**Polibotánica**
ISSN electrónico: 2395-9525
polibotanica@gmail.com
Instituto Politécnico Nacional
México
http://www.polibotanica.mx

# *Mammillaria scoria* (Cactaceae) UNA NUEVA ESPECIE DE QUERÉTARO, MÉXICO

# *Mammillaria scoria* (Cactaceae) A NEW SPECIES FROM QUERÉTARO, MEXICO

**González-Zamora, P., D. Aquino, D. Sánchez**

*Mammillaria scoria* (Cactaceae) UNA NUEVA ESPECIE DE QUERÉTARO, MÉXICO
*Mammillaria scoria* (Cactaceae) A NEW SPECIES FROM QUERÉTARO, MEXICO

POLIBOTÁNICA
**Instituto Politécnico Nacional**

Núm. 60: 1-13 México. Julio 2025
DOI: 10.18387/polibotanica.60.1

Núm. 60: 1-13 Julio 2025 ISSN electrónico: 2395-9525

# *Mammillaria scoria* (Cactaceae) una nueva especie de Querétaro, México

# *Mammillaria scoria* (Cactaceae) a new species from Querétaro, Mexico

**Pedro González-Zamora** https://orcid.org/0000-0002-2702-5828
*Grupo de Estudio de Cactáceas y Vida Silvestre del Occidente, A. C.*
*C.P. 28454, Comala, Colima, México.*

**David Aquino** https://orcid.org/0000-0003-0797-6754
*Jardín Botánico, Instituto de Biología, Universidad Nacional Autónoma de México*
*Cto. Zona Deportiva s/n, Ciudad Universitaria, C.P. 04510*
*Coyoacán, Ciudad de México, México*

**Daniel Sánchez** / dsanchez@ib.unam.mx
https://orcid.org/0000-0002-8621-0222
*Estación de Biología Chamela, Instituto de Biología*
*Universidad Nacional Autónoma de México, Apartado Postal 21*
*San Patricio-Melaque, Jalisco 48980, México*

González-Zamora, P., D. Aquino, D. Sánchez

*Mammillaria scoria* (Cactaceae) UNA NUEVA ESPECIE QUE CRECE SOBRE ROCAS ÍGNEAS EXTRUSIVAS EN QUERÉTARO, MÉXICO

*Mammillaria scoria* (Cactaceae) A NEW SPECIES GROWING ON EXTRUSIVE IGNEOUS ROCK FROM QUERÉTARO, MEXICO

POLIBOTÁNICA
Instituto Politécnico Nacional

Núm. 60: 1-13. Julio 2025

DOI: 10.18387/polibotanica.60.1

**A**BSTRACT: *Mammillaria* ser. *Stylothelae* is a well-recognized group in southern Chihuahuan Desert. Some members of this series have been regarded as highly polymorphic species. Recent analyses showed that some populations of those species complex can be accepted as independent species. In this study, we measured, statistically analyzed and compared quantitative and qualitative characters in plants during field work and plants in cultivation to identify a new species of de *M.* ser. *Stylothelae* from central Querétaro, Mexico. We compared it with close geographical and morphological species of the series as *M. crinita*, *M. duwei*, *M. nana*, *M. painteri*, and *M. tezontle*. The new taxon is distinguished by the globose growth form up to 24 mm tall, with 1–2 (mean=1.7) central spines and 17–21 (mean=18.86) radial spines, presence of fibrous roots, naked axils, and non-arillate seeds. The new species inhabits the xerophytic scrub and grows on basic extrusive igneous rock.
**Key words**: Cacteae, Linear Discriminant Analysis, *Mammillaria* ser. *Stylothelae*, morphometrics, taxonomy.

**R**ESUMEN: *Mammillaria* ser. *Stylothelae* es un grupo bien reconocido en el sur del Desierto Chihuahuense. Algunos miembros de esta serie has sido considerados como especies altamente polimórficas. Análisis recientes mostraron que algunas poblaciones de estos complejos de especies pueden ser aceptadas como especies independientes. En este estudio medimos, analizamos estadísticamente y comparamos caracteres cuantitativos y cualitativos en plantas en el campo y en cultivo, para identificar a una nueva especie de *M.* ser. *Stylothelae* del centro de Querétaro, México. Comparamos el nuevo taxón con especies geográfica y morfológicamente cercanas de la serie como *M. crinita*, *M. duwei*, *M. nana*, *M. painteri* y *M. tezontle*. El nuevo taxón se distingue por su forma de crecimiento globosa de hasta 24 mm de alto, con 1 a 2 (media=1.7) espinas centrales y 17–21 (media=18.86) espinas radiales, presencia de raíces fibrosas, axilas desnudas y semillas sin arilo. La nueva especie habita el matorral xerófilo creciendo en afloramientos de escoria volcánica.
**Palabras clave**: Cacteae, Análisis Discriminante Lineal, *Mammillaria* ser. *Stylothelae*, taxonomy.

## INTRODUCTION

*Mammillaria* Haw. is the most diverse genus in Cactaceae. Recently, the taxonomic limits of the genus have been discussed in two phylogenomic analyses (Breslin *et al.*, 2021; Chincoya *et al.*, 2023). Both studies recovered a clade, named *Mammillaria* S.Str. that grouped most of the members of the genus. This lineage inhabits different ecosystems of North America, Central America and Antilles, and is diverse in the desertic and semidesertic regions of central and northern Mexico (Pilbeam, 1999). Korotkova *et al.* (2021) recognized ca. 143 species in *Mammillaria* s.str. Some infrageneric groups, traditionally recognized in *Mammillaria*, have been corroborated as monophyletic assemblages. Examples included *M.* ser. *Polyedrae* K. Schum. (Aquino-García, 2014), *M.* ser. *Supertextae* D. R. Hunt (Cervantes *et al.*, 2021), *M.* ser. *Polyacanthae* K. Schum. (Cervantes *et al.*, 2021), and *M.* ser. *Stylothelae* (Pfeiff.) K. Schum. (Chincoya *et al.*, 2023).

