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Research Article

# *Sinocrassula obliquifolia* (Crassulaceae), a new species from China

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## Abstract

Based on a comprehensive morphological and molecular data analysis, we have confirmed and described a new species within the genus *Sinocrassula*, which is distributed in Sichuan Province, China. Morphologically, the new species resembles *Sinocrassula diversifolia* and *S. indica*, but it is distinctly different from them in its asymmetrical leaves, leaf apex with glands, triangular petals that are white at the base and adorned with dense purple-red stripes and spots on the surfaces upward, and rectangular nectar scales. A phylogenetic analysis utilizing four plastid markers and one nuclear marker supports the conclusion that the new species is sister to *S. ganluoensis*.

**Key words:** Hengduan mountains, phylogeny, rosette, species diversity, taxonomy

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## Introduction

Crassulaceae are a morphologically diverse and systematically complex group of angiosperms, comprising 35 genera and approximately 1,400 species (Berger 1930; Eggli 2003; Thiede and Eggli 2007; Messerschmid et al. 2020). Known for their heat resistance and rapid growth, members of the Crassulaceae family are highly adaptable and easy to cultivate. This adaptability makes them excellent for soil improvement and essential components in vertical gardens and green roofs (Zhu 2015). *Sinocrassula* A. Berger is a small genus within the family Crassulaceae, comprising approximately ten species distributed across various regions, including Bhutan, China, India, Nepal, Pakistan, Sikkim, and Vietnam (Wang et al. 2012, 2022; Fu and Ohba 2013; Averyanov et al. 2014). Despite the distinct characteristics of *Sinocrassula*, defining monophyletic groups within the genus has proven to be extremely challenging due to the frequent intergradation of morphological traits among taxa, as well as the extensive diversity in morphology and growth habits (Fu and Ohba 2013). Some species of *Sinocrassula* (e.g., *S. indica*) have been used as traditional medicine, or enjoyed as a vegetable and infused in herbal teas (Zhao et al. 2004; Xie and Yoshikawa 2012). In recent years, an increasing number of species of *Sinocrassula* have been discovered in Asia (e.g., *S. jiaozishanensis* Chao Chen, J. Guan Wang & Z.R. He, *S. vietnamensis* Aver. & V.V. Byalt) (Averyanov et al.

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2014; Wang et al. 2022). The discovery of new species may provide more medicinal resources and increase the species diversity of *Sinocrassula*.

In July 2023, we conducted two field surveys in Sichuan Province, where we identified two populations of *Sinocrassula* in Shimian and Hanyuan counties. After carefully culturing the plants and performing a morphological study, we discovered that these populations are distinctly different from all other species within the genus. Additionally, we conducted a phylogenetic analysis, which indicated that these populations form a well-supported clade that is sister to *S. ganluoensis* (Li et al. 2024). We propose those populations as a new species of *Sinocrassula*.

## Materials and methods

### Morphological studies

The living plants of the new species were cultivated in the greenhouse at Yunnan University. Plant morphologies were photographed using a Nikon SMZ1270 stereo microscope (Nikon). Morphological comparisons among the new species and its related species were from field observations, herbarium investigations, and the literature (e.g., Fu and Ohba 2013; Averyanov et al. 2014; Wang et al. 2022). Voucher specimens of the new species have been deposited in the Herbarium of Yunnan University (YUKU; herbarium acronyms follow Index Herbarium by Thiers 2024).

### Taxonomic sampling

In order to clarify the phylogenetic position of the new species, two samples of the new species and its putative closely related taxa of *Sinocrassula* from China were included in the phylogenetic analysis. In total, 22 accessions representing 12 species of *Sinocrassula* were used for the phylogenetic analysis. Based on previous phylogenetic studies (Messerschmid et al. 2020; Wang et al. 2022), *Kungia aliciae* (Raym.–Hamet) K. T. Fu was selected as the outgroup.

