A re-examination of the circumscription of Saxifraga mengtzeana (Saxifragaceae)

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Abstract

In the Flora of China account (Pan et al. 2001) of Saxifraga mengtzeana Engl. & Irmsch., eight synonyms were attributed to it and one variant, recognised as S. epiphylla Gornall & Ohba, was split from it. This study re-evaluates the taxonomic status of some of the synonyms and of the segregated species in the light of new evidence presented here. Morphological and molecular evidence demonstrate that populations from north-western Yunnan and Sichuan are genetically differentiated from those in south-eastern Yunnan and neighbouring Guangxi. Observations in the field and in cultivation show that the peltate petiole attachment diagnostic of S. mengtzeana var. peltifolia Engl. & Irmsch. is developmentally labile. Similar observations combined with molecular data show that viviparous phenotypes, formerly treated as S. epiphylla, although largely under genetic control, occur sporadically throughout the ranges of both northern and southern taxa. Populations from north-western Yunnan and Sichuan are best recognised as S. geifolia Balf.f., whereas those from south-eastern Yunnan and neighbouring Guangxi are S. mengtzeana. Peltate-leaved variants of the latter are given no status and are relegated to complete synonymy. Viviparous phenotypes of S. mengtzeana are demoted to the rank of forma, as f. epiphylla; analogous phenotypes of S. geifolia are newly described as f. vivipara. Keywords China, Saxifragaceae, Phylogeny, Morphology, Taxonomy
combined with molecular data show that viviparous phenotypes, formerly treated as *S. epiphylla*, although largely under genetic control, occur sporadically throughout the ranges of both northern and southern taxa. Populations from north-western Yunnan and Sichuan are best recognised as *S. geifolia* Balf.f., whereas those from south-eastern Yunnan and neighbouring Guangxi are *S. mengtzeana*. Peltate-leaved variants of the latter are given no status and are relegated to complete synonymy. Viviparous phenotypes of *S. mengtzeana* are demoted to the rank of forma, as f. *epiphylla*; analogous phenotypes of *S. geifolia* are newly described as f. *vivipara*.

**Keywords**
China, Saxifragaceae, Phylogeny, Morphology, Taxonomy

**Introduction**

*Saxifraga* L., the largest genus in Saxifragaceae, comprises more than 440 species that are widely distributed throughout arctic and montane regions of the Northern Hemisphere (Pan et al., 2001; Tkach et al., 2015; Ebersbach et al., 2017). Recent molecular phylogenetic research recognised at least 13 sections and 9 subsections within the genus (Tkach et al. 2015). *Saxifraga sect. Irregulares* Haw., characterised by asymmetric flowers with two unequally elongated and three short petals, was the earliest lineage of *Saxifraga* to diverge (Solits et al., 2001; Tkach et al., 2015; Zhang et al., 2020; Magota et al., 2021). Section *Irregulares* currently comprises 20 species, including seven recently described from China. It is distributed in eastern Asia (Wang et al., 2008; Zhang et al. 2017; Zhang et al. 2019; Zhang et al., 2021a; Zhang et al., 2021b; Zhang et al., 2022). Most members are confined to local areas (Pan et al., 2001; Magota et al., 2021). The diversity of *S. sect. Irregulares* has been under-estimated, and more investigations and phylogenetic analyses are needed to clarify the patterns of variation and the delimitation of species (Zhang et al., 2021). The purpose of this study was to re-evaluate the taxonomic and phylogenetic status of taxa that were associated with or synonymised under *S. mengtzeana* Engl. & Irmsch. in the account of this species in *Flora Reipublicae Popularis Sinicae* (Pan 1992) and in *Flora of China* (Pan et al. 2001); see Table 1 and Appendix A.

Taxa of particular focus in the present study are *Saxifraga mengtzeana*, *S. henryi* Balf.f., *S. epiphylla* Gornall & H.Ohba and *S. geifolia* Balf.f. Two others (*S. lancangensis* and *S. ovatocordata*) will be the subjects of future studies. Our approach involved using both morphological and chloroplast sequence data. It is possible to synonymise some of the names in Table 1 through consideration of type specimens (Appendix A), since both Balfour (1916) and Engler & Irmscher (1913, 1916/19) cited some of the same material in their treatments of the group, despite working in isolation. Thus, as pointed out by Pan et al. (2001), the holotype of *S. aculeata*Balf.f. (*A. Henry 10316B*; Fig. 1A) is an isosyntype and designated lectotype of the earlier names *S. mengtzeana* and *S. mengtzeana* var. *cordatifolia* (Gornall et al. 2000).

