



Persicaria subterranea, a new species of Polygonaceae (Polygonoideae: Persicarieae) from Xizang of southwest China

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(Manuscript received 22 March 2024; Accepted 27 May 2024; Online published 4 June 2024)

ABSTRACT: *Persicaria subterranea* Bo Li, a new species from Xizang in southwestern China, is described and illustrated in this study. Gross morphology and pollen micromorphology corroborate its placement within *Persicaria* sect. *Cephalophilon*. Unique to this section, *P. subterranea* is the only species known to exhibit subterranean cleistogamous flowers, making it distinct within the sect. *Cephalophilon*. Morphologically, it shows the closest resemblance to *P. glacialis* (Meisn.) H. Hara and its variety, *P. glacialis* var. *przewalskii* (A.K. Skvortsov & Borodina) M.J. Kong & S.P. Hong. However, it could be readily distinguished from these related taxa by leaf shapes and indumentum, inflorescence structure, number of stamens, and achene morphology. In addition, we provide diagnostic characteristics, a detailed morphological description, line drawing, and information on the distribution and habitat for this new species, as along with comparable photographs of the three related taxa.

KEY WORDS: Capitate inflorescence, *Cephalophilon*, cleistogamy, palynology, *Persicaria glacialis*, *Polygonum*, Tibet.

INTRODUCTION

The genus *Persicaria* Mill. was historically classified as a section within *Polygonum* L., as supported by numerous taxonomists over the years (Meisner, 1856; Bentham and Hooker, 1880; Dammer, 1893; Steward, 1930; Tutin *et al.*, 1991; Li, 1998; Li *et al.*, 2003). Nevertheless, a growing body of evidence from morphological (Ronse Decraene and Akeroyd, 1988; Ronse Decraene *et al.*, 2000; Keskin and Severolu, 2020), palynological (Hedberg, 1946), anatomical (Haraldson, 1978), and molecular phylogenetic studies (Kim and Donoghue, 2008a; Galasso *et al.*, 2009; Sanchez *et al.*, 2009; Burke *et al.*, 2010; Sanchez *et al.*, 2011; Schuster *et al.*, 2015; Cao *et al.*, 2022) has consistently reinforced the separation of *Persicaria* from *Polygonum* as an independent genus. According to the most updated classification of the subfamily Polygonoideae, *Persicaria* is sister to a clade comprising *Koenigia* L. and *Bistorta* (L.) Scop. and they together form the tribe Persicarieae (Schuster *et al.*, 2015).

Generally, *Persicaria* could be easily distinguished from other genera of the subfamily by a combination of morphological, palynological, and anatomical characteristics, such as many-flowered, spike-like or capitate inflorescences; 4–5-parted tepals with trifold venation; 4–8 stamens; pollen grains spheroidal (globose) and rough reticulate (Haraldson, 1978; Ronse Decraene and Akeroyd, 1988; Brandbyge, 1993; Ronse Decraene *et al.*, 2000). As currently defined, *Persicaria* contains approximately 100 annual or perennial herbs which were provisionally divided into six sections, viz., sect.

Persicaria, sect. *Amphibia* Tzvelev, sect. *Cephalophilon* (Meisn.) H. Gross, sect. *Echinocaulon* (Meisn.) H. Gross, sect. *Tovara* (Adans.) H. Gross, and sect. *Truelloides* Tzvelev (Galasso *et al.*, 2009). Among these sections, sect. *Cephalophilon* has been consistently supported as a sister of the rest in various phylogenetic analyses (Kim and Donoghue, 2008a, b; Schuster *et al.*, 2015; Cao *et al.*, 2022; Zhang *et al.*, 2022). Approximately 20 species within this section have been recognized, predominantly found in East Asia (Haraldson, 1978; Li *et al.* 2003; Freeman, 2005). Morphologically, species in sect. *Cephalophilon* are distinguishable from their congeneric counterparts by having broadly elliptic to ovate leaves with lobes at the base and winged petioles, stem without prickles, and capitate inflorescences (Haraldson, 1978; Hou, 2006; Kim and Donoghue, 2008a; Freeman, 2005).