*Mammillaria* ser. *Stylothelae* comprises plants with globose to short cylindrical stems, solitary or branched, thin and conic tubercules, axiles with or without bristles, acicular central and radial spines with at least one uncinate central spine, and the presence of alkaloids in flowers and fruits (Hunt, D. R., Taylor, N. P., & Charles, G, 2006; Lüthy, 1995).The series includes 20–25 spp., which are distributed in the southern region of the Chihuahuan Desert, Sierra Madre Oriental, and foothills of the Mexican Transvolcanic Belt with an affinity of igneous soils (Hernández, H. M., & Gómez-Hinostrosa, C., 2015; Pilbeam, 1999).

Recent publications have increased the number of species in *M.* ser. *Stylothelae*. Morphometrics studies and botanical exploration have recognized three new species in the series, *M. morentiniana* Gonz.-Zam., D.Aquino, J.Mohl & Dan.Sánchez (González-Zamora *et al.*, 2022), *M. arreolae* P.Carrillo & Ortiz-Brunel (Ortiz-Brunel *et al.*, 2023), and *M. monochrysacantha* Gonz.-Zam., D.Aquino & Dan.Sánchez (González-Zamora, P., Aquino, D., Rodríguez, A., Sánchez, D., 2023). Morphometric (González-Zamora *et al.*, 2022) and phylogenetic (Ortiz-Brunel, 2025) analyses suggest that different lineages have been erroneously grouped under *Mammillaria crinita* DC. This polymorphic taxon has a wide geographic distribution (Hunt, Taylor, N. P., & Charles, G, 2006; Pilbeam, 1999).

During fieldwork at the municipality of Colón, Querétaro, we observed plants similar to *Mammillaria duwei* Rogoz. & P. J. Braun and *Mammillaria nana* Backeb. ex Mottram. Those specimens show 0–3 reddish central spines but do not present thickened roots, unlike *M. duwei* and *M. nana* (Arias & Aquino, 2019). Besides, we noted that individuals grow on slight slope of outcrops of volcanic scoria, a substrate shared with *Mammillaria tezontle* W. A. Fitz Maur. & B. Fitz Maur. (Fitz & Fitz-Maurice, 1995). Therefore, the present work has allowed to characterize a new species within *M*. ser *Stylothelae*.

## MATERIAL AND METHODS

**Taxon sampling**: We examined specimens from the herbaria DES, MEXU, and QMEX (Thiers, 2024+) to identify localities and plan fieldwork in the Mexican states of Guanajuato, Querétaro and San Luis Potosí. We conducted fieldwork in Querétaro at Colón municipality during November 2021 and June 2022. We also documented the morphological variation of five morphological and geographical close species *M. duwei*, *M. nana,* and *M. tezontle*, as well as *M. crinita* and *M. painteri* Rose. Specimens were preserved and deposited in IBUG and MEXU (Thiers, 2024+). The six sampled sites and specimen vouchers are detailed in Table 1.

**Character sampling and statistical analyses**: At each site, we photographed ten plants using a millimeter ruler in different view planes. Table 2 lists the quantitative characters documented in the specimens. We used the image analyzer ImageJ (Schneider *et al.*, 2012) to count and measure the variation of characters in each individual.

**Table 1.** Localities and vouchers included in the morphological analysis.
**Tabla 1.** Localidades y especímenes de respaldo incluidos en el análisis morfológico.

| Taxon | Locality | Collector/Herbarium |
|---|---|---|
| *Mammillaria crinita* | Tolimán, Querétaro | P. González-Zamora 22 / IBUG |
| *M. crinita* | Zimapán, Hidalgo | P. González-Zamora 25 / IBUG |
| *M. duwei* | Victoria, Guanajuato | P. González-Zamora 29 / IBUG |
| *M. nana* | Lourdes, SLP | P. González-Zamora 10 / IBUG |
| *M. painteri* | Amealco, Querétaro | P. González-Zamora 111 / IBUG |
| *M. scoria* | Colón, Querétaro | P. González-Zamora 83 / IBUG |
| *M. tezontle* | Villa Hidalgo, SLP | P. González-Zamora 115 / IBUG |

We calculated measures of central tendency and standard deviation for the quantitative characters (Table 3). We calculated the Pearson correlation coefficient between characters (CCP). Non-correlated characters were retained for subsequent analyses (Table 2). These variables were transformed using natural logarithm to ensure a normal distribution and homogeneity of variance. We performed a Multivariate Analysis of Variance (MANOVA) and post hoc tests to confirm significant differences between species (Tabachnick & Fidell, 2012). Finally, a Linear Discriminant Analysis (LDA) was performed using species as group variable. All statistical analyses were conducted using PAST 4.10 (Hammer *et al.*, 2001).

**Morphological characterization**: We built a comparative table that included the most discriminant quantitative characters from LDA and useful qualitative characters to delimit species in *M*. ser. *Stylothelae* (Table 2). Both vegetative and reproductive morphological characters were meticulously documented during fieldwork and further verified in cultivated plants, ensuring a comprehensive and precise description of the new taxon.

**Evaluation of the Conservation Status**: We estimated the Area of Occupancy (AOO) and Extent of Occurrence (EOO) using the GeoCAT tool (Bachman *et al.*, 2011) and based on the IUCN Red List Categories and Criteria (IUCN, 2024).

**Table 2.** List of quantitative characters used in the statistical analyses. Asterisk denotes correlated characters.
**Tabla 2.** Lista de los caracteres cuantitativos usados en los análisis estadísticos. El asterisco señala a los caracteres correlacionados.

| Character | Acronym | Character | Acronym |
|---|---|---|---|
| Stem height | STLE | Length of radial spines | LRSP |
| Stem diameter | STWI | Areole length | AREL* |
| Number of central spines | NCSP | Areole width | AREW* |
| Length of central spines | LCSP | Areole length/width ratio | ARER |
| Number of radial spines | NRSP | | |

## RESULTS

Table 3 compares the central tendency values of the analyzed species. MANOVA revealed significant differences ($P<0.01$), and post hoc tests confirmed significance between each pair of species ($P<0.01$). LDA explained 86.91% of the total variation across two axes, 64.6% for axis 1 and 22.31% for axis 2. The loadings matrix (WcovC) identified NCSP and LCSP as the characters with the highest discriminant power on axis 1, while LRSP showed the strongest loading on axis 2. As illustrated in Figure 1, the new species forms a well-delimited group, clustering around central values on axis 1 and negative values on axis 2. The jackknifed confusion matrix from the LDA correctly assigned 98% of observations to their respective groups, with an overall accuracy of

95.71% for *a priori* assignments (Table 4). Finally, Table 5 and Figure 2 highlight a unique combination of morphological characters that distinguish *Mammillaria* sp. nov. from other taxa.

