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Echeveria mendezii (Crassulaceae), a new species from southern Michoacán, Mexico

Echeveria mendezii (Crassulaceae), una especie nueva del sur de Michoacán, México

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Abstract:

Background and Aims: *Echeveria* (Crassulaceae) is an American genus of ca. 204 species. Approximately 164 occur in Mexico, of which about 96% are endemic to the country, making it the center of diversification and endemism of the genus. Bibliographic research and exploration in the municipality Arteaga, Michoacán, led to the discovery of a species of *Echeveria* that does not correspond to any of those previously described. The objectives of the article are to describe a species of *Echeveria* as new to science, to compare it with *E. sotoi*, the morphologically similar species, and to evaluate its conservation status.

Methods: Explorations were carried out in the regions where plants of the new species of *Echeveria* were located (Michoacán, municipality Arteaga), as well as in the type locality of *E. sotoi* (Michoacán, municipality Aquila), the morphologically most similar species. Morphological descriptions of the plants were prepared and specimens were herborized to deposit them in the herbaria IBUG, IEB, and MEXU. Morphometric analyses of leaves, bracts, cincinni and seeds were performed. Finally, the conservation status of the new species was assessed using the IUCN Red List Categories and Criteria.

Key results: *Echeveria mendezii* is proposed as a new species to science. It is similar to *E. sotoi*; qualitative and morphometric analyses reveal significant differences in leaf, cincinni, calyx segments and seeds between the two. *Echeveria mendezii* is endemic to the Balsas Basin Province in Michoacán and assessed as Critically Endangered (CR).

Conclusions: *Echeveria mendezii* belongs to the *Gibbiflorae* series. The species to which it most resembles is *E. sotoi*, where important discrepancies include the shape and color of the leaves, characteristics of the cincinni (total length, number of flowers, size of the peduncle and internodes), and the size of the seeds.

Key words: Arteaga, Critically Endangered species, endemic species, *Gibbiflorae*.

Resumen:

Antecedentes y Objetivos: *Echeveria* (Crassulaceae) es un género americano integrado por unas 204 especies. Aproximadamente 164 se encuentran en México, de las que alrededor de 96% son endémicas del país, lo que lo convierte en el centro de diversificación y endemismo del género. Por otro lado, investigación bibliográfica y exploraciones realizadas en el municipio Arteaga, Michoacán, condujeron al descubrimiento de una especie de *Echeveria* que no corresponde con ninguna de las descritas anteriormente. Los objetivos del artículo son describir una especie de *Echeveria* como nueva para la ciencia, compararla con *E. sotoi*, la especie morfológicamente más similar, y evaluar su estado de conservación.

Métodos: Se llevaron a cabo exploraciones en las regiones donde se localizaron plantas de la nueva especie de *Echeveria* (Michoacán, municipio Arteaga), así como en la localidad tipo de *Echeveria sotoi* (Michoacán, municipio Aquila), la especie morfológicamente más similar. Se elaboraron descripciones morfológicas de las plantas y se prepararon especímenes para depositarlos en los herbarios IBUG, IEB y MEXU. Se realizaron análisis morfométricos de hojas, brácteas, cincinos y semillas. Por último, se evaluó el estado de conservación de la nueva especie utilizando las categorías y criterios de la IUCN.

Resultados clave: Se propone *Echeveria mendezii* como nueva especie para la ciencia y se compara con *E. sotoi*. Análisis cualitativos y morfométricos revelan diferencias significativas en hojas, cincinos, segmentos del cáliz y semillas entre ambas. *Echeveria mendezii* es endémica de la provincia de la Cuencas del Balas, en Michoacán. Se le asigna el estatus en Peligro Crítico (CR).

Conclusiones: *Echeveria mendezii* pertenece a la serie *Gibbiflorae*. La especie con la que más se asemeja es *E. sotoi*, con la que presenta importantes discrepancias en cuanto a la forma y el color de las hojas; las características de los cincinos (longitud total, número de flores, tamaño del pedúnculo y de los entrenudos) y el tamaño de las semillas.

Palabras clave: Arteaga, especies endémicas, especies en Peligro Crítico, *Gibbiflorae*.

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Introduction

Echeveria DC. (Crassulaceae) is a genus composed of perennial to subshrubby herbaceous plants that are succulent, glabrous or pubescent, acaulescent, caulescent, or stoloniferous. Their leaves are arranged in compact or lax rosettes, either sessile or positioned at the apex of the stem. The inflorescence may be a spike, raceme, cincinnus, thyrses, or panicle. The flowers are pentamerous, with apocarpous capsules (Walther, 1972; Kimnach, 2003).

The genus comprises approximately 204 species (Pérez-Calix and Guadián-Marín, 2025), distributed from the southwestern United States of America to Central and South America (Thiede, 1995; Pérez-Calix and Franco, 2004). Of these, about 164 species (80%) occur in Mexico, and 158 (96%) are considered endemic to various regions of the country (Pérez-Calix and Guadián-Marín, 2025). Due to this diversity, Mexico is recognized as the center of diversification and endemism of the genus (Thiede, 1995; Pérez-Calix and Franco, 2004).

Given the morphological diversity within this genus, some authors have proposed subdividing it into series (Berger, 1930; Walther, 1972; Moran, 1974). However, phylogenetic evaluations (Carrillo-Reyes et al., 2009; Vázquez-Cotero et al., 2017; de la Cruz-López et al., 2019) indicated that most of these groups are artificial. In this context, one of the series suggested to be monophyletic is *Gibbiflorae* (Baker) Berger (Berger, 1930).

Gibbiflorae (sensu Kimnach, 2003) consists of medium-to large-sized plants, generally glabrous, acaulescent or caulescent. When present, the stem may be fragile or robust, short to quite tall, and sometimes stoloniferous at the base. Leaves are arranged in rosettes, or loosely at the apex of the stem, often narrowing toward the base into a pseudo-petiole. The inflorescence is a panicle or thyrses, with a commonly robust, bracteate peduncle, and an elongated rachis bearing three or more cincinni branches. Sepals are unequal. The corolla is medium to large, cylindrical-urceolate to campanulate, pentagonal, and colored red-pink, scarlet, crimson, yellow, or combinations of these, often somewhat glaucous-pruinose. Lobes have a blunt keel externally, and a prominent basal cavity internally. Nectaries are large, thick, and truncate, with pale

white to cream yellow coloration, or red. Styles range from cream or white-cream, to shades of red, purple, or nearly black.

Following the study of Pérez-Calix and Guadián-Marín (2025), the series *Gibbiflorae* included 38 species, to which two recently described ones should be added (Ortiz-Brunel et al., 2025; Reyes Santiago et al., 2025), leading to a total number of 40, distributed from northern Sinaloa, Mexico, to northern Guatemala. Of these, 39 are endemic to Mexico, mostly from highly restricted areas; 24 have been described in the 21st century.

In the state of Michoacán, the series is represented by *Echeveria coruana* I.García, D.Valentín & Costea, *E. fulgens* var. *fulgens* Lem., *E. fulgens* var. *obtusifolia* (Rose) Kimnach, *E. gibbiflora* DC., *E. michihuacana* L.E. Cruz-López, J.Reyes & Verg.-Silva, *E. pistioides* I.García, I.Torres & Costea, *E. purhepecha* I.García, *E. subrigida* Rose, and *E. sotoi* Rosales & Quirarte. The first seven occur in the Transmexican Volcanic Belt, inhabiting temperate forests (oak, montane cloud forest, and pine) or tropical deciduous forest, at elevations between 1700 and 2650 m, mainly on outcrops of extrusive igneous rocks (lava fields) in areas with very shallow soils. The last species grows in the Pacific Lowland physiographic province (Morrone et al., 2017), in xerophytic scrub on limestone outcrops, between 350 and 500 m elevation.

Except for the two varieties of *Echeveria fulgens*, as well as *E. gibbiflora* and *E. subrigida*, the remaining species are considered highly restricted endemics, known only from their type locality and, in some cases, nearby areas. Additionally, specimens of *E. grisea* E.Walther have been reported, but their identification is uncertain.

References have also been found to an *Echeveria* species that has not yet been assigned a scientific name. The earliest mention of this plant is by Uhl (2002), who reported collections made near Uruapan. A clearer reference is provided by Pilbeam (2008), documenting the finding of an *Echeveria* along the Arteaga - Las Juntas road, in the municipality Arteaga, Michoacán. A few years later, de la Cruz-López et al. (2019), in their study of phylogenetic relationships in *Echeveria*, included samples of a plant collected at km 263 of the Arteaga - Uruapan highway, referred to as JE-8624. In that publication, the plant was identified



as *Echeveria* aff. *gibbiflora*. Finally, Rosales-Martínez et al. (2024), in their description of *Echeveria sotoi*, noted that “another similar species is mentioned in Pilbeam (2008) under the name *Echeveria* “Juntas”; although this plant may represent an undescribed species, further studies are required to determine its true identity.”

