Saxifraga cataphracta (Saxifragaceae), a new species from Southwest China

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January 30, 2024

Abstract

Saxifraga cataphracta, a new species of Saxifragaceae from Southwest China, is described and illustrated. Morphological and molecular evidence (matK, psbA-trnH, psaJ-rpl33) indicate that S. cataphracta belongs to S. sect. Irregulares, and closely related to S. geifolia and S. mengtzeana. The new species can be diagnosed by its leaf blade abaxially with white or virescent interveinal streaks, involucre and bracts conspicuous, capsule beaks winged when mature.

Abstract

Saxifraga cataphracta, a new species of Saxifragaceae from Southwest China, is described and illustrated. Morphological and molecular evidence (*matK* ,*psbA-trnH* , *psaJ-rpl33*) indicate that *S. cataphracta*belongs to *S.* sect. *Irregulares* , and closely related to *S. geifolia* and *S. mengtzeana* . The new species can be diagnosed by its leaf blade abaxially with white or virescent interveinal streaks, involucre and bracts conspicuous, capsule beaks winged when mature.

Keywords

Saxifraga section *Irregulares* , taxonomy, morphology, DNA sequences

Introduction

Saxifraga L., the largest genus of Saxifragaceae, encompasses 450–500 species that are widely distributed throughout arctic and montane regions of the Northern Hemisphere (Ebersbach et al. 2017, Tkach et al. 2015, Pan, Gornall and Ohba 2001). Recent molecular phylogenetic research is monophyletic with 13 sections and 9 subsections been recognised, providing that *S.* sect. *Micranthes* (Haw.) D. Don is excluded(Tkach et al. 2015, Deng et al. 2015). *Saxifraga*sect. *Irregulares* Haw. is the earliest lineage of Saxifraga to diverge, which is characterized by asymmetric flowers with two unequally elongated and three short petals (Magota et al. 2021, Tkach et al. 2015, Zhang et al. 2020, Soltis Douglas E 2001). Section *Irregulares*currently comprises 21 species, including eight recently described species from China (Wang Fa-Guo 2008, Zhang et al. 2021, Zhang et al. 2019, Zhang et al. 2018, Zhang et al. 2017, Zhao et al. 2019, Zhang et al. 2022b, Chen et al. 2022). Its distribution is concentrated in eastern Asia, and most members are confined to local areas (Magota et al. 2021, Pan et al. 2001).

The new species described here first came to our attention in 2021 when we examined the specimens in the herbarium of the Kunming Institute of Botany (KUN). We recognized it immediately as a new species of*Saxifraga*sect. *Irregulares* , as it possesses asymmetric flowers with two elongated petals, while its leaf

blade abaxially with white or virescent interveinal streaks, which cannot be found in known species of *S*.sect. *Irregulares* . In May 2022, we conducted a field expedition for this undescribed specimen and confirmed its distinctiveness. Here we describe and illustrate the new species and provide morphological and molecular phylogenetic evidences to support its taxonomic status and relationships.

Materials and methods

Morphological comparison: Morphological data were recorded from field collections and herbarium specimens. Voucher specimens of our collections were deposited in the herbarium of the Kunming Institute of Botany (KUN), Kunming, China. Herbarium specimens of the *S* . sect.*Irregulares* were examined from CDBI, CSFI, GXMG, IBK, IBSC, IMC, KUN, NAS, PE, SM, SYS, SZ and WUK (acronyms follow*https://sweetgum.nybg.org/science/ih/*), either by examining the specimens directly or their digital images provided by the National Plant Specimen Resource Center (*http://www.cvh.ac.cn/index.php*), and JSTOR Global Plants web portal (*https://plants.jstor.org/*).

Molecular analyses: We sampled 17 collections representing 11 species of *Saxifraga* sect. *Irregulares* , including the new species.*Saxifraga sinomontana* J.T.Pan & Gornall from *S.* sect. *Ciliatae*Haw. was selected as the outgroup based on previously molecular phylogenetic analyses (Tkach et al. 2015). Leaf materials were collected in the field and from dried herbarium specimens, and sequences for other taxa were obtained from GenBank (Table 1).