During a field survey in the Xizang Autonomous Region of southwest China in 2016, we discovered several populations of an unnamed *Persicaria* species in Lulu Wetland National Nature Reserve of Lhasa City, which at first glance resembled *P. glacialis* (Meisn.) H. Hara of the sect. *Cephalophilon* in gross morphology. Closer examination, however, revealed an exceptional feature: the plant exhibited both aerial chasmogamous flowers arranged in sessile capitate inflorescences and subterranean cleistogamous flowers borne on short-peduncled, head-like inflorescences along the lower stem. This subterranean cleistogamous flowering is a rare mode of reproduction within the Polygonaceae, previously reported in only a few species of the family (Suyama and Ueda, 2013). Furthermore, this unnamed plant also differs from *P. glacialis* in leaf shape and indumentum,



inflorescence structure, number of stamens, shape and sculpture of achenes. After thorough morphological comparisons, consultation of literature as well as herbarium specimens, we have ascertained that this unnamed plant represents a new, hitherto undescribed species of *Persicaria*, namely *P. subterranea* Bo Li, which is formally reported here.

MATERIAL AND METHODS

Field surveys were carried out in Xizang Autonomous Region from 2016 to 2023. Herbarium specimens of *Persicaria* deposited at CDBI, HITBC, IBSC, KUN, HNWP, NAS, PE, QFNU, SZ, WUK, and XZ (acronyms according to Thiers 2020+) were examined from 2017 to 2023. Morphological observations and descriptions of the putative new species were based on living plants growing in Lalu Wetland National Nature Reserve of Lhasa City and herbarium specimens collected from Nyingchi City. Morphological variation was measured using a ruler and a micrometer. High-resolution images of the type materials of *P. glacialis* and other species of the sect. *Cephalophilon* were also examined in JSTOR Plant Science (<http://plants.jstor.org>).

For scanning electron microscopy (SEM) observations, mature achenes and well-developed unopened flowers were removed from dry specimens. All samples were first cleaned in 95% alcohol with ultrasound. Achene samples were directly mounted onto cupreous stubs and then coated using JFC-1100E sputter coater (JEOL Ltd., Japan). Pollen grain samples in unopened flowers were treated according to the standard acetolysis method (Erdtman, 1960) and then coated. Observations and micrographs were conducted under JSM-6360LV SEM (JEOL Ltd., Japan) at a voltage of 7 KV. The terminology for achenes and pollen grains follows Kong and Hong (2018) and Kong *et al.* (2021), respectively. Voucher specimens were deposited at the herbarium of the Xishuangbanna Tropical Botanical Garden (HITBC), Chinese Academy of Sciences.

RESULTS AND DISCUSSION

Morphological comparisons

In *Persicaria*, though the presence of capitate inflorescences is observed both in sect. *Cephalophilon* and in a few taxa within sect. *Echinocaulon* (Meisn.) H. Gross, this trait likely represents a case of convergent evolution between the two groups, as suggested by the phylogenetic analysis of *Persicaria* (Kim and Donoghue, 2008a). In plants of sect. *Cephalophilon* and those of sect. *Echinocaulon* having capitate inflorescences, the absence of the multicellular stiff trichomes is a key characteristic to distinguish the former from the latter. Based on our morphological observations, *P. subterranea* is a member of the sect. *Cephalophilon*. Within the section, *P.*

subterranea (Figs. 1, 2) is most similar to *P. glacialis* var. *glacialis* (Fig. S1) and its variety, *P. glacialis* var. *przewalskii* (A.K. Skvortsov & Borodina) M.J. Kong & S.P. Hong (Fig. S2), in habit and gross morphology, but flowers of the latter two taxa bear on a long peduncled capitate inflorescence which is opposite to the leaves (Figs. S1B, S2B), while those of *P. subterranea* are forming a sessile cluster on aerial inflorescences (Figs. 1C, E) or having a short peduncle on subterranean inflorescences (Fig. 1H). Besides, *P. subterranea* differs from *P. glacialis* and its variety in leaf shapes, indumentum, number of stamens, and achene morphology as below.

Pollen micromorphology

Pollen micromorphology, including size, aperture type, and detailed exine ornamentation, has proven to be of significant information not only in the generic delimitation of Polygonaceae (e.g., Hedberg, 1946; Hong and Hedberg, 1990; Ayodele, 2005; Hou, 2006; Paul and Chowdhury, 2020) but also in the recognition of sections in *Persicaria* (e.g., Hong and Hedberg, 1990; Wang and Feng, 1994; Yasmin *et al.*, 2010; Kong *et al.*, 2021). Generally, pollen grains of sect. *Cephalophilon* are spherical, ranging from 23.85–51.16 μm in size, mostly tricolpate or partially pantoporate with narrow furrows and bearing a reticulum of relatively higher exine ridges (Hedberg, 1946; Kong *et al.*, 2021). The combination of different pollen characteristics, such as aperture type, pollen size, and detailed exine ornamentation, is somewhat systematically informative in the serial classification of the section (Kong *et al.*, 2021). The pollen grains of *P. subterranea* show a typical *Cephalophilon*-Type characteristic (Figs. 3A, B, C) as recognized by Hedberg (1946), further supporting its sectional placement within sect. *Cephalophilon*.

