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A new member of genus *Rhodiola* (Crassulaceae) from Tibet (China)

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Summary. A new species, *Rhodiola chayaensis* G. Gao et X.-Y. Chen, from Chaya County, Tibet, China, is described and illustrated. It is morphologically most similar to *R. humilis* but differs in its densely many-flowered inflorescences (15–35 flowers per branch vs. 1–3 flowers), larger and obtuse leaves (8–15 × 0.9–2 mm, apex obtuse vs. ca. 6 × 1.5 mm, apex subacute), longer sepals (5–6 mm vs. ca. 3 mm), and white linear-elliptic petals (5.7–6 mm long vs. ovate, 2.5–3 mm long). Molecular phylogenetic analyses based on the nrITS region corroborate its recognition as a distinct species, with the three accessions forming a strongly supported, exclusive monophyletic clade (BS = 100 %, PP = 1.00) sister to *R. alterna* + *R. sacra*. The new species is a perennial herb known only from rocky slopes at 3900–4100 m in the Hengduan Mountains. A provisional IUCN assessment of Data Deficient (DD) is proposed.

Новый представитель рода *Rhodiola* (Crassulaceae) из Тибета (Китай)

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Ключевые слова: Гималаи и Хэндуаньшань, молекулярная филогения, охранный статус, эндемик, nrITS.

Аннотация. Описан и проиллюстрирован новый вид – *Rhodiola chayaensis* G. Gao et X.-Y. Chen из уезда Чая, Тибет, Китай. Морфологически он наиболее близок к *R. humilis*, но отличается густыми многоцветковыми соцветиями (15–35 цветков на ветвь против 1–3 цветков), более крупными и тупыми листьями (8–15 × 0,9–2 мм, верхушка тупая, против ок. 6 × 1,5 мм, верхушка слегка заострённая), более длинными чашелистиками (5–6 мм против ок. 3 мм) и белыми линейно-эллиптическими лепестками (5,7–6 мм длиной против яйцевидных, 2,5–3 мм). Молекулярный филогенетический анализ по региону ITS ядерной ДНК подтверждает его обособленность как самостоятельного вида: три образца формируют чётко поддерживанную монофилетическую кладу (BS = 100 %, PP = 1,00), сестринскую по отношению к *R. alterna* + *R. sacra*. Новый вид – многолетнее травянистое растение, известное только со скалистых склонов на высоте 3900–4100 м в горах Хэндуань. Предварительно предлагается оценка МСОП «Недостаточно данных» (Data Deficient, DD).

The Qinghai-Tibet Plateau and Hengduan Mountain, with special geographical location, complex terrain and highly rich floristic components, have become one of the hot spots for the origin and evolution of biodiversity (Myers et al., 2000).

In June to August 2023, during a series of expeditions to western Hengduan Mountain and the northern Lancang River basin for the project “The Second Tibetan Plateau Scientific Expedition and Research”, we collected some interesting specimens of Crassulaceae J. St.-Hil. (Fig. 1).

By consulting “Flora of China” (Fu, Ohba, 2001), “Flora of Tibet” (Wu, 1985), “Flora of British India” (Hooker, 1879), “Annotated Checklist of the Flowering Plants of Nepal” (Press et al., 2000), floras of adjacent countries and regions, and relevant taxonomic literature and specimens, it was found that these specimens is a new species, which we describe here as *Rhodiola chayaensis* G. Gao et X.-Y. Chen. The specimen of the new species was collected

from Chaya County in the southeast of Qamdo Prefecture, Tibet. The type specimens are stored in the herbarium of Yibin University (HYBU).

The vast majority of *Rhodiola* L. plants grow in alpine regions. There are approximately 90 species of *Rhodiola* worldwide; among them, 73 species are reported in China, and new species have been reported in recent years (Mayuzumi, Ohba, 2004). By 2023, 11 species of *Rhodiola* had been listed in the National Key Protected Wild Plants List of China, making the investigation and conservation of *Rhodiola* diversity essential. Based on an integrated consideration of molecular phylogenetic, morphological, and geographical evidence, we selected seven species as the taxa most closely related to and most easily confused with *R. chayaensis*, and prepared a key and Table 1 for them.

