**Saxifraga viridiflora** (Saxifragaceae), an unusual new species from Guangxi, China

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**Abstract**

*Saxifraga viridiflora*, a remarkable new species of the genus *Saxifraga* sect. *Irregulares* (Saxifragaceae) from Guangxi, is described and illustrated herein. This new species morphologically differs from all known *S*. sect. *Irregulares* taxa by its greenish petals, verruculose sepals, and thick leathery leaf blade abaxially scarlet with white spots.

**Keywords**

China, Guangxi, new species, Saxifragaceae, taxonomy

**Introduction**

*Saxifraga* Linnaeus, the largest genus of Saxifragaceae, comprises more than 440 species widely distributed throughout the Northern Hemisphere (Pan et al. 2001; Tkach et al. 2015a, b). Previous molecular phylogenetic studies suggested that *Saxifraga* is monophyletic, providing that *S*. sect. *Micranthes* (Haw.) D. Don is excluded

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(Soltis et al. 1996; Prieto et al. 2013; Deng et al. 2015; Tkach et al. 2015a, b). Recent molecular phylogenetic research covered at least 13 sections and 9 subsections within the genus (Tkach et al. 2015b). S. sect. *Irregulares* Haw., characterized by zygomorphic flowers with two elongated petals and stamens with club-shaped filaments (Tkach et al. 2015b), is the ancestral clade of *Saxifraga* first described by Haworth (Haworth 1803; Soltis et al. 2001; Zhang et al. 2015; Tkach et al. 2015b; Zhang et al. 2019b). This section currently comprises 16 species mainly distributed in East Asia (Magota et al. 2021).

China has a vast territory with a wide range of complex and diverse topographies and soils and covering several climate types, which contribute to the wealth of Chinese botanical diversity (Sun et al. 2017; Chen et al. 2018). Twelve species of *Saxifraga* sect. *Irregulares* are native to China, including the recently reported new species, *S. daqiaoensis* F.G.Wang & F.W.Xing (Wang et al. 2008), *S. kegangii* D.G.Zhang, Y.Meng & M.H.Zhang (Zhang et al. 2017), *S. luoxiaoensis* W.B.Liao, L.Wang & X.J.Zhang (Zhang et al. 2018), *S. shennongii* L.Wang, W.B.Liao & J.J.Zhang (Zhang et al. 2019a), and *S. damingshanensis* W.B.Liao, W.Y.Zhao & J.H.Jin (Zhao et al. 2019).

In 2021, we inadvertently found a peculiar plant photograph posted on Baidu Tieba (https://tieba.baidu.com/), one of the most used Chinese communication platforms, and immediately deemed it to be a new species of *Saxifraga* sect. *Irregulares*, as it possesses zygomorphic flowers with two elongated petals and stamens with club-shaped filaments, but its petals are greenish, which cannot be found in any existing species of *Saxifraga* sect. *Irregulares*. We contacted the author of this photograph, Mr. Luo Dexuan, for phenological and geographical information regarding this specimen, and conducted fieldwork for this undescribed specimen. Subsequent morphological comparisons supported the status of the taxon as a new species, and it is described herein.

**Taxonomy treatment**

*Saxifraga viridiflora* X.J.Zhang, T.Deng, J.T.Chen & H.Sun, sp. nov.
urn:lsid:ipni.org:names:77221295-1
Figs 1, 2

**Type.** China. Guangxi: Guilin City, Yongfu County, Baishou Town, 109°46’58.99”E, 25°5’15.5”N, 586 m alt., 27 June 2021, X.J. Zhang, D.X. Luo Zhangxj98 (Holotype: KUN!; Isotypes: JIU!, SYS!).

**Diagnosis.** *Saxifraga viridiflora* is easily distinguished from any other species of *Saxifraga* sect. *Irregulares* by having greenish petals (vs. white petals). *S. viridiflora* morphologically resembles *S. epiphylla* and *S. kegangii*, but is distinct from the latter two in its leaf blade abaxially scarlet with white spots (vs. abaxially greenish/reddish with brown or yellow-green spots), and sepals with verruculose surface (vs. sepals without verruculose surface) (Table 1).
Figure 1. Saxifraga viridiflora X.J. Zhang, T. Deng, J.T. Chen & H. Sun, sp. nov. A flower, petals 5, greenish B fruit, capsule winged when mature C inflorescence D infructescence E pedicels glandular pubescent; sepals red, glabrous, abaxially white verruculose F adaxial leaf surface dark green, crisped villous G, J abaxial leaf surface scarlet, with white spotted, crisped villous H rhizomes crisped villous, petiole base unsheathed I petiole with crisped villous K, L plants and habitat.
Figure 2. Photograph of the holotype of *Saxifraga viridiflora* X.J. Zhang, T. Deng, J.T. Chen & H. Sun, sp. nov. (Zhang98, KUN1519096).
**Table 1.** Diagnostic characters of *Saxifraga viridiflora* and comparison with other related species of *S. sect. Irregulares.*