With regard to the recognised variants of *Saxifraga mengtzeana*, var. *peltifolia* Engl. & Irmscher was described for those plants with a peltate insertion of the basal leaf petiole and was based on *A. Henry 9118* (Engler & Irmscher 1913). Balfour (1916) described *S. henryi* Balf.f. on the basis of the same collection. Variants with a foliar embryo in the basal leaf sinus were not mentioned by Engler & Irmscher (1913, 1916/19) nor by Balfour (1916), but they seem to have been first recognised by Pan (1992), who misapplied the name *Saxifraga aculeata* to them. The type collections of *S. aculeata*, however, lack foliar embryos and, as explained earlier, are the same taxon as the type of *S. mengtzeana* (Gornall et al. 2000). The viviparous taxon was distinguished as a separate species and given its first formal name as *S. epiphylla*, Gornall & H. Ohba (Gornall et al. 2000) based on Feng 12638 (Fig. 1B). Soon afterwards Chuang (2001) described *S. mengtzeana* var. *foliatata* H.Chuang for the taxon with foliar embryos; Chuang cited Wang 82433 as the holotype but included Feng 12638 among the paratypes, thus ensuring synonymy of the two names.

Type material of *Saxifraga mengtzeana* and *S. epiphylla* comes from south-eastern Yunnan. The only two synonymised taxa from outside southern Yunnan are *S. geifolia* Balf.f. and *S. ovatocordata* Hand.-Mazz.
(the latter from western Sichuan and not considered further here). Balfour (1916) described *S. geifolia* based on *G. Forrest 11438* (Fig. 2) from lat. 27°45′N in north-western Yunnan. It was included in *S. mengtzeana* in the *Flora of China* (Pan et al., 2001) although morphologically, the leaf shape of the holotype specimen is rounder than the triangular-ovate leaf shape of *S. mengtzeana*. Geographically, the type locality of *S. geifolia* is some 500 km distant from the type locality of *S. mengtzeana*. The morphological and geographical differences suggest that *S. geifolia* may be distinct rather than conspecific with *S. mengtzeana*.

**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 *Saxifraga mengtzeana* and related taxa were examined in CDBI, CSFI, GXMG, IBSC, KUN, PE, and SM (acronyms follow Thiers 2018), 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/). Leaf length relative to width (aspect ratio) and the angle of leaf apex (Fig. 3) were measured for quantitative analysis (summarise sampling: 23 populations, 33 individuals, 267 records). In addition, observations were made of the shape of the leaf apex (subacute vs. obtuse), the leaf texture (thick, leathery and slightly succulent vs. papery or slightly leathery), and markings on the adaxial leaf surface (concolorous vs. with white or virescent streaks). Voucher specimens for the morphological observations are cited under Additional specimens examined in the taxonomic treatment and in Table 2.

**Phylogenetic reconstruction:** We sampled 21 collections representing *Saxifraga mengtzeana* and related taxa. Leaf materials were collected in the field and from dried herbarium specimens (Table 2). Sequences for other taxa were obtained from GenBank (Table 2). *Saxifraga sinomontana* from *Saxifraga* sect. *Ciliatae* was selected as the outgroup, based on previously proposed phylogenetic relationships based on molecular analyses (Tkach et al., 2015).

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 sequences were aligned in MAFFT 7 (Katoh et al., 2019). Phylogenetic reconstruction was performed using maximum likelihood (ML) and Bayesian inference (BI). ML analysis was implemented in IQ-Tree with 1,000 bootstrap (BS) replicates to assess clade support (Nguyen et al., 2015). Bayesian analysis used MrBayes version 3.2.6 (Huelsenbeck et al. 2001). As identified by Modeltest 2.1.7, the GTR+Γ model of sequence evolution was selected using the Akaike information criterion (AIC) for both ML and BI analyses (Posada., 2008).