**Table 3.** Central tendency measures for *Mammillaria scoria* and close species included in the analysis. M=mean, SD=standard deviation, Min=minimum, Max=maximum.
**Tabla 3.** Medidas de tendencia central en *Mammillaria scoria*. y especies cercanas incluidas en el análisis. M=media, SD=desviación estándar, Min=mínimo, Max=máximo.

| Species | N | | STLE | STWI | NCSP | LCSP | NRSP | LRSP | ARER |
|---|---|---|---|---|---|---|---|---|---|
| *M. crinita* | 20 | M | 25.75 | 30.62 | 3.65 | 5.45 | 20.11 | 4.84 | 0.90 |
| | | SD | 5.12 | 5.18 | 0.61 | 1.08 | 2.144 | 0.83 | 0.06 |
| | | Min | 13.2 | 20.2 | 2 | 3.01 | 16 | 2.7 | 0.73 |
| | | Max | 33.6 | 39.1 | 4 | 7.8 | 25 | 6.9 | 0.99 |
| *M. duwei* | 10 | M | 19.9 | 30.8 | 1.09 | 7.16 | 27.06 | 3.88 | 0.83 |
| | | SD | 6.31 | 6.15 | 0.32 | 1.08 | 2.806 | 0.6 | 0.08 |
| | | Min | 10 | 23 | 0 | 4.5 | 22 | 3 | 0.64 |
| | | Max | 34 | 46 | 2 | 10 | 34 | 5 | 0.98 |
| *M. nana* | 10 | M | 20.2 | 32.2 | 1.09 | 6.88 | 28.18 | 5.62 | 0.74 |
| | | SD | 5.16 | 6.32 | 0.28 | 1.41 | 1.84 | 1.23 | 0.07 |
| | | Min | 14 | 21 | 1 | 3 | 23 | 3 | 0.62 |
| | | Max | 34 | 44 | 2 | 9 | 32 | 8 | 0.88 |
| *M. painteri* | 10 | M | 24.94 | 24.81 | 3.57 | 3.04 | 19.74 | 2.65 | 0.91 |
| | | SD | 3.59 | 4.77 | 0.71 | 0.45 | 2.35 | 0.4 | 0.03 |
| | | Min | 19.73 | 18.2 | 2 | 2.1 | 15 | 1.6 | 0.82 |
| | | Max | 31.9 | 36.1 | 5 | 3.9 | 25 | 3.4 | 1 |
| *M. scoria* | 10 | M | 18.2 | 19.50 | 1.7 | 4.25 | 18.86 | 2.68 | 0.61 |
| | | SD | 3.98 | 2.85 | 0.78 | 1.1 | 2.05 | 0.46 | 0.07 |
| | | Min | 13 | 12.9 | 0 | 1.98 | 13 | 1.47 | 0.5 |
| | | Max | 24.2 | 22.2 | 3 | 7 | 24 | 3.8 | 0.78 |
| *M. tezontle* | 10 | M | 16.23 | 25.87 | 2.52 | 2.12 | 17.36 | 2.54 | 0.95 |
| | | SD | 3.22 | 3.22 | 0.68 | 0.39 | 1.59 | 0.56 | 0.02 |
| | | Min | 13.05 | 19.44 | 1 | 1.1 | 14 | 1.5 | 0.90 |
| | | Max | 24.16 | 32.08 | 4 | 3.1 | 20 | 3.89 | 1 |

**Table 4.** Jackknifed confusion matrix from the Lineal Discriminant Analysis.
**Tabla 4.** Matríz de confusión con remuestreo de Jackknife del Análisis Discriminante Lineal.

| Specie | *M. scoria* | *M. crinita* | *M. nana* | *M. duwei* | *M. tezontle* | *M. painteri* | Total |
|---|---|---|---|---|---|---|---|
| *M. crinita* | 0 | 196 | 0 | 0 | 2 | 2 | 200 |
| *M. nana* | 0 | 1 | 87 | 12 | 0 | 0 | 100 |
| *M. duwei* | 0 | 0 | 4 | 96 | 0 | 0 | 100 |
| *M. painteri* | 0 | 0 | 0 | 0 | 7 | 93 | 100 |
| *M. scoria* | 98 | 0 | 0 | 1 | 0 | 1 | 100 |
| *M. tezontle* | 0 | 0 | 0 | 0 | 100 | 0 | 100 |

**Table 5.** Comparative of the morphology of *Mammillaria scoria* and close species included in the analyses.
**Tabla 5.** Comparativa de la morfología de *Mammillaria scoria* y especies cercanas incluidas en los análisis.

| **Characters** | ***M. crinita*** | ***M. duwei*** | ***M. nana*** | ***M. painteri*** | ***M. scoria*** | ***M. tezontle*** |
|---|---|---|---|---|---|---|
| Type of root | fibrous | thickened | thickened | fibrous | fibrous | fibrous |
| Axile bristles | present | present | present | absent | absent | absent |
| Number of central spines | 3.65 ± 0.61 | 1.09 ± 0.32 | 1.09 ± 0.28 | 3.57 ± 0.71 | 1.7 ± 0.78 | 2.52 ± 0.68 |
| Length of central spines | 5.45 ± 0.108 | 7.16 ± 1.08 | 6.88 ± 1.41 | 3.04 ± 0.45 | 4.25 ± 1.1 | 2.12 ± 0.39 |
| Number of radial spines | 20.11 ± 2.14 | 27.06 ± 2.80 | 28.18 ± 1.84 | 19.74 ± 2.38 | 18.86 ± 2.05 | 17.36 ± 1.59 |
| Length of radial spines | 4.84 ± 0.83 | 3.88 ± 0.6 | 5.62 ± 1.23 | 2.64 ± 0.4 | 2.68 ± 0.46 | 2.54 ± 0.56 |
| Type of seed | arillate | non-arillated | non-arillated | non-arillated | non-arillated | arillate |