| Characters                        | *S. viridiflora* sp. nov. | *S. epiphylla* | *S. kegangii*         |
|----------------------------------|---------------------------|----------------|-----------------------|
| Foliar embryo                    | absent                    | present        | absent                |
| Leaf shape                       | reniform to orbicular     | ovate          | fan-shaped to orbicular|
| Leaf margin                      | shallowly crenate to subentire | undulate, thickly dentate | entire or 8–10-crenate |
| Leaf texture                     | thick leathery to fleshy  | leathery       | leathery              |
| Abaxial surface of leaf blade    | scarlet, with white spotted | gray-green to red, with brown or yellow-green spotted | adaxially glabrous, abaxially glabrous or sparsely hispid |
| Trichomes on leaf                | both surfaces crisped villous | both surfaces glandular hispid | white, the base of three smallest petal with yellow spot |
| Petals                           | greenish                  | white, the base of three smallest petal with yellow spot | greenish, abaxially and marginally glandular hairy, without verruculose |
| Sepals                           | red, glabrous, abaxially white verruculose | greenish, abaxially and marginally glandular hairy, without verruculose | greenish, abaxially and marginally glandular hairy, without verruculose |

**Description.** Perennial herbs, 12–30 cm tall. Stolons absent. Rhizomes rather short. Leaves all basal; petiole 5–12 cm long, crisped villous dark-purple (ca. 6 mm); leaf blade reniform, thick leathery, 2.5–4.0 cm long × 3.5–5.3 cm wide, base cordate, margin undulate, apex obtuse, both surfaces crisped villous dark-purple (5.0–9.0 mm long), adaxially greenish, abaxially purple or dark red, with white spots. Inflorescence paniculate, ca. 20 cm long. 5–10-flowered; branches 2.0–3.0 cm long, glandular pubescent, 1–2-flowered; pedicels slender, 1.0–2.0 cm long, glandular pubescent. Flowers zygomorphic; sepals 5, spreading to reflexed, narrowly ovate, 2.5–3.5 mm long × 1.5–2 mm wide, glabrous, abaxially red, with white verruculose, adaxially greenish, 3–5-veined, apex obtuse. Petals 5, greenish, margin entire, glabrous, apex acute; the three smallest lanceolate, 3.0–4.0 mm long × 1.0–1.2 mm wide, 3-veined; the two largest lanceolate oblanceolate, 0.7–1.4 cm long × 1.0–1.2 mm wide, 3-veined. Stamens 10, 3.2–4.0 mm long. Ovary ovoid, 1.5–2.0 mm long, disc obscure; styles divergent ca. 1.0–1.8 mm long. Capsule beaks winged when mature, carpels 5–7 mm long × 3–4 mm wide. Seeds elliptic, the two sides slightly bent, ca. 0.6 mm long.

**Etymology.** The specific epithet refers to the flowers of this new species that are green throughout the flowering period, differing from those of all other known *Saxifraga* sect. *Irregulares* species. The Chinese name is given as “绿花虎耳草” (lǜ huā hǔ ěr cǎo), referring to the greenish petals of the new species.

**Phenology.** In a two year personal observation of this new species in its native range, Guangxi. Guilin City (Luo Dexuan, pers. comm.), *S. viridiflora* was flowering from April to July and fruiting from June to August.

**Distribution and ecology.** The new species, *Saxifraga viridiflora*, is currently known only from Yongfu County, Guangxi Province, China. It was observed to grow on dry limestone under dense jungles at altitudes between 500 and 600 m.

**Paratypes.** China. Guangxi. Guilin City, Yongfu County, Baishou Town, 109°46′49.3″E, 25°5′16.1″N, 547 m alt., 10 July 2021, X.J. Zhang, L.J. Li, J.Y. Peng, P.R. Luo Deng12030 (KUN); same locality, 575 m alt., 27 June 2021, X.J. Zhang, D.X. Luo Zhangxj99 (KUN).
Discussion

The new species *Saxifraga viridiflora* has zygomorphic flowers and stolons absent, which indicate a position in *S*. sect. *Irregulares* ser. *Rufescentes*. *Saxifraga viridiflora* is distinct from all known sect. *Irregulares* taxa by its greenish petals, verruculose sepals, and thick leathery leaf blade abaxially scarlet with white spots.