**Results**

**Morphology**

Analysis of the morphological variation shows that it can be divided into two reasonably well-marked groups (Figs. 4-6) based on leaf outline: a) a northern group with rotund to ovate, more or less isodiametric leaves with bluntly crenate margins, and b) a south-eastern group with triangular-ovate leaves, longer than wide, with more coarsely dentate margins. Plants with a peltate petiole insertion are restricted to the south-eastern group, but those with foliar embryos occur in both groups (Fig. 4).

In addition to the differences in leaf shape, other distinctive features associated with the geographical groups include the leaf apex (subacute in the south vs. obtuse in the north), leaf texture (thick, leathery and slightly succulent in the south vs. papery or slightly leathery in the north), and markings on the adaxial leaf surface (concolorous in the south vs. with white or virescent streaks in the north) (Figs. 7&8). Comparison with type specimens shows that the southern group corresponds to *Saxifraga mengtzeana* (including *S. epiphylla*) and the northern group corresponds to *S. geifolia*. The south-eastern populations flower from September to November, whereas those in the northern flower May to September.
Plants with a peltate petiole insertion are restricted to the south-eastern group and co-occur with phenotypes that have petioles inserted at the base of the leaf-blades. The difference is not clear-cut, however, because the point of insertion of the petiole can vary such that intermediate phenotypes occur. Furthermore, observations of plants of the related, peltate-leaved *S. daqaoensis* in cultivation show that the peltate feature is developmentally plastic with new leaves having basifixed petioles and only in later leaves are the petioles in a peltate position; and individuals may vary from one year to the next.

Plants with foliar embryos occur in populations of both *Saxifraga mengtzeana* and *S. geifolia*, alongside plants without such embryos. Field studies at the type locality of *S. epiphylla* in Malipo County, Yunnan, showed that, even here, the population is polymorphic for this feature. Sometimes the embryos are very small, reduced to a tiny, leafless bud. Furthermore, we found foliar embryos in some plants in PingBian County, which is adjacent to Mengtze, the type locality of *S. mengtzeana* (Fig. 6). Examination of specimens of these two species, including the types, shows very little difference apart from the foliar embryos (Fig. 1, Table 3).

**Phylogenetic analyses**

Thirteen taxa were included in the phylogenetic analysis (Fig. 9). The resulting concatenated matrix dataset contained 3970 bp. The 50% majority-rule consensus tree based on maximum likelihood bootstraps (ML) and Bayesian posterior probability (PP) of the chloroplast DNA sequences both showed that four accessions from south-eastern Yunnan, two individuals with foliar embryos (*Saxifraga epiphylla*) and two without foliar embryos (*S. mengtzeana*), grouped together (PP=1.00, ML=100) and were sister to *S. viridiflora*. Five accessions from north-western Yunnan and Sichuan, two individuals with foliar embryos and three without foliar embryos (*S. geifolia*), formed a monophyletic clade with a strong support (PP=1.00, ML=100) and were sister to the clade of *S. mengtzeana + S. viridiflora*. Specimens previously recorded as *S. mengtzeana* (S. sp. guangxi1 and S. sp. guangxi2) from Guilin of Guangxi Province grouped together with *S. damingshanensis + S. kwangsiensis*, but the support for these relationships is too weak to warrant firm conclusions about their identity.

**Discussion**

Morphological and molecular patterns of variation are consistent in distinguishing a northern taxon from a south-eastern taxon. The former corresponds to *Saxifraga geifolia*, with rotund to ovate, more or less isodiametric, cordate leaves with bluntly crenate margins, an obtuse leaf apex, a papery or only slightly leathery texture, and whose adaxial surface is streaked with white or pale green. The south-eastern taxon matches *S. mengtzeana*, with triangular-ovate (longer than wide), cordate leaves, with more coarsely dentate margins and a subacute apex, a thick, leathery and slightly succulent texture, and a concolorous adaxial surface. Despite some morphological overlap between the northern and south-eastern populations, the differences are sufficient to warrant the recognition of two distinct species, particularly in the light of the support for such an arrangement given by the molecular data. The two gene pools are likely reproductively isolated from one another not only by geographical distance but also by flowering time, with the northern populations blooming in summer, from May to September, and the south-eastern ones in the autumn, September to November.

