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Graptopetalum trujilloi (Crassulaceae), a new haplostemonous and critically endangered species endemic to western Mexico: comments on taxa of subg. *Glassia*

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Abstract

Graptopetalum trujilloi (subg. *Glassia*, Crassulaceae), a new haplostemonous species from San Gabriel municipality, Jalisco, Mexico is described and illustrated. Its morphologically closest species is *G. rosanevadoense*. It differs from the latter in having a smaller habit, more numerous primary branches per inflorescence, larger mean flower density per 10 cm of the scape, fewer flowers per basal branch, smaller flower diameter, petals greenish with transversal inconspicuous red stripes, narrower petals, filaments greenish to distally reddish and carpels abaxially obtuse. A key to the haplostemonous species of *Graptopetalum* is provided and, according to IUCN criteria, the species was assessed as critically endangered (CR).

Resumen

Se describe e ilustra *Graptopetalum trujilloi* (Crassulaceae), una especie haplostémona nueva del municipio de San Gabriel, Jalisco, México. Su especie morfológicamente más cercana es *G. rosanevadoense*. Se diferencia de esta última en tener un hábito más pequeño, más ramas primarias por inflorescencia, un promedio más alto de densidad de flores por cada 10 cm del escapo, menos flores por rama basal, diámetro de la flor más pequeño, pétalos verdosos con franjas transversales rojas inconspicuas, pétalos más estrechos, filamentos verdosos a distalmente rojizos y carpelos obtusos abaxialmente. Se proporciona una clave para las especies haplostémonas de *Graptopetalum* y, de acuerdo con los criterios de la UICN, la especie se evaluó como en peligro crítico (CR).

Keywords: Allopatric speciation, Armería River, Nueva Galicia, Pentandrous, Sierra de Tapalpa.

Introduction

Graptopetalum Rose (1911: 296) is a genus of the Crassulaceae family comprising 21 species from semi-arid environments in Arizona, southern US to Oaxaca, Mexico, including the one here described (Moran & Uhl 1968, Thiede 2003, Thiede & Eggli 2007, Vega-Aviña *et al.* 2020, Vázquez-García *et al.* 2021a). Eight species of *Graptopetalum* (38%) are endemic to the western Mexico (Acevedo-Rosas *et al.* 2018, Vázquez-García *et al.* 2021a), one from the state of Colima: *G. glassii* Acevedo-Rosas & Cházaro-Basáñez (2003: 378) from the municipalities of Colima, Ixtlahuacán and Tecomán (Cházaro-Basáñez & Acevedo-Rosas 2008, Naturalista 2021); one from Michoacán: *G. pentandrum* Moran (1971: 56) from the waterfalls of El Salto, 4 km north of Aguililla (Kimnach 1987), and Los Chorros del Varal, 20 km southwest of Los Reyes (Cházaro-Basáñez & Flores 1992, Cházaro-Basáñez *et. al.* 2004); one from the state of Nayarit: *G. marginatum* Kimnach & Moran (2002: 74) from Mirador del Águila (Cházaro-Basáñez *et. al.* 2012); and five from the state of Jalisco: *G. amethystinum* (Rose 1905: 11) Walther (1931: 73) from the Sierra de Bolaños (Cházaro-Basáñez & Flores 1999), *G. fruticosum* Moran in Moran & Uhl (1968: 152) from southern

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and central part of the state (Lomelí-Sención 1988), *G. pachyphyllum* Rose (1922: 45) from the region of Ojuelos (Cházaro-Basáñez & Thiede 1995), *G. rosanevadoense* A.Vázquez & Acev.-Rosas in Vázquez-García *et al.* (2021: 162) from the Nevado de Colima (Vázquez-García *et. al* 2021a) *G. superbum* (Kimnach 1987: 142) Acev.-Rosas in Acevedo-Rosas & Cházaro-Basáñez (2003: 380) from Los Corrales ravine, Juchitlán (Cházaro-Basáñez & Flores 1992), and *G. trujilloi*, proposed here as new.

In September 2008, J. A. Vázquez-García and collaborators visited San Gabriel municipality, Jalisco, and collected plants of a *Graptopetalum* species. Preliminary field observations and data measurements on living specimens that later bloomed in Zapopan, Jalisco, generated suspicion that it might be a new species, but supplementary material was needed. Santiago Rosales recently revisited the locality in June 2021 to document in situ variability and habitat characteristics. Based on a comprehensive revision of the haplostemonous species of *Graptopetalum* and subsequent field surveys, we confirm that the plants from San Gabriel municipality belong to a new species, that we here describe.

Among the above-mentioned species of *Graptopetalum* five comply with the subg. *Glassia* Byalt (2012: 79), endemic to Western México (Fig. 1), a region known as Nueva Galicia. Some of these species constitute a well-supported subclade characterized by sharing the synapomorphy of haplostemony (pentandrous flowers), a common character to five species: *G. glassii*, *G. pentandrum*, *G. rosanevadoense*, *G. superbum*. However, the monophyly of this clade remains to be tested with the inclusion of all the species including the one here proposed as new.