### DNA extraction, amplification, and sequencing

Total genomic DNA was extracted from silica-dried material using the TIANGEN plant genomic DNA extraction kit (TIANGEN Biotech., Beijing, China) following the manufacturers' protocols. Four chloroplast DNA markers (*psb*A-*trn*H, *trn*L-F, *rbc*L, *mat*K)] and one nuclear marker (ITS) were amplified and sequenced using previous primers and protocols (Wang et al. 2022).

### Phylogenetic analyses

Sequences from GenBank and the newly generated data (Table 1) were aligned using MAFFT v7.450 (Katoh and Standley 2013), followed by manual refinement in BioEdit (Hall 1999). Single alignments were concatenated to a matrix using the 'Concatenate Sequence' plugin in PhyloSuite v1.2.2 (Zhang et al. 2020). ModelFinder (Kalyaanamoorthy et al. 2017) was used

**Table 1.** Species information and corresponding GenBank accession numbers of *Sinocrassula* and close relative genus used in this study.

| Species | Voucher | Location | *trn*L-*trn*F | *psb*A-*trn*H | *rbc*L | ITS | *mat*K | Reference |
|---|---|---|---|---|---|---|---|---|
| *Kungia aliciae* | Mayuzumi CH00061 (TI) | Sichuan, China | AB480632 | – | – | AB480591 | – | Mayuzumi and Ohba 2009 |
| *Sinocrassula ambigua* | Chen et al. YUS12973 (YUKU) | Deqin, Yunnan, China | PQ629032 | PQ629054 | PQ629039 | PQ611189 | PQ629047 | Xu et al. 2025 |
| *S. ambigua* | Chen et al. YUS12672 (YUKU) | Deqin, Yunnan, China | PQ629030 | PQ629055 | PQ629038 | PQ611188 | PQ629046 | Xu et al. 2025 |
| *S. ambigua* | Chen et al. YUS6698 (YUKU) | Deqin, Yunnan, China | PQ629035 | PQ629059 | PQ629040 | PQ611190 | PQ629048 | Xu et al. 2025 |
| *S. densirosulata* | Chang XC19075 (SZ) | China | MW206800 | MW206800 | MW206800 | – | MW206800 | Unknown |
| *S. diversifolia* | Chen et al. YUS9407 (YUKU) | Gongshan, Yunnan, China | **PQ629070** | **PQ629074** | **PQ629066** | **PQ623396** | **PQ629062** | This study |
| *S. diversifolia* | Chen et al. YUS9477 (YUKU) | Gongshan, Yunnan, China | **PQ629071** | **PQ629075** | **PQ629067** | **PQ623397** | **PQ629063** | This study |
| *S. ganluoensis* | Zhao et al. YUS6699 (YUKU) | Ganluo, Sichuan, China | PQ505691 | PQ505693 | PQ505695 | PQ496498 | PQ505697 | Li et al. 2024 |
| *S. ganluoensis* | Zhao et al. YUS13920 (YUKU) | Kangding, Sichuan, China | PQ505692 | PQ505694 | PQ505696 | PQ496499 | PQ505698 | Li et al. 2024 |
| *S. holotricha* | Zhao et al. YUS13475 (YUKU) | Jiulong, Sichuan, China | PQ629034 | PQ629056 | PQ629042 | PQ611192 | PQ629050 | Xu et al. 2025 |
| *S. holotricha* | Zhao et al. YUS12867 (YUKU) | Yuexi, Sichuan, China | PQ629031 | PQ629057 | PQ629043 | PQ611193 | PQ629051 | Xu et al. 2025 |
| *S. indica* | zjq20160061 (SANU) | Xizang, China | MN794334 | MN794334 | MN794334 | – | MN794334 | Zhao et al. 2020 |
| *S. indica* var. *obtusifolia* | Wang et al. YUS13936 (YUKU) | Deqin, Yunnan, China | PQ505699 | PQ505701 | PQ505703 | PQ496500 | PQ505705 | Li et al. 2024 |
| *S. indica* var. *obtusifolia* | Wang et al. YUS13959 (YUKU) | Deqin, Yunnan, China | PQ505700 | PQ505702 | PQ505704 | PQ496501 | PQ505706 | Li et al. 2024 |
| *S. jiaozishanensis* | Chen et al. JZS001 (YUKU) | Luquan, Yunnan, China | MZ343264 | MZ343262 | MZ343263 | – | MZ343261 | Wang et al. 2022 |
| *S. jiaozishanensis* | Chen et al. JZS002 (YUKU) | Luquan, Yunnan, China | MZ343269 | MZ343267 | MZ343268 | – | MZ343266 | Wang et al. 2022 |
| *S. jiaozishanensis* | Chen et al. YUS5900 (YUKU) | Luquan, Yunnan, China | PQ629036 | PQ629058 | PQ629044 | PQ611194 | PQ629052 | Xu et al. 2025 |
| *S. obliquifolia* | Zhao et al. YUS9064 (YUKU) | Hanyuan, Sichuan, China | **PQ629072** | **PQ629076** | **PQ629068** | **PQ623398** | **PQ629064** | This study |
| *S. obliquifolia* | Huang et al. YUS9366 (YUKU) | Shimian, Sichuan, China | **PQ629073** | **PQ629077** | **PQ629069** | **PQ623399** | **PQ629065** | This study |
| *S. yunnanensis* | Chen s.n. (HIB) | Yunnan, China | – | – | – | KC988288 | KC988295 | Chen et al. 2014 |
| *S. yunnanensis* | Mayuzumi C00115 (TI) | Yunnan, China | AB480669 | – | – | AB088582 | – | Mayuzumi and Ohba 2004 |
| *S. yunnanensis* | Chen et al. YUS6697 (YUKU) | Heqing, Yunnan, China | PQ629037 | PQ629060 | PQ629045 | PQ611195 | PQ629053 | Xu et al. 2025 |
| *S. yunnanensis* | Chen et al. YUS13776 (YUKU) | Heqing, Yunnan, China | PQ629033 | PQ629061 | PQ629041 | PQ611191 | PQ629049 | Xu et al. 2025 |