Total genomic DNA was extracted from leaf material using DP305 Plant Genomic DNA kits (Tiangen, Beijing, China) following the manufacturer's protocol. Three chloroplast regions (*matK* , *psba-trnH* ,*psaJ-rpl33*) were extracted from the chloroplast genome data performed on GetOrganelle pipeline (Jin et al. 2020). A concatenation-based approach was conducted and aligned in MAFFT 7 (Katoh, Rozewicki and Yamada 2019). Phylogenetic analysis based on maximum likelihood was implemented in IQ-Tree with 1,000 bootstrap (BS) replicates to assess clade support (Nguyen et al. 2015). Bayesian inference tree was generated using MrBayes version 3.2.6 (Huelsenbeck John P. 2001).

Results

Morphology

Morphological comparison of the new species and known species of*Saxifraga* sect. *Irregulares* indicates that the new species is closely related to *S. geifolia* Balf.f. and *S. mengtzeana* Engl. & Irmsch. The new species resembles *S. geifolia* and *S. mengtzeana* in leaf blade with foliar embryo in the adaxial sinus (Figs. 1&2), which distinguish them from other species in *S.* sect. *Irregulares* . The new species differs from latter two species by its leaf blade abaxially with white or virescent interveinal streaks (vs. leaf blade abaxially with spots), involucre and bracts conspicuous (vs. involucre obscure, bracts linear), and capsule beaks winged when mature (vs. capsule beaks divergent) (Figs. 1&2). The morphological comparisons are presented in Table 2.

Molecular analyses

A total of 12 taxa were included in the molecular phylogenetic analysis (Fig. 3). The resulting concatenated matrix dataset contained 3895 bp. The 50% majority-rule consensus tree based on maximum likehood bootstraps (ML) and Bayesian posterior probability (PP) of three chloroplast regions (*matK* , *psba-trnH* , *psaJ-rpl33*) both showed that three accessions of the new species grouped together (PP=100, ML=99) and were sister to *Saxifraga geifolia* with well support (PP=87.77, ML=84).

Discussion

The new species *Saxifraga cataphracta* has asymmetric flowers with two elongated petals and stolons absent, which indicate a position in *S.* sect.*Irregulares* ser. *Rufescentes* J.T.Pan. Previously phylogenetic analyses reveal that spots on abaxial leaf surface are phylogenetically informative within *S.* sect. *Irregulares* ser. *Rufescentes* , that is, the ser. *Rufescentes* can be divided into two subclades according to spots on leaves (abaxially spotted vs. abaxially unspotted) (Zhang et al. 2020). The new species *S. cataphracta* was

nested in the spotted subclade (contained *S. geifolia* , *S. mengtzeana* , *S. viridiflora* X.J.Zhang, T.Deng, J.T.Chen & H.Sun,*S. daqiaoensis* F.G.Wang & F.W.Xing, *S. luoxiaoensis* W.B.Liao, L.Wang & X.J.Zhang, *S. kwangsiensis* Chun & F.C.How ex C.Z.Gao & G.Z.Li, *S. damingshanensis* W.B.Liao, W.Y.Zhao & J.H.Jin, and *S. kegangii* D.G.Zhang, Ying Meng & M.H.Zhang). However, *S. cataphracta* is distinct from all other spotted species by its abaxial leaf surface covered white or virescent streaks rather than spots (Figs 1&2). Additionally, foliar embryos were found in *S. cataphracta* . There are only two species with foliar embryos in known species of*S.* sect. *Irregulares* —*S. geifolia* and *S. mengtzeana* . It is worth noting that *S. geifolia* was restored, and *S. epiphylla* (with foliar embryos) was synonymized under*S. mengtzeana* recently (Zhang et al. 2022a). Of these three species with foliar embryos, *S. cataphracta* is morphologically similar to *S. geifolia* , as the leaf blade of these two species is rotund to reniform, more or less isodiametric, while the leaf blade of*S. mengtzeana* is triangular-ovate leaves, longer than wide (Fig. 2). Molecular phylogenetic analyses also reveal a close relationship between *S. cataphracta* and *S. geifolia* (Fig. 3). However,*S.cataphracta*can easily be distinguished from *S. geifolia* by its unusual streaks in the abaxial leaf surface and other morphological features as discussed above (see Results).