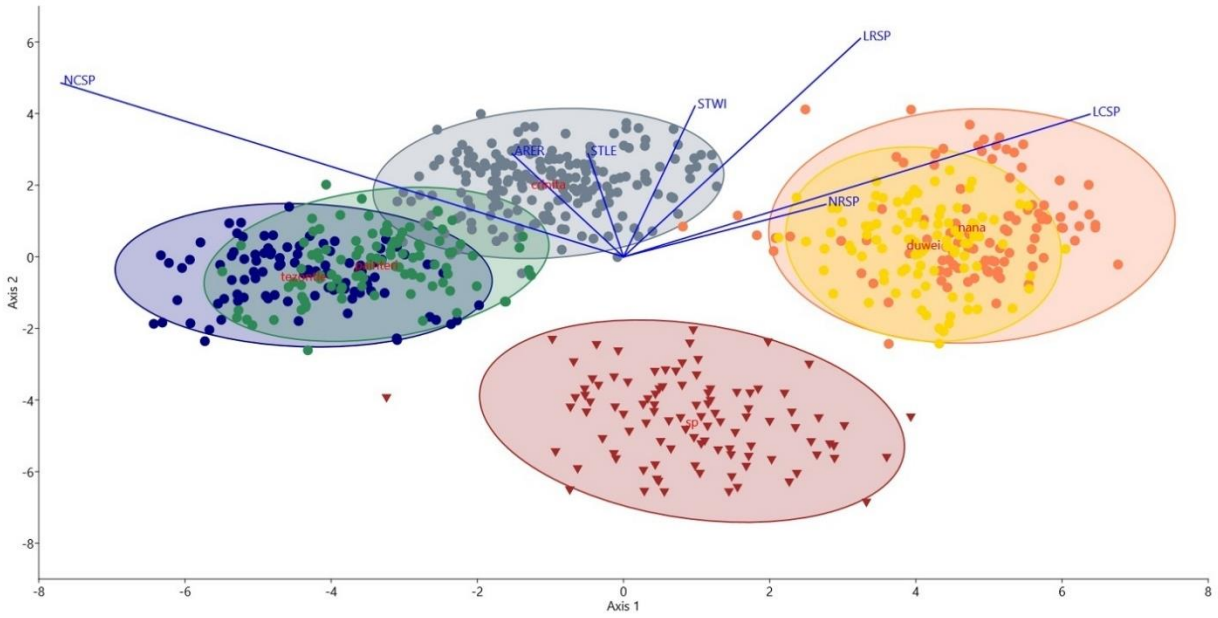


**Figure 1.** Scatter plot of the two first axis of the Linear Discriminant Analysis of seven quantitative characters and six species of *Mammillaria* ser. *Stylothelae*. Blue circles: *M. tezontle*; green circles: *M. painteri*; gray circles: *M. crinita*; yellow circles: *M. duwei*, orange circles: *M. nana*; and red triangles: *M. scoria*.
**Figura 1.** Gráfico de dispersión de los dos primeros ejes del Análisis Discriminante Lineal de siete caracteres cuantitativos y seis especies de *Mammillaria* ser. *Stylothelae*. Círculos azules: *M. tezontle*; círculos verdes: *M. painteri*; círculos grises: *M. crinita*; círculos anaranjados: *M. duwei*, círculos amarillos: *M. nana*; y triángulos rojos: *M. scoria*.

Núm. 60: 1-13 Julio 2025 ISSN electrónico: 2395-9525


**Figure 2.** Comparison of the morphology of *Mammillaria scoria* and close species included in the analyses. Rows represent species: *M. crinita* (A–D); *M. duwei* (E–H); *M. nana* (I–L); *M. painteri* (M–P). *M. scoria*. (Q-T). *M. tezontle* (U–X). Columns represent characters: Stem and root morphology (col. 1); areole and spines morphology (col. 2); plants in habitat (col. 3); SEM pictures of seeds (col. 4).

**Figura 2.** Comparativa de la morfología de *Mammillaria scoria* y especies cercanas incluidas en el análisis. Las filas representan especies: *M. crinita* (A–D); *M. duwei* (E–H); *M. nana* (I–L); *M. painteri* (M–P). *M. scoria*. (Q-T). *M. tezontle* (U–X). Las columnas representan caracteres: Morfología del tallo y raíz (col. 1); morfología de la areola y espinas (col. 2); plantas en hábitat (col. 3); imágenes de MEB de las semillas (col. 4).

Núm. 60: 1-13 Julio 2025 ISSN electrónico: 2395-9525

**Taxonomic treatment**

*Mammillaria scoria* Gonz.-Zam., D.Aquino & Dan.Sánchez sp. nov. (Fig. 3). Type: Mexico. Querétaro: Mpio. Colón, 1974 m.s.n.m, 22 November 2021, P. González-Zamora 56 (holotype MEXU, isotype IBUG).

Paratype: Mexico. Querétaro: Mpio. Colón, 1950 m.s.n.m., 30 June 2022, *D. Aquino et al. 527* (MEXU).