Based on these references, a botanical exploration was conducted in the municipality Arteaga, Michoacán, with the intention of locating the plants. During this survey, four populations of *Echeveria* were discovered, where samples were collected for further identification. Although the specimens were identified as belonging to the *Gibbiflorae* series, they could not be assigned to any species previously described in the predominant literature (Britton and Rose, 1905; Walther, 1972; Meyrán and López-Chávez, 2003; Kimnach, 2003; Pilbeam, 2008; Pérez-Calix, 2008; Jimeno-Sevilla et al., 2019), nor to species described after those works (Reyes Santiago et al., 2019, 2025; de la Cruz-López et al., 2021; Rosales-Martínez et al., 2024; Vázquez-García et al., 2024; Pérez-Calix and Guadián-Marín, 2025; Ortiz-Brunel et al., 2025).

Traditionally, species delimitation in *Echeveria* has been based on morphological traits – presence or absence of indumentum, leaf characteristics, type of inflorescence, features of peduncle bracts, floral traits, among others, using qualitative and straightforward morphometric approaches, generating taxonomic uncertainty within the genus. Therefore, this study employed a statistical framework incorporating measurements of previously ignored structures, such as cincinnus length, number of flowers per cincinnus, and floral internode distances.

Accordingly, the objectives of this study are to 1) describe and illustrate the *Echeveria* inhabiting the municipality Arteaga, Michoacán, as a new species; 2) compare it with *Echeveria sotoi*; and 3) assess its conservation status.

Materials and Methods

Four botanical exploration trips, during the latter part of fall (November), and towards the end of winter (February), were conducted to observe plants in their natural habitat. These surveys targeted the localities where the

previously undescribed *Echeveria* was believed to inhabit (Michoacán, municipality Arteaga, along the Arteaga - Las Juntas road, Fig. 1), as well as the type locality of *Echeveria sotoi* (Michoacán, municipality Aquila, approximately 5 km northeast of Pichilinguillo, along the road to Santiaguillo, Fig. 1). The latter species was selected for comparison, considering it being the most morphologically similar. The distribution map (Fig. 1) was generated using QGIS v. 3.22 (QGIS Development Team, 2021).

In both populations, total plant height, stem length and thickness, total inflorescence length, peduncle length, basal diameter, and rosette diameter were recorded. Length measurements were taken in centimeters using a measuring tape, while rosette diameter was determined by measuring from the tip of one leaf to the tip of the opposite leaf. In the location of *E. mendezii* sp. nov., 34 plants were measured, and in that of *E. sotoi*, 8, without any established selection or sampling method.

At the same time, considering that the plants in this group are succulents and that the process of herbarium preparation alters the shape and size of their organs, live specimens were collected to carry out morphological descriptions, including characteristics of the rosette, leaves, inflorescence, flowers, fruit, and seed (Table 1).

Floral structures were observed and measured under a Leica M80 stereomicroscope (Heerbrugg, Switzerland). Subsequently, specimens were pressed and prepared for herbarium storage and deposited in the herbaria IBUG, IEB, and MEXU (acronyms according to Thiers, 2026).

Simultaneously, morphometric analyses were conducted independently for each character using PAST v. 4.04 (Hammer et al., 2001), including measurements of leaves (length, width at the widest part, base width, and base diameter), bracts of the panicle peduncle (length, width at the widest part, base width, and base diameter), cincinnus (total length, number of flowers, and flower internode length), and seeds (length, width). Normality was assessed using Shapiro-Wilk tests, parametric datum was analyzed using Student's t-tests for independent samples, and non-parametric data using Mann-Whitney U tests ($\alpha=0.05$). The samples included 27 leaves of *E. mendezii* sp. nov., and 22 of *E. sotoi*; 25 panicles of *E.*





Figure 1: Type localities of *Echeveria mendezii* Pérez-Calix & Ram.-Oviedo, sp. nov. (Arteaga, Michoacán, Mexico) and *E. sotoi* Rosales & Quirarte (Aquila, Michoacán, Mexico). Elaborated by S. M. Ramírez Oviedo.

mendezii sp. nov., and 23 of *E. sotoi*; 28 bracts from the panicle peduncle of *E. mendezii* sp. nov., and 8 of *E. sotoi*; and 7 seeds of *E. mendezii* sp. nov., and 5 of *E. sotoi*.

Finally, the conservation status of the new species was evaluated by estimating its area of occupancy (AOO) and extent of occurrence (EOO), using the GeoCAT tool (Bachman et al., 2011) and by applying the IUCN Red List Categories and Criteria (IUCN, 2012).

Regarding the conservation status assigned to the new species and that proposed for *Echeveria sotoi* (Rosales-Martínez et al., 2024), the geographic coordinates of the localities where these species occur are not reported in this paper.

Results

Statistical analyses

Student's t-tests for two independent samples (parametric), and Mann-Whitney U tests (non-parametric), revealed significant differences in 11 of the 13 quantitative traits between *Echeveria mendezii* Pérez-Calix & Ram.-Oviedo sp. nov. and *E. sotoi*. Meanwhile, only two traits of the peduncle bracts—width and base width—failed to delimit the species, as presented below.

Rosette leaves

Leaf size (differed significantly across all four traits (length, maximum width, base width, and base diameter;



Table 1: Morphological comparison, distribution, and habitat of *Echeveria mendezii* Pérez-Calix & Ram.-Oviedo, sp. nov. and *Echeveria sotoi* Rosales & Quirarte.

Character	<i>Echeveria mendezii</i> Pérez-Calix & Ram.-Oviedo	<i>Echeveria sotoi</i> Rosales & Quirarte
Plant		
Total length (cm)	(50-)70-152(-198)	84-136(170)
Stem		
Posture	erect, curved-ascending or rarely pendent	usually erect or, very rarely, curved or tilted
Length (cm)	(5)10-51(-73)	14-65
Base diameter (cm)	(1.5)2-3(-3.5)	1.8-2(-3)
Rosette		
Diameter (cm)	(25)30-63	(15)32-45(-50)
Leaf		
Form	narrowly elliptic-spatulate to elliptic-spatulate	oblanceolate to oblanceolate-obovate
Length (cm)	12.6-31	(8)17.5-25
Width (cm)	4.3-11	(3.)5-8(9.5)
Base width (cm)	1.1-2.4	1-1.8
Base diameter (cm)	0.9-2	0.7-1.5
Color	gray-violet to light gray-green above, gray-violet to gray-violet-pinkish beneath	light green to purplish-green or orangish-pink on both surfaces
Inflorescence		
Total length (cm)	60-90	(60-)70-101(140)
Number of cincinni	(7)10-18	(3-)6-14
Peduncle		
Length (cm)	30-74	46-71(100)
Base diameter (mm)	0.7-0.9	0.7-1.5(-2)
Base peduncle bracts		
Form	narrowly elliptical-spatulate	oblanceolate
Length (cm)	6.3-16.8	3-10.6(-15)
Width (mm)	1.5-5.4	2.6-3.7
Base width (cm)	0.7-1.2	0.8-1
Base diameter (cm)	0.4-1.2	0.4-0.7
Cincinni		
Total length (cm)	3.5-7.5(10)	9.5-16
Number of flowers	(3)6-9	(9)11-15
Peduncle length (cm)	1.3-1.6	1.5-3.3
Peduncle diameter (mm)	ca. 2	1-2
Internodes (length, mm)	(3)4-9(12)	11-16.0(-21)
Flower		
Pedicel, length (mm)	5.5-7.9(9.3)	4-6
Calyx lobule		
Shortest		
Form	narrowly triangular	triangular
Length (mm)	5.7-6.7	5.3-6
Base width (mm)	2.1-2.9	2.9-3.5



Table 1: Continuation.

