 3 Oct. 2021, *Xiao-Wei Qin et al. 20211003, 20231016* (Holotype: IBSC0918558; Isotype: IBSC0918559, IBSC0918560, IBSC0918561).

Description. ***Lianas*** over 5 m long, with climbing adventitious roots, dioecious, perennial, densely villous when young, becoming glabrous when mature. ***Roots*** dimorphic; basal roots terrestrial, feeding; adventitious roots produced along the aerial nodes, clasping the phorophyte. ***Stems*** climbing upwards, internodes terete, striated, with red stripes when they are young, swollen nodes. ***Leaves*** dimorphic, distichously-alternate, petiolate, blades chartaceous, glandular. ***Trophophyll leaves*** with petiole 2.5–3 cm long, cylinder-shaped in cross-section, red, pubescence; leaf-blades 7–9 × 5–6 cm, cordate to elliptic, adaxially dark green, glabrous, abaxially surface pale green, sparsely villous, especially along the veins, base usually cordate, symmetric, apex short-acuminate to long-acuminate; mid-vein red, 5–7 pairs, red, all basal, when 7, the outermost pair inconspicuous. ***Gonophyll leaves*** with petiole 0.3–0.4 cm long, cylinder-shaped in cross-section, pale green, densely pubescence; leaf-blades 12.5–18 × 3.5–6.5 cm, elliptic or ovate-lanceolate; 7–9 pairs of secondary

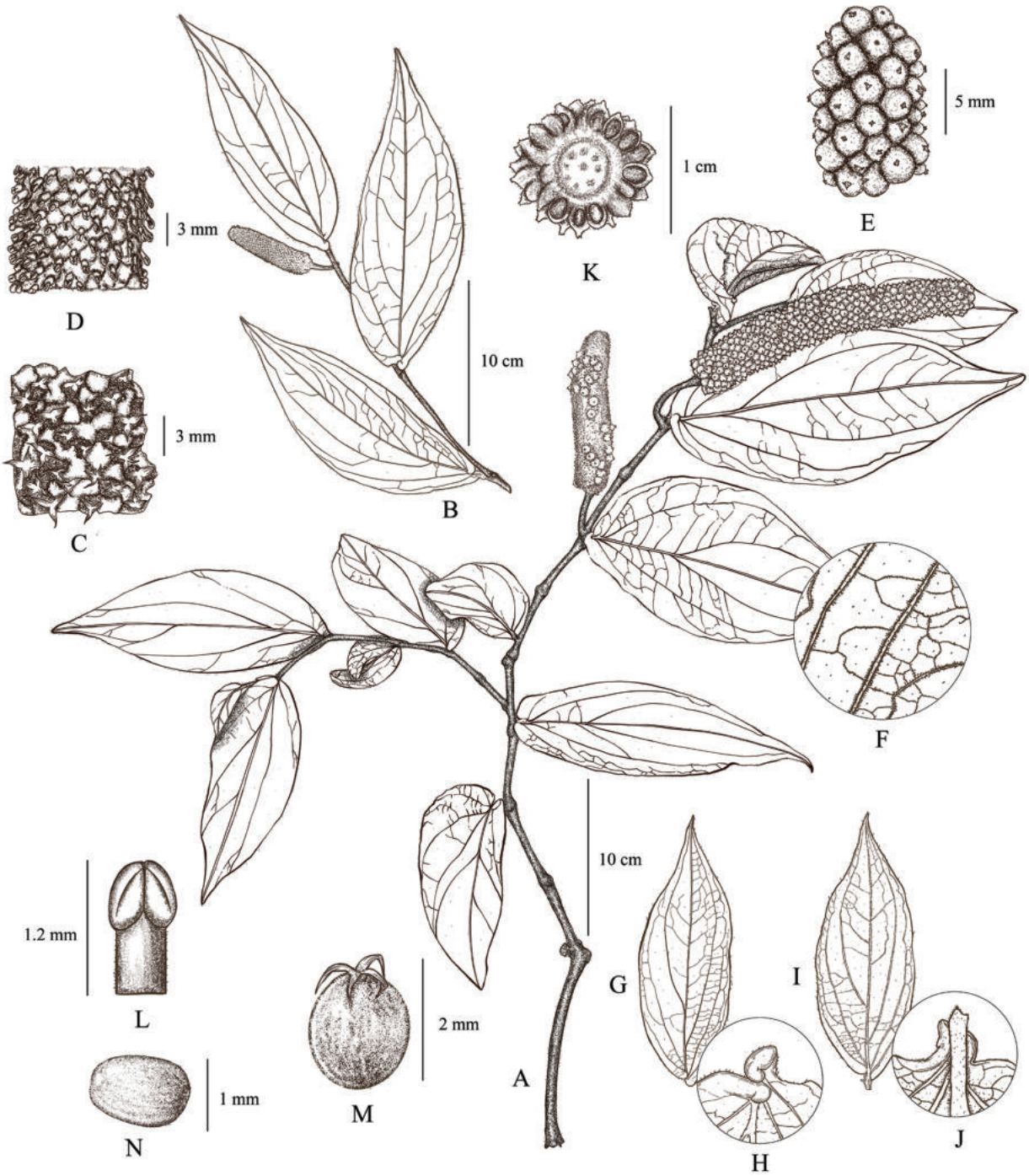

Figure 2. Line drawing of *Piper motuoense* X.W. Qin, F. Su & C.Y. Hao **A** branch with infructescence **B** branch with staminate spike **C** magnified view of pistillate spike **D** magnified view of staminate spike **E** magnified view of infructescence **F** detail of the indument along the secondary nerves of the abaxial leaf surface **G** adaxial surface of gonophyll leaf **H** adaxial surface of gonophyll leaf base **I** abaxial surface of gonophyll leaf **J** abaxial surface of gonophyll leaf base **K** cross-section of infructescence **L** stamen **M** carpel **N** seed. Illustration by Fan Su, based on the holotype.

veins; when 9 veins, the outermost pair is very weak; apical pair 2–4 cm above base, reaching leaf apex, alternate, others basal, reticulate veins prominent; adaxial surface dark green, glabrous or sparsely villous on the mid-vein, abaxial surface pale green, densely villous, especially on the veins; base auriculate-cordate, asymmetrical, bilateral clinging to leaves petiole and healing together,

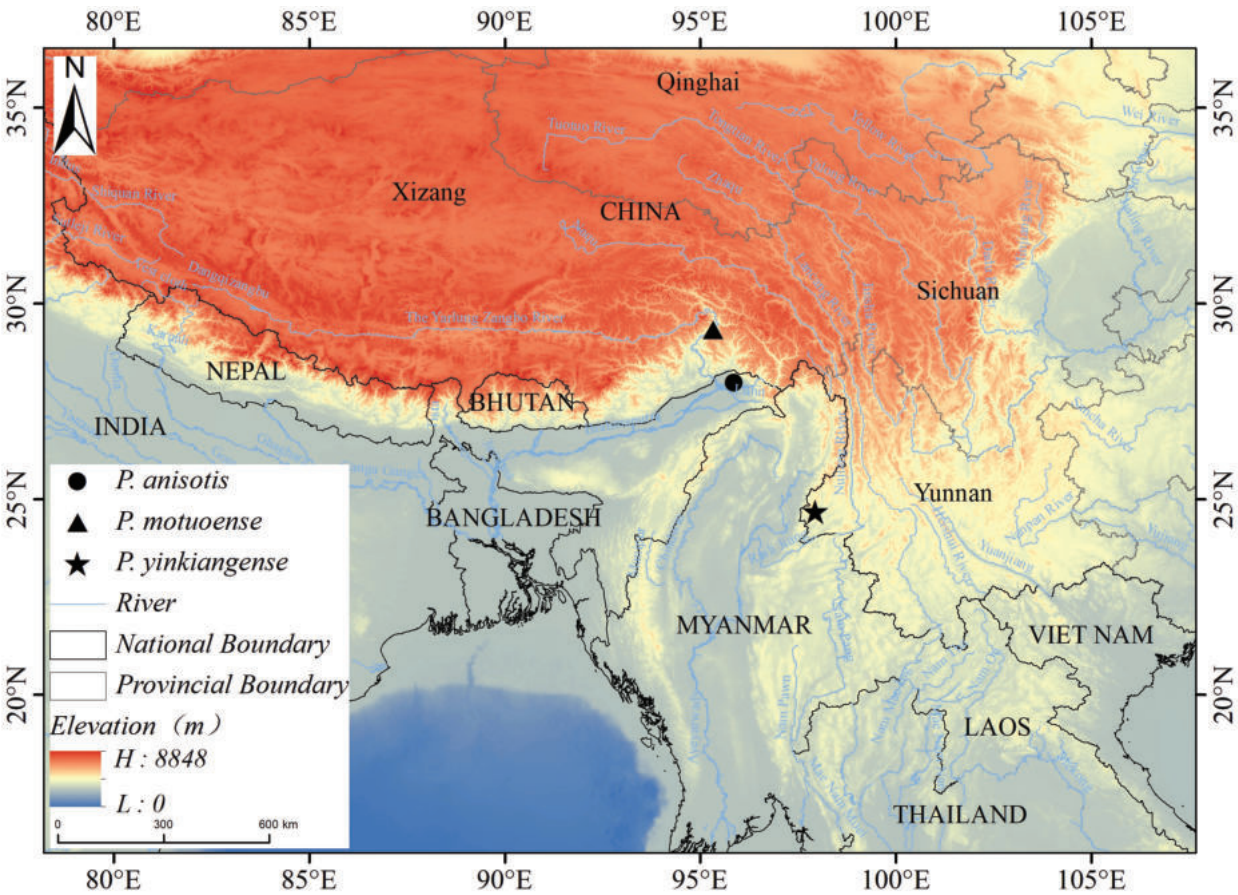

Figure 3. The geographical distribution of *P. motuoense* sp. nov., *P. yinkiangense* and *P. anisotis*.

apex long acuminate. ***Inflorescence*** a pedunculate spike, leaf-opposed, pendulous; peduncle flexible, cylindrical; spadix cylindrical, the fertile rachis hairy, with densely compacted flowers; floral bracts sessile, imbricate, ca. 1 mm in diam., orbicular or suborbicular, piligerous, margin irregular, undulate. ***Staminate inflorescences*** 5.5–8 cm long, peduncles 3–4 cm long, villous; spike 2.5–4 × 0.5–0.7 cm, villous, pale green when young, pale yellow to white when mature; **stamens** 1, filaments 0.6–1 mm long, stout, hyaline, anthers 0.4–0.7 × 0.2–0.5 mm, 2-thecous, reniform, white before dehiscence, black after dehiscence, dehiscence lateral. ***Pistillate inflorescences*** 6–8 cm long, peduncles 2–3 cm long, piliferous; spike 4–5 × 0.5–0.7 cm, pale green when young, pale yellow to white when mature; **ovary** 1.6–2 × 1.4–1.8 mm, sessile, free from the neighbouring ones, obovoid, green, **style** 1–1.2 mm long, **stigmas** 3–5, 0.8–1 mm long, filiform, reflexed, cream-coloured at anthesis, becoming tan to light grey post-anthesis. ***Infructescence*** leaf-opposed, 5–7 × 1–1.2 cm; cylindrical; with densely compacted fruits; pendulous, cylindrical, piliferous. ***Drupes*** 3–3.5 × 2.5–3 mm, sessile, free from the neighbouring ones, subglobose, remaining attached to rachis at maturity, piligerous, persistent style 0.3–0.5 mm long, cylindrical; epicarp green, mesocarp pale green, translucent, endocarp dark yellow. ***Seeds*** 1–1.2 × 0.6–0.8 mm, obovoid, ochre to dark yellow, testa smooth.

Phenology. Flowering from June to October; fruiting from September to November.

Etymology. The specific epithet refers to its distribution, Motuo County, Xizang, in China.

Vernacular name. Chinese: 墨脱胡椒 (mò tuō hú jiāo). 'Mò Tuō' is a place name, which is the literal translation of the specific epithet *motuoense* and 'hú jiāo' is the Chinese name of *Piper*.

Habitat and distribution. The new species is currently known only from its type locality in Beibeng Town, Motuo County, Xizang Autonomous Region (Fig. 3). The new species grows very well in the type locality, as it has been recorded in three different sites (Beibeng, Damu and Tiger's Mouth). It occurs in wet tropical rainforest at elevations of 490–1700 m and often climbs on taller trees or rocks.

Comments. *P. motuoense* was initially misidentified as *P. anisotis* from India, and Motuo is close to Assam in India. After examination of material of *P. anisotis* we found that the new species differs in a number of characters. We also compared it with *P. yinkiangense*. The differences amongst these three species are summarised in Table 1.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

Data curation: XZJ. Formal analysis: RF. Investigation: XWQ, FS, LY, XZJ. Writing – original draft: FS, XWQ, CYH. Writing – review and editing: CYH, FS.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Research Article

Re-assessment of type material of *Plagiothecium novae-seelandiae* Broth. and descriptions of four new *Plagiothecium* taxa (Bryophyta, Plagiotheciaceae) from Australasia

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Abstract

A re-examination of the original collection of *Plagiothecium novae-seelandiae* described by Brotherus in 1916 indicated that this material is not homogeneous. Re-examination of the diagnosis of this species and morphological analysis supports that two separate taxa should be distinguished – *Plagiothecium novae-seelandiae* var. *novae-seelandiae* and *P. novae-seelandiae* var. *brotheri* **var. nov.** Also, comparisons with the original collection of *Hypnum lamprostachys* (= *P. lamprostachys*) showed differences, which supported their treatment as separate taxa. Revision of the genus *Plagiothecium* from Australasia (CANB, CHR, HO, MEL, WELT) and types of other species described from this part of the world (*P. funale* and *P. lucidum*) supported by the study of their diagnoses, qualitative and quantitative characteristics as well as mathematical analyses (PCA, HCA) allowed the division of the examined material into six separate groups – six separate taxa. Thereby, three distinct taxa are proposed – *P. cordatum* **sp. nov.**, *P. semimortuum* **sp. nov.**, and *P. semimortuum* var. *macquariense* **var. nov.** All taxa mentioned above are described in detail, their current known distribution and ecological preferences are also included. In addition, images illustrating their most important taxonomic features, as well as an original key to distinguish individual taxa are presented.

Key words: Australia, new taxa, New Zealand, *Plagiothecium cordatum*, *P. novae-seelandiae* var. *brotheri*, *P. semimortuum*, *P. semimortuum* var. *macquariense*, taxonomic revision

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Introduction

In terms of species richness within the genus *Plagiothecium* Schimp., Australasia, comprised of Australia and New Zealand (Deverson 2005), is the most depauperate region in the world. Since the beginning of bryological research in this region of the world, only eleven names related to the described genus have appeared (Mitten 1856, 1882; Wilson 1859; Jaeger and Sauerbeck 1876–1877; Brotherus 1916; Ireland 1992; Ochyra 2002; Wynns 2015; Wynns et al. 2018). This low number of taxa compared to other regions of the world is possibly

a result of relatively few revisions and the many morphological complexities associated with the genus (Ireland 1992; Ochyra 2002). Moreover, this fact may probably be influenced by geology, geography, biotic and abiotic factors, so it is difficult to assess this fact at this stage.

The earliest references to *Plagiothecium* in Australasia were from Tasmania and New Zealand concern *P. denticulatum* (Hedw.) Schimp., then known as a *Hypnum denticulatum* Hedw. (Mitten 1856; Wilson 1859). Several years later, Hampe (1860) described a new species, *H. lamprostachys* Hampe, which is now known as *Plagiothecium lamprostachys* (Hampe) A.Jaeger (Jaeger and Sauerbeck 1876–1877). Over the next few decades, this taxon was documented from other parts of Australia (Mitten 1882; Weymouth 1894; Rodway 1914, 1916). During this same period, Brotherus (1916) published the new species, *P. novae-seelandiae* Broth.

At the turn of the 20th century there appeared a number of names that were incorrectly published or have been transferred to other genera: *P. amblystomum* Müll.Hal., *nom. nud*., *P. howei* Kindb. *nom. nud.*, and *P. novae-valesiae* Broth. are synonymous with *Ectropothecium novae-valesiae* (Broth.) Ireland (Ireland 1992); *P. howeanum* A.Jaeger, *nom. nud.* is synonymous with *Ectropothecium leucochlorum* (Hampe) Broth.; and *P. helvolum* Müll.Hal., *in herb.* is synonymous with *Sauloma tenella* (Hook.f. & Wilson) Mitt. (Fife 2019).

In the first decades of the 20th century, the perception of the genus *Plagiothecium* in Australasia was greatly influenced by the publications of Dixon (1929) who recognized *P. denticulatum* and *P. novae-seelandiae* for New Zealand. At the same time, he treated *P. lamprostachys* as a synonym of *P. denticulatum* and in relation to the latter indicated that "the (...) status of *P. novae-seelandiae* therefore, is open to question." Probably for this reason, in this part of the world *P. lamprostachys* was forgotten for many decades, and in later studies *P. novae-seelandiae* was reduced to a synonym of *P. denticulatum* (e.g., Sainsbury 1955). Thus, for the ensuing years, *P. denticulatum* was reported as the only representative of this genus (e.g., Sainsbury 1955; Scott and Stone 1976; Ramsay 1984; Streimann and Curnow 1989; Beever et al. 1992) for Australasia. However, Sainsbury (1955) did indicate the remarkable variability of this taxon. By the end of the 20th century *Plagiothecium laetum* Schimp. was also recognized for the area (Vitt 1974), but later the presence of this typical Northern Hemisphere taxon was questioned by Fife (2019), and subsequently excluded from the flora of Australasia.

The end of the 20th century sees the revision by Ireland (1992), which shed new light on the perception of the genus *Plagiothecium* in Australasia. This researcher stated that there is a significant difference between *P. denticulatum* and *P. novae-seelandiae*, proposing the resurrection of the latter, as a separate species and deletion of *P. denticulatum* from the moss flora of Australasia. Additionally, Ireland (1992) published the first occurrence of *Plagiothecium lucidum* (Hook.f. & Wilson) Paris from Australia and New Zealand. Ten years later, the presence of *P. lucidum* in Australasia was confirmed by Ochyra et al. (2000).

The beginning of the 21st century brings Ochyra's (2002) publication in which he indicated that plants in the original collections of *P. lamprostachys*, in terms of leaf shape and general habit, match perfectly the type collections of *P. novae-seelandiae*. Thus, he proposed to synonymize the latter with *P. lamprostachys* (Ochyra 2002). This point of view was almost immediately adopted

by all Australasian bryologists (e.g., Streimann and Klazenga 2002; Klazenga 2012; Seppelt et al. 2013; Fife 2019). Streimann and Klazenga (2002), like Ireland (1992) and Ochyra et al. (2000), also additionally reported *P. lucidum*. A few years later appears a review by Wynns (2015) and Wynns et al. (2018). Wynns (2015) not only understood *P. lamprostachys* and *P. novae-seelandiae* as separate taxa, but also described two new species from this area in his Ph.D. thesis – *P. funale* J.T.Wynns and *P. humile* J.T.Wynns. However, in a later study (Wynns et al. 2018), *P. humile* was no longer distinguished and was omitted. We have been unable to find material which formed the basis of *P. humile*, *nom. inval.*

The complicated taxonomic history and relatively small number of species was the impetus to provide a revision of the genus for Australasia with the aim of testing the assumptions and taxonomic concepts presented by previous researchers.

Materials and methods

All collections of the genus *Plagiothecium* deposited in CANB, CHR, HO, MEL, and WELT– almost 400 specimens – were examined. After the revision, only those specimens with symmetrical leaves were selected for further analysis.

Thus, 27 specimens were selected, including four specimens (types) of *Hypnum lamprostachys* (=*Plagiothecium lamprostachys*) (BM000677526!, BM000677527!, BM000677528!, NY322494!); two specimens (types) of *P. funale* (CHR267040!, MO2408073!); five specimens (types) of *P. novae-seelandiae sensu lato* (CHR534780!, CHR534781!, PC0132644!, PC0132645!, PC0132646!); three specimens of material later named *Plagiothecium cordatum*, as well as 11 specimens of *Plagiothecium semimortuum sensu lato*. The two specimen types *P. lucidum* (PC0132689!, PC0132690!) were also analyzed. Thanks to this, all taxa described so far from Australasia were examined.

Selected specimens were used not only for mathematical analyses, but also for the description of new taxa. The mathematical analyses were performed mainly on nomenclatural types of taxa previously known from Australasia and the similar but later-named *P. semimortuum* (Figs 1, 2).

The selection of features for the following study was made on the basis of methodology adopted by Wolski (2017, 2019) and Wolski and Nowicka-Krawczyk (2020). Thus, the features include not only the most taxonomically important ones, but also other characteristics basic to the description of individual taxa: qualitative and quantitative features of gametophytes and sporophytes of the examined plants. Therefore, color, luster, and habit were tested first. From a uniform turf, one stem was chosen; the length of the whole stem was measured, and the arrangement of the leaves on the stem was evaluated.

Then, all the leaves were torn off from the central part of the stem, and six leaves were randomly selected for further measurements. For each of the examined leaves, the shape, symmetry, folding, and concavity were evaluated. They were also measured in terms of the length and the width at their widest points and the length of both costae. Additionally, the shape, curvature, and serration of the leaf apex were observed.

For each of the selected leaves, five groups of cells were measured: from the upper, the middle and the lower part of the leaf. Laminal cell shape was assessed, additionally, alar cells were measured, and their shape was assessed. Decurrent leaf base cells were measured, and the number of rows of cells was

counted. The cross-section was taken from the central part of the stem and six cross-sections of the stems were randomly chosen. First, the diameter of the obtained stem cross-section was measured, then five epidermal cells and five parenchymal cells were randomly selected.

In addition, the length of the sporophyte was assessed, color of the seta, length and width of the capsules, its arrangement on the seta, shape and length of operculum – of course only if these elements were present in the material. Similarly, in the case of other features – they were omitted from the description when a given element was not present or the feature was impossible to determine. Due to the poor condition of specimens, this situation occurred in the case of some gametophytic features of *P. lamprostachys*. Moreover, sporophytes were missing for *P. novae-seelandiae* var. *brotheri* (PC0132644, CHR534780), *P. cordatum* (CHR538916) and *P. semimortuum* var. *macquariense* (HO610220).

All research in the presented manuscript was based on our own macroscopic and microscopic analysis of herbarium collections. Only in one case, and only for the purposes of the cluster analyses (Figs 1, 2), was data used based on *P. funale* literature (Wynns 2015; Wynns et al. 2018). However, when describing this species, only data collected from the analysis of herbarium specimens were taken into account (MO2408073, CHR267040).

On the basis of features recognized in the literature as the most taxonomically important — length and width of leaf, length and width of cells from midleaf (e.g., Wolski and Nowicka-Krawczyk 2020; Wolski et al. 2021) — grouping analyses of the studied taxa were carried out. Due to the incommensurability of the data (length and width of leaf to length and width leaf cell), Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) were used to arrange the points in the ordering space.

These analyses are a basic tool that allows for grouping the examined specimens and thus showing the similarity between them. All mathematical analyses were performed in the PQSTAT v. 1.8.6 program. All other above-mentioned features considered representative of this genus were used to describe individual taxa (e.g., Wolski 2017, 2019; Wolski, Nowicka-Krawczyk 2020; Wolski et al. 2022a, b).

Results

The analyzed types as well as other material of *Hypnum lamprostachys* (=*Plagiothecium lamprostachys*) (BM000677526!, BM000677527!, BM000677528!, NY322494!), *P. novae-seelandiae* (CHR534780!, CHR534781!, PC0132644!, PC0132645!, PC0132646!), and *P. funale* (CHR267040!, MO2408073!) showed remarkable heterogeneity, wherein two separate morphotypes have been distinguished within *P. novae-seelandiae*. They differ both in several qualitative and quantitative features (Figs 1–11). Thus, the PCA and HCA analysis shows the division of the examined specimens and their grouping into five separate groups, with one of them showing internal differentiation (Figs 1, 2). In PCA, individual axes explain in total 76.9% of the variability (the first axis 45.7%, the second axis 31.2%) (Fig. 1).

Among the studied materials, the first group consists of the types of *Hypnum lamprostachys* (= *Plagiothecium lamprostachys*) and *P. novae-seelandiae*, wherein the *P. lamprostachys* specimens (BM000677526!, BM000677527!, BM000677528!, and NY322494!) stand out, clearly different from the other spec-

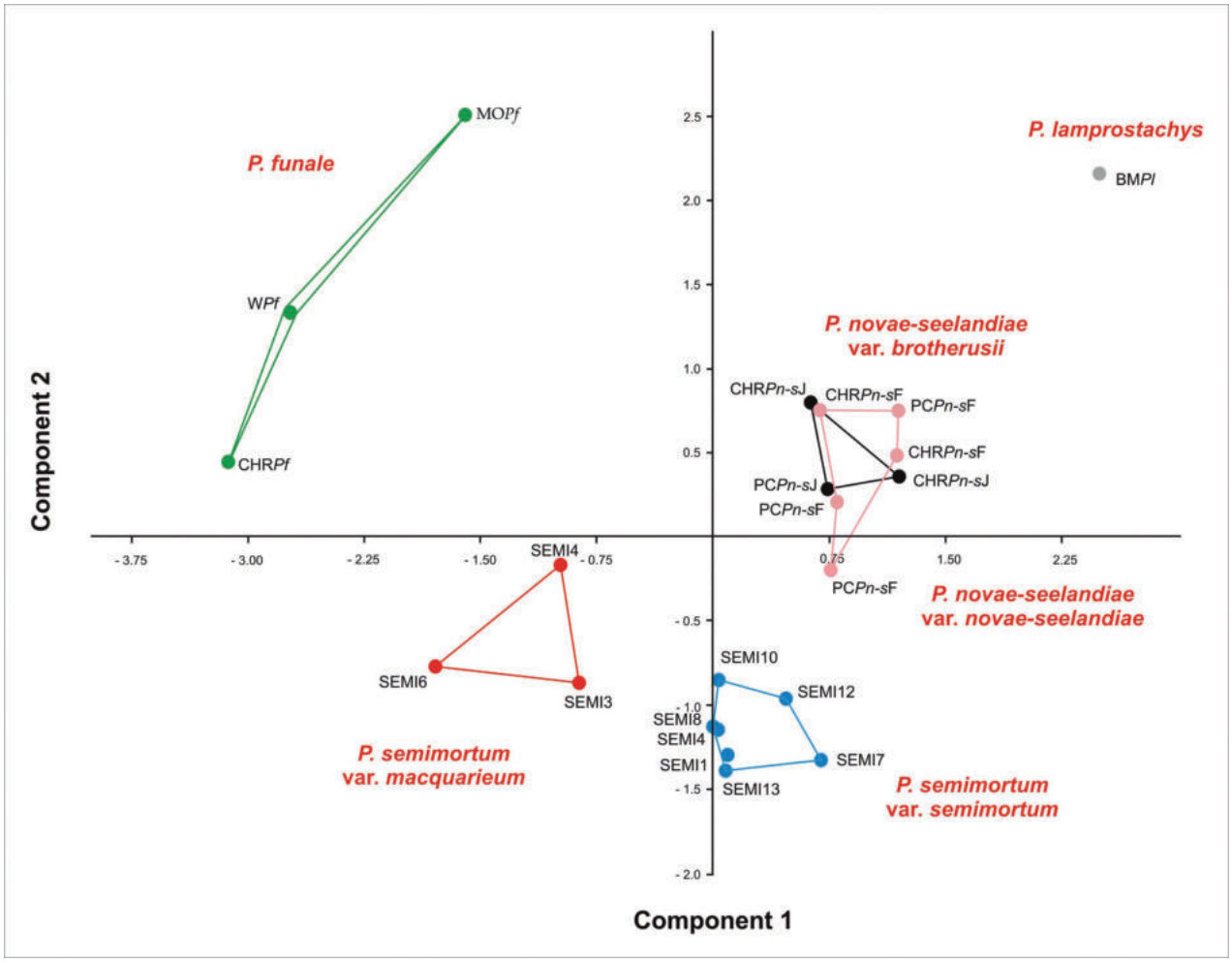

Figure 1. PCA analysis of the tested specimens. Explanation: CHR – Christchurch herbarium, PC – Paris herbarium, BM – Natural History Museum Herbarium, MO – Missouri herbarium, *Pn-s* – *Plagiothecium novae-seelandiae*, *Pl* – *Plagiothecium lamprostachys*, *Pf* – *Plagiothecium funale*, F – complanate leaves, J – julaceaous leaves, W – data on *P. funale* based on literature analysis (Wynns 2015; Wynns et al. 2018), SEMI1, 10, 12, 13, 14, 17, 18 – *P. semimortuum* var. *semimortuum*, SEMI3, 4, 6 – *P. semimortuum* var. *macquariense*.

imens. *Plagiothecium lamprostachys* material is characterized by asymmetric or slightly asymmetrical, long, broad (2.5–2.6 × 1.0–1.2 mm), ovate, concave leaves, apex entire, and long, broad laminal cells (140–150 × 12–13 µm) (Fig. 3). The other specimens (*P. novae-seelandiae*) form a non-heterogeneous group (Figs 1, 2).

Plagiothecium novae-seelandiae was described by Brotherus in 1916. In the diagnosis, the author indicated that the specimen is densely foliate, more or less complanate-foliate, the leaves are concave, long-decurrent, broadly ovate, asymmetrical, with elongate, loosely rhomboidal cells (Brotherus 1916). Examination of isolectotypes of *P. novae-seelandiae* (CHR534780!, CHR534781!, PC0132644!, PC0132645!, PC0132646!) showed that this material is not homogeneous, but is a mixture of two different morphotypes (Figs 1, 2, 4, 5). The existence of two groups of morphotypes within *P. novae-seelandiae* is confirmed by the mathematical analyses performed. However, the overlap of these groups in the PCA analysis is only related to the two-dimensional possibility of showing the results, and the distinctiveness of the above-mentioned groupings is confirmed by the HCA analysis (Figs 1, 2).

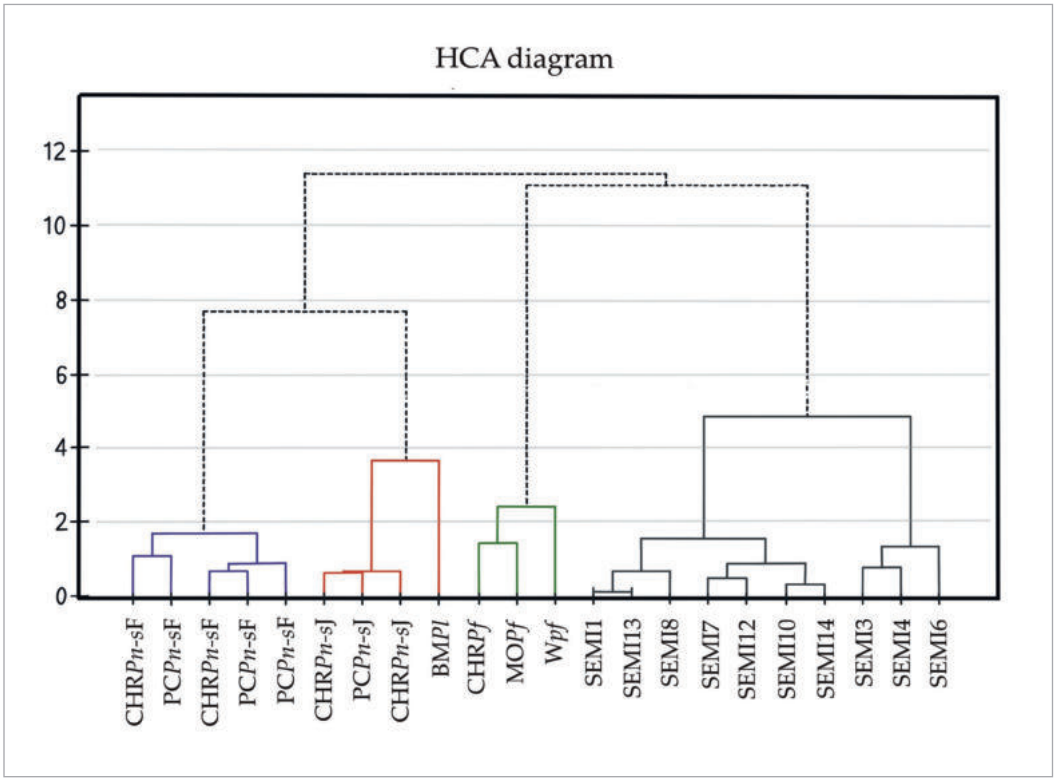

Figure 2. Dendrogram (HCA) of the examined specimens. Explanation: see Fig. 1.

One of the morphotypes (CHR534781!, CHR534780p.p.!, PC0132644p.p.!, PC0132645!, PC0132646!, H3301105, available online!) with complanate stems, is characterized by a dominance of asymmetric leaves, serrate leaf apices, wide cells, making the cell areolation very loose (100–130 × 12–17 µm). This description fits very well with the diagnosis of *P. novae-seelandiae* given by Brotherus (1916). The second morphotype (CHR534780p.p.!, PC0132644p.p.!) is characterized by julaceous stems, a dominance of symmetrical leaves, entire, non-serrate leaf apices, narrow cells, making the cell areolation tight (100–140 × 7.5–10 µm) (Figs 4, 5). Specimens of *P. novae-seelandiae* with julaceous stems (CHR534780p.p.!, PC0132644p.p.!) differ from *P. lamprostachys* in habit, shape, symmetry and size of the leaves (Figs 1–3) as described above.

Taking into account the above facts, it can be indicated that plants with complanate-foliate, asymmetric leaves, serrate apices, wide cells, making the cell areolation loose refer to *P. novae-seelandiae* which was described by Brotherus (1916) (Fig. 4). The second morphotype, refers to the new variety proposed here – *P. novae-seelandiae* var. *brotheri* (Fig. 5).

Another group of specimens are material representing *P. funale* (Figs 1, 2). They differ from other examined specimens by leaves loosely arranged on the stem, lanceolate, clearly asymmetric, short and narrow (1.6–2.2 × 0.6–0.8 mm), concave, folded, short leaves, elongate and entire, non-serrate apices, long and narrow laminal cells (120–150 × 6–7 µm) and wedge-shaped, narrow decurrencies composed of rectangular cells (Fig. 6).

Narrow decurrencies are a feature that distinguishes *Plagiothecium funale* from other taxa of this genus with wide decurrencies, encompassing all those taxa currently known from Australasia. However, the analysis also indicated the presence of another taxon with narrow decurrencies, distinguished by

julaceous stems, short and narrow (1.7–2.0 × 0.7–0.9 mm), longitudinally folded, concave, lanceolate, symmetric leaves with heart-shaped leaf bases, entire, non-serrate leaf apices, and long and narrow cells (140–165 × 5–7 µm), making the cell areolation tight. Specimens with such features (Fig. 7) we propose to call *Plagiothecium cordatum* sp. nov.

The last two taxa are plants with a unique set of gametophytic qualitative and quantitative features (Figs 8, 9). The unique feature, otherwise not found among taxa of this genus, is the absence of protoplast in the upper part of the leaf at maturity.

The first group (SEMI1, SEMI13, SEMI8, SEMI7, SEMI12, SEMI10 and SEMI14) (Figs 1, 2, 8) is material with erect, julaceous stems, symmetrical, concave, transversely undulate leaves, with a leaf from 1/3 to 2/3 devoid of protoplasts, short and wide laminal cells (60–90 × 10–12 µm), which makes the cell areolation very loose, and a decurrency constructed of spherical and inflated cells (Fig. 8). Specimens with such characteristics we propose to name here *Plagiothecium semimortuum* sp. nov. The second group of specimens (SEMI3, SEMI4, SEMI6) (Figs 1, 2, 9) differs from the previous one in narrower leaves, longer and narrower laminal cells (112.5–125 × 7.5–10 µm) and a different habitat – lowland areas. Specimens with such features (Fig. 9) we propose here to call *Plagiothecium semimortuum* var. *macquariense* var. nov.

Discussion

The genus *Plagiothecium* in Australasia has been misunderstood, and perceptions have changed considerably. First, practically all specimens from this part of the world were identified as *P. denticulatum*, then *P. novae-seelandiae*, and later *P. lamprostachys*. Thus, a single taxon name was replaced by successive names without a careful and detailed revision of the group (e.g., Mitten 1856, 1882; Wilson 1859; Brotherus 1916; Ireland 1992; Ochyra 2002). This is one of the reasons for the low number of taxa reported so far from Australasia. The second important contributing factor to the low number of taxa was the relatively small number of studies on this genus (Ireland 1992; Ochyra 2002; Wynns 2015; Wynns et al. 2018). Thus, for such a huge and diverse continent, the number of taxa recorded until the beginning of the 21st century is extremely low, especially in comparison with other parts of the world, not just the relatively well-studied Northern Hemisphere (e.g., Nyholm 1965; Buck and Ireland 1989; Smith 2001; Wolski et al. 2021).

Dixon (1929) was a big influence on the perception of this genus, for example, his synonymization of *P. lamprostachys* with *P. denticulatum* led to the loss of the concept of that species for decades. A similar influence was Sainsbury (1955), who synonymized *P. novae-seelandiae* with the aforementioned *P. denticulatum*. On the other hand, the confusion of Australian and New Zealand specimens with *P. denticulatum* is not so surprising. Because both the habit and the most important microscopic features (e.g., serrate leaf apex, loose areolation of cells, distinct decurrency composed of inflated cells) resemble this most common Northern Hemisphere taxon (Wolski et al. 2021). However, as in many other cases (e.g., *Plagiothecium schofieldii* G.J.Wolski & W.R.Buck and *P. lamprostachys*), despite the morphological similarity, geographical and molecular differences between them are indisputable (Wynns et al. 2018; Wolski et al. 2021), as are subtle morphological differences.

Although *P. denticulatum* has been reported from Australasia for decades, Ireland (1992) rightly excluded it from the local moss flora. As in the case of *P. denticulatum*, the same was with *P. laetum* (Vitt 1974). This species was most likely confused by Vitt with the similar *P. lucidum*, in terms of leaf symmetry and cell dimensions. However, as in the case of *P. denticulatum*, we now know that *P. laetum* is a taxon occurring only in the Northern Hemisphere, and thus was excluded from Australasia by Fife (2019).

Ochyra (2002) indicated that the types of *P. lamprostachys* match perfectly to the type collections of *P. novae-seelandiae*. This synonymization further influenced the understanding and perception of this genus in Australasia. Current research indicates that indeed one of the morphotypes of *P. novae-seelandiae* is similar to *P. lamprostachys*, but they are not identical, which is indicated by the statistical analyses. Treating these species separately was already proposed by Wynns (2015), and it is supported here.

Interestingly, none of the earlier researchers (e.g., Ireland 1992; Ochyra 2002; Fife 2019) indicated that the original collection of *P. novae-seelandiae* consisted of two separate morphotypes. Only Wynns (2015) mentioned it, but generally ignored the issue. However, even a cursory analysis signifies that the two previously mentioned morphotypes of *P. novae-seelandiae* differ in many important taxonomic features – e.g., habit, foliage, symmetry, concavity of leaf, serration of apex, cell dimensions. These differences are supported by the statistical analyses presented above. Morphological studies combined with the analysis of the diagnosis indicate that the taxon mentioned by Brotherus (1916) is material characterized by, for example, complanate-foliate habit, domination of asymmetrical leaves, serrate leaf apices, wide cells, which makes the cell areolation loose (100–130 × 12–17 µm). Specimens with such a set of features were named *Plagiothecium novae-seelandiae* [var. *novae-seelandiae*] (CHR534781!, CHR534780p.p.!, PC0132644p.p.! PC0132645!, PC0132646!). But, the morphotype with julaceous stems, dominance of symmetrical leaves, entire, non-serrate apices, narrow cells, which makes the cell areolation tight (100–140 × 7.5–10 µm) is here named *Plagiothecium novae-seelandiae* var. *brotheri*.

Wynns (2015), in his doctoral thesis, described two new species from Australasia – *Plagiothecium funale* and *P. humile*. However, in his publication based on his thesis (Wynns et al. 2018), he does not mention the latter. On the other hand, the former – *P. funale* can be distinguished easily from the other taxa recorded currently from Australasia by asymmetrical, concave, undulate leaves, short and smooth apex, long and narrow cells and wedge-shaped, and narrow decurrencies composed of rectangular cells. The last feature – wedge-shaped decurrencies, composed of rectangular, non-inflated cells – is a very important and the most unique feature compared to other species. Decurrent angular rounded cells forming distinct auricles are characteristic of all previous species (e.g., Sainsbury 1955; Scott and Stone 1976; Ireland 1992; Fife 2019; Ochyra 2002).

In the genus *Plagiothecium*, the decurrency is one of the most important taxonomic features (Wolski et al. 2021). Although this feature plays a fundamental role in the division of individual taxa into sections of this genus, unfortunately it is often overlooked when analyzing material – therefore, it is always necessary to analyze these structures, which in the case of this genus often remain on the stem after dissection. Without checking the decurrency, it is very easy to confuse some even distantly related species that are similar in some

respects, e.g., *P. denticulatum* and *P. nemorale* (Mitt.) A.Jaeger (e.g., Wolski and Nowicka-Krawczyk 2020; Wolski et al. 2021).

Plagiothecium cordatum, like *P. funale*, is characterized by a unique set of gametophyte features, including, and most importantly, a wedge-shaped decurrency composed of uninflated cells (Wynns 2015; Wynns et al. 2018). This feature distinguishes these taxa from other taxa in this part of the world. The other characteristics, e.g., julaceous stem, short and narrow (1.7–2.0 × 0.7–0.9 mm), concave, clearly and strongly folded leaves with a heart-shaped base, entire, non-serrate leaf apices, and long and narrow cells (140–165 × 5–7 µm) make it quite easy to distinguish *P. cordatum* from *P. funale*.

This research has also allowed the description of *Plagiothecium semimortuum* var. *semimortuum* and *P. semimortuum* var. *macquariense*. Both have a unique feature not found in any other species of the genus. The leaf cells are devoid of protoplasts occupying as much as 2/3 of the leaf length. The absence of the protoplasts in part of the leaf is unusual for the genus *Plagiothecium* (Smith 2001; Wolski et al. 2021), but not for some types of mosses. Many taxa, especially those growing in open, sunny habitats, are characterized by a lack of protoplasts in the leaf or part of the leaf, e.g., *Bryum argenteum* Hedw., *Gigaspermum mouretii* Corb., *Orthotrichum diaphanum* Brid., *Polytrichum piliferum* Hedw., *Tortula muralis* Hedw. and others (e.g., Noguchi 1995; Smith 2001).

These two taxa, *Plagiothecium semimortuum* var. *semimortuum* and *P. semimortuum* var. *macquariense*, due to the decurrent angular rounded cells, which form distinct auricles clearly have been referred to *P. lamprostachys* and *P. novae-seelandiae sensu lato* (Sainsbury 1955; Scott and Stone 1976; Ramsay 1984; Ireland 1992; Fife 2019; Ochyra 2002), and because of this morphology, they should be included in *Plagiothecium* sect. *Plagiothecium*.

Despite some similarities, *P. semimortuum* var. *semimortuum* and *P. semimortuum* var. *macquariense* differ in a number of qualitative and quantitative gametophytic features: the size and folding of the leaf, the serration of the leaf apex, the dimensions of the cells, but also the habitat – mountains versus lowlands. All these features confirm the validity of distinguishing the above-mentioned taxa.

Taxonomic treatments

***Plagiothecium lamprostachys* (Hampe) A.Jaeger, Bericht über die Thätigkeit der St. Gallischen Naturwissenschaftlichen Gesellschaft 1876–1877: 449 (1878)**

Hypnum lamprostachys Hampe, Linnaea 30: 639 (1860).

Type. Australia, Hab. ad fl. Tarwin. ***Lectotype*** (selected by Ochyra 2002): Austral felix Tarwin, Herb. Hamp. – 1881. *Hypnum lamprostachys* Hpe. leg. *F. Mueller N°59*, 1855 (BM-Hampe!). ***Isolectotypes*:** (BM000677526!, BM000677527!, BM000677528!, NY322494!).

Description. Plants medium size, yellowish to yellow-green, with metallic luster, forming dense mats; stems 1.5–2.5 cm long, in cross-section rounded, the central strand well-developed; leaves asymmetrical to almost asymmetrical, ovate, concave, rather imbricate and closely arranged on the stem, those leaves from the middle of stem 2.5–2.6 mm long and the width measured at the widest point 1.1–1.2 mm (Fig. 3); the apex acute, entire, not denticulate;

Figure 3. Selected taxonomic features of *P. lamprostachys* **A** shape and dimensions of the leaf **B** leaf apex **C** cells from the middle part of the leaf **D** leaf basal cells (from the type of material of *H. lamprostachys* BM000677528!, photo. G. J. Wolski, 01 August 2023).

costae two, extending usually to 1/2 of the leaf length; laminal cells more or less symmetrical, arranged in fairly even rows, 140–150 × 12–13 µm in the middle of leaves; due to the wide cells, cell areolation loose; decurrency of 4 rows of rounded and inflated cells, forming distinct auricles, 200–250 µm long; sporophytes so far unknown; sexual condition unknown.

Plagiothecium lamprostachys type material was recorded near the Tarwin River in Australia (Hampe 1860).

***Plagiothecium novae-seelandiae* var. *novae-seelandiae* Broth., Proceedings of the Linnean Society of New South Wales 41: 594 (1916)**

Type. New Zealand, Kelly's Range, Kelly's Creek, on dripping rocks, and at top of Otira Gorge, 2830 ft., damp rocks in scrub, leg. *T. W. Naylor Beckett*. ***Lectotype*** (selected by Ireland 1992): New Zealand, Mosses of Westland, Damp rocks in scrub at top of Otira Gorge, 2830 ft, *Plagiothecium Novae Seelandiae* Broth., leg. *T. W. Naylor Beckett 918*, 11 Feb. 1903 (H3301105, available online!). ***Isolectotypes*:** (CHR534780p.p.!, PC0132645!, NY322492!, NY322493!). ***Syntypes*:** New Zealand, Mosses of Westland, Kelly's Creek, Kelly's Range, on dripping rocks, *Plagiothecium Novae Seelandiae* Broth., leg. *T. W. Naylor Beckett 996*, 3 Feb. 1903 (CHR534781!, PC0132644p.p.!, PC0132646!, DUKE156811, S-B160226, UC1911437).

Description. Plants medium size, green, with metallic luster, forming rather dense mats, complanate-foliate; stems 4–6 cm long, in cross-section rounded, 300–350 µm in diameter, the central strand well-developed; leaves asymmetrical, not overlapping on the stem to slightly imbricate, rather flat to undulate, sometimes one side of the leaf flat or folded over the rest of the leaf, leaves from the middle of stem 1.7–2.2 µm long and the width

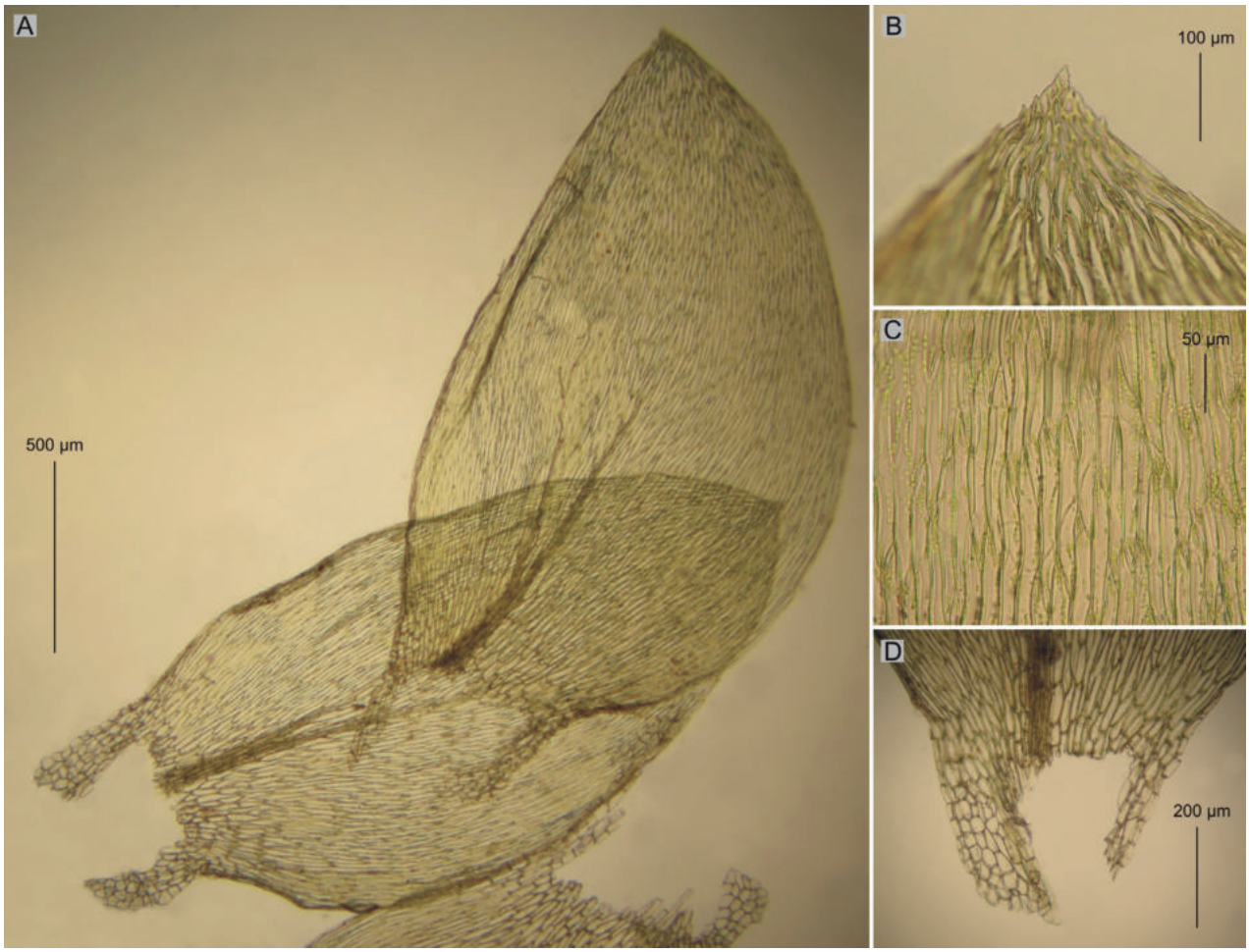

Figure 4. Selected taxonomic features of *Plagiothecium novae-seelandiae* var. *novae-seelandiae* **A** shape and dimensions of leaves **B** serrate leaf apex **C** dimensions and shape of cells from middle part of the leaf **D** decurrency (from the type material of *P. novae-seelandiae* PC0132644p.p.!, photo. G. J. Wolski, November 21, 2021).

measured at the widest point 1.0–1.5 mm; the apex acute and denticulate; costae two, rather thick and strong, extending usually to ½ of the leaf length; laminal cells more or less symmetrical, the length and width variable but dependent on location: 110–140 × 10 µm at apex, 100–130 × 12–17 µm at midleaf, and 75–150 × 17.5–20 µm toward insertion; due to the wide cells, cell areolation loose; decurrency of 3–5 rows of rounded and inflated cells, forming distinct auricles, 200 µm long. Sporophytes 2.5–4.0 cm long, setae reddish-orange; capsules horizontal, 1.7–2.8 × 0.7–1.0 mm (Fig. 4); sexual condition unknown.

Plagiothecium novae-seelandiae var. *novae-seelandiae* types were recorded from New Zealand, Kelly's Range, Kelly's Creek (CHR534781!, PC0132644p.p.!, PC0132646!, DUKE156811, S-B160226, UC1911437) and at top of Otira Gorge (H3301105, available online!, CHR534780p.p.!, PC0132645!, NY322492!, NY322493!), on dripping rocks (H3301105, available online!, CHR534780p.p.!, PC0132645!, NY322492!, NY322493!, CHR534781!, PC0132644p.p.!, PC0132646!, DUKE156811, S-B160226, UC1911437), damp rocks in scrub (H3301105, available online!, CHR534780p.p.!, PC0132645!, NY322492!, NY322493!).

***Plagiothecium novae-seelandiae* var. *brotheri* G.J.Wolski var. nov.**

Type. *Holotype*: Mosses of Westland, New Zealand, on dripping rocks, Kelly's Creek, Kelly's Range, *Plagiothecium Novae Seelandiae* Broth., leg. *T. W. Naylor Beckett 996*, 3 Feb. 1903 (PC0132644p.p.!). ***Paratype*:** Mosses of Westland, New Zealand, damp rocks in scrub at top of Otira Gorge, 2830 ft, *Plagiothecium Novae Seelandiae* Broth., leg. *T. W. Naylor Beckett 918*, 11 Feb. 1903 (CHR534780p.p.!).

Description. Plants medium size, green, julaceus, with metallic luster; stems 3–4 cm, in cross-section rounded, 250–300 µm in diameter, the central strand well-developed; leaves symmetrical to almost symmetrical, imbricate, concave, ovate, slightly folded, leaves from middle of stem 1.7–2.4 mm long and width measured at widest point 0.9–1.0 mm; leaf margins recurved; the apex acuminate, not denticulate; costae two, rather thick and strong, extending usually to 1/3 of the leaf length; laminal cells more or less symmetrical, the length and width variable but dependent on location: 90–120 × 7.5–10 µm at apex, 100–140 × 7.5–10 µm at midleaf, and 100–125 × 10–12.5 µm toward insertion; due to relatively narrow, cell areolation quite tight; decurrency of 5–6 rows of rounded and inflated cells, forming distinct auricles, 200–250 µm long (Fig. 5); sporophytes so far unknown; sexual condition unknown.

Plagiothecium novae-seelandiae var. *brotheri* type material was recorded from New Zealand, Kelly's Creek, Kelly's Range (PC0132644p.p.!) and at top of Otira Gorge (CHR534780!), on dripping rocks (PC0132644p.p.!) and damp rocks in scrub (CHR534780!).

Etymology. The present taxon is part of the *P. novae-seelandiae* collection from which Brotherus (1916) described a new species, therefore this taxon — *P. novae-seelandiae* var. *brotheri* — is named in honor of Brotherus.

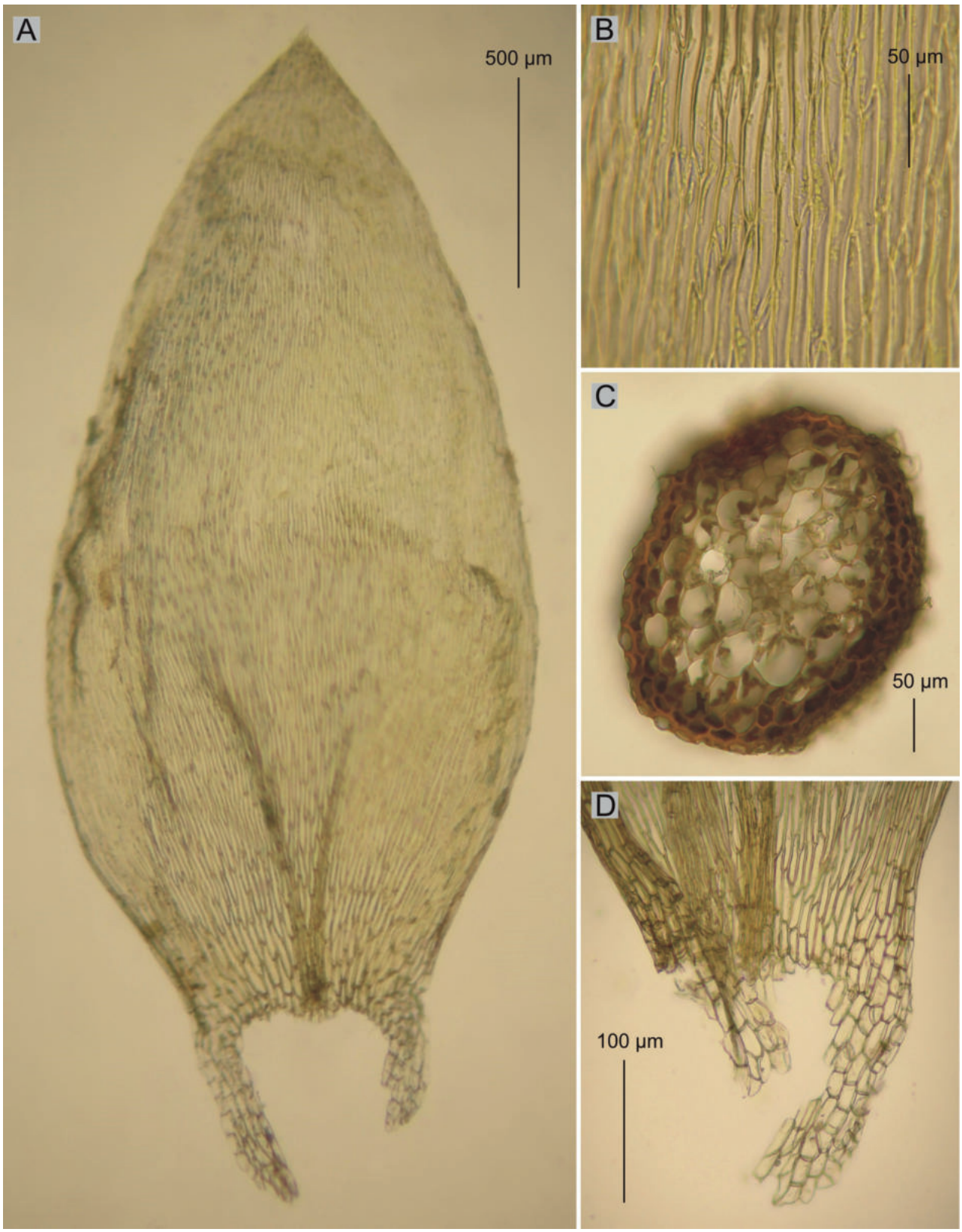

Figure 5. Selected taxonomic features of *Plagiothecium novae-seelandiae* var. *brotheri* **A** shape and dimensions of leaf **B** dimensions and shape of cells from middle part of the leaf **C** stem cross-section **D** decurrency (from the type material of *P. novae-seelandiae* PC0132644p.p.!, photo. G. J. Wolski, November 22, 2021).

***Plagiothecium funale* J.T.Wynns, Cladistics 34(5): 483. 2018 [11 October 2017]**

Type. *Holotype*: New Zealand, Nelson Province, growing on bark of *Nothofagus menziesii* in beech forest along highway between Reefton and Spring Junction, leg. *L. Visch 618*, 14 Jan. 1974 (DUKE156843). ***Isotypes*:** (MO2408073!, CHR267040!).

Description. Plants medium-size, yellowish to yellow-green, forming fairly dense mats; stems 2.0–4.0 cm long, in cross-section rounded, the central strand well developed, epidermal cells thick-walled, the parenchyma thin-walled; leaves asymmetrical, lanceolate, plicate and undulate, i.e., transversely folded, concave, long-acuminate; leaves from middle of stem 1.6–2.2 µm long and width measured at widest point 0.6–0.8 µm; apex not denticulate; costae two, weak and thin, not exceeding more than ⅓ of the leaf length; laminal cells asymmetrical, length and width variable but dependent on location: 100–150 × 6–7 µm at midleaf, cell areolation narrow; decurrency of 2–3 rows of rectangular cells forming triangular or wedge-shaped auricles, 150–200 µm long; sporophytes orange, seta reddish below, 2 cm long; capsules cylindrical and inclined; sexual condition unknown (Fig. 6).

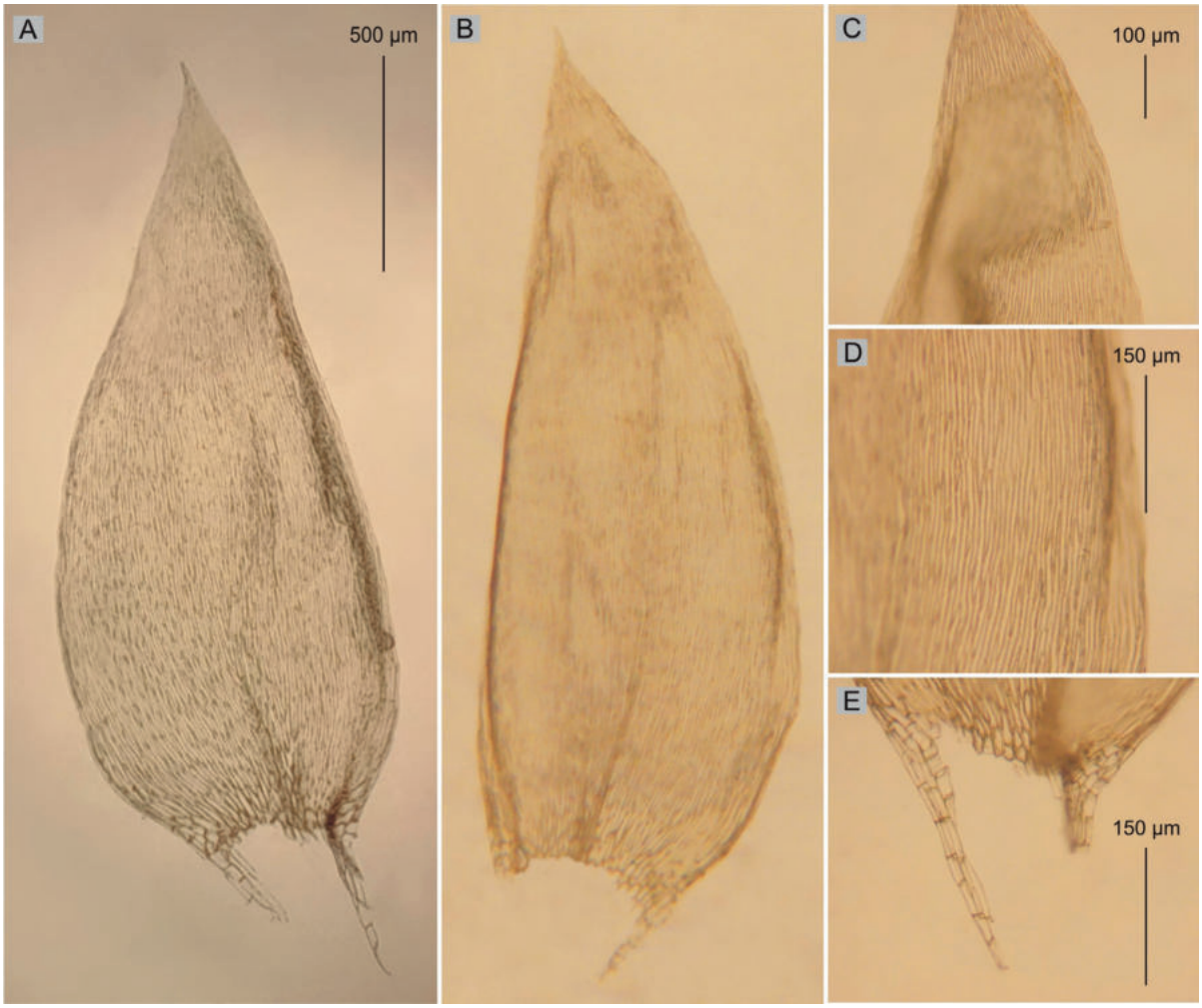

Figure 6. Selected taxonomic features of *Plagiothecium funale* **A, B** shape and dimensions of leaves **C** folding of the apex of the leaf **D** dimensions and shape of cells from middle part of the leaf **E** narrow decurrency composed of rectangular cells (from the type of material of *P. funale* CHR267040!, MO2408073!, photo. G. J. Wolski, November 2022 and July 2023).

Plagiothecium funale types were recorded from New Zealand, Nelson Province, along highway between Reefton and Spring Junction (MO2408073!, CHR267040!), on bark of *Nothofagus menziesii* in beech forest (MO2408073!, CHR267040!).

Plagiothecium cordatum **G.J.Wolski, sp. nov.**

Type. *Holotype*: New Zealand, Boundary Creek, McKerrow Range, ca 4000 alt., leg. *Colin D. Meurk*, 17 Jan. 1974 (CHR538916!).

Description. Plants small, ascending and julaceous, yellow to yellow-green, with metallic luster, forming dense mats; stems 1.0–2.0 cm long, in cross-section rounded, with a diameter of 220–240 µm, the central strand well-developed, epidermal cells thick-walled, the parenchyma thin-walled; leaves symmetrical, lanceolate, concave, longitudinally folded, imbricate, closely arranged on the stem, those leaves from the middle of stem 1.7–2.0 mm long and the width measured at the widest point 0.7–0.9 mm; the apex acuminate, entire, not denticulate; leaf base cordate-rounded; costae two, weak and thin, extending usually to ½ of leaf length; laminal cells asymmetrical, the length and width variable but dependent on location: 140–165 × 5–7 µm at the apex, 135–160 × 5–7.5 µm at midleaf, 65–100 × 10 µm toward insertion; due to cell width, cell areolation very narrow; decurrency of 3–4 rows of rectangular cells, forming narrow, wedge-shaped auricles, 300 µm long (Fig. 7); sporophytes so far unknown; sexual condition unknown.

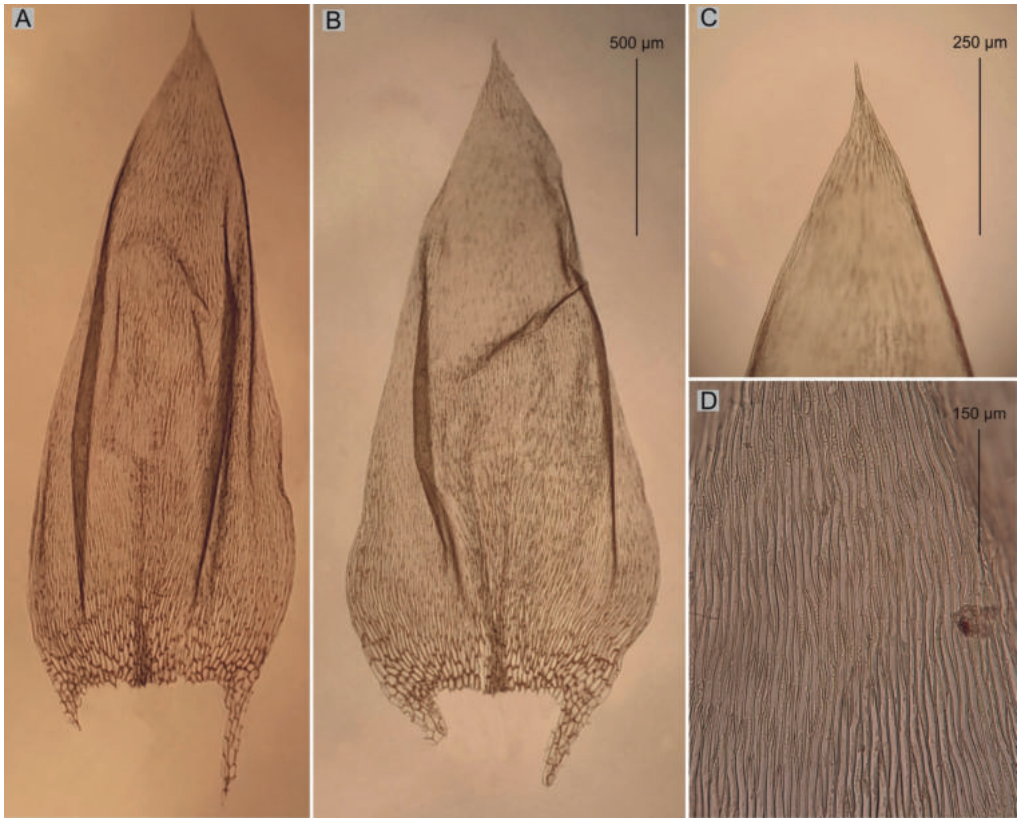

Figure 7. Selected taxonomic features of *Plagiothecium cordatum* **A, B** shape and dimensions of leaves **C** leaf apex **D** dimensions and shape of cells from middle part of the leaf (from the type of material of *P. cordatum* CHR538916!, photo. G. J. Wolski, November 12, 2022).