Note. Accession numbers in bold indicates newly generated data for this study.

to select the best-fitting likelihood model for Maximum Likelihood (ML) and Bayesian Inference (BI) using the bias-corrected Akaike information criterion (AICc). Maximum likelihood bootstrapping was performed with 5,000 rapid bootstrap (BS) analyses followed by a search for the best-scoring tree in a single run through IQ-tree v2.1.2 (Nguyen et al. 2015). Bayesian inference was conducted for the combined dataset using MrBayes v3.1.2 (Huelsenbeck and Ronquist 2001) with two runs of four Markov chain Monte Carlo (MCMC) chains, each beginning with a random tree and sampling every 1000 generations for 20,000,000 generations. Finally, the concatenated trees were generated and visualized with their Maximum-Likelihood Bootstrap Support values (ML-BS) and Bayesian Inference Posterior Probability (BI-PP) in Figtree v1.4.3 (Rambaut 2017).

## Results and discussion

A total of 23 accessions representing 12 species from the genus *Sinocrassula*, along with one outgroup (*Kungia aliciae*), were included in the phylogenetic analysis. The concatenated dataset was 6,433 bp in length and GTR + F + I + G4 was selected as the best evolutionary model of nucleotide substitutions. The inferred phylogenetic trees from the ML and BI analyses revealed identical topologies. Two samples of the new species formed a highly supported clade (ML-BS = 99; BI-PP = 1.00, Fig. 1), and were found to be sister to *Sinocrassula ganluoensis* (ML-BS = 100, BI-PP = 1.00, Fig. 1). Then, they together are sister to *S. diversifolia* (ML-BS = 74, BI-PP = 0.94, Fig. 1). Although the new species is closely related to *S. ganluoensis* and *S. diversifolia*, it can be easily distinguished from these two species by its asymmetrical leaves and triangular petals, which are white at the base with dense purple-red stripes and spots on the both surfaces upward. Morphologically, the new species is most similar to *S. indica* (Table 2). However, the phylogenetic analysis showed that they have a distant relationship (Fig. 1).