Geographically, *Saxifraga viridiflora* was only found in Yongfu County of Guangxi Province, China. It grows only on dry rocks under dense jungles in limestone area, whereas other related species of sect. *Irregulares* usually grow on damp cliffs and rocks nearby valleys. Here we argue that the environmental heterogeneity plays an important role in the differentiation of the species in sect. *Irregulares*, given the leaf blade of *Saxifraga viridiflora* is thick leathery or fleshy (grow on dry rocks), while the leaf blade of other related species of sect. *Irregulares* are mainly papery or leathery (grow on damp rocks).

Notably, only seven species of *Saxifraga* sect. *Irregulares* were recorded in “Flora of China” (Pan et al. 2001). However, six new species of *S*. sect. *Irregulares* were discovered in China in recent years, provided that *Saxifraga viridiflora* is counted. Furthermore, most of these new species were confined to a narrow geographical range. Species richness of *S*. sect. *Irregulares* has been quite underrated, and more field investigations and phylogenetic analyses are needed to infer its biodiversity and speciation history.

Since several new species of *S*. sect. *Irregulares* have been published in recent years, we include here an identification key to include all species known so far for this section.

Identification key to *Saxifraga* sect. *Irregulares*

1. Stolons arising from axils of basal leaves, filiform .................. *S. stolonifera*
   – Stolons absent ............................................................................................ 2
2. Aerial stems developed; leaves cauligenous ........................................... *S. sendaica*
   – Aerial stems not developed; leaves radical ................................................ 3
3. Leaf blade abaxially spotted ........................................................................ 4
   – Leaf blade abaxially usually concolorous .................................................. 12
4. Leaf blade elliptic to oblong, base cuneate .............................................. *S. kwangsiensis*
   – Leaf blade fan-shaped or ovate to broadly so, base cordate or peltate .......... 5
5. Leaf blade with foliar embryos in sinus adaxially ....................................... *S. epiphylla*
   – Leaf blade without foliar embryos .................................................................. 6
6. Leaf base peltate .......................................................................................... 7
   – Leaf base cordate ......................................................................................... 8
7. Leaf blade papyraceous, apex acute .......................................................... *S. mengtzeana*
   – Leaf blade thickly coriaceous, apex obtuse ................................................. *S. daqiaoensis*
8. Leaf margin lobed ....................................................................................... 9
   – Leaf margin shallowly crenate to subentire ................................................... 11
9. Capsule beaks winged; leaf lobes margin irregularly dentate ....................... *S. luoxiaoensis*
   – Capsule beaks divergent; leaf lobes margin entire ....................................... 10
10. Abaxial surface of leaf blade purple spotted ............................................ *S. damingshanensis*
    – Abaxial surface of leaf blade yellow spotted ............................................ *S. shennongii*
Saxifraga viridiflorum, a new species from Guangxi, China

11 Leaf blade abaxially gray-green with yellow-green spots
   – Leaf blade abaxially scarlet with white spots .............................. S. viridiflora
12 Longest petal serrate at margin ..................................................... S. fortunei
   – Longest petal entire at margin ..................................................... 13
13 Leaf cleft ......................................................................................... 14
   – Leaf shallowly lobed ...................................................................... 15
14 Upper petals nearly lanceolate, not spotted ............................... S. acerifolia
   – Upper petals widely ovate, spotted ............................................ S. cortusifolia
15 Bracts leafy ..................................................................................... S. nipponica
   – Bracts linear .................................................................................. 16
16 Flowering stem and inflorescence reddish long glandular villous
   ........................................................................................................ S. rufescens
   – Flowering stem and inflorescence shortly glandular pubescent .... S. imparilis

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References
Chen YS, Deng T, Zhou Z, Sun H (2018) Is the east Asian flora ancient or not? National Science Review 5(6): 920–932. https://doi.org/10.1093/nsr/nwx156
Deng J, Drew BT, Mavrodiev EV, Gitzendanner MA, Soltis PS, Soltis ED (2015) Phylogeny, divergence times, and historical biogeography of the angiosperm family Saxifragaceae. Molecular Phylogenetics and Evolution 83: 86–98. https://doi.org/10.1016/j.ympev.2014.11.011
Haworth AH (1803) Miscellanea naturalia: Sive dissertationes variae ad historiam naturalem spectantes. Typis J. Taylor, Londini, 155 pp.
Magota K, Sakaguchi S, Lee JS, Yamamoto M, Takahashi D, Nagano AJ, Setoguchi H (2021) Phylogeographic analysis of Saxifraga fortunei complex (Saxifragaceae) reveals multiple origins of morphological and ecological variations in the Japanese Archipelago. Molecular Phylogenetics and Evolution 163: e107230. https://doi.org/10.1016/j.ympev.2021.107230
Pan JT, Gu CZ, Huang SM, Wei ZF, Jin SY, Lu LD, Akiyama S, Alexander C, Bartholomew B, Cullen J, Gornall RJ, Hultgård U-M, Ohba H, Soltis DE (2001) Saxifragaceae. In: Wu ZY,
Raven PH, Hong DY (Eds) Flora of China, vol. 8. Science Press, Beijing and Missouri Botanical Garden Press, St. Louis, 269–452. http://foc.eflora.cn/content.aspx?TaxonId=10800