Plagiothecium cordatum so far has been recorded from New Zealand, McKerrow Range, Boundary Creek (CHR538916), South Island, Fiordland National Park, Corland Burn, South Branch, 2 km north of Mount Burns (AK352034) and from Macquarie Island, Sawyer Creek (HO610227) (Fig. 7). This species was noted on the south side of southernmost waterfall, on undercut bank at edge of creek (HO610227), on *Nothofagus menziesii* forest epiphytic on trunk of silver beech (AK352034).

Etymology. The name of this taxon – *Plagiothecium cordatum* refers to the heart-shaped (Latin: *cor* – heart) base of leaves of this species.

***Plagiothecium semimortuum* var. *semimortuum* G.J.Wolski, sp. nov.**

Type. *Holotype*: Australia, Victoria, Mt. Stirling at the head of the Delatite River, along steep eastern face, 37°07'S, 146°28'E, alt. 5400 ft., growing on granite rock ledges and crevices along steep eastern face, growing together with *Andreaea australis*, leg. *J. H. Williams 229W*, 8 Mar. 1953 (MEL1016042!). ***Isotype*:** (WELT-M28128!).

Description. Plants medium size, ascending and julaceous, yellow-green to dark-green, with metallic luster, forming dense mats; stems 1.0–1.5 cm long, in cross-section rounded, with a diameter of 220–250 µm, the central strand well-developed, epidermal cells thick-walled, 10–15 × 10–12.5 µm, the parenchyma thin-walled, 9.0–14 × 8.0–13 µm; leaves symmetrical, ovate, folded, imbricate, closely arranged on the stem, concave, therefore leaves splitting when flattened, leaves from 1/3 up to 2/3 without protoplasts, those leaves from the middle of the stem 1.6–2.0 mm long and the width measured at the widest point 0.9–1.2 mm; the apex acute, not denticulate; costae two, rather thick and strong, extending usually to ½ of the leaf length, 250–300 µm; laminal cells more or less symmetrical, the length and width variable but dependent on location: 65.0–85 × 10–12.5 µm at apex, 60–90 × 10–12 µm at midleaf, and 65–100 × 15–17.5 µm toward insertion, due to the wide cells, cell areolation loose; decurrency of 4–5 rows of rounded and inflated cells, forming distinct auricles, 250–300 µm long (Fig. 8); sporophytes (immature) with setae reddish at base and yellowish-orange above, 1.5–1.8 cm long; the capsules inclined, 2.0 mm long, operculum long, conical and mammillate; sexual condition unknown.

Plagiothecium semimortuum var. *semimortuum* so far has been recorded from Australia, near Melbourne (MEL1031370, MEL1016042, CBG50739), Tasmania (HO302794, HO556631, HO133456) and from New Zealand (CHR651872, CHR532442, CHR464681, CHR104940). Specimens of *P. semimortuum* var. *semimortuum* were noted on the ground between plants (CHR651872); on humus between boulders (CHR532442); on shaded rock in exposed southerly sub-alpine herbfields with small scattered low shrubs (CBG50739); within rainforest gully (HO133456); on granite rock ledges and crevices along steep eastern face (MEL1016042, MEL1031370); on alpine heathland (HO556631); crevices in boulder fields (CHR104940); on mat of senescent tussock on vertical side of small valley, *Chionochloa pallens-Chionochloa australis* tussockland with scattered shrubs (CHR 464681). All specimens of *P. semimortuum* var. *semimortuum* have been collected in mountainous areas of Australasia (820–1769 m alt).

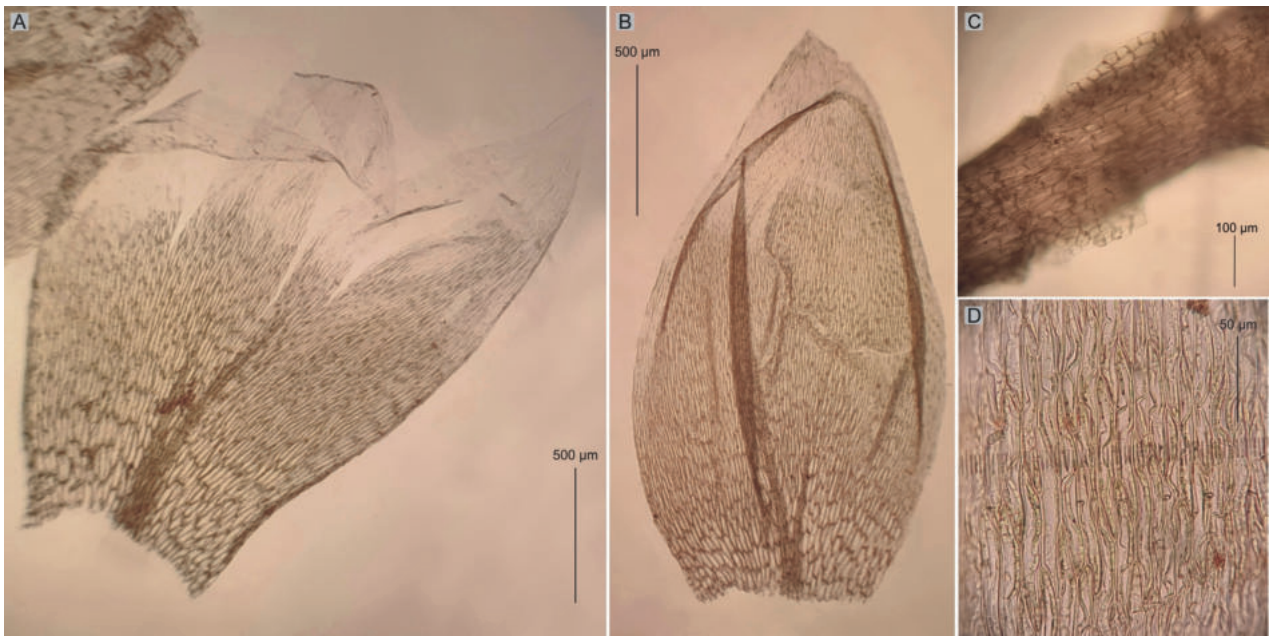

Figure 8. Selected taxonomic features of *Plagiothecium semimortuum* var. *semimortuum* **A, B** shape and dimensions of leaves **C** decurrency on the stem **D** dimensions and shape of cells from middle part of the leaf (from the type of material of *Plagiothecium semimortuum* var. *semimortuum* MEL1016042 and WELT-M28128, photo. G. J. Wolski, November 13, 2022).

Etymology. The name of this species – *Plagiothecium semimortuum* (Latin: *semi* – half; *mortum* – dead) refers to the leaves without protoplasts; they are dead even up to half the leaf.

***Plagiothecium semimortuum* var. *macquariense* G.J.Wolski, var. nov.**

Type. *Holotype*: Australia, Tasmania, Macquarie Island, NW slope of Mt. Haswell, Caroline Cove, 54°44'S, 158°51'E, in *Poa foliosa* dominated vegetation on northwest slopes of Mt. Haswell, 120 m alt., leg. *R. D. Seppelt 15316*, 30 Jan. 1985 (HO610220!).

Description. Plants small, ascending and julaceous, yellow-green, with metallic luster, forming dense mats; stems 0.5–1.0 cm long, in cross-section rounded, with a diameter of 250–280 µm, the central strand well-developed, epidermal cells thick-walled, 7–13 × 6–11 µm, the parenchyma thin-walled, 9–11 × 8–10 µm; leaves symmetrical, narrowly ovate, folded, imbricate, closely arranged on the stem, concave, therefore leaves splitting when flattened, leaves from 1/3 up to 2/3 without protoplasts, those leaves from the middle of stem 1.9–2.2 mm long and the width measured at the widest point 0.9–1.1 mm; the apex acute and denticulate; costae two, rather thick and strong, extending usually to ⅓ of leaf length; laminal cells more or less symmetrical, length and width variable but dependent on location: 112.5–140 × 7.5–10 µm at the apex, 112.5–125 × 7.5–10 µm at midleaf, 88–112 × 15 µm toward insertion; due to the width of the cells, cell areolation tight; decurrency of 4–5 rows of rounded and inflated cells, forming distinct auricles, 200 µm long; sporophytes so far unknown; sexual condition unknown (Figs 9, 10).

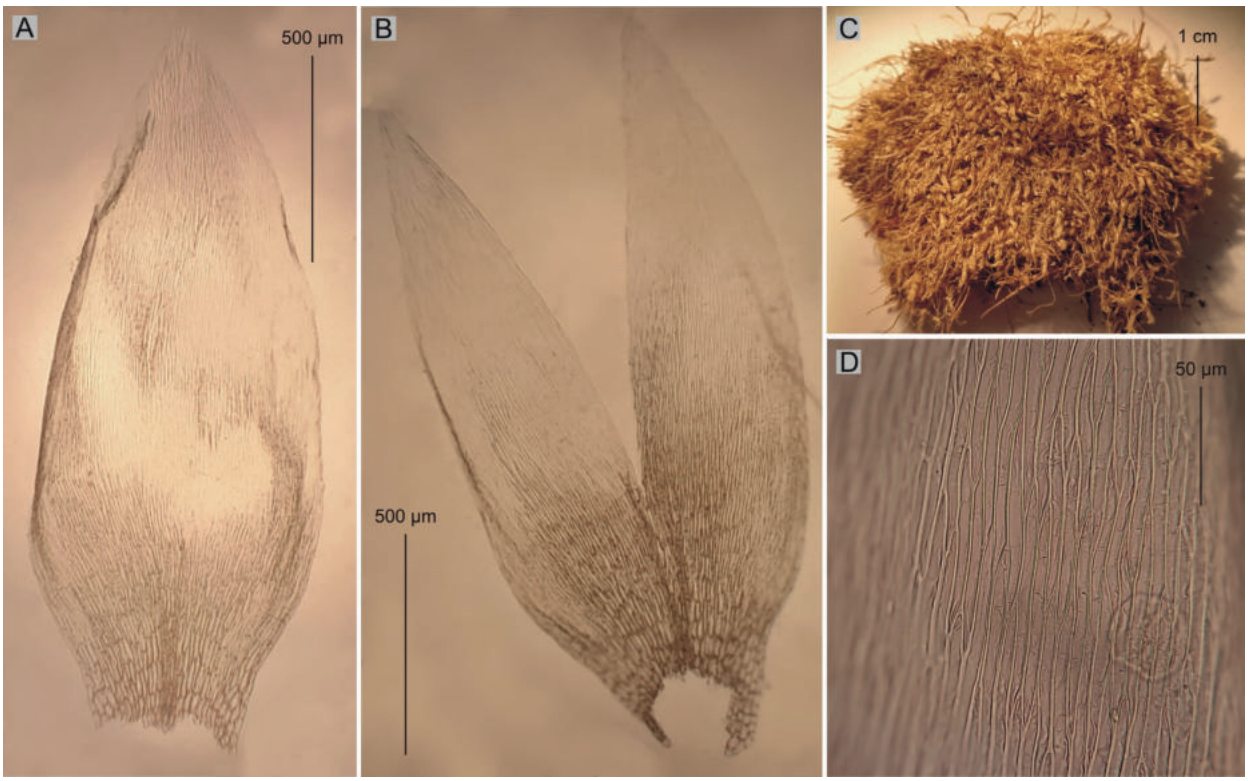

Figure 9. Selected taxonomic features of *Plagiothecium semimortuum* var. *macquariense* **A, B** shape and dimensions of leaf **C** julaceous turf **D** dimensions and shape of cells from middle part of the leaf (from the type of *P. semimortuum* var. *macquariense* HO610220, photo. G. J. Wolski, November 13, 2022).

Plagiothecium semimortuum var. *macquariense* so far has been recorded from Australia – Macquarie Island (HO610219, HO610227, HO610220) and mainland Tasmania (HO71698) (Fig. 11). Specimens were noted in *Poa foliosa* (Hook.f.) Hook.f. dominated vegetation on northwest slopes of Mt. Haswell (HO610220); in *Pleurophyllum* Hook.f. dominated plateau herbfield (HO610219); on undercut bank at edge of creek (HO610227). Each specimen of *P. semimortuum* var. *macquariense* was collected in lowland areas (70 to 200 m alt).

Etymology. The name of this variety — *Plagiothecium semimortuum* var. *macquariense* — refers to Macquarie Island (Australia, Tasmania), from which the plant was first recorded, and where the holotype (HO610220) was collected.

Key to the species of *Plagiothecium* known from Australasia

1 Decurrency composed of rectangular, non-inflated cells, forming wedge-shaped groups (Fig. 10F, G) **2**
– Decurrency composed of spherical, inflated cells, forming distinct auricles (Fig. 10A–E) **4**
2 Leaves with long-acuminate apex (Fig. 12) ..... ***P. lucidum***
– Leaves with acute to short-acuminate apex **3**
3 Leaves asymmetric, lanceolate, transversely folded (Fig. 10F) ..... ***P. funale***
– Leaves symmetric, julaceous on the stem and imbricate (Fig. 10G), longitudinally folded ..... ***P. cordatum***
4 Leaves up to 2/3 devoid of protoplasts **5**
– Leaves without protoplast-free areas **6**

5 Cells in middle part of leaf short and broad (60–90 × 10–12 µm) making the cellular areolation loose, specimens growing on mountains..... ..... ***P. semimortuum* var. *semimortuum***

– Cells from middle part of leaf long and narrow (112.5–125 × 7.5–10 µm) which makes the cell areolation tight, specimens recorded in lowlands .... ***P. semimortuum* var. *macquariense***

6 Plants complanate-foliate; leaves asymmetrical (Fig. 10B).....**7**

– Plants julaceous; leaves symmetrical (Fig. 10A); apex not serrate; cell areolation narrow (100–140 × 7.5–10 µm) ..... ***P. novae-seelandiae* var. *brotheri***

7 Leaves quite short and wide (1.7–2.2 × 1.0–1.5 mm), clearly asymmetrical (Fig. 10B); apex serrate ..... ***P. novae-seelandiae* var. *novae-seelandiae***

– Leaves concave, long and wide (2.5–2.6 × 1.0–1.2 mm), asymmetric or slightly asymmetrical (Fig. 10C); apex not serrate.....***P. lamprostachys***

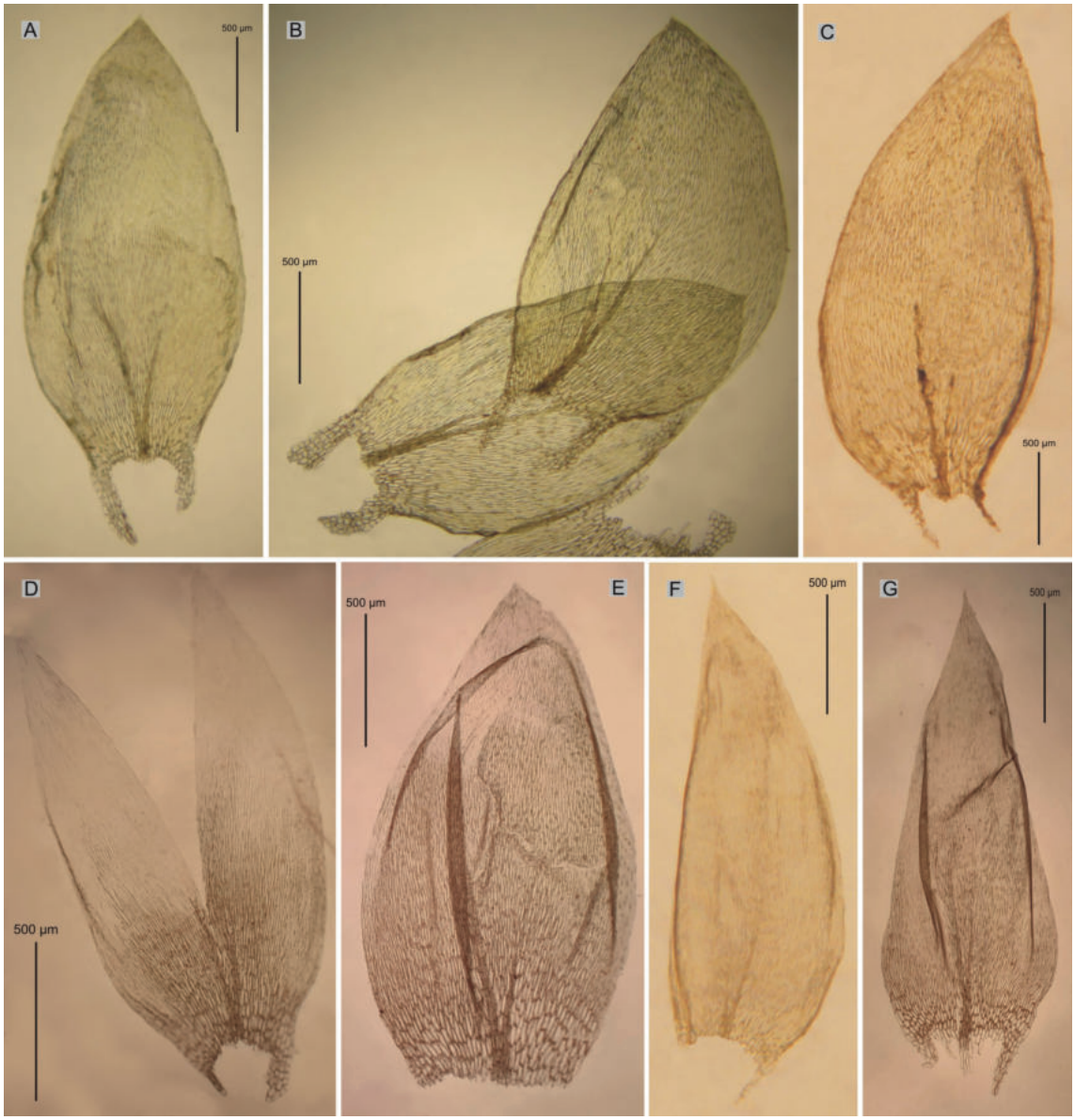

Figure 10. Comparison of leaf shapes and dimensions of all described taxa **A** *P. novae-seelandiae* var. *brotheri* **B** *P. novae-seelandiae* var. *novae-seelandiae* **C** *P. lamprostachys* **D** *P. semimortuum* var. *macquariense* **E** *P. semimortuum* var. *semimortuum* **F** *P. funale* **G** *P. cordatum* (based on the types of the above-mentioned taxa, see Figs 3–9).

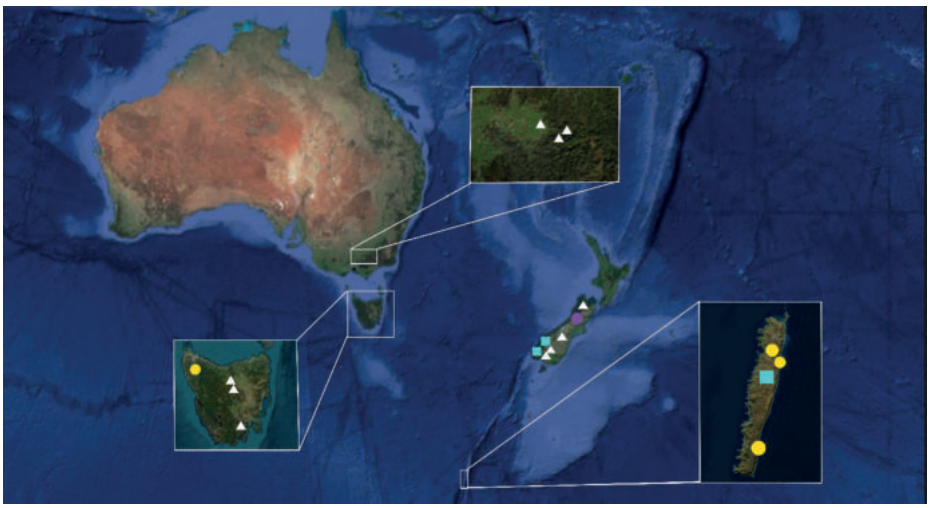

Figure 11. Distribution of the newly described taxa. Explanation: white triangles – *P. semimortuum* var. *semimortuum*; yellow circles – *P. semimortuum* var. *macquariense*; purple circles – *P. novae-seelandiae* var. *brother*; aquamarine squares – *P. cordatum* (Google Maps, accessed September 15, 2023).

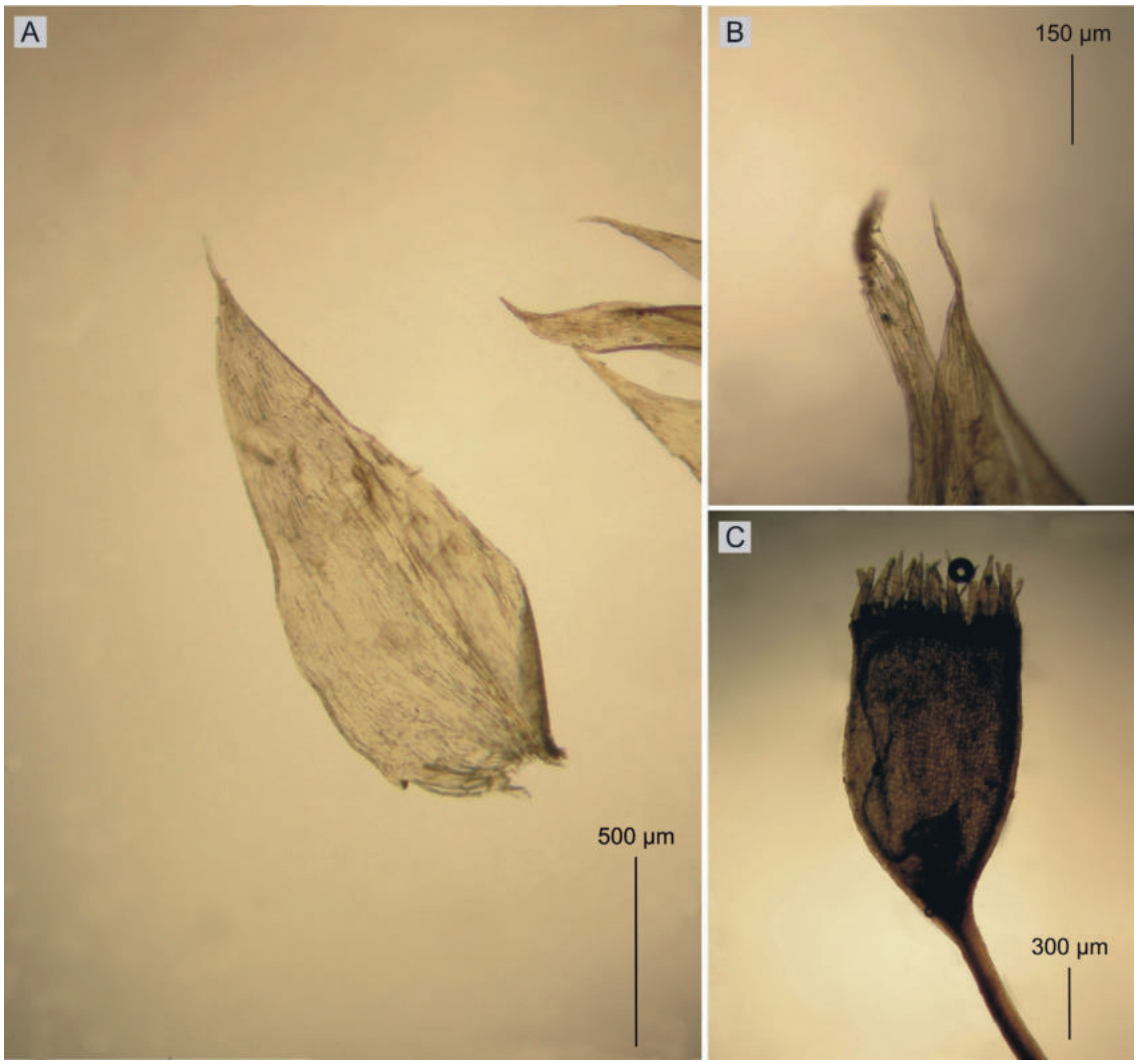

Figure 12. Selected taxonomic features of *Plagiothecium lucidum* **A** shape and dimensions of leaf **B** leaf apex **C** shape and arrangement of capsule (from the type of *P. lucidum* PC0132689!, PC0132690!, photo. G. J. Wolski, November 18, 2021).

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

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Author contributions

Conceptualization: GJW. Data curation: GJW. Investigation: ML, WRB, DCC, GJW. Project administration: GJW. Supervision: GJW. Visualization: GJW, ML. Writing – original draft: GJW, ML, DCC, WRB. Writing – review and editing: WRB, DCC, ML, GJW.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Research Article

A new species of *Typhonium* (Araceae) from Vietnam

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Abstract

Typhonium obtusum is described as a new species endemic to Vietnam. It is unique in the genus in having an oblong-elliptic spathe limb with an obtuse apex and yellowish-greenish filiform staminodes with a down-curved acumen. The ecology, distribution and assessment of the conservation status of the new taxon, as well as a key to all known *Typhonium* species in Vietnam, are provided.

Key words: Araceae, endemic, new species, *Typhonium obtusum*, Vietnam

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Introduction

The genus *Typhonium* (Schott 1829) of the Araceae is estimated to have about 80 to 100 species distributed over the world (Sriboonma et al. 1994; Hetterscheid and Boyce 2000; Boyce et al. 2012; Hetterscheid 2013; Low et al. 2021; POWO 2024). A latest checklist of 70 accepted *Typhonium* species names is provided online (POWO 2024). Indochina was proved to be the centre of *Typhonium* diversity with about 40 species described (Low et al. 2021; Pham et al. 2023). The genus was revised several times for Vietnam (Gagnepain 1942a, b; Pham-Hoang 1993, 2003; Nguyen and Vu 2004; Nguyen 2005, 2017). In fact, the last three decades have witnessed many new discoveries which make the total number of *Typhonium* in the country to be 23 (Nguyen and Croat 1997; Hetterscheid and Boyce 2000; Hetterscheid and Nguyen 2001; Nguyen 2005, 2008; Nguyen and Croat 2010; Hetterscheid 2013; Luu et al. 2017; Van et al. 2017, 2021; Nguyen et al. 2021, 2022a, b; Nguyen-Phi et al. 2023; Pham et al. 2023; Serebryanyi et al. 2023).

As part of ongoing study of *Typhonium* in Vietnam, we have collected several putatively new taxa, one of which was found in Phu Yen Province, central Vietnam. At the first glance, the plant looks like *T. rhizomatosum* A.Galloway and P.Schmidt (Galloway 2012) and *T. cordifolium* S.Y.Hu (Hu 1968) as all of them share the following in common: the general appearance of leaves and spathe

limbs and the structure of inflorescences (Nguyen et al. 2022b; Nguyen-Phi et al. 2023). However, after our careful examination of its morphological characteristics, it turns out that our plant is, indeed, a new species that we describe here, based on living collections.

Material and methods

The studied material was collected from Phu Yen Province, Central Vietnam. Specimens were sampled and processed using methods guided by the Royal Botanic Gardens, Kew (Bridson and Forman 1999); the herbarium acronyms follow Thiers (2024). Detailed photographs and description of taxonomically important characters of the new species were taken of fresh materials in the field using a digital camera. Taxonomic identification was based on morphological vegetative and reproductive characters following the aforementioned literature.

Taxonomic treatment

***Typhonium obtusum* Luu, X.B.Nguyen-Le & H.C.Nguyen, sp. nov.**
urn:lsid:ipni.org:names:77336459-1
Fig. 1

Type. Vietnam. Phu Yen Province, Tay Hoa District, Hoa Thinh Ward; 12°54'30.1"N, 109°14'15.1"E, 30 m elevation; 5 August 2015; Nguyen Le Xuan Bach & Nguyen Hieu Cuong *PY495-505* (holotype SGN!; isotypes SGN!, PHH!).

Diagnosis. *Typhonium obtusum* is morphologically similar to *T. rhizomatosum* and *T. cordifolium* in having ovate leaf blades with cordate base, oblong and elongate spathe limb as long as the spadix and an elongated fusiform spadix appendix. However, the novel taxon can be distinguished from *T. rhizomatosum* by its subcylindrical (vs. globose to subglobose) tubers without (vs. with) rhizomatous offsets, stipitate and fusiform (vs. sessile and conical) spadix appendix) and oblong-elliptic (vs. narrowly triangular ovate) spathe limb and from *T. cordifolium* by its subcylindrical (vs. subglobose) tubers, leaves without (vs. with) adventitious buds, oblong-elliptic (vs. narrowly triangular ovate) spathe limb and stipitate and fusiform (vs. sessile and cylindrical) spadix appendix.

Description. Herbs, seasonally dormant, 10–17 cm tall; tuber underground, subcylindrical, fleshy, 2–2.5 cm long, 1–1.5 cm in diameter, with many filiform roots. ***Leaves*** 2–3 together. ***Petiole*** smooth, slender, 5–9 cm long, 1.8–2.2 mm in diameter, white to brown at base, green towards the apex. ***Leaf blade*** entire or trilobate, strongly cordate, glabrous, adaxially green, abaxially lighter green, concave, 3.2–4.7 cm long, 3–4 cm wide; entire leaf blade ovate, rounded at apex, venation pinnate with abaxially prominent midrib, lateral veins 5–8, brochiododromous, collective veins at 2–5 mm from margin; anterior lobes ovate, broadly elliptic to obovate, 2.5–3.7 cm long, 2.3–3.0 cm wide, obtuse to rounded at apex with a minute mucro, mid-rib abaxially prominent, lateral veins 4–6, brochiododromous, collective veins at 1–2 mm from margin; lateral lobes elliptic to ovate, 2.2–3.1 cm long, 0.6–1.6 cm wide, obtuse at apex, oblique at base. ***Inflorescences*** solitary; ***peduncle*** white, 2.5–6 cm long, ca. 4 mm in diameter; ***spathe*** 5–6 cm long, tube and limb separated by a constriction, outside green-brown, inside purple-brown; ***spathe tube*** ovoid, 1.1–1.3 cm long, 7–8 mm in diameter;

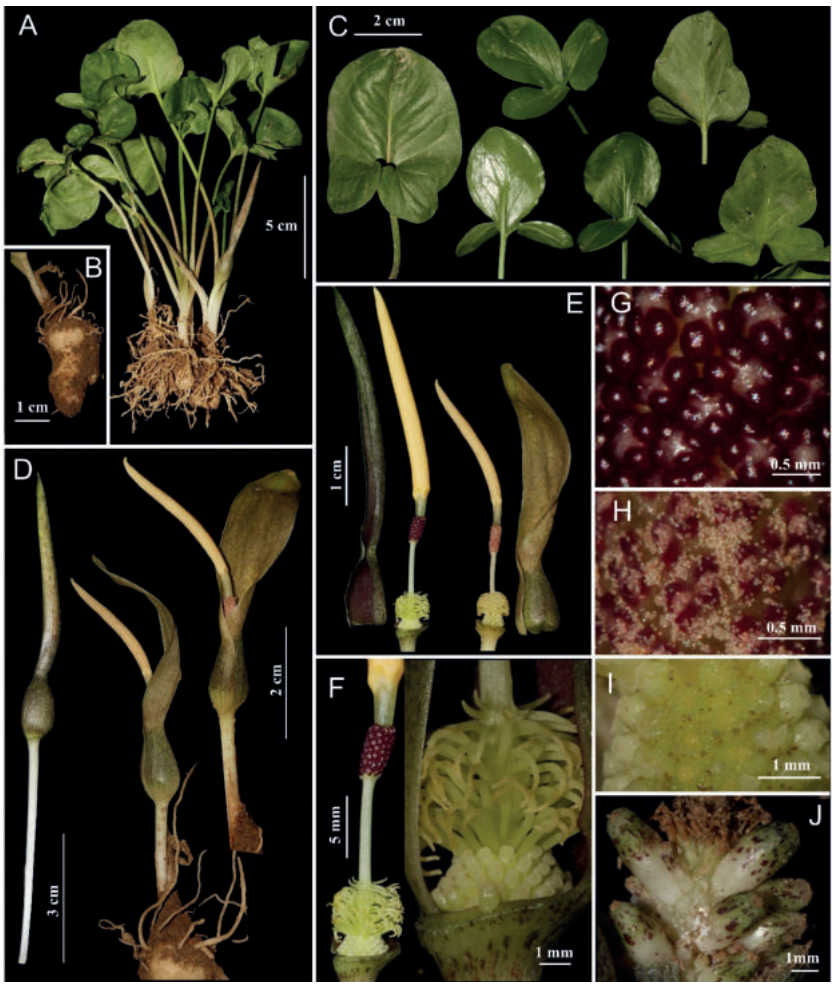

Figure 1. *Typhonium obtusum* **A** whole plants **B** stem **C** different forms of leaf blade **D** inflorescence **E** spathe and spadix **F** male, sterile and female zones **G** stamens **H** thecae, opened **I** pistils, cross-dissection **J** fruits.

spathe limb oblong-elliptic, 4–4.5 cm long, 1.1–1.3 cm wide, obtuse at apex, hardly open at base at anthesis; ***spadix*** equal or slightly shorter than spathe, sessile; ***female part*** conical, 1.6–2 mm long, 3.9–4.3 mm in diameter at the base, 2–3 mm in diameter at the top, with 3–4 rows of crowded pistils; ***ovary*** obovate, ca. 1 mm long, 0.6–0.8 mm in diameter, yellowish-greenish, with purple spots, unilocular, uniovulate placentation, transparently white; ***ovule*** light yellow, on a basal placenta and hold obliquely on a funicle; ***stigma*** sessile, disciform, 0.3–0.5 mm in diam., 0.1–0.2 mm high, light yellow, penicillate; ***interstice*** 1–1.3 cm long, lower part ca. 4 mm densely covered with staminodes, upper part naked, smooth, white to yellowish; ***staminodes*** filiform, subulate, 1–3 mm long, 0.4 mm in diameter, apically curved downward, yellowish-greenish; ***male part*** cylindrical, ca. 4.5 mm long, ca. 2.5 mm in diameter; ***stamens*** free, sparsely to (mostly) densely arranged; ***thecae*** globular, ca. 0.3 mm in diameter, dark purple, opening by apical slit; ***pollens*** translucent white; ***appendix*** stipitate, elongated fusiform, pale yellowish, 2.5–3.9 cm long, 2–3 mm in diameter, stipe ca. 3.5 mm long, pale yellow. ***Fruits*** ovoid to capsule-shaped, 3–4 mm long, 1.5–1.8 mm in diameter, white at base, green towards the apex with many dark purple spots.

Etymology. The species is named for the obtuse apex of its spathe limb.

Vernacular name. Bán hạ mo tù (Vietnamese); Obtuse-spathed typhonium (English, here proposed).

Table 1. Morphological differences between *Typhonium obtusum* and close species.

	T. obtusum	*T. hayatae*	*T. inopinatum*	*T. medusae*	*T. varians*	*T. rhizomatosum*	*T. cordifolium*
Tuber	subcylindrical, without rhizomatous offsets	globose, without rhizomatous offsets	subcylindrical, globose, without rhizomatous offsets	depressed, without rhizomatous offsets	depressed, without rhizomatous offsets	globose to subglobose, with rhizomatous offsets	subglobose, without rhizomatous offsets
Leaf blade	ovate, smooth	–	ovate to triangular or hastate, smooth	broadly triangular, 10 cm long, 14 cm wide, hairy	broadly triangular, more or less distinctly trilobate to subpentalobate, smooth	ovate to elliptical-ovate, smooth	narrowly ovate elliptic to narrowly elliptic, acuminate, with a bulbil when mature
Spadix appendix	2.5–3.9 cm long, 0.2–0.3 cm in diameter, pale yellowish, fusiform, stipe ca. 0.35 cm long, base gradually narrowing	6–14 cm long, 0.5–1.5 cm in diameter, conical, stipe short, base truncate	4–6 cm long, 0.4–0.5 cm in diameter, yellow, yellowish-brown, elongate conical, subsessile, base truncate	1 cm long, 0.3 cm in diameter, reddish-brown, elongate conical, stipe 0.15 cm long, base truncate	4.5–9 cm long, to 1 cm in diameter, dark grey, elongate conical, stipe 0.5 cm long, base truncate	8 cm long, 0.35 cm in diameter, beige, conical, sessile, base truncate	3.6–7.7 cm long, 0.1–0.2 cm in diameter, brick orange, cylindrical, sessile, base gradually narrowing
Spathe tube	ovoid, 1.1–1.3 cm long, 0.7–0.8 cm in diameter, green with brown dots	oblong-ovoid 2.5–4.5 cm long, 1–2 cm wide, dark brownish-purple	ovoid, 0.8–1.5 cm long, ca. 1 cm in diameter, green	ovoid, 1.8–2 cm long, 1.2–1.5 cm in diameter, white with pinkish or purplish-brown flushing	ovoid, ca. 2.5 cm long, ca. 1.5 cm in diameter, glossy green	subglobose, 1 cm long, 0.8 cm in diameter, outside bright pale green, inside as outside, but with pale pink flush	ovoid, 1.2 cm long, 1 cm in diameter, light brown-green outside, brown or reddish-brown inside
Spathe limb	oblong-elliptic, 4–4.5 cm long, 1.1–1.3 cm wide, green with brown mottling	widely ovate in lower part, narrowly triangular in upper part, 12–26 cm long, 7.5–12 (–15) cm wide, dark brownish-purple	narrowly ovate to lanceolate, 5.5–7 cm long, 1.2–2 cm wide, basally brownish, apically green	orbicular, 2.7–3 cm long, 3 cm wide, whitish-greenish with a dense pinkish-brownish or brownish mottling	triangular ovate, 7–14 cm long, 4–7.5 cm wide, dark green flushed with dirty brown	narrowly triangular ovate, 7–9.5 cm long, 0.9–1.5 cm wide, bright pale green with brown longitudinal veins	narrowly triangular ovate, 5–9 cm long, to 3 cm wide, light brown-green
Staminode	slender filiform, decurved, yellowish-greenish	unknown	filiform, horizontally spread and slightly curved, yellow	subulate, upper ones straight, lower ones variously curved, mostly downwards, pale yellow or cream	subulate, upper ones straight, lower ones strongly curved downward, pale yellow	cylindrical, mostly perpendicular to axis, creamy white	cylindrical, spreading, dark yellow
Ovary	obovoid, yellowish-greenish	unknown	ellipsoid, yellowish-greenish	elongate, tapering to the base, basal half white, upper part spotted reddish-pink	more or less ellipsoid, pale green	elongate obovate, creamy white	elongate, white
Stigma	light yellow	unknown	yellow	reddish-pink	dirty whitish-greyish	creamy white	white
Distribution	C. Vietnam	S. Vietnam	N. and Central India to Thailand	C. Thailand	N. Thailand	Thailand	Thailand, Myanmar, S. Vietnam

Ecological notes. The new species was found growing in clumps on basalt soils in open places of rural farms. It appears in September to December and becomes dormant in January to August. Flowering and fruiting were seen in August.

Distribution. *Typhonium obtusum* has been recorded only from the type locality.

Conservation status. Data Deficient (DD) (IUCN Standards and Petitions Subcommittee 2022). The new species has, so far, been found in one location and further inventory should be employed for a certain assessment.

Taxonomic notes. The key morphological similarities and differences of *T. obtusum* versus *T. rhizomatosum* and *T. cordifolium* are presented in the diagnosis. In addition, the two latter are different from the new species by their unique characters in the genus: *T. cordifolium* with adventitious buds

appearing at the mature leaf blade apex or sometimes at the top of the sheath, while *T. rhizomatosum* often forms large colonies thanks to its rhizomatous offsettings (Murata et al. 2010; Boyce et al. 2012; Nguyen-Phi et al. 2023).

The new species may be morphologically close to *T. hayatae* Sribonnma & J.Murata (Sriboonma et al. 1994), *T. inopinatum* Prain (King and Prain 1898), *T. medusae* Hett. & Sookch. (Hetterscheid et al. 2001) and *T. varians* Hett. & Sookch. (Hetterscheid et al. 2001), as they have a short spathe limb and similar general shape and structure of the spadix and filiform staminodes. However, these species are easily distinguishable from the new taxon as they have elongate conical, sessile or shortly stipitate spadix appendix with truncate base. Furthermore, *T. hayatae* has globose tuber, long spadix appendix (6–14 cm) and spathe limb (12–26 cm); *T. inopinatum* has globose tuber, ovate-lanceolate spathe limb that is shorter than the spadix appendix and yellow staminodes; *T. medusae* has depressed tuber, velvety petioles, hairy leaf blades, orbicular spathe limb, pale yellow or cream staminodes and elongate conical appendix; *T. varians* has depressed tuber, dark grey spadix appendix 4.5–9 cm long, triangular ovate spathe limb of 7–14 cm length and 4–7.5 cm in diameter and pale pink anthers. Their different morphological characters are summarised in Table 1.

Key to the 24 presently known Vietnamese species of *Typhonium*

1 Sterile interstice of spadix entirely covered with staminodes ....***T. flagelliforme***
– Only base of sterile interstice of spadix covered with staminodes **2**
2 Leaves perfectly trifoliolate **3**
– Not as above.....**4**
3 Plant with 3 leaves; appendix stipitate; female section of spadix with 5–6 rows of pistils ..... ***T. thatsonense***
– Plant with 1 leaf; appendix sessile; female section of spadix with 2–3 rows of pistils.....***T. hangiae***
4 Inflorescence appearing before the leaves.....**5**
– Inflorescence appearing together with the leaves **6**
5 Spathe 6–9 cm long; staminodes ca. 6 mm long ..... ***T. penicillatum***
– Spathe 14–30 cm long; staminodes ≤ 3 mm long .....***T. hayatae***
6 Spathe limb elongate, narrowly lanceolate-triangular.....**7**
– Spathe limb wide, oblong-elliptic, ovate to lanceolate.....**15**
7 Staminodes red with a light yellow acumen **8**
– Staminodes unicolourful.....**9**
8 Spathe tube globose, to 1.5 cm long; staminodes 5 mm long, clavate ....***T. bachmaense***
– Spathe tube oblong or cylindrical, 2 cm long; staminodes 12 mm long, acute.....***T. kbangense***
9 Spathe limb white.....***T. praelongum***
– Not as above.....**10**
10 Spathe limb corrugated.....***T. corrugatum***
– Not as above.....**11**
11 Leaf 3-lobed **12**
– Not as above.....**13**
12 Stigma funnel-shaped and lobed.....***T. stigmatilobatum***
– Stigma disciform and unlobed .....***T. huense***

13 Leaves with 7 leaflets, leaflets linear to or linear-lanceolate ..... ***T. lineare***
– Not as above **14**
14 Spathe limb much shorter than spadix appendix ..... ***T. vermiforme***
– Spathe limb as long as spadix appendix ..... ***T. dongnaiense***
15 Spadix longer than spathe **16**
– Spadix as long as or shorter than spathe **18**
16 Staminodes folded 180° apically ..... ***T. phuocbinhense***
– Staminodes straight up to parallel to axis **17**
17 Male zone cylindrical, staminodes cylindrical to conical ..... ***T. khonkaenensis***
– Male zone subglobose, staminodes clavate ..... ***T. acetosella***
18 Leaves developing bulbils at the top and/or the base, upper surface ften grey variegated ..... ***T. cordifolium***
– Not as above **19**
19 Spathe limb very strongly circinnately recoiled over the entire length ..... ***T. circinnatum***
– Not as above **20**
20 Tuber producing rhizomatous offsets about 5 cm apart ..... ***T. rhizomatosum***
– Not as above **21**
21 Staminodes ≤ 3 mm long **22**
– Staminodes > 5 mm long **23**
22 Spathe tube above the ground; spathe limb oblong-elliptic, with obtuse apex ..... ***T. obtusum***
– Spathe tube underground; spathe limb triangular ovate, with acute apex ..... ***T. vietnamense***
23 Staminodes red with a light yellow acumen, upward straight or slightly curved ..... ***T. blumei***
– Staminodes whitish, curly ..... ***T. trilobatum***

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

Conceptualization, Hong Truong Luu, Xuan Bach Nguyen-Le; Formal analysis, Hong Truong Luu, Nga Nguyen-Phi, Xuan Bach Nguyen-Le, Hong Thien Van; Funding acquisition, Hong Truong Luu; Investigation, Xuan Bach Nguyen-Le, Hieu Cuong Nguyen; Methodology, Hong Truong Luu, Nga Nguyen-Phi, Quoc Dat Nguyen, Quoc Dat Nguyen; Supervision, Hong Truong Luu; Visualization, Hong Truong Luu, Nga Nguyen-Phi, Xuan Bach Nguyen-Le; Writing – original draft, all authors; Writing – review & editing, Hong Truong Luu, Nga Nguyen-Phi, Xuan Bach Nguyen-Le. All authors have read and agreed to the published version of the manuscript.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Research Article

Using scanning electron microscopy and molecular data to discover a new species from old herbarium collections: The case of *Phlomoides henryi* (Lamiaceae, Lamioideae)

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Abstract

Phlomoides is one of the largest genera of Lamiaceae with approximately 150–170 species distributed mainly in Eurasia. In this study, we describe and illustrate a new species, *P. henryi*, which was previously misidentified as *P. bracteosa*, from Yunnan Province, southwest China. Molecular phylogenetic analyses revealed that *P. henryi* is found within a clade in which most species lack basal leaves. In this clade, the new species is morphologically distinct from *P. rotata* in having an obvious stem and, from the rest, by having transparent to white trichomes inside the upper corolla lip. In addition, micro-features of trichomes on the calyx and leaf epidermis can differentiate the new species from other species grouped in the same clade and a key, based on trichome morphology for these species, is provided. The findings demonstrate that the use of scanning electron microscopy can reveal inconspicuous morphological affinities amongst morphologically similar species and play an important role in the taxonomic study of the genus *Phlomoides*.

Key words: Micromorphology, *Phlomoides*, *Phlomis*, Phlomideae, taxonomy, trichomes

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Introduction

The tribe Phlomideae (Lamiaceae, Lamioideae) was originally established by Scheen et al. (2010) to include seven genera, *Eremostachys* Bunge, *Lamiophlomis* Kudô, *Notochaete* Benth., *Phlomis* L., *Phlomoides* Moench, *Paraeremostachys* Adylov et al. and *Pseuderemostachys* Popov. Subsequent phylogenetic and taxonomic studies (Bendiksby et al. 2011; Mathiesen et al. 2011; Salmaki et al. 2012b) have revised generic boundaries and *Phlomoides* was expanded to include *Eremostachys*, *Lamiophlomis*, *Notochaete*, *Paraeremostachys* and *Pseuderemostachys*. Recently, two monotypic genera, *Metastachydium*

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Airy Shaw ex C.Y. Wu & H.W. Li and *Pseudomarrubium* Popov were also transferred to *Phlomoides* (Zhao et al. 2023a, b), leaving only two genera retained in Phlomideae, *Phlomoides* and *Phlomis*. The re-defined *Phlomoides* is easily distinguished from its sister genus *Phlomis* by: (1) being generally perennial herbs (vs. small shrubs, occasionally perennial herbs); (2) having leaves cordate to triangular-ovate, simple or laciniate to bipinnatisect (vs. lanceolate to oblong-lanceolate, not deeply lobed); (3) the upper lip of corolla dome-shaped with apex hairy or fringed-incised (vs. laterally compressed, flattened, sickle-shaped, apex not fringed-incised) and (4) a basic chromosome number of x = 11 (vs. x = 10) (Azizian and Cutler 1982; Astanova 1984; Ghaffari 2006; Fang et al. 2007; Mathiesen et al. 2011; Salmaki et al. 2012a; Zhao et al. 2021b).

As currently defined, *Phlomoides* consists of approximately 150–170 species and ranks the second largest genus within subfamily Lamioideae (Salmaki et al. 2012a, b; F Zhao et al. 2021). Species of *Phlomoides* are mainly distributed from central Europe to the Russian Far East, but highly diversified in three regions: Central Asia (59 spp.; Czerepanov (1995)), the Iranian highlands (ca. 41 spp.; Salmaki et al. (2012a)) and China (58 spp.; Xiang et al. (2014); Zhao et al. (2021a, 2024)). In China, most species are found in the southwest region and 29 species and 11 varieties are endemic and geographically restricted (Li and Hedge 1994). The existing infrageneric classification of Chinese *Phlomoides* (= *Phlomis* section *Phlomoides* Briq.) was established by Hsuan (1977), who divided Chinese species into two subsections and 17 series, based on external morphology (e.g. the absence/presence of the basal leaves, shape of stem leaves, length and density of trichomes on stems and leaves etc.). However, most infrageneric categories were not recovered as monophyletic (Zhao et al. 2024) and those external and quantitative characters used for traditional taxonomy are highly variable amongst different species or at different populations for the same species. In contrast, some micro-features probably have taxonomic significance within *Phlomoides*. For example, Seyedi and Salmaki (2015) and Khosroshahi and Salmaki (2019) found trichome morphology to be important for the delimitation of sections and species of *Phlomoides*. In addition, trichome characters have significant taxonomic values in other genera of Lamiaceae (Gairola et al. 2009; Xiang et al. 2010; Hu et al. 2012; Yao et al. 2013). However, micro-features of trichomes and other characters of Chinese *Phlomoides* species are poorly known.

During the past ten years, phylogenetic and taxonomic studies have focused on *Phlomoides* from China (Xiang et al. 2014; Zhao et al. 2021a, b, 2023a, b, 2024) resolving some taxonomic puzzles. In the process of the continuing taxonomic study of the genus, two collections attracted our attention when investigating historical specimens. One collection with three sheets were collected by Augustine Henry in 1898 (*A. Henry 10216*) from Mengtze (now Mengzi County), Yunnan Province and were identified as *P. bracteosa* (Royle ex Benth.) Kamelin & Makhm. (= *Phlomis bracteosa* Royle ex Benth.). Two sheets were deposited at K (*A. Henry 10216A*, K000928267; *A. Henry 10216* K, without barcode) and another at LE (without barcode). Another collection was collected by F. Ducloux in 11 August 1907 (*F. Ducloux 369*) from Yunnan "Lao Kouy [Chan]" deposited at E (without barcode) without any identification, but external morphology indicates that this specimen represents the same species as the Henry's collections at K and LE. However, characters (e.g. floral leaves with petioles 5–15 mm long,

bracts subulate, simple long trichomes on calyces, bracts and both sides of leaves) shown in these specimens are obviously different from those of *P. bracteosa* (upper floral leaves sessile, lower floral leaves with petioles up to 20 mm long, bracts lanceolate-linear, branched trichomes on calyces, bracts and both sides of leaves). Fortunately, we re-discovered the plant in the wild from the possible locality where specimens were collected by Henry, after more than 125 years since the first collection in 1887. Molecular phylogenetic analyses and macro- and micro- morphological studies demonstrate that the species is a new species, *P. henryi* and we describe and illustrate it in this study.

Materials and methods

Taxon sampling

In total, we sampled 49 out of 58 (84.48%) Chinese species of *Phlomoides* for molecular phylogenetic analyses. Sampling is primarily based on previous molecular phylogenetic studies of *Phlomoides* (Zhao et al. 2024) and only samples of the potential new species and *P. bracteosa* were newly sequenced. Fresh leaves of the putative new species (*P. henryi*) were collected and dried with silica-gel in the field (Jianshui County, Yunnan Province) and herbarium materials of *P. bracteosa* were collected from the herbarium BM.

In addition, six species from the subclade comprising the potential new species, as well as *P. bracteosa*, were sampled to investigate macro-micro-features of trichomes on flora bracts and leaves. The list of sampled species and their origins are given in Table 1 and voucher specimens were deposited in the Herbarium of the Kunming Institute of Botany (KUN) and Institute of Botany (PE), Chinese Academy of Sciences.

DNA extraction, selection of markers and molecular phylogenetic analyses

Total genomic DNA was extracted using the CTAB method (Doyle and Doyle 1987). Previous studies revealed that plastid DNA phylogeny can better resolve relationships of *Phlomoides* than the tree inferred from the nuclear ribosomal

Table 1. List of sampled *Phlomoides* species to investigate macro/micro features of trichomes and their voucher information.

Taxon	Geographical origin	Voucher information	Collection date
P. henryi	China, Yunnan Province, Honghe Hani and Yi Autonomous Prefecture, Jianshui County, on the forest edge, 23°57'52.54"N, 102°59'49.47"E, alt. 1279 m.	*F. Zhao et al. XCL2222* (KUN)	3 Sep. 2022
P. bracteosa	India, Uttarakhand, Bhyundar Valley, alt. 3430 m.	*Anonymous 6583* (PE)	16 Aug. 1975
P. breviflora	China, Tibet, Nielamu County, Qu Town, 28°4'44"N, 86°0'2.109"E, alt. 3246 m	*Y.P. Chen et al. EM1139* (KUN)	12 Sep. 2019
P. macrophylla	China, Xizang Province, Yadong County, on the way from Yadong to Nathu La Pass.	*Y.P. Chen et al. EM1094* (KUN)	9 Sep. 2019
P. nyalamensis	China, Xizang Province, Nyalam County, Zhangmu Town, on the way from Lixin to Xuebugang, 27°56'37.0356"N, 85°58'28.1712"E, alt. 2896 m.	*Y.P. Chen et al. EM1145* (KUN)	13 Sep. 2019
P. tibetica	China, Xizang Province, Linzhi City, Shergyla Mountain.	*C.L. Xiang et al. XCL1458* (KUN)	15 Sep. 2016
P. milingensis	China, Xizang Province, Linzhi City, Miling County, Lilong Town, Lilonggou, 29°1'45.6"N, 93°53'34.7"E, alt. 3188 m.	*C.L. Xiang et al. XCL1469* (KUN)	16 Sep. 2016
P. rotata	China, Xizang Province, Changdu City, Zuogong County, Dondara Mountain, 29°42'59.9"N, 98°1'7.3"E, alt. 5034 m.	*C.L. Xiang et al. XCL1419* (KUN)	12 Sep. 2016

internal and external transcribed spacer regions (nrITS and nrETS) (Zhao et al. 2023a, b; 2024). In order to test systematic placement of the new species, nine plastid DNA regions (*atpB-rbcL*, *psbA-trnH*, *rpl16*, *rpl32-trnL*, *rps16*, *trnK*, *trnL-trnF*, *trnS-trnG*, *trnT-L*) were selected for phylogenetic reconstruction. Primers, polymerase chain reaction (PCR), sequencing and alignment followed those described in Zhao et al. (2024). The sequences newly generated in this study together with their GenBank accession numbers are listed in Appendix 1.

The combined dataset of nine plastid DNA regions was analysed using Bayesian Inference (BI) and Maximum Likelihood (ML). Three species of *Phlomis* were selected as outgroup, based on previous studies (Zhao et al. 2023a). The best-fit substitution model was selected by the jModelTest v.2.1.7 (Darriba et al. 2012) under the Akaike Information Criterion (AIC) score. BI and ML analyses were conducted on the Cyberinfrastructure for Phylogenetic Research Science (CIPRES) Gateway v.3.3 (Miller et al. 2010), using MrBayes (Ronquist et al. 2012) and RAxMLv.8.2.9 (Stamatakis 2014), respectively. Details for parameter settings follow the previous study of Zhao et al. (2021). All the phylogenetic trees with posterior probabilities (PP) and bootstrap values (BS) were exhibited and annotated in FigTree v.1.4.2 (Rambaut 2014).

Morphological investigations

Species concept, definitions of characters and depiction generally follow Li and Hedge (1994). Type specimens and protologues for all species of *Phlomoides* in China were collated. Morphological features were based on herbarium as well as field investigations. Specimens at B, BM, C, CDBI, E, FI, GH, HIB, IBSC, K, KUN, LE, M, MA, MAO, MICH, MO, MW, NAS, P, PE, S, SG, TI, W, WUK and XJBI (herbarium acronyms followed Thiers 2022) and our collections from the field were examined for characterisation and morphological comparison. Additional morphological information (including habit, habitat, root, leaf, calyx, flower etc.) was taken from field observations, as well as literature (Hsuan 1977; Wu et al. 1977; Li 1985; Li and Hedge 1994).

Micro-features of leaf epidermis and floral bracts were investigated using Light Microscopy (LM) and Scanning Electron Microscopy (SEM). Photographs and morphological observations were taken using a Leica DM2500 light microscope (Leica Microsystems GmbH, Wetzlar, Germany). Mature leaves and floral bracts were taken from our collection (Table 1) for SEM investigation. Materials were mounted on to stubs and coated with gold, using a ZEISS EVO LS10 scanning electron microscope (Carl ZEISS NTS, Germany) with 10 kV voltage (Kunming Institute of Botany, Yunnan, China). Terminology of morphological characteristics of trichomes followed Khosroshahi and Salmaki (2019).

Results

Molecular phylogeny and systematic placement of *Phlomoides henryi*

A total of 18 sequences were newly sequenced in the present study and they were submitted to GenBank under accession nos. OR674852–OR674869. The aligned length of the combined plastid dataset was 9259 bp (2380 bp for *atpB-rbcL*, 421 bp for *psbA-trnH*, 1361 bp for *rpl16*, 681 bp for *rpl32-trnL*, 967 bp

for *rps16*, 958 bp for *trnK*, 868 bp for *trnL-trnF*, 831 bp for *trnS-trnG* and 792 bp for *trnT-L*), respectively. The topologies of the BI and ML trees were consistent with each other, only the Bayesian 50% majority-rule consensus tree being presented, with the posterior probabilities (PP) and Bootstrap support (BS) and values being superimposed near the nodes (Fig. 1).

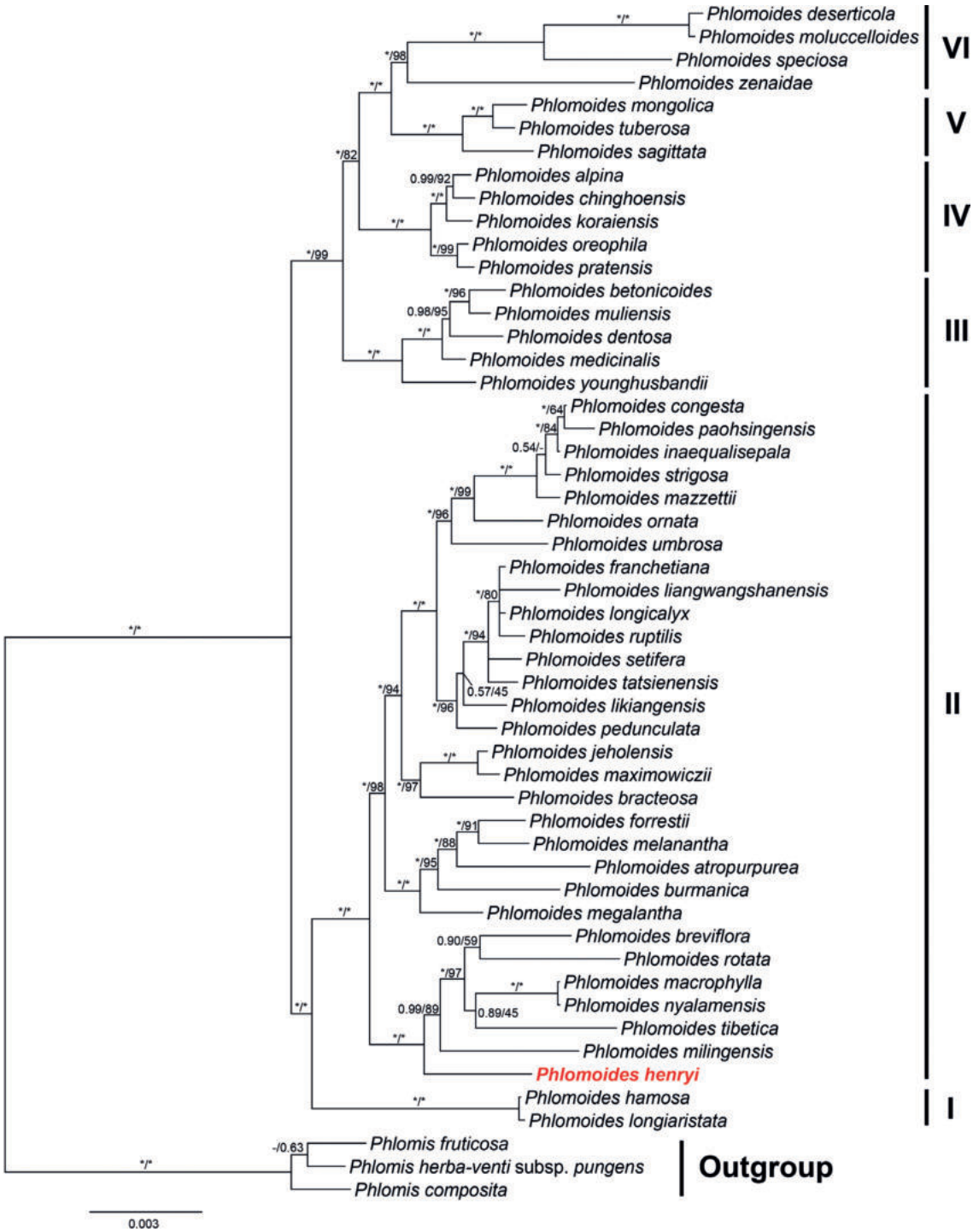

Figure 1. Phylogeny of *Phlomoides* inferred by Bayesian Inference (BI), based on the combined plastid dataset cpDNA. Support values displayed on the branches follow the order BI-PP/ML-BS (" * " indicates PP = 1.00 or BS = 100%, "-" indicates incongruent relationship between BI and ML tree.

Monophyly of the genus *Phlomoides* was recovered (Fig. 1: PP =1.00/BS = 100%). The backbone topologies of *Phlomoides* recovered in present study are largely consistent with those of previous studies (Zhao et al. 2024), clade I is sister to Clade II with strong support values (Fig. 1: 1.00/100%), then sister to a large clade consisting of Clades III, IV, V and VI. Chinese *Phlomoides* species can subdivided into six clades (Fig. 1).

As shown in Fig. 1, the new species, *Phlomoides henryi* is distantly related to *P. bracteosa*. Instead, *P. henryi* is sister to a subclade (Fig. 1: 1.00/100%) comprising *P. milingensis* (C.Y. Wu & H.W. Li) Kamelin & Makhm., *P. tibetica* (C. Marquand & Airy Shaw) Kamelin & Makhm., *P. macrophylla* (Wall.) Kamelin & Makhm., *P. nyalamensis* (H.W. Li) Y. Zhao & C.L. Xiang, *P. breviflora* (Benth.) Kamelin & Makhm., and *P. rotata* (Benth. ex Hook.f.) Mathiesen, while *P. bracteosa* is sister to *P. maximowiczii* (Regel) Kamelin & Makhm. and *P. jeholensis* (Nakai & Kitag.) Kamelin & Makhm.

Trichome morphology of bracts and leaf epidermis

Two basic types of trichomes can be observed in *Phlomoides*: eglandular hairs and glandular hairs, as reported by Khosroshahi and Salmaki (2019). Both kinds of hairs can be divided into simple (unbranched) and branched trichomes. Simple eglandular trichomes were subdivided by length: short (< 500 μm) (Fig. 2A, B), long (500–2000 μm) (Fig. 2C) and extremely long (> 2000 μm); branched eglandular trichomes were subdivided into symmetrically stellate (Fig. 2D), stellate with central long branch (Fig. 2E) and bi- or trifurcate (Fig. 2F). Simple glandular trichomes were subdivided by stalk length: sub-sessile/sessile glandular trichomes (Fig. 2G), short-stalked glandular trichomes (< 500 μm) (Fig. 2H) and long-stalked glandular trichomes (> 500 μm). Branched glandular trichomes contain only one type (Fig. 2I). For the eight species examined in this study, extremely long simple non-glandular trichomes and long-stalked glandular trichomes were not observed.

Figs 3, 4 and Table 2 show the morphology and distribution of trichomes on leaves and bracts of the investigated taxa. Sub-sessile/sessile glandular trichomes occur widely in every part of each species of *Phlomoides* (Table 2). Short stalked glandular trichomes were observed on the abaxial leaf surface in five species and on the bracts of only one species, i.e. *P. breviflora*. Branched glandular trichomes were only recorded on the abaxial leaf surface of *P. breviflora*.

Simple short eglandular trichomes were observed in every species on leaf and bract surface, but were missing in the abaxial leaf of *Phlomoides nyalamensis*, since it was nearly glabrous (Fig. 4J). Adaxial leaf surfaces were often covered by simple eglandular trichomes, except for *P. bracteosa* (Fig. 4C), which has dense branched eglandular trichomes on the adaxial leaf surface. Simple long eglandular trichomes were most common on bracts (Fig. 3B, H, J, L, O). Abaxial leaf surfaces often had branched eglandular trichomes, but these are not present in the new species (Fig. 4B).

Trichomes were transparent to white or brown to black in *Phlomoides*. Trichomes inside the upper corolla lip of the new species (*P. henryi*), *P. bracteosa* and *P. rotata* were transparent to white, while the other five species were brown to black. Bract trichomes of *P. tibetica* and *P. milingensis* were brown to black (Fig. 3K, M), the other six species were transparent to white (Fig. 3A, C, E, G, I, O).