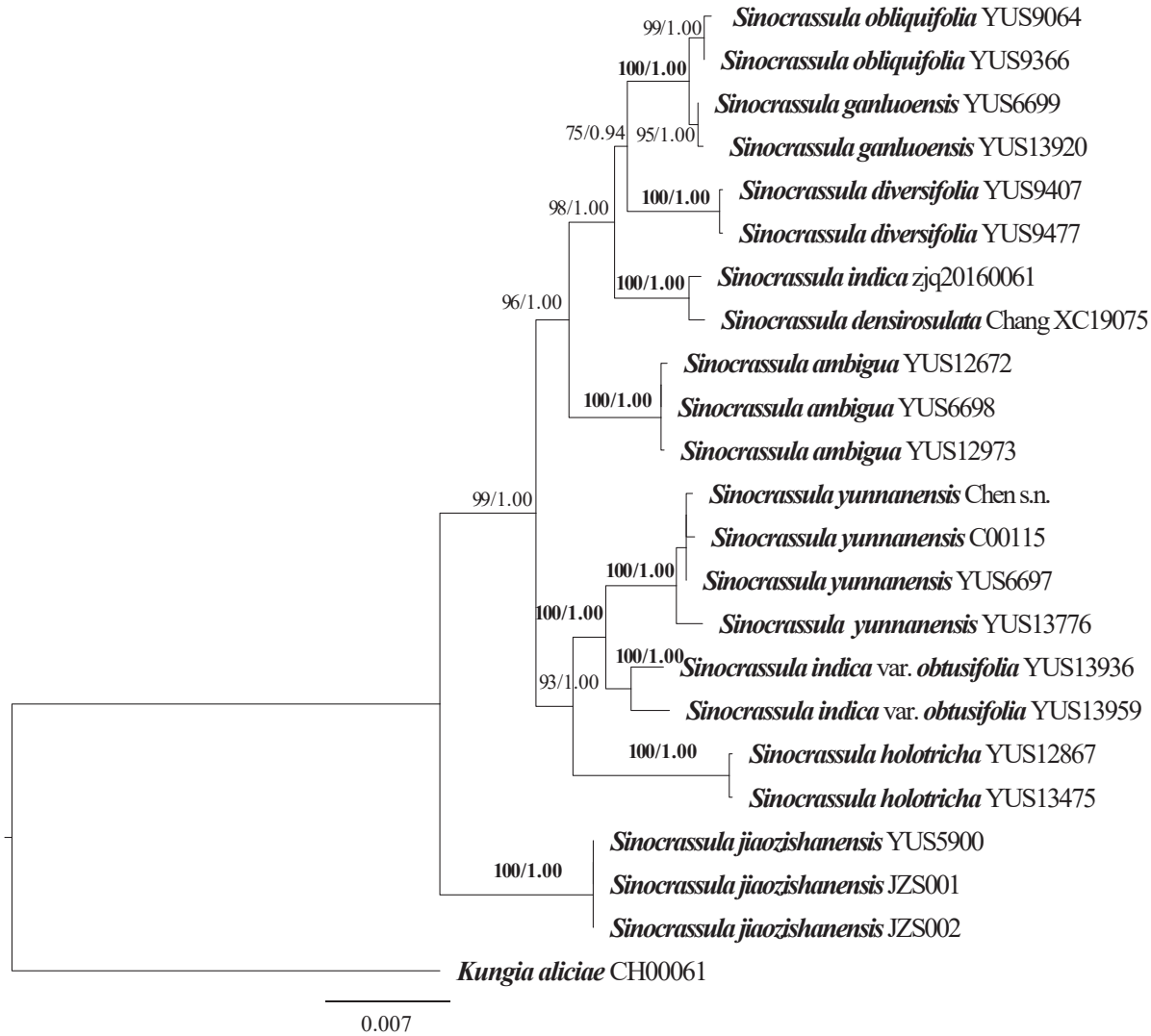



**Figure 1.** The maximum likelihood phylogeny of *Sinocrassula* and its allies based on four chloroplast markers (*psb*A-*trn*H, *trn*L-F, *rbc*L, and *mat*K) and one nuclear marker (ITS). Values associated with branches are Maximum Likelihood Bootstrap Support (ML-BS) and Bayesian Inference Posterior Probability (BI-PP). Bold indicated it received full ML-BS and BI-PP support.

**Table 2.** Morphological comparison of *Sinocrassula diversifolia*, *S. ganluoensis*, *S. indica*, and *S. obliquifolia*.

| Character | *S. diversifolia* | *S. ganluoensis* | *S. indica* | *S. obliquifolia* |
|---|---|---|---|---|
| Life cycle | — | Perennial | Biennial | Biennial |
| Plant surface | Glabrous, many parts purple-spotted | Glabrous | Glabrous | Glabrous, many parts purple-spotted |
| Basal leaves | Rosette lax, many parts brown-spotted, broadly obovate | Rosette compact, orbicular-lanceolate | Rosette, spatulate-oblong | Rosette, asymmetrical leaves ovoid to lanceolate |
| Stem leaves | Alternate, dimorphic | Alternate, Linear, lanceolate | Alternate, broadly oblanceolate, subobovate, ovate-orbicula | Alternate alternate, lanceolate, many parts with purple spots |
| Sepals | Triangular-lanceolate | Ovate-lanceolate | Broadly triangular | Broadly triangular |
| Bracts | Resembling distal stem leaves but smaller | Lanceolate | Resembling distal stem leaves but smaller | Lanceolate |
| Inflorescences | Corymbiform | Corymbiform | Paniculate, often corymbiform | Corymbiform |