Character	<i>Echeveria mendezii</i> Pérez-Calix & Ram.-Oviedo	<i>Echeveria sotoi</i> Rosales & Quirarte
Intermediate		
Form	narrowly triangular, narrowly oblong	triangular, oblong-triangular
Length (mm)	7.7-9.8	6.6-8.9
Base width (mm)	3-3.4	3.1-4.2
Largest		
Form	narrowly oblong	oblong-ovate
Length (mm)	10-12.1	8.5-9.2
Base width (mm)	3-3.8	4.2-4.5
Corolla		
Length (mm)	17.4-19.4	(12-)16.5-17.5(-19)
Color	externally salmon pink, orange in the overlapping area of the corolla lobes, pruinose	pink-salmon to reddish-pink
Androeceum		
Antisepalous stamens		
Total length (mm)	7.1-8.8	(9.8-)10.5-11.5
Antipetalous stamens		
Total length (mm)	5.9-6.6	(7.3-)8-8.8
Nectar scales		
Form	reniform	reniform
Length (mm)	0.7-1	(0.8)1-1.4
Width (mm)	2-2.9	(1.9)2-2.6
Diameter (mm)	ca. 1	(0.8)12
Color	cream-white	white
Gynoecium		
Length (mm)	11-12.6(13.6)	11-11.6(13.6)
Diameter (mm)	4.5-5	5-6(7.1)
Styles		
Length (mm)	(3)4.3-5.8	4.1-4.7
Color	dark cherry red	dark cherry red
Fruit		
Length (mm)	8-10.1	ca. 10
Width (mm)	1.8-2.4	ca. 2.1
Seed		
Form	ellipsoid or botuliform	pyriform
Length (mm)	(0.3)0.5-0.6	0.7-0.8
Width (mm)	ca. 0.2	0.3-0.4
Physiographic subprovince	Balsas Basin	Pacific Lowlands
Geological substrate	intrusive igneous granite-granodiorite rocks	limestone rocks
Altitude (m a.s.l.)	600-900	350-500
Vegetation community	tropical deciduous forest	thorn forest



E. mendezii sp. nov. > *E. sotoi*; all $p \leq 0.008$). Leaf length was longer in *E. mendezii* sp. nov. (23.0 ± 3.31 cm, $n=27$) than in *E. sotoi* (18.3 ± 2.18 cm, $n=22$; $t(47)=5.75$, $p<0.001$). Median maximum width also differed ($U=130.5$, Monte Carlo $p=0.0008$): *E. mendezii* sp. nov. (9.0 cm (6.2-10.0)) > *E. sotoi* (6.1 cm (5.4-7.3)). Similarly, base width ($t(47)=6.39$, $p<0.001$) and base diameter ($t(47)=2.75$, $p=0.008$) were greater in *E. mendezii* sp. nov. (1.80 ± 0.29 cm, 1.42 ± 0.25 cm) than in *E. sotoi* (1.31 ± 0.22 cm, 1.24 ± 0.21 cm) (Fig. 2). These traits thus provide clear quantitative delimitation between the taxa.

Peduncle bracts

Peduncle bracts exhibited significant differences in length and base diameter between *E. mendezii* sp. nov. and *E. sotoi*, but not in width or base width. No significant differences were documented for width ($t_{34}=0.88$, $p=0.38$) or base width ($t_{34}=0.19$, $p=0.85$). In contrast, length differed significantly ($t_{34}=3.37$, $p=0.002$) with *E. mendezii* sp. nov. (mean $\pm$ SD: 12.19 ± 3.28 cm, $n=28$) exceeding *E. sotoi* (10.64 ± 1.63 cm, $n=8$). Likewise, median base diameter of the foliar bracts differed significantly

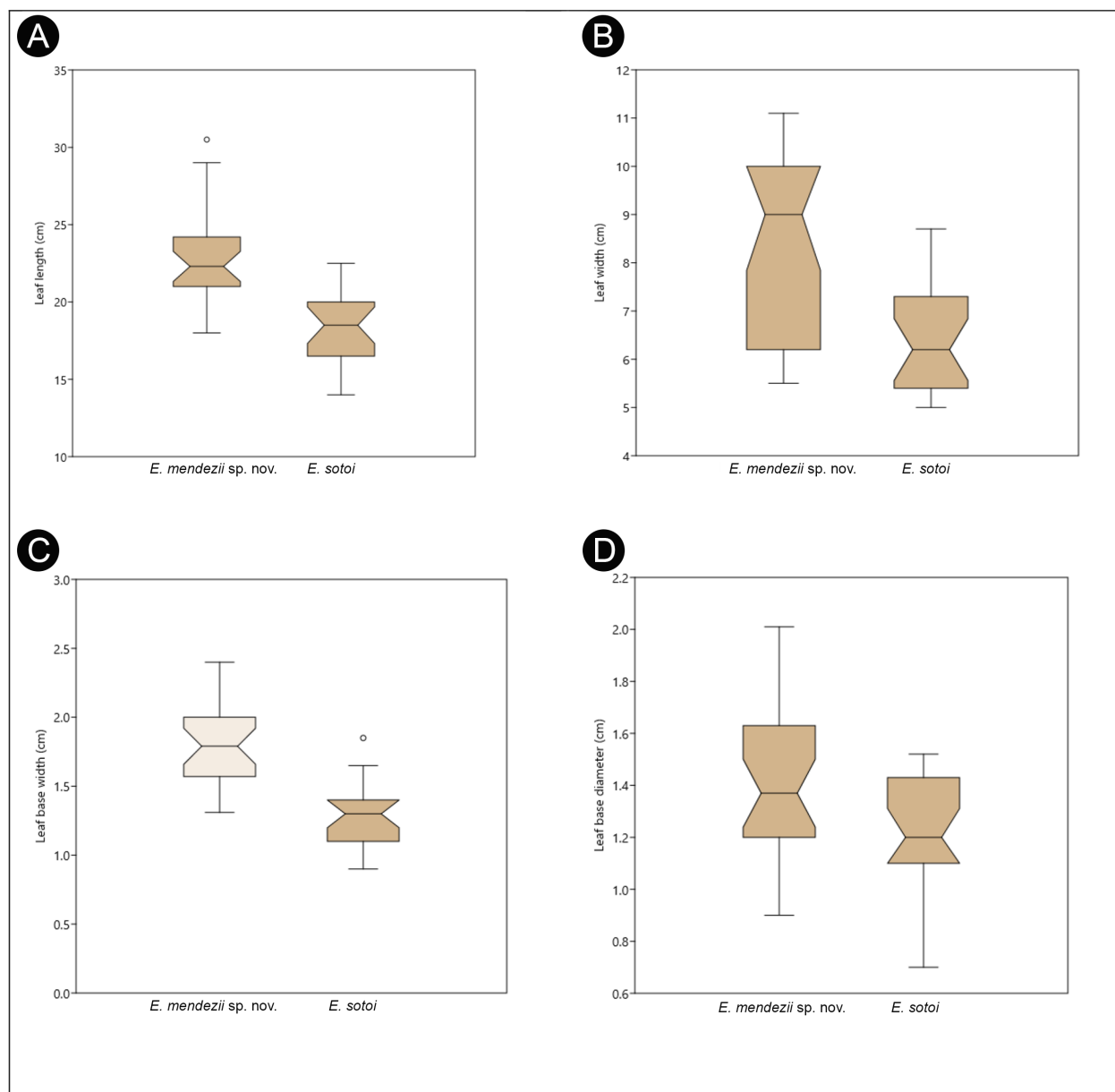


Figure 2: Variables of the leaf rosette of *Echeveria mendezii* Pérez-Calix & Ram.-Oviedo, sp. nov. and *E. sotoi* Rosales & Quirarte. A. length of the rosette leaf (cm); B. width of the rosette leaf (cm); C. width of the base of the rosette leaf (cm); D. diameter of the base of the rosette leaf (cm).

($U=58.5$, Monte Carlo $p=0.04$): *E. mendezii* sp. nov. (0.73 cm (Interquartile Range (IQR) IQR: 0.61-1.04)) > *E. sotoi* (0.60 cm (IQR: 0.58-0.65)) (Fig. 3).

Cincinni

The total length of the cincinnal and their flower counts revealed clear morphological separation between *E. mendezii* sp. nov. ($n=25$) and *E. sotoi* ($n=23$), as confirmed by Mann-Whitney U tests. Cincinni length showed highly significant differences in medians ($U=0$, Monte

Carlo $p=0.0001$): *E. mendezii* sp. nov. averaged 6.4 cm (IQR: 5.7-7.3 cm), while *E. sotoi* measured 13 cm (IQR: 13-15 cm). Similarly, median flower number per cincinni differed markedly ($U=15$, Monte Carlo $p=0.0001$): 7 flowers (IQR: 7-8) in *E. mendezii* sp. nov. versus 12 flowers (IQR: 10-13) in *E. sotoi*. Overall, *E. sotoi* cincinni were consistent in being approximately twofold longer ($U=0-15$ across metrics, Monte Carlo $p=0.0001$), providing robust inflorescence-based delimitation between these taxa (Fig. 4).