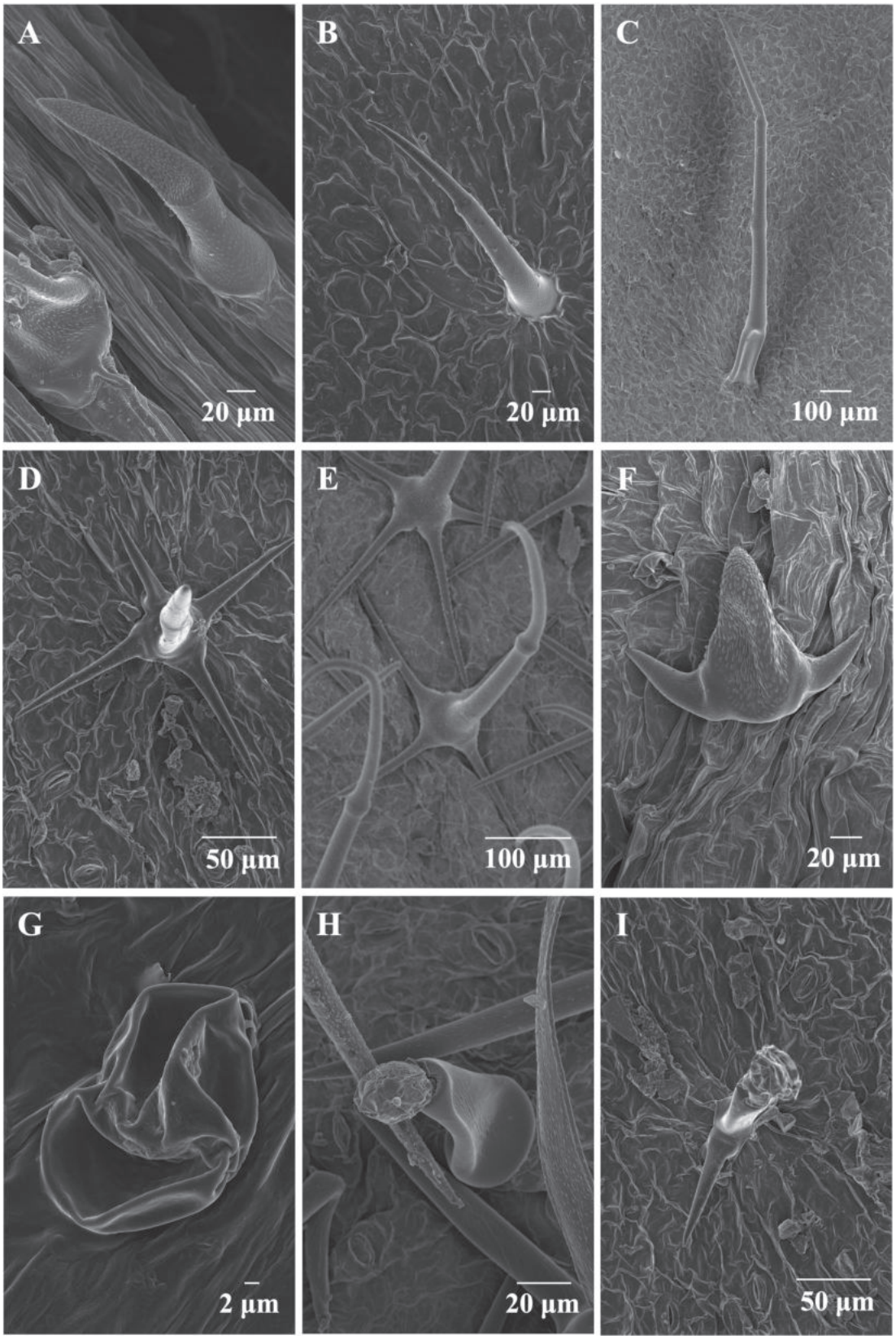

Figure 2. Different types of trichomes of *Phlomoides* **A** short simple non-glandular trichomes (*P. macrophylla*) **B** short simple non-glandular trichomes (*P. breviflora*) **C** long simple non-glandular trichomes (*P. henryi*) **D** symmetrically non-glandular stellate (*P. breviflora*) **E** non-glandular stellate with central long branch (*P. bracteosa*) **F** bi- or trifurcate non-glandular stellate (*P. nyalamensis*) **G** sub-sessile/ sessile glandular trichomes (*P. macrophylla*) **H** simple glandular trichomes of (*P. bracteosa*) **I** branched glandular trichomes (*P. breviflora*).

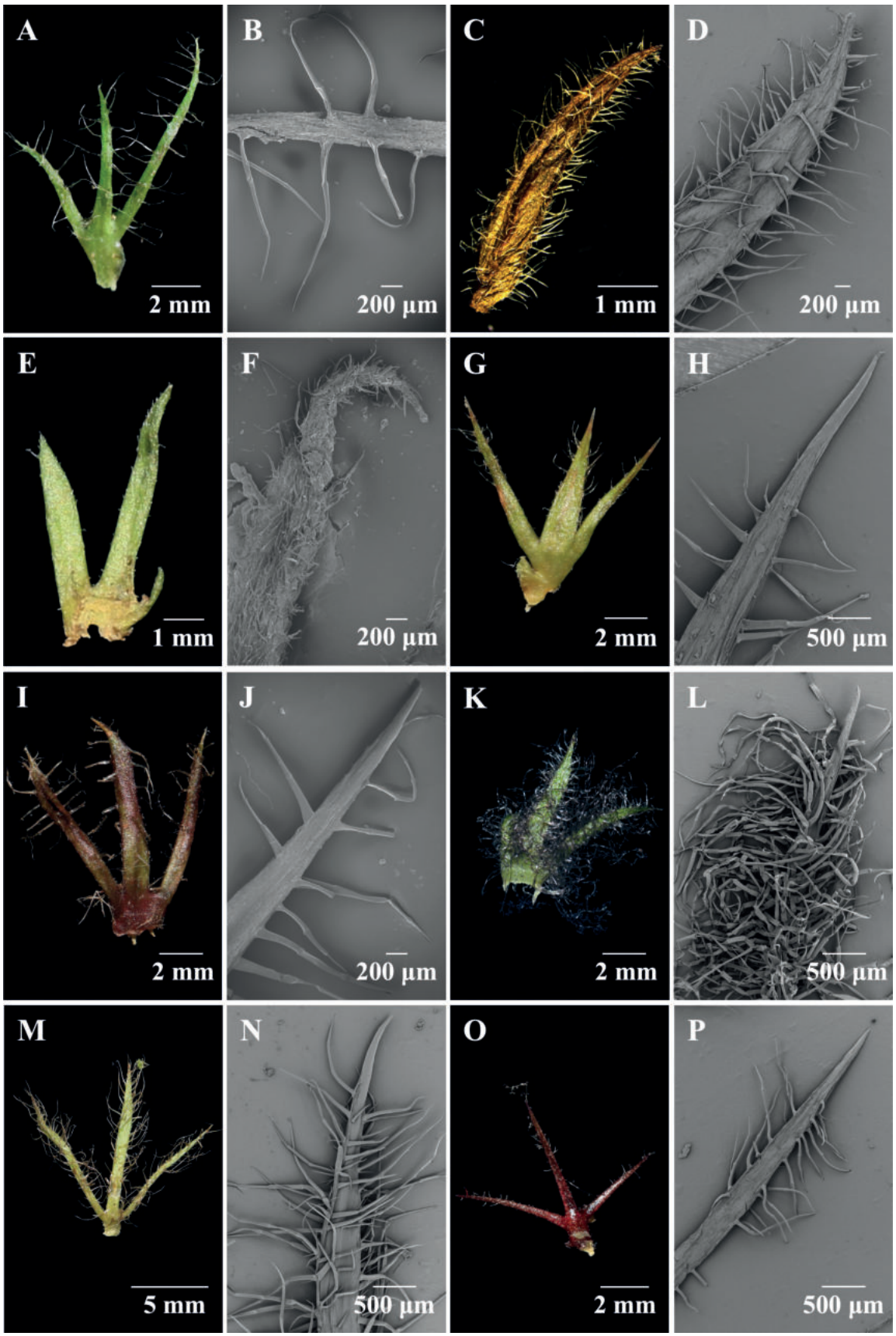

Figure 3. Photos of bracts, SEM of bracts of *Phlomoides henryi* and related species **A, B** *P. henryi* **C, D** *P. bracteosa* **E, F** *P. breviflora* **G, H** *P. macrophylla* **I, J** *P. nyalamensis* **K, L** *P. tibetica* **M, N** *P. milingensis* **O, P** *P. rotata*. **A, C, E, G, I, K, M, O** photos of bracts **B, D, F, H, J, L, N, P** SEM of bracts.

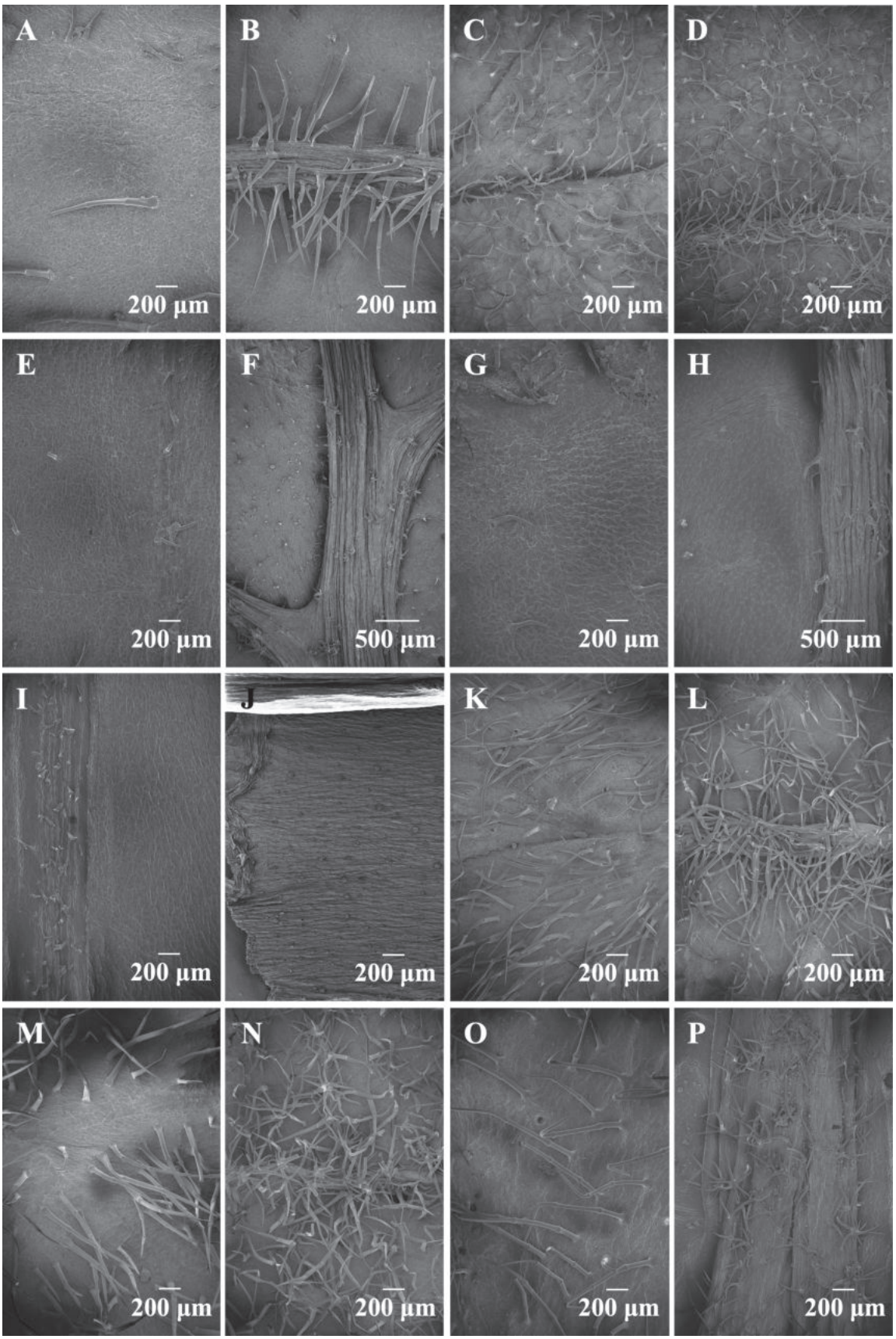

Figure 4. SEM of both sides of leaves of *Phlomoides henryi* and related species **A, B** *P. henryi* **C, D** *P. bracteosa* **E, F** *P. breviflora* **G, H** *P. macrophylla* **I, J** *P. nyalamensis* **K, L** *P. tibetica* **M, N** *P. milingensis* **O, P** *P. rotata* **A, C, E, G, I, K, M, O** SEM of adaxial leaves **B, D, F, H, J, L, N, P** SEM of abaxial leaves.

Table 2. Distribution of different types of trichome in the examined *Phlomoides* spp.

Tissue	Species	Eglandular hairs					Glandular hairs		
		Simple		Branched			Simple		Branched
		Short	Long	Symmetrically stellate	Stellate with central long branch	Bi- or trifurcate	Sub-sessile/ sessile	Short stalked	
Adaxial leaf	*P. henryi*	+	+	–	–	–	+	–	–
	P. bracteosa	+	–	+	+	+	+	–	–
	P. breviflora	+	–	–	–	–	+	–	–
	P. macrophylla	+	–	–	–	–	+	–	–
	P. nyalamensis	+	–	–	–	–	+	–	–
	P. tibetica	+	+	–	–	–	+	–	–
	P. milingensis	+	+	–	–	–	+	–	–
	P. rotata	+	+	–	–	–	+	–	–
Abaxial leaf	*P. henryi*	+	+	–	–	–	+	–	–
	P. bracteosa	+	–	+	+	+	+	+	–
	P. breviflora	+	–	+	+	+	+	+	+
	P. macrophylla	+	–	+	+	+	+	+	–
	P. nyalamensis	–	–	–	–	+	+	–	–
	P. tibetica	+	+	–	+	–	+	+	–
	P. milingensis	+	–	–	+	+	+	+	–
	P. rotata	+	–	+	+	+	+	–	–
Bract	*P. henryi*	+	+	–	–	–	+	–	–
	P. bracteosa	+	+	+	+	+	+	–	–
	P. breviflora	+	–	+	+	–	+	+	–
	P. macrophylla	+	+	–	–	–	+	–	–
	P. nyalamensis	+	+	–	–	–	+	–	–
	P. tibetica	+	+	–	–	–	+	–	–
	P. milingensis	+	+	–	+	+	+	–	–
	P. rotata	+	+	–	–	–	+	–	–

Discussion

Herbaria house millions of specimens that embody the plant diversity on the Earth. Many new species have been lurking in herbaria for many years before being published. Bebber et al. (2010) estimated that 84% of new species' descriptions were from old specimens collected more than five years prior to publication and 25% from specimens more than 50 years old. During the taxonomic review of some groups of Lamiaceae, we have also found some new species from old herbarium specimens (Chen et al. 2014; Dong et al. 2015), indicating taxonomic work, based on herbaria, is still a very important resource for the discovery of new taxa.

The resulting phylogenetic tree of *Phlomoides* in this study was similar to that in previous study (Zhao et al. 2024). The new species, *P. henryi*, was nested within Clade II and formed a separate branch (Fig. 1: 1.00/100%) that is sister to a subclade containing *P. rotata* and five species with brown to black trichomes on the upper corolla. Geographically, *Phlomoides henryi* is distributed in southern Yunnan, while the other six species in this subclade were mainly distributed in the Qinghai-Tibetan Plateau and Himalaya. The new species is

morphologically distinct from the other six species in this subclade. For example, trichomes on the upper corolla lip of *P. henryi* and *P. rotata* are colourless and perceptually transparent to white, but brown to black in the other five species. Morphologically, *P. rotata* is distinct from all other species of *Phlomoides* by the very short stem producing a rosette of leaves with the plant often less than 10 cm high, while *P. henryi* is generally taller than 1 m. As we observed, all the species with trichomes brown to black were embedded within this subclade. The sister clade to that containing *P. henryi* contains 23 species that are mainly distributed in Hengduan Mountains. *Phlomoides henryi* is similar to other species in Clade I and Clade II in lacking basal leaves. Only four species have basal leaves in Clade II, i.e. *P. rotata*, *P. tibetica*, *P. milingensis* and *P. atropurpurea*, while all the species in Clades III–VI have basal leaves.

As above mentioned, we believe that the differences merit recognition of the new species and we describe it below.

Phlomoides is a morphologically diverse and taxonomically difficult group with many characters used for traditional taxonomy being highly variable. In this study, we investigated trichome micro-morphology on bracts and leaves of *Phlomoides henryi* and related species. We found that trichomes are a useful character to distinguish some morphologically similar species. Based on the colour of trichomes, we can separate two groups of those species. *Phlomoides nyalamensis*, *P. macrophylla*, *P. tibetica*, *P. milingensis* and *P. breviflora* have brown to black trichomes on the upper corolla lip, while the other species (*P. rotata*, *P. bracteosa* and the new species described here, *P. henryi*) have transparent to white trichomes on the upper corolla lip. Trichome density and bract trichome colour can separate *P. tibetica* from the similar *P. milingensis*. Both species are distributed in Xizang at an altitude from 3500–4500 m and Hsuan (1977) placed them within Series *Tibeticae*. *Phlomoides tibetica* has floral bracts with black simple trichomes and no branched trichomes, while *P. milingensis* has floral bracts with brown simple and branched trichomes. Similarly, the new species described here, *P. henryi*, can be distinguished from the six related species in the subclade by the absence of branched trichomes on the abaxial leaf surface (Fig. 5B). *Phlomoides bracteosa* can easily be separated from these six species by having branched trichomes on the adaxial leaves (Fig. 5C). Azizian and Cutler (1982) have found that adaxial and abaxial leaf surfaces have different trichome types, but in that work, *Phlomoides* was treated as a section of *Phlomis* and they only discussed the differences amongst *Phlomis* sect. *Phlomis*, *Phlomis* sect. *Phlomoides* and *Eremostachys* and not at the species level. Subsequent studies did not observe trichomes on different structures (Seyedi and Salmaki 2015; Khosroshahi and Salmaki 2019). However, here we found different structures were covered with significantly different trichomes and these differences can be used as evidence to separate morphologically similar species. Future studies should focus on micro-morphological investigation of trichomes and other characters (i.e. appendages, calyces, roots, mericarps) and those micro-features are probably helpful for taxonomy and species identification of *Phlomoides* species.

In order to distinguish those species grouped with the new species in the phylogenetic tree (Fig. 2), as well as *P. bracteosa*, we provide a key, mainly based on macro- and micro-morphological trichomes.

Key to *P. henryi* and morphologically similar species

1 Upper corolla lip with trichome transparent to white **2**
– Upper corolla lip with trichomes brown to black **4**
2 No branched trichomes on leaf and bract ..... ***P. henryi***
– With branched trichomes on leaf and bract..... **3**
3 Floral bracts with branched trichomes, bracts linear to lanceolate .... ***P. bracteosa***
– Floral bracts with simple trichomes only, bracts needle-like to subulate .... ***P. rotata***
4 Floral bracts with trichomes brown to black **5**
– Floral bracts with trichomes transparent to white **6**
5 Floral bracts with black simple trichomes, no branched trichomes .... ***P. tibetica***
– Floral bracts with brown simple and branched trichomes..... ***P. milingensis***
6 Floral bracts less than 1 cm long, with branched trichomes ..... ***P. breviflora***
– Floral bracts more than 1 cm long, with only simple trichomes..... **7**
7 Flower purple ..... ***P. nyalamensis***
– Flower white..... ***P. macrophylla***

Taxonomic treatment

***Phlomoides henryi* Y.Zhao & C.L.Xiang, sp. nov.**
urn:lsid:ipni.org:names:77330835-1
Fig. 5

Type. China, Yunnan Province, Honghe Hani and Yi Autonomous Prefecture, Jianshui County, on the forest edge, 23°57'52.54"N, 102°59'49.47"E, alt. 1279 m, 3 Sep 2022, *F. Zhao, Y. Zhao & C.L. Xiang XCL2222* (holotype: KUN!; isotypes: KUN!, CSH!).

Diagnosis. Within the subclade, *Phlomoides henryi* is morphologically similar to *P. rotata* for having transparent to white trichomes inside the upper corolla lip rather than brown to black and is distinct from all other species by lacking branched hairs. *P. bracteosa* has similar transparent to white trichomes inside the upper corolla lip, but with branched trichomes on both sides of leaves and floral bracts. The differences between *P. henryi*, *P. rotata* and *P. bracteosa* are listed in Table 3.

Perennial herbs. Roots robust, linear-tuberous. Stems 1–1.5 m tall, subquadrangular, robust, simple pilose. Basal leaves absent; stem leaves with petioles 4–15 cm long, with simple trichomes, broadly ovate to ovate-oblong, papery, 10–18 × 15–24 cm, adaxially green with sparse simple trichomes, abaxially light green, with sparse simple trichomes, denser and longer on the main vein, base cordate, margin serrate or crenate, apex acute to acuminate. Verticillasters axillary, 8–20-flowered; floral leaves with petioles 5–35 mm long, lanceolate, base rounded to cuneate, 1–6 × 0.5–4 cm, gradually reduced upwards; bracts subulate, 6–10 mm long, with sparse long simple trichomes, ca. 2 mm long. Calyx tubular, 10–11 × 4–5 mm, pubescent outside with sparse long simple trichomes on veins, conspicuously 10-veined; teeth 5, truncate, ca. 1.5 mm long, apical spines 3–4 mm long, with sparse long simple trichomes. Corolla light purple to pink, ca. 2.1 cm long, 2-lipped; posterior lip ca. 7 mm long, galeate, densely stellate tomentose outside, margin denticulate, bearded inside; anterior lip 3-lobed, ca. 7 × 8 mm, middle lobe largest, oblong, ca. 5 × 3 mm, lateral

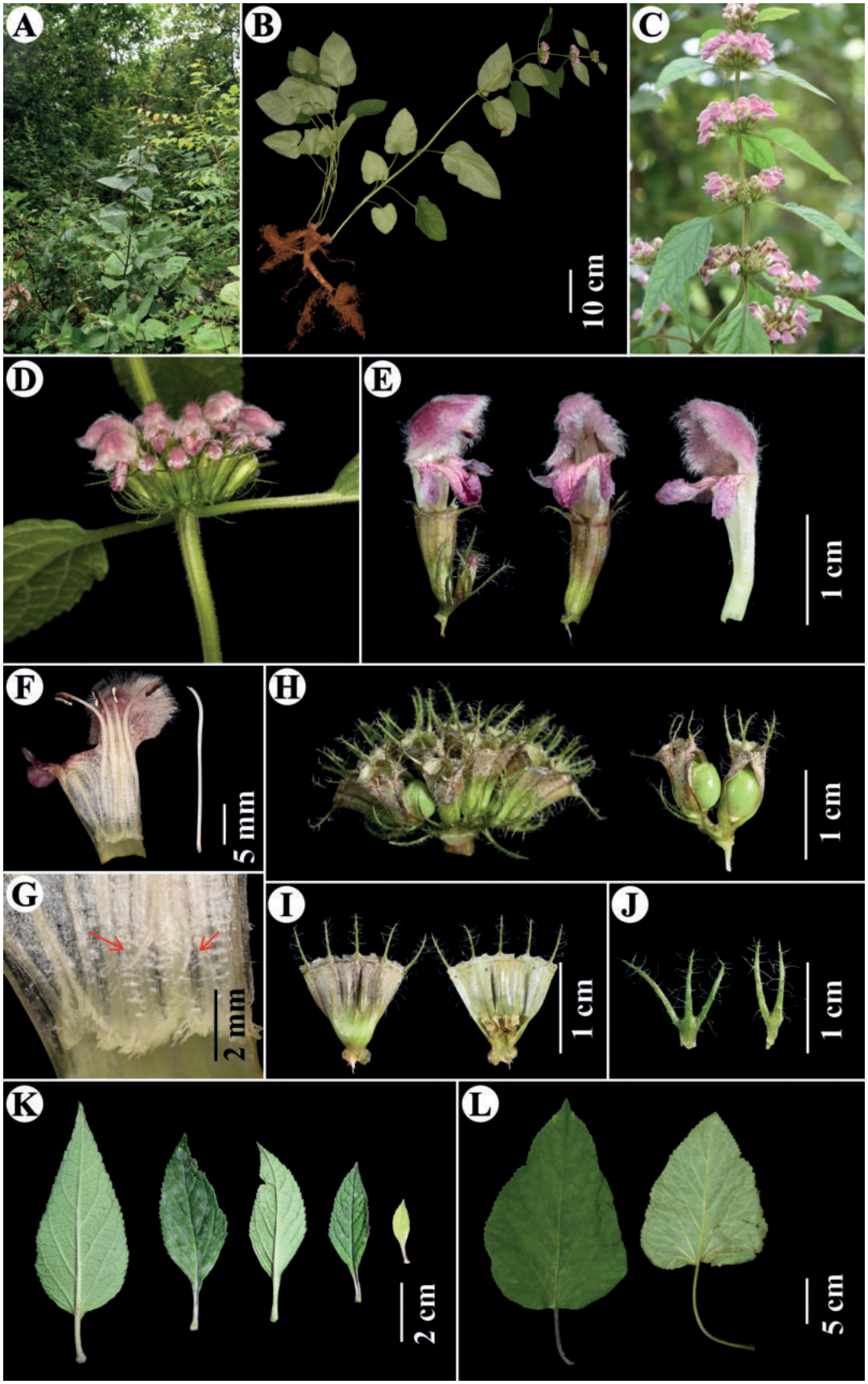

Figure 5. *Phlomoides henryi* Y.Zhao & C.L.Xiang **A** habitat **B** plant with linear-tuberous roots **C** inflorescence **D** verticillaster **E** flowers **F** dissected flower **G** appendages at base of posterior filaments **H** fruiting calyces **I** dissected calyces **J** bracts **K** floral leaves **L** stem leaves. Photographs by Yue Zhao, except C by Li Chen.

Table 3. Morphological comparisons amongst *Phlomoides henryi*, *P. rotata* and *P. bracteosa*.

Characters	*P. henryi*	*P. rotata*	*P. bracteosa*
Height	100–150 cm	2.5–10 cm	20–50 (–100) cm
Basal leaves	absent	rosette basal leaves	absent
Floral leaf shape	narrowly lanceolate	lanceolate, oblanceolate, or linear	Ovate to lanceolate
Floral leaf petiole length	5–35 mm	Lack obvious petiole	Upper floral leaves sessile, lower floral leaves with petiole 5–20 mm long
Floral bracts shape	Subulate	Needle-like to subulate	Linear to lanceolate, often with enlarged bracts
Branched trichomes	No branched trichomes	With branched trichomes on abaxial leaves	With branched trichomes on both sides of leaves and bracts

lobes ovate; tube glabrous outside, ca. 1.5 cm, annulate pilose inside. Stamens 4, included, with cobwebby indumentum, posterior filaments with reflexed appendages at base. Style unequally 2-lobed. Nutlets oblong-globose, glabrous.

Etymology. The new species is named after the collector Augustine Henry (1857–1930), who collected more than 15,000 dry specimens and seeds from China.

Phenology. Flowering from July to September and fruiting from October to December.

Distribution, habitat and ecology. Based on present collections, *P. henryi* is only known from its type locality, i.e. Muyang Mountain in Jianshui County, Yunnan Province, China. It is restricted to the edge of the forest at an elevation near 1280 m.

Chinese name. jiàn shuǐ cǎo cāo sū (建水草糙苏).

Additional specimen examined. *Phlomoides henryi*: ***Paratypes***. China, Yunnan Province, Honghe Hani and Yi Autonomous Prefecture, Jianshui County, 6 September 2019, *Jianshui Exped. 2164* (KUN); Yunnan Province, Mengtze, 1898, *A. Henry 10216* (K000928267, K without barcode, LE without barcode); Yunnan Province, "Lao Kouy [Chan], 11 August 1907, *F. Ducloux 369* (E).

Phlomoides bracteosa: India. Choor & Kidarlonta, 1832, *J.F. Royle 633* (Type: K, K000894384); State of Punjab: Kangra, Lahul, Bhaga Valley, alt. 3000 m, 26 July 1933, *T.R. Chand 74A* (MICH, 1519061); State of Uttarakhand: Bhyundar Valley – Valley of flowers (N.E. road Josimath to Badrinath), alt. 3430 m, 16 August 1975, *Anonymous 6583* (PE, 1290791).

Phlomoides breviflora: China. Xizang Province: Yadong County, on the way from Yadong to Dingga, alt. 2850 m, 11 June 1975, *Qinghai-Tibet Exped. 750283* (Holotype: KUN, 1218974!; Isotype: PE, 00835569!, 00835570!); Nielamu County, Qu Town, alt. 3240 m, 12 September 2019, *Y.P. Chen, Y. Zhao & B.Y. Zhang EM1139* (KUN). India. Sikkim: Nayathang-Phalut, alt. 3500 m, 2 June 1960, *H. Hara et al. 5551* (TI); West Bengal: Darjeeling, Phalut, alt. 3500 m, 5 June 1960, *H. Hara et al. 5555* (TI); Darjeeling, Garibans-Tanglu, alt. 2700 m, 7 June 1969, *H. Hara et al. 5557* (TI). Nepal. Bagmati Province: Rasuwa District, Gossain than (Gosainkund), Benth in Wall. *Cat. Herb. Ind. n. 2066* (Type: K, K001115039!).

Phlomoides macrophylla: Nepal. Gandaki Province: Mustang, Annapurna Conservation area, Trekking route Jomosom-Nayapul, Near Ghorepani village (way to Tikhedhunga). China. Xizang Province: Yadong County, Shang Yadong Village, alt. 3448 m, 30 August 2023, *Y. Zhao et al. XCL2703* (KUN); Yadong County, on the way from Yadong County to the Pass of Naiduila Mountain, 9 September 2019, *Y.P. Chen, Y. Zhao & B.Y. Zhang EM1145* (KUN).

Phlomoides nyalamensis: China. Xizang Province: Nyalam County, Zhangmu Town, on the way from Lixin to Xuebugang, open spaces in forests, alt. 2700–2800 m, 29 June 1975, *Qinghai-Xizang Comp. Exped. 6622* (Holotype,

KUN 1218985! Isotype, KUN 1218984!); Nyalam County, Zhangmu Town, Lixin Village, damp hillside, alt. 2800 m, 24 August 1972, *Tibetan herbal medicine Exped. 1461* (PE, 00835826); Nyalam County, Zhangmu Town, on the way from Lixin to Xuebugang, edge of forests, alt. 2896 m, 13 September 2019, *Y.P. Chen, Y. Zhao & B.Y. Zhang EM1145* (KUN).

Phlomoides tibetica: China. Xizang Province: in open alpine pastures of turf in well drained situations, alt. 4200–4500 m, 6 July 1924, *F. K. Ward 5901* (Holotype: K, K000894378!; isotype: BM, BM000950520, E, E00301982!); Linzhi City, Bomi County, Northern Galongla Mountain, 3800–3900 m, 16 August 1982, *S.Z. Cheng & B.S. Li 00160* (PE, 00923472); Linzhi City, on the way from Lulang Town to the Pass of Sejila Mountain, 4108 m, 15 September 2016, *C.L. Xiang et al. 1456* (KUN). Bhutan. Trashigang District, Shingbe Town, 3800 m, 27 May 1949, *F. Ludlow, G. Sherriff & J.H. Hicks 20673* (BM).

Phlomoides milingensis: China. Xizang Province: Mainling County, Zedanggang, alt. 4400 m, 26 July 1972, *Tibetan herbal medicine Exped. 3883* (holotype: PE, 00835583; isotype: PE, 00923457); Mainling County, Nanyi Mountain, alt. 3400–3500 m, 28 July 1972, *Tibetan herbal medicine Exped. 4228* (PE, 00835584; PE, 00923459); Gongbo'gyamda County, Xueka, 10 August 1974, *Anonymous 2129* (PE, 00832244).

Phlomoides rotata: China: Xizang, Shannan City, Cona County, near radar station, alt. 4280 m, 17 July 1975, *C.Y. Wu et al. 75-893* (KUN, 0216402); Naqu City, Lhari County, meteorological station, alt. 4500 m, 8 June 1976, *Qinghai-Xizang Comp. Exped. 10491* (KUN, 0216409); Nyingchi City, Gongbo'gyamda County, Mira pass, alt. 4920 m, 30 August 1974, *Qinghai-Xizang Comp. Exped. 74-2027* (KUN, 0216384); Sichuan, Liangshan Yi Autonomous Prefecture, Muli County, on the way from Mogalaji to Nonsa pasture, alt. 4312 m, 30 August 2015, *C.L. Xiang 1219* (KUN, 1264607); Yunnan, Diqing Tibetan Autonomous Prefecture, Deqin County, Baimaxueshan, alt. 4300 m, 4 June 2000, *Z.K. Zhou et al. 159* (KUN, 0699320); Qinghai, Yushu Tibetan Autonomous Prefecture, Yushu County, Hongtu Mountain, alt. 4900 m, 3 September 2013, *J.W. Zhang et al. Zh678* (KUN, 1260768).

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

YZ and CLX conceived this research. YZ, FZ, JFX, YPC and CLX collected materials. YZ and FZ performed the experiments. YZ, AP, YPC and CLX analysed the data. All co-authors contributed to the manuscript and revised it critically.

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Data availability

DNA sequences associated with this work are available from GenBank (https://www.ncbi.nlm.nih.gov/genbank/) or from the corresponding author upon reasonable request.

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Appendix 1

Specimen information (taxon, voucher, herbarium, country) for samples newly-sequenced in the present study with GenBank accession numbers for *atpB-rbcL*, *psbA-trnH*, *rpl16*, *rpl32-trnL*, *rps16*, *trnK*, *trnL-trnF*, *trnS-trnG* and *trnT-L*, respectively. Herbarium abbreviations are listed after the vouchers. The accession numbers marked with an asterisk represent sequences newly generated. Only GenBank accession numbers are listed for sequences downloaded from NCBI.

Phlomis composita Pau, ON820555, ON820616, ON835580, ON835627, ON835674, ON835721, ON843184, OR632134, ON843231; ***Phlomis fruticosa*** L., ON820556, ON820615, ON835581, ON835628, ON835675, ON835722, ON843185, OR632135, ON843232; ***Phlomis herba-venti*** subsp. ***pungens*** (Willd.) Maire ex DeFilipps, ON820557, ON820614, ON835582, ON835629, ON835676, ON835723, ON843186, ON815620, ON843233; ***Phlomoides alpina*** (Pall.) Adylov, Kamelin & Makhm., OR631925, OR631967, OR642305, OR632009, OR632051, OR642347, OR642389, OR632137, OR632093; ***Phlomoides atropurpurea*** (Dunn)

Kamelin & Makhm., OQ672946, OQ672946, OQ672946, OQ672946, OQ672946, OQ672946, OQ672946, OQ672946, OQ672946; ***Phlomoides betonicoides*** (Diels) Kamelin & Makhm., MN617020, MN617020, MN617020, MN617020, MN617020, MN617020, MN617020, MN617020, MN617020; ***Phlomoides bracteosa*** (Royle ex Benth.) Kamelin & Makhm., *C.R. Lancaster 72* (BM), India, Srinagar, Pahalgam, Gully, alt. 2286 m, OR674852*, OR674855*, OR674856*, OR674858*, OR674860*, OR674863*, OR674864*, OR674867*, OR674869*; ***Phlomoides breviflora*** (Benth.) Kamelin & Makhm., OQ672923, OQ672923, OQ672923, OQ672923, OQ672923, OQ672923, OQ672923, OQ672923, OQ672923; ***Phlomoides burmanica*** (Mukerjee) Kamelin & Makhm., ON820563, ON820630, ON835588, ON835635, ON835682, ON835729, ON843192, OR632142, ON843239; ***Phlomoides chinghoensis*** (C.Y. Wu) Kamelin & Makhm., ON820580, ON820611, ON835605, ON835652, ON835699, ON835746, ON843209, ON815622, ON843256; ***Phlomoides congesta*** (C.Y. Wu) Kamelin & Makhm., ON820567, ON820608, ON835592, ON835639, ON835686, ON835733, ON843196, OR632145, ON843243; ***Phlomoides dentosa*** (Franch.) Kamelin & Makhm., OR631929, OR631973, OR642309, OR632015, OR632057, OR642351, OR642395, OR632149, OR632099; ***Phlomoides deserticola*** Sennikov, OQ672935, OQ672935, OQ672935, OQ672935, OQ672935, OQ672935, OQ672935, OQ672935, OQ672935; ***Phlomoides forrestii*** (Diels) Kamelin & Makhm., OR631934, OR631976, OR642313, OR632018, OR632060, OR642355, OR642398, OR632153, OR632102; ***Phlomoides franchetiana*** (Diels) Kamelin & Makhm., ON820561, ON820621, ON835586, ON835633, ON835680, ON835727, ON843190, OR632155, ON843237; ***Phlomoides hamosa*** (Benth.) Mathiesen, ON820558, ON820604, ON835583, ON835630, ON835677, ON835724, ON843187, OQ672937, ON843234; ***Phlomoides henryi*** Y.Zhao & C.L.Xiang, *F. Zhao, Y. Zhao & C.L. Xiang XCL2222* (KUN), China, Yunnan Province, Jianshui County, Limin Town, Muyang Mountain, alt. 2179 m, OR674853*, OR674854*, OR674857*, OR674859*, OR674861*, OR674862*, OR674865*, OR674866*, OR674868*; ***Phlomoides inaequalisepala*** (C.Y. Wu) Kamelin & Makhm., OR631937, OR631979, OR642317, OR632021, OR632063, OR642359, OR642401, OR632160, OR632105; ***Phlomoides jeholensis*** (Nakai & Kitag.) Kamelin & Makhm., OR631938, OR631980, OR642318, OR632022, OR632064, OR642360, OR642402, OR632162, OR632106; ***Phlomoides koraiensis*** (Nakai) Kamelin & Makhm., OR631939, OR631981, OR642319, OR632023, OR632065, OR642361, OR642403, OR632163, OR632107; ***Phlomoides liangwangshanensis*** Y. Zhao, H.L. Zheng & C.L. Xiang, OR631940, OR631982, OR642320, OR632024, OR632066, OR642362, OR642404, OR632165, OR632108; ***Phlomoides likiangensis*** (C.Y. Wu) Kamelin & Makhm., OR631942, OR631984, OR642322, OR632026, OR632068, OR642364, OR642406, OR632167, OR632110; ***Phlomoides longiaristata*** (C.Y. Wu & H.W. Li) Salmaki, ON820559, ON820603, ON835584, ON835631, ON835678, ON835725, ON843188, ON815625, ON843235; ***Phlomoides longicalyx*** (C.Y. Wu) Kamelin & Makhm., OR631943, OR631985, OR642323, OR632027, OR632069, OR642365, OR642407, OR632168, OR632111; ***Phlomoides macrophylla*** (Benth.) Kamelin & Makhm., OR631944, OR631986, OR642324, OR632028, OR632070, OR642366, OR642408, OR632169, OR632112; ***Phlomoides maximowiczii*** (Regel) Kamelin & Makhm., ON820565, ON820622, ON835590, ON835637, ON835684, ON835731, ON843194, OR632170, ON843241; ***Phlomoides mazzettii*** Lazkov, OR631945, OR631987, OR642325, OR632029, OR632071, OR642367, OR642409, OR632171, OR632113; ***Phlomoides medicinalis*** (Diels) Kamelin & Makhm., OR631946, OR631988, OR642326, OR632030, OR632072, OR642368, OR642410,

OR632172, OR632114; ***Phlomoides megalantha*** (Diels) Kamelin & Makhm., OR631947, OR631989, OR642327, OR632031, OR632073, OR642369, OR642411, OR632173, OR632115; ***Phlomoides melanantha*** (Diels) Kamelin & Makhm., OR631948, OR631990, OR642328, OR632032, OR632074, OR642370, OR642412, OR632174, OR632116; ***Phlomoides milingensis*** (C.Y. Wu & H.W. Li) Kamelin & Makhm., OR631949, OR631991, OR642329, OR632033, OR632075, OR642371, OR642413, OR632175, OR632117; ***Phlomoides moluccelloides*** (Bunge) Salmaki, OQ672938, OQ672938, OQ672938, OQ672938, OQ672938, OQ672938, OQ672938, OQ672938, OQ672938; ***Phlomoides mongolica*** (Turcz.) Kamelin & A.L. Budantzev, ON820576, ON820617, ON835601, ON835648, ON835695, ON835742, ON843205, OR632176, ON843252; ***Phlomoides muliensis*** (C.Y. Wu) Kamelin & Makhm., OR631950, OR631992, OR642330, OR632034, OR632076, OR642372, OR642414, OR632177, OR632118; ***Phlomoides nyalamensis*** (H.W. Li) Y. Zhao & C.L. Xiang, OR631952, OR631994, OR642332, OR632036, OR632078, OR642374, OR642416, OR632179, OR632120; ***Phlomoides oreophila*** (Kar. & Kir.) Adylov, Kamelin & Makhm., OR631953, OR631995, OR642333, OR632037, OR632079, OR642375, OR642417, OR632180, OR632121; ***Phlomoides ornata*** (C.Y. Wu) Kamelin & Makhm., ON820570, ON820618, ON835595, ON835642, ON835689, ON835736, ON843199, OR632181, ON843246; ***Phlomoides paohsingensis*** (C.Y. Wu) Kamelin & Makhm., OR631954, OR631996, OR642334, OR632038, OR632080, OR642376, OR642418, OR632182, OR632122; ***Phlomoides pedunculata*** (Y.Z.Sun) Kamelin & Makhm., OQ672936, OQ672936, OQ672936, OQ672936, OQ672936, OQ672936, OQ672936, OQ672936, OQ672936; ***Phlomoides pratensis*** (Kar. & Kir.) Adylov, Kamelin & Makhm., ON820579, ON820612, ON835604, ON835651, ON835698, ON835745, ON843208, ON815626, ON843255; ***Phlomoides rotata*** (Benth. ex Hook.f.) Mathiesen, ON820564, ON820602, ON835589, ON835636, ON835683, ON835730, ON843193, ON815627, ON843240; ***Phlomoides ruptilis*** (C.Y. Wu) Kamelin & Makhm., OR631955, OR631997, OR642335, OR632039, OR632081, OR642377, OR642419, OR632183, OR632123; ***Phlomoides sagittata*** (Regel) C.L.Xiang & Y.Zhao, ON820578, ON820620, ON835603, ON835650, ON835697, ON835744, ON843207, ON815617, ON843254; ***Phlomoides setifera*** (Bureau & Franch.) Kamelin & Makhm., OR631956, OR631998, OR642336, OR632040, OR632082, OR642378, OR642420, OR632186, OR632124; ***Phlomoides speciosa*** (Rupr.) Adylov, Kamelin & Makhm., ON820592, ON820631, ON835617, ON835664, ON835711, ON835758, ON843221, ON815629, ON843268; ***Phlomoides strigosa*** (C.Y. Wu) Kamelin & Makhm., OR631957, OR631999, OR642337, OR632041, OR632083, OR642379, OR642421, OR632187, OR632125; ***Phlomoides tatsienensis*** (Bureau & Franch.) Kamelin & Makhm., OR631960, OR632002, OR642340, OR632044, OR632086, OR642382, OR642424, OR632190, OR632128; ***Phlomoides tibetica*** (C. Marquand & Airy Shaw) Kamelin & Makhm., OR631961, OR632003, OR642341, OR632045, OR632087, OR642383, OR642425, OR632193, OR632129; ***Phlomoides tuberosa*** (L.) Moench, ON820575, ON820624, ON835600, ON835647, ON835694, ON835741, ON843204, ON815631, ON843251; ***Phlomoides umbrosa*** (Turcz.) Kamelin & Makhm., ON820571, ON820605, ON835596, ON835643, ON835690, ON835737, ON843200, OR632198, ON843247; ***Phlomoides younghusbandii*** (Mukerjee) Kamelin & Makhm., MW405448, MW405448, MW405448, MW405448, MW405448, MW405448, MW405448, MW405448, MW405448; ***Phlomoides zenaidae*** (Popov) Adylov, Kamelin & Makhm., OQ672945, OQ672945, OQ672945, OQ672945, OQ672945, OQ672945, OQ672945, OQ672945, OQ672945.

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Research Article

Bulbophyllum romklaoense (Orchidaceae), a new species from Thailand

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Abstract

Bulbophyllum romklaoense (*B.* sect. *Lemniscata*) from northern Thailand is described and illustrated as a species new to science. It is most similar to *B. muscarirubrum* and *B. triste*, but differs by having inflorescences with only 4–6 reddish-brown flowers, falcate-subovate lateral sepals that are connate only in the upper half along the interior margins, petals with erose to fimbriate margins and a lip with long cilia in the distal half on the lower surface. A comparison with other similar species in the section, as well as notes on ecology, phenology, conservation assessment and a key to *B.* sect. *Lemniscata* in Thailand are also provided.

Key words: *Bulbophyllum* sect. *Lemniscata*, critically endangered, Epidendroideae, Phitsanulok Province, Southeast Asia

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Introduction

Bulbophyllum Thouars is the largest genus in Orchidaceae, encompassing approximately 2170 accepted species (POWO 2023). This mega-genus is characterised by a rhizome with 1- or 2-leaved pseudobulbs, an inflorescence that arises from the base of the pseudobulb, a mostly moveable lip attached to a distinct column foot and usually (2–)4 often unequal waxy pollinia (Vermeulen et al. 2014a). The genus is widely distributed in tropical to subtropical regions throughout America, Africa, Asia and Australia (Dressler 1993; Vermeulen et al. 2014a). In Thailand, about 163 species have been recorded, including five new species and a new record published in the last decade (Seidenfaden 1979, 1995; Chayamarit et al. 2014; Vermeulen et al. 2014b, 2017, 2021; Pingyot et al. 2019).

Ban Romklao Botanic Garden (BRBG), a satellite garden of Queen Sirikit Botanic Garden in Chiang Mai (QSBG), was established in 1999 in Ban Romklao, Chat Trakan District, Phitsanulok Province, under the royal initiative. The garden covers an area of approximately 222 hectares, situated at an elevation of between 750 and 1300 m. It encompasses three distinct natural vegetation types: dry evergreen forest, mixed deciduous forest and lower montane forest. Adjacent to BRBG in the north and west is Phu Soi Dao National Park where Thailand's

highest sandstone mountain (2100 m a.s.l.) is found. In 2007, Mr. Nawin Inthakul, a living collection keeper, discovered a small *Bulbophyllum* on an oak tree in the lower montane forest of BRBG during his routine native plant check listing and collected some material. The living specimens were brought to the nearby BRBG orchid nursery, where they bloomed in February 2008. Subsequently, specimens were sent to the authors of the present paper for identification. However, they could not match them with any known species and, therefore, interpreted them as the representative of a new species, which is described in this article.

Material and methods

The unknown *Bulbophyllum* specimens were collected in BRBG in Phitsanulok Province and both living and alcohol material were sent to QSBG in Chiang Mai. Alcohol material was preserved in 70% ethanol. The living plants were transplanted into an orchid ex-situ collection at the QSBG nursery, while the alcohol specimen was deposited in the Herbarium (QBG). For morphological examinations, dissections and measurements, a stereomicroscope was employed. The key to species of *B.* sect. *Lemniscata* in Thailand was drafted, based on the keys to *B.* sect. *Tripudianthes* and *B.* sect. *Pleiophyllus* in Seidenfaden (1979).

Taxonomy

***Bulbophyllum romklaoense* Pingyot & Thawara, sp. nov.**
urn:lsid:ipni.org:names:77336764-1
Figs 1–3

Diagnosis. *Bulbophyllum romklaoense* resembles *B. muscarirubrum* Seidenf. and *B. triste* Rchb.f. *Bulbophyllum romklaoense* differs from both by having 4–6-flowered inflorescences (vs. 10–24(–50)-flowered inflorescences in *B. muscarirubrum* and *B. triste*), falcate-subovate lateral sepals (vs. narrowly ovate lateral sepals in *B. muscarirubrum* and *B. triste*), petals with erose to fimbriate margins (vs. petals with ± entire margins in *B. muscarirubrum* and *B. triste*) and a lip with long cilia in the distal half on the lower surface (vs. lip entirely glabrous in *B. muscarirubrum* and *B. triste*). *Bulbophyllum romklaoense* also differs from *B. triste* by having a peduncle which is about as long as the rachis (vs. peduncle longer than twice as long as the rachis in *B. triste*).

Type. Thailand. Phitsanulok Province, Chat Trakan District, Ban Romklao Botanic Garden, ca. 1300 m a.s.l., 15 February 2008, *Inthakul N887-50* (holotype QBG!, isotypes QBG! (2 sheets)).

Description. Epiphyte with short rhizome and pseudobulbs close together. ***Pseudobulbs*** subglobose, surface slightly bullate, 10.5–25 mm in diameter, 2-leaved, pale green to purplish-green, covered with a thin and translucent-white sheath when young. ***Leaves*** shed at flowering time, narrowly ovate to oblong, 3.3–8 cm long, 0.7–1 cm wide, apex acute, base cuneate, thinly herbaceous, glabrous. ***Inflorescences*** arising from base of pseudobulb, ca. 2 cm long, prostrate, racemose, 4–6-flowered, flowers in the same inflorescence open simultaneously; peduncle 8–11 mm long, ca. 1 mm in diam., with one peduncle-scale; rachis ca. 10 mm long; floral bracts reddish, broadly lanceolate, 3.5–5.6 mm long, 1.5–2.3 mm wide, 3-veined, apex acuminate, margins entire. ***Flowers*** ca. 6 mm wide;

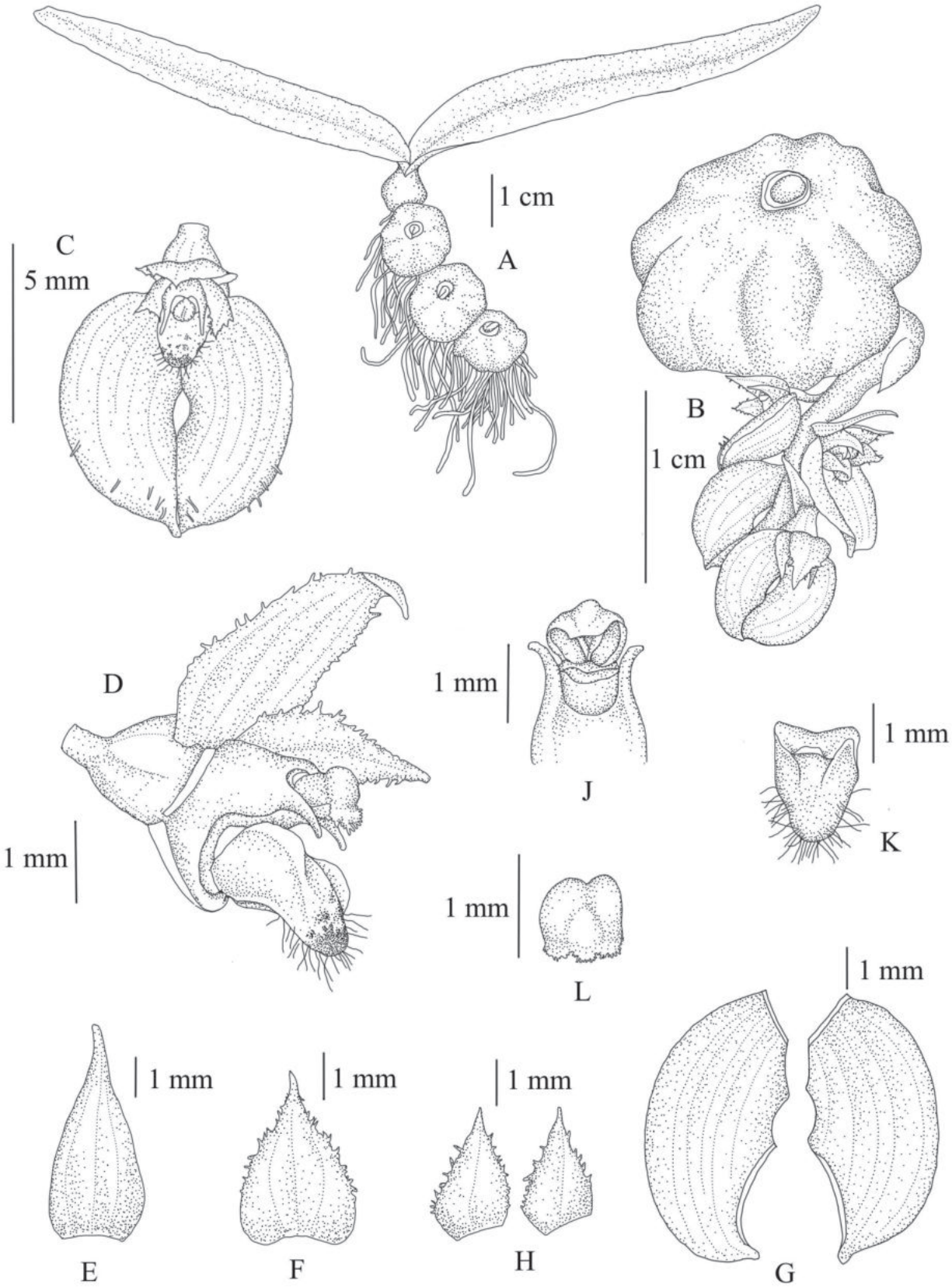

Figure 1. *Bulbophyllum romklaoense* Pingyot & Thawara **A** habit **B** pseudobulb with inflorescence arising from the base **C** flower, front view **D** flower, side view (right petal and right lateral sepal removed) **E** floral bract **F** dorsal sepal **G** lateral sepals (flattened & indumentum removed) **H** petals **J** column, top part **K** lip **L** anther cap (from *Inthakul* N887-50). Drawn by T. Pingyot.

ovary ca. 1.6 mm long, ca. 2 mm in diam., pedicel very short, inconspicuous. ***Sepals*** greenish-yellow with dense reddish-purple-brown dots especially in upper half; dorsal sepal broadly ovate, 3.7–4 mm long, 2.4–3 mm wide, apex acuminate, margins erose to fimbriate in upper half, 3-veined, adaxially papillose; lateral sepals connate in upper half along interior margins, forming a suborbicular blade in outline, individual sepals falcate-subovate, 6–6.5 mm long, 3.6–3.8 mm wide, 5-veined, adaxially sparsely ciliate in distal part, apex cuspidate, margins entire, outer margins decurved. ***Petals*** pale green with reddish-purple dots, ovate, 2.4–3 mm long, 1.7–2 mm wide, apex acuminate, margins erose to fimbriate, except near base, 1-veined, adaxially sparsely papillose and ciliate; ***lip*** white with reddish-purple dots and a large purple blotch on epichile, triangular, ca. 2 mm long, 1.3–1.5 mm wide, thickened, entire, adaxially with longitudinal ridges, with long cilia in distal half on lower surface. ***Column*** white with faint reddish-purple dots, ca. 1.5 mm long, ca. 1 mm wide, winged along lower margins; stelidia subulate, ca. 0.6 mm long, curved, pointing forwards; anther cap white, sometimes with purple marks, ca. 1 mm wide; pollinia 4; stigma concave, ca. 1 mm long. ***Fruit*** not seen.

Habitat and phenology. Epiphytic on oak trees (*Lithocarpus* spp.) in open evergreen broad-leaved lower montane forest, ca. 1300 m a.s.l. Fl. January–February.

Distribution. Northern Thailand. This new species is currently known only from the type locality, which is located less than 7 km from the Lao PDR border. It is possible that this species occurs in Lao PDR or in other areas around the Phu Soi Dao Plateau (Fig. 3).

Etymology. Named after its type locality at Ban Romklao (Romklao Village).

Conservation status proposed. This new species is known only from the type locality, situated in the protected area of BRBG. However, the Extent of Occurrence (EOO) and the Area of Occupancy (AOO) are less than 100 km^2 and 10 km^2, respectively. The number of mature individuals is less than 50. Moreover, its habitat is frequently threatened by forest fires and climatic changes, such as warmer and drier conditions that increase drought and extend the fire season. These factors have led to significant habitat destruction. Thus, this species is preliminarily assessed as Critically Endangered (CR; B1+B2ab(iii,v)+C2a(i)), based on current information and according to the IUCN Red List Categories and Criteria (IUCN 2022).

Additional specimen examined. Thailand. Phitsanulok Province, Ban Romklao Botanic Garden, ca. 1300 m a.s.l., 15 February 2008, *Inthakul N887-50* sub *Suksathan 5476* (cultivated plant of the holotype (QBG)).

Note. Vermeulen et al. (2014a) redefined *Bulbophyllum* sect. *Lemniscata* Pfitz. by including *B.* sect. *Tripudianthes* Seidenf. (except *B. blepharistes* Rchb.f.) and *B.* sect. *Pleiophyllus* J.J. Sm. *Bulbophyllum romklaoense* also belongs to section *Lemniscata*, characterised by its two-leaved pseudobulbs, deciduous leaves, elongate racemes, 4 pollinia and connate lateral sepals. This section contains ca. 37 species, mainly distributed in South and South-East Asia (Vermeulen et al. 2014a, 2021; Averyanov et al. 2019; Zhou et al. 2022; Nguyen et al. 2023). Currently, 26 species in this section are known from Thailand. According to Seidenfaden's key (1979), *B. romklaoense* would belong to section *Pleiophyllus* by its 2-leaved pseudobulb and lateral sepals that are not much longer than the dorsal sepal.

Vermeulen et al. (2014b) synonymised *Bulbophyllum tripaleum* Seidenf. under *B. dhaninivatii* Seidenf. because the only differentiating character is the

Figure 2. *Bulbophyllum romklaoense* Pingyot & Thawara *in vivo* **A** habit (vegetative stage) **B** habit (flowering stage) **C** pseudobulb with inflorescence arising from the base **D** flower, front view **E** flowers, side view **F** lateral sepals. Photographed by P. Suksathan.

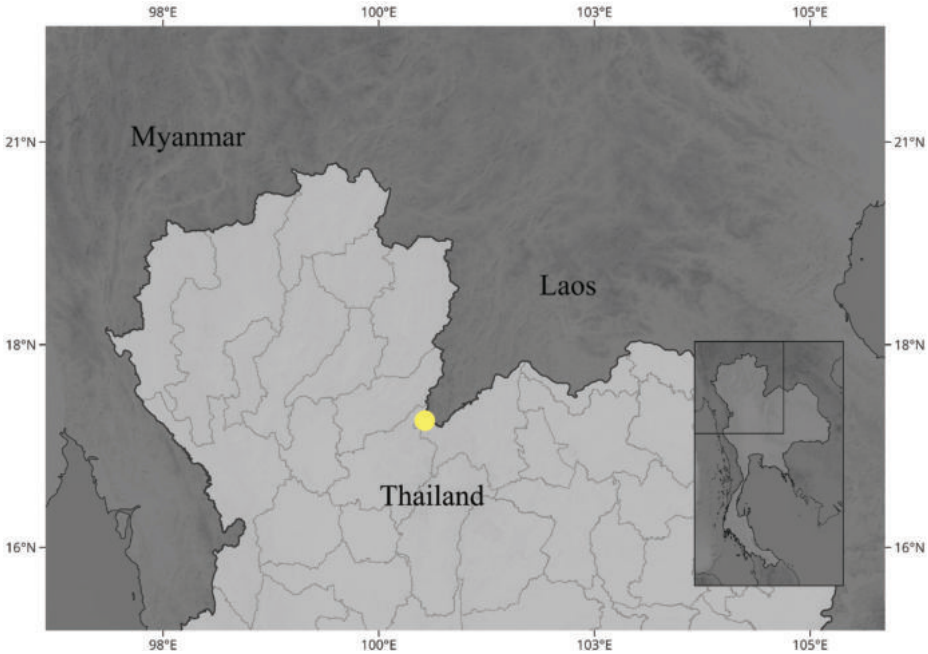

Figure 3. The distribution of *Bulbophyllum romklaoense* Pingyot & Thawara. The inset figure shows the position of this species on the complete map of Thailand.

presence of palea on the sepal apices, but this character is considered to be variable. We also observed this variability in a population of *B. dhaninivatii* at Phu Luang in Loei Province (north-eastern Thailand). Therefore, *B. tripaleum* is here treated as a synonym of *B. dhaninivatii* and is excluded from the key.

Key to species of *Bulbophyllum* sect. *Lemniscata* in Thailand

1 Lateral sepals with exterior margins connate ..... ***B. polliculosum***
– Lateral sepals free or with interior margins partially connate or connate throughout **2**
2 Lateral sepals longer than twice as long as dorsal sepal, interior margins connate throughout their length, except near base **3**
– Lateral sepals up to twice as long as dorsal sepal, interior margins free or only partially connate **13**
3 Dorsal sepal and petal apex without long thread **4**
– Dorsal sepal and petal apex with long thread (ca. 10 mm long), terminating in ± club-shaped tip ..... ***B. guttifilum***
4 Dorsal sepal up to 8 mm long **5**
– Dorsal sepal longer than 9 mm **12**
5 Lateral sepals with glabrous surface, rarely with a few ciliate hairs at surface or along edges; lip without globular vesicles **6**
– Lateral sepals with rugose-papillose surface; lip with shiny globular vesicles in upper half ..... ***B. rugosisepalum***
6 Lateral sepals 25–55 mm long **7**
– Lateral sepals less than 20 mm long ..... ***B. khaoyaiense***
7 Dorsal sepal with entire or sometimes very finely erose margins **8**
– Dorsal sepal with hairy-erose to distinctly erose-fimbriate margins **10**

8 Petals with entire margins, adaxially glabrous ..... ***B. notabilipetalum***
– Petals with fimbriate to erose margins, adaxially papillose to hairy **9**
9 Petals with fimbriate margins; dorsal sepal 5–6 mm long .... ***B. kanburiense***
– Petals with finely erose margins; dorsal sepal 7–8 mm long ... ***B. dickasonii***
10 Floral bracts ovate, broadest above base ..... ***B. tripudians***
– Floral bracts triangular, broadest at base **11**
11 Lip 3.4–5.5 mm long, epichile only slightly convex adaxially ..... ***B. sphenoglossum***
– Lip shorter, up to 3 mm long, epichile distinctly convex adaxially ... ***B. wallichii***
12 Dorsal sepal narrowly triangular, apex acuminate ..... ***B. sanitii***
– Dorsal sepal elliptic, apex obtuse to acute ..... ***B. refractum***
13 Sepal apex with long palea; palea much longer than sepals **14**
– Sepal apex without or with short palea; palea if present not longer than sepals **16**
14 Palea lamellate, with 6–10 lamellae, rectangular and radiating from an axis **15**
– Palea terete, finely rugose on surface ..... ***B. lemniscatoides***
15 Inflorescence racemose, longer than 10 cm ..... ***B. lemniscatum***
– Inflorescence subumbellate, less than 6 cm long ..... ***B. dhaninivatii***
16 Sepals hairy on abaxial surface **17**
– Sepals glabrous on abaxial surface **21**
17 Petals ovate, margins fimbriate ..... ***B. hirtum***
– Petals linear, margins not fimbriate **18**
18 Scape over 10 cm long, longer than rachis (sometimes twice as long) **19**
– Scape less than 1 cm long, as long as or shorter than rachis.... ***B. dhaninivatii***
19 Inflorescence lax-flowered; dorsal sepal 2.4–2.5 mm long .... ***B. reichenbachii***
– Inflorescence dense-flowered; dorsal sepal 6 mm long or more **20**
20 Dorsal sepal to 12 mm long; sepals with scattered long hairs on abaxial side; petals ca. 4 mm long, often twisted in upper half ..... ***B. comosum***
– Dorsal sepal 6–8.4 mm long; sepals with short coarse hairs on abaxial side; petals 1.6–2.6 mm long, never twisted ..... ***B. pallidum***
21 Inflorescence lax-flowered, rachis clearly visible, flowers white to yellow ... **22**
– Inflorescence dense-flowered, rachis hardly visible, flowers purplish, reddish or brownish **24**
22 Petal margins entire or sometimes slightly erose; ovary glabrous ..... ***B. suavissimum***
– Petal margins erose-serrate or fimbriate; ovary pubescent **23**
23 Petals fimbriate along margins; dorsal sepal ca. 8.5 mm long ..... ***B. auricomum***
– Petals finely erose-serrate along margins; dorsal sepal ca. 5.4 mm long ... ***B. sukhakulii***
24 Flowering contemporary with leaves; floral bracts white, very conspicuous, ca. 10 mm long ..... ***B. albibracteum***
– Flowering after shedding of leaves, floral bracts not as above **25**
25 Inflorescence 4–6-flowered; lip ciliate ..... ***B. romklaoense***
– Inflorescence 10–24(–50)-flowered; lip not ciliate **26**
26 Scape much longer than rachis ..... ***B. triste***
– Scape as long as or shorter than rachis ..... ***B. muscarirubrum***

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Conflict of interest

The authors have declared that no competing interests exist.

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Author contributions

Conceptualization: NT, PS, SR, TP. Data curation: PS, TP. Methodology: TP, NT. Supervision: SR. Writing – original draft: TP, NT, SR. Writing – review and editing: NT, TP, PS, SR.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Research Article

Atlas Florae Europaeae notes, 33. Taxonomic synopsis of East European species of the *Cytisus ratisbonensis* group (Fabaceae)

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Abstract

A group of species of *Cytisus* sect. *Tubocytisus* with strictly lateral inflorescences, commonly referred to as *C. ratisbonensis* s.l., is critically revised in Eastern Europe on the basis of morphology and comprehensive treatment of herbarium specimens and observations. Seven species and two presumed hybrids are recognised. Complete accounts are provided for each species, with synonyms, typifications, brief morphological descriptions, data on ecology and distributions, taxonomic and nomenclatural annotations. *Cytisus polonicus* is described as new to science, separated from *C. ratisbonensis* on the basis of morphology and diploid (vs. tetraploid) chromosome count. The lectotype of *C. elongatus* is superseded and a new lectotype is designated; this name has priority for the species previously known as *C. triflorus*. Six species names are newly placed to the synonymy: *Chamaecytisus pineticola* under *Cytisus ruthenicus* s. str., and *Cytisus czerniaevii*, *C. leucotrichus*, *C. lindemannii*, *C. ponomarjovii* and *Chamaecytisus korabensis* under *Cytisus elongatus*. The presumed hybrid between *C. ruthenicus* and *C. elongatus*, which was incorrectly known as *C. czerniaevii*, is described here as *C. semerenkoanus*. *Cytisus lithuanicus*, which has been an obscure name since its original publication, is resurrected for a newly-recognised octoploid species, which is endemic to eastern Poland, western Belarus and north-western Ukraine. The name *C. cinereus* is re-instated for the species previously known as *C. paczoskii*, and *C. horniflorus* is added to its synonymy; its complete distribution area is circumscribed, and its occurrence in Austria, Poland, Romania, Serbia and Slovakia is documented. *Cytisus kreczetoviczii* and *C. elongatus* are reported for the first time from Belarus, and the latter species also from Bosnia and Herzegovina, Montenegro and Slovenia. *Cytisus borysthenicus* and *C. elongatus* are reported as new to some territories in European Russia. *Cytisus ratisbonensis* s. str. is treated as absent from Eastern Europe. The neglected protologue of *C. ruthenicus* is discovered, and the nomenclature of all other names is verified and corrected when necessary. The original material of *C. borysthenicus* is re-discovered. Five further lectotypes and one neotype are designated. Distribution areas are circumscribed on the basis of numerous herbarium collections and documented observations, identified or verified by the authors. Chromosome counts published for nameless taxa from Belarus, Ukraine and Russia are assigned to the species according to their herbarium vouchers: *C. borysthenicus*, *C. kreczetoviczii* and *C. lithuanicus* are octoploid (2n = 100), *C. ruthenicus* is tetraploid (2n = 50) and octoploid (2n = 100), and *C. semerenkoanus* and *C. elongatus* are tetraploid (2n = 50).