Morphological comparison

Through morphological comparison, it was found that *R. chayaensis* is similar to *R. humilis* (Hook. f. et Thomson) S. H. Fu. However, *R. chayaensis* differs from *R. humilis* in leaf shape and size (linear-oblongate, apex obtuse, 8–15 × 0.9–2 mm vs. linear-oblongate to linear-rhomboid, apex slightly acute, ca. 6 × 1.5 mm), sepal size (5–6 mm long vs. ca. 3 mm long), petal shape and size (white, linear-elliptic, 5.7–6 × 1.5 mm vs. ovate, 2.5–3 mm long), and the number of flowers per inflorescence (15–35-flowered, densely many-flowered vs. 1–3-flowered, often solitary).

In addition, *R. chayaensis* superficially resembles *R. amabilis* (H. Ohba) H. Ohba in overall habit but differs from it in sexual system (monoecious vs. perfect flowers), inflorescence flower number (15–35 per branch vs. 1–3(–5) per branch), sepal length (5–6 mm vs. 4.5–5.5 mm), and distribution (Tibet, China vs. Nepal, eastern Himalayas). These consistent differences support the recognition of *R. chayaensis* as a distinct species. The detailed



Fig. 1. Distribution map of *Rhodiola chayaensis* in China (red stars).

morphological distinctions among *R. chayaensis* and other similar species are summarized in Table 1.

Phylogenetic analyses

Total genomic DNA was extracted from silica-gel-dried leaves using a modified CTAB protocol (Doyle J. J., Doyle J. L., 1987). The nrITS region was

amplified with the primers ITS1 and ITS4 (White et al., 1990) and Sanger-sequenced by Sangon Biotech (Shanghai). Three new sequences were deposited in GenBank (PP133724, PP133725, PP150123). The new sequences were aligned with MUSCLE v5 (Edgar, 2004) against nrITS sequences of 22 additional *Rhodiola* species retrieved from GenBank,

Table 1. Morphological comparison of seven similar species of *Rhodiola*

Character	<i>R. chayaensis</i>	<i>R. humilis</i>	<i>R. amabilis</i>	<i>R. hobsonii</i>	<i>R. bupleuroides</i>	<i>R. smithii</i>	<i>R. saxicola</i>
Leaf blade	linear-ob lanceolate, apex obtuse	linear-ob lanceolate to linear-rhomboid, apex subacute	linear to linear-lanceolate, apex rounded or obtuse	ob lanceolate to oblong, apex subacute	narrowly to broadly elliptic, narrowly to broadly ovate, obovate, or suborbicular	linear to oblong, apex long caudate	linear-ob lanceolate or narrowly ob lanceolate
Leaf size (mm)	8–15 × 0.9–2	4–6 × 1–1.5	1.7–2.5 × 1.2–1.8	10–18 × 2–4.5	3–60(90) × 4–22(–45)	5.5–35 × 1.2–2.2	10–17 × 3.5–5.5
Sexual system	gynomo-noecious	monoecious	completely bisexual	unisexual	completely bisexual	completely bi-sexual	unisexual
Inflorescence	apical, 8–12-branched, 15–35-flowered	ca. 1–2-branched, 1–3-flowered	1–5-flowered	cyme, 3–10-branched	umbel-shaped	umbel-shaped	cyme with 4–9 flowers
Pedicels	sessile	sessile	0–3 mm	sessile	sessile	sessile	ca. 3 mm
Petal shape	linear-elliptic	ovate, apex attenuate	narrowly elliptic to elliptic	ovate	obovate or narrowly obovate	ovate-oblong	linear
Petal size (mm)	5.7–6 × 1.5	2.5–3 × ca. 1.5	5–7.5 × 1.7–2	8 × 3	1.5–4 × 0.5–1.6	3.7–6.2 × 1.4–2	ca. 3.7 × 1 (bisexual) / ca. 25 × 0.6 (pistillate)
Sepal shape	linear-diamond	ovate-oblong	triangular-lanceolate	triangular-to ovate-lanceolate	narrowly oblong, oblong-ovate, or narrowly triangular	lanceolate, apex emarginate	calyx obscure
Sepal size (mm)	5–6	ca. 3 × 1.5	4.5–5.5 × 0.9–1.3	5 × 2	1–5 × 0.3–1.2	2.5–4 × 1–1.8	ca. 1.5
Phenology	Aug.–Sep.	Sep.	Aug.–Sep.	Jul.	Aug.–Sep.	Jul.–Sep.	Jul.
Ecology	humid valleys, 3780 m a. s. l.	alpine meadows, 3900–4500 m a. s. l.	exposed moss-covered rocks, 2300–3900 m a. s. l.	forests, thickets, rock crevices, 2600–4100 m a. s. l.	thickets, rock crevices, 2400–5700 m a. s. l.	thickets, rock crevices, 4000–5000 m a. s. l.	rocks in dry river, 4100 m a. s. l.