Geographically, *Saxifraga cataphracta* was distributed in northeastern Yunnan, Chongqing and southern Sichuan, which is on the east of the distribution area of *S . geifolia* (Fig. 4). Here we argue that the environmental heterogeneity plays an important role in the differentiation of these species. More investigations and phylogenetic analyses are needed to infer the speciation, trait evolution and biogeographic history of *S.* sect. *Irregulares* .

Taxonomy Treatment

*Saxifragacataphracta*X.J. Zhang, T. Deng et H. Sun *sp. nov.* **Figs. 1**

Type: CHINA. Yunnan. Zhaotong City, Yiliang County, Wumengshan National Nature Reserve, Xiaocaoba Town, Chaotianma, 104°21'49"E, 27deg49'23"N, 1775 m alt., 30 May 2022, C. Zhang *Zhang1388* (Holotype: KUN!; Isotypes: BNU!, KUN!).

Diagnosis: *Saxifraga cataphracta* resembles *S. geifolia* and *S. mengtzeana* , but is distinct from the latter two in its leaf blade abaxially with white or virescent streaks, involucre and bracts conspicuous, capsule beaks winged when mature.

Description: Perennial herbs, 15-30 cm tall. Stolons absent. Rhizomes short. Leaves all basal; petiole 3–9 cm long, crisped glandular hairy purple, barely sheathing at the base; leaf blade rotund to reniform, leathery, 1.6-3.6 cm long x 1.8-3.8 cm wide, both surfaces glandular hispid or nearly glabrous, abaxially greenish or red to dark-purple, with white or virescent interveinal streaks, base cordate, occasionally with a foliar embryo in sinus, margin coarsely dentate, apex acute. Involucral bracts several, triangular-lanceolate, 5.0–7.0 mm long x 2.0–3.0 mm wide, both surfaces nearly glabrous, margin crisped glandular hairy; bracts linear-lanceolate, 4.0–6.0 mm long x 1.5–2.0 mm wide, both surfaces nearly glabrous, margin glandular hairy. Inflorescence paniculate, ca. 20 cm long. 10-20-flowered; branches 3.0-11.0 cm long, glandular pubescent, 3-5-flowered; pedicels slender, 1.4-2.5 cm long, glandular pubescent. Flowers zygomorphic; sepals 5, spreading, oblong to narrowly lanceolate, 2.0-3.8 mm long x 1.5-2.0 mm wide, adaxially glabrous, abaxially sparsely glandular hairy or glabrous, marginally glandular hairy. Petals 5, white, margin entire; shortest 3 petals ovate, 2.0-3.5 mm long x 1.2-1.8 mm wide, apex acute to acuminate, base with yellow spots; longer petal narrowly lanceolate, 6.0-15.0 mm long x 1.0-2.0 mm wide; longest petal linear-lanceolate, 20.0-25.0 mm long x 1.2-2.2 mm wide. Stamens 10, 2.5-4.5 mm long. Ovary ovoid, 1.5-2.5 mm long, with a semiannular nectary disc; styles divergent ca. 1.5-1.8 mm long. Capsule beaks winged when mature, carpels 4.0-5.0 mm long x 5.0-7.0 mm wide.

Phenology: Flowering and fruiting were observed from April to July.

Etymology: The specific epithet *cataphracta* , meaning chain mail or breast-plate, refers to the cataphract-like streaks on abaxial leaf surface of this new species, differing from all other known *Saxifraga* sect. *Irregulares*species. The Chinese name is given as "铁甲虎耳草" (tiě jiǎ hǔ ěr cǎo), referring to its cataphract-like

streaks on abaxial leaf surface.

Distribution and ecology: The new species, *Saxifraga cataphracta* , is currently known from northeastern Yunnan, Chongqing and southern Sichuan. It was observed to grow on moist rocks under forest nearby valleys, alt. 1200–2400 m.

Paratypes: CHINA. Chongqing: Nanchuan District, Jinfo Mountain, 1900 m alt.,1 June 1957, J.H. Xiong No. 91132 (SZ). **Sichuan:**Leshan City, Mount Emei, 23 June 1957, *G.H. Yang No. 55486* (SZ); Leshan City, Mount Emei, 21 June 1952, J.H. Xiong, X.J. Jiang et X.S. Zhang No. 31215 (IBK); **Yunnan:** Zhaotong City, Yiliang County, Wumengshan National Nature Reserve, Chaotianma, 1700 m alt., 19 May 2016, *H.J. Dong & F. Zhao WM-0516* (KUN).