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Key words: Belarus, *Chamaecytisus*, chromosome counts, Leguminosae, mapping, nomenclature, Russia, typification, Ukraine

Introduction

A group of *Cytisus* (Cytiseae, Fabaceae) with a tubular calyx (*C.* sect. *Tubocytisus* DC., *Chamaecytisus* Link) was often treated as a separate genus (Klásková 1958; Holubová-Klásková 1964; Tzvelev 1987). There is no up-to-date phylogeny of Cytiseae Bercht. & J.Presl, a large taxon with uncertain generic limits which underwent a number of major changes in history. The only phylogenetic analysis available (Cubas et al. 2002), which was based on two markers of nrDNA (ITS) and cpDNA (*trn*L-*trn*F) and used rather limited sampling, suggested the integrity of the *Cytisus* group, which can be consequently treated as a single genus. A similar conclusion was reached on the basis of morphology of *Cytisus* s.l. as a whole (Cristofolini 1991; Cristofolini and Conte 2002).

The taxonomic concept in *Cytisus* sect. *Tubocytisus* had changed dramatically with time. In Eastern Europe, only one or very few species with strictly lateral inflorescences were recognised in the 19th century. Ledebour (1843) and Schmalhausen (1895) accepted a single species only, named *C. biflorus* L'Her., and this concept had been dominant for a long time. Any attempt to separate local taxa (e.g. Gruner (1869a, 1869b); Wołoszczak (1886)) attracted very few followers only (e.g. Paczoski (1914)).

Kreczetowicz (1940) was the first to critically revise the variability and taxonomy of *C.* sect. *Tubocytisus* in Eastern Europe (also taking into account the material from Central Europe, Western Siberia and the Caucasus). He noted the diagnostic value of plant habit, flower size and, first of all, pubescence of all parts of the plants. He accepted nearly all previously-described species, added some new taxa and formally named interspecific hybrids. Besides, he introduced the type concept to the group. This revision was promoted by broad-scale taxonomic treatments in "Flora of the USSR" (Kreczetowicz 1941), "Flora of the Caucasus" (Grossheim 1952) and "Flora Europaea" (Heywood and Frodin 1968), which were widely followed in regional treatments. The concept, shaped by Kreczetowicz (1940), became standard in all further revisions including most recent reference books and compilations (Wissjulina 1954; Borisova 1964; Heydemann 1986; Tzvelev 1987; Czerepanov 1995; Nikiforova 2012; Fedoronchuk 2019; Ivanov 2019).

Outside Eastern Europe, these species were treated in some critical revisions. In Poland, Zieliński (1975) accepted a single species with two subspecies, based on the characters of habit. Uncritically following Alexeev (1968), he disregarded the diagnostic value of pubescence and flower size. Skalická (1983) made cursory notes on East European species, but her treatment was based on very few specimens and therefore she was not able to estimate the variability and diagnostic value of the characters. Cristofolini (1991) attempted to make a broad-scale, comprehensive revision of *C.* sect. *Tubocytisus* with new infrasectional arrangements and synonymisations. His revision was based on extremely scarce sampling of East European collections, with very few type specimens seen; this fact explains some unconvincing decisions made in this work, which were not accepted by later authors.

Despite recent attempts of further taxonomic splitting (e.g. Ivchenko and Shevera (1992); Ivanov (2019)), practical identification of narrowly-delimited species in this group is very difficult. If not revised by monographers, herbarium collections are often misidentified. The differences in pubescence may be imprecisely described and difficult to apply; these practical difficulties led to an opposition to the approach advocated by Kreczetowicz (1940) and Tzvelev (1987). Alexeev (1968), Yakovlev and Svyazeva (1984), Majorov (2014) and Sagalaev (2018) treated all East European taxa of this group as a single variable species and explained its variability by adaptations to diverse local conditions and clinal variation.

Kreczetowicz (1940) and Tzvelev (1987) noted that hybrids (morphologically intermediate individuals of presumably hybrid origin) occur within a zone where the distribution areas of their presumed parental species overlap. One of such presumed hybrids falls into the variability of polymorphic taxa (i.e. *C. ssyreiszczikovii* V.I.Krecz. and its presumed parent *C. zingeri* (Nenukow) V.I.Krecz. were synonymised with *C. ruthenicus* Fisch. ex Otto: Cristofolini (1991); Sennikov et al. (2021)), whereas three others (*C. kreczetoviczii* Wissjul. interpreted as an intermediate between *C. wulffii* V.I.Krecz. and *C. ruthenicus*: Tzvelev (1987); *C. czerniaevii* V.I.Krecz. = *C. ruthenicus* and *C. lindemannii* V.I.Krecz.: Kreczetowicz (1940); unnamed hybrids between *C. borysthenicus* Gruner and *C. ruthenicus*) are evaluated in the present work.

These taxonomic contradictions and a certain disorder in herbarium collections obscured the taxonomy and distribution of East European species of *Cytisus* sect. *Tubocytisus* with lateral inflorescences, which, according to different sources, may be known as *C. ratisbonensis* Schaeff., *C. hirsutus* L., *C. ruthenicus* or a number of narrowly and variously defined species. In connection with mapping of this group for Atlas Florae Europaeae, we decided to revise the taxonomy, nomenclature and distributions of its taxa, based on our exhaustive examination of major herbarium collections and literature.

In this particular paper, we examined the taxonomic limits and the species composition of the *C. ratisbonensis* group, which is generally characterised by appressed to subpatent hairs which are densely covering calyces, pedicels, petioles and young branches, and the flowers collected in long racemes of abbreviated axillary fascicles. These characters are widely accepted in the main taxonomic literature (Kreczetowicz 1940; Skalická 1983; Tzvelev 1987; Cristofolini 1991), although may be doubted by some researchers (Yakovlev and Svyazeva 1984; Pifkó and Barina 2016). The taxa previously referred to this group, but excluded in our work, are considered elsewhere (Sennikov and Tikhomirov 2024b).

Materials and methods

This taxonomic revision used a traditional, morphology-based approach. Diagnostic characters were re-evaluated taking into account the variability observed in herbarium specimens. Taxonomic entities with stable diagnostic characters and certain distribution areas were recognised at species rank, whereas their morphologically intermediate forms found in and around the zone of co-occurrence were treated as presumably hybridogeneous species. Morphological descriptions were compiled on the basis of herbarium specimens and literature.

An original identification key and a comparative table were constructed on the basis of these characters.

Distributional areas were revised on the basis of available herbarium collections and documented observations, and taxonomic treatments and checklists were critically evaluated in order to avoid conflicting identifications. Accepted and rejected country-level records are listed in the text under species distribution data; administrative territories or regions are detailed for larger countries. Europe is defined as in Atlas Florae Europaeae (e.g. Kurtto et al. (2018)). Crimea is treated as a separate territory for the purpose of our mapping (as in Kurtto et al. (2018)). Data were collected for complete distribution areas, also outside Eastern Europe.

Herbarium specimens were revised *de visu* or as scanned images via JSTOR (https://www.jstor.org), JACQ Virtual Herbaria (https://www.jacq.org), Muséum national d'Histoire naturelle (https://science.mnhn.fr) and Hungaricana (https://gallery.hungaricana.hu/en/Herbarium); these data were complemented with observations documented by photographs which were available online via iNaturalist (https://www.inaturalist.org/). A complete description of the resulting dataset (3699 specimens or observations) with point distribution maps is published elsewhere (Sennikov and Tikhomirov 2024a). The list of specimens or observations examined (with vouchers documenting our new records) is made available through Internet Archive (Tikhomirov and Sennikov 2023).

All available literature were consulted for nomenclatural novelties and distributional records relevant to *Cytisus* in Eastern Europe. Protologues were analysed, original material and type designations were assessed according to the nomenclatural Code (Turland et al. 2018). Lectotypes or neotypes were designated when no typification had been traced; specimens agreeing in morphological characters with the original descriptions and matching the provenance indicated in the protologues were chosen. Nomenclatural synonyms were cited selectively; more complete lists of homotypic synonyms can be found in Pifkó (2015). Images of most important type collections or representative herbarium specimens are reproduced for each accepted species. The diagnostic characters of the pubescence of each species were illustrated by images from scanned specimens.

As an important biological character supporting the species delimitations, chromosome counts available from Eastern Europe were examined on the basis of published literature (Parfionaŭ et al. 1975; Semerenko 1984). Their herbarium vouchers were traced from MSK and matched against the current taxonomy.

Results

Diagnostic characters

The diagnostic characters were extensively discussed by Kreczetowicz (1940) and Cristofolini (1991), and the life forms were studied in detail by Semerenko (2009). We provide our own notes, based on a large set of specimens examined and on field observations. The main diagnostic characters are summarised in Table 1.

Table 1. Main diagnostic characters in the *Cytisus ratisbonensis* group.

Species	Stems	Branching pattern	Leaflets, shape	Leaflets, pubescence above	Calyx, length (mm)	Calyx, pubescence
Cytisus borysthenicus	erect, up to 120(200) cm tall	basal	lanceolate	densely and evenly hairy	10–12	appressed, 0.4–0.6 mm
Cytisus cinereus	erect, basally ascending, up to 40–60(80) cm tall	basal	elliptic to obovate	glabrous	11–14	laxly appressed to subpatent, 0.6–1.2(1.5) mm
Cytisus kreczetoviczii	erect, up to 80 cm tall	basal	lanceolate to elliptic	sparsely hairy	10–12	(laxly) appressed, 0.4–0.6(0.8) mm
Cytisus lithuanicus	erect, basally prostrate, up to 40(60) cm tall	diffuse	obovate	glabrous	12–14	laxly appressed, 0.6–0.8 mm
Cytisus polonicus	prostrate, up to 20 cm above ground	basal	obovate to elliptic	glabrous	(7)8–10	(laxly) appressed, 0.6–0.8(1) mm
Cytisus ratisbonensis	prostrate, up to 20 cm above ground	basal	obovate to elliptic	glabrous	11–14	laxly appressed, 0.8–1.2(1.6) mm
Cytisus ruthenicus	erect, up to 120(200) cm tall	basal	obovate	glabrous	10–12	appressed, 0.4–0.6 mm (or absent)
Cytisus semerenkoanus	erect, basally ascending, up to 60(80) cm tall	basal	elliptic to obovate	sparsely hairy to subglabrous	10–12	appressed and subpatent, 0.4–0.9 mm
Cytisus elongatus	erect, basally ascending, up to 40–60(80) cm tall	basal	elliptic to obovate	densely hairy	11–12	subpatent, 0.8–1.2 mm
Cytisus wulffii	prostrate, up to 20 cm above ground	diffuse	obovate to oblong	hairy	14–15	laxly appressed, 0.5–1 mm

Life form and habit

All species are shrubs of small or medium size with lignified stems, typically with no main trunk, which differ in growth type and branching pattern of their twigs.

Some species (*C. polonicus* Sennikov & Val.N.Tikhom., *C. ratisbonensis*, *C. wulffii*) have main stems which are predisposed for prostration, thus forming horizontally growing, apically ascending branches. Such prostrate shrubs grow over rocky grounds in mountainous areas.

The other species with generally erect stems can be classified according to the length of ascending basal parts of their main stems, forming compact or lax shrubs. *Cytisus borysthenicus* and *C. ruthenicus* have basally suberect stems and very little tendency to ascending. *Cytisus cinereus* Host and *C. elongatus* Waldst. & Kit. have basally ascending stems that run shortly underground, thus forming lax shrubs. The main stems in *C. lithuanicus* Gilib. are long ascending; when their basal parts are covered by soil, they may produce adventitious nodal roots, with a large part of the shrub thus being underground; this type of shrub is transitional to prostrate.

The branching pattern of stems may be basal (*C. borysthenicus*, *C. cinereus*, *C. elongatus*, *C. polonicus*, *C. ratisbonensis*, *C. ruthenicus*) with rather long and thick branches, or diffuse (*C. lithuanicus*, *C. wulffii*) with shorter and thinner branches.

The plant height differs considerably. The prostrate shrubs (*C. polonicus*, *C. ratisbonensis*, *C. wulffii*) ascend up to 20 cm above the ground. The compact erect shrubs (*C. borysthenicus*, *C. ruthenicus*) may grow very robust, up to 150 cm tall, whereas the lax erect shrubs (*C. cinereus*, *C. elongatus*) are typically lower, up to 60(80) cm tall. The semi-prostrate shrubs (*C. lithuanicus*) are up to 40(60) cm tall.

Inflorescence

This revision is limited to the species with a single type of inflorescence, i.e. lateral. Flowers are collected in small axillary fascicles, which are borne on lignified twigs of the previous year; flowering occurs in late summer. As a rule, no flowers are borne on the new growth of twigs. Exceptions are extremely uncommon; we have seen only one specimen of *C. cinereus* that abnormally developed apical inflorescences on the new growth in secondary flowering.

Flowers

Flowers are pedicellate, pedicels of various lengths. There is a tendency for certain species to produce longer (*C. lithuanicus*) or shorter (*C. polonicus*) pedicels, but this character is too variable and cannot be reliably used as diagnostic because the pedicel length depends on the flowering period and ecological conditions.

Corolla is of various shades of yellow (Tzvelev 1987), which cannot be reliably observed in dry collections. The length of corolla is variable; some species have noticeably smaller (e.g. *C. polonicus*) or larger (e.g. *C. ratisbonensis*) flowers. The standard may be glabrous or variously pubescent. This may be an auxiliary diagnostic character in some species pairs (*C. ruthenicus* with glabrous standard and *C. borysthenicus* with hairy standard), although this difference is blurred because of the variability in the other species (*C. cinereus*, *C. elongatus*). Size of flowers and type of pubescence are most easily observed in calyces, and we recommend these characters for identification keys.

Leaves

Leaves are composite, of three leaflets which are mostly obovate to nearly elliptic in most species, except *C. borysthenicus* in which the leaflets are lanceolate or narrowly lanceolate. The leaflets are invariably glabrous or hairy above, except for presumed hybrids, in which the leaflets can be variously hairy to subglabrous. This character is easy to observe and clearly diagnostic.

Pubescence

Pubescence is a key character that distinguishes taxa at the level of species, especially in East European treatments (Kreczetowicz 1940; Tzvelev 1987). It is invariably present in all species, except for *C. ruthenicus*, in which a glabrous morphotype is known and described as *C. ruthenicus* var. *zingeri* Nenukow. Such plants are connected with the hairy morphotype by intermediate forms and, therefore, deserve the rank of variety (Sennikov at al. 2021).

The type of pubescence on young branches, pedicels and calyces is most characteristic of certain species (Fig. 1). It may be composed of appressed or subappressed hairs of various lengths; the length of hairs is fixed within a certain range and can be used for species identification. The shortest hairs (0.2–0.4 mm, *C. ruthenicus*) are appressed, whereas longer hairs tend to be spreading and less appressed to subpatent when their length increases (0.6–1.2(1.6) mm, *C. cinereus*). Patent hairs are a distinct type of pubescence which is characteristic of the *C. hirsutus* group; such hairs are erect and very long (1.5–2.2 mm).

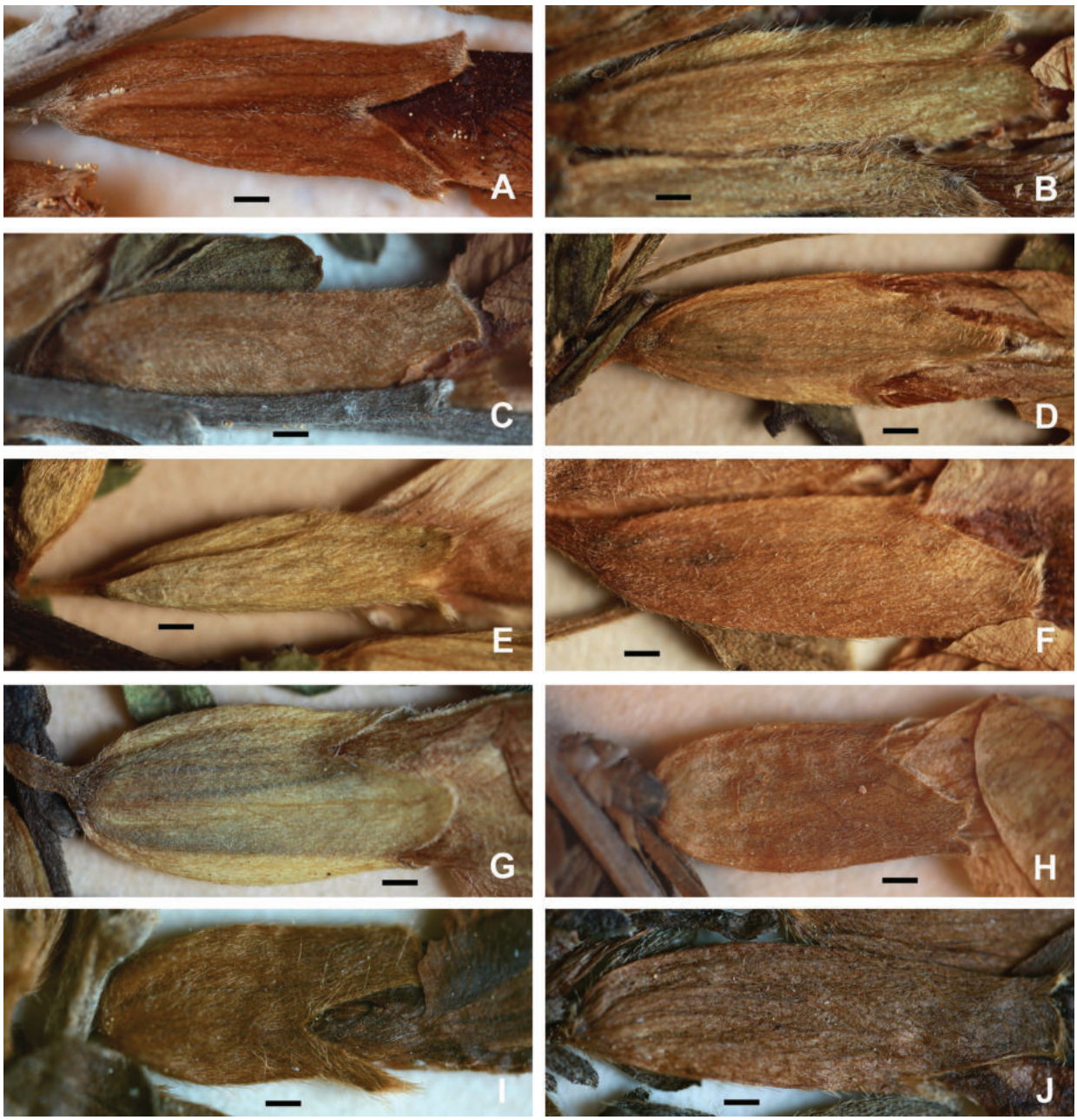

Figure 1. Pubescence on calyces in the *Cytisus ratisbonensis* group **A** *C. borysthenicus* **B** *C. cinereus* **C** *C. kreczetoviczii* **D** *C. lithuanicus* **E** *C. polonicus* **F** *C. ratisbonensis* **G** *C. ruthenicus* **H** *C. semerenkoanus* **I** *C. elongatus* **J** *C. wulffii*. Scale bars: 1 mm.

Chromosome counts

There are very few reports on chromosome numbers in *Cytisus* sect. *Tubocytisus* from Eastern Europe. In those cases when vouchers were traced, this information proved to be informative and taxonomically valuable.

Forissier (1973) reported an octoploid chromosome count for *C. ruthenicus*, based on cultivated material originating from Central Russia (two samples from Moscow and Riazan Regions). This material has not been examined, and its taxonomic identity is doubtful.

Parfionaŭ et al. (1975) made an extensive sampling of *C.* sect. *Tubocytisus* in Belarus for chromosome counts because of taxonomic difficulties and

uncertain species limits in this group. They counted chromosome numbers in 24 individuals identified as *Chamaecytisus* sp. in Belarus and in two individuals identified as *C. ruthenicus* in Ukraine.

Based on the combination of the chromosome counts and morphology, Semerenko (1984) inferred the existence of different, yet poorly understood taxa in Belarus. She distinguished one widespread tetraploid and two octoploids with limited distributions in the south-western and south-eastern parts of the country.

In the absence of taxonomic expertise, Parfionaŭ et al. (1975) were not able to identify their samples of *Cytisus* to the level of species. Based on the voucher specimens at MSK, we can provide the following identifications: 2n = 50 (Minsk, Gomel, Grodno Regions of Belarus, Zhitomir Region of Ukraine) – *Cytisus ruthenicus*, 2n = 50 (Gomel Region) – *C. semerenkoanus*, 2n = 100 (Brest Region) – *C. lithuanicus*, 2n = 100 (Gomel Region) – *C. ruthenicus* and *C. kreczetoviczii*.

Similarly, we decipher the following chromosome counts included in Semerenko (1984): 2n = 100 (Ukraine) – *C. borysthenicus*, 2n = 50 (Kursk and Lipetsk Regions of Russia) – *C. elongatus*.

Putative hybridisation

Hybridisation and polyploid formation were a key factor in evolution of plant taxonomic diversity (Soltis and Soltis 2009). High polyploid chromosome numbers in *Cytisus* sect. *Tubocytisus* suggest that hybridisation may have played an important role in speciation of this group. At present, in spite of rather inconspicuous morphological differences, most of its species are clearly delimited. Morphologically intermediate individuals of presumably recent hybrid origin are observed between *C. borysthenicus* and *C. ruthenicus* (*C. kreczetoviczii*) and between *C. ruthenicus* and *C. elongatus* (*C. semerenkoanus*). Such individuals are found co-occurring in mixed populations of the parental taxa, but also without connection to the presumed parents.

Herbarium specimens of *C. kreczetoviczii* are observed to have lower seed set, which may indicate partial hybrid sterility. However, no experimental studies have been performed to prove this observation.

Taxonomy and nomenclature

1. *Cytisus ruthenicus* Fisch. ex Otto in Allg. Gartenzeit. 12: 347 (1844)

– *Cytisus ratisbonensis* subsp. *ruthenicus* (Fisch. ex Otto) Syr. in Trudy Bot. Sada Imp. Yur'evsk. Univ. 13(1–2): 209 (1912) – *Chamaecytisus ruthenicus* (Fisch. ex Otto) Klásk. in Preslia 30: 214 (1958) – *Chamaecytisus ratisbonensis* subsp. *ruthenicus* (Fisch. ex Otto) Ziel. in Arbor. Kórnickie 20: 78 (1975).

= *Cytisus ruthenicus* var. *zingeri* Nenukow in Litvinov, Spisok Rast. Gerb. Russk. Fl. Bot. Muz. Rossiisk. Akad. Nauk 8(52): 1 (1916) – *Cytisus zingeri* (Nenukow) V.I.Krecz. in Bot. Zhurn. SSSR 25: 260 (1940) – *Chamaecytisus zingeri* (Nenukow) Klásk. in Preslia 30: 214 (1958). Type. Russia. Nizhni Novgorod Region, Balakhna District. Chernoretsk State Forest District, pine forests on sands, 22.06.1914, *I.M. Shvetsov* [Herbarium Florae Rossicae No. 2552(pt.)]

(lectotype LE01024070, two fragments from the right (with well-developed leaves and pods), designated by Sennikov and Tikhomirov in Sennikov et al. (2021: 58); isolectotypes H1279755, KW000114831, KW000114832, LE01024071, LE01024072, M0210776, MW0593001, NNSU, NS0031789, and many other collections).

= *Cytisus ssyreiszczikovii* V.I.Krecz. in Bot. Zhurn. SSSR 25: 261 (1940) – *Chamaecytisus ruthenicus* var. *ssyreiszczikovii* (V.I.Krecz.) Tzvelev, Fl. Evropeiskoi Chasti SSSR 6: 222 (1987) – *Chamaecytisus ssyreiszczikovii* (V.I.Krecz.) Vasjukov & Tatanov in Turczaninowia 19: 67 (2016). Type. Russia. Ulianovsk Region and District. Belyi Klyuch Village, mixed forest with oak on the watershed between Volga and Sviyaga Rivers, 02.08.1917, *A.P. Shennikov* (lectotype LE01017901, designated by Vasjukov and Tatanov (2016: 67)).

= *Chamaecytisus pineticola* Ivchenko in Ukr. Bot. Zhurn. 49: 84 (1992), syn. nov. Type. Ukraine. "In adjacentibus Kioviae, prope Irpenj, margines pineti," 25.05.1976, *I.S. Ivchenko* (holotype KW).

Type. Crimea. "Ex Tauria", *P.S. Pallas* in Herb. Bieberstein (lectotype LE01043886, designated here). Fig. 2.

Description. Upright shrubs with erect stems up to 120(200) cm tall and long branches. Leaves with obovate leaflets, glabrous above, with appressed hairs 0.2–0.4 mm long below, petioles sparsely covered with appressed hairs. Flowers strictly lateral, 1–4 in axils, on pedicels 5–7 mm long, yellow; calyx 10–12 mm long, with appressed hairs 0.4–0.6 mm long; standard suborbicular, glabrous above.

Distribution. Europe: Poland (Zieliński 1975; Danielewicz 2020), Moldova (Heydemann 1986), Belarus (Semerenko 1999; Dubovik 2016), Ukraine (Tzvelev 1987; Fedoronchuk 2019, 2022), Crimea (Yena 2012), Russia (central, southern and south-eastern parts: Tzvelev 1987), Kazakhstan (north-western part: Tulaganova 1981; Abdulina 1999). Asia: Russia (south-western Siberia: Kurbatsky 1994; northern Caucasus: Zernov 2006), Georgia, Kazakhstan (north-western and northern parts: Tulaganova 1981). Apparently, the species is present also in Slovakia (Holub and Bertová 1988), although the relevant herbarium material has not been revised. Its presence in Hungary and Romania is also expected.

Ecology. In the forest zone, the species is largely confined to rather dry pine and mixed forests, growing mostly in open places (forest margins and clearings); in the forest steppe and steppe zones, the species is found in open places in forested dry creeks.

Chromosome counts. 2n = 50 (Parfionaŭ et al. 1975, as *Chamaecytisus* sp. and *C. ruthenicus*); material collected from native populations in Gomel, Grodno and Minsk Regions of Belarus and Zhitomir Region of Ukraine; vouchers at MSK. 2n = 100 (Semerenko 1984); material collected from native populations in Gomel Region; vouchers at MSK. Dubious record: 2n = 100 (Forissier 1973, as *Chamaecytisus ruthenicus*); material received from the Main Botanical Garden in Moscow, originating from Moscow and Riazan Regions of Russia; vouchers unknown.

Notes on nomenclature. *Cytisus ruthenicus* was originally named by F. von Fischer who cultivated plants from the southern course of the Volga River and the southern Ural Mountains in the private botanical garden of Count Alexei Razumovsky. Fischer cultivated rather variable plants received from various collectors, evidently from Friedrich Helm (the Urals) and possibly from Johan

Peter Falk (Volga). As evident from herbarium vouchers, subsequently transferred from Gorenki to the Imperial Botanical Garden in St. Petersburg, Fischer introduced the plants from Volga under the provisional name "*Cytisus supinus* s. *volgensis*" (Fischer 1808: 110, 1812: 68). The epithet "ruthenicus" appeared later on herbarium labels and with seeds distributed by Fischer; for the first time, it appeared in print in the first catalogue of plants cultivated in the Botanical Garden in Petersburg (Fischer 1824: 25). Since then, it was mentioned in a number of publications, all without any descriptive matter.

Wołoszczak (1886) has been commonly cited as the place of valid publication of *C. ruthenicus*, also by those who published new nomenclatural combinations based on this species name. The material used and distributed by Wołoszczak (Kerner 1893) largely belongs to *C. cinereus*, with a minor admixture of *C. ruthenicus*. Nevertheless, the species name was validly published earlier (Otto 1844) with a sole reference to an extensive description under *C. supinus* M.Bieb. non L. (Marschall von Bieberstein 1819), which is referable to the same plants as intended by Fischer.

Under *C. supinus*, Marschall von Bieberstein (1819: 476) described plants with foliose inflorescences and appressed pubescence on calyces and pedicels, and hairy pods. He discussed Fischer's plants named "*Cytisus supinus* s. *volgensis*" as a variety of his species. In the personal collection of Bieberstein at LE, there is a specimen labelled "*C. supinus*" and collected from "Tauria" (Crimea), which is in complete agreement with the characters stated by Bieberstein and represents a typical specimen of *C. ruthenicus* as currently understood (Tzvelev 1987). This specimen is designated as a lectotype of *C. ruthenicus* here.

In spite of the change in the presumed basionym, all combinations published without references to the actual basionym or explicitly based on *C. ruthenicus* "Fisch. ex Woł." are validly published as based on *C. ruthenicus* Fisch. ex Otto under Art. 41.4 and 41.8(a).

Notes on taxonomy and distribution. The name *Cytisus zingeri* belongs to a variety with completely glabrous pods, branches and leaves, which is known from several localities at the confluence of Oka and Volga Rivers in Nizhni Novgorod and Vladimir Regions and in two localities in Kurgan Region (Sennikov et al. 2021). This variety has no separate distribution area, commonly co-occurs with the hairy plants at the same locality (Nenukow 1916), and plants with intermediate characters are common.

Cytisus ssyreiszczikovii was described as a presumed hybrid between *C. ruthenicus* and *C. zingeri*; in our circumscription, such less hairy plants clearly fall within the variability of the species.

Cytisus ruthenicus was frequently confused with *C. ratisbonensis* because of their leaves glabrous above; it differs from the latter by upright, taller stems and a longer pubescence on young shoots, petioles and calyces. *Cytisus ruthenicus* has not been formally reported from Romania, but apparently passed under the misapplied name *C. ratisbonensis* var. *biflorus* in Grinţescu (1957).

Similarly, its presence of Slovakia was implied by Holub and Bertová (1988), who noted the occurrence of taller plants in the eastern part of the country.

In the Caucasus, *C. ruthenicus* was included in *C. caucasicus* (Grossheim 1952; Gvinianidze 1981), which was synonymised with *C. ruthenicus* by Tzvelev (1987). *Cytisus caucasicus* was described as different from *C. ruthenicus* in a greater pubescence of the plant, which is less appressed and longer than in

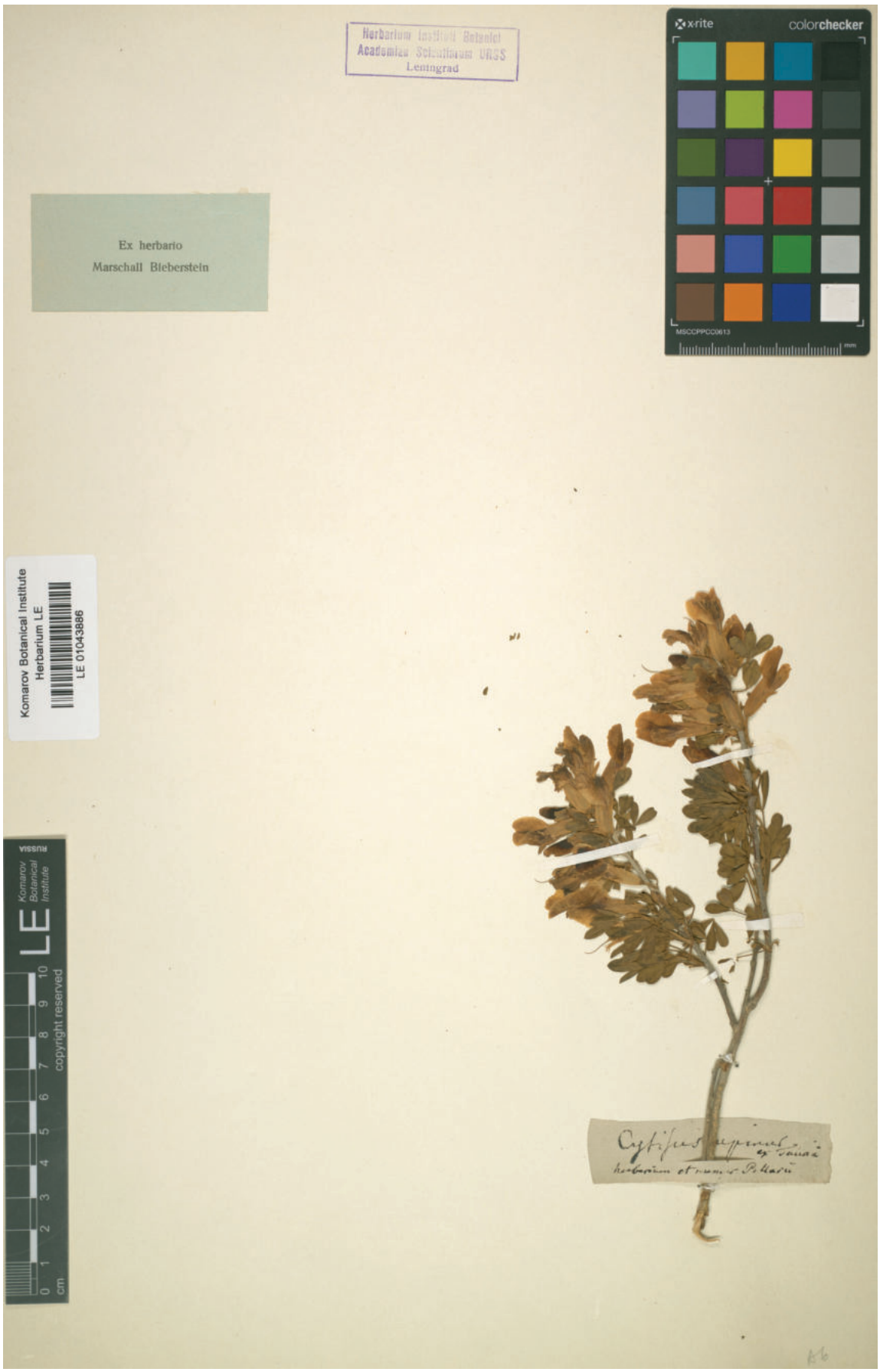

Figure 2. Lectotype of *Cytisus ruthenicus* Fisch. ex Otto.

the latter species (Grossheim and Schischkin 1928). Our revision of herbarium collections confirms a broad distribution of *C. ruthenicus* in the Caucasus and its separation from *C. caucasicus*.

Chamaecytisus pineticola was distinguished from *C. ruthenicus* by its occurrence in Ukrainian pine forests rather than Russian steppes and by presumed differences in the density of pubescence and flower size (Ivchenko and Shevera 1992). As evident from the protologue, the authors misapplied the name *C. ruthenicus* to *C. cinereus*, because the collections distributed by Wołoszczak under *C. ruthenicus* belong to *C. cinereus,* and their comparisons are, therefore, incorrect. Besides, the authors compared their new species with *C. borysthenicus*, which was presumably different in a denser pubescence, broader leaflets and nearly glabrous standard. The scattered pubescence on the upper side of its lanceolate leaflets indicated in the protologue (Ivchenko and Shevera 1992) corresponds to the hybrid between *C. borysthenicus* and *C. ruthenicus*, which is quite common along the Dnepr River, but authentic specimens from the type population (KW) undoubtedly belong to *C. ruthenicus* s. str.

2. *Cytisus kreczetoviczii* Wissjul. in Zerov, Fl. URSR 6: 586 (1954)

– *Chamaecytisus kreczetoviczii* (Wissjul.) Holub in Folia Geobot. Phytotax. 11: 83 (1976) – *Chamaecytisus ruthenicus* var. *kreczetoviczii* (Wissjul.) Skalická in Rad. Akad. Nauka Um. Bosne Hercegovine 72: 241 (1983) – *Cytisus ruthenicus* subsp. *kreczetoviczii* (Wissjul.) Cristof. in Webbia 45: 214 (1991).

Type. Ukraine. "Prope flum. Gruzkyj Jelanczyk, loco Charcysska balka dicto, in decliviis calcareis sarmaticis," 23.05.1926, *Yu.D. Kleopov* (lectotype KW000022339, designated by Krytzka et al. (1999: 610); isolectotypes KW000022338, KW000022340, possible isolectotype KW000022341). Fig. 3.

Description. Upright shrubs with erect stems up to 80 cm tall and long branches. Leaves with lanceolate to elliptic leaflets, sparsely hairy above, with appressed hairs 0.1–0.2(0.4) mm long below, petioles sparsely covered with laxly appressed (partly subpatent) hairs. Flowers strictly lateral, 1–4 in axils, on pedicels 4–6 mm long, yellow; calyx 10–12 mm long, with (laxly) appressed hairs 0.4–0.6(0.8) mm long; standard suborbicular, glabrous or sparsely hairy above.

Distribution. Europe: Belarus (new record), Ukraine, Russia (Tzvelev 1987). Reported for the first time from Belarus here.

Ecology. Alluvial sands in larger river valleys, riverside slopes, often on exposed calcareous substrates.

Chromosome counts. 2n = 100 (Parfionaŭ et al. 1975, as *Chamaecytisus* sp.); material collected from native populations in Gomel Region; vouchers at MSK.

Notes on nomenclature. The type specimen of *Cytisus kreczetoviczii* was interpreted as holotype by Krytzka et al. (1999: 610). Since the holotype specimen was not indicated in collections by the author and the type collection was represented by multiple duplicates, Fedoronchuk et al. (2003: 96) formally designated a lectotype. However, in this case, the earlier holotype indication is correctable to lectotypification because of its having been published prior to 2001 (Turland et al. 2018).

Notes on taxonomy and distribution. This is a variable taxon, which occupies an intermediate position between *C. borysthenicus* and *C. ruthenicus* in the

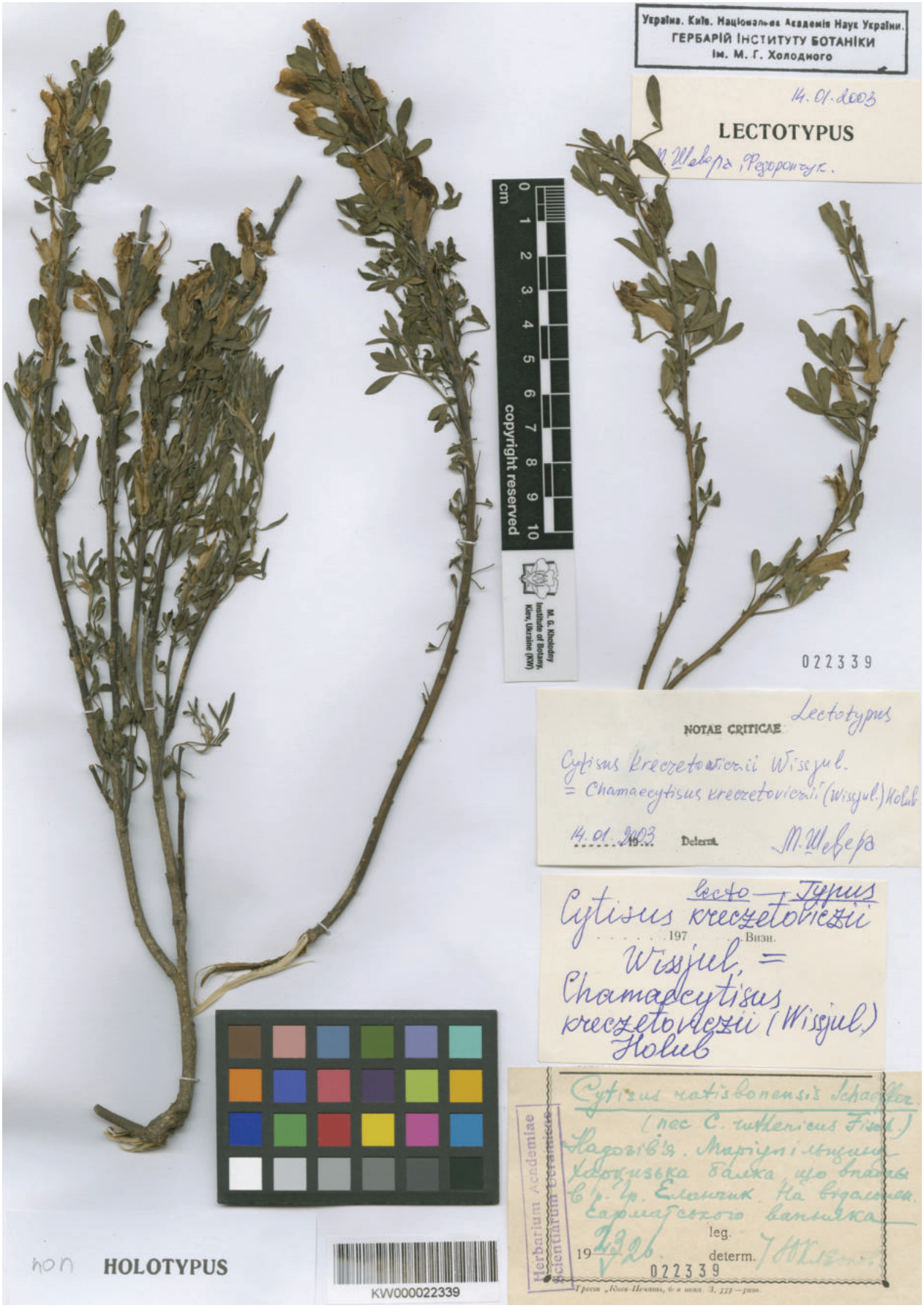

Figure 3. Lectotype of *Cytisus kreczetoviczii* Wissjul.

shape of leaves and the pubescence of the upper side of leaves. Taxonomically, these plants were recognised as a locally endemic species in Ukraine (Wissjulina 1954) and as an unnamed hybrid in Russia (Tzvelev 1987). Tzvelev (1987) misinterpreted *C. kreczetoviczii* as another alleged hybrid, between *C. ruthenicus* and *C. wulffii*. The latter taxon has hairy upper surfaces of leaves, but its creeping habit and a narrowly restricted distribution in the mountainous Crimea makes its participation in any hybridisation outside the mountains highly unlikely. *Cytisus kreczetoviczii* has tall and erect branches and narrowly lanceolate leaves (Wissjulina 1954), and its occurrence within the overlapping distributions of *C. ruthenicus* and *C. borysthenicus* agrees with its intermediate morphology between the two latter species. The reduction of this taxon to *C. ruthenicus*, as proposed by Skalická (1983) and Cristofolini (1991), is not justified because *C. kreczetoviczii* differs from *C. ruthenicus* by its stems, petioles and pedicels covered with subappressed hairs 0.6–0.8 mm long (vs. 0.4–0.6 mm long in *C. ruthenicus*) and its lanceolate to elliptic (vs. obovate) leaflets variously hairy (vs. glabrous) above. This taxon largely occurs in mixed populations together with its parental species, although some localities (including the type one) can be found without direct connection with the parents. It advances further northwards than *C. borysthenicus* and occurs in Belarus in the absence of the latter.

3. *Cytisus borysthenicus* Gruner in Bull. Soc. Imp. Naturalistes Moscou 41(4): 446 (1869)

– *Cytisus biflorus* subsp. *borysthenicus* (Gruner) Pacz. in Trudy Bot. Sada Imp. Yur'evsk. Univ. 15(2–3): 95 (1914) – *Chamaecytisus borysthenicus* (Gruner) Klásk. in Preslia 30: 214 (1958) – *Chamaecytisus biflorus* subsp. *borysthenicus* (Gruner) Elenevsky & Radygina in Elenevsky et al., Rast. Saratov. Pravober.: 41 (2000).

Type. Ukraine. Zaporozhie Region: "In demissis ad Borysthenem infra urbem Alexandrowsk [Zaporozhie]," [26.07].1865, *L. Gruner* (lectotype MW0475698, designated here). Fig. 4.

Description. Upright shrubs with erect stems up to 120(200) cm tall and long branches. Leaves with lanceolate leaflets, densely and evenly hairy above, with dense appressed hairs 0.1–0.2(0.3) mm long below, petioles densely covered with appressed hairs. Flowers strictly lateral, 1–4 in axils, on pedicels 2–5 mm long, yellow; calyx 10–12 mm long, with appressed hairs 0.4–0.6 mm long; standard suborbicular, hairy above.

Distribution. Europe: Ukraine, Crimea (Yena and Khlevnaya 2015a, 2015b; Fedoronchuk 2022), Russia (southern part: Kreczetowicz 1940; Borisova 1964). Asia: Russia (north-western Caucasus: Kreczetowicz 1940; Grossheim 1952; Ivanov 2019; south-western Siberia: Kreczetowicz 1940; Kurbatsky 1994), Kazakhstan (north-western part: Tulaganova 1981). New to Bashkiria, Bryansk and Kursk Regions of Russia. The presence in Belarus and European Kazakhstan is expected, but not confirmed.

Ecology. Alluvial sands in larger river valleys, sandy steppes, open sands, sparse pine forests on sands, mostly along rivers.

Chromosome counts. 2n = 100 (Semerenko 1984, as *Chamaecytisus* sp.); material collected from native populations in Ukraine; vouchers at KW.

Notes on nomenclature. Leopold Gruner (Lipschitz 1950; Leonov et al. 2014) explored the flora of steppic, sandy and calcareous areas near the confluence of the Konka River with the Dnepr River (now Zaporozhie Region, Ukraine).

Gruner (1869a, 1872) found *Cytisus borysthenicus* in a single place between the Konka River and Alexandrowsk Town (now Zaporozhie), rather frequent on small hills of partly open sands. While describing the new species, Gruner (1869a: 137) left it unnamed; in the second part of his synopsis (Gruner 1869b: 446), he mentioned in a note under *Cuscuta monogyna* that the latter species was collected on *Cytisus borysthenicus*. Since both papers were part of the same work and it was the only species of *Cytisus* recognised in the territory, the name of that species has been commonly accepted as validly published with a cryptic reference to the description via the title of the work (Art. 38.12 and 38.14, see also Ex. 19 under Art. 38.11).

Gruner (1869a, 1869b) visited the locality of *C. borysthenicus* twice, on 20 June and 26 July 1865. He collected sterile twigs and only one flowering branch with three flowers during his first visit and observed abundant plants of *Cuscuta monogyna* on these shrubs during the second visit.

Herbarium collections of Leopold Gruner are known at LE and MW (Lipschitz 1950). A minor part of his collections is placed at KW (formerly at CW: Leonov et al. (2014)). Some specimens are deposited at OXF (Clokie 1964), acquired as part of the collections of William Wilson Saunders (Druce 1897).

Kreczetowicz (1941) stated that the type of this species name is kept in Moscow, but it was not found anywhere including MW (Gubanov 2002). Lipsky (1899) recorded 237 specimens collected by Gruner in Ukraine and accessioned to the collections of the Imperial Botanical Garden in Saint-Petersburg (now part of the Komarov Botanical Institute, LE). This figure is much smaller than the number of taxa recorded by Gruner in his work, meaning that his collection acquired by LE was highly incomplete. We were also not able to trace any specimen collected by Gruner and labelled as *C. borysthenicus* in any Herbarium.

As a matter of surprise, one specimen representing Gruner's collection of *Cuscuta monogyna*, with *Cytisus borysthenicus* as a host plant, has recently resurfaced at MW. This specimen was clearly associated by Gruner with the protologue of *C. borysthenicus* and is, therefore, part of the original material of the latter name. Although the fragment of *C. borysthenicus* on this specimen is a sterile branch densely covered by a parasite, it is perfectly adequate to identify the species and may serve as lectotype.

The original description of *C. borysthenicus* is ambiguous. The ecology (sandy hills) and the hairy standard indicate this species as currently understood, whereas the obovate-lanceolate leaves, glabrous above, clearly refer to *C. ruthenicus*. This discrepancy was neglected by Paczoski (1914) and Kreczetowicz (1940), who resurrected the name *C. borysthenicus* and applied it to the psammophilous species with narrowly lanceolate leaves, hairy above. *Cytisus borysthenicus*, *C. ruthenicus* and their hybrid co-occur in the *locus classicus* of the first species (Sennikov and Tikhomirov 2024a), and the original description of *C. borysthenicus* was apparently based on specimens of both species.

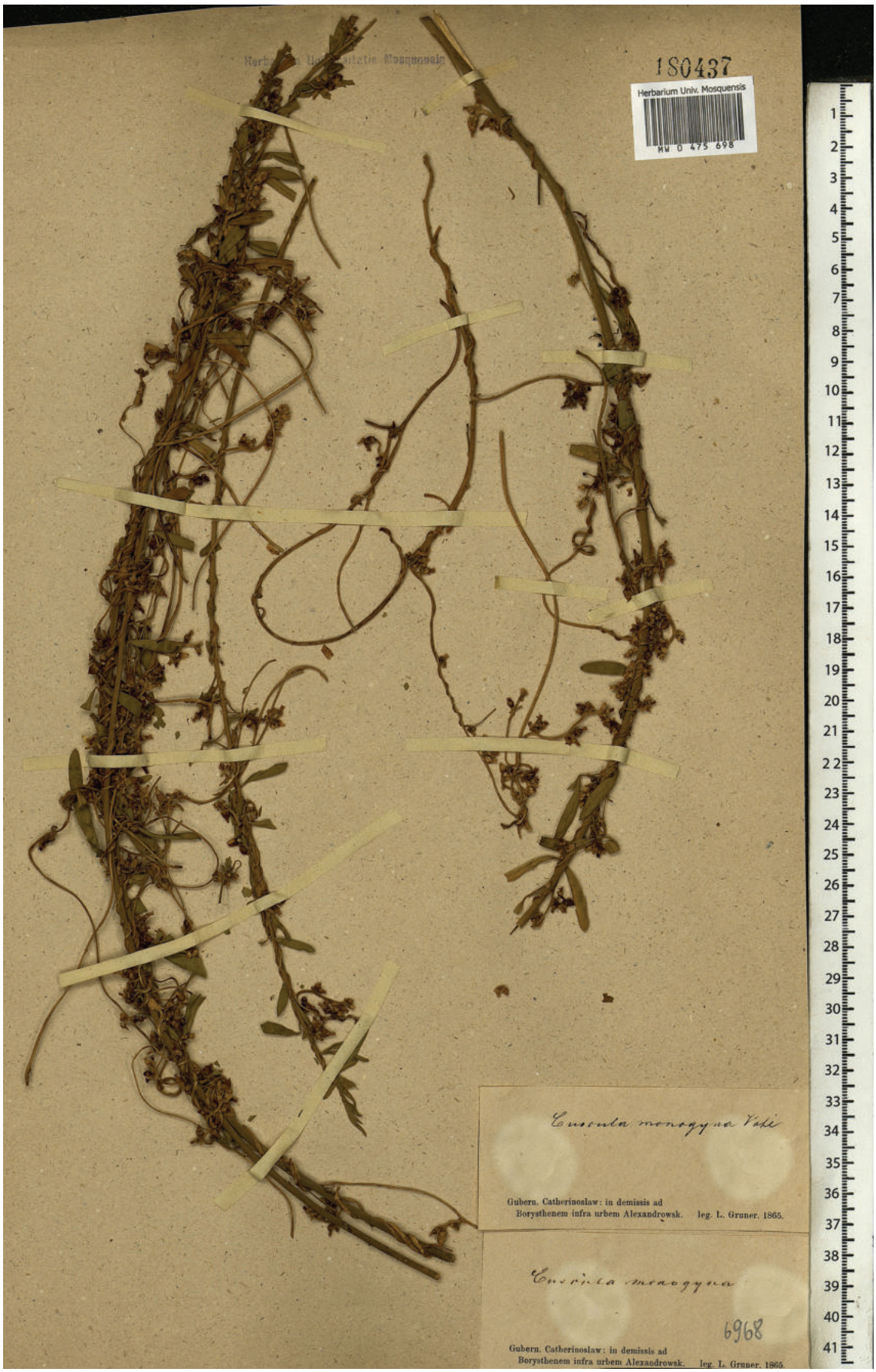

Figure 4. Lectotype of *Cytisus borysthenicus* Gruner.

So far, the original material of *C. borysthenicus*, which is taxonomically referable to *C. ruthenicus*, has not been found. Gruner's specimen of *Cuscuta monogyna* on *Cytisus borysthenicus* apparently belongs to the species as established by Paczoski (1914), Kreczetowicz (1940), Tzvelev (1987) etc. To fix this species name in its established interpretation, we designate the only available element of the original material as lectotype.

Notes on taxonomy and distribution. This species is largely confined to the systems of southern East European rivers and was probably dispersed with sand deposits. Its distribution extends much further north-east and north-west than was indicated by Tzvelev (1987).

4. *Cytisus semerenkoanus* Sennikov & Val.N.Tikhom., sp. hybr. nov.

urn:lsid:ipni.org:names:77336839-1

Type. Belarus. Gomel Region, Dobrush District, vicinities of Dobrush Town, margin of pine forest with moss cover, 19.05.1979, *L.V. Semerenko & I.V. Shvets* (holotype MSK, isotypes MSK, MSKU). Fig. 5.

Etymology. The species name is given in honour of Larisa Vasilievna Semerenko (Parfionaŭ et al. 2018), who advanced our knowledge by her studies on the karyology and biology of *Cytisus* in Belarus.

Description. Upright shrubs with erect, basally ascending stems up to 60(80) cm tall and long branches. Leaves with elliptic to obovate leaflets, sparsely hairy to subglabrous above, with lax hairs 0.2–0.6 mm long below, petioles sparsely covered with appressed and subpatent hairs. Flowers strictly lateral, 1–4 in axils, on pedicels 3–6 mm long, yellow; calyx 10–12 mm long, with appressed and subpatent hairs 0.4–0.9 mm long; standard suborbicular, hairy to subglabrous above.

Distribution. Europe: Poland, Moldova, Belarus, Ukraine, Russia. Asia: Russia (Caucasus), Abkhazia.

Ecology. In the forest zone, this taxon is found in dry forests on rich soils (oak forests and mixed broadleaved-pine forests with steppe plants), mostly in open places; in the forest steppe and steppe zones, it occurs in sparse forests and open steppe-like places.

Chromosome counts. 2n = 50 (Parfionaŭ et al. 1975, as *Chamaecytisus* sp.); material collected from native populations in Gomel Region; vouchers at MSK.

Notes on nomenclature. Kreczetowicz (1940) described an alleged hybrid between *C. ruthenicus* and *C. elongatus* under the name *C. czerniaevii*, but the original material of the latter name belongs to *C. elongatus* rather than to the hybrid. For this reason, the hybrid is described here under a new name.

Notes on taxonomy and distribution. Kreczetowicz (1940) described this taxon as a hybrid between *Cytisus lindemannii* (our synonym of *C. elongatus*) and *C. ruthenicus*, and this interpretation was accepted by Tzvelev (1987). Based on the intermediate morphology, we agree on the presence of hybrids between *C. ruthenicus* and *C. elongatus*. The distribution of *C. semerenkoanus* extends much further eastwards and northwards than the current distribution of its presumed parent, *C. elongatus*, which we explain by the extinction of the latter due to postglacial climate changes and hybridisation processes.

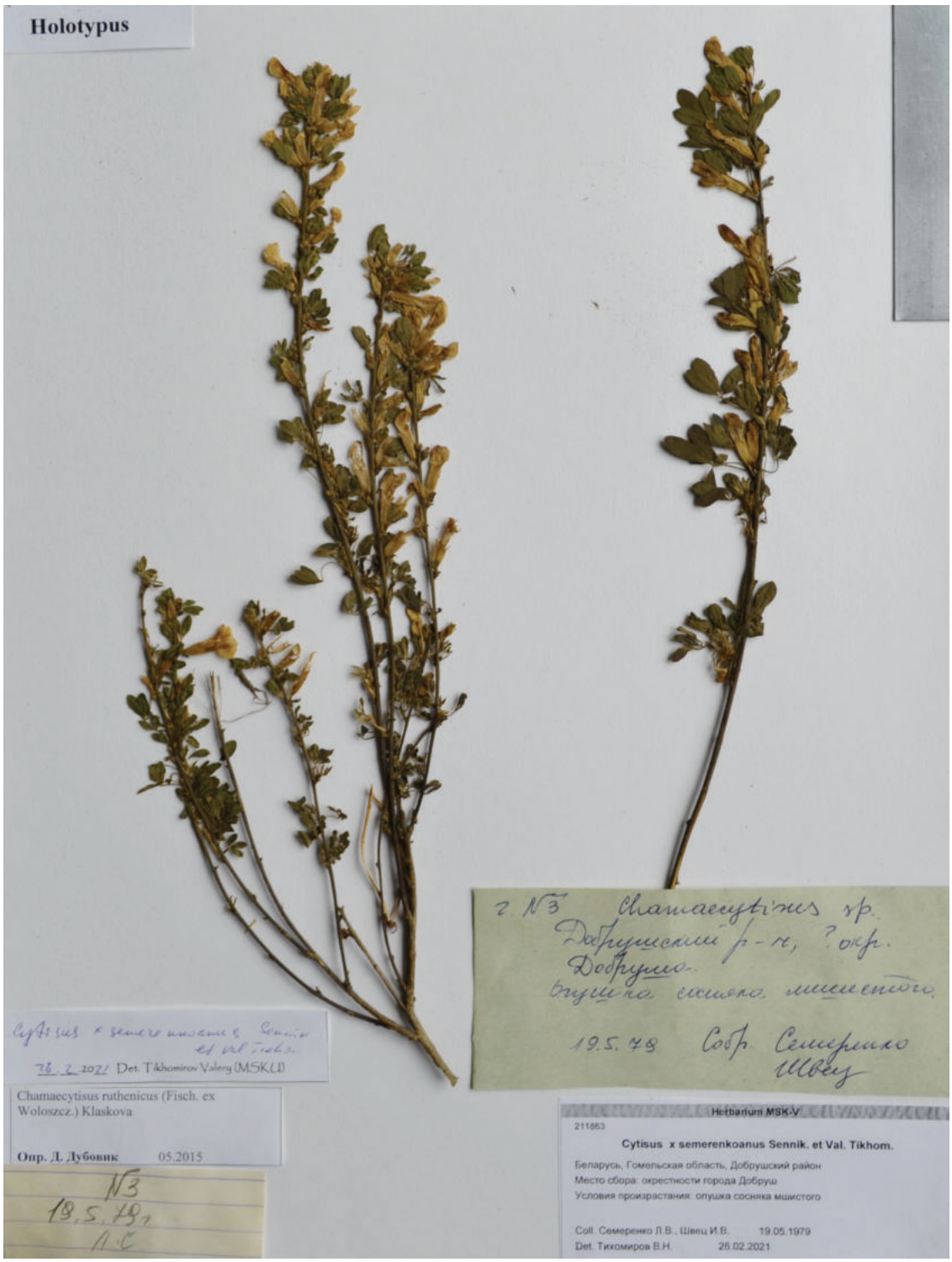

Figure 5. Holotype of *Cytisus semerenkoanus* Sennikov & Val.N.Tikhom.

5. *Cytisus elongatus* Waldst. & Kit., Descr. Icon. Pl. Hung. 2: 200, t. 183 (1804)

– *Chamaecytisus elongatus* (Waldst. & Kit.) Link, Handbuch 2: 155 (1831) – *Cytisus hirsutus* subsp. *elongatus* (Waldst. et Kit.) Briq., Etud. Cytis. Alp. Marit.: 168 (1894) – *Chamaecytisus ciliatus* subsp. *elongatus* (Waldst. & Kit.) Soó in Feddes Repert. 85: 439 (1974) – *Chamaecytisus glaber* var. *elongatus* (Waldst. & Kit.) Kuzmanov in Jordanov, Fl. Narodna Republ. Bulg. 6: 86 (1976).

= *Cytisus leucotrichus* Schur in Oesterr. Bot. Z. 10: 179 (1860), syn. nov. – *Chamaecytisus leucotrichus* (Schur) Czerep., Sosud. Rast. SSSR: 229 (1981) – *Chamaecytisus triflorus* subsp. *leucotrichus* (Schur) Holub in Bertová, Fl. Slovenska 4(4): 35 (1988). Type. Romania. "Rothen Berg bei Mühlbach [Sebeș]", [05].07.1853, *F. Schur* (lectotype LW00205768, designated by Pifkó (2009a: 153); isolectotype LW00205839).

= *Cytisus lindemannii* V.I.Krecz. in Bot. Zhurn. SSSR 25: 259 (1940), syn. nov. – *Chamaecytisus lindemannii* (V.I.Krecz.) Klásk. in Preslia 30: 214 (1958). Type. Ukraine. "Elisabethgrad" [Kropyvnytskyi], 06.05.1873, *E. Lindemann* (holotype LE01024081; isotype LE01024082). Fig. 6.

= *Cytisus czerniaevii* V.I.Krecz. in Bot. Zhurn. SSSR 25: 261 (1940), syn. nov. – *Chamaecytisus czerniaevii* (V.I.Krecz.) Tzvelev, Fl. Evropeiskoi Chasti SSSR 6: 223 (1987). Type. Ukraine. Kharkov Region, Zmiev District, Hamlet of Fedorchenko, 24.04.1910, *G.I. Širjaev* (lectotype KW000114840, designated here). Other original material. Ukraine. Kharkov Region: Steppes near Chuguev, 19.05.1852, *V.M. Cherniaev* (KW). Sumy Region, Lebedin District, "prope Grun, in steppis princ. Kapnist" [near Grun', in steppes of Count Kapnist = 'Mikhailovskaya Tselina' Nature Reserve], 09.06.1905, *G.I. Širjaev* (KW000114839).

= *Cytisus ponomarjovii* Seredin in Novosti Sist. Vyssh. Rast. 13: 192 (1976), syn. nov. – *Chamaecytisus ponomarjovii* (Seredin) Czerep., Sosud. Rast. SSSR: 229 (1981). Type. Russia. Krasnodar Territory, Tuapse District, 1 km NW of Dzhubga Village, oak forest, 08.07.1973, *R.M. Seredin* (holotype LE).

= *Chamaecytisus korabensis* Pifkó & Barina in Stud. Bot. Hung. 47(1): 164 (2016), syn. nov. Type. Albania. Qarku i Dibrës: [Korab-Koritnik Nature Park,] Mali i Bardhë Mts, near peak Maja e Pelpenikut, above village Sllatinë, on evaporites, 41.78419°N, 20.45978°E, 1928 m, 17.06.2013, *Z. Barina* & *D. Pifkó* 22354 (holotype BP759110; isotype BP759111).

Type. Romania. Historical Banat Region: "In sylvis Beregh, Banaticis et Croaticis", 1800, *P. Kitaibel* (lectotype W20030003241, left-hand fragment, designated here: https://w.jacq.org/W20030003241). Possibly Ukraine. ["In comitatis Bereghensis" = Bereg County, "in sylvis",] Herb. Waldstein (superseded lectotype PR155757/738a, designated by Chrtek and Skočdopolová (1982: 226)).

Description. Upright shrubs with erect, basally ascending stems up to 40–60(80) cm tall and long branches. Leaves with elliptic to obovate leaflets, densely hairy above, with lax hairs 0.4–0.8 mm long below, petioles rather densely covered with laxly appressed to subpatent hairs. Flowers strictly lateral, 1–4 in axils, on pedicels 2–4 mm long, yellow; calyx 11–12 mm long, with subpatent hairs 0.8–1.2 mm long; standard suborbicular, glabrous or hairy above.

Distribution. Europe: France (along the valley of Rhône: Tison and de Foucault (2014)), Italy, Albania, Serbia, Greece, Bulgaria, Turkey (Cristofolini 1991), Bosnia and Herzegovina (new record), Montenegro (new record), Slovenia (new record), Croatia (Lovašen-Eberhardt 1997), North Macedonia (Micevski 2001), Austria (Cristofolini 1991), Hungary (Pifkó 2009b), Slovakia (Cristofolini 1991), Romania (Grinţescu 1957), Moldova (Heydemann 1986), Ukraine (Kreczetowicz 1940; Fedoronchuk 2022), Belarus (new record), Russia (south-western part) (Kreczetowicz 1940; Borisova 1964; Tzvelev 1987). Asia: Russia (western and central Caucasus: Grossheim (1952); Zernov (2006); Ivanov (2019)), Abkhazia (Kolakovsky 1985), Georgia (Ajaria: Gvinianidze (1981)), Turkey (Artvin

Province: Kreczetowicz (1940)). Reported for the first time from Belarus and Bosnia and Herzegovina here. New to Bryansk and Lipetsk Regions of Russia. The actual distribution in Asian Turkey and the Balkans may be more extensive, but has been obscured due to the confusion with *C. hirsutus* (Gibbs 1970).

Ecology. In the forest zone, this species occurs in sparse forest stands and on forest margins with steppe herbaceous species, mostly in xerophilous oak forests, at elevations below 500(700) m; in the forest steppe and steppe zones, it is found among sparse shrubs in dry creeks, steppe-like meadows and steppes. It also occurs in oak forests and steppe-like meadows in the mountains.

Chromosome counts. 2n = 50 (Semerenko 1984); material collected from native populations in Kursk and Lipetsk Regions; vouchers at MSK. Dubious record: 2n = 48 (Frahm-Leliveld (1957), as *Cytisus elongatus*); cultivated material; vouchers unknown.

Notes on nomenclature. Skalická (1986) and Cristofolini (1991) accepted *Cytisus triflorus* Lam. as the priority name for this species. Its lectotype actually belongs to *C. hirsutus* L. (Sennikov and Tikhomirov 2024b).

Cytisus elongatus was described from present-day Romania (Caraş-Severin, Banat) and Ukraine (former Bereg County) (Waldstein and Kitaibel 1804). The original description of *C. elongatus* refers to plants with elongated branches and numerous flowers in lateral inflorescences, flowers shortly pedicellate and "slightly larger than in *C. supinus*", branches with appressed hairs, leaves greyish-pubescent on both sides and calyces grey because of dense pubescence. The presumed original material (Pifkó 2007) is apparently heterogeneous, but the original description and drawing clearly indicate the intention to describe a species of *C. ratisbonensis* s.l. with the calyces having long subappressed pubescence and the leaves being hairy on the upper side, which unambiguously point at the species known as *C. lindemannii* (Tzvelev 1987) or *C. triflorus* (Cristofolini 1991).

According to the published diaries of P. Kitaibel (Gombocz 1945), he collected *C. elongatus* in Bereg County (7 July 1803, forest near Bereg, present-day Beregovo Town, mentioned as *C. elongatus*) and in Banat Region (26 July – 11 August 1800, many places, mentioned, according to Pifkó (2007), as *C. patens*). This means that the taxonomic concept of *C. elongatus* had been shaped on the basis of the Banat material prior to the travel to Bereg County. In Bereg County, besides the locality mentioned in the diary, where the plants were collected in fruits due to the late season, the species could have been collected anywhere on the route in northern and north-eastern Hungary.