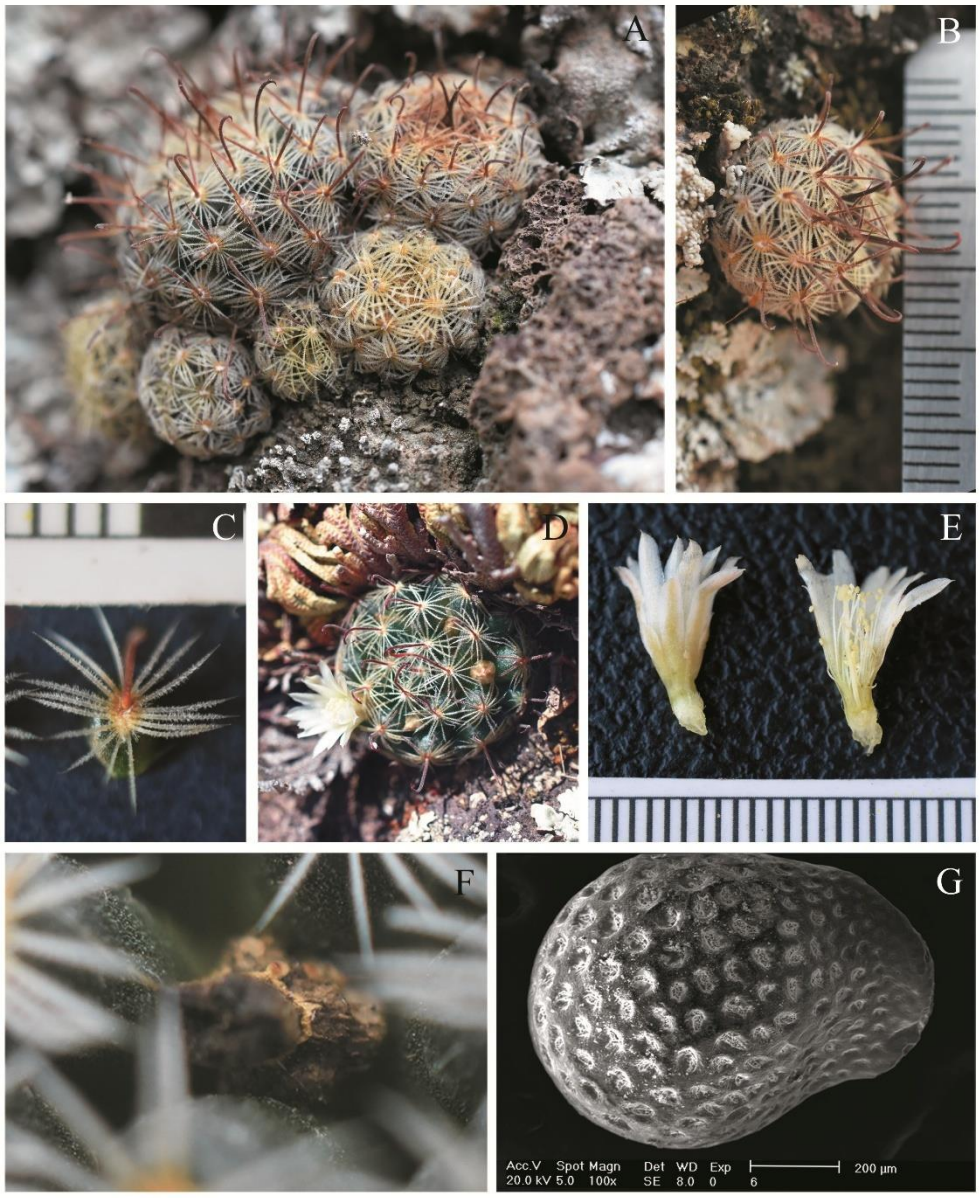


**Figure 3.** *Mammillaria scoria*. A: adult plant and aggregated juvenile plants; B: detailed size and growth form and size; C: areole shape and spine morphology; D: plant bearing flowers; E: close-up of flower morphology; F: dried fruit inserted between tubercles; G: Seed micromorphology.

**Figura 3.** *Mammillaria scoria*. A: planta adulta y plantas juveniles agregadas; C: detalle del tamaño y forma de crecimiento; C: morfología de la areola y las espinas; D: planta con flores; E: acercamiento a la morfología de la flor, F: fruto seco inserto entre los tubérculos, G: micromorfología de la semilla.

**Diagnosis**: *Mammillaria scoria* is distinguished by having, on average, 1.7 [(0)1–2(3)] central spines and 18.86 [(13)17–21(24)] radial spines (Table 3; Figs. 2–3). It possesses fibrous roots, lacks axile bristles, and produces non-arillate seeds (Figs. 2–3). The new taxon differs from *M. duwei* (Figs. 2E–2H) and *M. nana* (2I–2L), which have thickened roots and bristles in the axile. On average, *M. scoria* has fewer central spines (1.7) compared to *M. crinita* (3.65) and *M. painteri* (3.57) (Fig. 2; Table 3). In contrast, *Mammillaria tezontle* is characterized by its circular areoles (Fig. 2V) and arillate seeds (Fig. 2X), features absent in *M. scoria* (Figs. 2R, 2T).

**Description**: Stem solitary, sometimes aggregate, dark green, globose, 13–24.2 mm length, 12.9–22.2 mm width, latex watery, roots fibrous, tubercles 7–9 mm length, 4–5 mm width at the base, axiles bristle–less, areoles (0.6)0.8–0.96(1.15) mm length, (0.3)0.5–0.6(1.1) mm width, oval, central spines (0)1–2(3), at least 1 uncinate, (2)4–6(7) mm length, reddish or yellow, pubescents; radial spines (13)17–21(24), (2)2.3–3(3.5) mm length, white to yellowish, acicular, pubescents. Flowers infundibuliform, 12–15 mm length, external tepals ca. 8 mm length, yellow with a darker middle stripe, lanceolate; internal tepals ca. 10 mm length, yellow, lanceolate; filaments yellow to greenish, anthers yellow, style pale yellow, stigma yellow, 3-lobed. Fruit 5–10 mm length, globose to short claviform, red color when fresh, rapidly dry, marron, often inserted in the tubercles. Seeds black, non-arillated, testa pitted 0.9–1 mm diameter.

**Phenology**: *Mammillaria scoria* blooms from June to July, followed by the development of globose fruits from August to September. We observed that plants in the field form globose fruits, which dehydrate and remain inserted between tubercules during the dry season (Fig. 3F). In cultivation, fruits can turn to short claviform and slightly emerge from tubercules.

**Etymology**: The specific epithet refers to the substrate where the new taxon grows. In geology, scoria is a general term for pyroclasts with predominantly spherical, closed vesicles (Mangan & Cashman, 1996).

**Distribution and habitat**: *Mammillaria scoria* is endemic to central Querétaro, Mexico. This species inhabits xerophytic scrub (Rzedowski, 1978), and grows on basic extrusive igneous rock at the northern slope face (Fig. 3A, 3B). Common elements in vegetation are *Bursera fagaroides* (Kunt) Engl., *Schinus molle* L., *Cissus verticillata* (L.) Nicolson & C. E. Jarvis, *Myrtillocactus geometrizans* (Mart. ex Pfeiff.) Console, and *Opuntia streptacantha* Lem.