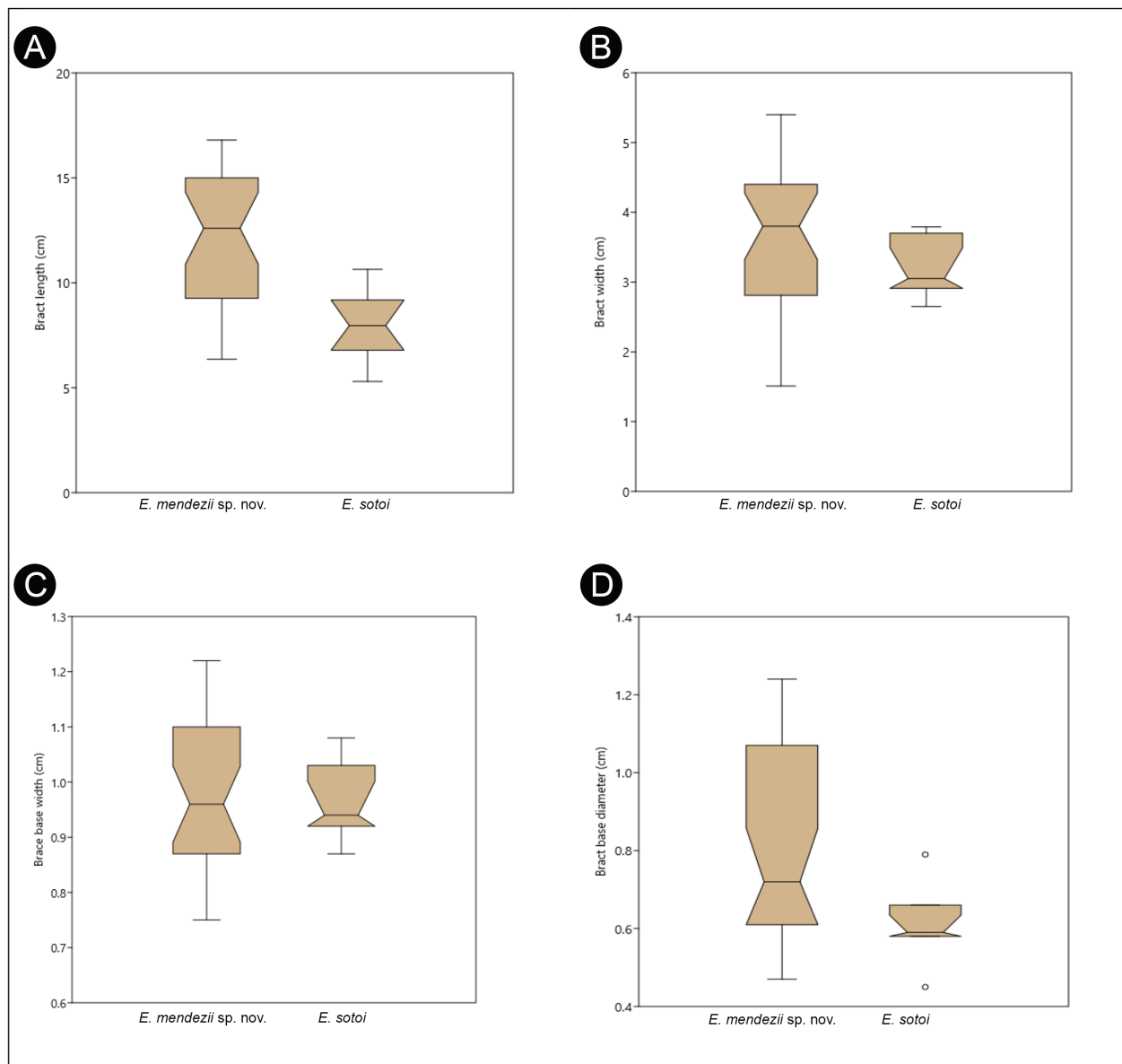


Figure 3: Peduncle bract variables *Echeveria mendezii* Pérez-Calix & Ram.-Oviedo, sp. nov. and *E. sotoi* Rosales & Quirarte. A. length of the leaf bract (cm); B. width of the leaf bract (cm); C. width of the base of the leaf bract (cm); D. diameter of the base of the leaf bract (cm).



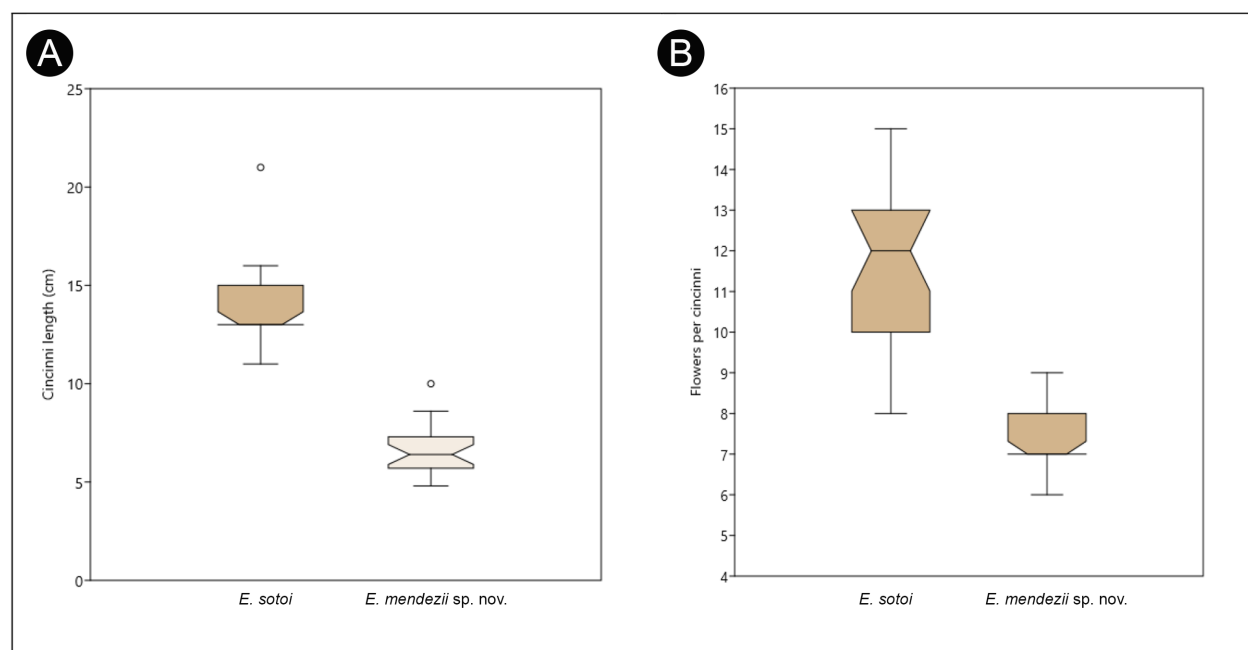


Figure 4: Cincinni variables *Echeveria mendezii* Pérez-Calix & Ram.-Oviedo, sp. nov. and *E. sotoi* Rosales & Quirarte. A. length of the cincinni inflorescence (cm); B. flowers per cincinni.

Internode length of the cincinni

The internode length of the cincinni was measured across the five basal segments, sequentially, where *E. mendezii* sp. nov. (n=25) and *E. sotoi* (n=23) exhibited consistent separation using either t-tests (parametric) or Mann-Whitney U tests (non-parametric) at all five positions. The mean internode length between the first and second flower differed significantly ($t=13.723$, $p<0.001$) between *E. mendezii* sp. nov. (mean= 8.24 ± 1.56 mm, n=25) and *E. sotoi* (mean= 15.78 ± 2.21 mm, n=23). Similarly, the median internode length between the second and third flower differed significantly ($U=0$, Monte Carlo $p<0.001$) between *E. mendezii* sp. nov. (median 6 mm (IQR 6-7), n=25) and *E. sotoi* (median 13 mm (IQR 11-14), n=23) (Fig. 5).

Additionally, the median internode length between the third and fourth flower differed significantly ($U=2$, Monte Carlo $p<0.001$): *E. mendezii* sp. nov. (median 5 mm (IQR 5-6), n=25) versus *E. sotoi* (median 10 mm (IQR 9-11), n=23). The median internode length between the fourth and fifth flower also differed significantly ($U=0$, Monte Carlo $p<0.001$): *E. mendezii* sp. nov. (median 4 mm (IQR

4-5), n=25) versus *E. sotoi* (median 10 mm (IQR 8-10), n=23). Finally, the median internode length between the fifth and sixth flower differed significantly ($U=0$, Monte Carlo $p<0.001$): *E. mendezii* sp. nov. (median 4 mm (IQR 3-4.5), n=25) versus *E. sotoi* (median 9 mm (IQR 8-10), n=23).

Across all five positions, *E. sotoi* consistently exhibited distances approximately twice as large as those of *E. mendezii* sp. nov. ($t=13.723$, $U=0-2$, all $p<0.001$), providing a diagnostic character for species circumscription (Fig. 5).

Seeds

Seed length and width showed complete separation between *E. mendezii* sp. nov. (n=7) and *E. sotoi* (n=5) via Mann-Whitney U tests (both $U=0$; Monte Carlo $p<0.002$). *E. sotoi* seeds were ~1.6 times longer (0.8 mm (IQR 0.75-0.8)) and 1.5-2 times wider (0.3-0.4 mm (IQR 0.3-0.4)) than those of *E. mendezii* sp. nov. (0.5 mm (IQR 0.4-0.5); uniform 0.2 cm wide), confirming species-level distinction (Fig. 6).