After the protologue of *C. elongatus* was published, Kitaibel collected further specimens of this species (Lőkös 2001). In 1805, he travelled to Banat for the second time (5 July, near "Szlatina" = Slatina-Timiș, Caraș-Severin County, Romania, as *C. elongatus*). In 1815, he revisited Transcarpathia and collected in "Rhonaszegh" (6 August, Coștiui, Maramureș County, Romania, as *C. elongatus*) and near Bereg (25 September, Beregovo, Ukraine). The actual collections of Kitaibel may not have been limited to the localities mentioned in the diaries, but these data may be used as guidance to shape our understanding of the collections. For example, Kitaibel had an opportunity to collect the species during his three travels to the Matra Mts. and also in other travels that included present-day Croatia and Romania.

Chrtek and Skočdopolová (1982) designated a lectotype of *C. elongatus* from the collections of F. de Paula von Waldstein at the National Museum in Prague. The specimens kept as *C. elongatus* in this collection are accompanied by a generic

label written by K. Sternberg, who possessed the collections after Waldstein's death, whereas their original label data are lacking. Four plants are kept on two sheets under a single label. Of these plants, two were designated as a lectotype.

Chrtek and Skočdopolová (1982) preferred the designated sheet because the other one was a mixed collection of two different plants. However, they failed to observe that the two lectotype plants are also apparently different. The lanceolate leaflets of the right-hand plant of the lectotype are in apparent conflict with the protologue that states "foliolis obovatis"; besides, its inflorescence looks capitate rather than elongated as stated in the protologue ("totos ramos annotinos undique dense tegentes"). The other fragment agrees with the protologue in morphology, but there is no evidence that this particular material can be associated with the protologue and was not collected in any of the numerous later travels of Kitaibel. Due to the lack of the association with the protologue, the lectotype of *C. elongatus* designated by Chrtek and Skočdopolová (1982) cannot be accepted and should be superseded in favour of some certain element of the original material that is in agreement with the protologue.

In search for the other original material, we examined online collections of B, BP, PRC and W. Specimens in Herbarium Willdenow at B, which are labelled "Hungaria", are likely original material because Willdenow received manuscripts and specimens from Waldstein and Kitaibel, of which hundreds are currently kept in Berlin (Hiepko 1972). Two of these specimens represent elongated branches, of which one (B-Willd 13622-03) has the leaves glabrous on the upper side and belongs to *C. cinereus*, whereas the other (B-Willd 13622-04) has the leaves hairy on the upper side and belongs to *C. triflorus* sensu Cristofolini. Plants collected from Bereg County are represented at PRC (PRC 454937), but their elongated branch has the leaves glabrous above and belongs to *C. cinereus*. Some original material collected in Banat is kept at BP (Pifkó 2007), including a specimen with elongated branches (Hb. Kitaibel XXIV: 161) collected near "Oravicza" (Oravița, Caraș-Severin County, Romania).

The most important specimen was found at W (W 20030003241). The plants on this sheet were identified as *C. elongatus* with a reference to the protologue; the label of this specimen written by Kitaibel is composite and reads "In sylvis Beregh, Banaticis et Croaticis". This label reflects Kitaibel's travels to Banat in 1800, to Croatia in 1802 and to Bereg County in 1803; it makes the specimen firmly linked to the protologue of *C. elongatus*. The sheet bears three fragments: a branch on the right side, densely leafy and abundantly flowering, corresponding to *C. cinereus*; a small fragment in immature fruit in the middle, also belonging to *C. cinereus* (possibly collected in 1803 from the locality in Bereg County mentioned in Gombocz (1945)); and an elongated branch in flower on the left side, whose calyces are villous and leaves are densely hairy above. The latter fragment fully agrees with the protologue of *C. elongatus*. We assume that the left-hand specimen belongs to the plants collected by Kitaibel in Banat in 1800 and used for the original description of *C. elongatus* and, therefore, designate it as a new lectotype.

This lectotype agrees with the usage in the Hungarian exsiccata (Kerner 1884; Anonymous 1919) and other specimens identified as *C. elongatus*, later usage favoured the application of this species name to *C. hirsutus* s.l. and the illustration was considered mismatching the original description (Kerner 1884). The usage of *C. elongatus* by Skalická (1986) and Pifkó (2009b) agrees with our lectotypification (except for their inclusion of plants belonging to *C. cinereus*);

the placement of *C. elongatus* to the synonymy of "*C. triflorus*" by Cristofolini (1991) also agrees with our taxonomy.

The treatment of *C. leucotrichus* has been controversial. Schur (1859) described this plant as deviating from *C. hirsutus* by a denser "white" (sericeous) pubescence and smaller leaves. Tzvelev (1987) and Cristofolini (1991) placed it to the synonymy of *C. hirsutus*, in spite of its dense subpatent pubescence on branches and leaves (vs. sparse patent pubescence in *C. hirsutus*). Holub and Bertová (1988) accepted and subordinated it to *C. triflorus*, which was a name for *C. elongatus* at that time. The type collection of *C. leucotrichus* is represented by large branches in fruit, which are densely covered by subappressed (partly subpatent) hairs. This type of pubescence matches the characters of "*C. triflorus*" (Cristofolini 1991) and *C. lindemannii* (Tzvelev 1987) and agrees with the taxonomic concept of *C. elongatus* accepted here.

Although Kreczetowicz (1940) already employed the type concept, he did not indicate a type of *Cytisus czerniaevii*. Neither did he cite any specimen in the protologue; instead, he listed two localities in Kharkov Region. We found three specimens corresponding to those localities and identified by Kreczetowicz as *Cytisus lindemannii* × *C. ruthenicus*, in agreement with the hybrid origin of *C. czerniaevii* indicated in its protologue. One specimen was collected by Vasily Cherniaev and formerly deposited at CWU (which was transferred to KW after the Second World War), in the Ukrainian collections of Cherniaev which were extracted from his personal herbarium and placed within the main collections of KW for the preparation of *Flora of the Ukrainian SSR* (Krytzka et al. 2002). This specimen apparently provided the reason for naming the hybrid. Two specimens were collected by Grigory Širjaev in the former Kharkov Region of the Russian Empire (now Kharkov and Sumy Regions of Ukraine).

All the original material of *C. czerniaevii* belongs to *C. elongatus*. Kreczetowicz (1940) stated that his hybrid differed from the species by its subglabrous standard, which is, however, variable in *C. elongatus* (Wissjulina 1954). For this reason, the name *C. czerniaevii* cannot be used for a hybrid between *C. ruthenicus* and *C. elongatus*, but is a synonym of the latter.

Krytzka et al. (1999: 610) believed that the holotype of *C. czerniaevii* is kept at LE, but cited the species provenance from the protologue instead of the label data. Fedoronchuk et al. (2003) did not mention the presence of the original material of *C. czerniaevii* at KW. This material was recognised as such in 2012 by M. Shevera (on herbarium labels).

Notes on taxonomy and distribution. Ledebour (1843) distinguished between the plants with appressed and subpatent hairs on the calyces, which he called *C. biflorus* L'Her. and *C. elongatus* Waldst. & Kit., respectively. The plants with the subpatent pubescence were reported from the steppe zone of Eastern Europe for the first time by Lindemann (1867), who used the nomenclature from Ledebour (1843).

Kreczetowicz (1940) believed that *C. elongatus* s. str. is replaced in steppes of Eastern Europe (Ukraine) and the North Caucasus by another taxon with a hairy (vs. glabrous) standard and a denser pubescence, which he named *C. lindemannii*. Skalická (1986) and Tzvelev (1987) accepted *C. lindemannii* in the same sense. Since this widely distributed species is variable in the length and density of pubescence and Kreczetowicz (1940) himself admitted that the pubescence on standard is variable within one species, we do not consider the western and eastern plants to be taxonomically different and restore the priority name for this species,

Figure 6. Holotype of *Cytisus lindemannii* V.I.Krecz.

C. elongatus. Cristofolini (1991) reduced *C. elongatus* to a synonym of "*C. triflorus*", but placed *C. lindemannii* in the synonymy of *C. ruthenicus*; the latter decision is against the original description and type material of *C. lindemannii*, which has the subappressed to patent pubescence (vs. appressed in *C. ruthenicus*) and the leaves hairy above (vs. glabrous above in *C. ruthenicus*) (Kreczetowicz 1940).

Kreczetowicz (1940), Grossheim (1952) and Portenier and Solodko (2002) treated *C. hirsutissimus* as endemic to the Caucasus, a mountainous species which reportedly differed from the steppic, lowland East European *C. lindemannii* (= *C. elongatus*) in longer pedicels and a patent (vs. subappressed) pubescence of the whole plant. These minor and variable characters cannot be considered species-specific, and *C. hirsutissimus* of these authors was correctly identified with "*C. triflorus*" (= *C. elongatus*) (Cristofolini 1991).

Seredin (1976) described *C. ponomarjovii* as a local endemic of the western Caucasus and distinguished it from *C. caucasicus* by its denser pubescence. Cristofolini (1991) omitted this species, which was accepted in very few works (Czerepanov 1995; Ivanov 2019). Portenier and Solodko (2002) correctly noted that *C. ponomarjovii*, a species of lower elevations, corresponds to '*C. hirsutissimus* C.Koch' of Russian authors (Kreczetowicz 1940; Grossheim 1952; Portenier and Solodko 2002), which is *C. triflorus* in the sense of Cristofolini (1991). We place it to the synonymy of *C. elongatus*, accordingly.

Chamaecytisus korabensis was recently described by Pifkó and Barina (2016) as a local endemic of north-western Albania, which was considered as related to "the *C. ratisbonensis* and *C. triflorus* agg." The protologue described and illustrated a minute plant collected at higher altitudes, with ascending stems covered by subappressed pubescence, leaves appressedly pubescent on both sides, and calyces 1–1.3 mm long with abundant subpatent hairs. These characters correspond to alpine forms of *C. elongatus*, which may be highly reduced in size in the subalpine mountain belt, whereas the differences in plant size played a major role in identification according to Pifkó and Barina (2016).

The earlier records of *C. lindemannii* from Belarus (Fedtschenko 1950) belong to *C. semerenkoanus*, but the presence of this species in the country is confirmed on the basis of recent collections.

Conservation status. Although the species is not included in national or regional Red Lists, it occurs in some protected areas, for example, in the Mikhailovskaya Tselina Nature Reserve in Ukraine and in the Utrish Nature Reserve in Russia.

6. *Cytisus ratisbonensis* Schaeff., Bot. Exped.: tab. in prim. lib. (1760)

– *Cytisus communis* Lindem. in Bull. Soc. Imp. Naturalistes Moscou 40(1): 494 (1867), nom. illeg. superfl. – *Cytisus hirsutus* subsp. *ratisbonensis* (Schaeff.) Briq., Étud. Cytises Alpes Mar.: 167 (1894) – *Chamaecytisus ratisbonensis* (Schaeff.) Rothm. in Feddes Repert. 53(2): 143 (1944).

Type. [icon] Schaeffer, Bot. Exped.: tab. in prim. lib. 1760 (presumably holotype).

Description. Prostrate shrubs up to 20 cm above ground with long branches. Leaves with obovate to elliptic leaflets, glabrous above, with appressed hairs 0.4–0.8 mm long below, petioles densely covered with appressed hairs. Flow-

ers strictly lateral, 1–4 in axils, on pedicels 3–5(7) mm long, pale yellow; calyx 11–14 mm long, with laxly appressed hairs 0.8–1.2(1.6) mm long; standard suborbicular, glabrous above.

Distribution. Europe: Austria (Heywood and Frodin 1968), Germany (Heywood and Frodin 1968), Czech Republic (Skalická 1995; Kaplan et al. 2019), Hungary (Pifkó 2009b), Bulgaria (Heywood and Frodin 1968; Cristofolini 1991), Croatia (Lovašen-Eberhardt 1997), Romania (Cristofolini 1991), Slovakia (Holub and Bertová 1988), Poland (Heywood and Frodin 1968; Danielewicz 2020). Reported from Moldova (Heydemann 1986), but no specimens were seen by us from this country and its presence is considered unlikely. The records from the Balkans, Romania and Hungary include other related taxa and may be unreliable. The records from Belarus belong to *C. lithuanicus*. The records from Ukraine (Tzvelev 1987) belong to *C. lithuanicus* and *C. polonicus*. Most of the records from Poland Zieliński (1975) belong to *C. cinereus* and *C. polonicus*.

Ecology. The species occurs in dry meadows among pine and oak mountain forests.

Chromosome counts. 2n = 48 (Dvořák and Dadákova 1976; Dvořák 1977); material from native populations collected in Czech Republic; vouchers at BRNU. The diploid counts (2n = 24) reported by Zieliński (1975) belong to *C. polonicus*. The tetraploid counts 2n = 48 reported by Zieliński (1975) belong to *C. cinereus*. The tetraploid counts 2n = 48 (Pogan et al. 1990), based on material from native populations collected in Poland, may belong to the same species (vouchers at KRAM, not controlled).

Notes on nomenclature. The herbarium collections of Jacob Christian Schaeffer may be kept at REG. So far, the only, but unambiguous original element available to us is the illustration in the protologue.

Notes on taxonomy and distribution. Before Kreczetowicz (1940), this species was treated very broadly to include many species of this group in Eastern Europe. Tzvelev (1987) and Semerenko (1999) still circumscribed this species too broadly, with the inclusion of *C. lithuanicus* which differs from *C. ratisbonensis* by its taller stems and shorter (up to 0.8 mm vs. 0.8–1.4 mm long) pubescence. Zieliński (1975) and Skalická (1995) treated *C. ratisbonensis* broadly, including plants with taller stems (up to 50 cm long) and larger flowers (calyx 10–13 mm long), which apparently belong to *C. lithuanicus* and *C. cinereus*. Holub and Bertová (1988) also included *C. ruthenicus* in this species. With exclusion of *C. polonicus*, *C. ratisbonensis* is treated as absent from Eastern Europe. It is retained in the present synopsis for the purposes of comparison.

7. *Cytisus polonicus* Sennikov & Val.N.Tikhom., sp. nov.

urn:lsid:ipni.org:names:77336840-1

– *Chamecytisus ratisbonensis* auct.: Tzvelev 1989; Fedoronchuk 2022.

Type. Poland. "Regio Cracoviensis: inter pagum Zabierzów et vicum Szczyglice, ad declive abruptum loessicum, 17.05.1973, *A. Pałkowa & T. Tacik* [Flora Poloniae Exsiccata No. 636] (holotype H1293884; isolectotypes KRAM249040 and distributed to other herbaria). Fig. 7.

Figure 7. Holotype of *Cytisus polonicus* Sennikov & Val.N.Tikhom.

Etymology. The new species is named after Poland, the country of its main distribution and type locality.

Description. Prostrate shrubs up to 20 cm above ground with long branches. Leaves with obovate to elliptic leaflets, glabrous above, with appressed hairs 0.4–0.8 mm long below, petioles densely covered with appressed hairs. Flowers strictly lateral, 1–4 in axils, on pedicels 3–5(7) mm long, pale yellow; calyx (7)8–10 mm long, with (laxly) appressed hairs 0.6–0.8(1) mm long; standard suborbicular, glabrous above.

Distribution. Europe: Poland, Ukraine. Its occurrence in western Belarus is expected due to the presence in Poland, 15 km from the border.

Ecology. The species occurs in dry meadows or on calcareous denudations, on open slopes of hills and mountain foothills.

Chromosome counts. 2n = 24 (Zieliński (1975), as *Cytisus ratisbonensis* subsp. *ratisbonensis*); material from native populations collected in Poland; vouchers at KOR and partly at KRAM.

Notes on taxonomy and distribution. This species is most similar to *C. ratisbonensis*, from which it differs by its smaller flowers and shorter pubescence. It replaces the latter species in southern and eastern Poland and Ukraine.

8. *Cytisus cinereus* Host, Fl. Austriac.: 2: 343 (1831)

– *Cytisus ratisbonensis* subsp. *cinereus* (Host) Jáv., Magyar Fl. 2: 609 (1924).

= *Cytisus horniflorus* Borbás, Balaton Fl.: 299 (1900), syn. nov. Type. Hungary. "In arenosis silvaticis ad Monor in Hung. centrali", 08.06.1887, *V. Borbás* (lectotype BP581457, designated by Pifkó (2005: 26)).

= *Cytisus paczoskii* V.I.Krecz. in Bot. Zhurn. SSSR 25: 261 (1940), syn. nov. **–** *Chamaecytisus paczoskii* (V.I.Krecz.) Klásk. in Preslia 30(2): 214 (1958). Type. Ukraine. Ternopol Region: "Silva prope pag. Kidancy (non procul stat. viae ferrariae Maximovka)", 26.04.1916, *A.I. Michelson* (holotype LE01024080).

Type. Cultivation, originated from Hungary. "Ex Hort." [Botanical Garden at Belvedere in Vienna, now Botanical Garden of the University of Vienna], Hb. Host 4148 (lectotype W1885-4148, designated here: https://w.jacq.org/W18850004148). Fig. 8.

Description. Upright shrubs with erect, basally ascending stems up to 60(80) cm tall and long branches. Leaves with elliptic to obovate leaflets, glabrous above (the basal leaves are slightly hairy above), with appressed hairs 0.4–0.8(1.2) mm long below, petioles sparsely covered with laxly appressed hairs. Flowers strictly lateral, 1–4 in axils, on pedicels 3–5 mm long, yellow; calyx 11–14 mm long, with laxly appressed to subpatent hairs 0.6–1.2(1.5) mm long; standard subrbicular, glabrous or hairy above.

Distribution. Europe: Austria, Slovakia, Serbia, Hungary, Romania, Poland, Ukraine (Tzvelev 1987; Fedoronchuk 2022), Moldova (Shabanova et al. 2014). As compared with the distribution area circumscribed by Tzvelev (1987), this species is new to Austria, Poland, Romania, Serbia, Slovakia and, due to the new synonymy, to Hungary. The only locality of this species previously reported from Moldova (Kreczetowicz 1940; Tzvelev 1987) is actually situated in Ukraine (Odessa Region); its voucher has not been found (Didukh 2009), but recent

Figure 8. Lectotype of *Cytisus cinereus* Host.

sources (Shabanova et al. 2014) reported a wide occurrence of the species in steppic areas of Moldova. The occurrence in Slovakia is logically expected.

Ecology. The species occurs in open places, meadows and forest margins on plains and slopes of hilly uplands, often on sandy or calcareous substrates.

Chromosome counts. 2n = 48 (Zieliński (1975), as *Cytisus ratisbonensis* subsp. *ratisbonensis*).

Notes on taxonomy and distribution. *Cytisus cinereus* was described from sandy and forested areas of Hungary (Host 1831) with a reference to "*C. biflorus*" in Waldstein and Kitaibel (1804). The latter work lists a few localities in central and eastern Hungary, which are the likely origin of the material cultivated in Vienna by Host. Both descriptions (Waldstein and Kitaibel 1804: 181; Host 1831: 343) mentioned the oblong leaves glabrous above, a rather appressed pubescence on the calyx, and long erect branches. These characters agree with those of *C. paczoskii*; Kreczetowicz (1940) distinguished his latter species from *C. lindemannii* (= *C. elongatus*) on the basis of its glabrous standard (described as glabrous by Waldstein & Kitaibel, but stated as pubescent by Host).

Cytisus cinereus and *C. horniflorus* were distributed in the same exsiccatae as different taxa (Anonymous 1919), but the plants are virtually identical.

Kreczetowicz (1940) described this taxon as a presumed hybrid between *C. lindemannii* (= *C. elongatus*) and *C. ratisbonensis*. We consider it a stabile taxon with its own diagnostic characters and distribution area, clearly deserving the species rank. Some authors classified this species as an infraspecific taxon of *C. ratisbonensis* (Jávorka 1924) or included it in the latter species (Pifkó 2005, 2009b), from which it differs by erect branches, larger flowers on longer pedicels, and a longer and denser pubescence of the whole plant.

Skalická (1983) and Cristofolini (1991) correctly recognised *C. paczoskii* (= *C. cinereus*) as a species close to *C. ruthenicus*, but different in a more developed pubescence. Due to the lack of material, they were not able to circumscribe its distribution.

In Poland, Zieliński (1975) identified plants of this species as *C. ratisbonensis* subsp. *ratisbonensis*, and so did Pifkó (2005, 2009b) in Hungary. For this reason, *C. paczoskii* (= *C. cinereus*) was treated as endemic to Eastern Europe (Tzvelev 1987). According to our data, its distribution includes the Pannonian Basin and the territories from the Podolian to Lesser Polish uplands.

Dubovik (2016) reported *C. paczoskii* as occurring in western Belarus. This record is based on a different interpretation of this species name, which Dubovik considered to belong to a presumed hybrid between *C. ratisbonensis* and *C. ruthenicus*. The plants identified as *C. paczoskii* by Dubovik largely belong to *C. lithuanicus*.

9. *Cytisus lithuanicus* Gilib., Hist. Pl. Europe 2: 275 (1798)

– *Chamecytisus ratisbonensis* auct.: Tzvelev (1987); Fedoronchuk (2022).

Type. Belarus. Brest Region, Kobrin District. Vicinities of Verkholesie Village, sandy hills with pines, 29.05.1979, *D.I. Tretiakov & N.V. Kozlovskaya* (neotype MSK, designated here; isoneotypes MSK, MSKU). Fig. 9.

Description. Upright shrubs with basally prostrate stems up to 40(60) cm tall and short branches. Leaves with obovate leaflets, glabrous above, with

appressed hairs 0.4–0.6(0.8) mm long below, petioles sparsely to densely covered with laxly appressed hairs. Flowers strictly lateral, 1–4 in axils, on pedicels 5–10 mm long, pale yellow; calyx 12–14 mm long, with laxly appressed hairs 0.6–0.8 mm long; standard broadly elongate, glabrous above.

Distribution. Europe: Poland, Belarus, Ukraine. This is the first attempt to circumscribe the distribution area of this species.

Ecology. The species occurs in margins of dry pine and mixed forests.

Chromosome counts. 2n = 100 (Parfionaŭ et al. (1975), as *Chamaecytisus* sp.); material collected from native populations in Brest Region of Belarus; vouchers at MSK.

Notes on nomenclature. The first name intended for this species, *Cytisus pubescens* Gilib., was originally introduced in Gilibert (1781), which is included in the list of suppressed works for species and infraspecific taxa, but validly published in a revised version of the same book (Gilibert 1793), which is not suppressed for nomenclatural purposes. Its intended replacement name, *C. lithuanicus*, was validly published in a generally accepted work of the same author (Gilibert 1798). Although the protologue of *C. lithuanicus* essentially recapitulated the information from the protologue of *C. pubescens*, it included no reference to the latter, whereas one of its elements, the illustration of *Cytisus VII* (Clusius 1601), was no longer considered taxonomically identical to the plants observed by Gilibert. As a result of these changes, *C. lithuanicus* is not a superfluous replacement of *C. pubescens*.

Gilibert (1781, 1798) provided an extensive morphological description of the species, which was poorly understood by subsequent authors because of the uncertain taxonomy of *Cytisus* in Belarus and Poland (Syreitschikow 1912; Kreczetowicz 1940). In eastern Poland and western Belarus, four species of *C.* sect. *Tubocytisus* may occur: octoploid (*C. lithuanicus* in our work), tetraploid (*C. cinereus* and *C. ruthenicus*) and diploid (*C. polonicus*) (Sennikov and Tikhomirov 2024a). To understand which of these four species was described by Gilibert, we compared the diagnostic characters extracted from the protologue of *C. lithuanicus* with the characters used as diagnostic in our work (Table 2).

The habit of *C. lithuanicus* described in the protologue agrees with the octoploid species, whereas the match with *C. ruthenicus* (tall erect shrub) is impossible and the correspondence with *C. polonicus* (prostrate shrub) is less likely. The most important character is the calyx length, which immediately rejects *C. polonicus* (shortest calyces), but perfectly matches the octoploid (longest calyces). The peduncle length also disagrees with *C. polonicus*, which typically has shorter pedicels (subsessile flowers), whereas the octoploid plants usually have longer pedicels (lax flowers). *Cytisus cinereus* is similar to the plant described by Gilibert in the calyx length, but its stems are usually taller and pedicels are

Table 2. Comparisons of selected diagnostic characters from the protologue of *Cytisus lithuanicus* (Gilibert 1781, 1798), interpreted using Stearn (1983), with those of *C. lithuanicus*, *C. polonicus* and *C. ruthenicus* (this work).

Characters / species	*C. lithuanicus*, protologue	*C. cinereus*	*C. lithuanicus*, our work	*C. polonicus*	*C. ruthenicus*
Habit	"frutex basi decumbens sed rami erecti"	erect, basally ascending, not prostrate	basally prostrate, with erect branches	prostrate	erect
Plant height	"pedalis & cubitalis" = 30–45 cm	up to 40–60(80) cm	up to 40(60) cm	up to 20 cm	up to 120(200) cm
Calyx length	"sex linearum" = 13.5 mm	11–14 mm	12–14 mm	(7)8–10 mm	10–12 mm
Peduncle length	"vix quator linearum" = less than 9 mm	3–5 mm	5–10 mm	3–5(7) mm	5–7 mm

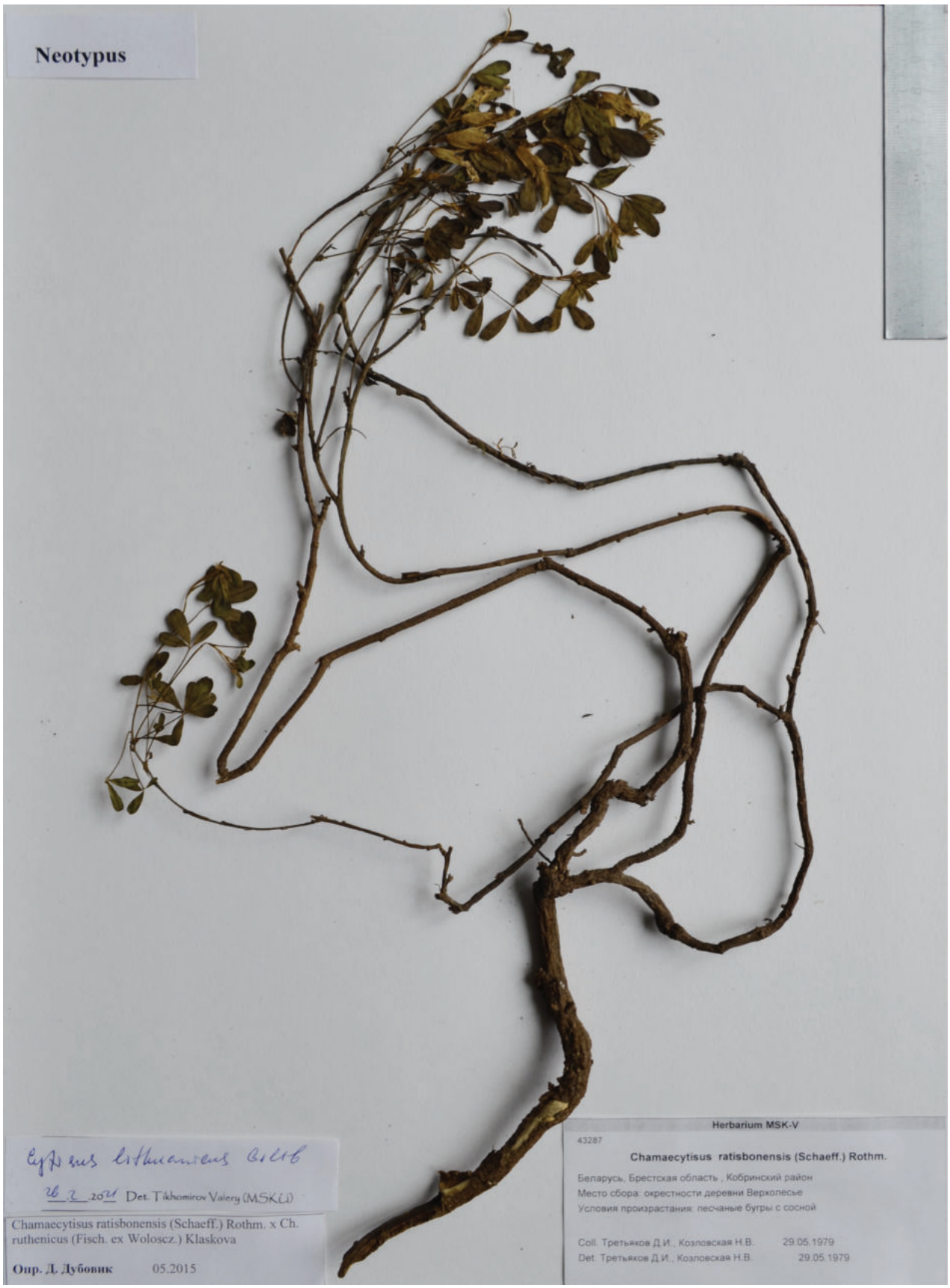

Figure 9. Neotype of *Cytisus lithuanicus* Gilib.

shorter; besides, the pubescence on the calyces of *C. cinereus* is long and laxly appressed to subpatent, and is usually perceived as golden-coloured because of its length and density (Kreczetowicz 1940; Heywood and Frodin 1968; Tzvelev 1987), whereas the calyces of *C. lithuanicus* were described as "albescens", thus indicating a shorter and sparser pubescence like in the octoploid plants.

All these characters strongly indicate that the only species corresponding to the protologue of *C. lithuanicus* can be the octoploid, for which we resurrect this species name here.

Cytisus lithuanicus was described from the western vicinity of Białystok (present-day Poland), which was part of the Grand Duchy of Lithuania at the time of description. The original material was missing in the personal herbarium of Gilibert (KW) already by the beginning of the 20th century (Syreitschikow 1912; Shiyan et al. 2013). In the absence of any material suitable for lectotypification, we designate as neotype a specimen matching the original description and belonging to the population which was caryologically tested.

Notes on taxonomy and distribution. This species was formerly included in *C. ratisbonensis* (Kreczetowicz 1940; Zieliński 1975; Tzvelev 1987) because of its morphological similarity. *Cytisus lithuanicus* differs from *C. ratisbonensis* and *C. polonicus* by its upright stems, and also from the latter species by its longer calyces (12–14 vs. (7)8–10 mm long) and pedicels (5–10 vs. 3–5(7) mm long).

10. *Cytisus wulffii* V.I.Krecz. in Bot. Zhurn. SSSR 25: 262 (1940)

– *Chamaecytisus wulffii* (V.I.Krecz.) Klásk. in Preslia 30(2): 214 (1958).

Type. Crimea. "Prope Yalta, in pineto supra Uchan-su", 7/16.05.1901, *W. Tranzschel* (lectotype LE01080947, designated here; isolectotypes LE01080946, LE01080948). Fig. 10.

Description. Small prostrate shrubs with abundantly branching stems up to 20 cm above ground. Leaves with obovate to oblong leaflets, hairy above, with numerous appressed hairs 0.3–0.7 mm long below, petioles sparsely covered with appressed to spreading hairs. Flowers strictly lateral, 1–4 in axils, on pedicels 3–5 mm long, yellow; calyx 14–15 mm long, with laxly appressed hairs 0.5–1 mm long; standard subrotund, partly hairy above.

Distribution. Europe: Crimea (Tzvelev 1987; Yena 2012; Fedoronchuk 2022).

Ecology. The species occurs on open gravelly and rocky slopes and in alpine meadows at the upper limit of pine forests.

Chromosome counts. Unknown.

Notes on nomenclature. Kreczetowicz (1940) indicated the type of *Cytisus wulffii* in the protologue. He wrote "Typus" on two specimens of the type gathering, which are, therefore, syntypes.

Notes on taxonomy and distribution. This species is most similar to *Cytisus polytrichus* M.Bieb., which occurs in the same area in the Crimea, but in the upper mountain zone and differs by patent (vs. appressed) hairs on its calyces and pedicels. Populations of both taxa may locally overlap (Pifkó and Barina 2016). *Cytisus wulffii* was originally reported also from the neighbouring area in the north-western Caucasus (Kreczetowicz 1940;

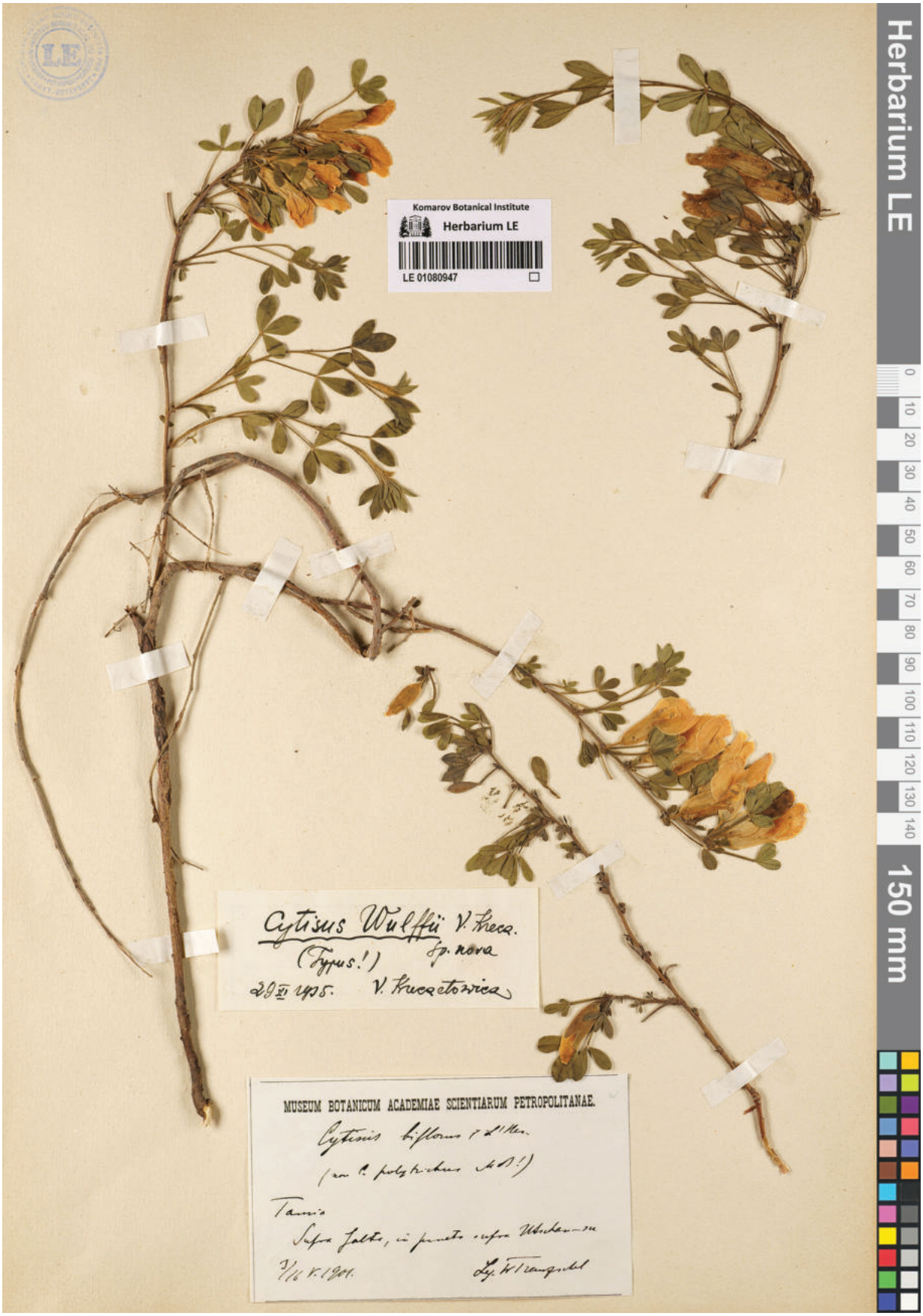

Figure 10. Lectotype of *Cytisus wulffii* V.I.Krecz.

Grossheim 1952; Zernov 2006); these records were rejected (Tzvelev 1987) and referred mostly to *C. elongatus*, which may look similar, but differs in subpatent pubescence.

Identification key to East European species of *Cytisus* sect. *Tubocytisus* (*C. ratisbonensis* group)

1 Leaves glabrous above **2**
– Leaves variously hairy above **6**
2 Pubescence completely appressed, sometimes plants are subglabrous to totally glabrous; calyces with appressed hairs 0.4–0.6 mm long; stems erect, up to 1(1.2) m tall ..... ***Cytisus ruthenicus***
– Pubescence with subappressed to subpatent hairs over 0.6 mm long; stems prostrate or erect and basally ascending, not so tall **3**
3 Flowers smaller; calyces (7)8–10 mm long, hairs 0.6–0.8(1) mm long ..... ***Cytisus polonicus***
– Flowers larger; calyces 11–14 mm long, hairs 0.6–1(1.6) mm long **4**
4 Calyces with laxly appressed hairs 0.6–0.8 mm long ... ***Cytisus lithuanicus***
– Calyces with laxly appressed or subpatent hairs 0.6–1.2(1.6) mm long **5**
5 Calyces with laxly appressed hairs 0.8–1.2(1.6) mm long; stems procumbent, up to 20 cm above ground ..... ***Cytisus ratisbonensis*** **(outside Eastern Europe)**
– Calyces with laxly appressed to subpatent hairs 0.6–1.2(1.5) mm long; stems erect, basally ascending, up to 60 cm tall ..... ***Cytisus cinereus***
6 Calyx 14–15 mm long; stems procumbent, up to 20 cm above ground ..... ***Cytisus wulffii***
– Calyx 10–12 mm long; stems erect or basally ascending, 30–150 cm tall **7**
7 Calyces with appressed or laxly appressed hairs up to 0.6(0.8) mm long **8**
– Calyces with mostly subpatent hairs up to 1.2 mm long **9**
8 Leaflets lanceolate or narrowly lanceolate, densely and evenly hairy above ..... ***Cytisus borysthenicus***
– Leaflets lanceolate to elliptic, sparsely hairy to subglabrous above ..... ***Cytisus kreczetoviczii***
9 Leaves densely and evenly hairy above; calyx with subpatent hairs 0.8–1.2 mm long ..... ***Cytisus elongatus***
– Leaves sparsely hairy to subglabrous or nearly glabrous above; calyx with appressed and subpatent hairs 0.4–0.9 mm long ..... ***Cytisus semerenkoanus***

Conclusions

Our treatment is a further development of Cristofolini (1991), which improves the taxonomic and distributional data from Eastern Europe and neighbouring territories, based on much greater sampling of herbarium specimens and observations, and also on the comprehensive examination of type specimens. It is largely congruent with Tzvelev (1987), but avoids excessive taxonomic splitting.

This revision provides a taxonomic backbone for further studies in *Cytisus* sect. *Tubocytisus*. Much further work is still required to establish chromosome counts for all its taxa and to uncover their evolutionary history. Distribution areas in the Balkans and some areas of Central Europe (Slovakia, Hungary) are

unclear because of the lumping approach in local treatments and require complete revision. Recent hybridisation processes remain understudied.

The taxa of *C. ratisbonensis* group can be distinguished by differences in leaf shape and pubescence and in calyx size and pubescence; life form and habit provide important complementary information. These taxa also differ in their distribution areas and in their preference for elevation, substrate and vegetation type.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

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Author contributions

ANS and VNT developed the taxonomic concept and revised the nomenclature. VNT collected and treated the material with the participation of ANS. ANS wrote the manuscript with the input from VNT. Both authors agreed to the final version of the manuscript.

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Data availability

The dataset of distributional records collected for the present work was published through the Internet Archive (available online: https://archive.org/details/cytisus-ratisbonensis-dataset).

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Research Article

Atlas Florae Europaeae notes, 35. Further critical notes on *Cytisus* sect. *Tubocytisus* (Fabaceae) in Europe

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Abstract

A few species names in *Cytisus* sect. *Tubocytisus* are re-assessed and taxonomically evaluated. Diagnostic characters are discussed and the species status of *C. absinthioides* Janka, *C. eriocarpus* Boiss., *C. frivaldszkyanus* Degen, *C. jankae* Velen. and *C. smyrnaeus* Boiss. is confirmed. The holotype of *Cytisus triflorus* Lam. was found to belong to *C. hirsutus* L. rather than to the *C. ratisbonensis* group as currently treated. *Cytisus lasiosemius* Boiss. is not the correct name for *C. frivaldszkyanus* Degen, but another synonym of *C. hirsutus*. *Cytisus litwinowii* V.I.Krecz., which was known solely from the holotype, is a synonym of *C. austriacus* L. s.str. *Chamaecytisus pseudojankae* Pifkó & Barina, reported from a small area shared between Albania, Greece and North Macedonia, is treated as a subalpine variant of *C. austriacus*. *Cytisus tmoleus* Boiss. is removed from the synonymy of *C. eriocarpus* and added to the synonymy of *C. pygmaeus* Willd. *Cytisus falcatus* subsp. *albanicus* Degen & Dörfl. and *C. pubescens* Gilib. are synonymised with *C. hirsutus*. *Cytisus microphyllus* Boiss. is moved from *C. austriacus* s.l. to the synonymy of *C. frivaldszkyanus*, and *C. pindicola* (Degen) Halácsy to the synonymy of *C. jankae*. *Chamaecytisus calcareus* (Velen.) Kuzmanov is accepted as *Cytisus calcareus* (Velen.) Sennikov & Val.N.Tikhom., **comb. nov.**, and its distribution is circumscribed. *Cytisus hirsutus* var. *ciliatus* (Wahlenb.) Hazsl. and *C. polytrichus* var. *subglabratus* Val.N.Tikhom. & Sennikov, **var. nov.** are recognised as glabrous variants of the corresponding species. Lectotypes of *C. ciliatus*, *C. hirsutissimus* K.Koch, *C. jankae*, *C. lasiosemius*, *C. pubescens*, *C. rhodopeus* J.Wagner ex Bornm. and *C. thirkeanus* K.Koch are designated. *Cytisus polytrichus* is reported from the Western Caucasus in place of *C. wulffii* auct.

Key words: Balkans, *Chamaecytisus*, Leguminosae, nomenclature, synonymy, taxonomy, typification

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Introduction

The genus *Cytisus* Desf. nom. cons. is one of the largest genera of tribe Cytiseae Bercht. & J.Presl (Talavera and Salgueiro 1999). Its circumscription is still uncertain due to the lack of modern phylogenetic work; old phylogenies (Cubas et al. 2002; Pardo et al. 2004) indicated unresolved relationships in the *Cytisus*-group in Cytiseae, with some taxa being currently treated as segregate genera *Adenocarpos* DC. or *Argyrocytisus* (Maire) Raynaud, *Calicotome* Link,

Chamaecytisus Link, *Cytisophyllum* O.Lang (e.g. Talavera and Salgueiro (1999); Freiberg et al. (2020); Govaerts et al. (2021)). Due to unresolved relationships with and a morphological similarity of these groups to the core lineages of *Cytisus*, a broad circumscription of *Cytisus* s.l. was advocated by taxonomic experts (Cristofolini 1991; Cristofolini and Conte 2002; Cristofolini and Troía 2006, 2017) and is followed here.

Cytisus sect. *Tubocytisus* DC. (= *Chamaecytisus* Link) is the largest part of *Cytisus* s.l. Its species number varies greatly according to the accepted concept, ranging from about 30 (Cristofolini and Troía 2006) to 43 (Govaerts et al. 2021). The species in this group may be very similar to each other, being different in minor characters of dimensions and pubescence (Cristofolini 1991; Cristofolini and Troía 2017). This fact poses a natural difficulty in the taxonomic delimitation of this group and is responsible for wide discrepancies and contradictions in taxonomic assessments between individual researchers (e.g. Gibbs (1970); Tzvelev (1987); Cristofolini (1991); Pifkó (2009)).

Published treatments of *Cytisus* sect. *Tubocytisus* varied in detail, but remained consistent in one major feature, i.e. a high level of taxonomic splitting, resulting in narrowly delimited taxa with faint, but constant differences in pubescence, dimensions, leaf shape and habit (Sennikov and Tikhomirov 2024a). Certain deviations observed between particular treatments may be better explained by some material being inaccessible to individual researchers, thus accounting for lumping of single species or misinterpretation of particular species names.

In the present contribution, we provide notes on some species of *Cytisus*, mostly in Central and Eastern Europe and the Balkans, which require taxonomic or nomenclatural corrections. This study is based on our examination of the original material and protologues of relevant species names, which allowed us to match otherwise discrepant taxonomic decisions made by various researchers (e.g. Gibbs (1970); Cristofolini (1991); Pifkó (2005, 2009); Pifkó and Barina (2016)).

The scope of this study is limited to a selection of species belonging to three groups of *C.* sect. *Tubocytisus*, i.e. *C. hirsutus* (stems erect or prostrate, inflorescences terminal and lateral, leaflets elliptic-lanceolate to oblanceolate, hairs long patent), *C. austriacus* (stems erect, inflorescences terminal, leaflets lanceolate, apically narrowed, hairs strigose, mostly appressed), *C. pygmaeus* (stems ascending, inflorescences terminal, leaflets elliptic-lanceolate to obovate-lanceolate, hairs long and short, appressed, subpatent or patent). One more species-rich and taxonomically problematic group, *C. ratisbonensis*, is treated separately elsewhere (Sennikov and Tikhomirov 2024a, b).

This revision contributes taxonomic and nomenclatural corrections to the mapping programme for “Atlas Florae Europaeae”.

Material and methods

This study is based on herbarium specimens, examined by traditional morphological method. The diagnostic characters used in this study are the same as in Cristofolini (1991) and Sennikov and Tikhomirov (2024a).

The synonymy is based on our examination of original material available through online resources (JSTOR, JACQ) and protologues. Type designations follow the latest rules of botanical nomenclature (Turland et al. 2018). New typifications are illustrated by scanned images of herbarium specimens.

Species descriptions are omitted. Instead, diagnostic characters are discussed and comparison tables are provided for species groups.

Country-level species distributions are compiled from reliable literature and accessible herbarium specimens (B, BR, H, JE, K, L, LE, LY, MA, MW, PRC, RB, U, W, WU), which were examined largely online as scanned images via JSTOR (https://www.jstor.org) and JACQ Virtual Herbaria (https://www.jacq.org). We also used human observations documented by photographs, which were available online via iNaturalist (https://www.inaturalist.org/). The distributions in the Balkans may be incomplete due to insufficient level of local studies and limited availability of herbarium material. Some species with critically revised circumscriptions are mapped. The list of specimens or observations examined and used in mapping is made available through Internet Archive (Tikhomirov and Sennikov 2023).

Results

Cytisus hirsutus group

Taxonomy. The diagnostic character of this species group is long patent (horizontally spreading) stiff hairs on calyces and pedicels. This group requires a thorough revision on the account of its high morphological variability. In our notes, we concentrate on selected species whose type material is known to us.

1. *Cytisus hirsutus* L., Sp. Pl. 2: 739 (1753)

= *Cytisus supinus* L., Sp. Pl. 2: 740 (1753). Type. [icon] *Cytisus* VII in Clusius, Rar. Pl. Hist.: 96 (1601) (lectotype designated by Cristofolini and Jarvis (1991: 498)).

= *Cytisus triflorus* Lam., Encycl. 2(1): 250. 1786, syn. nov. – *Chamaecytisus triflorus* (Lam.) Skalická in Preslia 58: 23 (1986). Type. Italy. "Des environs de Naple", [1785], *M. Vahl* in Herb. Lamarck (holotype P). Fig. 1.

= *Cytisus pubescens* Gilib. in Usteri, Del. Opusc. Bot. 2: 365 (1793), syn. nov. Type. [icon] *Cytisus* VII in Clusius, Rar. Pl. Hist.: 96 (1601) (lectotype designated here).

= *Cytisus falcatus* Waldst. & Kit., Descr. Icon. Pl. Hung. 3: 264, t. 238 (1812) – *Chamaecytisus falcatus* (Waldst. & Kit.) Holub in Folia Geobot. Phytotax. 18(2): 204 (1983) – *Chamaecytisus triflorus* subsp. *falcatus* (Waldst. & Kit.) Pifkó in Stud. Bot. Hung. 38: 13 (2007). Type. Croatia. "In alpe Plissivicza et in monte Merszin", *P. Kitaibel* in Herb. Kitaibel XXIV: 170 (lectotype BP, designated by Kováts (1992: 40)).

= *Cytisus hirsutissimus* K.Koch, Linnaea 19(1): 62 (1846) – *Cytisus hirsutus* var. *hirsutissimus* (K.Koch) Boiss., Fl. Orient. 2: 51 (1872) – *Chamaecytisus hirsutus* subsp. *hirsutissimus* (K.Koch) Ponert in Feddes Repert. 83(9–10): 619 (1973) – *Chamaecytisus hirsutissimus* (K.Koch) Czerep., Sosud. Rast. SSSR: 229 (1981). Type. Turkey. Trabzon Province: "Litus australis Pontus Euxini", [1843], *Thirke* (lectotype LE 00013762, designated here; isolectotype LE). Fig. 2.

Figure 1. Holotype of *Cytisus triflorus* Lam.

= *Cytisus lasiosemius* Boiss. in Tchihatcheff, Asie Min., Bot. 1: 12 (1860), syn. nov. – *Chamaecytisus lasiosemius* (Boiss.) Pifkó in Barina, Distrib. Atlas Vasc. Pl. Albania: 466 (2017) – *Chamaecytisus heuffelii* subsp. *lasiosemius* (Velen.) Niketić in Bull. Nat. Hist. Mus. Belgrade 14: 84 (2021). Type. Turkey. "Asia Minor, OEst, 1858" [= between Samsun and Tekkeköy], 1858, *P.A. Tchihatcheff 629* (lectotype P 02952886, designated here). Fig. 3.

= *Cytisus falcatus* subsp. *albanicus* Degen & Dörfl. in Denkschr. Kaiserl. Akad. Wiss., Wien. Math.-Naturwiss. Kl. 64: 717 (1897), syn. nov. – *Chamaecytisus triflorus* var. *albanicus* (Degen & Dörfl.) Micevski, Fl. Republ. Makedonija 1(5): 1135 (2001). Type. North Macedonia. "In locis humosis ad Neresi prope Üsküb [Skopje]", 02.05.1893, *I. Dörfler 126* (syntype WU 068283).

Type. Italy. Sassari: Olbia ("Prope Olbyam in Galloprovincia"), Herb. Burser XXII: 5 (lectotype UPS, designated by Cristofolini and Jarvis (1991: 498)).

Taxonomy. This species has dimorphic inflorescences (Cristofolini 1991) and leaves densely hairy above. Cristofolini (1991) included various glabrescent forms into this species, which we prefer to exclude because such forms are not parts of the infraspecific variability in the material that we have examined.

Distribution. Europe: mountain areas from western France to the Eastern Carpathians longitudinally, from southern Poland to southern Italy latitudinally (Cristofolini 1991; Cristofolini and Troía 2017).

Notes on nomenclature. In the protologue of *Cytisus supinus*, Linnaeus (1753) cited three synonyms borrowed from Clusius (1601), of which one synonym ("*Cytisus* VII. species altera Clus. hist. 1. p. 96") was cited twice. This erratic way of citation evokes the idea of corrupted references. We checked these double-cited references against the relevant synonyms in Bauhin (1671), which were linked with Clusius (1601) by Linnaeus (1753) and in the earlier treatments of Clusius (1583). The first instance of this reference, cited by Linnaeus (1753), belongs to *Cytisi* VII. species altera (Clusius 1601: 97), which is not accompanied by any illustration. The second citation actually refers to *Cytisus* VII (Clusius 1601: 96) with an illustration, which was designated by Cristofolini and Jarvis (1991: 498) as a lectotype of *C. supinus*. Although Cristofolini and Jarvis (1991) cited *Cytisus* VII. species altera as the lectotype, they unambiguously referred to the same illustration as Linnaeus, thus making the same technical citation error. We provide a correct citation here.

The protologue of *Cytisus triflorus* was based on the only cited specimen collected by Martin Vahl in Naples in 1785 (collection date from Lanzoni (1930)). This specimen was designated as a lectotype by Skalická (1986), but is most likely the holotype.

The species name *Cytisus triflorus* was misfortunately resurrected from oblivion by Skalická (1986) and accepted by Cristofolini (1991) for a segregate of *C. ratisbonensis* s.l., which is superficially similar to and often confused with *C. hirsutus*. Skalická (1986) examined the type specimen of this species name on the basis of a photograph which apparently did not show its features of pubescence. We requested a high-quality scanned image of the type from P-Lam; its examination revealed that the calyces, pedicels and petioles of this plant are covered by long upright setose hairs, which do not cover the plant tissues. These hairs are clearly distinct from the subappressed pubescence of dense thin hairs in the *C. ratisbonensis* group, which completely covers the plant parts,

Figure 2. Lectotype of *Cytisus hirsutissimus* K.Koch.

and correspond to the characters of *C. hirsutus*. Since the usage of this plant name after Skalická (1986) is relatively new and unstable (e.g. in Eastern Europe, the name *C. lindemannii* is still used for this species: Czerepanov (1995), Fedoronchuk (2019)) and the taxonomy of the *C. ratisbonensis* group has been in flux, the disappearance of this species name will not be of principal inconvenience for the users of plant nomenclature.

Cytisus pubescens Gilib. was originally introduced in Gilibert (1782), which is included in the list of suppressed works, thus disavowing valid publication of all new names of species and infraspecific taxa published in this book. This species name was validly published in a revised version of the same book (Gilibert 1793) which was reprinted from its original, also suppressed edition (Gilibert 1785). Since the reprint was not explicitly suppressed, its species plant names are considered validly published and may compete for priority (e.g. Ardenghi (2015)).

There are no extant herbarium specimens associated with the protologue of *C. pubescens* (Shiyan et al. 2013). The only element of its original material in existence is an illustration cited in the protologue, *Cytisus* VII (Clusius 1601: 96). This illustration is drawn from plants occurring in Spain ("praesertim Baetica"; this Roman Province largely corresponds to Andalucia) and represents *C. hirsutus* (Cristofolini and Jarvis 1991). Although Gilibert (1793) clearly described a plant of the *C. ratisbonensis* group under his *C. pubescens*, the illustration cited in the protologue mandates the reduction of this species name to a synonym of *C. hirsutus*, which is formally effected here by lectotypification.

Cytisus falcatus was described as a relative of *C. hitsutus* (Waldstein & Kitaibel, 1812). Its pods are hairy and leaflets are sparsely hairy above, thus indicating the synonymy with *C. hirsutus* rather than *C. ciliatus* as treated by Micevski (2001) and Pifkó (2005). Cristofolini (1991) erroneously added *C. falcatus* to the synonymy of *C. triflorus* (which was a member of the *C. ratisbonensis* group in his sense).

The main collection of K.Koch was acquired to B in 1913 (Ulbrich 1917) and subsequently destroyed with few exceptions (Lack 1978). The specimens of *Cytisus* described by Koch survived at LE only (Edmondson and Lack 1977), and this material is designated as a lectotype of *C. hirsutissimus* here. Thirke labelled his collections with very generic designations. but Koch (1846) recorded that Thirke's collecting activities took place around Trabzon and, to a lesser extent, Samsun in 1843.

We traced two specimens from the original collection of *C. hirsutissimus* at LE. As the protologue states that calyces of this species are covered by horizontally spreading hairs (Koch 1846), thus corresponding to the diagnostic characters of *C. hirsutus*, we designate a specimen (LE 00013762) whose characters are in complete agreement with the protologue.

Some authors (Kreczetowicz 1940; Grossheim 1952; Portenier and Solodko 2002) treated *C. hirsutissimus* as endemic to the Caucasus, which reportedly differed from the East European *C. lindemannii* (= *C. elongatus*) in longer pedicels and a patent (vs. subappressed) pubescence of the whole plant. These minor and variable characters cannot be considered species-specific, and *C. hirsutissimus* of these authors was correctly identified with *C. triflorus* (Cristofolini 1991). Gibbs (1970) placed *C. hirsutissimus* in the synonymy of *C. hirsutus* on account of its lateral inflorescences (his treatment maintained the difference between *C. hirsutus* and *C. supinus*, thus artificially dividing a single species with dimorphic inflorescences, whereas *C. triflorus* is a species with monomorphic lateral inflorescences). Our designated lectotype confirms the latter synonymisation.

Cytisus lasiosemius Boiss. was described from Asiatic Turkey ("inter Samsun et Tekekoi [Tekkeköy]", now Bayraktepe National Park, Samsun Province). In the protologue, Boissier (Tchihatcheff 1860) compared the new species with *C. supinus* (= *C. hirsutus*), and distinguished it from the latter by acute leaflets and hairy standard. These characters are variable within *C. hirsutus*, and Gibbs (1970)

Figure 3. Lectotype of *Cytisus lasiosemius* Boiss (Tchihatcheff 629).

rightly placed *C. lasiosemius* to the synonymy of his *C. supinus*. On the contrary, Cristofolini (1991) accepted *C. lasiosemius* as a priority name for *C. frivaldszkyanus* Degen, which also has rather patent hairs. This treatment cannot be accepted because the pubescence of *C. lasiosemius* is composed of long, sparsely situated horizontal hairs on its stems, petioles and pedicels, typical of *C. hirsutus*, whereas the pubescence of *C. frivaldszkyanus* is very densely covering the stems, petioles and pedicels and consists of both long and short curved hairs, like in the *C. ratisbonensis* group (Sennikov and Tikhomirov 2024a). We confirm the opinion of Gibbs (1970) and add *C. lasiosemius* to the synonymy of *C. hirsutus*.

The original material of *C. lasiosemius* consists of a few specimens collected by P.A. Tchihatcheff in Turkey during 1858 (Tchihatcheff 1860). These specimens are accompanied by tiny field tickets with different field numbers, thus indicating that they are different gatherings. Niketić (2021) designated a complete herbarium sheet at P with three gatherings as a lectotype, which is inadmissible. We restrict this choice to a single gathering numbered 629.

1a. *Cytisus hirsutus* var. *ciliatus* (Wahlenb.) Hazsl. in Verh. K.K. Zool.-Bot. Ges. Wien 1: 201 (1852)

– *Cytisus ciliatus* Wahlenb., Fl. Carp.: 219 (1814) – *Cytisus prostratus* var. *ciliatus* (Wahlenb.) W.D.J.Koch, Syn. Deut. Schweiz. Fl. 1: 155 (1837) – *Cytisus hirsutus* subsp. *ciliatus* (Wahlenb.) Simonk. in Math. Term. Közlem. 22: 376 (1888) – *Chamaecytisus triflorus* subsp. *ciliatus* (Wahlenb.) Holub in Bertová, Fl. Slovenska IV(4): 38 (1988).

= *Cytisus glaber* L.f., Suppl. Pl.: 328. 1782, non Lam. 1779, nom. illeg. (Art. 53.1) – *Chamaecytisus glaber* Rothm. in Feddes Repert. Spec. Nov. Regni Veg. 53: 143 (1944). Type. Not designated.

= *Cytisus serotinus* Kit. ex DC., Prodr. 2: 156 (1825) – *Cytisus hirsutus* var. *serotinus* (Kit. ex DC.) Soó in Veröff. Geobot. Inst. Rübel Zürich 6: 254 (1930). Type. Western Ukraine (Mukachevo) or Romania (Satu Mare). Locality unknown, 1815, *P. Kitaibel* (holotype G-DC barcode G00477721; isotypes BM barcode BM000750883, M barcode M0210789).

Type. Slovakia. Žilinský kraj: "Hradska hola" [Hradská Hora], 30.07.1813, *G. Wahlenberg* (lectotype UPS V-1016663, designated here). Fig. 4.

Distribution. Europe: certainly present in Slovakia, Ukraine, Hungary, Romania and the Balkans; reported as "*C. falcatus*" from North Macedonia (Micevski 2001).

Notes on taxonomy and distribution. This taxon was described from the vicinities of Liptovský Hrádok in present-day Slovakia (Wahlenberg 1814) and occurs in the mountains surrounding the Pannonian Plain and in the Balkans (Holub and Bertová 1988; Pifkó 2009 and our data). *Cytisus ciliatus* is closely related to *C. hirsutus*, but differs from the latter by the upper side of its leaf laminae and by pod surfaces being glabrous or nearly so (vs. regularly hairy). So far, we have no evidence that the distribution of hairy and glabrous plants of *C. hirsutus* is separate; this distinction denotes the same casual loss of pubescence as observed in some other species of *Cytisus* (*C. ruthenicus* var. *zingeri* Nenjukov: Sennikov et al. (2021); *C. polytrichus* var. *subglabratus* Val.N.Tikhom. & Sennikov, see below) and corresponds to the rank of variety.

Figure 4. Lectotype of *Cytisus ciliatus* Wahlenb.

Some authors (Bernard 1977) interpreted the name *Cytisus glaber* as corresponding to *C. hirsutus*, which cannot be true because of its leaves glabrous above. Judging from the glabrous leaves of the plant and its occurrence in "Austria", *C. glaber* is an earlier (albeit illegitimate and therefore unusable) synonym of *C. ciliatus* Wahlenb. (*C. hirsutus* s.l.). Tzvelev (1987) formally accepted *Chamaecytisus glaber* (with *C. elongatus* mis-added to its synonymy) and applied it to west Ukrainian and cultivated plants of Central European origin with erect stems, leaves glabrous above, lateral inflorescences and patent pubescence, which agrees with our interpretation.

Cytisus serotinus is a plant with the leaves glabrous above, which belongs to the *C. hirsutus* group. It was originally recognised due to its presumed late flowering season, but merely coincides with *C. ciliatus*.

Notes on nomenclature. Wahlenberg (1814) distinguished *Cytisus ciliatus* from *C. hirsutus*, which was the original name for his material, by the pubescence of its leaves and pods. In the collections of UPS, where the Herbarium of Wahlenberg is housed, two specimens of the original material were found, both corresponding to the original description and the provenance cited in the protologue. One specimen bears precise collection data, but the draft name of the taxon (*C. hirsutus* [...] glabris) written by Wahlenberg, whereas the second specimen bears the final plant name (*C. ciliatus*), but generalised collection data ("e montibus Carpaticis") written by C.P. Thunberg. As both specimens correspond to the taxon as circumscribed by Wahlenberg and are undoubtedly linked with the protologue, we prefer the specimen with exact provenance from the author's collection as a lectotype.

Despite all searches, we were not able to trace any herbarium material linked with the protologue of *C. glaber* (Linnaeus filius 1782), in which a species with the leaves glabrous above and slightly hairy below was described from "Austria". The only original element, an illustration of "Cytisus glaber, siliqua angusta" in Bauhin and Cherler (1650: 373) was rejected by Cristofolini (1991) as conflicting with the original description (calyces depicted as campanulate, whereas the protologue stated the calyx being "oblongus subventricosus"), although this presumed conflict may be explained by the crude nature of this drawing. So far, this species name remains untypified and interpreted on the basis of the protologue (Tzvelev 1987).

A later synonym belonging to the same taxon is *C. serotinus* Kit. ex DC. (Candolle 1825), described from historical "Hungary" without a further specification. Pifkó (2005) designated a lectotype at BP; since no specimens were cited by Candolle as syntypes, his only specimen used for the original description is the holotype, and the lectotype at BP has no standing. The only original specimen in Candolle's herbarium at G is lacking a precise provenance, which can be derived from comparisons with the main collections of P. Kitaibel kept at BP (Jávorka 1957) and from the diaries of Kitaibel (Gombocz 1945; Lőkös 2001).

Three specimens identified as *C. serotinus* are preserved in the herbarium of Kitaibel at BP (Pifkó 2005), collected near Mukachevo in present-day Ukraine and at Gödöllő in present-day Hungary. Kitaibel (Lőkös 2001) also mentioned that he collected this species near Szatmár (now Satu Mare in Romania, near the border with Hungary and Ukraine). The specimen at G-DC is dated as received in 1815 and seemingly was collected during that year on the way from Mukachevo to Satu Mare (Lőkös 2001).

2. *Cytisus polytrichus* M.Bieb., Fl. Taur.-Caucas. 3: 477 (1819)

– *Cytisus hirsutus* var. *polytrichus* (M.Bieb.) Briq., Étud. Cytises Alpes Mar.: 171 (1894) – *Cytisus hirsutus* subsp. *polytrichus* (M.Bieb.) Hayek in Repert. Spec. Nov. Regni Veg. Beih. 30(1): 898 (1926) – *Chamaecytisus polytrichus* (M.Bieb.) Rothm. in Feddes Repert. Spec. Nov. Regni Veg. 53: 144 (1944) – *Chamaecytisus hirsutus* subsp. *polytrichus* (M.Bieb.) Ponert in Feddes Repert. 83: 619 (1973).

= *Cytisus demissus* Boiss., Fl. Orient. 2: 54 (1872) – *Cytisus hirsutus* var. *demissus* (Boiss.) Halácsy, Consp. Fl. Graec. 1: 337 (1900) – *Chamaecytisus polytrichus* var. *demissus* (Boiss.) Kuzmanov in Jordanov, Fl. Narodna Republ. Bulg. 6: 82 (1976). Type. Greece. "In Olymp. Thessaliae", *P. Aucher-Éloy 1111* (holotype G; isotypes BM 000750882, K 000829496, MPU 023084).

Type. Crimea. "Taur. merid.", Herb. Bieberstein (lectotype LE 01080952, designated by Krytzka et al. (1999: 611)).

Distribution. Europe: France, Italy, Balkans, Greece, Crimea (Cristofolini 1991); Asia: Russian Western Caucasus.

Notes on taxonomy and distribution. *Cytisus polytrichus* sharply differs from *C. hirsutus* in its creeping stems, small leaves and constantly axillar flowers (Cristofolini 1991).

Plants of this species have been known from the Western Caucasus under a wrong name, *C. wulffii* auct. (Kreczetowicz 1940; Grossheim 1952). The latter species is endemic to the Crimea and differs from *C. polytrichus* in appressed (vs. strictly patent) hairs on its leaves and calyces (Sennikov and Tikhomirov 2024a).

Notes on nomenclature. Krytzka et al. (1999) designated the only suitable specimen at LE as lectotype, following the unpublished annotation by N.N. Tzvelev.

2a. *Cytisus polytrichus* var. *subglabratus* Val.N.Tikhom. & Sennikov, var. nov.
urn:lsid:ipni.org:names:77336842-1

Type. Russia. Krasnodar Region: Krasnaya Poliana, Chugush Mt., Osmanova Poliana, alt. 2140 m, rocky subalpine meadows, 11.07.1982, *E. Mordak 1920* (holotype LE 01070725).

Diagnosis. Leaves and young branches subglabrous.

Distribution. Asia: Russian Western Caucasus. So far, known from the holotype.

Notes on taxonomy and distribution. Plants of this variety were found within the same distribution area as the type variety, thus indicating infrapopulation variability.

Cytisus austriacus group

Table 1

Taxonomy. The diagnostic characters of this species group are erect stems, dense capitate inflorescences and long thin silky hairs on calyces and pedicels. The knowledge on this group is highly incomplete, especially regarding the variability of *Cytisus austriacus* L. s.l.

Table 1. Diagnostic characters in the *Cytisus austriacus* group.