**Conservation status**: *Mammillaria scoria* is only known from the type locality. The population, consisting of 120 adult and 200 juvenile plants, highlights the limited distribution and vulnerability of the species. It occupy an area of ca 0.20 $km^2$. EOO resulted in 0.29 $km^2$ and AOO de 0.087 $km^2$. Following the criteria and categories of the IUCN Red List, we propose *Mammillaria scoria* as Critically Endangered (IUCN, 2024). (Fitz-Maurice, W.A. & Fitz-Maurice, B., 1997) suggest that there exists a continuous reduction of individuals of *M. tezontle* due to competition and superficiality of the substrate. Also, the change in land use for extracting build material has reduced the number of individuals to less than 10 adult plants of *M. tezontle* (pers. obs.). The same factors could occur in the location of *M. scoria*, hence we call to regional authorities to promote the conservation of this species.

**Taxonomic notes**: *Mammillaria scoria* can be accepted as an independent taxon by a unique combination of characters. The number and length of spines, as well as the absence of thickened root, axile bristles, and arillate seed are constant characters along the development in both habitat and cultivation plants (Figs. 2–3). We suggest the inclusion of *M. scoria* in *M.* ser. *Stylothelae*, based on the morphological evidence presented in this work. A phylogenetic analysis could confirm its inclusion in the series, but also, the close relationship with *M. nana* or *M. tezontle*. However, we proposed that the globose "dwarf" growth form shared with *M. tezontle* is resulted of parallelism, due to adaptation to scoria rocks (Figs. 2S, 2W). Interestingly, (Pilbeam, 1999) reported the presence of *M. nana* in El Marqués, Querétaro. Likely, this record was confused with

the new species, since they shared the oblong areoles and the color and indument of central and radial spines.
Finally, we present an identification key for *Mammillaria scoria* and close species of *Mammillaria* ser. *Stylothelae* with yellow stamens and pubescent spines.

1. Central spines >5 ……. Other species in the series (see González-Zamora *et al.* 2022)
1. Central spines <5 …… 2
2. Axiles bearing bristles ……..…...…… 3
3. Radial spines (16)18–23(25), central spines (2)3–4 ……. *M. crinita*
3. Radial spines (22)25–30(34), central spines 0–1(2) ..... 4
4. Central spines 0–1(2), white to yellow …… *M. duwei*
4. Central spines (0)1(2), reddish …… *M. nana*
2. Axiles non–bearing bristles …… 5
5. Seed with aril ……...……. *M. tezontle*
5. Seed without aril ……...……... 6
6. Circular areoles ……..……...……. *M. painteri*
6. Oblong areoles ……..……... *M. scoria*

**Additional specimens examined:** *Mammillaria crinita* DC. Mexico. Hidalgo: Mpio. Tecozautla, south shore of Presa Zimapán, 1568 m elev., 28 March 1995, *W.A. Fitz Maurice & B. Fitz Maurice 2372* (MEXU); east shore of Presa Zimapán, 1609 m elev., 17 July 1995, *W.A. Fitz Maurice & B. Fitz Maurice 2379* (MEXU). Mpio. Zimapán, Cerro cercano al cementerio del poblado de Tenguedho, a 2.7 km al este del libramiento de Zimapán, 2017 m elev., 18 October 2015, *E. Asturiano et al. 92* (MEXU); east of Aguas Blancas, 1908 m elev., 12 December 1994, *W.A. Fitz Maurice & B. Fitz Maurice 2346* (MEXU). Guanajuato: Mpio. Atarjea, aproximadamente 5 a 6 km sobre la terracería Aldama – Atarjea, 2216 m elev., 19 June 2014, *S. Arias & D. Aquino 2225* (MEXU); +/- 9 km de Xichú, por la brecha a Atarjea, 1249 m elev., 30 May 1996, *E. Pérez-Calix & S. Zamudio 3340-A* (IEB). Mpio. Victoria, ca. 2 km al N de Puerto de Palmas, sobre camino a Álamos de Martínez, 1634 m elev., 17 November 1995, *R. T. Bárcenas et al. 817* (MEXU), near La Laguna, 1300 m elev., 20 March 1996, *W.A. Fitz Maurice & B. Fitz Maurice 2391* (MEXU), South of Las Higueras, 1900 m elev., 04 November 1996, *W.A. Fitz Maurice & B. Fitz Maurice 2397* (MEXU). Querétaro: Mpio. Cadereyta de Montes, este de Tolimán, 2159 m elev., 03 September 2022, *D. Aquino & P. González-Zamora 540* (MEXU); Mesa León, 1900 m elev., 26 October 1997, *W.A. Fitz Maurice & B. Fitz Maurice 2402* (MEXU); Barranca del Sordo, 2048 m elev., 01 September 2004, *E. Sánchez et al. 76* (MEXU); El Palmito, 2064 m elev., 27 October 2004, *E. Sánchez 92* (MEXU); San Pablo Toliman – Higuerillas, 1948 m elev., 08 February 2002, *E. Sánchez 122* (MEXU). Mpio. Colón, N de Colón, 1898 m elev., 03 September 2022, *D. Aquino & P. González-Zamora 539* (MEXU); north of Colón, 1900 m elev., 18 October 1991, *W.A. Fitz Maurice & B. Fitz Maurice 2182* (MEXU); 2.6 km al OSO de San Martín, 2025 m elev., 20 May 2014, *O. Rubio 876* (IEB). Mpio. Peñamiller, near Molinitos, 1900 m elev., 21 December 1994, *W.A. Fitz Maurice & B. Fitz Maurice 2384* (MEXU). Mpio. Tolimán, km 48 South of Tolimán, 2100 m elev., 01 March 1992, *W.A. Fitz Maurice & B. Fitz Maurice 2187* (MEXU, DES), South of Camarco [Camargo], 1500 m elev., 10 March 1995, *W.A. Fitz Maurice & B. Fitz Maurice 2370* (MEXU), Panales, 1766 m elev., 19 November 1986, *U. Guzmán 685* (ANSM), km 49.3 de la carretera Bernal – Toliman, 1950 m elev., 25 April 2013, *O. Rubio 523* (QMEX), laderas de rocas ígneas cercanas a Tolimán, Querétaro, 1634 m elev., 27 November 1973, *H. Sánchez-Mejorada 2193* (MEXU).
*Mammillaria duwei* Rogoz. & P. J. Braun. Mexico. Guanajuato: Mpio. San Luis de la Paz, entre San Luis de la Paz y sitio La Luz, 2023 m elev., 28 February 1987, *L. Scheinvar 4816* (MEXU). Mpio. Victoria, east of San Luís de la Paz, 1850 m elev., 17 March 1987, *W.A. Fitz Maurice & B. Fitz Maurice 1641* (MEXU, DES); cerro al NE del Rancho La Luz, a 19 km al E de San Luís