Prieto JAF, Arjona JM, Sanna M, Pérez R, Cires E (2013) Phylogeny and systematics of Micranthes (Saxifragaceae): An appraisal in European territories. Journal of Plant Research 126(5): 605–611. https://doi.org/10.1007/s10265-013-0566-2

Soltis DE, Kuzoff RK, Conti E, Gornall R, Ferguson K (1996) matK and rbcL gene sequence data indicate that Saxifraga (Saxifragaceae) is polyphyletic. American Journal of Botany 83(3): 371–382. https://doi.org/10.1002/j.1537-2197.1996.tb12717.x

Soltis DE, Kuzoff RK, Mort ME, Zanis M, Fishbein M, Hufford L, Koontz J, Arroyo MK (2001) Elucidating deep-level phylogenetic relationships in Saxifragaceae using sequences for six chloroplastic and nuclear DNA regions. Annals of the Missouri Botanical Garden 88(4): 669–693. https://doi.org/10.2307/3298639

Sun H, Zhang JW, Deng T, Boufford DE (2017) Origins and evolution of plant diversity in the Hengduan Mountains, China. Plant Diversity 39(4): 161–166. https://doi.org/10.1016/j.pld.2017.09.004

Tkach N, Röser M, Hoffmann MH (2015a) Molecular phylogenetics, character evolution and systematics of the genus Micranthes (Saxifragaceae). Botanical Journal of the Linnean Society 178(1): 47–66. https://doi.org/10.1111/boj.12272

Tkach N, Röser M, Miehe G, Muellner-Riehl AN, Ebersbach J, Favre A, Hoffmann MH (2015b) Molecular phylogenetics, morphology and a revised classification of the complex genus Saxifraga (Saxifragaceae). Taxon 64(6): 1159–1187. https://doi.org/10.12705/646.4

Wang GF, Ye YS, Xing FW (2008) Saxifraga daqiaoensis (Saxifragaceae), a new species from Guangdong, China. Annales Botanici Fennici 45(3): 237–239. https://doi.org/10.5735/085.045.0313

Zhang JJ, Zhao WY, Meng KK, Liao WB, Wang L, Chen SF (2019a) Saxifraga shennongii, a new species of Saxifragaceae from Hunan Province, China. Phytotaxa 418(1): 079–088. https://doi.org/10.11646/phytotaxa.418.1.4

Zhang MH, Zhang XS, Nie ZL, Zhang DG, Meng Y (2017) Saxifraga kegangii (Saxifragaceae), a new species from Hunan Province of central China. Phytotaxa 309(2): 159–165. https://doi.org/10.11646/phytotaxa.309.2.7

Zhang MH, Wang CY, Zhang C, Zhang DG, Li KG, Nie ZL, Meng Y (2019b) Phylogenetic relationships and biogeographic history of the unique Saxifraga sect. Irregulares (Saxifragaceae) from eastern Asia. Journal of Systematics and Evolution 58(6): 958–971. https://doi.org/10.1111/jse.12547

Zhao WY, Meng KK, Fan Q, Jin JH, Liao WB (2019) Saxifraga damingshanensis (S. sect. Irregulares, Saxifragaceae), a new species from Guangxi, China. Phytotaxa 133: 95–103. https://doi.org/10.3897/phytokeys.133.36704

Zhang XJ, Liu ZC, Meng KK, Ding QL, Wang L, Liao WB (2018) Saxifraga luoxiaensis (Saxifragaceae), a new species from Hunnan and Jaingxi, China. Phytotaxa 350(3): 291–296. https://doi.org/10.11646/phytotaxa.350.3.8

Zhang ZX, Chen SL, Gornall RJ (2015) Morphology and anatomy of the exine in Saxifraga (Saxifragaceae). Phytotaxa 212(2): 105–132. https://doi.org/10.11646/phytotaxa.212.2.1