	C. absinthioides	***C. austriacus***	***C. frivaldszkyanus***	***C. jankae***	***C. calcareus***
stems	tall (30–60 cm), erect, hairs 0.3–0.6 mm long, appressed, sericeous	tall (20–50(70) cm), erect, hairs 1.5–2.5 mm long, appressed	low (10–30 cm), ascending, hairs 1.5–2.0 mm long, subpatent	low (10–20 cm), ascending, hairs (0.7–)1.0–2.0 mm long, laxly appressed	low (10–40 cm), ascending, hairs (0.7–)1.0–2.0 mm long, laxly appressed
leaves	leaflets narrowly lanceolate, acute, hairs 0.3–0.6 mm long, appressed, sericeous	narrowly lanceolate to lanceolate, acute, hairs 1.5–2.5 mm long, appressed	leaflets elliptic-lanceolate to obovate, broadly acute, hairs 0.8–1.5 mm long, subpatent	lanceolate or slightly oblanceolate, acute, hairs (0.5–)0.8–1.5 mm long, appressed	leaflets elliptic-lanceolate to obovate, broadly acute, hairs (0.5–)0.8–1.5 mm long, appressed
pedicels	hairs 0.3–0.6 mm long, appressed	hairs 1–2 mm long, laxly appressed	hairs 1.0–2.0 mm long, subpatent to patent	hairs 1.0–2.0 mm long, laxly appressed	hairs 1.0–2.0 mm long, laxly appressed to subpatent
calyx	7–9 mm long, hairs 0.3–0.8 mm long, appressed	10–13 mm long, hairs 1–2.5 mm long, laxly appressed to subpatent	10–12 mm long, hairs 1.3–2.5 mm long, subpatent to patent	(8–)10–13 mm long, hairs 1.0–2.2 mm long, laxly appressed	10–13 mm long, hairs 1.5–2.5 mm long, laxly appressed to subpatent
pods	hairs appressed	hairs appressed	hairs patent	hairs appressed	hairs appressed to subpatent

3. *Cytisus austriacus* L., Sp. Pl., ed. 2, 2: 1042 (1763)

– *Chamaecytisus austriacus* (L.) Link, Handb. 2: 155 (1831).

= *Cytisus supinus* var. *noeanus* Briq., Étud. Cytises Alpes Mar.: 182 (1894) – *Cytisus austriacus* subsp. *noeanus* (Briq.) Jáv., Magyar Fl. 2: 608 (1924). Type. Greece. "Rumelia" [Nicopolis], 06.1846, *Noe* [251] (syntype K 000829490).

= *Cytisus litwinowii* V.I.Krecz. in Bot. Zhurn. SSSR 25: 256 (1940), syn. nov. – *Chamaecytisus litwinowii* (V.I.Krecz.) Klásk. in Preslia 30: 214 (1958). Type. Russia. Belgorod Region: Korocha Town, "Pushkarnoe forest" [west of Pushkarnoe Village], hills, on calcareous substrate, 05.1893, *I. Schirajewsky* (holotype LE 01080951). Fig. 5.

= *Chamaecytisus pseudojankae* Pifkó & Barina in Stud. Bot. Hung. 47(1): 169 (2016), syn. nov. Type. Albania. District of Korçë (Rrethi i Korçës), Thatë Mountains (Mali i Thatë), ca 1.7 km north of village "Zvezdë", on the south-eastern ridge of Mount "Zvezdë" (1,833 m), in rocky grassland, on limestone, 40.74774°N, 20.86148°E, 1477 m elev., 25.05.2007, *Z. Barina, D. Pifkó & Cs. Németh 11736* (holotype BP 750418; isotype W 2010-03241).

Type. Historical Hungary ("Ungaria"). Herb. Burser XXII: 3, left-hand specimen (lectotype UPS, designated by Cristofolini in Turland and Jarvis (1997: 468)).

Distribution. Europe: mountainous regions from Austria to western Ukraine and from southern Poland to Greece and European Turkey, with the presence in southern East European uplands; Asia: Turkey, Russian Caucasus (Gibbs 1970; Tzvelev 1987; Cristofolini 1991).

Notes on taxonomy. This species is highly variable in respect of the pubescence on its leaves and calyces and is currently recognised in a broad sense, with some infraspecific taxa (Cristofolini 1991). Our current treatment is focused on the typical plants, corresponding to *C. austriacus* s. str.

A short-leaved variant of the species was separated as *C. austriacus* subsp. *microphyllus* "(Boiss.) Boiss." by Cristofolini (1991), probably because of *Baldacci 315* (BM 000750880) which was the basis for the treatment of *C. austriacus* var. *microphyllus* in Baldacci (1899). This collection from Mt. Smolikas in north-western Greece consists of subalpine plants of *C. austriacus* s. str. which

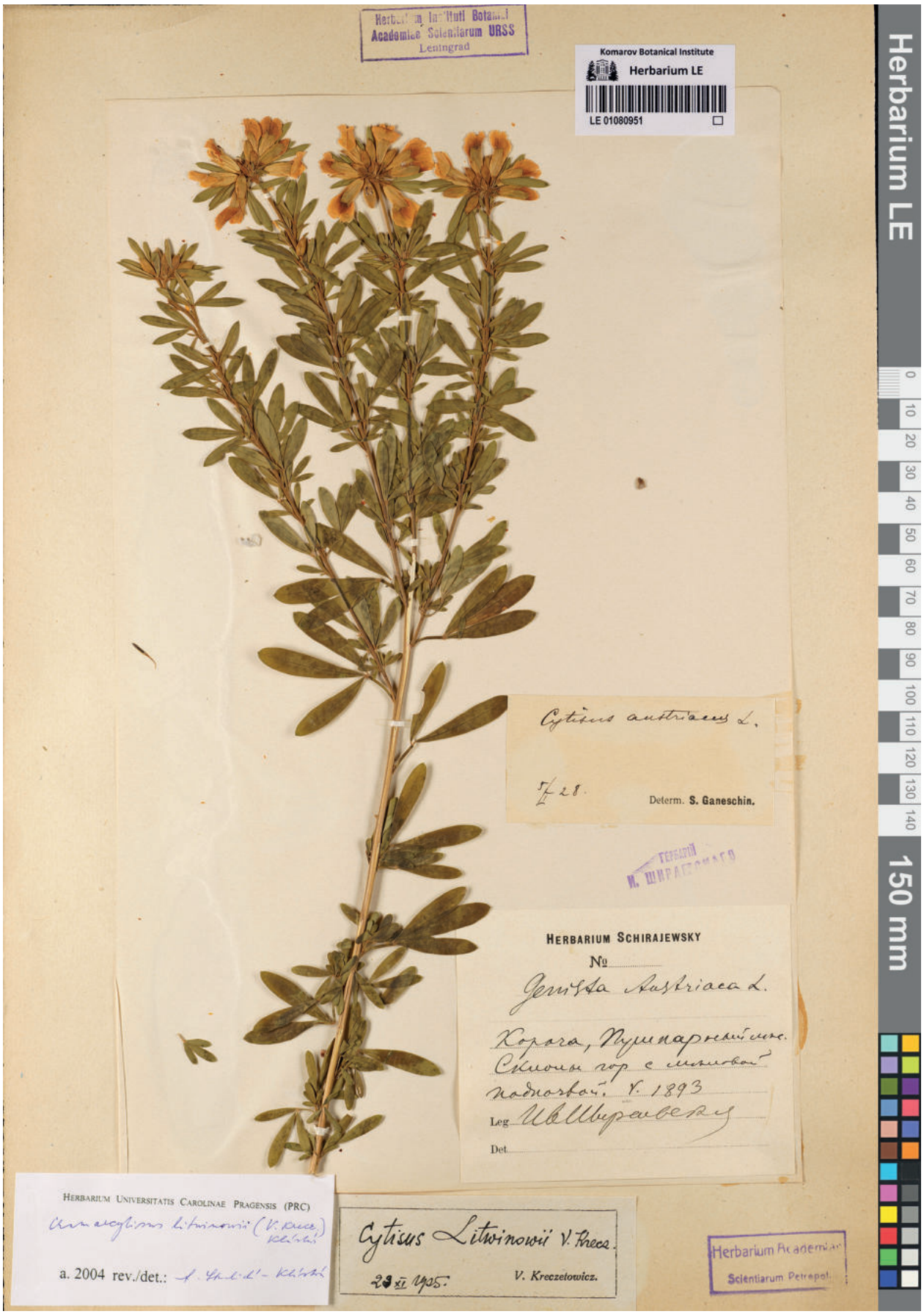

Figure 5. Holotype of *Cytisus litwinowii* V.I.Krecz.

have regrown after damage and developed smaller leaves, otherwise being in agreement with the type.

Notes on nomenclature. *Cytisus litwinowii* V.I.Krecz. was described as a local endemic of the Central Russian Upland, confined to calcareous substrates (Kreczetowicz 1940). This plant was originally distinguished because of its lesser developed pubescence and golden-yellow flowers, which are smaller than in *C. blockii* V.I.Krecz. (= *C. kerneri* Błocki). Another reason to distinguish this plant as a separate taxon was its confinement to the area of presumably relic pine forests and shrublands of the steppe area of Central European Russia, which reportedly harboured endemic taxa of Tertiary age (Kozo-Polansky 1931). However, this area of endemism has been confuted by other researchers, who considered its age being early postglacial and its relics being taxonomically indistinct (Grosset 1964). Among the presumed endemics of this territory, *Daphne julia* K.-Pol. turned out to be a synonym of *D. cneorum* L. (Grosset 1964) and *Tanacetum alaunicum* K.-Pol. was synonymised with *Chrysanthemum zawadskii* Herbich (Tzvelev 1994), whereas *Cotoneaster alaunicus* Golitsin appeared to be a synonym of *C. integerrimus* Medik. (Sennikov 2011).

Further authors (Heywood and Frodin 1968; Tzvelev 1987) accepted *C. litwinowii* and distinguished it from *C. austriacus*, which also occurs in Central European Russia, by its leaflets glabrous or very poorly (sparsely) pubescent above (vs. densely appressed-hairy in *C. austriacus*). Following these authorities, *C. litwinowii* was accepted in major compilations (Yakovlev et al. 1996; Govaerts et al. 2021).

We examined the holotype of *C. litwinowii* at LE and realised that the leaflets of this plant, which had grown in the shade, are regularly pubescent above, but the hairs are poorly recognisable due to overpressing. As pubescence of leaflets was the main diagnostic characters for *C. litwinowii* and no other material of the taxon is known, but the holotype, we reduce it to a synonym of *C. austriacus*. The placement of *C. litwinowii* in the synonymy of *C. blockianus* Pawł. (Cristofolini 1991), which was accepted by some databases (Roskov et al. 2006), cannot stand because the latter species does not occur east of the Carpathians (Tzvelev 1987). Besides, the bright flower colour of *C. litwinowii* agrees particularly with the characters of *C. austriacus*, rather than the pale flower colour of *C. blockianus* (Tzvelev 1987).

Pifkó and Barina (2016) described *C. pseudojankae* Pifkó & Barina as a strongly branching plant with undeveloped axillar shoots, small, narrowly lanceolate leaflets and laxly appressed pubescence, which they compared with the *C. austriacus* aggr., but placed in the *C. eriocarpus* aggr. Such plants were considered endemic to a restricted area near Lake Prespa at the borders of Albania, North Macedonia and Greece (Pifkó and Barina 2016; Bergmeier et al. 2020). According to the description and drawing of *C. pseudojankae* in Pifkó and Barina (2016), this taxon is very similar to *C. austriacus* in its strong and upright stems (vs. weak and ascending stems in *C. eriocarpus* s.l.), habit and narrowly lanceolate leaf shape.

The original material of *C. pseudojankae* (Pifkó and Barina 2016) consists of plants superficially looking like having lateral flowers; however, these plants are typical members of the *C. austriacus* group with capitate inflorescences, and the seemingly lateral flowers observed in *C. pseudojankae* are a result of its abundant branching, with the uppermost branches, much abbreviated, going

to flower and thereby forming a pseudolateral inflorescence. Their leaves are similar to those of the plants treated as *C. austriacus* subsp. *microphyllus* by Cristofolini (1991).

4. *Cytisus jankae* Velen. in Abh. Königl. Böhm. Ges. Wiss. 1889: 31 (1890)

– *Chamaecytisus jankae* (Velen.) Rothm. in Feddes Repert. 53: 144 (1944) – *Chamaecytisus heuffelii* subsp. *jankae* (Velen.) Niketić in Bull. Nat. Hist. Mus. Belgrade 14: 83 (2021).

= *Cytisus austriacus* var. *pindicola* Degen in Nuovo Giorn. Bot. Ital., nov. ser. 6: 152 (1899), "pindicolus", syn. nov. – *Cytisus pindicola* (Degen) Halácsy, Consp. Fl. Graec. 1(2): 338 (1901). Described from a few localities in north-western Greece (syntypes K 000829489, PRC 454944, 454945, WU-Halácsy 0072806).

Type. Bulgaria. Razgrad Region: "In colle Golem Jug prope Razgrad", 07.1885, *J. Velenovský* (lectotype PRC 451243, single plant above the label, designated here). Fig. 6.

Distribution. Europe: Balkan Peninsula (Albania, Bulgaria, Greece, North Macedonia, Serbia) (Diklić 1972; Kuzmanov 1976; Micevski 2001; Assyov and Petrova 2012; Barina et al. 2018; Niketić 2021). Fig. 7.

Notes on taxonomy. Cristofolini (1991) placed *C. jankae* next to *C. austriacus*, thus indicating their affinity. Both species share capitate inflorescences, lanceolate leaves and rather appressed pubescence on all green parts, but *C. jankae* differs from *C. austriacus* s.str. by its constantly small size and prostrate habit. Its recent subordination to *C. heuffelii* (Niketić 2021), which differs in its calyx being 7–8 mm long (vs. 10–13 mm long in *C. jankae*), is hardly justified.

According to their original material, *C. pindicola* belongs to the synonymy of *C. jankae* as typified here. The synonymisation of *C. pindicola* with *C. frivaldszkyanus* proposed by Barina et al. (2018) is not supported by their diagnostic characters (Table 1).

Notes on nomenclature. The original material of *Cytisus jankae* Velen., mounted as a single specimen (PRC 451243), is highly heterogeneous and consists of six fragments of small plants with stems ascending from woody caudices, with capitate inflorescences and narrow leaves, which are referable to three species. In spite of its apparent heterogeneity, this entire specimen has been recently designated as a lectotype of the species name (Niketić 2021).

Two linear-leaved fragments (top centre, bottom left) on this specimen belong to *C. absinthioides* Janka, which is another species of the Balkans. This species is sometimes (Cristofolini 1991; Govaerts et al. 2021) merged with *C. eriocarpus* Boiss. (syn. *C. smyrnaeus* Boiss.), which is characterised by its leaflets being broadly obovate to elliptic rather than narrowly lanceolate and is totally different in its habit and long spreading pubescence. *Cytisus absinthioides* is characterised by typically upright, strongly branched stems, regular presence of abbreviated sterile shoots in the leaf axils, small flowers (with calyces 7–8 mm long), rather short subpatent pubescence on the stems and dense appressed pubescence of silvery appearance on the leaflets.

Two plants on the left and right sides are characterised by decumbent to ascending stems, narrowly lanceolate or oblanceolate leaflets and subpatent

Figure 6. Lectotype of *Cytisus jankae* Velen. (plant above the label).

Figure 7. Distribution of *Cytisus jankae* Velen.

pubescence on stems and calyces, with less developed sterile shoots in leaf axils. These plants correspond to *C. pygmaeus* Willd., occurring in the Balkans and Turkey.

The plant mounted above the label is similar to *C. pygmaeus*, but differs from the latter in a densely appressed pubescence, the feature corresponding to the original description of *C. jankae* which reads "foliolis linearibus vel lineari-spathulatis ... calycis adpresse sericei ..." (Velenovský 1890). The small fragment alongside the label probably belongs to the same species. As this plant is in good agreement with the protologue, we designate it as a lectotype of *C. jankae*.

Other low-growing and small-leaved variants presumably belonging to the same group are *C. pseudopygmeus* Davidov and *C. georgievii* Davidov, described from the Pontic part of Bulgaria (Davidoff 1902) and synonymised with *C. jankae* by Kuzmanov (1976). We refrain from any assessment of these species names because we were not able to examine any original material.

Cytisus pindicola (Degen) Halácsy agrees with the type of *C. jankae*, but slightly differs from the latter in slightly shorter hairs on stems (0.7–1 mm long vs. 1–2 mm long in *C. jankae*) and leaves (0.5–0.8 mm long vs. 0.8–1.5 mm long in *C. jankae*) and in shorter calyces (8–10 mm long vs. 10–13 mm long in *C. jankae*). *Cytisus pindicola* was previously placed in a subspecies of *C. austriacus* (Cristofolini 1991, as *C. austriacus* subsp. *microphyllus*), but differs from the latter in shorter leaves and a different habit.

The original material of *Cytisus austriacus* var. *pindicola* Degen (Baldacci 1899) consists of four gatherings which were distributed under a single number, as *Baldacci 110*. K.I. Christensen intended to designate a lectotype at W, but the only specimen in that collection is a mixture of four indistinguishable gatherings (Reich et al. 2021). Lectotypification is advisable with Degen's material at BP.

5. *Cytisus calcareus* (Velen.) Sennikov & Val.N.Tikhom., comb. nov.
urn:lsid:ipni.org:names:77336843-1

– *Cytisus pygmaeus* var. *calcareus* Velen., Fl. Bulg. Suppl. 1: 71 (1898) – *Chamaecytisus calcareus* (Velen.) Kuzmanov in Jordanov, Fl. Narodna Republ. Bulg. 6: 103 (1976).

Type. Bulgaria. "Supra Belledihan in calcareis", 05.1893, *J. Velenovský* (lectotype PRC 451952, designated by Kuzmanov (1976: 103)).

Distribution. Europe: Balkan Peninsula (Bulgaria, Greece, North Macedonia, Serbia) (Kuzmanov 1976; Assyov and Petrova 2012). The occurrences outside Bulgaria are confirmed or reported here (Fig. 8). Pifkó and Barina (2016) removed the report of *Chamaecytisus calcareus* from Albania in favour of their *C. pseudojankae*, which we synonymise with *C. austriacus*.

Notes on taxonomy. This miniature plant belongs to the *C. austriacus* group because of its terminal inflorescences, which are rather dense and surrounded by floral leaves. It differs from *C. austriacus* by its short habit, much smaller and shorter, subelliptic (vs. lanceolate) leaves, and from *C. jankae* by the same shape of leaves (although of similar size) and by subpatent (vs. appressed) pubescence of calyces. This species was omitted by Cristofolini (1991) and is currently recognised only in Bulgaria (Kuzmanov 1976; Assyov and Petrova 2012).

Notes on nomenclature. Velenovský (1898) considered this taxon to be intermediate between *C. pygmaeus* and *C. austriacus*. The original material represents a mixture of *C. austriacus* (Kovarna, 08.1897, *Škorpil* (PRC)) and a taxon currently recognised as *C. calcareus* (Kuzmanov 1976). Kuzmanov (1976) designated the latter gathering as lectotype, thus fixing the application of the species name.

Figure 8. Distribution of *Cytisus calcareus* (Velen.) Sennikov & Val.N.Tikhom.

6. *Cytisus absinthioides* Janka in Oesterr. Bot. Z. 22: 175 (1872)

– *Chamaecytisus absinthioides* (Janka) Kuzmanov in Taxon 21: 336 (1972) – *Chamaecytisus heuffelii* subsp. *absinthioides* (Velen.) Niketić in Bull. Nat. Hist. Mus. Belgrade 14: 82 (2021).
– *Cytisus eriocarpus* auct.: Cristofolini (1991).
– *Chamaecytisus eriocarpus* auct.: Pifkó and Barina (2016); Barina et al. (2018).

Type. Bulgaria. "In montibus ad radices m. Perimdagh prope Nevrekop Macedoniae orientalis", 21.08.1871, *V. Janka* (lectotype WU 0033170, designated by Pifkó and Barina (2016: 172); isolectotypes BEOU (s. n.), BP 296809, GOET 005095, W-Reichenb 44808, WU-Halácsy).

Distribution. Europe: Balkan Peninsula (Bulgaria, Greece, Kosovo, North Macedonia) (Diklić 1972; Kuzmanov 1976; Micevski 2001; Assyov and Petrova 2012; Niketić 2021). Fig. 9.

Notes on taxonomy. *Cytisus absinthioides* strikingly differs from any other species of the *C. austriacus* group by its habit, resembling some plants of *Artemisia* due to its tall branched stems with regularly developed sterile branches in leaf axils and dense appressed sericeous pubescence on its leaves and calyces. Its calyces and pods are distinctly small (Janka 1872).

Some recent interpretations (Cristofolini 1991) placed *C. absinthioides* to the synonymy of *C. eriocarpus*, which was treated as a broadly defined and variable species. This placement is not justified because *C. eriocarpus* clearly differs in its habit, leaf shape, subpatent pubescence and longer calyces.

Pifkó and Barina (2016) and Barina et al. (2018) reported the presence of *C. eriocarpus* in Albania, but their description matches *C. absinthioides*. The

Figure 9. Distribution of *Cytisus absinthioides* Janka.

earlier records of *C. eriocarpus* in Greece (Strid 1986) employed the same taxonomic concept and should also belong to the same species (Kuzmanov 1976; Micevski 2001; Assyov and Petrova 2012).

7. *Cytisus frivaldszkyanus* Degen in Oesterr. Bot. Z. 43: 422 (1893)

– *Chamaecytisus frivaldszkyanus* (Degen) Kuzmanov in Jordanov, Fl. Narodna Republ. Bulg. 6: 110 (1976); Kuzmanov in Taxon 24: 504 (1975), comb. inval. (Art. 41.1).

= *Cytisus microphyllus* Boiss., Diagn. Pl. Orient., ser. 2, 2: 5 (1856), non Link (1825), nom. illeg. (Art. 53.1), syn. nov. – *Cytisus austriacus* var. *microphyllus* Boiss., Fl. Orient. 2: 53 (1872) – *Cytisus austriacus* subsp. *microphyllus* (Boiss.) Cristof. in Webbia 45(2): 210 (1991). Type. Greece. "In monte Pelione", *P. Aucher-Éloy 1109* (holotype G; isotypes BM 000750890, K 000829488).

= *Cytisus rhodopeus* J.Wagner ex Bornm. in Bot. Jahrb. Syst. 59(5): 465 (1925) – *Chamaecytisus absinthioides* subsp. *rhodopeus* (J.Wagner ex Bornm.) Kuzmanov in Taxon 21: 336 (1972), comb. inval. (Art. 41.1) – *Chamaecytisus absinthioides* var. *rhodopeus* (J.Wagner ex Bornm.) Micevski, Fl. Macedon. 1(5): 1140 (2001), comb. inval. (Art. 41.1). Type. Bulgaria. "In graminosis decliv. m. Osogovska Planina", 08.1887, *J. Velenovský* (PRC 456104, lectotype designated here). Fig. 10.

– *Cytisus lasiosemius* auct.: Cristofolini (1991).

– *Chamaecytisus supinus* subsp. *lasiosemius* auct.: Niketić (2021).

Type. Bulgaria. "In declivibus dumetosis montis Rhodopes centralis pr. Stanimak (inter Hvojna et Bačkova)", 06.1892, *J. Wagner 39* (syntypes JE, PRC); "In declivibus dumetosis prope Slivno (Balkan)", 07.1893, *J. Wagner* (syntypes JE, PRC); "In dumetosis montis "Čatal Kaje" prope Slivno", 21.07.1893, *J. Wagner 31* (syntype PRC); "Bela Cerkva", *Skorpil* (syntype not traced).

Distribution. Europe: Balkan Peninsula (Bulgaria, Greece, North Macedonia, Serbia) (Kuzmanov 1976; Micevski 2001; Assyov and Petrova 2012; Barina et al. 2018; Niketić 2021) (Fig. 11). This species was reported from Albania (Barina et al. 2018), but the background of this report has not been examined by us.

Notes on taxonomy. This species with subpatent to patent pubescence was accepted by Cristofolini (1991), but under a wrong name, *C. lasiosemius*, probably because of the unavailability of the type collection of the latter species name.

Notes on nomenclature. Degen (1893) described *Cytisus frivaldszkyanus* from a few localities in present-day Bulgaria, citing four syntype gatherings. The examined material is fairly homogeneous, and the application of the species name is unambiguous. So far, we refrain from lectotypification because the main collection of Degen at BP has not been examined by us.

Cytisus rhodopeus was first mentioned in the synonymy of *C. eriocarpus* by Degen (1893) and validly published by Bornmüller (1925) without any descriptive matter, but with a reference to the description of *C. absinthioides* in Velenovský (1891). Five syntypes from Bulgaria were cited in the original description (Velenovský 1891), which deviated much from the description of the true *C. absinthioides* provided by Janka (1872) by a longer calyx (13–15 mm long vs. 7–8 mm long in *C. absinthioides*) with patent (vs. appressed) hairs.

Figure 10. Lectotype of *Cytisus rhodopeus* J.Wagner ex Bornm.

Through the kindness of P. Mráz, we traced a specimen in the collection of J. Velenovský at PRC, which exactly corresponds to the protologue by its diagnostic characters and taxonomic references on its label (to *C. absinthioides* Janka and "*C. eriocarpus* Boiss. var.", as Velenovský (1891) also noted a relationship

Figure 11. Distribution of *Cytisus frivaldszkyanus* Degen.

with the latter species). This specimen fully reflects the taxonomic concept of Velenovský (1891) and is designated as a lectotype of *C. rhodopeus* here.

Cristofolini (1991) accepted *C. austriacus* subsp. *microphyllus* "(Boiss.) Boiss." as the correct name for a small-leaved segregate of *C. austriacus*, citing *C. pindicola* (Degen) Halácsy in its synonymy. The type collection of *C. microphyllus* Boiss. is quite dissimilar from *C. pindicola* and belongs to *C. frivaldszkyanus* because of its strong suberect stems, partly obovate (vs. lanceolate) leaflets and pods with nearly patent (vs. appressed) hairs.

Cytisus pygmaeus group

Table 2

Taxonomy. The diagnostic characters of this species group are mostly prostrate habit and pseudolateral inflorescences. This group is very poorly known and may be an artificial assemblage of superficially similar species. Their distributions need to be verified due to common confusions and misidentifications.

Table 2. Diagnostic characters in the *Cytisus pygmaeus* group.

	C. pygmaeus	***C. eriocarpus***	***C. smyrnaeus***
stems	low (10–20 cm), much branching, hairs 0.3–0.6 (–1.5) mm long, appressed	low (10–20 cm), much branching, hairs 2 mm long, patent	low (10–20 cm), much branching, hairs 0.5–1.0 mm long, appressed to subpatent
leaves	leaflets lanceolate, acute, hairs 0.4–1.0 mm long, appressed	leaflets broadly elliptic to obovate, subrotund, hairs 1.3–1.5 mm long, subpatent	leaflets broadly elliptic to obovate, subrotund, hairs 0.9–1.2 mm long, appressed, sericeous
pedicels	hairs 0.5–0.7 mm long, subpatent	hairs 2–2.5 mm long, patent	hairs 0.5–0.7 mm long, subpatent
calyx	11–14 mm long, hairs 0.5–1.2 mm long, subpatent	10–12 mm long, hairs 2.0–2.5 mm long, subpatent	11–14 mm long, hairs 0.7–1.2 mm long, patent
pods	hairs subappressed	hairs subpatent	hairs subappressed

8. *Cytisus pygmaeus* Willd., Sp. Pl., ed. 4, 3(2): 1127 (1802)

– *Chamaecytisus pygmaeus* (Willd.) Rothm. in Feddes Repert. 53: 144 (1944) – *Chamaecytisus austriacus* subsp. *pygmaeus* (Willd.) Ponert in Feddes Repert. 83: 619 (1973).

= *Cytisus tmoleus* Boiss., Diagn. Pl. Orient., ser. 1, 2: 11. 1843, syn. nov. – *Cytisus eriocarpus* subsp. *tmoleus* (Boiss.) Cristof. in Webbia 45(2): 207 (1991) – *Chamaecytisus tmoleus* (Boiss.) Rothm. in Feddes Repert. Spec. Nov. Regni Veg. 53: 144 (1944). Type. Turkey. "Asia Minor", *P. Aucher-Éloy 1101* (syntypes K 000829770, P 02952916, 02952919).

= *Cytisus chrysotrichus* Boiss., Diagn. Pl. Orient., ser. 1, 2: 12 (1843). Type. Turkey. Bursa Province: "In dumosis Olympi Bithyniae" [= Uludağ Mt.], 06.1842, *E. Boissier* (syntypes K 000829766, 000829767, LE 01207296–01207299, NY 1843152).

= *Cytisus thirkeanus* K.Koch in Linnaea 19(1): 61 (1846). Type. Turkey. Trabzon Province: "Asia minor. Litus australis Pontus Euxini", [1843], *Thirke* (lectotype LE 00013761, designated here; isolectotypes LE 00013760, G-Boiss 00365031). Fig. 12.

Type. Turkey. [Galatia], *D. Sestini* (lectotype B-Willd 13632-010, designated by Pifkó and Barina (2016: 172); isolectotype HAL 0100154).

Distribution. European and Asiatic Turkey, Bulgaria, Greece (Kuzmanov 1976; Cristofolini 1991; Assyov and Petrova 2012), Romania (Fig. 13). Other European records, from North Macedonia and Serbia (Diklić 1972; Micevski 2001), seem to belong mostly to *C. jankae* or *C. calcareus*. A record of *C. jankae* from Romania (Grinţescu 1957) is treated as belonging to *C. pygmaeus* here.

Notes on taxonomy. The leaves of this species may vary slightly from oblong-lanceolate to oblanceolate. Plants with the leaves looking more lanceolate were described as *C. pygmaeus* and *C. chrysotrichus*, whereas plants with rather oblanceolate leaves were named *C. tmoleus* and *C. thirkeanus*. This difference, albeit very subtle, led Cristofolini (1991) to classify *C. pygmaeus* as a subspecies of *C. austriacus*, whereas he placed the plants described as *C. tmoleus* to *C. eriocarpus*. Having examined some material from Asiatic Turkey, we observed both types of leaves in the same plants; this makes the distinction practically impossible.

The pubescence on calyces of *C. pygmaeus* is variable, ranging from semi-patent to subappressed. The type collection of *C. pygmaeus* has clearly semi-patent hairs.

Niketić (2021) provisionally accepted the occurrence of *C. pygmaeus* in Serbia, although the relevant materials have not been examined. Micevski (2001) listed it among doubtful records in North Macedonia. The collections identified as *C. pygmaeus* which we examined from the Balkans belong to *C. jankae*, and we assume that the distribution of *C. pygmaeus* in Europe may be much more limited than it is currently believed.

Notes on nomenclature. Willdenow (1802) described the species without mentioning floral characters. His indication of "Galatia" in the protologue corresponds to the fruiting specimen of D. Sestini in Willdenow's personal collection. A duplicate of this collection was separated to HAL, which allowed Pifkó and Barina (2016) to designate a lectotype at B.

The synonymy above was established already by Boissier (1872), except for the placement of *C. tmoleus*, which he considered to differ in a denser, sericeous

Figure 12. Lectotype of *Cytisus thirkeanus* K.Koch.

Figure 13. Distribution of *Cytisus pygmaeus* Willd.

indumentum of the plant. According to our observations, the density of indumentum in *C. pygmaeus* may look variable, depending on ecological conditions, and the plants described as *C. tmoleus* can be regarded as an extreme variant.

9. *Cytisus eriocarpus* Boiss., Diagn. Pl. Orient., ser. 1, 2: 11 (1843)

– *Cytisus supinus* subsp. *eriocarpus* (Boiss.) Stoj. & Stef., Fl. Bulg. 2: 624 (1925) – *Chamaecytisus eriocarpus* (Boiss.) Rothm. in Feddes Repert. 53: 144 (1944).

Type. Turkey. İzmir Province: "Tmolus ad Bozdagh", 06.1842, *E. Boissier* (K 000829776, lectotype designated by Gibbs (1970: 17); isolectotypes BM 000630427, E 00296045, GOET 005097, K 000829774, KW, LE 01207308, 01207311, 01207312, MEL 2347576, NY 01843146, P 02952858).

Distribution. Asiatic Turkey. European records (Cristofolini 1991; Barina et al. 2018) may be erroneous due to the synonymisation or inclusion of *C. absinthioides* and *C. frivaldszkyanus*.

Notes on taxonomy. This species is very similar to *C. frivaldszkyanus* due to its abundant patent pubescence. However, it differs from the latter in its broadly elliptic to obovate, nearly rotund leaflets, which are apically subrotund (vs. elliptic-lanceolate to obovate, broadly acute in *C. frivaldszkyanus*). *Cytisus eriocarpus* is similar to *C. hirsutus*, from which it differs in its pubescence (abundant short hairs mixed with long patent hairs vs. only long patent hairs in *C. hirsutus*) and smaller subrotund leaflets, as already noted in the protologue (Boissier 1843).

Notes on nomenclature. Gibbs (1970) inadvertently designated a specimen at K as the lectotype of *C. eriocarpus*.

10. *Cytisus smyrnaeus* Boiss., Diagn. Pl. Orient., ser. 1, 2: 10 (1843)

Type. Turkey. "Montes Smyrnae", 06.1842, *E. Boissier* (syntypes BP 208133, E 00296047, FR 003144, GOET 005096, JE 00014575, 00014576, 00014577, K 000829774, KW, MEL 2347575, P 02952937, 02952942, 02952944, 02952950, 02952951, 02952952, JE 00014575, 00014576, 00014577, W 9918, 0031010).

Distribution. Asiatic Turkey.

Notes on taxonomy. *Cytisus smyrnaeus* is a poorly known species, probably endemic to Asiatic Turkey. It is most closely similar to *C. eriocarpus*, from which it differs by the lack of patent hairs on its stems and pedicels (Pifkó and Barina 2016).

Gibbs (1970) and Cristofolini (1991) added *C. smyrnaeus* to the synonymy of *C. eriocarpus*, which was treated broadly and included plants with different kinds of pubescence.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

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ANS and VNT developed the taxonomic concept, revised the nomenclature, collected and treated the material. ANS wrote the manuscript with the input from VNT. Both authors agreed to the final version of the manuscript.

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Data availability

The dataset of distributional records collected for the present work was published through the Internet Archive (available online: https://archive.org/details/cytisus-balkans).

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Research Article

Ophiorrhiza reflexa (Rubiaceae), a new species from a karst region in Guangxi, China

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Abstract

Ophiorrhiza reflexa, a new species from Guangxi, China, is described and illustrated in this study. It is morphologically similar to *O. alatiflora* due to the branched inflorescence, distylous flowers and the tubular-funnelform corolla with five longitudinal wings. The new species can be distinguished from *O. alatiflora* by its erect inflorescence, its smaller and equal-sized calyx lobes 0.5–0.7 mm long, its corolla tubes winged to the middle and the wings straight and its strongly reflexed corolla lobes at anthesis. *Ophiorrhiza reflexa* is assessed as least concern (LC) according to IUCN Categories and Criteria.

Key words: China, new taxon, *Ophiorrhiza*, Rubiaceae, taxonomy

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Introduction

Ophiorrhiza Linnaeus (1753) is a notably species-rich and taxonomically complicated genus in the family Rubiaceae, comprising about 200–300 species (Deb and Mondal 1997; Chen and Taylor 2011; Li 2020) and mainly distributed in tropical and subtropical Asia (Darwin 1976; Lo 1990; Deb and Mondal 1997; Chen and Taylor 2011; Deng and Huang 2012; Hareesh et al. 2015; Wong 2019; Hu et al. 2021; Schanzer and Nabatov 2022; Liu et al. 2023). Species of the genus are annual or perennial herbs and rarely sub-shrubs that can be easily recognised by their obcordate and compressed fruits, which are dehiscent with two valves along a transverse slit at the top (Darwin 1976; Lo 1990; Chen and Taylor 2011; Wu et al. 2019). Though the genus is well-defined by this distinctive fruit shape, demarcation of species within the genus is sometimes very difficult due to the high morphological variation (Nakamura et al. 2006, 2007; Duan and Lin 2007, 2009; Wu et al. 2017c) and insufficient knowledge of flowers in most species (Hooker 1880; Schanzer 2004; Wu et al. 2017a, b).

China is one of the diversification centres of *Ophiorrhiza*. Approximately 72 species (with 50 endemics) of the genus have been recorded in this country and they are mainly distributed in southern and south-western China, especially in Guangxi Province and Yunnan Province (Chen and Taylor 2011; Huang et al. 2017; Wu et al. 2017a, b, c, 2018; Tu et al. 2018; Duan et al. 2019; Wen et al. 2019; Hu et al. 2021; Liu et al. 2023).

During our field survey in Napo County, western Guangxi, in 2013, we collected a peculiar population of plants in full blossom. The individuals were first identified as *Ophiorrhiza alatiflora* H.S.Lo as they shared similar habitats and morphological characters, such as branched inflorescences, distylous flowers with tubular-funnelform corollas and a corolla with five longitudinal wings. After revisiting the area including the type locality of *O. alatiflora* and further examining the specimens, however, these individuals from Napo County can be distinguished from *O. alatiflora* mainly by their inflorescences which are erect from their earliest developmental stages (vs. drooping when young, then erect), their smaller calyx lobes (0.5–0.7 vs. 0.9–1.8(–2.5) mm long) which are equal in size (vs. usually unequal), the nature of the longitudinal wings on the corolla tube (wings extending from top to middle and straight vs. wings extending along entire length and obviously undulate) and the strongly reflexed corolla lobes (vs. spreading) at anthesis. Therefore, the specimens are assumed to represent an undescribed new taxon, which is here described.

Material and methods

Most materials are deposited at the Herbarium of Forest Plants in Central South University of Forestry and Technology (**CSFI**). Herbarium acronyms follow Thiers (2023). Morphological observations of the new species were derived from field observations, as well as a study of dry specimens. The morphological terms employed here follow Chen and Taylor (2011). The conservation status of this new species is evaluated, based on field observations in accordance with IUCN Red List guidelines (IUCN 2023).

Taxonomic treatment

***Ophiorrhiza reflexa* L.Wu & Q.R.Liu, sp nov.**
urn:lsid:ipni.org:names:77336995-1
Figs 1, 2

Diagnosis. The new species is most similar to *O. alatiflora*, but can be distinguished from the latter by the inflorescences which are erect from the earliest developmental stages (vs. drooping when young, then erect), the small and equally-sized calyx lobes 0.5–0.7 mm long (vs. 0.9–1.8, sometimes to 2.5 mm long and usually unequal), the longitudinal wings on the corolla tube which run to the middle of the tube and are straight (vs. wings running along entire length and obviously undulate) and the strongly reflexed corolla lobes (vs. spreading) at anthesis.

Type. China. Guangxi Zhuang Autonomous Region: Napo County, Pingmeng Town, Guijiao Village, growing in limestone areas, under evergreen broad-leaved forests, rare, 23°0'30"N, 105°51'53"E, 1080 m alt., 25 Oct 2013 (fl.), *L. Wu, C. Du & S.S. Mo 4031* (holotype: CSFI 080032!; isotypes: BNU! CSFI! IBK!).

Description. Perennial herbs or subshrubs, suberect, up to 100 cm tall. Stems terete to slightly compressed, glabrous. Leaves in subequal pairs; petiole 4–6 cm long, smooth; blade thickly papery, adaxially green, abaxially pale green, broadly ovate to elliptic-ovate, 11–17 × 5–8 cm, glabrous on both surfaces, base broadly cuneate to obtuse, apex acuminate or subacute, margin entire; lat-

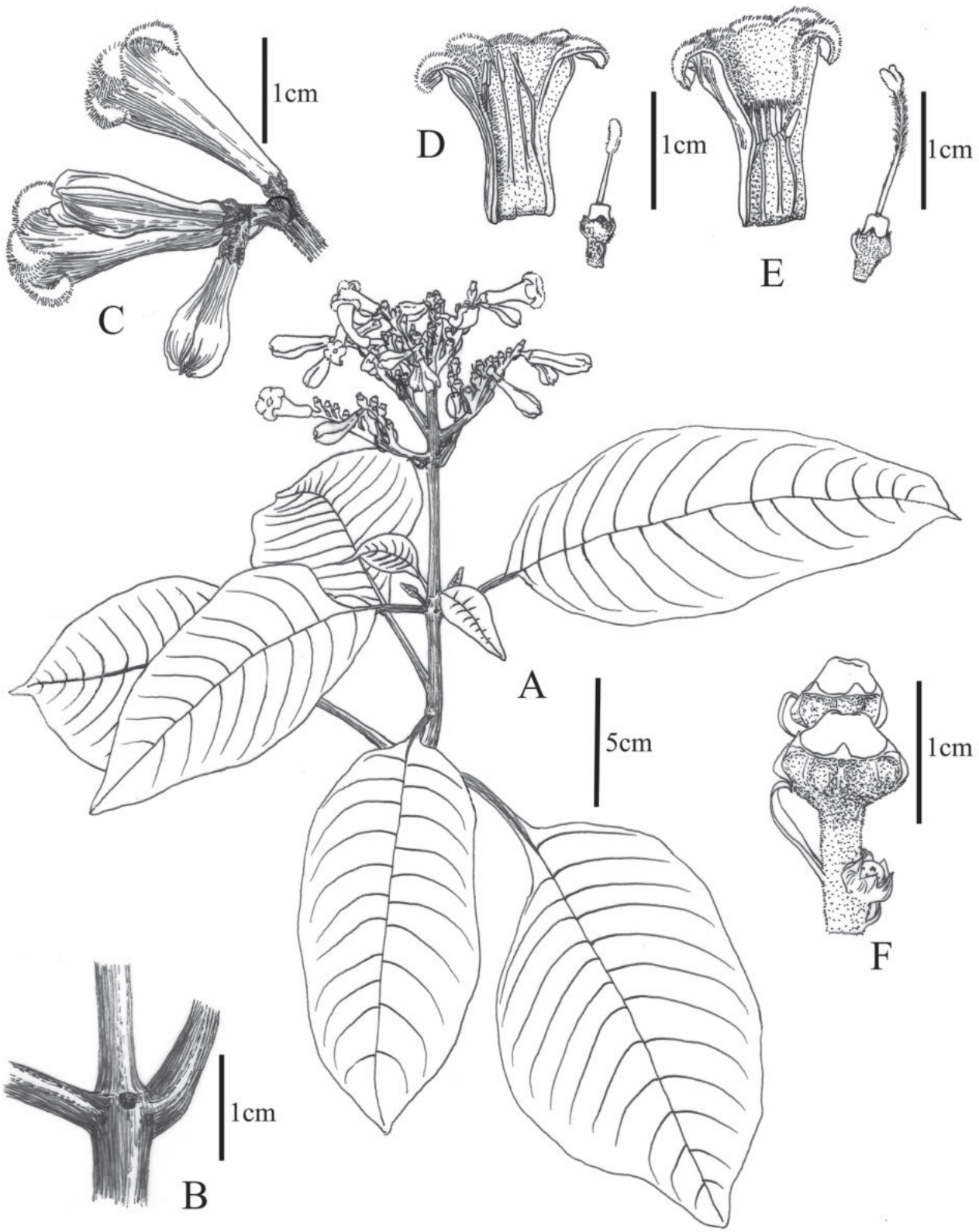

Figure 1. *Ophiorrhiza revoluta* **A** flowering branch **B** stipule **C** part of inflorescence **D** longitudinally dissected short-styled flower **E** longitudinally dissected long-styled flower **F** capsules. Drawn from the holotype by X.Y. Zeng.

eral veins 9–11 on each side of the mid-rib; stipules caducous, triangular ovate, ca. 1.5 mm long, apex obtuse. Cymes terminal, erect from youngest developmental stages, many-flowered; peduncle stout, 3–6 cm long, puberulent; bracts

linear-lanceolate, 8–19 × 1–3 mm, glabrous on both surfaces, apex acute; pedicels 1–3 mm long, puberulent. Flowers heterostylous. Calyx densely pilosulous to puberulent; hypanthium turbinate, 5-ribbed; lobes 5, equal, 0.5–0.7 mm long, triangular, subglabrous abaxially, with a gland in each sinus. Corolla white or sometimes slightly pink at apex, tubular-funnelform, outside glabrous; tube 1.3–1.5 cm long, outside longitudinally winged from apex to middle, wings straight, ca. 0.8 mm wide; lobes 5, ovate-triangular, ca. 4 × 3 mm, reflexed, inside densely pubescent, apex acute. Stamens 5; anthers linear, 2.5–3 mm long. Stigma bilobed; ovary 2-celled. Long-styled flowers: inside with a ring of white hairs at the middle of the corolla tube and puberulent from the middle up to the throat; stamens included, positioned near the middle of the corolla tube; style densely pubescent; stigma positioned near corolla throat, lobes ovate-elliptic, ca. 1.4 mm long. Short-styled flowers: sparsely pubescent at the middle of the corolla tube; stamens reaching slightly beyond corolla throat, not exserted; style included near the middle of the corolla tube, glabrous; stigma lobes lanceolate-elliptic, 2–3 mm long. Capsules rhomboid, ca. 4 × 9 mm, glabrous.

Phenology. Flowering from October to January; fruiting from March to June.

Distribution and habitat. *Ophiorrhiza reflexa* grows in moist places under evergreen broad-leaved forests in the limestone region of Napo County, Guangxi, China (Fig. 4).

Preliminary conservation status. Three populations of *Ophiorrhiza reflexa* with more than 1000 individuals at each site have been found during our field investigations. The three sites all belong to Laohutiao Provincial Nature Reserve, which is well-protected and not under threat (Tang et al. 2013). All individuals are distributed in an area of ca. 50 km^2 (10 × 5 km) and have remained roughly stable for the past 10 years. According to currently available data, *O. reflexa* is preliminarily assessed as Least Concern (LC) according to IUCN Categories and Criteria (IUCN 2023).

Additional specimens examined (paratypes). China. Guangxi Zhuang Autonomous Region: Napo County, Baisheng Town, Nongming Village, 1200 m alt., 14 May 2013 (fr.), L. Wu 3706 (BNU! CSFI!); same locality as holotype, 25 Oct 2013 (fl.), L. Wu, C. Du, S.S. Mo 4033 (BNU! CSFI! IBK!); Napo County, Pingmeng Town, Guigan Village, under evergreen broad-leaved forests, 1100 m alt., 7 Jan 2014 (fl.), L. Wu 4173 (BNU! CSFI!); ibid., 10 May 2017 (fr.), L. Wu & Z.J. Wen 5891 (CSFI!).

Etymology. The species epithet refers to the reflexed corolla lobes. The Chinese name is given as 'fan-ban-she-gen-cao (反瓣蛇根草)'.

Notes. *Ophiorrhiza* is a taxonomically difficult genus despite its easy distinction at genus level by the unique fruits. Misidentification or synonymy have become a major problem (Schanzer 2004; Wu et al. 2017c). As mentioned above, the reason is mainly the high morphological variation and insufficient knowledge of important characters, especially flowers (e.g. *Ophiorrhiza nigricans* H.S.Lo was synonymised as *O. japonica* Blume by Duan and Lin (2007); *O. pseudonapoensis* L.Wu & Q.R.Liu has been misidentified as *O. napoensis* H.S. Lo until Liu et al. (2023)).

Based on our field investigations of *Ophiorrhiza* in China and careful studies of relevant literature and specimens, about 88% of the known species are confirmed to be distylous plants. At least 52 species have been observed

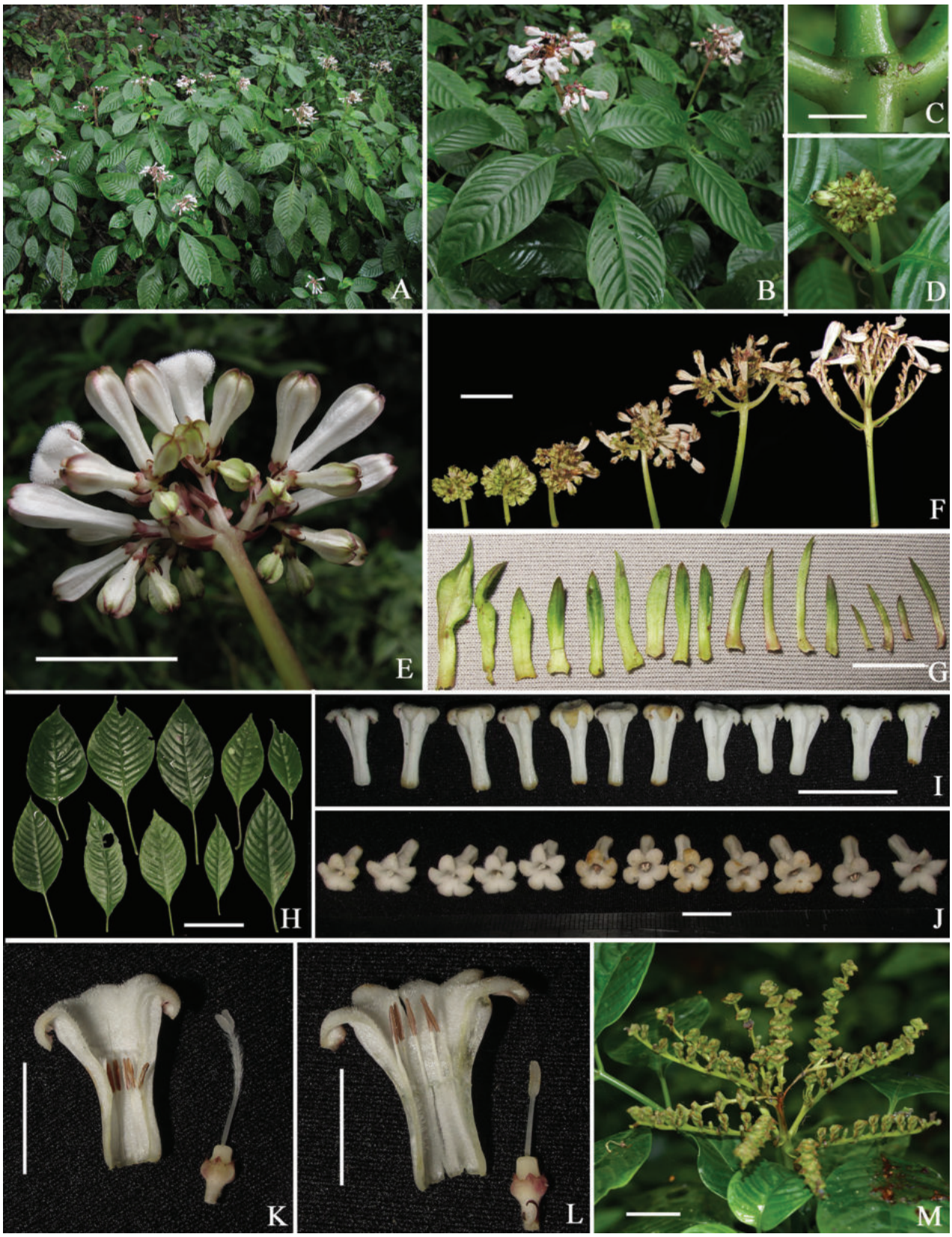

Figure 2. *Ophiorrhiza reflexa* **A, B** habit **C** stipule **D** young inflorescence **E** inflorescence in lateral view **F** inflorescences in different development stages **G** bracts from lower part to upper part of inflorescence **H** leaves **I** corollas in lateral view **J** corollas in top view **K** longitudinally dissected long-styled flower **L** longitudinally dissected short-styled flower **M** infructescence. Photos by L. Wu. Scale bars: 3 mm (**C**); 1 cm (**G, J–L**); 2 cm (**E, F, I, M**); 10 cm (**H**).

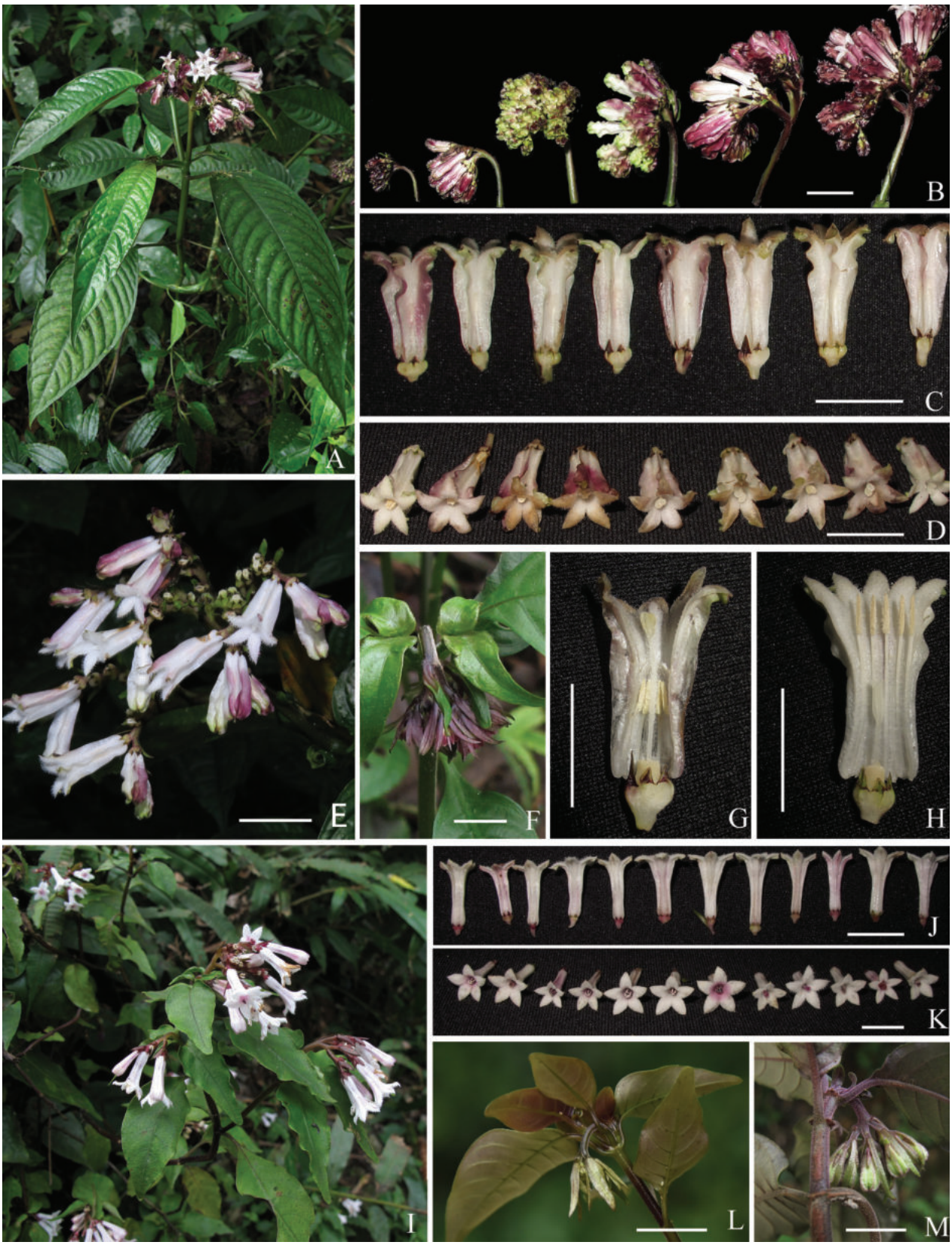

Figure 3. Morphological comparison of *Ophiorrhiza alatiflora* and *O. japonica* **A–H** *O. alatiflora* **A** habit **B** inflorescences in different developmental stages **C** calyces and corollas in lateral view **D** corollas in top view **E** inflorescence **F** young inflorescence **G** longitudinally dissected long-styled flower **H** longitudinally dissected short-styled flower **I–M** *O. japonica* **I** habit **J** corollas in lateral view **K** corollas in top view **L, M** young inflorescence. Photos by L. Wu. Scale bars: 1 cm (**C–H, J–M**); 2 cm (**B**).

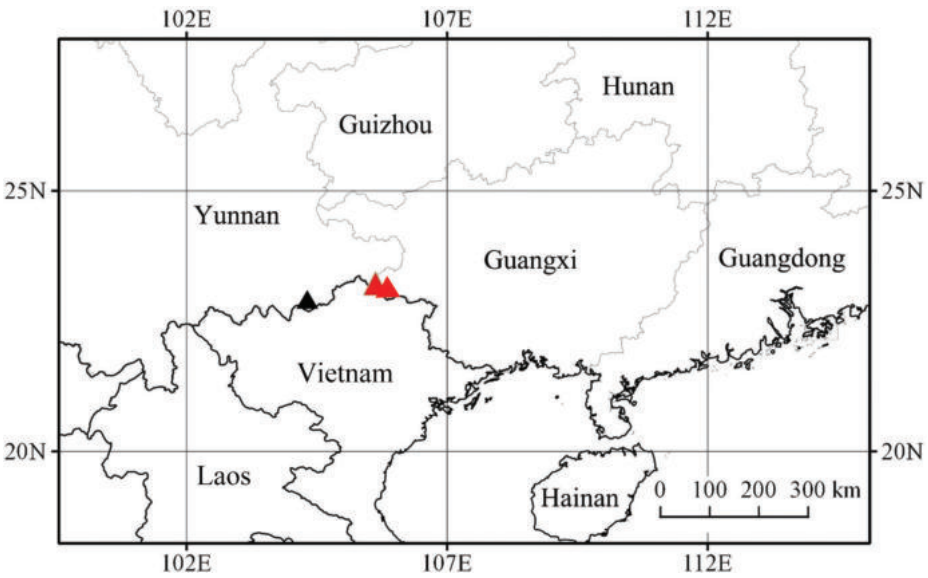

Figure 4. Geographical distribution of *Ophiorrhiza reflexa* (red triangle, Napo County) and *O. alatiflora* (blac triangle, Malipo County).

by us with both long- and short-styled flowers in the same population. Meanwhile, we found that the growth pattern of the inflorescence is relatively stable in Chinese *Ophiorrhiza* species. Nearly half of the Chinese *Ophiorrhiza* species have inflorescences that are erect from the youngest developmental stages (see Fig. 2D, F), whereas the other half have inflorescences drooping when young, then gradually becoming erect (see Fig. 3B, F). In the study of *Ophiorhiza* species from the Pacific Islands, Darwin (1976) made similar observations and pointed out that the morphology of the inflorescence was taxonomically useful. However, until now, inflorescences have not received sufficient attention in most of the past studies (Lo 1990, 1999; Deb and Mondal 1997; Chen and Taylor 2011).

Ophiorrhiza reflexa is most similar to *O. alatiflora*, both of them growing in limestone hills under dense monsoon forests. However, the former differs from the latter mainly by its erect (vs. drooping when young, then erect) inflorescences (Figs 2D, F, 3B, F), 0.5–0.7 mm long and equal calyx lobes (vs. 0.9–1.8, sometimes to 2.5 mm long and unequal, sometimes distinctly, calyx lobes; Figs 2E, K, L, 3C, G, H), strongly reflexed (vs. spreading) corolla lobes at anthesis (Figs 2E, F, K, L, 3C–E, G, H) and corolla outside with straight (vs. obviously undulate) wings from top to middle (vs. along entire length) (Figs 2E, L, 3C, G). Additionally, *Ophiorrhiza reflexa* is morphologically similar to *O. japonica* Blume, the most widely distributed *Ophiorrhiza* species in China. Both of them have caducous stipules, linear-lanceolate bracts, heterostylous flowers and tubular corollas with a villous ring positioned near the middle of the corolla tube in long-styled flowers. However, the new species differs from *O. japonica* by the erect (vs. drooping when young, then erect) and lax (vs. congested or somewhat lax) inflorescences (Figs 2D, F, 3I, L, M), the strongly reflexed (vs. spreading) corolla lobes at anthesis (Figs 2E, I–F, 3I–K) and the longitudinally winged corolla with ca. 0.8 (vs. ca. 0.5) mm wide wings (Figs 2L, 3J). Further distinctive characteristics of the three species are shown in Table 1.

Table 1. Morphological comparison of *Ophiorrhiza reflexa*, *O. alatiflora* and *O. japonica*.

	O. reflexa	***O. alatiflora***	***O. japonica***
Leaf blade	broadly ovate to elliptic-ovate, 11–17 × 5–8 cm, base broadly cuneate to obtuse, apex acuminate or subacute	ovate or oblong-ovate, 5–13 × 2–7 cm, base cuneate, apex shortly acuminate or subacute	ovate to narrowly lanceolate, 1–11 × 0.7–3.5 cm, base cuneate to obtuse, apex acute to acuminate
Secondary veins	9–13 pairs	7–12 pairs	4–8 pairs
Inflorescence	erect from youngest developmental stages	drooping when young, then gradually erect	drooping when young, then gradually erect
Calyx lobes	equal, 0.5–0.7 mm long	unequal, 0.9–1.8 mm long, sometimes to 2.5 mm long	equal, 0.4–1.2 mm long
Corolla	tubular-funnelform, outside longitudinally winged from top to middle, wings straight, ca. 0.8 mm wide	tubular-funnelform , outside longitudinally winged along entire length, wings undulate, 0.8–1 mm wide	tubular-funnelform to funnelform, outside longitudinal winged from top to middle, wings to 5 mm wide
Corolla lobes	ovate-triangular, reflexed, ca. 4 × 3 mm	triangular, spreading, ca. 3–3.5 × 2.5 mm	triangular to ovate, spreading, ca. 2.5–4 × 2.5–3.5 mm

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

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Data availability

All of the data that support the findings of this study are available in the main text.

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Checklist

Revised checklist of endemic vascular plants of Kazakhstan

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Abstract

We compiled a checklist of endemic vascular plants occurring in Kazakhstan, employing an exhaustive examination of literature sources, herbarium collections, databases and field observations. Our study reveals that 451 taxa can be considered endemic to Kazakhstan, constituting 7.97% of the total vascular plant diversity in the country. These endemic taxa, originating from 139 genera and 34 families, predominantly thrive in the southern regions of Kazakhstan, specifically in the mountain ridges of the Kazakh part of the Tian Shan, including Karatau (123 taxa), Dzungarian Alatau (80 taxa) and Trans-Ili and Kungey Alatau (50 taxa). Notably, 107 endemic species are granted legal protection. Detailed information regarding life form, life cycle, conservation status and geographical distribution across floristic regions was meticulously compiled for each endemic taxon. Of the six groups of life forms, herbs include the highest part of endemic taxa (367 taxa), followed by dwarf semishrubs (25 taxa), shrubs (23 taxa), subshrubs (20 taxa), undershrubs (13 taxa) and trees (3 taxa). The observed life cycles are perennials (408 taxa), annuals (33 taxa) and biennials (10 taxa). This paper serves as a fundamental groundwork for prospective investigations aimed at assessing population sizes and hotspots of plant endemism throughout Kazakhstan, crucial for determining conservation status of endemic plants.

Key words: Biodiversity hotspots, Central Asia, conservation, endemism, floristic division

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Introduction

Endemic plants hold particular importance in studying the history of flora and vegetation of diverse geographical regions, since they represent an important element of biodiversity and serve as vital benchmarks for identifying areas of high biodiversity value. In recent years, much attention has been paid to the study of endemic plants, as evidenced by a large number of scientific

publications (Tojibaev et al. 2020a; Baasanmunkh et al. 2022; Erst et al. 2022; Chung et al. 2023; Villaseñor et al. 2023).

Kazakhstan occupies a central position within Eurasia and holds a notable distinction of being the ninth largest country globally, with 2,724,900 km^2 of land area. The territory of Kazakhstan is characterised by a remarkable ecological heterogeneity (Abdulina 1999; Akzhigitova et al. 2003), marked by prominent zonal boundaries, notably the demarcation between the cold-temperate and temperate regions of Northern Eurasia and the Irano-Turanian warm region with the Mediterranean-like type of climate, the latter encompassing the southern part of Kazakhstan.

The remarkable diversity of natural conditions in Kazakhstan contributes to the exceptional richness of its flora, its notable originality and a significant number of endemic plant species in Kazakhstan. According to the latest inventory, 5,658 vascular plant species, representing 159 families and 1,067 genera, occur in the country (Abdulina 1999).

The investigation of endemic plant species, which represent a vital and highly vulnerable component of biodiversity, has garnered significant attention in numerous countries. The number of endemic plants in the countries neighbouring Kazakhstan varies, with China exhibiting the highest number of endemic species at 14,939 (Huang et al. 2011). There are over 2,700 endemic taxa in Russia (Kamelin and Budantsev 2019), Mongolia has 102 taxa (Baasanmunkh et al. 2022), Kyrgyzstan has 393 taxa (Lazkov and Sultanova 2014) and Uzbekistan has 378 taxa (Sennikov et al. 2016). Based on a comprehensive review of the "Flora of Kazakhstan" (Pavlov 1956–1966), Goloskokov (1969) counted 760 endemic species from 199 genera and 47 families in Kazakhstan. Otherwise, various sources estimated the presence of 709 to 823 species of endemic plants in Kazakhstan (Pavlov 1956–1966; Bykov 1966; Goloskokov 1969; Baitenov 2001; Gemedjieva et al. 2010).

The scientific literature contains a substantial body of work focused on the investigation of endemic taxa in Kazakhstan. However, these publications predominantly revolve around limited geographical areas, such as specific mountain ranges, floristic regions or administrative divisions (Pavlov 1970; Goloskokov 1979; Baitenov 1982; Anapiev 1996; Bakeev and Atikeeva 2015; Ishmuratova et al. 2015, 2016a, 2016b; Sadyrova et al. 2017; Mukhtubaeva et al. 2017; Kupriyanov 2022). Reports focusing on endemic plant species within certain families and genera have also been published, including studies on Poaceae (Kupriyanov et al. 2018), Apiaceae (Klyuykov and Ukrainskaya 2018), Asteraceae (Kupriyanov 2018), Ranunculaceae (Shchegoleva 2019a), Chenopodiaceae (Osmanali et al. 2019) and *Oxytropis* (Perezhogin et al. 2020).