Additional specimens examined: China. Chongqing: Nanchuan District, 29 May 1957, *J.H. Xiong* , *Z.L. Zhou No. 91056*(IBSC, SZ); Nanchuan District, 29 May 1957, *G.F. Li No. 61621*(SZ); Nanchuan District, 24 July 1957, *No. 95341* (SM); Nanchuan District, 26 June 1981, *S.X. Tan No. 1804* (IMC); Nanchuan District, 17 May 1986, *Z.Y. Liu No. 8403* (PE); WanZhou District, Longju Town, 13 May 1998, Z.Y. Liu No. 973275 (IMC). **Sichuan:**Leshan City, Mount Emei, 22 June 1952, *X.J. Jiang & X.S. Zhang No. 31242* (SZ); Leshan City, Mount Emei, 27 June 1956, *L.C. Hu No. 50209* (SZ); Leshan City, Mount Emei, 5 July 1956, *L.C. Hu No. 0130* (SZ); Leshan City, Mount Emei, 12 June 1957, G.H. Yang No. 55311 (IBSC); Leshan City, Mount Emei, 8 July 1957, *P.Q. Duan & L.C. Hu No. 327* (SZ); Leshan City, Mount Emei, 7 June 1980, L.W. Wang & Z.Y. Zhang No. 874 (PE); Leshan City, Mount Emei, 4 May 2022, *C. Zhang & J.L. Li Zhang1069* (KUN).

Conflict of Interest Statement

The authors declare that there is no conflict of interest.

Data Archiving Statement

All data used in the study are included in this paper.

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Table 1. Voucher information and GenBank accessions for phylogenetic analysis

Taxon	**Voucher**	**GenBank accession number**	**GenBank accession number**	**G**
		matK	*psba-trnH*	*p*
Saxifraga cataphracta 1	Zhang1388 (KUN)	***	***	*
Saxifraga cataphracta 2	Zhang1069 (KUN)	***	***	*
Saxifraga cataphracta 3	WM-0516 (KUN)	***	***	*
Saxifraga geifolia 1	deng11135 (KUN)	***	***	*
Saxifraga geifolia 2	deng11665 (KUN)	***	***	*
Saxifraga geifolia 3	zwy-972 (SYS)	***	***	*
Saxifraga mengtzeana 1	zhangxj104 (KUN)	***	***	*
Saxifraga mengtzeana 2	zhangxj106 (KUN)	***	***	*
Saxifraga viridiflora 1	deng12030 (KUN)	***	***	*
Saxifraga viridiflora 2	zhangxj98 (KUN)	***	***	*
Saxifraga damingshanensis	zwy-1208 (SYSU)	***	***	*
Saxifraga daqiaoensis	deng12102 (KUN)	***	***	*
Saxifraga kegangii	BJ4668 (JIU)	***	***	*
Saxifraga kwangsiensis	deng12168 (KUN)	***	***	*

Taxon	Voucher	GenBank accession number	GenBank accession number	G
Saxifraga luoxiaoensis	LXP-13-16785(SYSU)	***	***	*
Saxifraga rufescens	deng13173 (KUN)	***	***	*
Saxifraga sinomontana	/	extracted from MN104589	extracted from MN104589	e
Saxifraga stolonifera	/	extracted from MN496079	extracted from MN496079	e

***: Accession numbers will be available after review process.

Table 2. Morphological comparisons amongst *Saxifraga cataphracta* , *S. geifolia* and *S. mengtzeana* .

Characters	S. cataphracta	S. geifolia
Foliar embryo	present	present
Leaf shape	rotund to reniform	ovate to reniform
Leaf margin	coarsely dentate	crenate-lobed
Leaf texture	leathery	papery or slightly leathery
Adaxial surface of leaf blade	concolorous, glandular hispid or nearly glabrous	with streaks, glandular hispid or nearl
Abaxial surface of leaf blade	white or virescent streaks	brown or purple spots
Involucre	triangular-lanceolate	obscure
Bracts	linear-lanceolate	linear
Capsule beaks	winged when mature	divergent
Flowering time	April to July	May to September