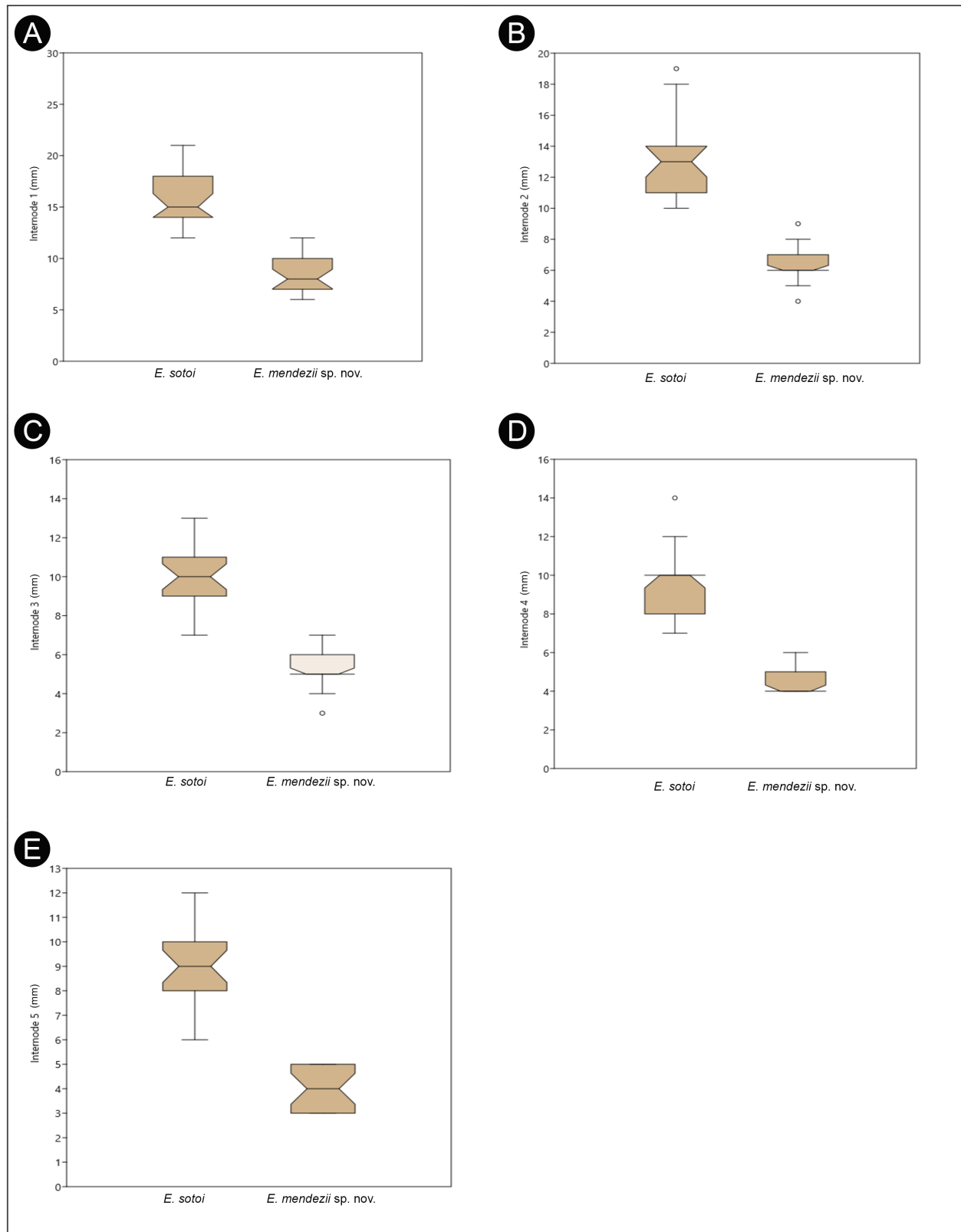


Figure 5: Floral internode variables *Echeveria mendezii* Pérez-Calix & Ram.-Oviedo, sp. nov. and *E. sotoi* Rosales & Quirarte. A. distance between flower internodes 1-2 (mm); B. distance between flower internodes 2-3 (mm); C. distance between flower internodes 3-4 (mm); D. distance between flower internodes 4-5 (mm); E. distance between flower internodes 5-6 (mm).

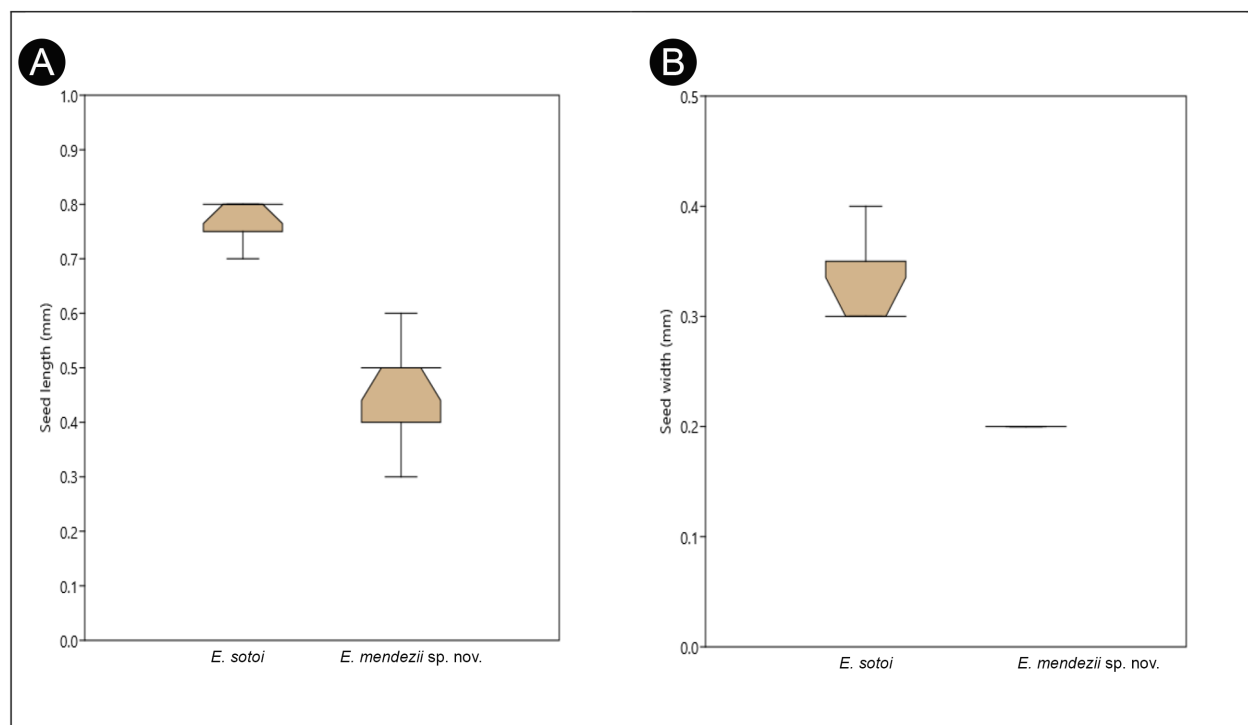


Figure 6: Seed variables *Echeveria mendezii* Pérez-Calix & Ram.-Oviedo, sp. nov. and *E. sotoi* Rosales & Quirarte. A. length of the seed (mm); B. width of the seed (mm).

Taxonomy

Echeveria mendezii Pérez-Calix & Ram.-Oviedo, sp. nov.
Figs. 7, 8.

TYPE: MEXICO. Michoacán: municipality Arteaga, 1.6 km south of La Lajita, road to Arteaga, 600 m, bosque tropical caducifolio, 12.XI.2024, *S. Ramírez-Oviedo and E. Pérez-Calix 190* (holotype: IEB!; isotypes: IBUG!, MEXU!).

Echeveria mendezii is similar to *E. sotoi* in habit, presence, length of the stem, length of the panicle, and color of the corolla and styles. However, *E. mendezii* differs primarily in leaf shape ((narrowly elliptic-spatulate to elliptic-spatulate vs. oblanceolate to oblanceolate-obovate), and color (gray-violet to light gray-green above, gray-violet to gray-violet-pinkish beneath vs. light green to purplish-green or orangish-pink on both surfaces); there are also notable differences in the cincinni, which are shorter (3.5-7.5(10) cm vs. 9.5-16 cm), bear fewer flowers (3)6-9 vs. (9)11-15), have shorter peduncles (1.3-1.6 cm

vs. 1.5-3.3 cm) and shorter internodes (3)4-9(12) mm vs. 11-16 (21) mm; the calyx segments are longer: the smallest measure 5.7-6.7 mm (vs. 5.3-6 mm), the intermediate 7.7-9.8 mm (vs. 6.6-8.9 mm), and the largest 10-12.1 mm (vs. 8.5-9.2 mm); stamens are shorter, antisealous stamens 7.1-8.8 mm (vs. (9.8)10.5-11.5 mm), antepetalous stamens 5.9-6.6 mm (vs. (7.3-)8-8.8); seeds are shorter and thinner (0.3)0.5-0.6 mm (vs. 0.7-0.8 mm).