The available information regarding the composition of endemic plant species in Kazakhstan, as documented in the "Flora of Kazakhstan" (Pavlov 1956–1966) and other related sources (Bykov 1966; Goloskokov 1969), is largely outdated. Since then, numerous species previously classified as endemic have been discovered beyond the borders of Kazakhstan or reduced to synonyms. In addition, in the last 10 years alone, more than 25 species of endemic plants have been described as new to science from the territory of Kazakhstan, for example: six species of *Tulipa* (*T. annae* J.de Groot & Zonn, *T. auliekolica* Perezhogin, *T. dianaeverettiae* J.de Groot & Zonn., *T. turgaica* Perezhogin, *T. salsola* Rukšāns & Zubov, *T. ivasczenkoae* Epiktetov & Belyalov) (Epiktetov and Belyalov 2013; Perezhogin 2013; de Groot and Zonneveld 2020; Rukšāns and Zubov 2022); five

apomictic species of *Taraxacum* (*T. atrochlorinum* Kirschner & Štěpánek, *T. corvinum* Kirschner & Štěpánek, *T. dzhungaricola* Kirschner & Štěpánek, *T. sublilacinum* Kirschner & Štěpánek) (Kirschner and Štěpánek 2017); three species of *Allium: A. koksuense* R.M.Fritsch, N.Friesen & S.V.Smirn., *A. lepsicum* R.M.Fritsch, N.Friesen & S.V.Smirn. and *A. toksanbaicum* N.Friesen & Veselova (Friesen et al. 2021a, 2021b); two species of *Hedysarum* (*H. tarbagataicum* Knjaz. and *H. ulutavicum* Knjaz.) (Knyazev 2019); *Myosotis kazakhstanica* O.D.Nikif. (Nikiforova 2018); *Gagea almaatensis* Levichev, A.Peterson & J.Peterson (Peterson et al. 2016); *Galatella bectauatensis* Kupr. & Koroljuk (Kupriyanov and Korolyuk 2013); *Rhaponticoides zaissanica* Kupr., A.L.Ebel & Khrustaleva (Kupriyanov 2020); *Astragalus saphronovae* Kulikov (Kulikov 2014); *Phlomis mindshelkensis* Lazkov (Lazkov 2014); *Phlomoides boroldaica* A.L.Ebel (Ebel et al. 2019); *Fritillaria kolbintsevii* Rukšāns & Zubov (Rukšāns and Zubov 2021; *Galium zaisanicum* Pinzhenina & Kupr. (Pinzhenina and Kupriyanov 2023); *Prangos multicostata* Kljuykov & Lyskov (Lyskov et al. 2016), *Sphaenolobium korovinii* Pimenov & Kljuykov (Pimenov and Kljuykov 2014) and *Nitraria iliensis* Banaev & Tomoshevich (Banaev et al. 2023).

Consequently, the current knowledge regarding the species diversity of endemic plants in Kazakhstan remains poorly available. In order to address this knowledge gap, our research endeavour aimed to compile the checklist of endemic vascular plants in Kazakhstan, based on an extensive analysis of literary sources, comprehensive revision of herbarium collections and data from field observations.

Materials and methods

For the compilation of an endemic plant checklist in Kazakhstan, extensive literature sources were consulted. Initially, nine volumes of the "Flora of Kazakhstan" (Pavlov 1956, 1958, 1960, 1961a, 1961b, 1963, 1964, 1965, 1966) were utilised, alongside the complete list of the country's flora (Abdulina 1999). The broad-scale inventory of Central Asian plants, "Conspectus Florae Asiae Mediae", spanning 11 volumes (Kovalevskaya 1968, 1971; Bondarenko and Nabiev 1972; Pakhomova 1974, 1976; Kamelin et al. 1981; Adylov 1983, 1987; Nabiev 1986; Adylov and Zuckerwanik 1993; Khassanov 2015), was also referenced. Additionally, the "Plants of Central Asia" series, consisting of 16 volumes (Grubov 1963–2008), was incorporated. Reports detailing endemic plants within specific geographical and administrative regions of Kazakhstan were used (Pavlov 1970; Goloskokov 1979; Baitenov 1982; Anapiev 1996; Bakeev and Atikeeva 2015; Ishmuratova et al. 2015, 2016a, 2016b; Mukhtubaeva et al. 2017; Sadyrova et al. 2017; Kupriyanov 2022). Furthermore, lists highlighting endemic plants within particular species-rich families and genera were considered, such as Ranunculaceae (Shchegoleva 2019a), Apiaceae (Klyuykov and Ukrainskaya 2018), Asteraceae (Kupriyanov 2018), *Achillea* (Kupriyanov and Kulemin 2023), *Oxytropis* (Perezhogin et al. 2020) and Chenopodiaceae (Suchorukow 2007; Osmanali et al. 2019). Lists encompassing endemic plants within broader geographical regions, which include parts of Kazakhstan, were also reviewed (Tolmachev 1974; Pyak et al. 2008; Tojibaev et al. 2020a; Erst et al. 2022). Additionally, we paid attention to the species described from Kazakhstan and new combinations published from 2013 to 2023, subsequent to the publication of the latest flora list by Abdulina (1999).

Following the compilation of a list of endemic taxa, we conducted a comprehensive re-assessment of the distribution of each species by cross-referencing

published floristic records encompassing the administrative and geographical regions of Kazakhstan (Goloskokov 1949; Stepanova 1962; Karmysheva 1973, 1982; Pavlov 1980; Baitenov 1985; Pugachev 1994; Safronova 1996; Kotukhov 2005; Aralbay et al. 2006; Kadenova et al. 2008; Aipeisova 2012, 2013; Ishmuratova et al. 2016a; Kokoreva et al. 2018; Ivashchenko 2020; Kupriyanov 2020; Sitpayeva et al. 2020; Kubentayev et al. 2021; Orazov et al. 2022, 2024; Khasanov et al. 2023; Kulymbet et al. 2023; Osmonali et al. 2023; Sumbembayev et al. 2023). Furthermore, in order to clarify the presence of presumably endemic plants of Kazakhstan in neighbouring countries, we consulted floristic records of those territories (Kamelin 1990; Yakovlev 2003; Kulikov 2005; Wu et al. 2008; Ryabinina and Knyazev 2009; Lazkov and Sultanova 2014; Knyazev 2016; Nowak et al. 2020; Vaganov and Shmakov 2020; Sennikov and Tojibaev 2021; Baasanmunkh et al. 2022), as well as publications documenting the discovery of former Kazakhstan endemics outside their native range (Ho and Fu 1993; Yakovlev 2003; Kurtto et al. 2004; German 2005; Mavrodiev et al. 2005; German 2006a, 2006b; German et al. 2006; Belkin 2009; Sennikov et al. 2011; Soskov 2011; German et al. 2012; German et al. 2013; Byalt and Bubyreva 2014; German 2014; Nobis et al. 2014; Pimenov and Kljuykov 2014; Vesselova 2016; German and Al-Shehbaz 2017; Lazkov and Sennikov 2017a, 2017b; Nobis et al. 2017; Pimenov 2017; Golovanov et al. 2018; Golovanov and Knyazev 2019; Ma and Xu 2019; Shchegoleva et al. 2019b; Zolotukhin and Chkalov 2019; Ovchinnikova 2021; Tojibaev et al. 2022; Sennikov and Lazkov 2023; Vaganov 2023; Juramurodov et al. 2024).

To verify endemic taxa distributions, we employed systematic reports detailing the flora of Kazakhstan and its neighbouring regions (Baitenov 1977; German and Chen 2009; Kljuykov et al. 2018; Smirnov et al. 2018; Nobis et al. 2020; Pimenov 2020; German and Veselova 2022; Sennikov et al. 2023). Additionally, we conducted a thorough examination of specimens housed in various herbaria, including LE, MW, TK, TASH, MHA, SVER, KUZ, ALTB, NS, NSK and MOSP (herbarium acronyms according to Thiers (2023)), as well as the data sourced from the Global Biodiversity Information Facility (GBIF 2023), the International Legume Database and Information Service (ILDIS) (Roskov et al. 2009), BrassiBase: Introdcution to a novel database on Brassicaceae evolution. Plant & Cell Physiology (Kiefer et al. 2014), World Plants. Synonymic Checklist and Distribution of the World Flora (Hassler 1994–2024) and the Compositae Working Group (CWG) (2023).

Within the scope of this investigation, we provide a list and an analysis of national endemic vascular plants growing strictly within Kazakhstan (see Appendix 1). This study considers two taxonomic levels of endemic plants: species and subspecies; taxa with a rank lower than subspecies were not considered. Additionally, we present a separate list encompassing sub-endemic taxa (see Suppl. material 1). In this paper, sub-endemics refer to taxa that were formerly considered endemics, but subsequently found in a neighbouring country or countries, based on published literature or herbarium material. In addition, we present a list of former endemics of Kazakhstan reclassified as synonyms of taxa with broader geographical distributions (see Suppl. material 2).

The distribution of each endemic taxon in Kazakhstan is given according to the floristic division of the country (Pavlov 1956). This division partitions Kazakhstan's territory into 29 distinct floristic regions and seven subregions (Fig. 1).

The systematic order and taxonomic position of the families are based on the classification of angiosperms by APG IV (2016). The names of the accept-

ed genera and species are mostly in accordance with Plants of the World Online (POWO 2023), with corrections according to recently-published taxonomic revisions. The authorship of species, genera and families has been critically cross-checked against the information provided in the International Plant Names Index (IPNI 2023).

Results

Based on a rigorous revision of endemic vascular plants in Kazakhstan, a total of 451 taxa have been identified as endemic to the country (Appendix 1), which account for 7.97% of the total number (5,658 species) of vascular plants in Kazakhstan (Abdulina 1999). The endemic taxa recognised in this study belong to 139 genera and 34 families. Notably, Kazakhstan is home to five monotypic endemic genera, i.e. *Karatavia* Pimenov & Lavrova, *Botschantzevia* Nabiev, *Tschulaktavia* Bajtenov ex Pimenov & Kljuykov, *Cancriniella* Tzvelev and *Sauria* Bajtenov. No endemic families are present in the country.

The greatest number of endemic taxa is registered in the following families: Asteraceae Bercht. & J.Presl (111 taxa from 29 genera), Fabaceae Lindl. (81 taxa from 6 genera), Apiaceae Lindl. (27 taxa from 13 genera), Lamiaceae Martinov (27 taxa from 8 genera), Boraginaceae Juss. (23 taxa from 10 genera), Brassicaceae Burnett (23 taxa from 8 genera), Amaryllidaceae J.St.-Hil. (22 taxa from 1 genus), Liliaceae Juss. (18 taxa from 3 genera), Rosaceae Juss. (17 taxa from 7 genera), Poaceae Barnhart (15 taxa from 8 genera) and Amaranthaceae Juss. (14 taxa from 10 genera) (Fig. 2A). The remaining 23 families are represented by one to 10 species each.

Genera with the greatest number of endemic taxa are as follows: *Astragalus* L. with 46 taxa, *Oxytropis* DC. with 22 taxa, *Allium* L. with 21 taxa, *Taraxacum* F.H.Wigg. with 20 taxa, *Jurinea* Cass. with 20 taxa, *Tulipa* L. with 13 taxa, *Lappula* Moench with 11 taxa, *Artemisia* L. with nine taxa, *Zygophyllum* L. with nine taxa and *Phlomoides* Moench with nine taxa. The remaining genera are represented by one to seven taxa (Fig. 2B).

The highest concentration of endemic plants was documented in two floristic regions: Karatau, with 123 taxa and Dzungarian Alatau, with 80 taxa. Additionally, a noteworthy range of 30 to 52 endemic taxa were observed in eight other floristic regions, namely Trans-Ili Kungey Alatau (50 taxa), Betpak-Dala (46 taxa), Western Tian Shan (46 taxa), Balkhash-Alakol (46 taxa), Chu-Ili Range (36 taxa), Eastern Upland (35 taxa), Western Upland (31 taxa) and Altai (27 taxa). On the other hand, a comparatively smaller number of endemic plants (not exceeding 5 taxa) were identified in six floristic regions: Caspian Region (4 taxa), Syrt (4 taxa), Kyzylkum (3 taxa), Mangyshlak (2 taxa), Kokchetav (2 taxa) and Buzachi (1 taxon). In the other two floristic regions (Bukeev, Southern Ustyrt), no endemic plants were found (Fig. 3A, B).

Amongst all endemic plants in Kazakhstan, 107 species, constituting 23.7% of the overall number of endemic taxa, are presently under the state-level legal protection (Baitulin 2014).

Amongst the six groups of life forms accepted by the Flora of Kazakhstan (Pavlov 1956), herbs include the greatest part of endemic taxa (367), followed by dwarf semishrubs (25 taxa), subshrubs (20 taxa), shrubs (23 taxa), undershrubs (13 taxa) and trees (3 taxa). The dominant life cycles are perennials (408 taxa), followed by annuals (33 taxa) and biennials (10 taxa).

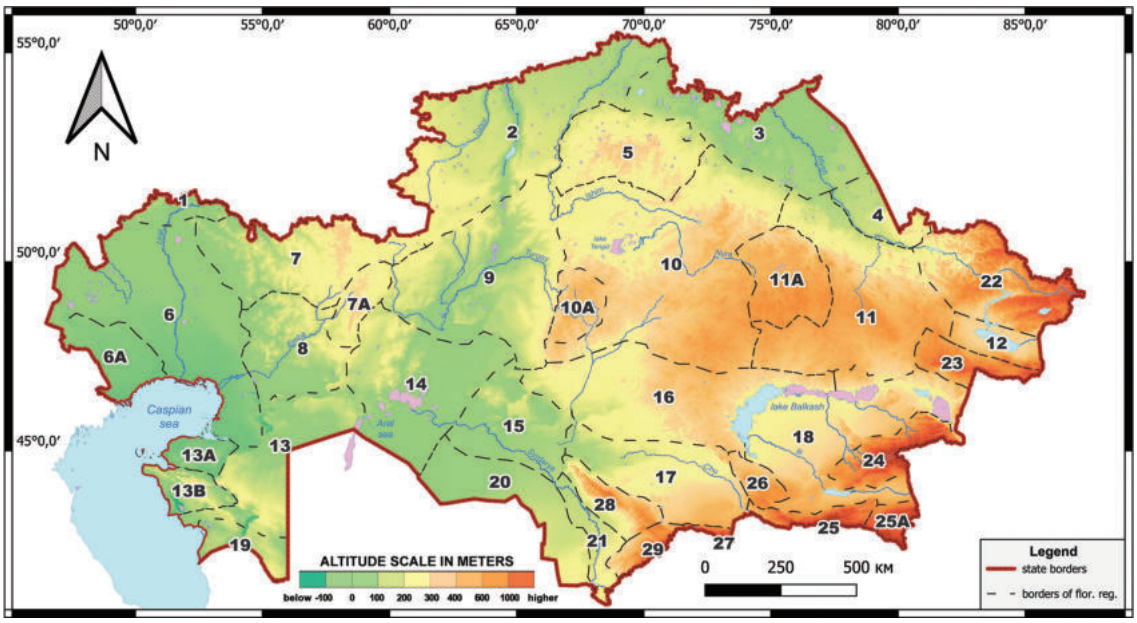

Figure 1. Map of the floristic division of Kazakhstan (Pavlov 1956): 1 – Syrt, 2 – Tobol-Ishim, 3 – Irtysh, 4 – Semipalatinsk pine forest, 5 – Kokchetav, 6 – Caspian Region, 6a – Bukeev, 7 – Aktobe, 7a – Mugojary, 8 – Emba, 9 – Turgay, 10 – Western Upland, 10a – Ulutau, 11 – Eastern Upland, 11a – Karkaraly, 12 – Zaysan, 13 – Northern Ustyrt, 13a – Buzachi, 13b – Mangyshlak, 14 – Aral Region, 15 – Kyzylorda, 16 – Betpak-Dala, 17 – Moiynkum, 18 – Balkhash-Alakol, 19 – Southern Ustyrt, 20 – Kyzylkum, 21 – Turkestan, 22 – Altai, 23 – Tarbagatai, 24 – Dzungarian Alatau, 25 – Trans-Ili Kungey Alatau, 25a – Ketmen-Terskey Alatau, 26 – Chu-Ili Range, 27 – Kyrgyz Alatau, 28 – Karatau, 29 – Western Tian Shan.

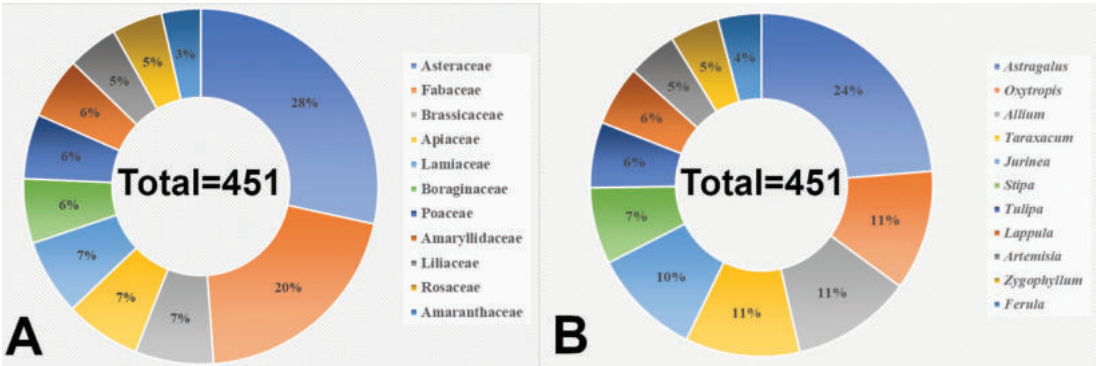

Figure 2. The largest families by the number of endemic taxa (**A**). The largest genera by the number of endemic taxa (**B**).

According to the results of our research, 341 taxa previously considered endemics are recognised as sub-endemics of Kazakhstan (see Suppl. material 1) because they were found in the neighbouring countries. The largest number of plants previously considered endemic to Kazakhstan was found in China – 152 taxa, Kyrgyzstan – 138 taxa, Uzbekistan – 71 taxa, Russia – 59 taxa, Mongolia – 59 taxa, Tajikistan – 31 taxa, Turkmenistan – 19 taxa. The total of 169 former endemic taxa of Kazakhstan were synonymised to taxa with wider distribution ranges (see Suppl. material 2).

Discussion

Based on our critical evaluation of vascular plants of Kazakhstan, 451 taxa are identified as endemic to the country (Appendix 1). This figure corresponds to

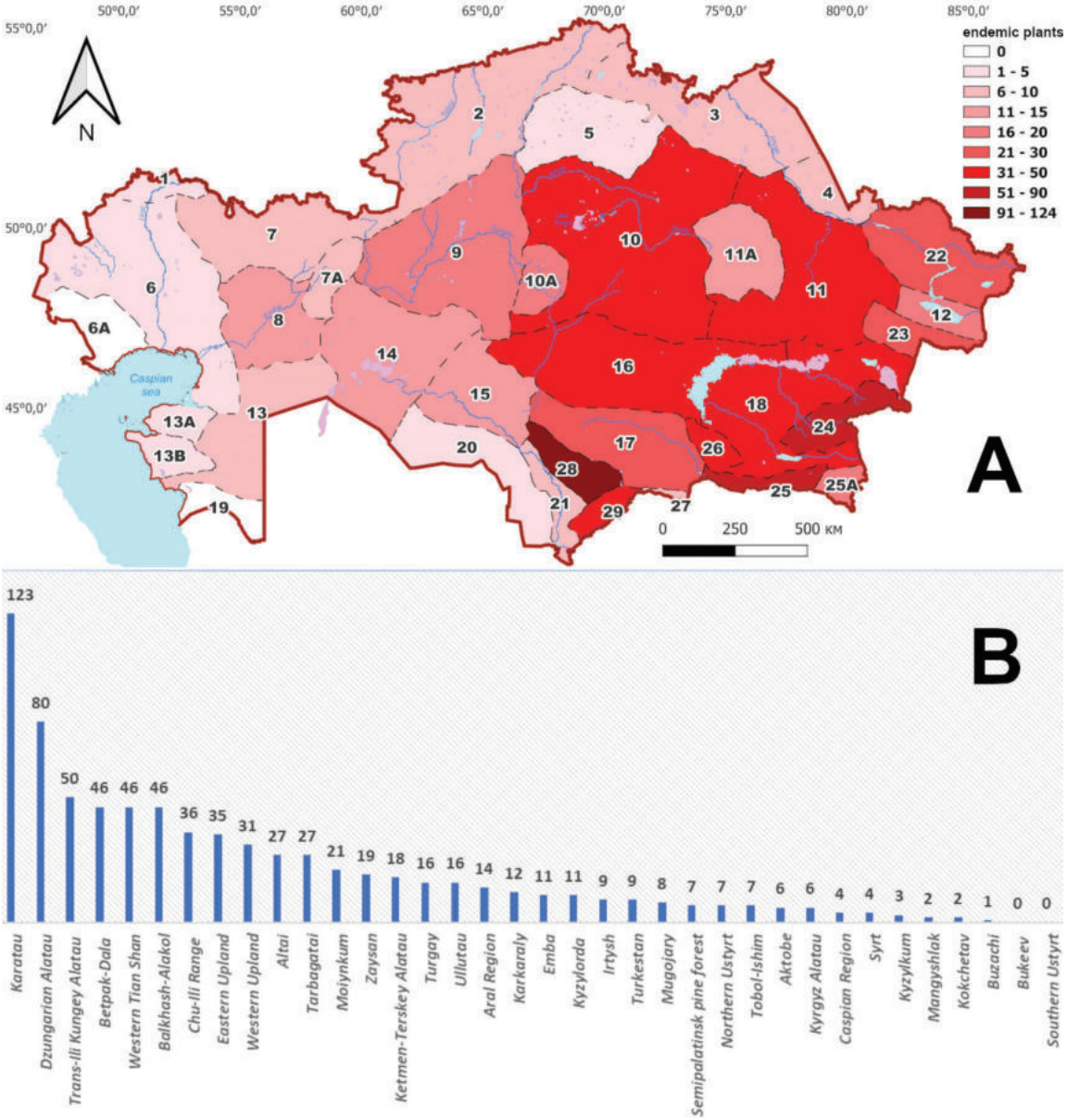

Figure 3. Endemic taxa richness in the floristic regions of Kazakhstan (**A**). The number of endemic taxa in the floristic regions of Kazakhstan (**B**).

55–63% of the previously-reported numbers, i.e. 709–823 species (Pavlov 1956–1966; Bykov 1966; Goloskokov 1969; Baitenov 2001; Gemedjieva et al. 2010). The substantial difference in the number of endemic taxa compared to earlier publications is due to their reliance on outdated information solely derived from the nine-volume edition of the Flora of Kazakhstan (Pavlov 1956–1966). Our review reveals that 341 taxa previously considered endemics are to be treated as sub-endemics of Kazakhstan (see Suppl. material 1), whereas 169 former endemic taxa were synonymised to taxa with wider distribution ranges (see Suppl. material 2). For example, two most recent publications removed two endemic taxa from Kazakhstan: *Allium valentinae* Pavlov was found in Kyrgyzstan (Sennikov and Lazkov 2023), whereas the generic status of *Pseudomarrubium* was rejected (Zhao et al. 2023). Such examples provide evidence of ongoing taxonomic and floristic studies that are constantly shaping the list of endemic plants of Kazakhstan.

Despite the extensive territory and diverse natural conditions of Kazakhstan, the occurrence of endemic taxa appears highly uneven in the country. The largest number of endemic plants is concentrated in mountainous areas, specifically in the southern and south-eastern parts of Kazakhstan, within the following floristic regions: Karatau (123 taxa), followed by the Dzungarian Alatau (80 taxa) and Trans-Ili Kungey Alatau (50 taxa). These results fully align with the analysis presented by Gemedjieva et al. (2010), who examined the distributions of endemic plants in Kazakhstan, despite their use of outdated taxonomic and distributional data. The distribution pattern of endemic taxa across the territory of Kazakhstan supports the assertion made by Körner (2002) that mountain systems serve as biodiversity and endemism hotspots due to the compression of distinct climatic zones over varying altitudes. According to the latest global analysis of seed plant endemism, the territory of Kazakhstan is assigned to the centre of neo-endemism (Cai et al. 2023). The mountainous regions of Tian Shan in the south and the Altai Mountains in eastern Kazakhstan appear to have favoured this, because the mountainous regions exhibit a great diversity in their plant lineages and, therefore, contribute to high levels of neo-endemism.

The distribution of endemic plants in Kazakhstan is presumably influenced by the geological and climatic history of the territory. Past climate change and geological history help to explain how diversification and relictualisation shape the distribution of neo- and paleoendemism and simultaneously phylogenetic endemism worldwide (Cai et al. 2023). The influence of geological history on speciation, differentiation, migration and extinction of species has been highlighted by many scientists (Takhtajan 1969; Raven and Axelrod 1974; Latham and Ricklefs 1993; Axelrod et al. 1996; Huang et al. 2011). A prime example illustrating this phenomenon is the endemic taxa richness in the ancient Karatau Mountains (123 taxa), located at the westernmost limit of the Tian Shan. The Karatau Mountains possess a complex geological composition, characterised by the presence of the oldest Precambrian shale formations in Central Asia, as well as the Lower Paleozoic formations consisting of metamorphosed limestones and shales, overlain by a quartzite stratum (Kamelin 1990). An important factor in the distribution of endemic plants is long-term climatic stability. Central Asia is known for the presence of ancient plant lineages which survived there due to the continuous history of suitable climatic conditions (e.g. in *Lactuca* s.l.: Kilian et al. (2017)). The influence of geological and climatic history on the distribution of endemic plants in Kazakhstan requires additional research, given the poorly-studied bedrock types in Central Asia.

In the flora of Kazakhstan, herbs include most of the endemic taxa. The life forms of plants reflect their adaptability to environmental conditions and form the units of ecological classification, grouping plants with similar adaptive structures (Aipeisova 2009). According to Yurtsev (1976) and Rabotnov (1978), studies of life forms contribute to the understanding of species biology and their roles within ecosystems. The diversity of life forms represents a cumulative effect of long-term evolutionary processes responding to gradual changes in regional ecological conditions (Keller 1938; Shennikov 1950; Serebryakov 1964).

Amongst endemic plants of Kazakhstan, perennials (408 taxa) are most numerous. A global analysis of the distribution of plant life cycles around the world has shown that annual plants predominate in hot and arid conditions, especially during the long dry season (Poppenwimer et al. 2022). The number of annuals and biennials in Kazakhstan is 43 taxa or 9% of the total number

of endemic plants of Kazakhstan. The distribution of endemic annuals over the territory of Kazakhstan is relatively uniform. The greatest number of annuals is noted in Western Upland (7 taxa), Zaysan (6 taxa) and Karatau (6 taxa). Amongst the families, the greatest number of annual endemic taxa is registered in Boraginaceae Juss. (17 taxa), Brassicaceae Burnett (8 taxa) and Amaranthaceae Juss. (6 taxa); in other families, 1–3 taxa are registered.

Given that numerous endemic plant species have restricted distributions, which makes them more prone to extinction (Myers et al. 2000; Pitman and Jørgensen 2002), it is crucial to emphasise the assessment and protection of such species (Baasanmunkh et al. 2022). Amongst 451 endemic taxa of Kazakhstan, 107 species are currently under state protection. We consider it necessary to further re-assess the status of protection of endemic plants of Kazakhstan using IUCN criteria.

During the critical examination of endemic plants in Kazakhstan, we found that some endemic plants were inaccurately attributed to other countries in the Plants of the World Online (POWO 2023). For instance, *Arthrophytum subulifolium* Schrenk and *Atriplex iljinii* Aellen, according to POWO, are supposedly present in Turkmenistan. However, *Arthrophytum subulifolium* Schrenk exclusively grows in a narrow region of the Chu-Ili Range in Kazakhstan (Osmanali et al. 2019), while *Atriplex iljinii* is solely found in the Mangistau, Aktobe and Kyzylorda Regions of Kazakhstan (Suchorukow 2007). *Stipa argillosa* Kotukhov and *Thalictrum bykovii* Kotukhov, along with *Gagea azutavica* Kotukhov, are incorrectly recorded in POWO as species native to the Altai Republic in the Russian Federation, whereas these species were described from East Kazakhstan (Kotukhov 1989, 1990, 1998).

At the same time, in the POWO database, certain species were erroneously assigned to Kazakhstan. For instance, the distributions of *Kamelinia tianschanica* F.O.Khass. & I.I. Malzev, *Cousinia xanthiocephala* Tscherneva, *Vicoa krascheninnikovii* Kamelin, *Phlomoides tschimganica* (Vved.) Adylov, Kamelin & Makhm. and *Erysimum aksaricum* Pavlov are limited to Uzbekistan (Kamelin 1976; Kupriyanov 2018; Tojibaev et al. 2020b). *Cousinia balchanica* Tscherneva and *Minuartia palyzanica* Proskur. were described from Turkmenistan (Proskuryakov 1987; Cherneva 1996), while *Taraxacum darschajense* Orazova and *Hedysarum ovczinnikovii* Karimova ex Kovalevsk. were reported to occur in Tajikistan (Orazova 1982; Adylov 1983) and *Crucianella schischkinii* Lincz. was found in both Uzbekistan and Tajikistan (Kamelin 2017). These errors are associated with the difficulty of matching administrative boundaries with plant distribution areas in complicated mountainous territories.

Conclusions

This checklist includes all strictly endemic plants of Kazakhstan, consisting of 451 taxa (species or subspecies) belonging to 139 genera and 34 families. The largest number of endemic taxa is concentrated in mountainous areas, specifically in the southern and south-eastern parts of Kazakhstan.

This paper serves as a fundamental groundwork for prospective investigations aimed at assessing population sizes and numbers of endemic taxa throughout Kazakhstan, crucial for determining their conservation status. Of course, this checklist of plant endemics of Kazakhstan is not final and will be revised in the future as a result of ongoing taxonomic and floristic studies.

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Additional information

Conflict of interest

All authors declare that they have no competing interests and personal relationships and agree on the contents of the paper.

Ethical statement

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Author contributions

Conceptualisation – SAK; methodology – SAK, YVP, DTA; formal analysis – OVB, BBK; writing – preparation of the initial draft – SAK, DTA, VPY, BBK; editing, SAK, DTA, GAL, ALE, ANK; author's supervision – SAK; project administration – SAK, KSI; acquisition of funding – IKS. All authors have read and agreed with the published version of the manuscript.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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Appendix 1. Annotated checklist of endemic taxa of Kazakhstan

In the checklist, families are listed in alphabetical order; lower-level taxa (genera, species and subspecies) within a family are also listed in alphabetical order.

The following information is given after the name of each taxon:

Life form (Lf) and life cycle (Lc) according to the Flora of Kazakhstan (Pavlov 1956); conservation status (Cs) according to the Red Book of Kazakhstan (Baitulin 2014). The species included in the Red Book of Kazakhstan are denoted by RB.

The distribution (D) of each taxon in Kazakhstan is given according to the floristic division of Kazakhstan (Pavlov 1956), where the territory of the country is divided into 29 floristic regions and seven subregions: 1 – Syrt, 2 – Tobol-Ishim,

3 – Irtysh, 4 – Semipalatinsk pine forest, 5 – Kokchetav, 6 – Caspian Region, 6a – Bukeev, 7 – Aktobe, 7a – Mugojary, 8 – Emba, 9 – Turgay, 10 – Western Upland, 10a – Ulutau, 11 – Eastern Upland, 11a – Karkaraly, 12 – Zaysan, 13 – Northern Ustyrt, 13a – Buzachi, 13b – Mangyshlak, 14 – Aral Region, 15 – Kyzylorda, 16 – Betpak-Dala, 17 – Moiynkum, 18 – Balkhash-Alakol, 19 – Southern Ustyrt, 20 – Kyzylkum, 21 – Turkestan, 22 – Altai, 23 – Tarbagatai, 24 – Dzungarian Alatau, 25 – Trans-Ili Kungey Alatau, 25a – Ketmen-Terskey Alatau, 26 – Chu-Ili Range, 27 – Kyrgyz Alatau, 28 – Karatau, 29 – Western Tian Shan.

Asterisks refer to annotations placed after the checklist.

Fam. 1. Amaranthaceae Juss.

Gen. 1. *Anabasis* L.

1. *Anabasis gypsicola* Iljin [*Lf*: Shrub. *Lc*: Per. *D*: 13, 16, 28]
2. *Anabasis turgaica* Iljin & Krasch. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 10a]

Gen. 2. *Arthrophytum* Schrenk

3. *Arthrophytum balchaschense* (Iljin) Botsch. [*Lf*: Subshrub. *Lc*: Per. *D*: 16, 17, 18, 25]
4. *Arthrophytum betpakdalense* Korovin & Mironov [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 16]
5. *Arthrophytum pulvinatum* Litv. [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 14]
6. *Arthrophytum subulifolium* Schrenk * [*Lf*: Subshrub. *Lc*: Per. *D*: 26]

Gen. 3. *Atriplex* L.

7. *Atriplex iljinii* Aellen * [*Lf*: Herb. *Lc*: An. *D*: 8, 13, 14]

Gen. 4. *Climacoptera* Botsch.

8. *Climacoptera turgaica* (Iljin) Botsch. [*Lf*: Herb. *Lc*: An. *D*: 2, 6, 9, 14]

Gen. 5. *Halimocnemis* C.A.Mey.

9. *Halimocnemis mironovii* Botsch. [*Lf*: Herb. *Lc*: An. *D*: 16, 26]

Gen. 6. *Horaninovia* Fisch. & C.A.Mey.

10. *Horaninovia capitata* Sukhor. [*Lf*: Herb. *Lc*: An. *D*: 18]

Gen. 7. *Nanophyton* Less.

11. *Nanophyton erinaceum* subsp. *karataviense* U.P.Pratov [*Lf*: Subshrub. *Lc*: Per. *D*: 28]

Gen. 8. *Petrosimonia* Bunge

12. *Petrosimonia hirsutissima* (Bunge) Iljin ex Pavlov [*Lf*: Herb. *Lc*: An. *D*: 9, 13, 15, 16, 17, 18]

Gen. 9. *Salsola* L.

13. *Salsola euryphylla* Botsch. [*Lf*: Undershrub. *Lc*: Per.*Cs*: RB. *D*: 14]

Gen. 10. *Suaeda* Forssk. ex J.F.Gmel.

14. *Suaeda scabra* Lomon. [*Lf*: Herb. *Lc*: An. *D*: 14]

Fam. 2. Amaryllidaceae J.St.-Hil.

Gen. 11. *Allium* L.

15. *Allium azutavicum* Kotukhov [*Lf*: Herb. *Lc*: Per. *D*: 22]
16. *Allium bajtulinii* Bajtenov & I.I.Kamenetskaya [*Lf*: Herb. *Lc*: Per. *D*: 25]
17. *Allium goloskokovii* Vved. [*Lf*: Herb. *Lc*: Per. *D*: 23, 24]
18. *Allium ivasczenkoae* Kotukhov [*Lf*: Herb. *Lc*: Per. *D*: 22]
19. *Allium iliense* Regel [*Lf*: Herb. *Lc*: Per. *D*: 26]
20. *Allium jaxarticum* Vved. [*Lf*: Herb. *Lc*: Per. *D*: 29]
21. *Allium kasteki* Popov. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 25]

22. *Allium koksuense* R.M. Fritsch, N. Friesen & S.V. Smirn. [*Lf*: Herb. *Lc*: Per. *D*: 24]
23. *Allium kujukense* Vved. [*Lf*: Herb. *Lc*: Per. *D*: 28, 29]
24. *Allium lasiophyllum* Vved. [*Lf*: Herb. *Lc*: Per. *D*: 25,25a]
25. *Allium lehmannianum* Merckl. ex Bunge [*Lf*: Herb. *Lc*: Per. *D*: 9, 10, 15, 16, 20]
26. *Allium lepsicum* R.M.Fritsch, N.Friesen & S.V.Smirn. [*Lf*: Herb. *Lc*: Per. *D*: 24]
27. *Allium oreoprasoides* Vved. [*Lf*: Herb. *Lc*: Per. *D*: 28]
28. *Allium sergii* Vved. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
29. *Allium scrobiculatum* Vved. [*Lf*: Herb. *Lc*: Per. *D*: 16, 17, 26]
30. *Allium subscabrum* (Regel) R.M.Fritsch [*Lf*: Herb. *Lc*: Per. *D*: 18, 26]
31. *Allium toksanbaicum* N.Friesen & Veselova [*Lf*: Herb. *Lc*: Per. *D*: 24]
32. *Allium turtschicum* Regel [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
33. *Allium victoris* Vved. [*Lf*: Herb. *Lc*: Per. *D*: 29]
34. *Allium viridulum* Ledeb. [*Lf*: Herb. *Lc*: Per. *D*: 11, 18, 23]
35. *Allium zaissanicum* Kotukhov [*Lf*: Herb. *Lc*: Per. *D*: 12]

Fam. 3. Apiaceae Lindl.

Gen. 12. *Autumnalia* Pimenov

36. *Autumnalia botschantzevii* Pimenov [*Lf*: Herb. *Lc*: Per. *D*: 28, 29]

Gen. 13. *Eryngium* L.

37. *Eryngium karatavicum* Iljin [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]

Gen. 14. *Ferula* L.

38. *Ferula glaberrima* Korovin [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 17]
39. *Ferula gypsacea* Korovin [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 21]
40. *Ferula leucographa* Korovin * [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
41. *Ferula malacophylla* Pimenov & J.V.Baranova [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
42. *Ferula pachyphylla* Korovin [*Lf*: Herb. *Lc*: Per. *D*: 28]
43. *Ferula sugatensis* Bajtenov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 25]
44. *Ferula taucumica* Baitenov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 18]
45. *Ferula xeromorpha* Korovin [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 21]

Gen. 15. *Hyalolaena* Bunge

46. *Hyalolaena tschuiliensis* (Pavlov) Pimenov & Kljuykov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 26]

Gen. 16. *Karatavia* Pimenov & Lavrova

47. *Karatavia kultiassovii* (Korovin) Pimenov & Lavrova [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28, 29]

Gen. 17. *Pachypleurum* Ledeb.

48. *Pachypleurum altaicum* Revuschkin [*Lf*: Herb. *Lc*: Per. *D*: 22]

Gen. 18. *Pilopleura* Schischk.

49. *Pilopleura goloskokovii* (Korovin) Pimenov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 24]

Gen. 19. *Prangos* Lindl.

50. *Prangos dzhungarica* Pimenov [*Lf*: Herb. *Lc*: Per. *D*: 24]
51. *Prangos equisetoides* Kuzjmina [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
52. *Prangos lachnantha* (Korovin) Pimenov & Kljuykov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 17]
53. *Prangos multicostata* Kljuykov & Lyskov * [*Lf*: Herb. *Lc*: Per. *D*: 23]

Gen. 20. *Schrenkia* Fisch. & C.A.Mey.

54. *Schrenkia congesta* Korovin [*Lf*: Herb. *Lc*: Per. *D*: 28, 29]

55. *Schrenkia involucrata* Regel & Schmalh. [*Lf*: Herb. *Lc*: Per. *D*: 16, 17, 26, 28, 29]
56. *Schrenkia kultiassovii* Korovin [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 29]
57. *Schrenkia papillaris* Regel & Schmalh. [*Lf*: Herb. *Lc*: Per. *D*: 28]

Gen. 21. *Schtschurowskia* Regel & Schmalh.

58. *Schtschurowskia margaritae* Korovin [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]

Gen. 22. *Seseli* L.

59. *Seseli betpakdalense* Bajtenov [*Lf*: Herb. *Lc*: Per. *D*: 16]
60. *Seseli mironovii* (Korovin) Pimenov & Sdobnina [*Lf*: Herb. *Lc*: Per. *D*: 16]

Gen. 23. *Sphaenolobium* Pimenov

61. *Sphaenolobium korovinii* Pimenov & Kljuykov [*Lf*: Herb. *Lc*: Per. *D*: 28, 29]

Gen. 24. *Tschulaktavia* Bajtenov ex Pimenov & Kljuykov

62. *Tschulaktavia saxatilis* (Bajtenov) Bajtenov ex Pimenov & Kljuykov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 24]

Fam. 4. Asparagaceae Juss.

Gen. 25. *Asparagus* Tourn. ex L.

63. *Asparagus vvedenskyi* Botsch. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 21]

Fam. 5. Asteraceae Bercht. & J.Presl

Gen. 26. *Alfredia* Cass.

64. *Alfredia integrifolia* (Iljin) Tulyag. [*Lf*: Herb. *Lc*: Per. *D*: 24]

Gen. 27. *Amberboa* (Pers.) Less.

65. *Amberboa takhtajanii* Gabrieljan [*Lf*: Herb. *Lc*: An. *D*: 12]

Gen. 28. *Arctium* L.

66. *Arctium alberti* (Regel & Schmalh.) S.López, Romasch., Susanna & N.Garcia [*Lf*: Herb. *Lc*: Per. *D*: 28, 29]
67. *Arctium arctiodes* (Schrenk) Kuntze [*Lf*: Herb. *Lc*: Per. *D*: 9, 10, 15, 16]
68. *Arctium grandifolium* (Kult.) S.López, Romasch., Susanna & N.Garcia RB. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28, 29]
69. *Arctium ugamense* (Karmysch.) S.López, Romasch., Susanna & N.Garcia [*Lf*: Herb. *Lc*: Per. *D*: 29]

Gen. 29. *Artemisia* L.

70. *Artemisia aralensis* Krasch. [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 7, 9, 10, 14]
71. *Artemisia camelorum* Krasch. [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 7, 7a, 8, 9, 10, 14, 15]
72. *Artemisia filatovae* Kupr. [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 10]
73. *Artemisia hippolyti* A.Butkov [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 16]
74. *Artemisia kasakorum* (Krasch.) Pavlov [*Lf*: Herb. *Lc*: Per. *D*: 8, 11]
75. *Artemisia kotuchovii* Kupr. [*Lf*: Herb. *Lc*: Per. *D*: 22]
76. *Artemisia quinqueloba* Trautv. [*Lf*: Subshrub. *Lc*: Per. *D*: 7, 8, 14, 15, 16]
77. *Artemisia saurensis* Kupr. [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 23]
78. *Artemisia valida* Krasch. ex Poljakov [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 21, 28]

Gen. 30. *Brachanthemum* DC.

79. *Brachanthemum kasakhorum* Krasch. [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 2, 10, 16, 18]

Gen. 31. *Cancriniella* Tzvelev

80. *Cancriniella krascheninnikovii* (Rubtzov) Tzvelev [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 16, 26]

Gen. 32. *Centaurea* L.

81. *Centaurea kryloviana* Serg. * [*Lf*: Herb. *Lc*: Per. *D*: 11, 12, 22]

Gen. 33. *Chondrilla* L.

82. *Chondrilla bosseana* Iljin [*Lf*: Herb. *Lc*: Per. *D*: 17, 18]
83. *Chondrilla macra* Iljin [*Lf*: Herb. *Lc*: Per. *D*: 16, 17]
84. *Chondrilla mujunkumensis* Iljin & Igolkin [*Lf*: Herb. *Lc*: Per. *D*: 17, 18]

Gen. 34. *Cousinia* Cass.

85. *Cousinia aspera* (Kult.) Karmysch. [*Lf*: Herb. *Lc*: Per. *D*: 29]
86. *Cousinia gomolitzkii* Juz. ex Tscherneva [*Lf*: Herb. *Lc*: Per. *D*: 28]
87. *Cousinia kasachstanica* Sennikov [*Lf*: Herb. *Lc*: Per. *D*: 27]
88. *Cousinia mindshelkensis* B.Fedtsch. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
89. *Cousinia perovskiensis* (Bornm.) Juz. ex Tschern. [*Lf*: Herb. *Lc*: Per. *D*: 14, 15, 16, 17, 18, 20, 24]
90. *Cousinia schepsaica* Karmysch. [*Lf*: Herb. *Lc*: Per. *D*: 29]
91. *Cousinia turkestanica* (Regel) Juz. [*Lf*: Herb. *Lc*: Per. *D*: 29]
92. *Cousinia xanthiocephala* Tscherneva [*Lf*: Herb. *Lc*: Per. *D*: 21]

Gen. 35. *Echinops* L.

93. *Echinops kasakorum* Pavlov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
94. *Echinops pubisquameus* Iljin [[*Lf*: Herb. *Lc*: Per. *D*: 28]
95. *Echinops subglaber* Schrenk [*Lf*: Herb. *Lc*: Per. *D*: 15, 16, 28]
96. *Echinops transiliensis* Golosk. [*Lf*: Herb. *Lc*: Per. *D*: 25, 26]

Gen. 36. *Galatella* Cass.

97. *Galatella bectauatensis* Kupr. & Koroljuk [*Lf*: Herb. *Lc*: Per. *D*: 11]
98. *Galatella polygaloides* Novopokr. [*Lf*: Herb. *Lc*: Per. *D*: 25a]
99. *Galatella saxatilis* Novopokr. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 25]

Gen. 37. *Hieracium* L.

100. *Hieracium bectauatense* Kupr. [*Lf*: Herb. *Lc*: Per. *D*: 11]

Gen. 38. *Jurinea* Cass.

101. *Jurinea almaatensis* Iljin [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 25]
102. *Jurinea bracteata* Regel & Schmalh. [*Lf*: Herb. *Lc*: Per. *D*: 24]
103. *Jurinea cephalopoda* Iljin [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 15, 21, 28]
104. *Jurinea czilikinoana* Iljin [*Lf*: Herb. *Lc*: Per. *D*: 28]
105. *Jurinea eximia* Tekutj. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
106. *Jurinea fedtschenkoana* Iljin [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 1, 7, 7a, 10]
107. *Jurinea hamulosa* Rubtzov [*Lf*: Herb. *Lc*: Per. *D*: 23, 24]
108. *Jurinea karatavica* Iljin [*Lf*: Herb. *Lc*: Per. *D*: 17, 18]
109. *Jurinea kazachstanica* Iljin [*Lf*: Herb. *Lc*: Per. *D*: 6, 7, 8, 14]
110. *Jurinea knorringiana* Iljin [*Lf*: Herb. *Lc*: Per. *D*: 28]
111. *Jurinea krascheninnikovii* Iljin [*Lf*: Herb. *Lc*: Per. *D*: 9, 11a, 15, 16, 17, 26]
112. *Jurinea lithophila* Rubtzov [*Lf*: Herb. *Lc*: Per. *D*: 24]
113. *Jurinea monticola* Iljin [*Lf*: Herb. *Lc*: Per. *D*: 28]
114. *Jurinea multiceps* Iljin [*Lf*: Herb. *Lc*: Per. *D*: 28]
115. *Jurinea pineticola* Iljin [*Lf*: Herb. *Lc*: Per. *D*: 3, 4]
116. *Jurinea rhizomatoidea* Iljin [*Lf*: Herb. *Lc*: Per. *D*: 28]
117. *Jurinea robusta* Schrenk [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 16, 25, 26]
118. *Jurinea serratuloides* Iljin [*Lf*: Herb. *Lc*: Per. *D*: 12, 23]
119. *Jurinea suidunensis* Korsh. [*Lf*: Herb. *Lc*: Per. *D*: 12, 18, 24]
120. *Jurinea xerophytica* Iljin [*Lf*: Herb. *Lc*: Per. *D*: 4, 9, 11, 12, 14]

Gen. 39. *Lamyropsis* (Kharadze) Dittrich

121. *Lamyropsis macracantha* (Schrenk) Dittrich [*Lf*: Herb. *Lc*: Per. *D*:23, 24]

Gen. 40. *Lepidolopha* C.Winkl.

122. *Lepidolopha gomolitzkii* Kovalevsk. & Safral. [*Lf*: Herb. *Lc*: Per. *D*: 28]
123. *Lepidolopha karatavica* Pavlov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
124. *Lepidolopha krascheninnikovii* Czil. ex Kovalevsk. & Safral. [*Lf*: Herb. *Lc*: Per. *D*: 28]
125. *Lepidolopha talassica* Kovalevsk. & Safral. [*Lf*: Herb. *Lc*: Per. RB. *D*: 29]

Gen. 41. *Rhaponticum* Vaill.

126. *Rhaponticum karatavicum* Regel & Schmalh. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]

Gen. 42. *Ligularia* Cass.

127. *Ligularia pavlovii* (Lipsch.) Cretz. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]

Gen. 43. *Pseudoglossanthis* Poljakov

128. *Pseudoglossanthis arctodshungarica* (Golosk.) Kamelin [*Lf*: Subshrub. *Lc*: Per. *Cs*: RB. *D*: 24]
129. *Pseudoglossanthis simulans* (Pavlov) Kamelin [*Lf*: Herb. *Lc*: Per. *D*: 29]

Gen. 44. *Pseudopodospermum* (Lipsch. &Krasch.) Kuth.

130. *Pseudopodospermum chantavicum* (Pavlov) Zaika, Sukhor. & N.Kilian [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 26]

Gen. 45. *Rhaponticoides* Vaill.

131. *Rhaponticoides kultiassovii* (Iljin) Negaresh [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
132. *Rhaponticoides phyllopoda* (Iljin) Negaresh [*Lf*: Herb. *Lc*: Per. *D*: 28, 29]
133. *Rhaponticoides zaissanica* Kupr., A.L. Ebel et Khrustaleva [*Lf*: Herb. *Lc*: Per. *D*: 12]

Gen. 46. *Saussurea* DC.

134. *Saussurea mikeschinii* Iljin [*Lf*: Subshrub. *Lc*: Per. *Cs*: RB. *D*: 28]
135. *Saussurea ninae* Iljin [*Lf*: Herb. *Lc*: Per. *D*: 24]
136. *Saussurea pseudoblanda* Lipsch. ex Filat. [*Lf*: Herb. *Lc*: Per. *D*: 24]

Gen. 47. *Scorzonera* L.

137. *Scorzonera dianthoides* (Lipsch. & Krasch.) Lipsch. [*Lf*: Herb. *Lc*: Per. *D*: 11]
138. *Scorzonera franchetii* Lipsch. [*Lf*: Herb. *Lc*: Per. *D*: 29]
139. *Scorzonera vavilovii* Kult. [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 28, 29]

Gen. 48. *Senecio* L.

140. *Senecio iljinii* Schischk. [*Lf*: Herb. *Lc*: Per. *D*: 24]
141. *Senecio nuraniae* Roldugin [*Lf*: Herb. *Lc*: An. *D*: 29]

Gen. 49. *Takhtajaniantha* Nazarova

142. *Takhtajaniantha veresczaginii* (Kamelin & S.V.Smirn.) Zaika, Sukhor. & N.Kilian [*Lf*. Herb. *Lc*: Per. D: 22]

Gen. 50. *Tanacetopsis* (Tzvelev) Kovalevsk.

143. *Tanacetopsis goloskokovii* (Poljakov) Karmysch. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 24, 25]
144. *Tanacetopsis pjataevae* (Kovalevsk.) Karmysch. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
145. *Tanacetopsis popovii* Kamelin & Kovalevsk. [*Lf*: Herb. *Lc*: Per. *D*: 28]

Gen. 51. *Tanacetum* L.

146. *Tanacetum corymbiforme* (Tzvelev) K.Bremer & Humphries [*Lf*: Herb. *Lc*: Per. *D*: 23, 24]
147. *Tanacetum kelleri* (Krylov & Plotn.) Takht. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 22]
148. *Tanacetum mindshelkense* Kovalevsk. [*Lf*: Herb. *Lc*: Per. *D*: 28]

149. *Tanacetum saryarkense* Kamelin [*Lf*: Herb. *Lc*: Per. *D*: 16, 26]
150. *Tanacetum saxicola* (Krasch.) Tzvelev [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 7a, 8]
151. *Tanacetum ulutavicum* Tzvelev [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 10a]

Gen. 52. *Taraxacum* F.H.Wigg.

152. *Taraxacum almaatense* Schischk. [*Lf*: Herb. *Lc*: Per. *D*: 25]
153. *Taraxacum arasanum* R.Doll [*Lf*: Herb. *Lc*: Per. *D*: 25]
154. *Taraxacum atrochlorinum* Kirschner & Štěpánek [*Lf*: Herb. *Lc*: Per. *D*: 25]
155. *Taraxacum botschantzevii* Schischk. [*Lf*: Herb. *Lc*: Per. *D*: 28]
156. *Taraxacum cornucopiae* Kirschner & Štěpánek [*Lf*: Herb. *Lc*: Per. *D*: 25]
157. *Taraxacum corvinum* Kirschner & Štěpánek [*Lf*: Herb. *Lc*: Per. *D*: 25]
158. *Taraxacum dzhungaricola* Kirschner & Štěpánek [*Lf*: Herb. *Lc*: Per. *D*: 24]
159. *Taraxacum glabellum* Schischk. [*Lf*: Herb. *Lc*: Per. *D*: 28]
160. *Taraxacum karatavicum* Pavlov [*Lf*: Herb. *Lc*: Per. *D*: 28]
161. *Taraxacum kasachiforme* R.Doll [*Lf*: Herb. *Lc*: Per. *D*: 25]
162. *Taraxacum kasachum* R.Doll [*Lf*: Herb. *Lc*: Per. *D*: 25]
163. *Taraxacum magnum* Korol. [*Lf*: Herb. *Lc*: Per. *D*: 25a]
164. *Taraxacum medeense* R.Doll [*Lf*: Herb. *Lc*: Per. *D*: 24, 25]
165. *Taraxacum perpusillum* Schischk. [*Lf*: Herb. *Lc*: Per. *D*: 24]
166. *Taraxacum pseudolugubre* R.Doll [*Lf*: Herb. *Lc*: Per. *D*: 25]
167. *Taraxacum pseudotianschanicum* R.Doll [*Lf*: Herb. *Lc*: Per. *D*: 8]
168. *Taraxacum saposhnikovii* Schischk. [*Lf*: Herb. *Lc*: Per. *D*: 23, 24]
169. *Taraxacum sublilacinum* Kirschner & Štěpánek [*Lf*: Herb. *Lc*: Per. *D*: 25]
170. *Taraxacum urdzharense* Orazova [*Lf*: Herb. *Lc*: Per. *D*: 23]
171. *Taraxacum violaceum* R.Doll [*Lf*: Herb. *Lc*: Per. *D*: 25]

Gen. 53. *Tragopogon* L.

172. *Tragopogon karelinii* S.A.Nikitin [*Lf*: Herb. *Lc*: Bi. *D*: 10, 16, 18, 23, 24]

Gen. 54. *Vickifunkia* C.Ren, L.Wang, I.D.Illar. & Q.E.Yang

173. *Vickifunkia kareliniana* (Stschegl.) C.Ren, L.Wang, I.D.Illar. & Q.E.Yang [*Lf*: Herb. *Lc*: Per. *D*: 23]

Fam. 6. Berberidaceae Juss.

Gen. 55. *Berberis* L.

174. *Berberis karkaralensis* Kornil. & Potapov [*Lf*: Shrub. *Lc*: Per. *Cs*: RB. *D*: 11a]

Fam. 7. Betulaceae Gray

Gen. 56. *Betula* L.

175. *Betula karagandensis* V.N.Vassil. [*Lf*: Tree. *Lc*: Per. *D*: 11a]
176. *Betula saviczii* V.N.Vassil. [*Lf*: Tree. *Lc*: Per. *D*: 10]

Fam. 8. Bignoniaceae Juss.

Gen. 57. *Incarvillea* Juss.

177. *Incarvillea semiretschenskia* (B.Fedtsch.) Grierson [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 26]

Fam. 9. Boraginaceae Juss.

Gen. 58. *Eritrichium* Schrad. ex Gaudin

178. *Eritrichium relictum* Kudab. [*Lf*: Herb. *Lc*: Per. *D*: 24]

Gen. 59. *Heliotropium* Tourn. ex L.

179. *Heliotropium parvulum* Popov [*Lf*: Herb. *Lc*: An. *Cs*: RB. *D*: 16, 18, 25]

Gen. 60. *Lappula* Moench

180. *Lappula baitenovii* Kudab. [*Lf*: Herb. *Lc*: Bi. *D*: 25]
181. *Lappula coronifera* Popov [*Lf*: Herb. *Lc*: An. *D*: 11]
182. *Lappula cristata* (Bunge) B.Fedtsch. *[*Lf*: Herb. *Lc*: An. *D*: 10, 11, 12]
183. *Lappula diploloma* (Fisch. & C.A.Mey.) Gürke [*Lf*: Herb. *Lc*: An. *D*: 9, 11]
184. *Lappula glabrata* Popov [*Lf*: Herb. *Lc*: Bi. *Cs*: RB. *D*: 16]
185. *Lappula ketmenica* Kudab. [*Lf*: Herb. *Lc*: An. *D*: 25a]
186. *Lappula kuprijanovii* Ovczinnikova [*Lf*: Herb. *Lc*: Bi. RB. *D*: 28]
187. *Lappula lipschitzii* Popov [*Lf*: Herb. *Lc*: An. *D*: 21]
188. *Lappula pavlovii* Golosk. [*Lf*: Herb. *Lc*: An. *D*: 24]
189. *Lappula saphronovae* Kamelin [*Lf*: Herb. *Lc*: Bi. *D*: 13b]
190. *Lappula zaissanica* (Aralbaev) Aralbaev [*Lf*: Herb. *Lc*: An. *D*: 12]

Gen. 61. *Lepechiniella* Popov

191. *Lepechiniella austrodshungarica* Golosk. [*Lf*: Herb. *Lc*: An.-Bi. *D*: 10, 24]
192. *Lepechiniella michaelis* Golosk. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 24]
193. *Lepechiniella omphaloides* (Schrenk) Popov [*Lf*: Herb. *Lc*: Bi. *D*: 10]
194. *Lepechiniella saurica* (Bajtenov & Kudab.) Ovczinnikova [*Lf*: Herb. *Lc*: An. *D*: 23]

Gen. 62. *Mattiastrum* (Boiss.) Brand

195. *Mattiastrum karataviense* (Pavlov ex Popov) Czerep. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]

Gen. 63. *Myosotis* L.

196. *Myosotis kazakhstanica* O.D.Nikif. [*Lf*: Herb. *Lc*: An. *D*: 10, 10a, 11, 11a]

Gen. 64. *Paracaryum* Boiss.

197. *Paracaryum integerrimum* Myrz. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]

Gen. 65. *Rindera* Pall.

198. *Rindera ochroleuca* Kar. & Kir. * [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 18]

Gen. 66. *Rochelia* Rchb.

199. *Rochelia leiosperma* (Popov) Golosk. [*Lf*: Herb. *Lc*: An. *D*: 24]

Gen. 67. *Sauria* Bajtenov

200. *Sauria akkolia* Bajtenov [*Lf*: Herb. *Lc*: Per. *D*: 17]

Fam. 10. Brassicaceae Burnett

Gen. 68. *Botschantzevia* Nabiev

201. *Botschantzevia karatavica* (Lipsch. & Pavlov) Nabiev [*Lf*: Dwarf semishrub. *Lc*: Per. *Cs*: RB. *D*: 28]

Gen. 69. *Clausia* Korn-Trotzky.

202. *Clausia kasakorum* Pavlov [*Lf*: Herb. *Lc*: Per. *D*: 10a]
203. *Clausia robusta* Pachom. [*Lf*: Herb. *Lc*: Per. *D*: 5]

Gen. 70. *Erysimum* Tourn. ex L.

204. *Erysimum kazachstanicum* Botsch. [*Lf*: Herb. *Lc*: Bi. *D*: 10, 10a, 11, 23]

Gen. 71. *Eutrema* R.Br.

205. *Eutrema halophilum* (C.A.Mey.) Al-Shehbaz & Warwick* [*Lf*: Herb. *Lc*: An. *D*: 2, 3, 4, 11, 12]
206. *Eutrema platypetalum* (Schrenk) Al-Shehbaz & Warwick [*Lf*: Herb. *Lc*: Per. *D*: 24]

Gen. 72. *Isatis* Tourn. ex L.

207. *Isatis canaliculata* (Vassilcz.) V.V.Botschantz. [*Lf*: Herb. *Lc*: Bi. *D*: 9, 10]
208. *Isatis deserti* (N.Busch) V.V.Botschantz. [*Lf*: Herb. *Lc*: An. *D*: 16]

Gen. 73. *Lepidium* L.

209. *Lepidium jarmolenkoi* V.M.Vinogr. [*Lf*: Herb. *Lc*: Per. *D*: 16]
210. *Lepidium karataviense* Regel & Schmalh. [*Lf*: Herb. *Lc*: Per. *D*: 28]
211. *Lepidium mummenhoffianum* Al-Shehbaz [*Lf*: Herb. *Lc*: Per. *D*: 24]
212. *Lepidium pavlovii* Al-Shehbaz & Mummenhoff [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28, 29]
213. *Lepidium robustum* (Pavlov) Al-Shehbaz [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
214. *Lepidium sagittatum* (Kar. & Kir.) Al-Shehbaz [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 23, 24]
215. *Lepidium trautvetteri* (Botsch.) Al-Shehbaz [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 16, 18]

Gen. 74. *Parrya* R.Br.

216. *Parrya longicarpa* Krasn. [*Lf*: Herb. *Lc*: Per. *D*: 26]
217. *Parrya papillosa* (Vassilcz.) D.A.German & Al-Shehbaz [*Lf*: Herb. *Lc*: An. *D*: 28, 29]
218. *Parrya pavlovii* A.N.Vassiljeva [*Lf*: Herb. *Lc*: Per. *D*: 28]
219. *Parrya pazijae* (Pachom.) D.A.German & Al-Shehbaz [*Lf*: Undershrub. *Lc*: Per. *D*: 28, 29]
220. *Parrya saurica* (Pachom.) D.A.German & Al-Shehbaz [*Lf*: Herb. *Lc*: Per. *D*: 23]
221. *Parrya vvedenskyi* (Pachom.) D.A.German & Al-Shehbaz [*Lf*: Herb. *Lc*: Bi. *D*: 28, 29]

Gen. 75. *Rhammatophyllum* O.E.Schulz

222. *Rhammatophyllum pachyrhizum* (Kar. & Kir.) O.E.Schulz [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 7a, 8, 9, 10, 10a, 11, 13, 14, 16, 22, 24]

Gen. 76. *Strigosella* Boiss.

223. *Strigosella myrzakulovii* Bajtenov [*Lf*: Herb. *Lc*: An. *D*: 28, 29]

Fam. 11. Campanulaceae Juss.

Gen. 77. *Sergia* Fed.

224. *Sergia sewerzowii* (Regel) Fed. [*Lf*: Herb. *Lc*: Per. *D*: 28, 29]

Fam. 12. Caryophyllaceae Juss.

Gen. 78. *Eremogone* Fenzl

225. *Eremogone turlanica* (Bajtenov) Czerep. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]

Gen. 79. *Dianthus* L.

226. *Dianthus karataviensis* Pavlov [*Lf*: Herb. *Lc*: Per. RB. *D*: 28, 29]
227. *Dianthus multisquameus* Bondarenko & R.M.Vinogr. [*Lf*: Herb. *Lc*: Per. *D*: 28, 29]

Gen. 80. *Gypsophila* L.

228. *Gypsophila aulieatensis* B.Fedtsch. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]

Gen. 81. *Silene* L.

229. *Silene anisoloba* Schrenk [*Lf*: Herb. *Lc*: Per. *D*: 10, 10a]
230. *Silene betpakdalensis* Bajtenov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 13, 16, 26]
231. *Silene jaxartica* Pavlov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
232. *Silene muslimii* Pavlov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 24, 26]

Fam. 13. Convolvulaceae Juss.

Gen. 82. *Cuscuta* L.

233. *Cuscuta camelorum* Pavlov [*Lf*: Herb. *Lc*: An. *D*: 28]

234. *Cuscuta elpassiana* Pavlov [*Lf*: Herb. *Lc*: An. *D*: 26]
235. *Cuscuta karatavica* Pavlov [*Lf*: Herb. *Lc*: An. *D*: 28]

Fam. 14. Crassulaceae J.St.-Hil.
Gen. 83. *Pseudosedum* (Boiss.) A.Berger
236. *Pseudosedum karatavicum* Boriss. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]

Fam. 15. Cyperaceae Juss.
Gen. 84. *Cyperus* L.
237. *Cyperus soongoricus* Kar. & Kir. [*Lf*: Herb. *Lc*: An. *D*: 12]

Fam. 16. Euphorbiaceae Juss.
Gen. 85. *Euphorbia* L.
238. *Euphorbia heptapotamica* Golosk. [*Lf*: Herb. *Lc*: An. *D*: 24]
239. *Euphorbia kalbaensis* Baikov & I.V.Khan [*Lf*: Herb. *Lc*: Per. *D*: 22]
240. *Euphorbia saurica* Baikov [*Lf*: Herb. *Lc*: Per. *D*: 23]
241. *Euphorbia yaroslavii* Poljakov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 25]

Fam. 17. Fabaceae Lindl.
Gen. 86. *Astragalus* L.
242. *Astragalus abbreviatus* Kar. & Kir. [*Lf*: Herb. *Lc*: Per. *D*: 24, 25, 25a, 26, 27]
243. *Astragalus arganaticus* Bunge [*Lf*: Herb. *Lc*: Per. *D*: 18, 24]
244. *Astragalus balchaschensis* Sumnev. [*Lf*: Herb. *Lc*: Per. *D*: 18]
245. *Astragalus brotherusii* Podlech [*Lf*: Herb. *Lc*: Per. *D*: 25]
246. *Astragalus chaetolobus* Bunge [*Lf*: Subshrub. *Lc*: Per. *D*: 4, 11, 22]
247. *Astragalus citoinflatus* Bondarenko [*Lf*: Herb. *Lc*: Per. *D*: 17]
248. *Astragalus clausii* C.A.Mey. [*Lf*: Herb. *Lc*: Per. *D*: 6]
249. *Astragalus cytisoides* Bunge [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 18]
250. *Astragalus fragiformis* Willd. [*Lf*: Undershrub. *Lc*: Per. *D*: 22]
251. *Astragalus georgii* Gontsch. [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 28]
252. *Astragalus inflatus* DC. [*Lf*: Undershrub. *Lc*: Per. *D*: 22]
253. *Astragalus jaxarticus* Pavlov [*Lf*: Herb. *Lc*: Per. *D*: 26, 28]
254. *Astragalus juvenalis* Delile [*Lf*: Herb. *Lc*: An. *D*: 10, 18]
255. *Astragalus karataviensis* Pavlov [*Lf*: Dwarf semishrub. *Lc*: Per. *Cs*: RB. *D*: 21, 28]
256. *Astragalus karatjubeki* Golosk. [*Lf*: Subshrub. *Lc*: Per. *D*: 16, 18]
257. *Astragalus kasachstanicus* subsp. *coloratus* Knjaz. [*Lf*: Herb. *Lc*: Per. *D*: 10, 11a]
258. *Astragalus kazymbeticus* Saposhn. ex Sumnev. [*Lf*: Herb. *Lc*: Per. *D*: 24]
259. *Astragalus kopalensis* Lipsky [*Lf*: Shrub. *Lc*: Per. *Cs*: RB. *D*: 24]
260. *Astragalus krascheninnikovii* Kamelin [*Lf*: Shrub. *Lc*: Per. *Cs*: RB. *D*: 16]
261. *Astragalus krasnovii* Popov [*Lf*: Herb. *Lc*: Per. *D*: 26]
262. *Astragalus leucocalyx* Popov * [*Lf*: Shrub. *Lc.* Per. *D*: 28]
263. *Astragalus lipschitzii* Pavlov [*Lf*: Undershrub. *Lc*: Per. *D*: 28, 29]
264. *Astragalus mokeevae* Popov [*Lf*: Subshrub. *Lc*: Per. *D*: 28]
265. *Astragalus neopopovii* Golosk. [*Lf*: Herb. *Lc*: Per. *D*: 24]
266. *Astragalus psammophilus* Golosk. [*Lf*: Subshrub. *Lc*: Per. *D*: 18]
267. *Astragalus pseudocytisoides* Popov *Lf*: Dwarf semishrub. *Lc*: Per. *Cs*: RB. *D*: 25, 26]

268. *Astragalus psilopus* Schrenk [*Lf*: Herb. *Lc*: Per. *D*: 18, 24]
269. *Astragalus pulposus* Popov [*Lf*: Herb. *Lc*: Per. *D*: 25]
270. *Astragalus pycnolobus* Bunge [*Lf*: Subshrub. *Lc*: Per. *D*: 12, 22]
271. *Astragalus rariflorus* Ledeb. * [*Lf*: Herb. *Lc*: Per. *D*: 11]
272. *Astragalus rubtzovii* Boriss. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 25a]
273. *Astragalus saphronovae* Kulikov [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 7, 13, 13b]
274. *Astragalus sarchanensis* Gontsch. [*Lf*: Herb. *Lc*: Per. *D*: 24]
275. *Astragalus semenovii* Bunge [*Lf*: Herb. *Lc*: Per. *D*: 18, 24, 25a]
276. *Astragalus sisyrodytes* Bunge [*Lf*: Herb. *Lc*: Per. *D*: 28]
277. *Astragalus spartioides* Kar. & Kir. [*Lf*: Subshrub. *Lc*: Per. *D*: 18]
278. *Astragalus speciosissimus* Pavlov [*Lf*: Subshrub. *Lc*: Per. *D*: 28]
279. *Astragalus subcaracugensis* Sitpaeva [*Lf*: Subshrub. *Lc*: Per. *D*: 9]
280. *Astragalus subternatus* Pavlov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
281. *Astragalus sumneviczii* Pavlov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 16]
282. *Astragalus terektensis* Fisjun [*Lf*: Herb. *Lc*: Per. *D*: 24]
283. *Astragalus transnominatus* M.N.Abdull. [*Lf*: Herb. *Lc*: Per. *D*: 26, 28]
284. *Astragalus tscharynensis* Popov [*Lf*: Undershrub. *Lc*: Per. *Cs*: RB. *D*: 24, 25]
285. *Astragalus turajgyricus* Golosk. [*Lf*: Herb. *Lc*: Per. *D*: 25]
286. *Astragalus unilateralis* Kar. & Kir. [*Lf*: Herb. *Lc*: Per. *D*: 4, 7, 8, 11, 12, 22]
287. *Astragalus virens* Pavlov [*Lf*: Herb. *Lc*: Per. *D*: 28]

Gen. 87. *Caragana* Lam.