Achene morphology

Within Polygonaceae, extensive research has demonstrated the taxonomic importance of achene morphology, not only at the generic level (Haraldson, 1978; Ronse Decraene *et al.*, 2000; Hou, 2006; Ayodele and Zhou, 2010; Kong *et al.*, 2018) but also at the species level (Qu *et al.*, 2006; Kantachot and Chantaranothai, 2011; Shahla *et al.*, 2014; Kong and Hong, 2018). A recent comprehensive study of achene morphology within *P.* sect. *Cephalophilon* revealed that characteristics such as size, shape, and surface sculpture are key for distinguishing certain taxa in this section (Kong and Hong, 2018). Except for four taxa that feature glossy, smooth-surfaced achenes, the remaining taxa of sect. *Cephalophilon* exhibit achenes that are dull and display various surface sculptures, including tuberculate, pitted, or irregularly ridged (Kong and Hong, 2018).

In our observation, the achenes of *P. subterranea* are broadly ovoid, trigonous, and dark brown to black (Fig.

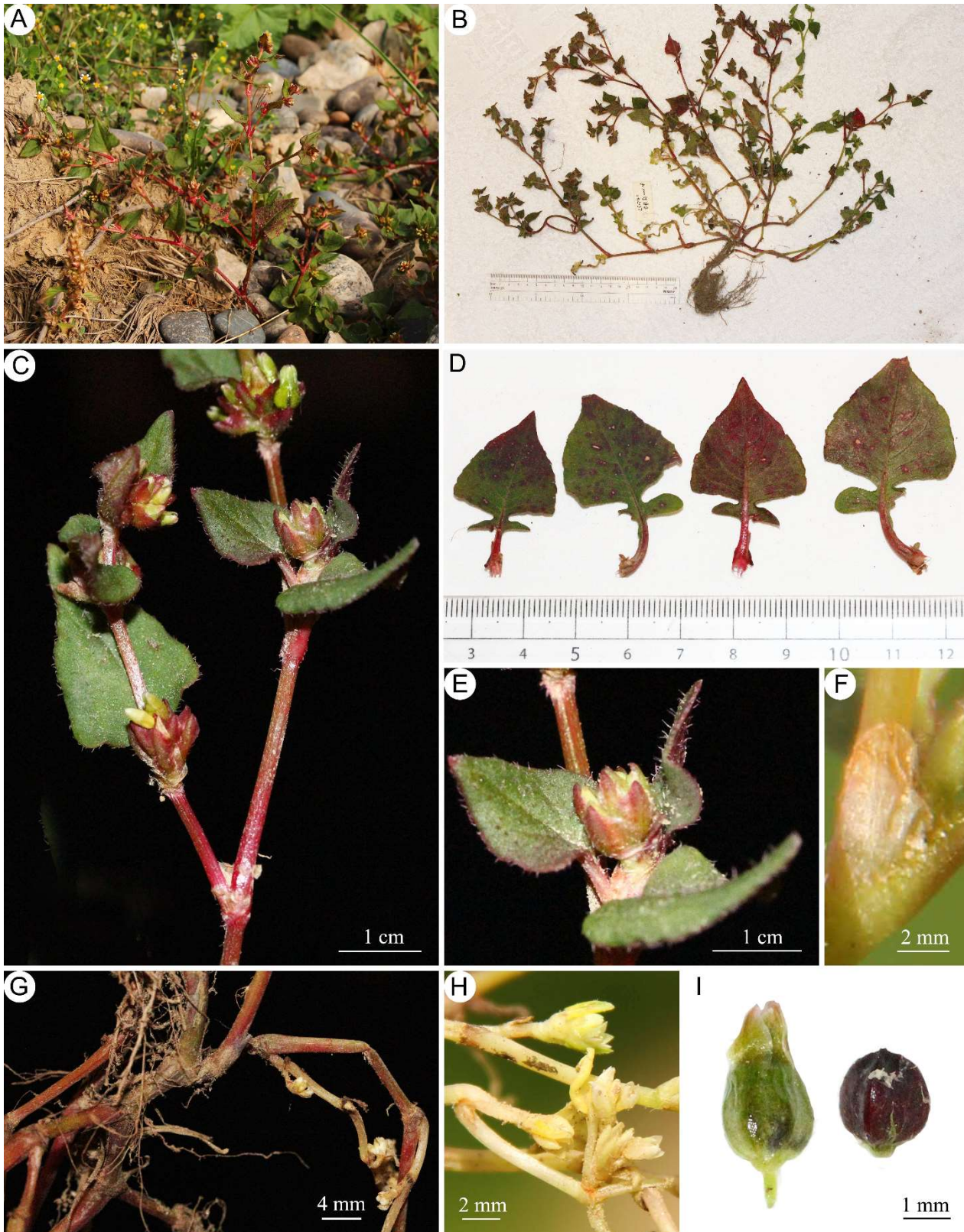


Fig. 1. Morphology of *Persicaria subterranea* Bo Li, *sp. nov.* **A:** Habitat. **B:** Habit. **C:** Stems and inflorescences. **D:** Leaves. **E:** Axillary sessile inflorescences. **F:** Ocrea. **G:** Stem base with subterranean inflorescences. **H:** Subterranean short-peduncled inflorescences. **I:** Persistent perianth and achene.