Perennial herbaceous to subshrubby plant, glabrous, (50)70-152(198) cm tall (including the inflorescence), caulescent; stems erect, curved-ascending or rarely pendent, (5)10-51(73) cm long, (1.5)2-3(3.5) cm thick, light green with grayish-brown mottling at the apex, becoming uniformly grayish-brown toward the base; leaves arranged helically, forming loose rosettes at the stem apex (25)30-63, leaf blades 12.6-31 cm long, 4.3-11 cm wide at the broadest part, 1.1-2.4 cm wide at the base, 0.9-2 cm thick at the base, narrowly elliptic-spatulate to elliptic-spatulate, narrowing in the lower portion to form a pseudopetiole, margin entire, apex acute-mucronate, flat



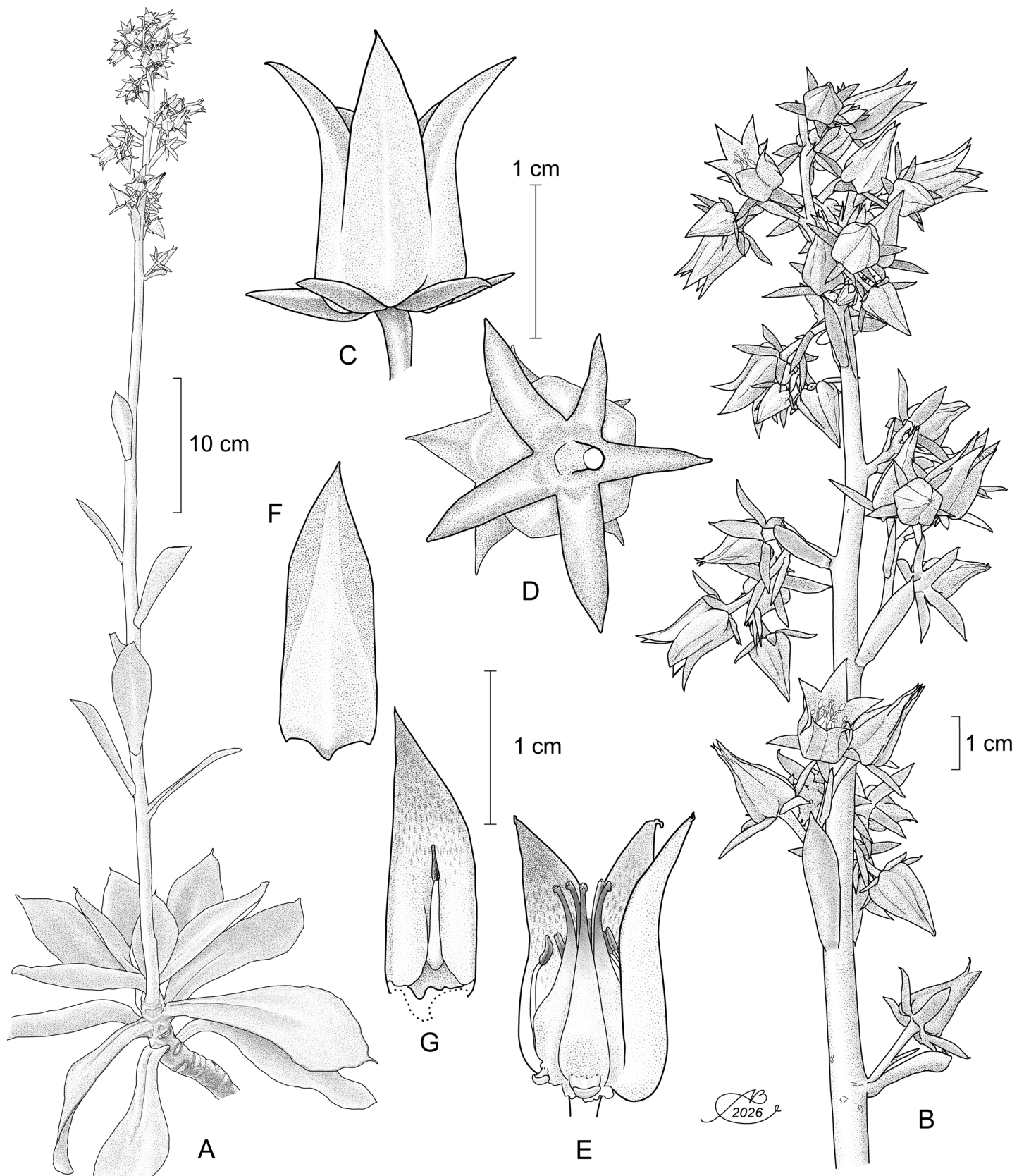


Figure 7: *Echeveria mendezii* Pérez-Calix & Ram.-Oviedo, sp. nov. A. habit; B. flower region of the panicle; C. lateral view of a flower; D. bottom view of a flower; E. dissection of a flower; F. petal outer side; G. petal inner side. Illustration by Alfonso R. Barbosa based on S. Ramírez-Oviedo and E. Pérez-Calix 190 (IEB).



Figure 8: *Echeveria mendezii* Pérez-Calix & Ram.-Oviedo, sp. nov. A. habit in its habitat; B. colony in its habitat; C. flower in lateral view; D. flower dissection; E. bottom view of the flower showing the calyx. Photographs: E. Pérez-Calix; Collage: Alfonso R. Barbosa.

to longitudinally folded, adaxial surface channeled in the middle-basal region, abaxial surface keeled at the base, gray-violet to light gray-green above, gray-violet to gray-violet-pinkish beneath; inflorescence a panicle, 60-90 cm tall overall, composed of (7)10-18 cincinni, peduncle 30-74 cm long, 0.7-0.9 mm in basal diameter, glabrous, not pruinose, light green, bracts 6.3-16.8 cm long, 1.5-5.4 cm wide at the broadest part, 0.7-1.2 cm wide at the base, 0.4-1.2 cm thick at the base, narrowly elliptic-spatulate, slightly narrowing toward the base, spur-like at the base, briefly tridentate; cincinni 3.5-7.5(10) cm long, the basal, the longest, bearing (3)6-9 flowers, cincinni peduncle 1.3-1.6 cm long, ca. 2 mm in diameter, basal bract of the cincinni peduncle 6.3-16.8 mm long, ca. 0.4 cm wide, oblong-obovate, internodes of the cincinni (3)4-9(12) mm long, usually the basal the longest; flowers on pedicel 5.5-7.9(9.3) mm long, 1-1.6 mm thick, green to green-reddish, pruinose; calyx of 5 segments, unequal, fused at the base forming a disk ca. 1.2 mm, bright green with light sepia-reddish base, segments unequal, the shortest 5.7-6.7 mm long, 2.1-2.9 mm wide at the base, narrowly triangular, intermediate 7.7-9.8 mm long, 3-3.4 mm wide, largest 10-12.1 mm long, 3-3.8 mm wide, narrowly oblong, apex acute; corolla tubular-campulose, pentagonal at anthesis, 17.4-19.4 mm long, ca. 10.2 mm in basal diameter, externally salmon-pink, orange in the overlapping area of the lobes, pruinose, internally yellow with reddish margins, cream to yellow with pinkish-reddish margins, lobes 5.4-6.5 mm wide, narrowly oblong, apex acute, keeled externally, with a basal swelling, channeled internally, with a cavity at the base; stamens antisepalous 7.1-8.8 mm total length, filaments 5-6.5 mm, antipetalous 5.9-6.6 mm total length, filaments 3.5-5 mm; nectary scales 0.7-1 mm high, 2-2.9 mm wide, ca. 1 mm thick, reniform, cream-white; gynoecium 11-12.6(13.6) mm long, 4.5-5 mm thick; style (3)4.3-5.8 mm long, dark cherry red; fruit erect, 8-10.1 mm long, 1.8-2.4 mm wide at the base; seeds (0.3)0.5-0.6 mm long, ca. 0.2 mm wide, ellipsoid or botuliform.

Etymology: the name of the new species is dedicated to Biologist Francisco Méndez García (Zamora, Michoacán, 1950). The biologist Méndez García played a

prominent role in the reestablishment of the School of Biology at the Universidad Michoacana de San Nicolás de Hidalgo. He joined this institution in 1974, a few months after its reopening. Since then, he has served as a professor, teaching various courses such as Comparative Animal Anatomy of Invertebrates, Comparative Anatomy of Vertebrates, Biogeography, General Biology, Animal Physiology, and Evolution.

Throughout his career at the university, he has also carried out administrative duties within the School of Biology, serving twice as director and as coordinator of the bird collection working group. During his tenure as director, he promoted—together with other faculty members—the development of biological collections, including the herbarium. Another notable achievement in his academic career was the founding, in 1986, of the Natural History Museum “Manuel Martínez Solórzano” in Bosque Cuauhtémoc, in Morelia, Michoacán (Ponce et al., 2023).