de la Paz por camino a Xichú, 2053 m elev., 01 June 1993, *H. Hernández & R. Bárcenas 2541* (MEXU).
*Mammillaria nana* Backeb. Mexico. Guanajuato: Mpio. San Diego de la Unión, brecha a Vergel de Guadalupe, 2115 m elev., 09 December 2015, *S. Arias & D. Aquino 2255* (MEXU); north of San Luís de la Paz, 2094 m elev., 27 January 1990, *W.A. Fitz Maurice & B. Fitz Maurice 1988* (MEXU); microondas west of km 113, carretera 57, 2054 m elev., 27 January 1990, *W.A. Fitz Maurice & B. Fitz Maurice 1989* (MEXU); west of El Vergel de Guadalupe, 2171 m elev., 27 March 1995, *W.A. Fitz Maurice & B. Fitz Maurice 2371* (MEXU). Mpio. San Miguel de Allende, 1.5 km N del cruce del libramiento Dolores Hidalgo y camino a la estación de ferrocarril de San Miguel de Allende, 1920 m elev., 16 August 1992, *R. T. Bárcenas 08* (MEXU). San Luis Potosí: Mpio. Santa María del Río, carretera a Lourdes, 1814 m elev., 02 September 2022, *D. Aquino & P. González-Zamora 533* (MEXU); Tepozán, 1890 m elev., 02 September 2022, *D. Aquino & P. González-Zamora 536* (MEXU); old road to Lourdes, 1700 m elev., 21 October 1989, *W.A. Fitz Maurice & B. Fitz Maurice 1980* (MEXU, DES); new road to Lourdes, 1800 m elev., 13 July 1991, *W. A. Fitz Maurice & B. Fitz Maurice 2144* (MEXU, DES). Mpio. Zaragoza, SE of Zaragoza, 1945 m elev., 29 October 1986, *W.A. Fitz Maurice & B. Fitz Maurice 1606* (MEXU); SW of Zaragoza, 1870 m elev., 29 October 1986, *W.A. Fitz Maurice & B. Fitz Maurice 1607* (MEXU); Cañón Yañez, 1900 m elev., 07 November 1986, *W.A. Fitz Maurice & B. Fitz Maurice 1609* (MEXU); K175 southeast of SLP, 1900 m elev., 07 November 1986, *W.A. Fitz Maurice & B. Fitz Maurice 1610* (MEXU).
*Mammillaria painteri* Rose. Mexico. Querétaro: Mpio. Amealco de Bonfil, Cañón Amealco, 1800 m elev., *W.A. Fitz Maurice & B. Fitz Maurice 2028* (MEXU, DES); Barranca de Amealco, +/- 10 km al S de Galindo, 1987 m elev., 23 March 1998, *S. Zamudio & L. Hernández 10682* (MEXU, IEB). Mpio. Cadereyta de Montes, al SE de Cadereyta de Montes, 2090 m elev., 13 October 2010, *U. Guzmán 3746* (IEB). Mpio. El Marqués, east of La Cañada, 1955 m elev., 02 March 1992, *W.A. Fitz Maurice & B. Fitz Maurice 2188* (DES); La Cañada, 1955 m elev., 06 May 1987, *L. Scheinvar 5051* (MEXU). Mpio. San Juan del Río, 12 km east of San Juan del Río, 1900 m elev., 01 May 1987, *W.A. Fitz Maurice & B. Fitz Maurice 1646* (MEXU, DES). Mpio. Tequisquiapan, Al suroeste de la Trinidad, en el camino a la mina, 2089 m elev., 07 July 2004, *E. Sánchez 70* (MEXU); La Trinidad, 2082 m elev., *E. Sánchez et al. 192* (MEXU).
*Mammillaria tezontle* W.A.Fitz Maur. & B.Fitz Maur. Mexico. San Luis Potosí: Mpio. Soledad de Graciano Sánchez, km 32.5 # 57 northeast of SLP, 1900 m elev., 25 October 1989, *W.A. Fitz Maurice & B. Fitz Maurice 1983* (MEXU); [ca.] Villa Hidalgo, 1900 m elev., *W.A. Fitz Maurice & B. Fitz Maurice 2015* (MEXU).

## DISCUSSION

Multivariate analysis revealed significant differences between *Mammillaria scoria* and comparative taxa. The new taxon presents on average 1.7 central spines (0.425 mm in length) and 18.86 radial spines (Table 3). Additionally, *M. scoria* lacks thickened roots, axile bristles, and arillate seed (Figs. 2Q–2T; see Diagnosis). This set of characters have proven useful in delineating species within *M.* ser. *Stylothelae* (González-Zamora *et al.*, 2022; González-Zamora *et al.*, 2023; Ortiz-Brunel *et al.*, 2023). *Mammillaria scoria* grows on extrusive basic igneous rock (CETENAL, 1973a) (Fig. 2S), similar to *M. tezontle*, which inhabits basalt igneous rock (CETENAL, 1973b) (Fig. 2W). However, the two species are separated by 206 km, and *M. tezontle* is distinguished by its arillate seeds (Fig. 2X). Although phenotypic plasticity could be invocated to explain the morphological variation found in *M. scoria*, plants in cultivation have developed the same morphology as plants in their habitat. They consistently lack thickened roots (Fig. 2Q) and spine length remains within the same range (Fig. 2R). We also observed this consistency of morphological characters in *M. tezontle* (Figs. 2U–2V) as previously reported (Fitz-Maurice & Fitz-Maurice, 2009).
As noted in previous work (González-Zamora *et al.*, 2022), the broad concept of *M. crinita* (Fitz-Maurice & Fitz-Maurice, 2009) is not supported. Recent phylogenomic analyses demonstrated

that different samples of *M. crinita* did not form a monophyletic group (Ortiz-Brunel, 2025). Morphological analyses confirmed *Mammillaria scoria* as a diagnosable entity.