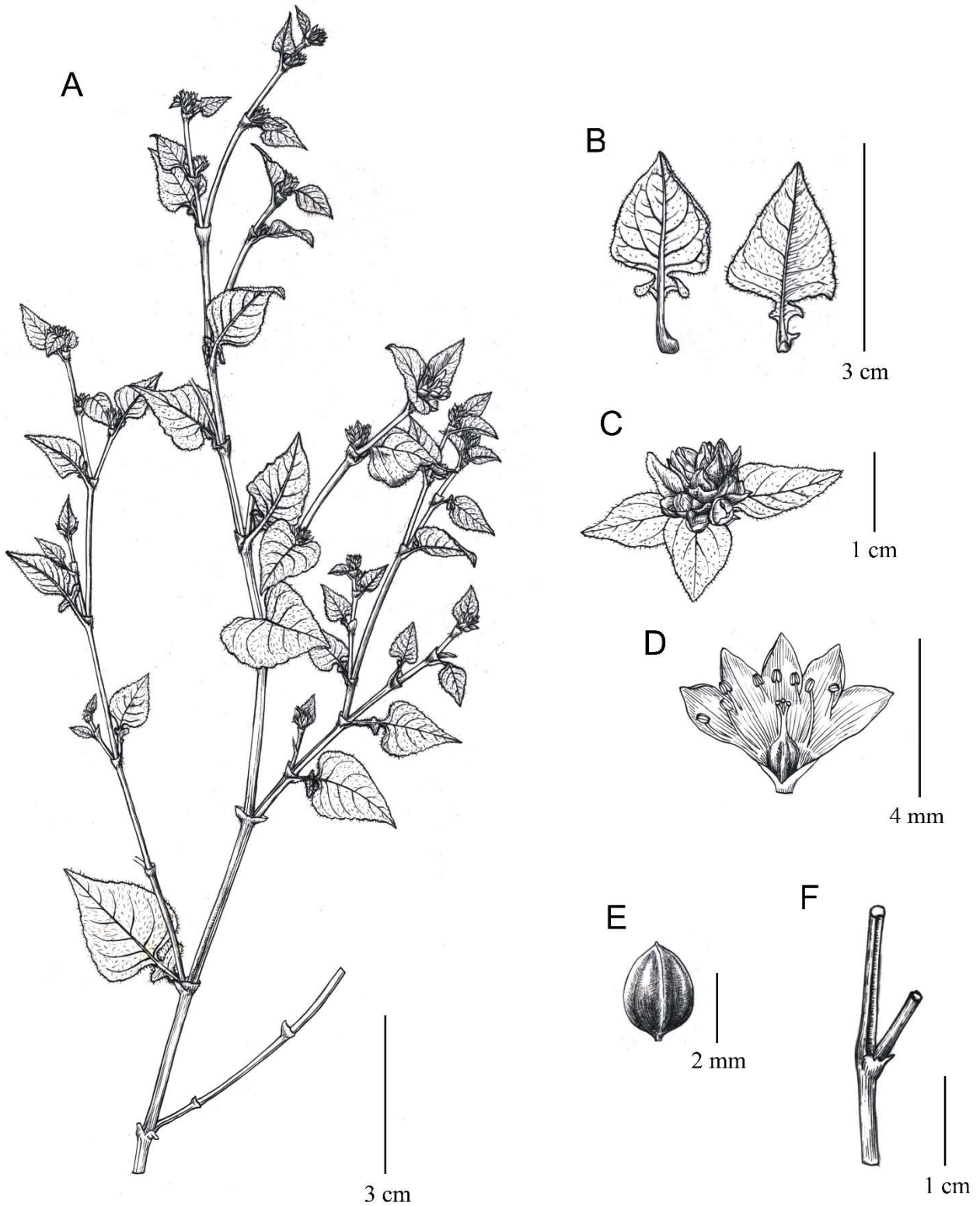


Fig. 2. Line-drawing of *Persicaria subterranea* Bo Li, *sp. nov.* **A:** Flowering branches. **B:** Leaves. **C:** Inflorescence. **D:** Dissected flower. **E:** Achene. **F:** Stem.

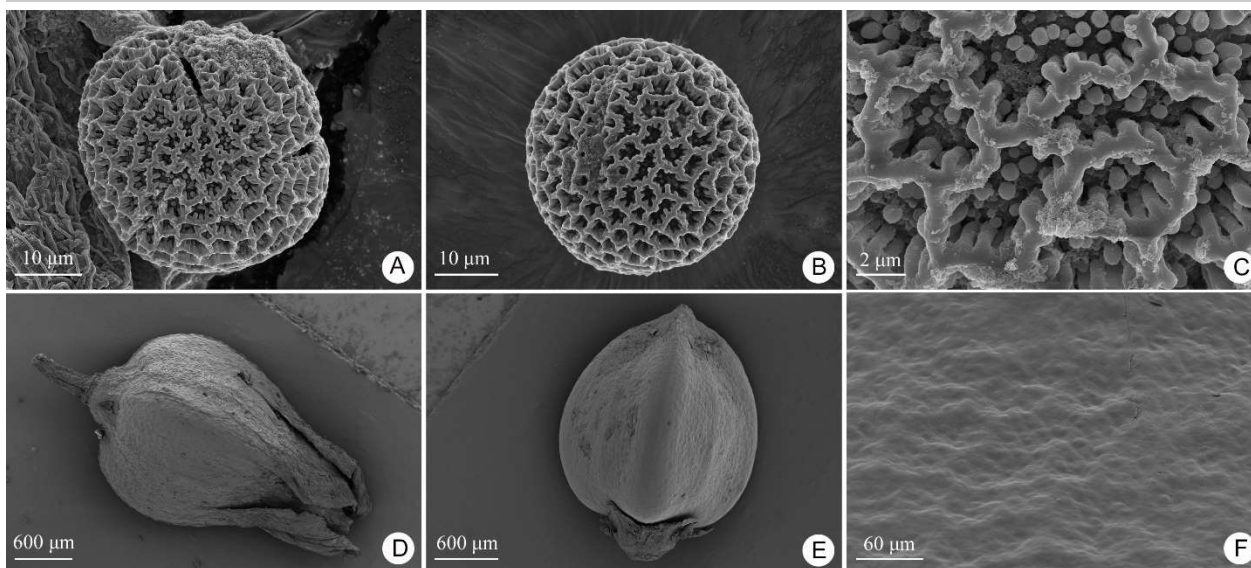


Fig. 3. SEM micrographs of pollen grains (A–C) and achenes (D–E) of *Persicaria subterranea*. **A:** Polar view. **B:** Equatorial view. **C:** Reticulate ornamentation. **D:** Achene included in persistent perianth. **E:** Whole view of achene. **F:** Achene surface sculpture.

11), mirroring the characteristics seen in *P. glacialis*. However, the achene surface of *P. subterranea* is glossy and the ridges are rounded (Figs. 11, 3E), while those of *P. glacialis* are dull and acute. Following the terminologies suggested by Kong and Hong (2018), the achene surface sculpture of *P. subterranea* is smooth, belonging to Type I (Figs. 3E, F), whereas *P. glacialis* var. *glacialis* and *P. glacialis* var. *przewalskii* possess a Type II-1 surface, characterized by tuberculate along the anticlinal wall (Fig. 2D in Kong and Hong, 2018).