Our observations have shown that the peltate-leaved variant of *Saxifraga mengtzeana*, var. *peltifolia* Engler & Irmscher (1913), occurs only in south-eastern Yunnan and falls within the pattern of variation of that species. The degree to which the petioles are peltate is variable and there are intermediates with the basifixed phenotypes; and there is a possibility that the character is developmentally labile. We propose, therefore, to abandon it as a taxon and synonymise it fully under *S. mengtzeana*.

The case of *Saxifraga epiphylla* is somewhat different. The trait of a leaf blade with foliar embryos in the adaxial sinuses is stable within a plant from year to year and is presumably therefore genetically determined. Its pattern of occurrence, however, whereby it occurs apparently somewhat randomly within populations of *S. mengtzeana*, suggests that the foliar embryos are not diagnostic of a species. Indeed, Zhang et al. (2020) compared the morphology of herbarium specimens of *S. mengtzeana* and *S. epiphylla* from KUN and PE and
found no features to support their separation except the presence of foliar embryos. Molecular data also strongly suggests that plants with foliar embryos do not form a monophyletic group, but rather are embedded within *S. mengtzeana* and *S. geifolia*. Since the character appears to be under genetic control and is an important feature of the phenotype, scattered within populations, we propose that taxonomic recognition is warranted at the rank of forma. This is easily accomplished in the case of *S. mengtzeana* where a valid description and a type specimen exists, but a new taxon needs to be established for the viviparous plants of *S. geifolia*, and for these we propose the name *S. geifolia f. vivipara*.

**Taxonomic treatment**


**Type**: China, Yunnan, Mengtzi, auf Felsen 1500-1800m. *A. Henry 10316* (syntype B, presumed destroyed; isosyntypes E! MO; A. Henry 10316B (syntype B, presumed destroyed; lectotype E! (Gornall et al. 2000); isolectotypes MO! PE!).


*Saxifraga aculeata* Balf. f., Trans. Bot. Soc. Edinburgh. 27(1): 70. 1916. TYPE: China, Yunnan, Mengtz. *A. Henry 10316B* (lectotype E!, designated here, or perhaps holotype; isolectotypes MO! PE!). Gornall et al. (2000) referred to the Edinburgh specimen of this collection as the holotype, since that is where I.B. Balfour worked. However, since the species was published before 1990 and duplicate types exist in other herbaria, the attribution of type status must be formalised by means of a lectotypification, provided here; see McNeill (2014).


**Description**: Herbs, perennial, 10-40 cm tall. Stolons absent. Rhizomes short. Leaves all basal; petiole 5-15 cm long, brown glandular hairy, barely sheathing at base; leaf blade triangular-cordate, thick leathery and slightly succulent, 4.5-8.5 cm long x 3.5-7.0 cm wide, both surfaces sparsely hispid or nearly glabrous, abaxially greenish or purple, with brown or purple spots, base cordate or peltate, occasionally with a foliar embryo in sinus, margin coarsely dentate, apex subacute. Inflorescence paniculate, ca. 25 cm long. 10-30-flowered; branches 2.4-5.0 cm long, glandular pubescent, 2-4-flowered; pedicels slender, 1.0-2.0 cm long, glandular pubescent. Flowers zygomorphic; sepals 5, spreading to reflexed, oblong-ovate, 2.0-3.0 mm long x 1.0-1.5 mm wide, adaxially glabrous, abaxially and marginally glandular pubescent. Petals 5, white, margin entire; shortest 3 petals triangular-ovate, 2.5-4.0 mm long x 1.8-2.2 mm wide, apex acute to shortly acuminate; longer petal narrowly ovate, 8.0-12.0 mm long x 1.5-2.7 mm wide; longest petal sublanceolate, 15.0-25.0 mm long x 3.0-5.5 mm wide. Stamens 10, 3.5-4.5 mm long. Ovary ovoid, 1.5-2.0 mm long, with a semiannular nectary disc; styles divergent ca. 1.5-1.8 mm long. Seeds elliptic, surfaces slightly bent, ca. 0.5 mm long.