| Length of flowering stems | — | 5–11.5 cm | 5–60 cm or shorter | 10–18 cm |
| Petals | Lanceolate, yellow, spotted with purple | Broad triangular, yellowish, deeply purplish red upward | Lanceolate to ovate, red, reddish, yellow or greenish yellow | Triangular, base white, spotted with purple upward |
| Nectar scales | Broadly quadrate | Quadrate | Quadrate, apex emarginate | Rectangler |
| Nectar scales size | 0.3–0.5 × 0.5–0.7 mm | 0.5 × 0.9 mm | — | 0.3–0.5 × 0.2–0.3 mm |
| Length of styles | 0.5–1.0 mm | 0.6–1 mm | Less than 1.0 mm | 1.0–1.5 mm |

The new species exhibits some typical characteristics of *Sinocrassula* including compact rosette, stem leaves alternate and lanceolate, bracts resembling distal stem leaves but smaller, flowers 5-merous, broadly triangular sepals, and ovoid carpels (Fu and Ohba 2013). A comparison of morphological characters among the new species and its morphologically similar species is shown in Table 2. The new species can easily distinguished from other species by its unique combination of asymmetrical leaves, rectangler nectar scales, and triangular petals which are white at the base and gradually transition to purple toward the tips (Fig. 2).

## Taxonomic treatment

***Sinocrassula obliquifolia* Jing Zhao, J.Guan Wang & X.M.Zhou, sp. nov.**
urn:lsid:ipni.org:names:77360183-1
Figs 2, 3

**Type.** China • Sichuan: Hanyuan County, Yaan City, elev. ca. 837 m, 29.333262°N, 102.571721°E, on the granite crevices, 6 July 2023, *Jing Zhao et al. YUS9064* (holotype YUKU!; isotype YUKU!).