## CONCLUSION

Based on these findings, we propose and describe a new species of *M*. ser. *Stylothelae* from Querétaro, Mexico, highlighting its unique morphological and ecological traits.

## ACKNOWLEDGEMENTS

Authors thank to the staff of DES, IBUG, and MEXU. We are grateful to Dr. Alfredo Flores Valdés and Miguel Aguilar González of the CINVESTAV Unidad Saltillo for MEB pictures of seeds. We appreciate the comments and suggestion of the editor and anonymous reviewers.

## LITERATURE CITED

Aquino-García, D. (2014). *Delimitación de las especies de Mammillaria serie Polyedrae (Cactaceae).* Tesis de Maestría, Universidad Nacional Autónoma de México, Ciudad de México.

Arias, S., Aquino, D. (2019). FAMILIA CACTACEAE I. *Flora del Bajío y de Regiones Adyacentes*.

Bachman, S., Moat, J., Hill, A. W., Torre, J. de, & Scott, B. (2011). Supporting Red List threat assessments with GeoCAT: geospatial conservation assessment tool. *ZooKeys*. (150), 117–126.

Breslin, P. B., Wojciechowski, M. F., & Majure, L. C. (2021). Molecular phylogeny of the Mammilloid clade (Cactaceae) resolves the monophyly of *Mammillaria*. *TAXON, 70*(2), 308–323.

Cervantes, C. R., Hinojosa-Alvarez, S., Wegier, A., Rosas, U., & Arias, S. (2021). Evaluating the monophyly of *Mammillaria* series *Supertextae* (Cactaceae). *PhytoKeys, 177*, 25–42.

CETENAL (1973a). Hoja Villa del Marqués (F-14-C-66), Querétaro. *Secretaría de Programación y Presupuesto. Comisión de Estudios del Territorio Nacional (actualmente INEGI)*, Escala 1:50000.

CETENAL (1973b). Hoja Villa Hidalgo (F-14-A-74), San Luis Potosí. *Secretaría de Programación y Presupuesto. Comisión de Estudios del Territorio Nacional (actualmente INEGI)*, Escala 1:50000.

Chincoya, D. A., Arias, S., Vaca-Paniagua, F., Dávila, P., & Solórzano, S. (2023). Phylogenomics and Biogeography of the Mammilloid Clade Revealed an Intricate Evolutionary History Arose in the Mexican Plateau. *Biology, 12*(4), 512.

Fitz-Maurice, W.A. & Fitz-Maurice, B. (1997). Fieldnotes – *Mammillaria tezontle* – a long-term study. *Cactus and Succulent Journal, 64*(4), 190–194.

Fitz-Maurice, W.A., & Fitz-Maurice, B. (1995). *Mammillaria tezontle* sp. nov. *Cactáceas y Suculentas Mexicanas, 40*(3), 59–62.

Fitz-Maurice, W.A., & Fitz-Maurice, B. (2009). *Stylothelae* Dilemmas, Old and New. *Cactus and Succulent Journal, 81*(4), 210–213.

González-Zamora, P., Aquino, D., Mohl, J., Sánchez, D. (2022). A new endemic species of *Mammillaria* (Cactaceae) from San Luis Potosí, Mexico. *Willdenowia, 52*(3), 359-372.

González-Zamora, P., Aquino, D., Rodríguez, A., Sánchez, D. (2023). *Mammillaria monochrysacantha* (Cactaceae), a new endemic species from Guanajuato, Mexico. *Phytotaxa, 618*(3), 243–253.

***Recibido:***
*6/marzo/2025*

***Aceptado:***
*12/junio/2025*

Hammer, O., Harper, D. A. T., & Ryan, P. D. (2001). PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia electrónica, 4*(1), 1–9, from https://palaeo-electronica.org/2001_1/past/issue1_01.htm.

Hernández, H. M., & Gómez-Hinostrosa, C. (2015). *Mapping the cacti of Mexico. Part II: Mammillaria.* Milborne Port, UK: dh Books.

Hunt, D. R., Taylor, N. P., & Charles, G (2006). *The New Cactus Lexicon, text, and atlas.* Milborne Port, UK: dh Books.

IUCN (2024). *Guidelines for using the International Union for Conservation of Nature Red List categories and criteria: Ver. 15.1,* from https://www.iucnredlist.org/resources/redlistguidelines.

Korotkova, N., Aquino, D., Arias, S., Eggli, U., Franck, A., Gómez-Hinostrosa, C., et al. (2021). Cactaceae at Caryophyllales.org – a dynamic online species-level taxonomic backbone for the family. *Willdenowia, 51*(2), 251-270.

Lüthy, J. M. (1995). *Taxonomische Untersuchung der Gattung Mammillaria Haw.* Ph.D. Dissertation, Universität Bern.

Mangan, M. T., & Cashman, K. V. (1996). The structure of basaltic scoria and reticulite and inferences for vesiculation, foam formation, and fragmentation in lava fountains. *Journal of Volcanology and Geothermal Research, 73*(1-2), 1–18.

Ortiz-Brunel, J. P. (2025). *Evolución y biogeografía de Mammillaria serie Stylothelae (Cactaceae).* PhD dissertation, Universidad de Guadalajara.

Ortiz-Brunel, J. P., Carrillo-Reyes, P., Sánchez, D., Ruíz-Sánchez, E., & Rodríguez, A. (2023). A morphological analysis of the *Mammillaria fittkaui* species complex (Cactaceae) reveals a new species from Jalisco, México. *Botanical Sciences, 101*(2), 619–631.

Pilbeam, J. (1999). *Mammillaria. The cactus handbook 6.* Southampton, UK: Cirio Publishing Services.

Rzedowski, J. (1978). *Vegetación de México.* Mexico: Editorial Limusa.

Schneider, C. A., Rasband, W. S., & Eliceiri, K. W. (2012). NIH Image to ImageJ: 25 years of image analysis. *Nature methods, 9*(7), 671–675.

Tabachnick, B. G., & Fidell, L. S. (2012). *Using multivariate statistics: (6th ed.).* Boston, US: My Publisher.

Thiers, B. M. (2024+). *Index Herbariorum: A global directory of public herbaria and associated staff.*