with *Pseudosedum longidentatum* (AB088609.1) designated as the outgroup (25 accessions in total; Table 1). Phylogenetic relationships were inferred by maximum likelihood (ML) using IQ-TREE 2 (Minh et al., 2020) under the best-fit substitution model selected by ModelFinder (Kalyaanamoorthy et al., 2017) according to the Bayesian information criterion, with nodal support assessed by 1000 ultrafast bootstrap (UFBoot) replicates (Hoang et al., 2018); Bayesian inference (BI) was performed in MrBayes v3.2.7 (Ronquist et al., 2012) under a GTR + I + Γ model. The 676-bp alignment contained 126 variables and 61 parsimony-informative sites; the ML and BI topologies were identical, so the ML tree is shown (Fig. 5). The three *R. chayaensis* accessions formed a strongly supported, exclusive monophyletic clade (BS = 100 %, PP = 1.00), sister to *R. alterna* + *R. sacra* (BS = 98 %, PP = 1.00), and were not nested

within any other sampled species. Together with the morphological distinctions documented above (Table 1), this exclusive molecular lineage supports the recognition of *R. chayaensis* as a new species.

***Rhodiola chayaensis* G. Gao et X.-Y. Chen, sp. nov.** (Fig. 2–4).

Type: “[China] Tibet, Chaya County, Bari Township, N30°18, E97°56, 3780 m a. s. l. 21 VIII 2023. X.-Y. Chen et al.” (HYBU! [GAO-CY-TB026]; iso – HYBU! [GAO-XZ-002]).

Distribution in China: Tibet (Qamdo Prefecture: Chaya County, northern margin of the Hengduan Mountains). Endemic.

Diagnosis: *Rhodiola chayaensis* resembles *R. humilis* but differs by its more inflorescences, smaller leaves, linear oval leaves, blunt apex, longer sepals, and longer erect (Table 1).