288. *Caragana media* Sanchir [*Lf*: Shrub. *Lc*: Per. *D*: 10, 11]

Gen. 88. *Chesneya* Lindl. ex Endl.

289. *Chesneya karatavica* Kamelin [*Lf*: Herb. *Lc*: Per. *D*: 28]

Gen. 89. *Hedysarum* L.

290. *Hedysarum bectauatavicum* Bajtenov [*Lf*: Herb. Lc: Per. Cs: RB. D: 11]
291. *Hedysarum chantavicum* Popov ex Bajtenov [*Lf*: Herb. *Lc*: Per. *D*: 26]
292. *Hedysarum karataviense* B.Fedtsch. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
293. *Hedysarum nikolai* Kovalevsk. [*Lf*: Herb. *Lc*: Per. *D*: 28]
294. *Hedysarum mindshilkense* Bajtenov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
295. *Hedysarum pallidiflorum* Pavlov [*Lf*: Herb. *Lc*: Per. *D*: 28]
296. *Hedysarum pavlovii* Bajtenov [*Lf*: Herb. *Lc*: Per. *D*: 28]
297. *Hedysarum tarbagataicum* Knjaz. [*Lf*: Herb. *Lc*: Per. *D*: 3, 11, 12, 22, 23]
298. *Hedysarum ulutavicum* Knjaz. [*Lf*: Herb. *Lc*: Per. *D*: 10a]
299. *Hedysarum villosissimum* Knjaz. [*Lf*: Herb. *Lc*: Per. *D*: 10, 11]

Gen. 90. *Onobrychis* Mill.

300. *Onobrychis alatavica* Bajtenov * [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 25]

Gen. 91. *Oxytropis* DC.

301. *Oxytropis alberti-regelii* Vassilcz. [*Lf*: Herb. *Lc*: Per. *D*: 29]
302. *Oxytropis almaatensis* Bajtenov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 25, 25a]
303. *Oxytropis bajtulinii* Kotukhov [*Lf*: Herb. *Lc*: Per. *D*: 22]
304. *Oxytropis biloba* Saposhn. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 23]
305. *Oxytropis bosculensis* Golosk. [*Lf*: Herb. *Lc*: Per. *D*: 25]
306. *Oxytropis brevicaulis* Ledeb. [*Lf*: Herb. *Lc*: Per. *D*: 2, 3, 9, 10, 11, 18]
307. *Oxytropis canopatula* Vassilcz. [*Lf*: Herb. *Lc*: Per. *D*: 28]
308. *Oxytropis cretacea* Basil. [*Lf*: Herb. *Lc*: Per. *D*: 1]
309. *Oxytropis echidna* Vved. [*Lf*: Undershrub. *Lc*: Per. *Cs*: RB. *D*: 28]
310. *Oxytropis fruticulosa* Bunge [*Lf*: Undershrub. *Lc*: Per. *D*: 24]

311. *Oxytropis gebleriana* Schrenk [*Lf*: Herb. *Lc*: Per. *D*: 1, 2, 3, 7a, 9, 10, 11, 16, 18]
312. *Oxytropis heteropoda* Bunge [*Lf*: Herb. *Lc*: Per. *D*: 24, 25]
313. *Oxytropis karataviensis* Pavlov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
314. *Oxytropis kyziltalensis* Vassilcz. [*Lf*: Herb. *Lc*: Per. *D*: 24]
315. *Oxytropis niedzweckiana* Popov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 25]
316. *Oxytropis pulvinoides* Vassilcz. [*Lf*: Herb. *Lc*: Per. *D*: 24]
317. *Oxytropis satpaevii* Bajtenov [*Lf*: Herb. *Lc*: Per. *D*: 11]
318. *Oxytropis subcapitata* Gontsch [*Lf*: Herb. *Lc*: Per. *D*: 28]
319. *Oxytropis subverticillaris* C.A.Mey. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 3, 10, 10a, 11]
320. *Oxytropis sumneviczii* Krylov [*Lf*: Herb. *Lc*: Per. *D*: 22]
321. *Oxytropis talgarica* Popov [*Lf*: Herb. *Lc*: Per. *D*: 25]
322. *Oxytropis tomentosa* Gontsch. [*Lf*: Herb. *Lc*: Per. *D*: 28]

Fam. 18. Frankeniaceae Desv.

Gen. 92. *Frankenia* L.

323. *Frankenia bucharica* subsp. *mironovii* (Botsch.) Chrtek [*Lf*: Subshrub. *Lc*: Per. *D*: 16, 25, 26]
324. *Frankenia bucharica* subsp. *transkaratavica* (Botsch.) Chrtek [*Lf*: Subshrub. *Lc*: Per. *D*: 17]

Fam. 19. Gentianaceae Juss.

Gen. 93. *Comastoma* Toyok.

325. *Comastoma irinae* (Pachom.) Czerep. [*Lf*: Herb. *Lc*: An. *D*: 25]

Fam. 20. Lamiaceae Martinov

Gen. 94. *Dracocephalum* L.

326. *Dracocephalum pavlovii* Roldugin [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 29]

Gen. 95. *Phlomoides* Moench.

327. *Phlomoides affinis* (Schrenk) Salmaki [*Lf*: Herb. *Lc*: Per. *D*: 10, 10a, 11, 16, 17, 18, 28]
328. *Phlomoides boraldaica* A.L.Ebel [*Lf*: Herb. *Lc*: Per. *D*: 28, 29]
329. *Phlomoides czuiliensis* (Golosk.) Adylov, Kamelin & Makhm. [*Lf*: Herb. *Lc*: Per. *D*: 26]
330. *Phlomoides eremostachydioides* (Popov) Y.Zhao & C.L.Xiang [*Lf*: Herb. *Lc: Cs*: RB. Per. *D*: 28]
331. *Phlomoides gymnocalyx* (Schrenk) Adylov, Kamelin & Makhm. [*Lf*: Herb. *Lc*: Per. *D*: 18, 24, 26]
332. *Phlomoides iliensis* (Regel) Adylov, Kamelin & Makhm [*Lf*: Herb. *Lc*: Per. *D*: 18, 24]
333. *Phlomoides pectinata* (Popov) Adylov, Kamelin & Makhm. [*Lf*: Herb. *Lc*: Per. *D*: 28]
334. *Phlomoides rotala* (Schrenk ex Fisch., C.A.Mey. & Avé-Lall.) Salmaki [*Lf*: Herb. *Lc*: Per. *D*: 18]
335. *Phlomoides septentrionalis* (Popov) Adylov, Kamelin & Makhm. [*Lf*: Herb. *Lc*: Per. *D*: 27, 28, 29]

Gen. 96. *Phlomis* L.

336. *Phlomis mindshelkensis* Lazkov [*Lf*: Herb. *Lc*: Per. *D*: 28]

Gen. 97. *Lagochilus* Bunge ex Benth.

337. *Lagochilus androssowii* Knorring [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 15, 28]
338. *Lagochilus longidentatus* Knorring [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 16, 28]
339. *Lagochilus taukumensis* Tzukerv. [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 18]

Gen. 98. *Leonurus* L.

340. *Leonurus incanus* V.I.Krecz. & Kuprian. [*Lf*: Herb. *Lc*: Per. *D*: 24]

Gen. 99. *Salvia* L.

341. *Salvia trautvetteri* Regel [*Lf*: Herb. *Lc*: Per. *D*: 28, 29]

Gen. 100. *Scutellaria* L.

342. *Scutellaria androssovii* Juz. [*Lf*: Herb. *Lc*: Per. *D*: 15, 28]
343. *Scutellaria karatavica* Juz. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
344. *Scutellaria kurssanovii* Pavlov [*Lf*: Herb. *Lc*: Per. *D*: 28]
345. *Scutellaria navicularis* Juz. [*Lf*: Subshrub. *Lc*: Per. *Cs*: RB. *D*: 18, 24]
346. *Scutellaria subcaespitosa* Pavlov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 27, 28, 29]
347. *Scutellaria titovii* Juz. [*Lf*: Herb. *Lc*: Per. *D*: 26]
348. *Scutellaria turgaica* Juz. [*Lf*: Herb. *Lc*: Per. *D*: 9, 10, 10a, 11, 11a, 16]

Gen. 101. *Thymus* L.

349. *Thymus crebrifolius* Klokov [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 10, 10a, 11a]
350. *Thymus eremita* Klokov [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 10a, 11]
351. *Thymus karatavicus* Dmitrieva [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 28, 29]
352. *Thymus magnificus* Klokov [*Lf*: Dwarf semishrub. *Lc*: Per. *D*: 25]

Fam. 21. Liliaceae Juss.

Gen. 102. *Fritillaria* L.

353. *Fritillaria kolbintsevii* Rukšāns & Zubov [*Lf*: Herb. *Lc*: Per. *D*: 24]

Gen. 103. *Gagea* Salisb.

354. *Gagea almaatensis* Levichev, A.Peterson & J.Peterson [*Lf*: Herb. *Lc*: Per. *D*: 25]
355. *Gagea iliensis* Popov [*Lf*: Herb. *Lc*: Per. *D*: 16,18]
356. *Gagea sarysuensis* Murz. [*Lf*: Herb. *Lc*: Per. *D*: 10, 11]
357. *Gagea ularsaica* I.G.Levichev [*Lf*: Herb. *Lc*: Per. *D*: 28, 29]

Gen. 104. *Tulipa* L.

358. *Tulipa alberti* Regel [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 10, 16, 18, 24, 26, 28, 29]
359. *Tulipa annae* J.de Groot & Zonn. [*Lf*: Herb. *Lc*: Per. *D*: 22, 24]
360. *Tulipa auliekolica* Perezhogin [*Lf*: Herb. *Lc*: Per. *D*: 2]
361. *Tulipa berkariensis* Rukšāns * [*Lf*: Herb. *Lc*: Per. *D*: 27, 28, 29]
362. *Tulipa brachystemon* Regel * [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 24]
363. *Tulipa dianae-verettiae* J.de Groot & Zonn. [*Lf*: Herb. *Lc*: Per. *D*: 22]
364. *Tulipa ivasczenkoae* Epiktetov & Belyalov [*Lf*: Herb. *Lc*: Per. *D*: 24]
365. *Tulipa kolbintsevii* Zonn. [*Lf*: Herb. *Lc*: Per. *D*: 24]
366. *Tulipa lemmersii* Zonn., Peterse & J.de Groot [*Lf*: Herb. *Lc*: Per. *D*: 29]
367. *Tulipa orthopoda* Vved. * [*Lf*: Herb. *Lc*: Per. *D*: 28, 29]
368. *Tulipa regelii* Krasn. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 26]
369. *Tulipa turgaica* Perezhogin [*Lf*: Herb. *Lc*: Per. *D*: 9]
370. *Tulipa salsola* Rukšāns & Zubov [*Lf*: Herb. *Lc*: Per. *D*: 24]

Fam. 22. Nitrariaceae Lindl.

Gen. 105. *Nitraria* L.

371. *Nitraria iliensis* Banaev & Tomoshevich [*Lf:* Shrub. *Lc:* Per. *D:*18, 24]

Gen. 106. *Tetradiclis* Steven ex M.Bieb.

372. *Tetradiclis corniculata* Khalk. [*Lf*: Herb. *Lc*: An. *D*: 12]

Fam. 23. Orobanchaceae Vent.

Gen. 107. *Euphrasia* L.

373. *Euphrasia integriloba* J.J.Dmitriev & N.I.Rubtzov [*Lf*: Herb. *Lc*: An. *D*: 24]
374. *Euphrasia karataviensis* Govor. [*Lf*: Herb. *Lc*: An. *D*: 28, 29]

Gen. 108. *Pedicularis* L.

375. *Pedicularis czuiliensis* Semiotr. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 26]
376. *Pedicularis interrupta* subsp. *tarbagataica* (Semiotr.) Kamelin [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 23]
377. *Pedicularis kokpakensis* Semiotr. [*Lf*: Herb. *Lc*: Per. *D*: 25a]
378. *Pedicularis masalskyi* Semiotr. [*Lf*: Herb. *Lc*: Per. *D*: 29]
379. *Pedicularis transversa* Baimukhambetova [*Lf:* Herb. *Lc:* Per. *D:* 25a]

Fam. 24. Plantaginaceae Juss.

Gen. 109. *Linaria* Mill.

380. *Linaria macrophylla* Kuprian. [*Lf*: Herb. *Lc*: Per. *D*: 8]

Fam. 25. Plumbaginaceae Juss.

Gen. 110. *Acantholimon* Boiss.

380. *Acantholimon karatavicum* Pavlov [*Lf*: Undershrub. *Lc*: Per. *D*: 17, 28]
382. *Acantholimon linczevskii* Pavlov [*Lf*: Undershrub. *Lc*: Per. *Cs*: RB. *D*: 28]
383. *Acantholimon mikeschinii* Lincz. [*Lf*: Undershrub. *Lc*: Per. *D*: 28]
384. *Acantholimon minshelkense* Pavlov [*Lf*: Subshrub. *Lc*: Per. *D*: 28]
385. *Acantholimon pavlovii* Lincz. [*Lf*: Undershrub. *Lc*: Per. *D*: 29]
386. *Acantholimon squarrosum* Pavlov [*Lf*: Undershrub. *Lc*: Per. *D*: 28]

Gen. 111. *Limonium* Mill.

387. *Limonium botschantzevii* (Lincz.) M.Malekm., Akhani & Borsch [*Lf*: Herb. *Lc*: Per. *D*: 21]
388. *Limonium michelsonii* Lincz. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 24, 25, 25a]

Fam. 26. Poaceae Barnhart

Gen. 112. *Agropyron* Gaertn,

389. *Agropyron cristatum* subsp. *tarbagataicum* (Plotn.) Tzvelev [*Lf*: Herb. *Lc*: Per. *D*: 22, 23]

Gen. 113. *Elymus* L.

390. *Elymus arcuatus* (Golosk.) Tzvelev [*Lf*: Herb. *Lc*: Per. *D*: 25]
391. *Elymus glaucissimus* (Popov) Tzvelev [*Lf*: Herb. *Lc*: Per. *D*: 25]
392. *Elymus sibinicus* Kotukhov [*Lf*: Herb. *Lc*: Per. *D*: 22]

Gen. 114. *Festuca* Tourn. ex L.

393. *Festuca irtyshensis* E.B.Alexeev [*Lf*: Herb. *Lc*: Per. *D*: 3]
394. *Festuca saurica* E.B.Alexeev [*Lf*: Herb. *Lc*: Per. *D*: 23]

Gen. 115. *Leymus* Hochst.

395. *Leymus divaricatus* (Drobow) Tzvelev [*Lf*: Herb. *Lc*: Per. *D*: 25, 28]

Gen. 116. *Limnas* Trin.

396. *Limnas veresczaginii* Krylov & Schischk. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 22]

Gen. 117. *Poa* L.

397. *Poa koksuensis* Golosk. [*Lf*: Herb. *Lc*: Per. *D*: 24]

Gen. 118. *Puccinellia* Parl.
398. *Puccinellia macropus* V.I.Krecz. [*Lf*: Herb. *Lc*: Per. *D*: 26]
Gen. 119. *Stipa* L.
399. *Stipa argillosa* Kotukhov * [*Lf*: Herb. *Lc*: Per. *D*: 22]
400. *Stipa austroaltaica* Kotukhov [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 22]
401. *Stipa karakabinica* Kotukhov [*Lf*: Herb. *Lc*: Per. *D*: 23]
402. *Stipa kempirica* Kotukhov [*Lf*: Herb. *Lc*: Per. *D*: 23]
403. *Stipa kotuchovii* M.Nobis [*Lf*: Herb. *Lc*: Per. *D*: 23]

Fam. 27. Polygonaceae Juss.
Gen. 120. *Atraphaxis* L.
404. *Atraphaxis muschketowii* Krasn. [*Lf*: Shrub. *Lc*: Per. *Cs*: RB. *D*: 25]
405. *Atraphaxis teretifolia* (Popov) Kom. [*Lf*: Shrub. *Lc*: Per. *Cs*: RB. *D*: 10, 11, 18]
Gen. 121. *Calligonum* L.
406. *Calligonum turbineum* Pavlov [Lf: Shrub. Lc: Per. *D*: 17, 18, 20]
Gen. 122. *Rumex* L.
407. *Rumex fischeri* Rchb. [*Lf*: Herb. *Lc*: Per. *D*: 24]
408. *Rumex komarovii* Schischk. & Serg. [Lf: Herb. Lc: Per. *D*: 11]

Fam. 28. Ranunculaceae Juss.
Gen. 123. *Aquilegia* L.
409. *Aquilegia karatavica* Mikeschin [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
410. *Aquilegia vitalii* Gamajun. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 24]
Gen. 124. *Delphinium* L.
411. *Delphinium austroaltaicum* A.L.Ebel [*Lf*: Herb. *Lc*: Per. *D*: 22]
412. *Delphinium connectens* Pachom. [*Lf*: Herb. *Lc*: Per. *D*: 25a]
413. *Delphinium pavlovii* Kamelin [*Lf*: Herb. *Lc*: Per. *D*: 28]
Gen. 125. *Ranunculus* L.
414. *Ranunculus karkaralensis* Schegol. [*Lf*: Herb. *Lc*: Per. *D*: 11a]
Gen. 126. *Thalictrum* Tourn. ex L.
415. *Thalictrum bykovii* Kotukhov * [*Lf*: Herb. *Lc*: Per. *D*: 22]

Fam. 29. Rosaceae Juss.
Gen. 127. *Alchemilla* L.
416. *Alchemilla goloskokovii* Juz. [*Lf*: Herb. *Lc*: Per. *D*: 24]
Gen. 128. *Amelanchier* Medik.
417. *Amelanchier turkestanica* Litv. [*Lf*: Shrub. *Lc*: Per. *D*: 11]
Gen. 129. *Cotoneaster* Medik.
418. *Cotoneaster alatavicus* Popov [*Lf*: Shrub. *Lc*: Per. *D*: 24, 25, 27, 29]
419. *Cotoneaster altaicus* G.Klotz ex J.Fryer & B.Hylmö [*Lf*: Shrub. *Lc*: Per. *D*: 25]
420. *Cotoneaster krasnovii* Pojark. [*Lf*: Shrub. *Lc*: Per. *D*: 18, 24, 25, 26]
421. *Cotoneaster neoantoninae* A.N.Vassiljeva [*Lf*: Shrub. *Lc*: Per. *D*: 24, 25]
422. *Cotoneaster polyanthemus* E.L.Wolf [*Lf*: Shrub. *Lc*: Per. *D*: 24, 25]
423. *Cotoneaster talgaricus* Popov [*Lf*: Shrub. *Lc*: Per. *D*: 24, 25, 25a]
Gen. 130. *Crataegus* L.
424. *Crataegus ambigua* subsp. *transcaspica* (Pojark.) K.I.Chr. [*Lf*: Tree. *Lc*: Per. *D*: 13b]
Gen. 131. *Potentilla* L.
425. *Potentilla karatavica* Juz. [*Lf*: Herb. *Lc*: Per. *D*: 28]

426. *Potentilla salsa* Yu.A.Kotukhov [*Lf*: Herb. *Lc*: Per. *D*: 22]
427. *Potentilla schrenkiana* Regel [*Lf*: Herb. *Lc*: Per. *D*: 23, 24]

Gen. 132. *Rosa* L.

428. *Rosa dsharkenti* Chrshan. [*Lf:* Shrub. *Lc*: Per. *D:* 18]
429. *Rosa iliensis* Chrshan. [*Lf:* Shrub. *Lc:* Per. *D:* 17, 18]
430. *Rosa potentilliflora* Chrshan. & Popov [*Lf*: Shrub. *Lc*: Per. *D*: 25]
431. *Rosa schrenkiana* Crép. [*Lf*: Shrub. *Lc*: Per. *D*: 24]

Gen. 133. *Spiraeanthus* (Fisch. & C.A.Mey.) Maxim.

432. *Spiraeanthus schrenkianus* (Fisch. & C.A.Mey.) Maxim. [*Lf*: Shrub. *Lc*: Per. *Cs*: RB. *D*: 16, 21, 26, 28]

Fam. 30. Rubiaceae Juss.

Gen. 134. *Galium* L.

433. *Galium kasachstanicum* Pachom. [*Lf*: Herb. *Lc*: Per. *D*: 25a]
434. *Galium turgaicum* Knjaz. [*Lf*: Herb. *Lc*: Per. *D*: 7a]
435. *Galium zaisanicum* Pinzhenina & Kupr. * [*Lf*: Herb. *Lc*: Per. *D*: 12]

Gen. 135. *Rubia* L.

436. *Rubia cretacea* Pojark. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 1, 6, 7a, 8, 13]
437. *Rubia pavlovii* Bajtenov & Myrz. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]

Fam. 31. Rutaceae Juss.

Gen. 136. *Haplophyllum* A.Juss.

438. *Haplophyllum eugenii-korovinii* Pavlov [*Lf*: Subshrub. *Lc*: Per. *Cs*: RB. *D*: 28]
439. *Haplophyllum multicaule* Vved. [*Lf*: Subshrub. *Lc*: Per. *D*: 5, 10, 14, 16, 18, 24, 26]

Fam. 32. Scrophulariaceae Juss.

Gen. 137. *Scrophularia* Tourn. ex L.

440. *Scrophularia dshungarica* Golosk. & Tzag. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 24]
441. *Scrophularia nuraniae* Tzag. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 29]

Fam. 33. Thymelaeaceae Juss.

Gen. 138. *Diarthron* Turcz.

442. *Dendrostellera ammodendron* (Kar. & Kir.) Botsch. [*Lf*: Shrub. *Lc*: Per. *D*: 17, 18, 24, 25]

Fam. 34. Zygophyllaceae R.Br.

Gen. 139. *Zygophyllum* L.

443. *Zygophyllum balchaschense* Boriss. [*Lf*: Herb. *Lc*: Per. *D*: 11, 16]
444. *Zygophyllum betpakdalense* Golosk. & Semiotr. [*Lf*: Herb. *Lc*: Per. *D*: 16]
445. *Zygophyllum borissovae* Beier & Thulin [*Lf*: Herb. *Lc*: Per. *D*: 10, 11, 11a, 16]
446. *Zygophyllum furcatum* C.A.Mey. [*Lf*: Herb. *Lc*: Per. *D*: 10, 11, 11a, 23, 24]
447. *Zygophyllum karatavicum* Boriss. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 28]
448. *Zygophyllum kopalense* Boriss. [*Lf*: Herb. *Lc*: Per. *Cs*: RB. *D*: 16,18,25,26]
449. *Zygophyllum steropterum* Schrenk [*Lf*: Herb. *Lc*: Per. *D*: 16, 17, 18, 26]
450. *Zygophyllum subtrijugum* C.A.Mey. [*Lf*: Herb. *Lc*: Per. *D*: 3. 4. 10, 10a, 11, 16]
451. *Zygophyllum taldykurganicum* Boriss. [*Lf*: Herb. *Lc*: Per. *D*: 18, 24]

Notes*:

**Arthrophytum subulifolium* Schrenk, according to POWO, is noted in Turkmenistan; however, according to our data and the scientific paper by Osmanali et al. (2019), this indication is incorrect. This species is a narrow-local endemic of the Chu-Ili Range in the south of Kazakhstan (Osmanali et al. 2019).

**Atriplex iljinii* Aellen, similar to *Arthrophytum subulifolium* Schrenk, is erroneously reported in Turkmenistan, as per the POWO database. The distribution of *A. iljinii* is poorly studied, known mainly from type specimens. This species is observed in the northwest of the Mangistau Region, as well as in the Aktobe and Kyzylorda (Aralkum Desert) Regions of Kazakhstan (Sucho-rukow 2007).

**Ferula leucographa* Korovin, according to POWO, is recorded in Uzbekistan; yet, according to the updated synopsis of *Apiaceae* of Kazakhstan and Central Asia (Pimenov 2020), the species grows only in Kazakhstan.

**Rindera ochroleuca* Kar. & Kir., as suggested by POWO, is observed in Altai in the Russian Federation; yet, our investigation did not find credible evidence supporting this information.

**Eutrema halophilum* (C.A.Mey.) Al-Shehbaz & Warwick was previously reported in China (Wu et al. 2008); however, German DA and Chen WL (2009) in their scientific paper did not confirm the presence of this species in China.

**Astragalus leucocalyx* Popov is recorded in POWO for Uzbekistan; nevertheless, Tojibaev et al. (2020b) in their scientific paper exclusively listed this species as occurring in Kazakhstan.

**Prangos multicostata* Kljuykov & Lyskov., according to the scientific paper by Pimenov (2020), is a synonym for *Prangos dzhungarica* Pimenov. Further study is required to investigate whether species status of *Prangos multicostata* is warranted.

**Centaurea kryloviana* Serg. is not recognised in POWO and GBIF, probably due to nomenclature errors. However, according to the scientific paper by Kupriyanov (2018), this species is endemic to eastern Kazakhstan.

**Astragalus rariflorus* Ledeb., previously noted for Western Siberia (Krylov 1933), yet we did not find herbarium materials of this species from this territory. This species is also not recorded in the Flora of Siberia (Malyshev 1994).

**Lappula cristata* (Bunge) B. Fedtsch. in JBIF is recorded for Western Siberia, on the territory of the Russian Federation (Bochkov and Seregin 2022); however, the presence of this species lacks substantial verification. Notably, the Flora of Siberia (Malyshev 1997) does not include any records of this species. Therefore, further investigation is necessary to elucidate the occurrence of *Lappula cristata* within the territory of the Russian Federation.

**Onobrychis alatavica* Bajtenov was omitted from the list of flora of Kazakhstan (Abdulina 1999). Conspectus Florae Asiae Mediae (Kamelin et al. 1981) noted that this species needs to be re-collected to confirm species status.

**Tulipa berkariensis* Rukšāns in POWO is recognised as a synonym of *Tulipa kaufmanniana* Regel., based on data from Everett (2013). Nevertheless, *T. berkariensis* from the Berkara Valley and other places in Kazakhstan has a lower amount of nuclear 2C DNA (based on the data flow cytometric measurement of nuclear DNA content) than authentic *T. kaufmanniana* from Uzbekistan (Zonneveld 2009). This discrepancy implies that *Tulipa berkariensis* should be recognised as a distinct taxonomic entity.

**Tulipa orthopoda* Vved. listed in POWO is recognised as a synonym for *Tulipa bifloriformis* Vved., based on Christenhusz et al. (2013) and Everett (2013). This scientific paper also notes that the species status of *Tulipa orthopoda* should be warranted, based on differences in morphological characters and flowering period, but further fieldwork is required to establish the variability of *T. bifloriformis* in the wild.

**Tulipa brachystemon* Regel in POWO is recognised as a synonym for *Tulipa tetraphylla* Regel, also according to Christenhusz et al. (2013) and Everett (2013). However, Zonneveld (2009) distinguishes *Tulipa brachystemon* Regel as an independent taxon, based on the nuclear DNA content (DNA value 2C).

**Galium zaisanicum* Pinzhenina & Kupr. was described quite recently (Pinzhenina and Kupriyanov 2023), presumably due to its recent identification it is absent in the GBIF and POWO systems.

**Stipa argillosa* Kotukhov in POWO is erroneously listed for the Altai Republic of the Russian Federation. This species is described from the territory of East Kazakhstan. Type: Southern Altai, south-eastern foothills of the Azutau Ridge, Bulgartabaty tract, foothill desert, outcrops of tertiary clays, clay-rubbly areas, 05/22/1991, Yu. Kotukhov (LE) (Kotukhov 1998). The Azutau Ridge borders the basin of Lake Markakol from the south and is entirely situated within the territory of Kazakhstan (Yegorina et al. 2003).

**Thalictrum bykovii* Kotukhov, as well as the previous species in POWO, is erroneously listed for the Altai Republic of the Russian Federation. This species was also described from the territory of East Kazakhstan. Type: Southern Altai, eastern spurs of Azutau Ridge, Mramornaya Mount, Middle belt, 900–1100 m above sea level, south-eastern slope, steppe shrub meadows, 14/06/1984, Yu. Kotukhov (LE).

Supplementary material 1

Checklist of subendemic taxa previously considered endemic in Kazakhstan

Authors: Serik A. Kubentayev, Daniyar T. Alibekov, Yuri V. Perezhogin, Georgy A. Lazkov, Andrey N. Kupriyanov, Alexander L. Ebel, Klara S. Izbastina, Olga V. Borodulina, Balsulu B. Kubentayeva

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Link: https://doi.org/10.3897/phytokeys.238.114475.suppl1

Supplementary material 2

Former endemics of Kazakhstan that are now reclassified as synonyms for species exhibiting broader geographical distributions

Authors: Serik A. Kubentayev, Daniyar T. Alibekov, Yuri V. Perezhogin, Georgy A. Lazkov, Andrey N. Kupriyanov, Alexander L. Ebel, Klara S. Izbastina, Olga V. Borodulina, Balsulu B. Kubentayeva

Data type: docx

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Research Article

An account of the genus *Cistanche* (Orobanchaceae) in Iraq and taxonomic considerations in the Middle East

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Abstract

Species limits in the genus *Cistanche* are poorly understood, despite the plants' long history of use in traditional herbal medicine and food across their range. Here we present a taxonomic account for the genus *Cistanche* in Iraq, where several taxa have been reported, most of them doubtfully. Using herbarium specimens, images of living material, and taxonomic literature, we found evidence of only one species occurring with certainty in Iraq: *Cistanche tubulosa*. We found no evidence for the occurrence of other *Cistanche* species in Iraq, including a putative new entity reported for the region. Our work highlights inconsistencies in the literature, and underscores the importance of examining multiple stable characters for delimiting species in the genus *Cistanche*.

Key words: Nomenclature, parasitic plant, speciation, taxonomy

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Introduction

Iraq has a rich flora with an estimated 3300 species owing to a convergence of phytogeographic regions and varied climate and topography (Zohary 1973; Ghazanfar and McDaniel 2016). Until the mid-twentieth century, there were no checklists or Floras for this young state (Frodin 2001; Ghazanfar and McDaniel 2016). In the 1950s, the first national checklist, The Flora of Iraq and its Phytogeographical Subdivision, was written by Michael Zohary (Frodin 2001; Ghazanfar and McDaniel 2016). In 1964 Karl-Heinz Rechinger published the Flora of Lowland Iraq (Rechinger 1964a) with contributions by multiple authors, including a treatment for the Orobanchaceae by H. Schiman-Czeika. A year later, the Flora of Iraq began as a collaborative project between the Royal Botanic Gardens, Kew and the Ministry of Agriculture, Baghdad (Frodin 2001; Ghazanfar and McDaniel 2016). From this project, volumes 1, 2 and 3, and volume 4 parts 1 & 2, 8 and 9 were published; volumes 5, 6 and 7 remained unpublished due to political instability in the region, and the project was suspended in the 1980s (Guest and Townsend 1966; Townsend and Guest 1966–1985; Frodin 2001; Ghazanfar and McDaniel 2016). Then in the 2010s, the Flora of Iraq project resumed as a collaboration between the Royal Botanic Gardens, Kew and the

Ministry of Agriculture, Baghdad, in 2013, Vol. 5(2) was published and vol. 5(1) is in press. Volumes 6 and 7 which cover around 900 species are in progress (Ghazanfar and McDaniel 2016). The family Orobanchaceae has been written for this ambitious project but remains, as yet, unpublished.

The genus *Cistanche* Hoffmanns. & Link (family Orobanchaceae), was first identified officially in 1799 by Ventenat under the name Orobanchoideae. A decade later, the genus *Cistanche* was described by Hoffmannsegg and Link (1813). The latest monograph for the family Orobanchaceae was published in 1930 by Beck-Mannagetta (Beck-Mannagetta 1930). He divided *Cistanche* species into four sections based on calyx and bracteole morphology; however the first comprehensive phylogeny for the genus *Cistanche* revealed that none of these sections are monophyletic, with the exception of *C.* sect. *Subcistanche* (Ataei et al. 2020). Moreover, this phylogeny revealed that *Cistanche* species form four well-supported, geographically differentiated clades which they described as the Northwest African Clade, Southwest Asian Clade, Widespread Clade and East Asian Clade. The East Asian Clade is the only clade that corresponds to a previously recognized taxonomic section (*C.* sect. *Subcistanche*). Despite progress in understanding the evolutionary relationships in the genus, a well-sampled phylogeny substantiated with detailed morphological and ecological data are absent, and species limits remain confused and uncertain.

Cistanche is a holoparasite that lacks vegetative traits traditionally used in taxonomy, including functional leaves and roots. The poor condition of herbarium specimens — particularly type specimens — has generated confusion in identification. Here we examine herbarium specimens, images of living material, and taxonomic literature to produce the first robust review of the genus *Cistanche* in Iraq, which will inform the treatment for the Flora, and other treatments for the genus in the Middle East.

Material and methods

Study species

We reviewed the names used for *Cistanche* in Iraq and neighbouring countries. The sources that were used to identify species of *Cistanche* putatively in Iraq, and the species in their accounts, were as follows:

Treatments including Iraq

1. Flora of Lowland Iraq (Rechinger 1964a). Rechinger's account referred to two species, *C. tubulosa* (Schenk) Wight ex Hook.f. and *C. salsa* (C.A.Mey.) Beck. He presented a key discriminating the species by height, pubescence and anther cell shape. *C. tubulosa* was described as a larger plant, 60–100cm, glabrous, and with obtuse anther cells. *C. salsa* was reported to grow up to 40 cm, lanate to glabrescent, and with acuminate anther cells. Five specimens of *C. tubulosa* and one of *C. salsa* were examined.
2. Flora Iranica (Rechinger 1964b), in which Iran, Persia, Afghanistan, parts of West-Pakistan, Iraqi Kurdistan, Azerbaijan and Turkmenistan listed *C. ridgewayana* Aitch. & Hemsl., *C. fissa* C.A.Mey.) Beck, *C. salsa*, *C. eremodoxa* Bornm., *C. laxiflora* Aitch. & Hemsl., *C. tubulosa* and *C. flava*

(C.A.Mey.) Korsh. There were no reports of *Cistanche* species in autonomous Iraqi Kurdistan.

3. The Flowering Parasitic Plants of Iraq (Karim 1978) cites only *C. tubulosa*. Karim (1978) was aware of seven plants and cited three host species.
4. In an unpublished PhD thesis that included a monographic treatment of genus *Cistanche*, Ataei (2017) cited two species in the exsiccatae for Iraqi specimens: *C. tubulosa* and *C. flava*. She referred to the *C. salsa* specimen cited by Rechinger (1964a), considering it to be a misidentified specimen of *C. ambigua* (Bunge) Beck. In the treatment she also referred to an, as yet, unpublished species found in Iraq, but no specimen from Iraq was cited.
5. In an unpublished thesis entitled taxonomical and ecological study of parasitic plants of Iraq, Al-Asady (2017) cited only one species, *C. tubulosa* to occur in Iraq. The *C. salsa* specimen of in the Flora of Lowland Iraq (Rechinger 1964a) was considered to be a misidentified specimen of *C. tubulosa*.
6. The Ecology and flora of Basrah (Al-Mayah et al. 2016) cites only *C. tubulosa*. Al-Mayah et al. (2016) refer to 'Zib AL-Zumal', 'Thenun AL-Jinn' and 'Halook' as common names for *C. tubulosa* in Iraq. They also cite *Haloxylon salicornicum* (Moq.) Bunge ex Boiss. (Amaranthaceae) and *Zygophyllum propinquum* Decne. (Zygophyllaceae) as host species.
7. In their book on parasitic plants, Al-Mayah and Al-Asady (2022) stated only *C. tubulosa* to occur in Iraq. They cite the following hosts: *Haloxylon salicornicum* (listed under its synonym: *Hammada salicornica* (Moq.) Iljin) (Amaranthaceae), *Zygophyllum propinquum* (listed under its synonym: *Tetraena propinqua*) (Zygophyllaceae) and *Capparis spinosa* L. (Capparaceae).

Treatments of neighbouring countries

1. The Flora of Syria, Palestine and Sinai (Post 1932) covers the region from the eastern Mediterranean seaboard to the Syrian Desert. This flora recorded *C. lutea* (Desf.) Hoffmanns. & Link, *C. tubulosa* and *C. salsa*. In the descriptions, *C. lutea* and *C. tubulosa* are described as glabrous and *C. salsa* as lanate. Of the three species, only *C. lutea* is reported to occur in the desertic regions contiguous with Iraq.
2. In the Flora of Turkey (Davis 1982), *C. salsa* is the only species recorded. It is described as having densely lanate bracts and bracteoles, and a glabrous calyx and corolla. It was cited in three regions, two were in Inner Anatolia and one was in Kars city which is only 370 km from the Iraqi Kurdistan border. Therefore, *C. salsa* is a possible candidate species for the Flora of Iraq.
3. The Flora of Saudi Arabia (Migahid 1989) recorded two species, *C. phelypaea* (L.) Cout. (generally considered an Atlantic species) and *C. tubulosa*. Other species that are not included in the Flora have not been recorded for Saudi Arabia. These are *C. violacea* and *C. rosea* Baker (Foley 2004). The distribution of these species is narrow, *C. rosea* is distributed in the far south west and *C. violacea* in the northwest, far from the border with Iraq.
4. The Flora of Kuwait (Daoud 1985) records only *C. tubulosa*, cites *Soda rosmarinus* (Bunge ex Boiss.) Akhani (listed under its synonym: *Seidlitzia rosmarinus* Bunge ex Boiss. (Amaranthaceae) as a host, and considers *C. tubulosa* var. *tomentosa* Hook.f.i.c as a Synonym.

Examination of protologues, types and representative specimens

Protologues for *Cistanche eremodoxa*, *C. salsa*, *C. ridgewayana*, *C. fissa*, *C. laxiflora*, *C. flava*, *C. ambigua*, *C. lutea* and *C. phelypaea* — the species identified as putatively in Iraq and adjacent regions of neighbouring countries — were examined as well the description of the unpublished putative species *C. chabaharensis* (Ataei 2017). Type specimens of these species were examined when they were available; type specimens of *C. flava* and *C. tubulosa* were unavailable, and are believed to be missing. The Natural History Museum, London (NHM) and the University of Vienna (WU) collections were examined, but they held no Iraqi specimens. An extensive survey of three herbaria: Kew (K), Edinburgh (E) and the Natural History Museum of Vienna (W) and examination of herbarium images from the National Herbarium in Baghdad (BAG) retrieved 62 specimens from Iraq. Specimens from adjacent countries were also examined for comparison. Images of living material in Iraq and adjacent countries sourced from social media were all examined, and cross-referenced with herbarium specimens.

Distribution mapping

Google Earth was used to create coordinate assumptions for those specimens for which true coordinates were unavailable (Fig. 1). Coordinates were exported to QGIS 3.4 with layers from the Natural Earth Quick Start Kit. Host species were recorded from specimen labels or based on identifications of host plant material mounted on the same sheet as the specimen. In the absence of excavation of host-parasite connections, the identity of the host was considered tentative (the parasite can appear some distance above ground from the host plant).

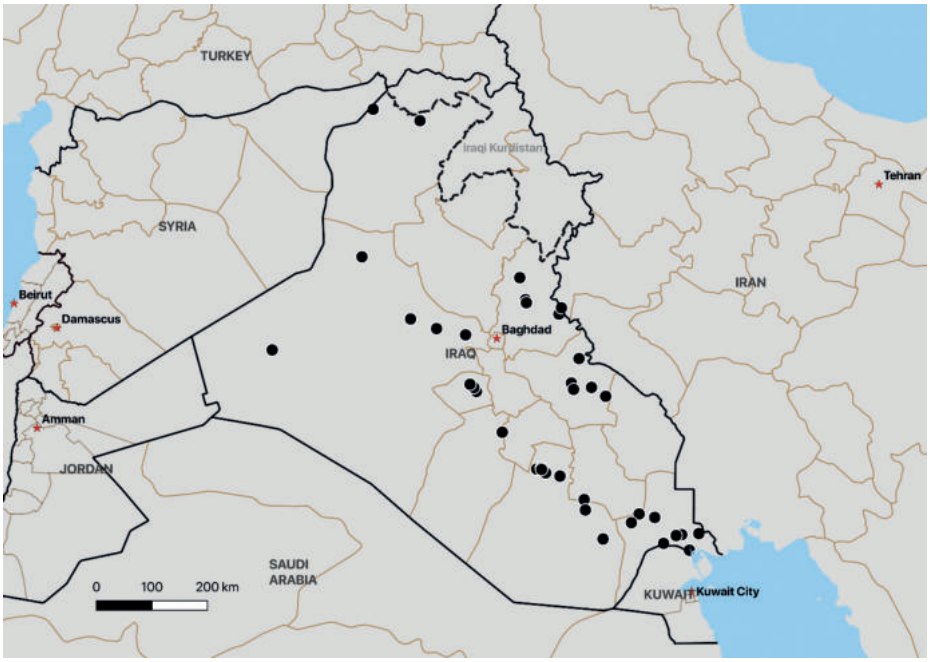

Figure 1. The locations of the material examined in Iraq.

Results and discussion

Cistanche species in Iraq

A literature review of Iraq and of adjacent countries, and of other relevant taxonomic studies, identified 10 published names and one unpublished name for species putatively in Iraq and adjacent countries. Species in adjacent countries, especially in Iran including, *C. eremodoxa*, *C. ridgewayana*, *C. fissa*, *C. laxiflora* and *C. ambigua*, were excluded from this investigation as their distributions and morphology suggest they are unlikely to exist in Iraq. Of the other species, two Atlantic/western European taxa were excluded on the basis that they are exceptionally unlikely to occur in the Middle East: *C. lutea* and *C. phelypaea*. Although *C. lutea* was cited in the Flora of Syria, Palestine and Sinai, the description does not provide adequate detail of morphological characters to discriminate between this and other species, including *C. tubulosa*. *Cistanche phelypaea*, as circumscribed currently, is a primarily Atlantic, coastal species, frequent from southwest Portugal south to Macaronesia and the coast of Morocco. We consider the inclusion of *C. phelypaea* in the Flora of Saudi Arabia to be equivocal, and cited with insufficient detail to merit further examination. Moreno Moral et al. (2017) consider *C. lutea* and *C. phelypaea* to be morphologically distinct. Wood (1997) records the presence of *C. phelypaea* and *C. rosea* Bakir in Yemen and considered *C. tubulosa* a synonym of *C. phelypaea*. Author AM during his time in Yemen at the University of Taiz, in 2000–2002, observed a putatively distinct form of *Cistanche* across regions. It parasitized *Halothamnus bottae* Jaub. & Spach (syn. *Salsola bottae* (Jaub. & Spach) Boiss) (Amaranthaceae) (absent from Iraq) and was pure yellow, without purple pigmentation. Further investigation is required. *Cistanche rosea*, which is widespread across the Arabian Peninsula, is readily distinguished by its deep rose-red corolla. Ataei et al. (2020) asserts that *C. lutea* and *C. phelypaea* do not occur in the Middle East. Both entities were excluded from further work for the treatment of the genus *Cistanche* in Iraq.

Finally, we considered *C. chabaharensis*, an as yet unpublished name referred to in the thesis of Ataei (2017) (Fig. 2B). This description placed focus on the glabrous, acute anthers; the key also described bract and bracteoles to possess non-sinuate margins, yellow corolla, and anther filaments glabrous at the base. However, on close examination of specimens cited by Ataei (2017) from Oman (McLeish, E00121976 E) and Iraq (Barkley & Abbas-Al-Ani, 6499 K), it was apparent both had woolly anthers that could not be distinguished from anthers of *C. tubulosa*, and that the bracts and bracteoles were sinuate. We consider it doubtful that this unpublished name represents a new entity found in Iraq; rather we believe this to be an entity that falls within the bounds of variability in *C. tubulosa* s.l. In summary, only three species warranted detailed investigation for the region in question: *C. tubulosa*, *C. salsa* and *C. flava* (Table 1; Fig. 3).

Morphology and evolutionary relationships

Here we consider the three taxa identified to potentially co-occur in the region. *Cistanche salsa* can be readily differentiated from *C. flava* and *C. tubulosa* by its hairiness; the latter two species are glabrous (see key). *Cistanche flava*

Figure 2. A herbarium specimen of *C. tubulosa* collected in Iraq, mistakenly identified as *C. flava* **B** the holotype of putative species *C. chabaharensis*; note the woolly anther (inset) typical of *C. tubulosa* **C** herbarium specimen of *C. tubulosa* in (W) collected in lowland of Iraq, mistakenly identified as *C. salsa*.

Table 1. Key morphological characters of *Cistanche* species putatively found in Iraq and adjacent territories.

Characters	*C. tubulosa*	*C. salsa*	*C. flava*
Scales	ovate- lanceolate, obtuse, glabrous, sinuate	ovate- lanceolate, obtuse, pilose on the outer side, scarious	long-lanceolate, obtuse, glabrous, scarious
Bract	ovate-lanceolate, glabrous, sinuate, equal or slightly longer than calyx	oblong-lanceolate, pilose on the outer side, longer than the calyx, entire	oblong-linear, glabrous, scarious, sinuate, twice long as the calyx or even as long as corolla
Bracteole	oblong- lanceolate, glabrous, sinuate, equal or shorter than calyx	linear-oblong, pilose on the outer side, entire, equal or slightly longer than calyx	oblong-linear, glabrous, sinuate, slightly shorter than calyx
Calyx	tubular, up to 1⁄2 total corolla length, 5 lobes, oblong to oblong-ovate, glabrous, sinuate	tubular, ca. 1/3 corolla length, 5 lobes, oblong, pilose on the outer side and at the margins, entire	tubular-campanulate, 5 lobes, oblong to oblong-ovate, glabrous, sinuate
Corolla	tubular-campanulate, 5 lobes, orbicular, glabrous, yellowish throughout or with violet limb (especially in bud)	campanulate, 5 lobes, orbicular, sparsely ciliate at the lobes, mauve and white	tubular-campanulate, 5 lobes, orbicular, glabrous, yellow to blue-violet
Anther	ovate, obtuse at ends, densely pilose	ovate, obtuse at base and slightly aristate at apex, densely pilose	ovate, obtuse at ends, densely pilose
Stigma	bilobate	bilobate	bilobate

is differentiated from *C. tubulosa* by its scarious, conspicuously long bracts which are twice as long as the calyx or even longer (Table 1; Figs 3A, D, 4C, D). Sánchez Pedraja et al. (2016) consider *C. flava* to be a synonym of *C. tubulosa*, however the distinct bract morphology is apparent both in living and dried material. Detailed, well-sampled investigations of both taxa are absent, and their distinction remains open to question; however recent molecular work provisionally supports their separation (Ataei et al. 2020).

The name *Cistanche tubulosa* s.l. is used from Africa and the Middle East to South and Central Asia and China, however as currently applied, the name refers to a widely distributed, polyphyletic group of plants (Aldughayman et al. 2024). In the most complete phylogeny (Ataei et al. 2020), specimens identified as *C. tubulosa* (or aff. *C. tubulosa*) were placed in a 'widespread clade', but four specimens identified as aff. *C. tubulosa* were nested in a separate clade sister to *C. flava*, along with other plants identified as *C. senegalensis* (an entity considered by Beck-Mannagetta to be closely related to *C. tubulosa*, but differentiated on the basis of subequal lower corolla lobes, oblong bracts and the absence of purple pigmentation). Additionally, two specimens identified as *C. tubulosa* are in a subclade which otherwise includes the Central Asian species, *C. laxiflora*. The type specimen of *C. tubulosa* is lost, and the correct application of the name *C. tubulosa* is yet to be clarified although it does seem to be misapplied to specimens in the *C. laxiflora* clade (Ataei et al. 2020; Aldughayman et al. 2024). Recently, a specimen collected from South Sinai near the type locality was designated a neotype (Aldughayman et al. 2024). This neotypification, alongside further phylogenetic work, is necessary to re-evaluate whether the name *Cistanche tubulosa* is a synonym for the name *C. tinctoria*, as has been proposed by Moreno Moral et al. (2017), and also to confirm whether the name *C. tubulosa* is the correct name for any Iraqi entity. To avoid compounding confusion, here we use the name *C. tubulosa*, consistent with most authors, until this re-evaluation is completed.

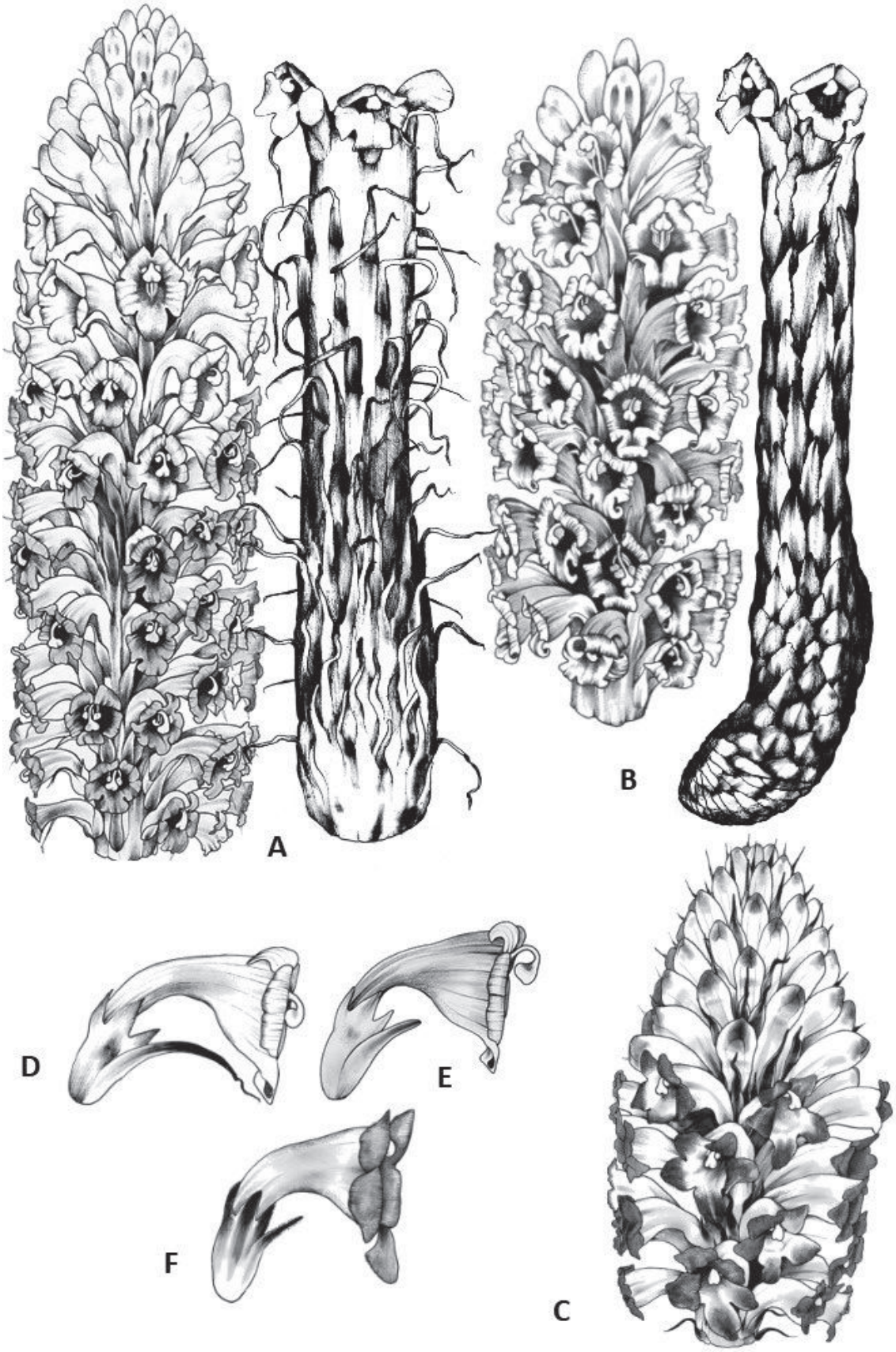

Figure 3. Illustrations of *Cistanche* species putatively found in Iraq and adjacent territories (inflorescences) **A** *C. flava* **B** *C. tubulosa* **C** *C. salsa* **D–F** corollas in profile of *C. flava*, *C. tubulosa* and *C. salsa,* respectively; note calyx and bract characteristics.

Figure 4. *Cistanche* species putatively found in Iraq and adjacent territories **A, B** *C. tubulosa* (photographed in Iran) **C, D** *C. flava* (photographed in Kazakhstan) **E, F** *C. tubulosa* (photographed in Iraq; note excavated stem bases in **E**). Used with permission: photographs **A, B** by Sajad Alipour; photograph **C** by Lina Valdschmit; photograph **D** by Bobur Karimov.

All material we examined from four Governorates: Karbala, Basrah, Muthanna and Wasit correspond to *C. tubulosa* (in its current, most widely-accepted circumscription). None of the material we examined pertained to either *C. salsa* or *C. flava*, based on our careful consideration of the traits emphasized above. Similarly, none of the specimens tentatively labelled *C. salsa* corresponded with that species either (Fig. 2C); indeed, we only found evidence of glabrous plants, ruling out the occurrence of *C. salsa* in Iraq based on the material available. Furthermore, material from Iraq identified as *C. flava* in a doctoral thesis (Ataei 2017) appears to have been identified in error (Fig. 2A): the unbroken bracts do not greatly exceed the calyx; we believe detached bracts may have caused confusion; phylogenetic analysis later confirmed the specimen in question nested with *C. tubulosa* (Ataei et al. 2020).

Our extensive investigation based on herbarium specimens revealed that *C. tubulosa* occurs in every Governorate of Iraq except for the Kurdistan Autonomous Region. This could be due to the wide distribution of potential hosts across three of four main ecological regions, namely the deserts west of the Euphrates River, Upper Mesopotamia and Lower Mesopotamia (Ghazanfar and McDaniel 2016; Hegazy and Doust 2016). *Cistanche* has not been recorded in the fourth ecological region, the northern highlands of Iraqi Kurdistan. This region is an extension of the great Eurasian alpine system, and not a typical habitat for *Cistanche* which is primarily desert-dwelling; moreover, hosts typically associated with *Cistanche* – shrubby Amaranthaceae such as *Haloxylon*, are absent from this ecological region (Ghazanfar and McDaniel 2016; Hegazy and Doust 2016). We conclude from this examination that despite multiple reports of various taxa, only one species occurs in Iraq with certainty: *Cistanche tubulosa*.

It is of note that the corolla colour of *C. tubulosa* varies with age and population, from pale lemon yellow, to deep orange-yellow, with varying levels of pink to violet pigmentation. Similarly, the height and stature vary from 15 cm to 130 cm depending on rainfall and, potentially, host species. The key below is based on our observations of multiple populations across the region.

Key to *C. tubulosa* and potentially co-occurring taxa in Iraq and immediately adjacent regions

1 Plants lanate to glabrescent; whitish, with purple pigmentation.....***C. salsa***
– Plants glabrous; cream to yellow with or without purple pigmentation.....**2**
2 Bracts short: ovate-lanceolate, sinuate, equal to or scarcely exceeding the calyx .....***C. tubulosa***
– Bracts long and slender: oblong-linear, glabrous, scarious, sinuate, 2 x the calyx ..... ***C. flava***

Taxonomic treatment

***Cistanche tubulosa* (Schenk) R. Wight ex Hook.f., Fl. Brit. India, 4. 2:324. 1884.**

Phelypaea tubulosa Schenk (1840).

Notes. A robust, thick, glabrous plant, (15)20–50(130) cm tall. Lower scales sinuate, imbricate, broadly lanceolate, up to 3 cm long. Upper scales sinuate,

ovate-lanceolate, grey, 4–10 m long. Bracts deeply sinuate, ovate-lanceolate, equal or slightly exceeding the calyx, grey, 14–22 mm long. Bracteoles sinuate, oblong-lanceolate, equalling or shorter than calyx, grey, 2–3 mm long. Calyx tubular, pentamerous, usually 1/2 the corolla length, with lobes subequal or one slightly shorter, oblong, obtuse. Corolla tubular-campanulate, pentamerous, lemon yellow to deep yellow, often with violet limb, 34–52 mm long, lobes equal, rounded. Stamens didynamous, epipetalous, densely woolly at the base. Anthers cordate, rounded at the base and acute at the apex, densely woolly. Ovary ovate. Style cylindrical, oblique. Stigma bilobate. Fruit a splitting capsule. Seeds small, black and numerous.

Habitats. Dunes, gravel substrates, mudstone, or seasonally arid saline habitats.

Hosts. *Haloxylon salicornicum* (Moq.) Bung, *Capparis spinosa*, *Zygophyllum propinquum* Decne (syn. *Tetraena propinqua*), *Tamarix* spp., *Salsola* spp.

Possible hosts. *Ephedra* spp., *Limonium* spp., *Anabasis* spp.

Specimens examined. Iraq: Diyala: Hamrin, near Shahraban, 34°16'06.8"N, 44°48'48.5"E, 8 May 1958, *s. col*. s,n. (E); Shahraban, 33°56'09.4"N, 44°55'10.8"E, 11 April 1957, *Haines Wheeler* 847 (E,K); Mandali, 33°42'48.9"N, 45°32'06.1"E, 26 March 1932, *E.R. Guest* 1742 (K, BAG); 30 km north east Mandali, 210 m, 33°48'35.5"N, 45°34'48.7"E, 26 April 1979, *Al-kaisi & Khayat* 50782 (K); **Basrah:** 77 km northwest of Zubair, 30°36'12.5"N, 47°00'36.7"E, 19 March 1964, *Fred Barkley & Hikmat Abbas Al-ani* 6499 (K,W); Near Jalibah, 30°27'57.0"N, 46°52'02.6"E, 8 April 1933, *s. col.* 5065 (K); 28 km south east by south of Zubair, 12 m, 30°16'33.4"N, 47°47'35.6"E, 23 March 1957, *E. R. Guest, A. Rawi & K. H. Rechinger* 16875 (K, BAG); 70 km east of Zubair, 30°17'35.3"N, 48°06'29.9"E, 13 February 1973, *Turner* 47457 (K); Between Zubair and Safwan, 30°15'41.7"N, 47°41'29.4"E, 23 March 1966, *H. Alizzi* 34341 (K); Rumaila, Toba railway station 20 km west of Ghubaishiyia, 30°32'56.0"N, 47°17'51.3"E, 27 March 1965, *Sharif Y. Haddad* 9535 (K); 30 km west of Jabal Sanam, 30°08'13.1"N, 47°27'36.6"E, 15 April 1963, *Khalid Alizzi* 32684 (K, BAG); Umm Qasr Port, 30°01'43.7"N, 47°56'05.3"E, 13 March 1973, *Husain Al-ali* 39929 (K); Jabal Sanam, 150 m, 30°07'43.5"N, 47°37'09.5"E, 6 March 1961, *s. col.* 29889 (BAG); Southern desert of Zubair, 30°20'00.0"N, 47°40'00.0"E, 23 March 1957, *K. H. Rechinger* 5247 (W); Shaib Al-batin, Jarishan, 30°04'06.1"N, 47°09'25.4"E, 24 March 1957, *K. H. Rechinger* (W); 6 km Southeast of Safwan, 30°05'08.2"N, 47°47'51.7"E, 23 March 1957, *K. H. Rechinger* 5245 (W); **Anbar:** 10 km N of Rutba, 33°09'48.3"N, 40°15'29.1"E, 28 February 1947, *Rawi & Gillett* 6326 (K); 10 km from Hit to Kubaysah, 33°38'19.9"N, 42°48'17.0"E, 85 m, 31 March 1976, *S. Omar, Alkaisi, K. Hamad & H. Hamid* 44354 (K); Ramadi east of Lake Tharthar, 33°29'28.6"N, 43°16'56.9"E, 3 April 1964, *Fred A. Barkley & Ramdan Eljumaili* 7263 (K); Shbaichan road 10 km north of Rawah, 34°34'24.8"N, 41°56'17.7"E, 260 m, 3 April 1962, *Khatib & Hlizzi* 31967 (K); 20 km north west Fallujah, 33°23'45.6"N, 43°48'58.9"E, 24 April 1982, *Omar & Alkhayat* 31967 (BAG); 10 km from Hit to Kubaysah, 33°38'19.9"N, 42°48'17.0"E, 85 m, 31 March 1976, *S. Omar, Alkaisi, K. hamad & H. Hamid* 44354 (BAG); Between Fallujah and Wadi Tharthar, 33°32'24.2"N, 43°37'13.0"E, 3 May 1957, *K. H. Rechinger* 11247 (W); **Muthanna:** 10 km south of Samawah, 31°15'03.0"N, 45°17'21.1"E, 20 m, 21 February 1947, *Rawi & Gillett* 6125 (K); 15 km west of Samawah, 31°18'44.5"N, 45°07'24.0"E, 20 m, 19 March 1955, *Ali Rawi* 14880 (K); 25 km to Busaiya from Al-Khidr Almai, 30°12'23.7"N, 46°20'46.6"E, 200 m, 24 February 1978, *Alkaisi, K. Hamad*

& H. Hamid 48514 (K); Al-Khidr Al-mai enclosure, 31°12'00.7"N, 45°33'11.5"E, 21 January 1978, *F. Karim, A. Sharief, K. Hamad & H. Hamid* 48066 (K); 50 km east of Busaiya to Al-khidr Al-mai, 30°39'58.4"N, 46°01'13.1"E, 21 January 1978, *F. Karim, A. Sharief, K. Hamad & H. Hamid* 48034 (K); 13 km west Samawah, 31°19'42.8"N, 45°12'30.5"E, 40 m, 26 March, *Ibrahim Al-mahallal* 15204 (K,BAG); **Wasit:** Kut, 32°39'07.9"N, 45°45'49.2"E, 19 April 1967, *Alizzi & S. Omar* 34893 (K); 55 km east of Kut, 32°26'50.8"N, 46°23'40.4"E, 6 March 1963, *F. A. Barkley* 33Ir4055 (K); 5 km from Badra to Kut, 32°33'17.2"N, 45°48'13.6"E, 90 m, 12 March 1977, *Al-kaisi & H. Hamid* 46525 (K,BAG); 51 km northeast of Kut between Jassan and Badrah, 33°01'52.0"N, 45°54'14.1"E, 5 April 1964, *Hikmat Abbas & F. R. Bharucha* 2613 (K,W); 80 km west of Shayk Sa'd, 32°35'05.8"N, 46°08'01.5"E, 30 m, 4 April 1958, *Ali Rawi & S. Haddad* 25520 (K); 10 km east of Zurbatiyah, 33°11'38.8"N, 46°04'38.3"E, 240 m, 13 March 1977, *Al-kaisi & H. Hamid* 46551 (BAG); **Karbala:** 8 km west of Karbala, 32°31'20.8"N, 44°00'59.8"E, 9 March 1947, *Rawi & Gillett* 6415 (K); Razazza, 32°37'59.4"N, 43°53'52.1"E, 38 m, 18 March 2019, *A. Haloob, Ikhlas, R. Hamshkan & Riyadh* 59879 (BAG); 2 km west of Ukhaidir, 32°26'25.5"N, 43°35'30.1"E, 60 m, 12 March 1980, *s.col*. 51219 (BAG); 18 km west of Karbala, 32°33'18.5"N, 43°53'14.1"E, 40 m, 4 May 1964, *Martin L. Grant* 18228 (W); **Dhi Qar:** Eridu, 30°49'49.9"N, 45°59'54.3"E, 1 February 1947, *Seton Lloyd* 6328 (K,BAG); **Nineveh:** Faidah Al-rbaswi, 36°37'09.7"N, 42°58'38.3"E, 7 April 1973, *F. Karim, M. Noori, H. Hamid & H. Kadhim* 40279 (K); 6 km from Rabia, 36°47'17.3"N, 42°06'55.9"E, 1 April 1973, *F. Karim, H. Hamid & H. Kadhim* 39944 (K); **Najaf:** Al-Hira, 31°53'18.1"N, 44°29'28.6"E, 8 m, 6 March 2018, *Riyadh, Yasin, Dhya'a, Adel & Sinan* 59291 (BAG). FPF, chelat-Amara, AL-Mayah and AL-Asady 16122 BSRA. FPF, wadi AL-Tib -Mayah and AL-Asady 15130 BSRA. DSD, Basrah-Nassiria road, 30km from Zubair towords Nassirya, AL-Mayah 1995 BSRA. DSD, Slop of jabal sanam, s.w. of Safwan, Basrah, I.A.AL-Mayah and J.Dehry 1597,BSRA. DSD, Zubair, AL-Mayah and AL-Asady 1404 BSRA. DSD,JARISHAN AL-Mayah and AL-Asady 1418 BSRA. DSD, Jabal Sanam AL-Mayah and AL-Asady 1419 BSRA.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

Majed Aldughayman conducted the research, Chris Thorogood and Julie Hawkins wrote the manuscript; Abdulridha A. A Al-Mayah contributed to the work.

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Data availability

All of the data that support the findings of this study are available in the main text.

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