TAXONOMIC TREATMENT

Persicaria subterranea Bo Li, *sp. nov.*

西藏冰川蓼 Figs. 1 & 2

Type: CHINA. Xizang Autonomous Region: Lhasa City, Lahu Wetland National Nature Reserve, growing in wet grassy slopes, 3321 m a.s.l., 29°41'1.37"N, 91°7'17.81"E, 24 Sep 2016, Bo Li LB0740 (Holotype: HITBC, barcode no. HITBC0114171; isotype: CSH, barcode CSH0204350).

Diagnosis: As currently known, *Persicaria subterranea* is the only species having subterranean cleistogamous flowers within the sect. *Cephalophilon* of *Persicaria*. It is morphologically most similar to *P. glacialis* and its variety *P. glacialis* var. *przewalskii* but could be readily distinguished from the latter two taxa by the following characteristics: leaf blade deeply pinnatifid with one pair of lateral lobes, sparsely strigose on both surfaces, margin shortly ciliate (*vs.* leaf blade unlobed or slightly 2-lobed at base, both surfaces and margin glabrous), aerial inflorescences sessile and subterranean inflorescences short-peduncled and sparsely strigose (*vs.* peduncle obvious, 0.8–1.7 cm in length, and glandular-hairy and pubescent in the upper portion), stamens 8 (*vs.*

stamens 5), achenes trigonous, glossy, surfaces smooth, and ridges rounded (*vs.* achenes trigonous or biconvex, dull, surfaces finely granular or pitted, ridges acute).

Description: Herbs annual. Stems 10–30 cm tall, glabrous, thin, ascending, much branched, rooting at base. Leaf blade triangular-ovate, 1.8–2.5 × 1.4–2.1 cm, both surface strigose, usually deeply pinnatifid at the base, lateral lobes oblong to lanceolate, 3–6 mm long; base truncate, apex acuminate, edge entire, ciliate; pinnate veins, lateral veins 3–8 pairs, depression adaxially and prominent abaxially, tertiary veins unobvious. Petioles 0.4–1.3 cm, narrowly winged. Ocrea caducous, brownish, tubular, membranous, glabrous, apex oblique. Inflorescences a sessile cluster, terminal or axillary, ca. 1 cm in diameter; subterranean inflorescences shorter, with an ocrea at each node, peduncles short, 1–2 mm long, 2–4 flowered. Bracts ovate or broadly ovate, margin membranous, middle green to dark red on aerial inflorescences or yellow on subterranean inflorescences, sparsely glandular. Pedicels much shorter than bracts. Perianth white or yellow, campanulate, 3.1–3.9 mm, 5-parted to 1/3 its length; tepals nearly equivalent. Stamens 8, included. Styles 3, connate at middle; stigmas capitate. Achenes 1.9–2.2 × 1.8–2.1 mm, dark brown to black, included in persistent perianth, broadly ovoid, glossy, trigonous, ridges rounded, surfaces smooth.

Phenology: *Persicaria subterranea* was observed flowering from June to August and fruiting from July to October.

Etymology: The specific epithet “*subterranea*” refers to the distinctness of the species in bearing subterranean inflorescences.

Vernacular: 西藏冰川蓼 (Pinyin: xī zàng bīng chuān liǎo)

Habitat and Distribution: Based on our field surveys



and specimen records, *P. subterranea* is currently known from Lhasa and Nyingchi cities of the Xizang Autonomous Region, western China, growing on wet grassy lands at an elevation of 3000–3400 m.

Additional specimens examined (paratypes): CHINA. Xizang Autonomous Region: Nyingchi City, on the way to Gongbo'gyamda County, 3170 m a.s.l., 8 August 2001, *H.N. Qin, S.Y. Dong, Y. Kang, Z.L. Wang & Y.L. Tu 123* (PE, barcode no. 015791841); Zayu County, on valley grassy slopes, ca. 3000 m a.s.l., 14 September 2012, *FLPH Tibet Expedition 12-1180* (PE, barcode no. 019678861)

ACKNOWLEDGMENTS

The authors are grateful to the keepers of CDBI, HITBC, IBSC, KUN, HNWP, NAS, PE, QFNU, SZ, WUK, and XZ for their assistance during the specimens' examination, to Dr. Xin-Xin Zhu for sharing pictures of *P. glacialis*, and to Miss. Yun-Xiao Liu for line-drawing illustration. This work was supported by the National Natural Science Foundation of China (grant no. 32360054).