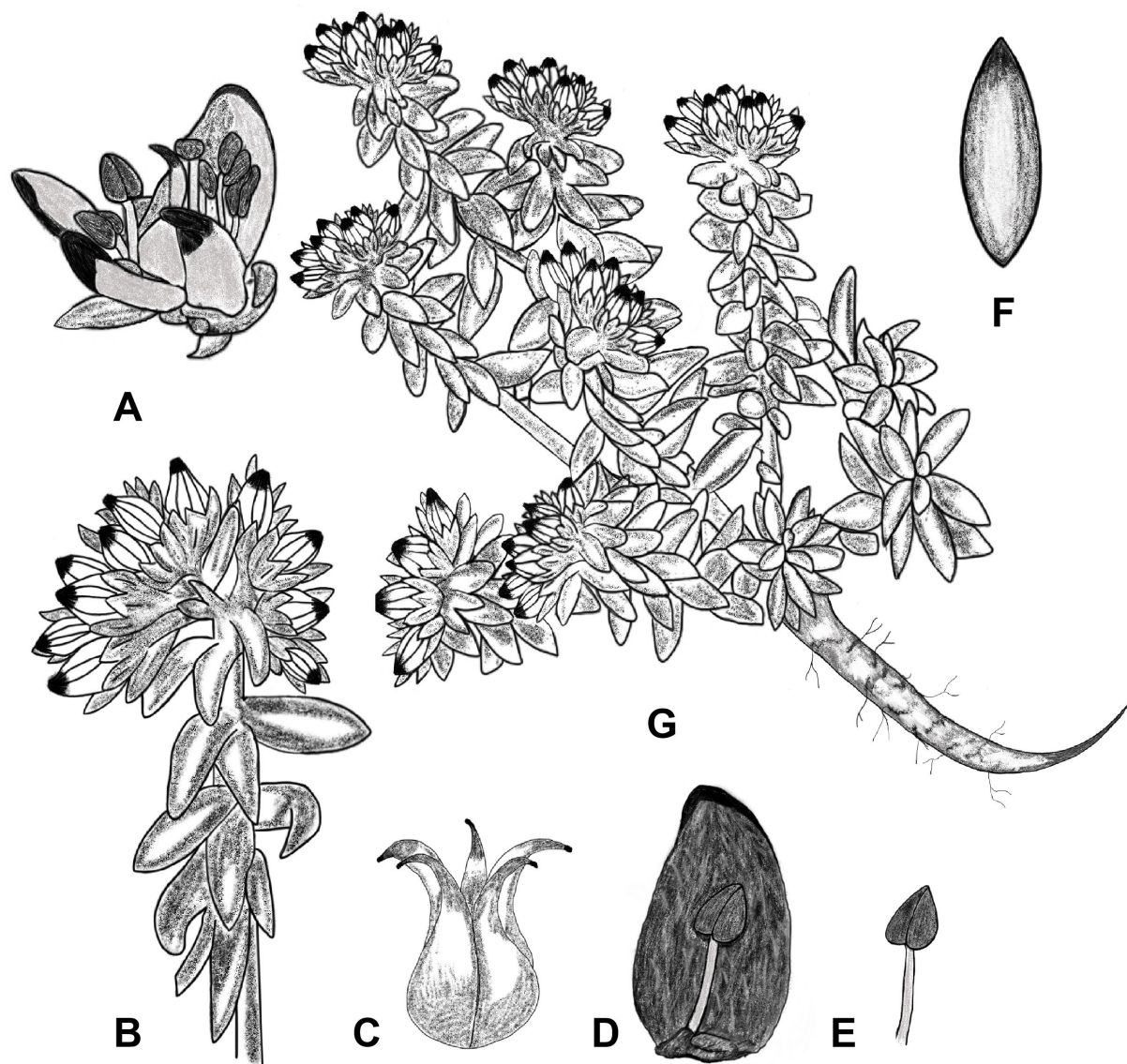


Fig. 2. *Rhodiola chayaensis* G. Gao et X.-Y. Chen, sp. nov.: A – flower; B – inflorescence; C – gynoecium with 5 carpels; D – petals and stamens; E – stamens; F – leaf; G – habit (Illustrated by Zhi-Min Jiang).

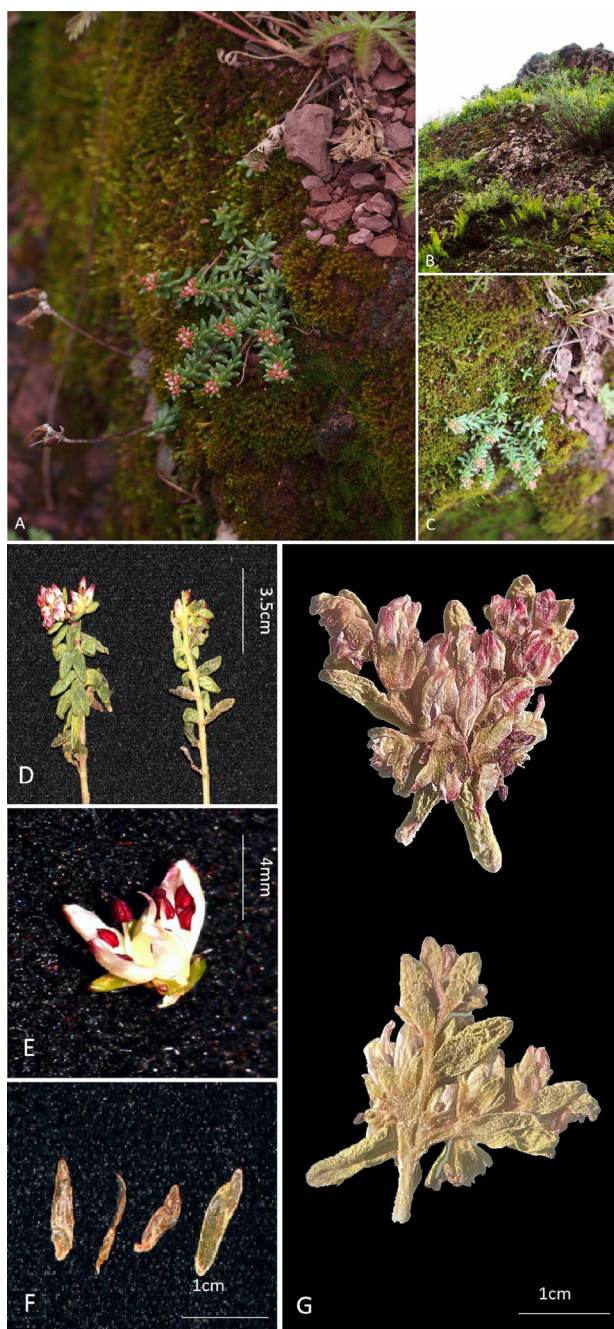


Fig. 3. *Rhodiola chayaensis* G. Gao et X.-Y. Chen, sp. nov.: A–C – habit; D – inflorescence; E – hermaphrodite flower; F – leaves; G – inflorescence.