**Distribution**: China (Yunnan: Honghe, Wenshan; Guangxi: Longlin).

**Additional specimens examined**: China, Yunnan: Yanshan County, 15 November 1939, C.W. Wang 84961 (KUN); Yanshan County, 18 November 1939, C.W. Wang 85101 (KUN); Malipo County, 31 October 1947, K.M. Feng 12638 (KUN); Maguan County, 8 October 2021, X.J. Zhang zhangxj104 (KUN); Guangxi: Longlin County, 28 October 2014, H.Z. Lv, D.X. Nong & H.F. Cen 451031141028053LY (GXMG).
Saxifraga mengtzeana f. epiphylla (Gornall & H.Ohba) X.J. Zhang & Gornall


**Distribution**: China (Yunnan: Honghe, Wenshan).

**Additional specimens examined**: China. Yunnan: Mengtze City, 11 October 1939, C.W. Wang 83396 (KUN); Pingbian County, 8 October 2021, X.J. Zhang zhangxj106 (KUN); Malipo County, 4 December 2021, X.J. Zhang zhangxj110 (KUN).


**Type**: China, Yunnan, on ledges of cliffs and humus-covered boulders; on the mountains in the north-east of the Yangtze bend. Lat. 27°45′N, September 1913, G. Forrest 11438. (holotype E!; isotypes KUN! PE!).

**Description**: Herbs, perennial, 15-36 cm tall. Stolons absent. Rhizomes short. Leaves all basal; petiole 5–12 cm long, brown glandular hairy, rarely sheathing at the base; leaf blade ovate to reniform, papery or slightly leathery, 3.6-5.5 cm long x 3.0-5.0 cm wide, both surfaces glandular hispid or nearly glabrous, abaxially greenish or purple, with brown spots, base cordate, occasionally with a foliar embryo in sinus, margin crenate-lobed, lobes crenulate or subentire, apex obtuse. Inflorescence paniculate, ca. 30 cm long. 15-30-flowered; branches 3.0-7.0 cm long, glandular pubescent, 3.5-5.0 mm wide; pedicels slender, 1.0-2.0 cm long, glandular pubescent. Flowers zygomorphic; sepals 5, spreading, oblong, 2.0-3.5 mm long x 1.5-2.0 mm wide, adaxially glabrous, abaxially and marginally glandular pubescent. Petals 5, white, margin entire; shortest 3 petals ovate, 2.0-4.0 mm long x 1.5-2.5 mm wide, apex acute to shortly acuminate; longer petal lanceolate, 8.0-15.0 mm long x 1.5-3.0 mm wide; longest petal linear-lanceolate to lanceolate, 12.0-20.0 mm long x 2.2-5.5 mm wide. Stamens 10, 3.5-4.2 mm long. Ovary ovoid, 1.5-2.0 mm long, with a semiannular nectary disc; styles divergent ca. 1.3-1.8 mm long. Seeds elliptic, surfaces slightly bent, ca. 0.5 mm long.