LITERATURE CITED

- Ayodele, A.E. 2005 The morphology and taxonomic significance of pollen in the West African Polygonaceae. *Thaiszia Journal of Botany* **15**: 143–153.
- Ayodele, A.E., Zhou, Z.K. 2010 Scanning electron microscopy of fruits in the West African Polygonaceae. *J. Syst. Evol.* **48(5)**: 336–343.
- Bentham, G., Hooker, J.D. 1880 *Genera Plantarum* 3(1). Lovell Reeve & Co., London, 459 pp.
- Brandbyge, J. 1993 Polygonaceae. In: Kubitzki, K. and V. Bittich. (eds.), *The Families and Genera of Vascular Plants* 2. Springer Verlag, Berlin, pp. 531–544.
- Burke, J.M., Sanchez, A., Kron, K., Luckow, M. 2010 Placing the woody tropical genera of Polygonaceae: a hypothesis of character evolution and phylogeny. *Am. J. Bot.* **97(8)**: 1377–1390.
- Cao, D.L., Zhang, X.J., Qu, X.J., Fan, S.J. 2022 Plastid phylogenomics sheds light on divergence time and ecological adaptations of the tribe Persicarieae (Polygonaceae). *Front. Plant Sci.* **13**: 1046253.
- Dammer, U. 1893 Polygonaceae. In Engler, H. and K. Prantl (eds.) *Die Natürlichen Pflanzenfamilien*. (3rd edition) 1a. Engelmann Verlag, Leipzig, pp. 1–36.
- Erdtman, G. 1960 The acetolysis method: a revised description. *Svensk Botanisk Tidskrift* **54**: 561–564.
- Freeman, C.C. 2005 Polygonaceae. In: *Flora of North America* Editorial Committee (eds.), *Flora of North America*. Vol. 5. Oxford University Press, New York, pp. 574–594.
- Galasso, G., Banfi, E., Mattia, F.D., Grassi, F., Sgorbati, S., Labra, M. 2009 Molecular phylogeny of *Polygonum* L. s.l. (Polygonaceae), focusing on European taxa: preliminary results and systematic considerations based on rbcL plastidial sequence data. *Atti della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano* **150**: 113–148.
- Haraldson, K. 1978 Anatomy and taxonomy in Polygonaceae subfamily Polygonaceae Meisn. emend. Jaretzky. *Symbolae Botanicae Upsalienses* **22**: 1–95.
- Hedberg, O. 1946 Pollen morphology in the genus *Polygonum* L. s.l. and its taxonomical significance. *Sven. Bot. Tidskr.* **40**: 371–414.
- Hong, S.P., Hedberg, O. 1990 Parallel evolution of aperture numbers and arrangement in the genus *Koenigia*, *Persicaria* and *Aconogonon* (Polygonaceae). *Grana* **29(3)**: 177–184.
- Hou, Y.T. 2006 Systematic studies on the tribe Polygoneae of China. Shandong Normal University, Jinan, 290 pp.
- Kantachot, C., Chantaranothai, P. 2011 Achene Morphology of *Polygonum* s.l. (Polygonaceae) in Thailand. *Trop. Nat. Hist.* **11(1)**: 21–28.
- Keskin, M., Severolu, Z. 2020 The genus *Persicaria* (Polygonaceae) in Turkey with a new taxon record. *EMU J. Pharm. Sci.* **3(2)**: 97–105.
- Kim, S.T., Donoghue, M.J. 2008a Molecular phylogeny of *Persicaria* (Persicarieae, Polygonaceae). *Syst. Bot.* **33(1)**: 77–86.
- Kim, S.T., Donoghue, M.J. 2008b Incongruence between cpDNA and nrITS trees indicates intensive hybridization within *Eupersicaria* (Polygonaceae). *Am. J. Bot.* **95(9)**: 1122–1135.
- Kong, M.J., Hong, S.P. 2018 Comparative achene morphology of *Persicaria* sect. *Cephalophilon* and related taxa (Polygonaceae). *Korean J. Pl. Taxon.* **48(2)**: 134–142.
- Kong, M.J., Song, J.H., Hong, S.P. 2021 Pollen morphology of *Persicaria* section *Cephalophilon* (Polygonaceae). *Pl. Syst. Evol.* **307(2)**: 16.
- Kong, M.J., Song, J.H., An, B.C., Son, S.W., Suh, G.U., Chung, M.J., Hong, S.P. 2018 A comparative study of achene morphology in Korean Polygonaceae. *Bangladesh J. Plant Taxon.* **25(2)**: 135–148.
- Li, A.J. 1998 Polygonaceae. In Li, A.J. (ed.) *Flora Reipublicae Popularis Sinicae* 25(1). Science Press, Beijing, pp. 1–237.
- Li, A.J., Bao, B.J., Grabovskaya-Borodina, A.E., Hong, S.P., McNeill, J., Mosyakin, S.L., Ohba, H., Park, C.W. 2003 Polygonaceae. In Li, A.J. (ed.) *Flora of China* 5. Science Press, Beijing; Missouri Botanical Garden Press, St. Louis, pp. 277–350.
- Meisner, C.F. 1856 Polygonaceae. In de Candolle, A. (ed.) *Prodomus systematis naturalis regni vegetabilis* 14. Masson, Paris, pp. 1–185.
- Paul, P., Chowdhury, M. 2020 Pollen morphology of selected Indian species from subfamily Polygonoidae (Polygonaceae). *Biologia* **75(8)**: 1083–1095.
- Qu, C.Y., Hou, Y.T., Li, A.L., Lu, F.J., Li, F.Z. 2006 Fruit shape and pericarp micromorphological characteristics of *Polygonum* section *Persicaria* from China. *Bot. J. Linn.* **26**: 275–285.
- Ronse Decraene, L.P., Akeroyd, J.R. 1988 Generic limits in *Polygonum* and related genera (Polygonaceae) on the basis of floral characters. *Bot. J. Linn.* **98(4)**: 321–371.
- Ronse Decraene, L.P., Hong, S.P., Smets, E. 2000 Systematic significance of fruit morphology and anatomy in tribes Persicarieae and Polygoneae (Polygonaceae). *Bot. J. Linn.* **134(1-2)**: 301–337.
- Sanchez, A., Schuster, T.M., Kron, K.A. 2009 A large-scale phylogeny of Polygonaceae based on molecular data. *Int. J. Plant Sci.* **170(8)**: 1044–1055.
- Sanchez, A., Schuster, T.M., Burke, J.M., Kron, K.A. 2011 Taxonomy of Polygonaceae (Polygonaceae): a new tribal classification. *Taxon* **60(1)**: 151–160.