Description. Perennial herb. Rhizome thick, erect or nearly erect. Flowering stems cespitose produce 8–12 branches from the tip of the rhizome; deciduous leaves, 7–11 cm long, glabrous, nearly smooth, pale green, about 10 mm thick. Leaves closely packed on the stem, sessile, thick herb, entire or nearly entire, 8–15 mm long, 0.9–2 mm wide, glabrous, no mastoid. Inflorescences terminal, densely many-flowered, 15–35-flowered, with bracteoles. Monoecious, petals 5, about 1 mm

thick in flowering, with pedicels, calyx 5–6 mm long, fleshy, green, hairless, tube about 0.5 mm long; lobes 4–5 mm long, 0.9–1.1 mm wide, linear diamond, apex obtusely rounded. Petals white, nearly suberect ascending during flowering, linear-elliptic, apex obtuse, 5.7–6 mm long, about 1.5 mm wide. Stamens in flowers shorter than petals, erect, white exogenous filaments about 2 mm long, 1.5–1.7 mm from the base, alternate flowers 3.5–4 mm long; anther ovate, about 0.5 mm long, no pollen. Nectar scale, wide oblong, 0.9–1 mm long, about 0.7 mm wide, yellow. Pistillate flower, 6–7 mm long, about 1 mm ovary, ventral from the base, erect, about 0.8 mm wide, tapering upward in the middle, stylus partially curved, stigma with mastoid.

Phenology: Flowers from July to August and fruits from August to September.

Etymology: The epithet refers to the Chinese name of Chaya County, the location of the type specimen collected.

Distribution and habitat: This species has been distributed in the Qamdo Chaya area on the northern margin of the Hengduan Mountains in Tibet (Fig. 1). It grows on rocky slopes at the elevation of 3900–4100 m a. s. l.

Conservation status: We proposed the IUCN conservation status of *R. chayaensis* as Data Deficient (IUCN, 2012) after conducted research.

Key to 7 species of *Rhodiola*

1. Flowers completely bisexual 2
- + Flowers unisexual or gynomonoecious 4
2. Leaf blade apex long-caudate; sepals lanceolate, apex acuminate
..... *R. smithii* (Raym.-Hamet) S. H. Fu
- + Leaf blade apex not long-caudate 3
3. Leaf blade narrowly to broadly elliptic, obovate, or suborbicular; sepals narrowly oblong, oblong-ovate, or narrowly triangular
R. bupleuroides (Wall. ex Hook. f. & Thomson) S. H. Fu
- + Leaf blade linear to linear-lanceolate, apex rounded or obtuse; sepals triangular-lanceolate
..... *R. amabilis*
4. Flowers gynomonoecious; leaf blade linear-oblancheolate, apex obtuse, 8–15 × 0.9–2 mm; inflorescence 15–35-flowered per branch
..... *R. chayaensis*
- + Flowers monoecious or unisexual 5
5. Leaf blade linear-oblancheolate to linear-rhombic, 4–6 × 1–1.5 mm; sepals ovate-oblong, ca. 3 × 1.5 mm; inflorescence 1–3-flowered per branch
..... *R. humilis*



Fig. 4. Holotype of *Rhodiola chayaensis* G. Gao et X.-Y. Chen, sp. nov. Digitized image of the holotype specimen labeled: X.-Y. Chen et al. GAO-CY-TB026 (Herbarium of Yibin University).