Distribution and habitat: *Echeveria mendezii* is known only from a series of scattered populations along an approximately 20 km stretch of the Arteaga - Las Cañas road, in the municipality Arteaga, Michoacán. It inhabits sandy slopes and rocky cliffs between 600-900 m a.s.l. (Table 1). The region belongs to the Balsas Basin Province; specifically the area known as the Arteaga Complex, composed of intrusive igneous granite-granodiorite rocks (SGM, 2006), and is interpreted as part of the Mesozoic Guerrero composite terrane, an accretionary assemblage of arc and oceanic crustal fragments formed along the western margin of North America (Centeno-García et al., 2008).

The vegetation corresponds to tropical deciduous forest (sensu Rzedowski, 2006), composed, among others, of the following trees: *Albizia occidentalis* Brandegees, *Bauhinia pauletia* Pers., *Bursera ariensis* (Kunth) McVaugh & Rzed., *B. bicolor* Engl., *B. fagaroides* (Kunth) Engl., *B. heteresthes* Bullock, *B. kerberi* Engl., *B. sarukhanii* Guevara & Rzed., *Byrsonima crassifolia* Steud., *Conzattia multiflora* Standl., *Diospyros aequoris* subsp. *balsensis* Provance, I.García & A.C.Sanders, *Euphorbia schlechtendalii* Boiss., *Haematoxylum brasiletto* H.Karst., *Havardia pallens*



Britton & Rose, *Lysiloma acapulcense* (Kunth) Benth., *L. divaricatum* (Jacq.) Benth., *Senna atomaria* (L.) H.S.Irwin & Barneby, *Swietenia humilis* Zucc., *Thevetia ovata* A.DC. The understory consists of shrubs such as *Caesalpinia pulcherrima* (L.) Sw., *Coursetia caribaea* var. *caribaea* (Jacq.) Lavin, *Eremosis corymbosa* (Mill.) Pruski, *Euphorbia cymosa* Poir., *Senna occidentalis* (L.) Link, *Verbesina oligantha* B.L.Rob., *Zapoteca formosa* (Kunth) H.M.Hern., *Zapoteca formosa* (Kunth) H.M.Hern., *Opuntia decumbens* Salm-Dyck, *O. karwinskiana* Salm-Dyck. Among the herbaceous plants are: *Acalypha vagans* Cav., *Achimenes* sp., *Aeschynomene paucifoliolata* Micheli, *Bouteloua aristoides* (Kunth) Griseb., *Celosia monosperma* Rose, *Cuphea* sp., *Dahlia coccinea* Cav., *Dalea foliolosa* var. *citrina* (Rydb.) Barneby, *Decachaeta ovatifolia* (DC.) R.M.King & H.Rob., *Desmodium macrodesmum* (Softbank) Standl. & Steyerl., *Eragrostis viscosa* Trin., *Euphorbia thymifolia* L., *Froelichia interrupta* (L.) Moq., *Gaudichaudia albida* Schltdl. & Cham., *Heterocentron subtripplinervium* A.Braun & Bouche., *Hofmeisteria dissecta* (Hook. & Arn.) R.M.King & H.Rob., *Lundellianthus jaliscensis* (McVaugh) Strother, *Mammillaria beneckeii* C.Ehrenb., *Muhlenbergia pereilema* P.M.Peterson, *Polystemma guatemalense* (Schltr.) W.D.Stevens, *Sclerocarpus divaricatus* Benth. & Hook.f. ex Hemsl., *Senna uniflora* (Mill.) H.S.Irwin & Barneby, *Sida prolifica* Fryxell & S.D.Koch, *Tephrosia vicioides* A.Rich., *Tetramerium nervosum* Nees y *Vernonia pallens* Sch.Bip.

Phenology: the new species flowers from November to January.

Preliminary conservation status: *Echeveria mendezii* is assessed as a microendemic species, known from few scattered populations on slopes northeast of Arteaga, Michoacán, each consisting of few individuals. Some sites experience landslides during periods of heavy rainfall, during which plants are washed away, causing population losses.

The calculated extent of occurrence (EOO) for *E. mendezii* is 8.9 km², and its area of occupancy (AOO) is 4 km² (calculated using 1 × 1 km grid cells). Both parameters meet the IUCN criteria B1+B2ab(iii) for Critically

Endangered (CR), based on the guidelines of the International Union for Conservation of Nature (IUCN, 2012).

Additional specimens examined: MEXICO. Michoacán, municipality Arteaga, ca. 4.9 km east of La Lajita, road to Las Cañas, 920 m, 12.XI.2024, *E. Pérez-Calix and S. Ramírez-Oviedo 7078* (IEB, MEXU); ca. 3.3 km west of La Juntas, road to Arteaga, 650 m, 12.XI.2024, *E. Pérez-Calix and S. Ramírez-Oviedo 7079* (IEB, MEXU); ca. 4.8 km east of La Lajita, road to Las Cañas, 800 m, *E. Pérez-Calix and S. Ramírez-Oviedo 7080* (IEB, MEXU).

Specimen examined of *Echeveria sotoi*: MEXICO. Michoacán, municipality Aquila, ca. 5 km al NE de Pichilinguillo, sobre el camino a Santiaguillo, 470 m, *E. Pérez-Calix 7082* (IEB).

Discussion

Echeveria mendezii is placed within the series *Gibbiflorae* (sensu Kimnach, 2003) due to the following characteristics: large stem, glabrous, caulescent habit; leaves loosely arranged at the apex of the stem and narrowing toward the base into a pseudopetiole; paniculate inflorescence with an elongated rachis and 10-13 cincinni branches; robust, bracteate peduncle; unequal sepals; large corolla, cylindrical-urceolate to campanulate, pentagonal, crimson in color; and dark wine-colored styles.

The species most similar to *Echeveria mendezii* is *E. sotoi* (Table 1). However, several morphological differences help to distinguish the two taxa. Among the most evident are leaf shape and dimensions, which, although overlapping in size with those of *E. sotoi*, tend to be longer and wider both at the broadest part and at the base, as well as thicker at the base (Table 1; Fig. 2); leaf blade coloration also differs (Table 1). Similarly, although inflorescence size overlaps, that of *E. sotoi* is generally longer (Table 1). The most marked differences occur in the cincinni, including total length, number of flowers, peduncle size, and internode length (Table 1; Figs. 4, 5). Calyx segments are larger in *E. mendezii*, stamens are shorter, and seeds are smaller (Table 1; Fig. 6).



These distinctions are supported by morphometric analyses, which proved invaluable in quantitatively separating the new species from its most morphologically similar congener, *E. sotoi*. Of 13 evaluated characteristics, 11 showed significant differences ($p \leq 0.05$) across independent datasets for leaves, inflorescences, bracts, and seeds. The high proportion of statistically significant traits (88%) strongly rejects the null hypothesis of conspecificity between the two taxa ($p < 0.001$), demonstrating that *E. mendezii* is morphologically distinct despite its cryptic similarity to *E. sotoi*. These results elucidate the value of quantitative approaches as a complement to traditional qualitative assessments and address concerns regarding pseudoreplication by revealing consistent divergence among organs of different plants. To our knowledge, this represents the first application of rigorous morphometric methods in *Echeveria* taxonomy and provides a useful framework for delimiting species boundaries and detecting cryptic diversity within the genus. Some of these differences were also noted by Rosales-Martínez et al. (2024), who stated that *E. sotoi* is distinguished by its shorter sepals and by cincinni that are not pendent when fully developed.

On the other hand, de la Cruz-López et al. (2019) included in their study a sample taken from a plant referred to as JE-8624, from Michoacán (km 263 of the Arteaga - Uruapan road), which they identified as *Echeveria* aff. *gibbiflora*. The geographic origin of this material likely corresponds to the region where *Echeveria mendezii* occurs. According to the authors, a specimen was deposited in the Herbario Nacional de México (MEXU) but attempts to locate it were unsuccessful. In the published cladogram, the sample appears as an independent taxon within *Gibbiflorae*.

Ecological preferences also differ between *Echeveria mendezii* and *E. sotoi*. *Echeveria mendezii* is restricted to tropical deciduous forest growing on granite and granodiorite outcrops at elevations of 600–900 m, while *E. sotoi* occurs in thorn forest associated with limestone outcrops at lower elevations, between 350–500 m.

With the publication of *Echeveria mendezii*, the number of species in series *Gibbiflorae* in Michoacán increases to six, marking the first species of the series recorded in the Sierra Madre del Sur sector of the state, a region known

for its diversity in the series, particularly in Guerrero and Oaxaca.

Conclusions

Echeveria mendezii is a morphologically and morphometrically distinct species of series *Gibbiflorae* in Michoacán. The concordance between qualitative diagnostic characters and quantitative analyses supports its recognition as a new species and elucidates the value of morphometric methods for delimiting closely related taxa in *Echeveria*. This integrative approach provides a foundation for future taxonomic studies aimed at resolving species boundaries and documenting hidden diversity within the genus.

Author contributions

Conceptualization: EPC, SMRO; Investigation: EPC, SMRO; Funding acquisition: EPC, SMRO; Resources: EPC, SMRO; Writing – original draft: EPC, SMRO; Writing – review & editing: EPC, SMRO; Validation: EPC, SMRO; Visualization: EPC, SMRO.