**Diagnosis.** *Sinocrassula obliquifolia* is similar to *S. indica* in having rosette, ovoid carpels, and broadly triangular sepals. However, this new species has shorter flowering stem (10–18 cm) (vs. 5–60 cm in *S. indica*), lanceolate stem leaves (vs. oblanceolate to ovate-orbicular stem leaves in *S. indica*), triangular petals (vs. lanceolate to ovate petals in *S. indica*), petals with a white base adorned with dense purple-red stripes and spots on the surfaces upward (vs. red, reddish, yellow, or greenish-yellow in *S. indica*) and rectangle nectar scales (vs. quadrate in *S. indica*). *S. obliquifolia* is also similar to *S. diversifolia* in having corymbiform inflorescences, petals, and stamens with purple spots. However, *S. obliquifolia* has a well-defined rosette (vs. less defined rosette in *S. diversifolia*), monomorphic stem leaves (vs. dimorphic stem leaves in *S. diversifolia*), triangular petals with dense purple-red stripes and spots on the surfaces upward

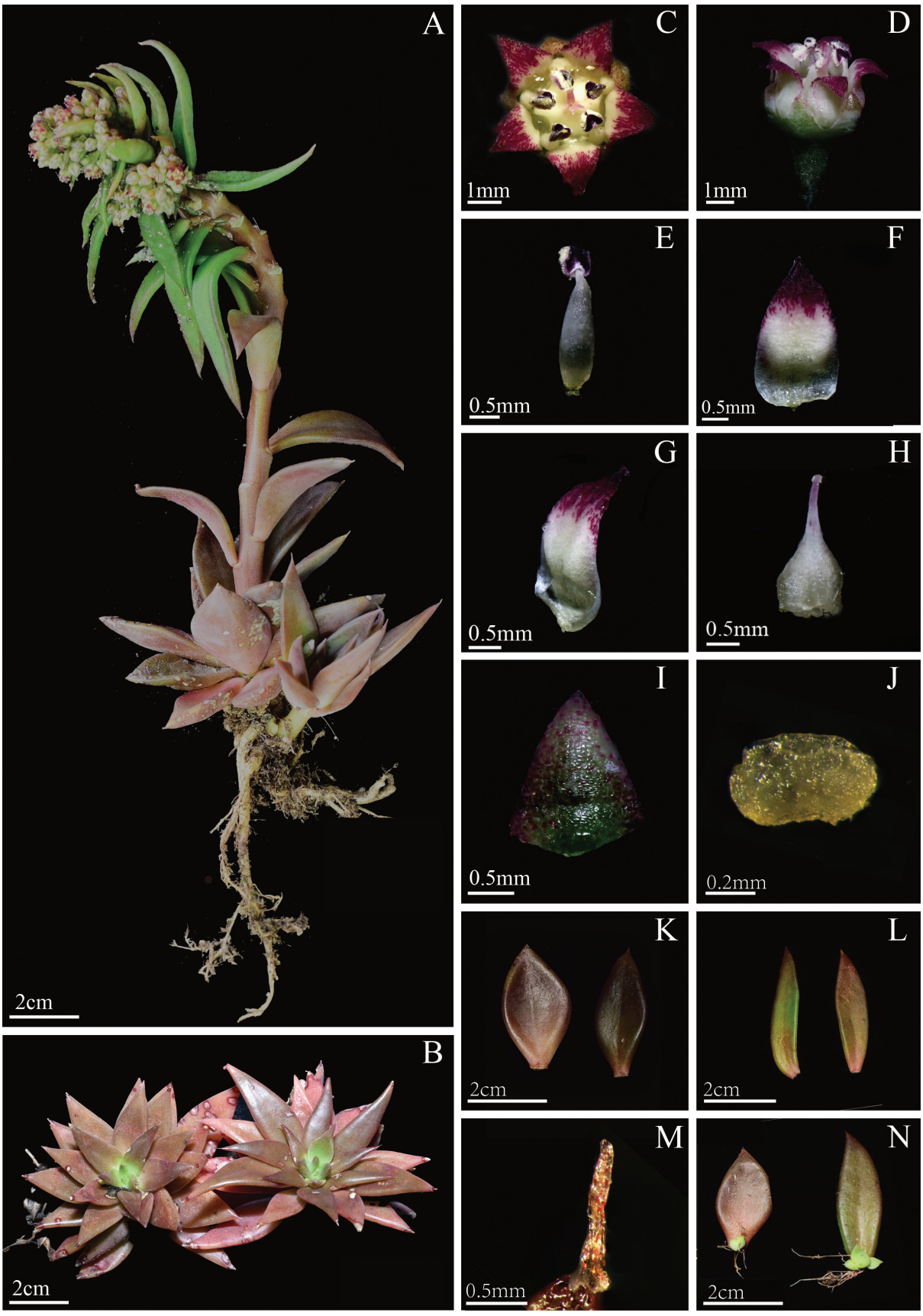