- Schuster, T.M., Reveal, J.L., Bayly, M.J., Kron, K.A.** 2015 An updated molecular phylogeny of Polygonaceae (Polygonaceae): Relationships of *Oxygonum*, *Pteroxygonum*, and *Rumex*, and a new circumscription of *Koenigia*. *Taxon* **64(6)**: 1188–1208.
- Shahla, S., Maassoumi, A.A., Hamdi, S.M.M., Mehregan, I. Nejadstari, T.** 2014 Fruit morphology of the genus *Rumex* L. (Polygonaceae) in Iran. *Journal of Biodiversity and Environmental Sciences* **5 (1)**: 655–663.
- Steward, A.N.** 1930 The Polygoneae of Eastern Asia. *Contributions from the Gray Herbarium of Harvard University* **5**: 1–129.
- Suyama, C., Ueda, K.** 2013 *Persicaria geocarpica* Suyama & K. Ueda (Polygonaceae), sp. nov., and its endemism and subterranean cleistogamy. *Acta Phytotax. Geobot.* **63(3)**: 135–142.
- Thiers, B.** 2020 (Continuously updated). Index herbariorum: a global directory of public herbaria and associated staff. New York Botanical Garden. Available from: <http://sweetgum.nybg.org/science/ih/> (accessed 10 February 2024)
- Tutin, T.G., Burges, N.A., Edmondson, J.R., Heywood, V.H., Moore, D.M., Valentine, D.H., Walters, S.M., Webb, D.A.** 1991. Polygonaceae. In Tutin, T.G. (ed.) *Flora Europaea* (2nd edition) 1. Cambridge University Press, London, pp. 91–108.
- Wang, J.X., Feng, Z.J.** 1994 A study on the pollen morphology of the genus *Polygonum* in China. *Acta Phytotaxonomica Sinica* **32**: 219–231.
- Yasmin, G., Khan, M.A., Shaheen, N., Hayat, M.Q., Zafar, Ahmad, M.M.** 2010 Pollen morphological diversity in selected species of *Persicaria* Mill. (Family: Polygonaceae). *J. Med. Plants Res.* **4**: 862–870.
- Zhang, L.S., Chen, C.L., Ma, X.X., Liu, J.Q.** 2022 Phylogenomics and evolutionary diversification of the subfamily Polygonaceae. *J. Syst. Evol.* **61 (4)**: 587–598.

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