- + Leaf blade oblanceolate to oblong, or linear-oblanceolate to narrowly oblanceolate, 10–18 mm long 6
6. Leaf blade oblanceolate to oblong, 2–4.5 mm wide; sepals triangular to ovate-lanceolate, ca. 5×2 mm; inflorescence a cyme with 3–10 flowers
 *R. hobsonii* (Prain ex Raym.-Hamet) S. H. Fu
- + Leaf blade linear-oblanceolate to narrowly oblanceolate, 3–5.5 mm wide; pedicels ca. 3 mm long; calyx inconspicuous; inflorescence a cyme with 4–9 flowers
 *R. saxicola* H. Ohba, S. Akiyama et S. K. Wu

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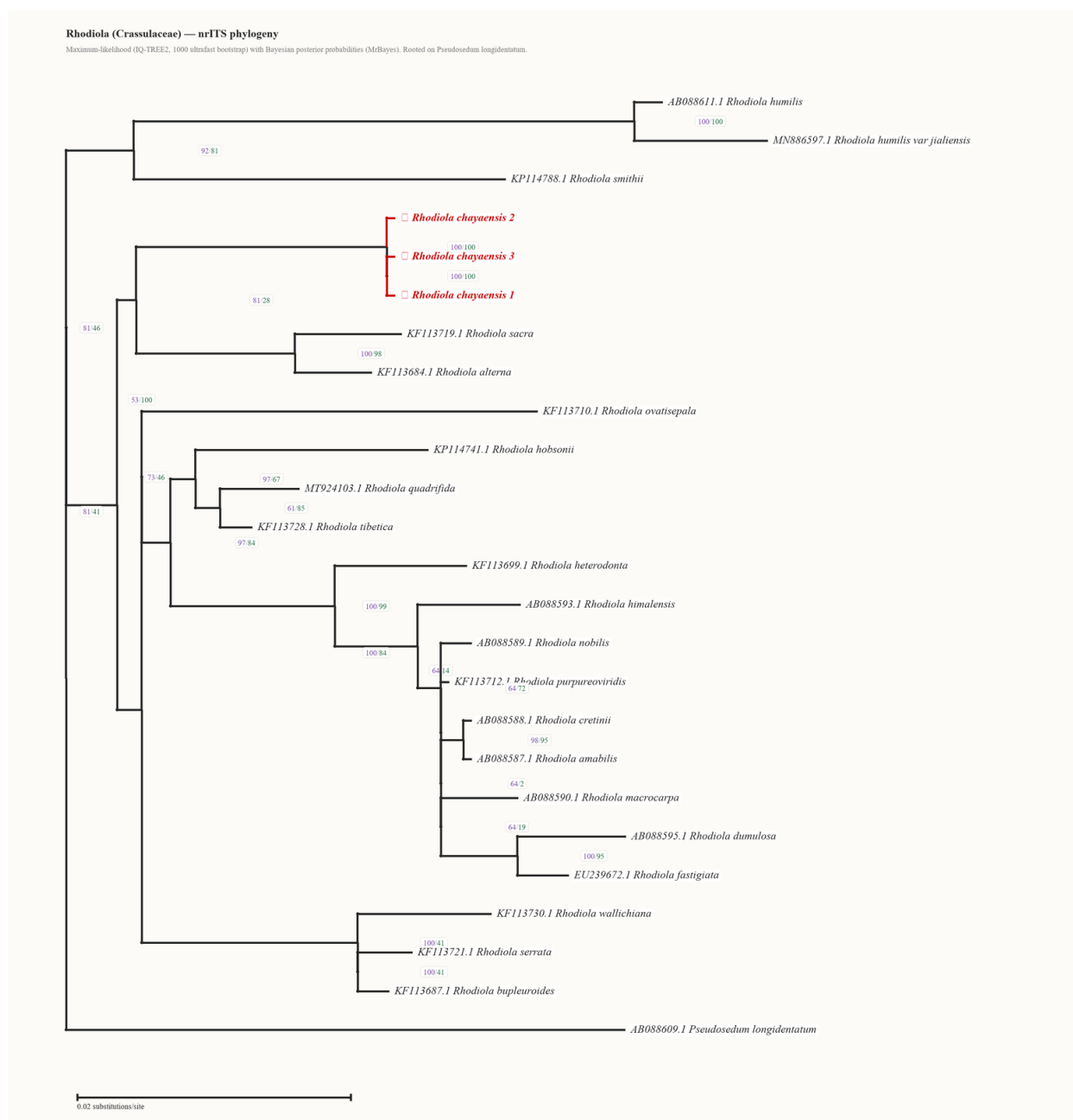


Fig. 5. Maximum-likelihood phylogenetic tree based on the nrITS sequences showing the position of *Rhodiola chayaensis*. Support values (BS / PP) are shown above the main branches. The new species name is boldfaced and marked with a red asterisk.

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