**Distribution**: China (northern Yunnan, Sichuan).

**Additional specimens examined**: China. Sichuan: Tianquan County, 14 May 1980, Q.Q. Wang 21876 (IBSC); Dechang County, 2 July 1976, Northwest Normal University Biology Department No. 12007 (PE); Xide County, 24 May 1979, No. 0335(SM); Ganhuo County, 17 June 1979, No. 514 (SM); Ganhuo County, 23 September 1976, No. 14325 (PE); Meigu County, 12 June 1979, No. 242 (SM); Jinyang County, 7 August 1978, No. 466 (SM); Huili County, 2 July 1968, Group H. Yun No. 56 (SM); Dujiangyan City, 26 May 2014, J.J. Zhou 140526002 (CSFI); Kangding City, 27 June 1965, Y.T. Zhang & K.Y. Lang 32 (PE); Kangding City, 8 August 1959, S. Jiang & C.L. Jin 02739 (PE); Baoxing County, 12 May 1959, X.S. Zhang & Y.X. Ren 4595 (PE); Tianquan County, 18 April 1953, X.L. Jiang 33880 (PE); Luding County, 3 July 1934, C.S. Liu 632 (PE); Leibo County, 9 May 1979, Leibo Exped. 156 (SM); Barkam City, 22 July 1960, No. 22299 (SM); Heishui County, 8 June 1959, No. 1325 (SM); Xingwen County, 15 May 1959, No. 0341 (KUN); Danba County, 20 July 1959, No. 02212 (KUN); Mountain Omei, 25 November 1940, W.P. Fang 15545 (KUN); Yuxi County, 28 June 1959, No. 3509 (KUN); Wenchuan County, 30 May 2021, J.T. Chen, J.Y. Peng & X.J. Zhang deng11135 (KUN); Jinchuan County, 27 May 2021, J.T. Chen, J.Y. Peng & X.J. Zhang deng10990 (KUN); Yunnan: Western Yunnan, 1930, G. Forrest 28748 (PE); Shangri-La, 11 June 1981, QTP Exped. 795 (KUN); Shangri-La, 6 November 1939, K.M. Feng 3247 (KUN); Gongshan County, 29 May 1960, No. 8795 (KUN); Gongshan County, 1 September 1940, K.M. Feng 7277(KUN); Lijiang City, 19 June 2021, T. Deng, J.T. Chen, J.Y. Peng & X.J. Zhang deng11665 (KUN); Gongshan County, 20 July 2021, H. Sun, T. Deng, X.H. Huang.
Saxifraga geifolia f. vivipara X.-J. Zhang & Gornall

**Type:** China. Yunnan. Lijiang City, Naxi Autonomous County of Yulong. 27°28′N, 99°25′E, 2844 m alt., 29 August 2020, P. J. Liu, J. T. Chen, Q. Liu & X. J. Zhang deng10084 (holotype KUN).

Species haec a *Saxifraga geifolia* Balf. f. differt sinu basalium foliorum embryonibus foliaceis instructis.

Diffs from *S. geifolia* Balf. f. in having foliar embryos in the sinus of the basal leaves.

**Distribution:** China (Northern Yunnan, Sichuan).


**Author Contributions**

Xin-Jian Zhang: Conceptualization (lead); writing – original draft (lead); formal analysis (lead); writing – review and editing (equal). Richard J. Gornall: Formal analysis (lead); writing – review and editing (equal). Jun-Tong Chen: Investigation (supporting); writing – review and editing (supporting). Hang Sun: Funding acquisition (lead); project administration (lead); supervision (lead). Tao Deng: Writing – review and editing (supporting); funding acquisition (lead); supervision (supporting).

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**Competing Interests Statement**

The authors declare that there is no conflict of interest.

**Data Accessibility Statement**

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

**References**


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doi:10.1093/molbev/msu300


doi:10.1093/molbev/msn083


doi:10.11646/phytotaxa.418.1.4


doi:10.11646/phytotaxa.350.3.8


Table 1. Synonyms of Saxifraga mengtzeana plus S. epiphylla as enumerated in Flora of China (Pan et al. 2001).

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<th>Scientific name</th>
<th>Reference</th>
<th>Date</th>
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<td>Saxifraga ovatocordata Handel.-Mazz.</td>
<td>Symb. Sin. 7(2): 425</td>
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Table 2. Voucher information and GenBank accessions for phylogenetic analysis

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<td>***</td>
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<tr>
<td>Saxifraga daqiaoensis</td>
<td>Guangdong</td>
<td>deng12102 (KUN)</td>
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<td>Saxifraga kegangii</td>
<td>Hunan</td>
<td>BJ4668 (JIU)</td>
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<td>Saxifraga kwangsiensis</td>
<td>Guangxi</td>
<td>deng12108 (KUN)</td>
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<tr>
<td>Saxifraga luxiawanensis</td>
<td>Hunan</td>
<td>LXP-13-16785(SYSU)</td>
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<td>Saxifraga rufescens</td>
<td>NY: Diqing</td>
<td>deng13173 (KUN)</td>
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<td>Saxifraga spp. guangxi1</td>
<td>Guangxi</td>
<td>deng11976 (KUN)</td>
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<tr>
<td>Saxifraga spp. guangxi2</td>
<td>Guangxi</td>
<td>deng12140 (KUN)</td>
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<td>Taxon</td>
<td>Locality</td>
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<td>GenBank accession number</td>
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<tr>
<td>Saxifraga sinomontana</td>
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<td></td>
<td>extracted from MN104589</td>
<td>extracted from MN104589</td>
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<tr>
<td>Saxifraga stolonifera</td>
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<td>extracted from MN496079</td>
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***: Accession numbers will be available after review process. SC: Sichuan; NY: Northern Yunnan; SY: Southeastern Yunnan; #: individuals with foliar embryos.