**Figure 2.** *Sinocrassula obliquifolia* **A, B** habit **C, D** flowers **E** stamen **F, G** petals **H** carpel **I** sepal **J** nectar scale **K** basal leaves **L** stem leaves **M** gland of basal leaf **N** leaves that abscise and bud during the flowering period, left: basal leaf, right: stem leaf.

(vs. lanceolate petals that are yellow with purple spots in *S. diversifolia*) and rectangle nectar scales (vs. broadly quadrate in *S. diversifolia*).

**Description.** Perennial herbs, terrestrial or lithophytic, 5.0–20.0 cm tall, rosette 5.0–8.0 × 6.0–8.0 cm. Roots fibrous. Basal leaves rosette, spirally arranged, asymmetrically ovoid to lanceolate, apex with glands, 2.0–3.0 × 1.0–2.0 cm. Flowering stems terminal, 10.0–18.0 cm, glabrous with purple spots. Stem leaves alternate, lanceolate, many parts with purple spots. Bract resembling distal stem leaves but smaller, lanceolate, 3.0–3.5 × 0.5–1.0 cm. Inflorescences corymbiform, ca. 2.0–3.0 cm in diameter. Flowers small, ca. 3–6 mm in diameter. Sepals broadly triangular, purple with red spots, 1.5–2.0 × 0.5–1.2 mm. Petals triangular, base white, with dense purple-red stripes and spots on the surfaces upward, 2.0–4.0 × 1.0–2.0 mm. Stamens ca. 2–3 mm, white, anthers oblong-cordate, ca. 0.5 mm, pollen yellow. Nectar scales broadly