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Declaration of Artificial Intelligence Use

The authors confirm that no artificial intelligence tools were used in the preparation of this manuscript. All content and interpretations are solely the responsibility of the authors.



Literature cited

- Bachman, S., J. Moat, A. W. Hill, J. de la Torre and B. Scott. 2011. Supporting Red List threat assessments with GeoCAT: geospatial conservation assessment tool. *ZooKeys* 150: 117-126. DOI: <https://doi.org/10.3897/zookeys.150.2109>
- Berger, A. 1930. Crassulaceae. In: Engler, A. and K. Prantl (eds.). *Die Natürlichen Pflanzenfamilien*. ed. 2. 18a. Verlag von Wilhelm Engelmann. Leipzig, Germany. pp. 402-412.
- Britton, N. L. and J. N. Rose. 1905. Crassulaceae. *North American Flora* 22(1): 7-74.
- Carrillo-Reyes, P., V. Sosa and M. E. Mort. 2009. Molecular phylogeny of the *Acre* clade (Crassulaceae): Dealing with the lack of definitions for *Echeveria* and *Sedum*. *Molecular Phylogenetics and Evolution* 53(1): 267-276. DOI: <https://doi.org/10.1016/j.ympev.2009.05.022>
- Centeno-García, E., M. Guerrero-Suastegui and O. Talavera-Mendoza. 2008. The Guerrero Composite Terrane of western Mexico: Collision and subsequent rifting in a supra-subduction zone. In: Draut, A. E., P. D. Clift and D. W. Scholl (eds.). *Formation and Applications of the Sedimentary Record in Arc Collision Zones*. Geological Society of America. Boulder, USA. pp. 279-308. DOI: [https://doi.org/10.1130/2008.2436\(13\)](https://doi.org/10.1130/2008.2436(13))
- de la Cruz-López, L. E., J. Reyes Santiago and F. Vergara-Silva. 2021. A new species of *Echeveria* (Crassulaceae) from Durango, Mexico, supported by morphology and DNA diagnostic characters. *Brittonia* 73: 374-382. DOI: <https://doi.org/10.1007/s12228-021-09684-7>
- de La Cruz-López, L. E., F. Vergara-Silva, J. Reyes Santiago, G. Espino Ortega, P. Carrillo-Reyes and M. Kuzmina. 2019. Phylogenetic relationships of *Echeveria* (Crassulaceae) and related genera from Mexico, based on three DNA barcoding loci. *Phytotaxa* 422(1): 33-57. DOI: <https://doi.org/10.11646/phytotaxa.422.1.3>
- Hammer, Ø., D. A. Harper and P. D. Ryan. 2001. PAST Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica* 4(1): 1-10.
- IUCN. 2012. IUCN Red List Categories and Criteria: Version 3.1. Second edition. Gland, Switzerland and Cambridge, UK.
- Jimeno-Sevilla, H. D., J. A. Vázquez-García, M. A. Muñiz-Castro, I. García-Ruiz, G. Hernández-Vera and J. Villa Castillo. 2019. *Echeveria sonianevadensis* (Crassulaceae), una nueva especie del Volcán Nevado de Colima del occidente de México y una clave para la serie *Gibbiflorae*. *Brittonia* 71: 156-165. DOI: <https://doi.org/10.1007/s12228-018-9560-2>
- Kimnach, M. 2003. *Echeveria*. In: Eggli, U. (ed.). *Crassulaceae. Illustrated Handbook of Succulent Plants*. Springer. Berlin, Germany. pp. 103-128.
- Meyrán, G. J. and L. López-Chávez. 2003. Las Crassuláceas de México. Sociedad Mexicana de Cactología, A.C. México, D.F., México. 234 pp.
- Moran, R. 1974. Division of the genus *Echeveria* into series. In: Jacobsen, H. (ed.). *Lexicon of Succulent Plants*. Blandford Press. London, UK. pp. 184-186.
- Morrone, J. J., T. Escalante and G. Rodríguez-Tapia. 2017. Mexican biogeographic provinces: Map and shapefiles. *Zootaxa* 4277(2): 277-279.
- Ortiz-Brunel, J. P., J. I. González-Olivares, C. S. Rosales-Martínez, J. D. Hernández-Campos and J. A. Quirarte-Tejeda. 2025. Una nueva especie gipsófila de *Echeveria* (Crassulaceae) de Guerrero, México. *Acta Botanica Mexicana* 132: e2485. DOI: <https://doi.org/10.21829/abm132.2025.2485>
- Pérez-Calix, E. 2008. Familia Crassulaceae. *Flora de Bajío y de regiones adyacentes* 115: 1-141. DOI: <https://doi.org/10.21829/fb.92.2008.156>
- Pérez-Calix, E. and M. I. S. Franco. 2004. Crasuláceas. In: García-Mendoza, A. J., M. J. Ordoñez and M. Briones-Salas (eds.). *Biodiversidad de Oaxaca. Instituto de Ecología, Universidad Nacional Autónoma de México-Fondo Oaxaqueño para la Conservación de la Naturaleza-World Wildlife Fund*. México, D.F., Mexico. pp. 209-217.
- Pérez-Calix, E. y J. I. Guadián-Marín. 2025. *Echeveria barbosa* (Crassulaceae), una especie nueva del estado de Guanajuato, México. *Acta Botanica Mexicana* 132: e2466. DOI: <https://doi.org/10.21829/abm132.2025.2466>
- Pilbeam, J. 2008. The genus *Echeveria*. *British Cactus & Succulent Society*. Essex, UK. 333 pp.
- Ponce S. J., P. R. Sánchez and S. F. Rodríguez. 2023. Pioneros de la Facultad de Biología. *Biológicas* 22(2): 1-18.
- QGIS Development Team. 2021. QGIS Geographic Information System Version 3.22 Białowieża. Open Source Geospatial Foundation. <https://qgis.org> (consulted April, 2026).
- Reyes Santiago, J., L. E. de la Cruz-López and F. Vergara-Silva. 2019. *Echeveria xochipalensis* (Crassulaceae), a new species from



- Guerrero, Mexico. Phytotaxa 399(1): 14-24. DOI: <https://doi.org/10.11646/phytotaxa.399.1.2>
- Reyes Santiago, J., A. Islas Luna and O. Anguiano. 2025. Five New Species of the Genus *Echeveria* (Crassulaceae) from the Mountains of Oaxaca, Mexico. Haseltonia 32(1): 17-35. DOI: <https://doi.org/10.2985/026.032.0105>
- Rosales-Martínez, C. S., J. A. Quirarte-Tejeda and J. D. Hernández-Campos. 2024. *Echeveria sotoi* (ser. *Gibbiflorae*, Crassulaceae), a new species from coastal Michoacán, Mexico. Phytotaxa 633(2): 125-137. DOI: <https://doi.org/10.11646/phytotaxa.633.2.3>
- Rzedowski, J., 2006. Vegetación de México 1ra. Ed. digital, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. México, D.F. México. http://www.biodiversidad.gob.mx/publicaciones/librosDig/pdf/VegetacionMx_Cont.pdf (consulted April, 2026).
- SGM. 2006. Carta Geológico-Minera, Arteaga E13-B79, Michoacán, 1:50.000. Servicio Geológico Mexicano. Pachuca, Mexico.
- Thiede, J. 1995. Quantitative phytogeography, species richness, and evolution of American Crassulaceae. In: Hart, H. and U. Eggli (eds.). Evolution and systematics of the Crassulaceae. Backhuys Publishers. Leiden, The Netherlands. pp. 89-123.
- Thiers, B. 2026 (continuously updated). Index Herbariorum: A Global Directory of Public Herbaria and Associated Staff. New York Botanical Garden's Virtual Herbarium. New York, USA. <http://sweetgum.nybg.org/science/ih/> (consulted February, 2026).
- Uhl, C. H. 2002. Chromosomes and hybrids of *Echeveria* (Crassulaceae) VII. Series *Gibbiflorae* (Baker) Berger. Haseltonia 9: 121-145.
- Vázquez-Cotero, C., V. Sosa and P. Carrillo-Reyes. 2017. Phylogenetic position of *Echeveria heterosepala* (Crassulaceae): a rare species with diagnostic characters of *Pachyphytum*. Botanical Sciences 95(3): 515-526. DOI: <https://doi.org/10.17129/botsci.1190>
- Vázquez-García, J. A., R. Cuevas Guzmán, C. S. Rosales-Martínez, J. G. Morales Arias and J. Padilla-Lepe. 2024. Two new species of *Echeveria* (Crassulaceae, Saxifragales) from the Sierra de Manantlán, Jalisco, Mexico. Phytotaxa 653(2): 115-133. DOI: <https://doi.org/10.11646/phytotaxa.653.2.2>
- Walther, E. 1972. *Echeveria*. California Academy of Sciences. San Francisco, USA. 426 pp.