Table 3. Comparison of Saxifraga mengtzeana, S. epiphylla and S. geifolia from morphological data.

<table>
<thead>
<tr>
<th>Characters</th>
<th>Saxifraga mengtzeana</th>
<th>Saxifraga epiphylla</th>
<th>Saxifraga geifolia</th>
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<tbody>
<tr>
<td>Stolons</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
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<tr>
<td>Foliar embryo</td>
<td>present or not</td>
<td>present or not</td>
<td>present or not</td>
</tr>
<tr>
<td>Leaf blade</td>
<td>triangular-cordate; base cordate or peltate; apex subacute;</td>
<td>triangular-cordate; base cordate; apex subacute;</td>
<td>ovate to reniform; base cordate; apex obtuse;</td>
</tr>
<tr>
<td>Leaf texture</td>
<td>slightly succulent</td>
<td>thick leathery</td>
<td>papery/slightly leathery</td>
</tr>
<tr>
<td>Leaf margin</td>
<td>coarsely dentate</td>
<td>coarsely dentate</td>
<td>crenate-lobed</td>
</tr>
<tr>
<td>Flowering time</td>
<td>September to November</td>
<td>September to November</td>
<td>May to September</td>
</tr>
<tr>
<td>Distribution</td>
<td>southeastern Yunnan</td>
<td>southeastern Yunnan</td>
<td>northern Yunnan, Sichuan</td>
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</tbody>
</table>

Figure legends

Figure 1. Lectotype of Saxifraga mengtzeana Engl. & Irmsch. (A: A. Henry 10316B[E]) and isotype of S. epiphylla Gornall & H. Ohba (B: K.M. Feng12638 [PE]).

Figure 2. Holotype of Saxifraga geifolia Balf. (G. Forrest 11438 [E]).

Figure 3. Measuring the angle of leaf apex (A) and leaf length relative to width (B).

Figure 4. Comparison of leaf characters for georeferenced Saxifraga mengtzeana (type locality and other sampling sites within southeastern Yunnan) and S. geifolia (type locality and other sampling sites from northern Yunnan and Sichuan).

Figure 5. Saxifraga geifolia from Sichuan (A) and northern Yunnan (B), Saxifraga mengtzeana from PingBian, southeastern Yunnan (C).

Figure 6. Distribution of Saxifraga mengtzeana (yellow region) and S. geifolia (green region) according to field collections and herbarium specimens, with sampling sites of S. mengtzeana (blue dots) and S. geifolia (red dots) for plants used in phylogenetic analyses. Type localities of S. geifolia (red star), S. mengtzeana (blue star), S. epiphylla (black star).

Figure 7. Saxifraga mengtzeana from the type locality of S. epiphylla in Malipo. A. Leaf blade without foliar embryo; B. Leaf blade with foliar embryo; C. Abaxial leaf surface; D. Flower; E. Inflorescence; F. Plant; G. Rhizomes.

Figure 8. Saxifraga geifolia from type locality. A. Leaf blade without foliar embryo, with virescent streaks; B. Leaf blade with foliar embryo; C. Abaxial leaf surface; D. Inflorescence; E. Rhizomes; F. Flower.

Figure 9. Bayesian consensus tree of species of Saxifraga sect. Irregulares derived from three chloroplast regions, with S. sinomontana as outgroup. Numbers above branches indicate ML bootstraps, numbers below branches are Bayesian posterior probability. #: individuals with foliar embryos.
Appendix A Types and taxonomic status of synonyms of *Saxifraga mengtzeana* plus *S. epiphylla* as enumerated in *Flora of China*