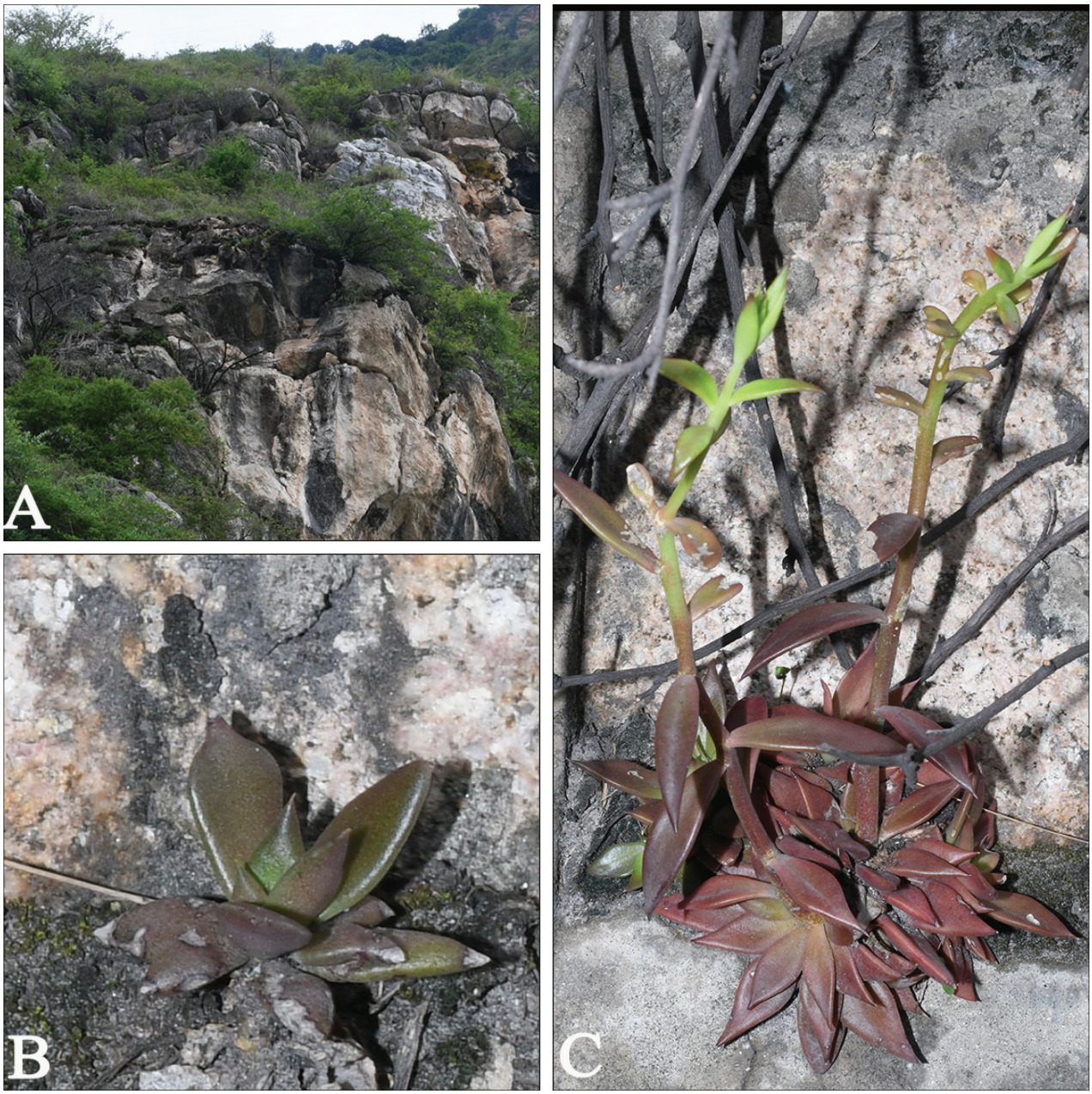



**Figure 3.** *Sinocrassula obliquifolia* **A** habitat **B, C** habit.

rectangular, ca. 0.3–0.5 × 0.2–0.3 mm. Carpels 5, ovoid, clockwise rotation, 1.0–2.0 × 0.5–1 mm, styles 1.0–1.5 mm. Flowering June–October which coincides with the rainy season and the shedding of the leaves and the emergence of new buds.

**Distribution and habitat.** *Sinocrassula obliquifolia* is currently known in central Sichuan Province, China. Two populations were found in granite crevices, as well as on dry stony or gravelly slopes at elevations ranging from 837 to 1140 m.

**Additional specimens examined (paratypes).** China • Sichuan: Shimian County, Yaan City, elev. ca. 1140 m, 29.258594°N, 102.371583°E, on the granite crevices, 12 May 2023, *Chuan-Jie Huang et al. YUS9366* (YUKU!).

**Etymology.** The epithet *obliquifolia* refers to the asymmetrical leaves of the basal leaves, a unique characteristic for this species within *Sinocrassula*. Its Chinese name is suggested as '斜叶石莲(xie ye shi lian)'.

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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: ZRH. Formal analysis: SLF. Resources: CJH, ML. Writing – original draft: RJL, JZ. Writing – review and editing: XMZ, JGW.

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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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