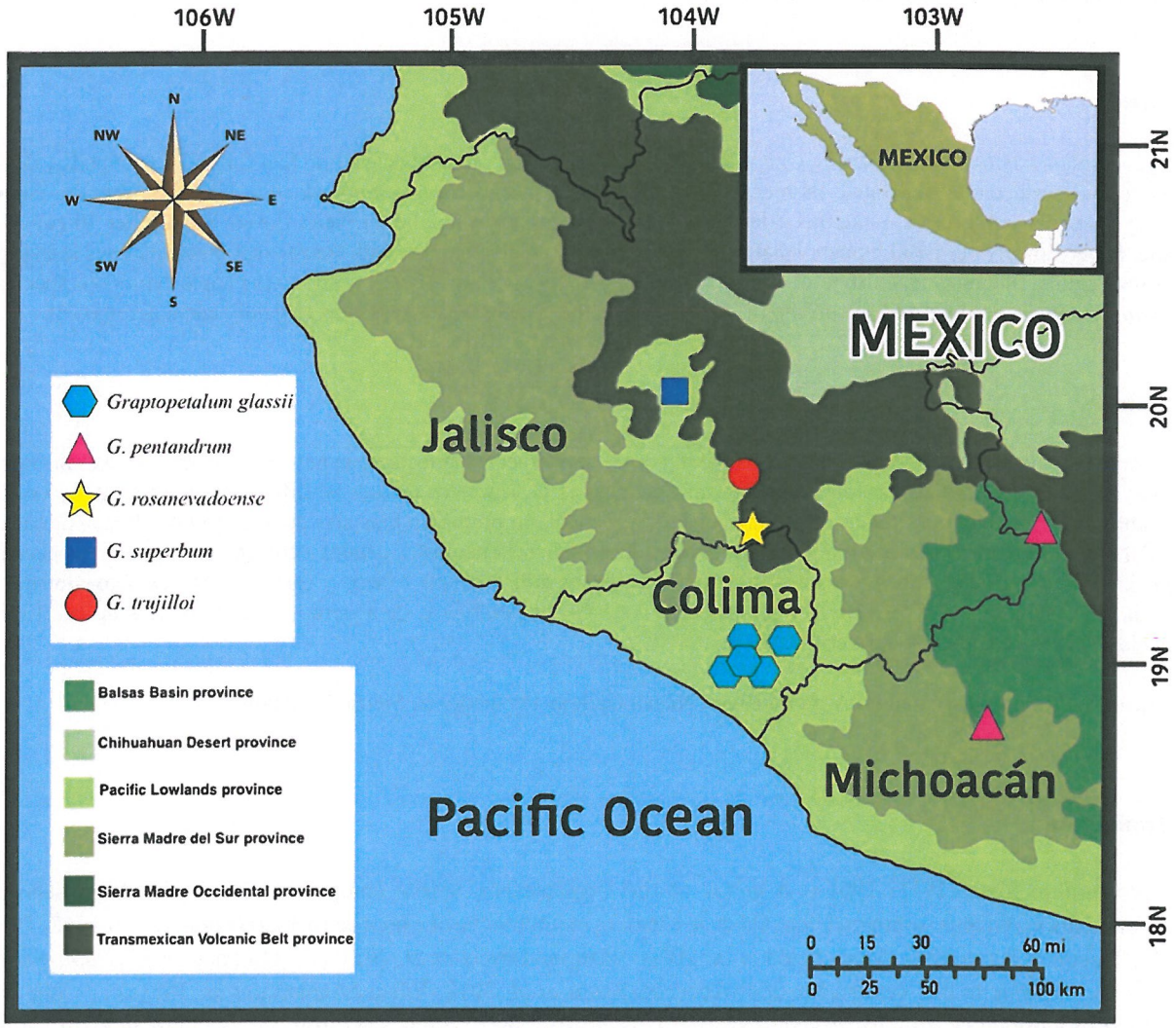

FIGURE 1. Distribution of haplostemonous species of *Graptopetalum* in western Mexico, overlayed on biogeographic provinces (Morrone 2017).

Material and methods

To document the morphological variation of the species, data measurements obtained from the collected specimens (7) and living plants (8) were complemented with the morphological characters observed during field surveys carried each season. We used the General lineage species concept of De Queiroz (2007) and in the broadest possible perspective (Christenhusz 2020).

Plants from San Gabriel municipality, Jalisco, were contrasted with morphological data against all the known haplostemonous species, *Graptopetalum glassii*, *G. pentandrum*, *G. rosanevadoense* and *G. superbum* (Table 1), and also against another geographically close species, *G. fruticosum*. We particularly focused on the comparison of morphological characters from protologues and descriptions, as well as living specimens of *G. trujilloi* (8 individuals from the only known population), *G. rosanevadoense* (8 individuals from 4 populations) and *G. superbum* (3 individuals from the only known population) (Fig. 2).

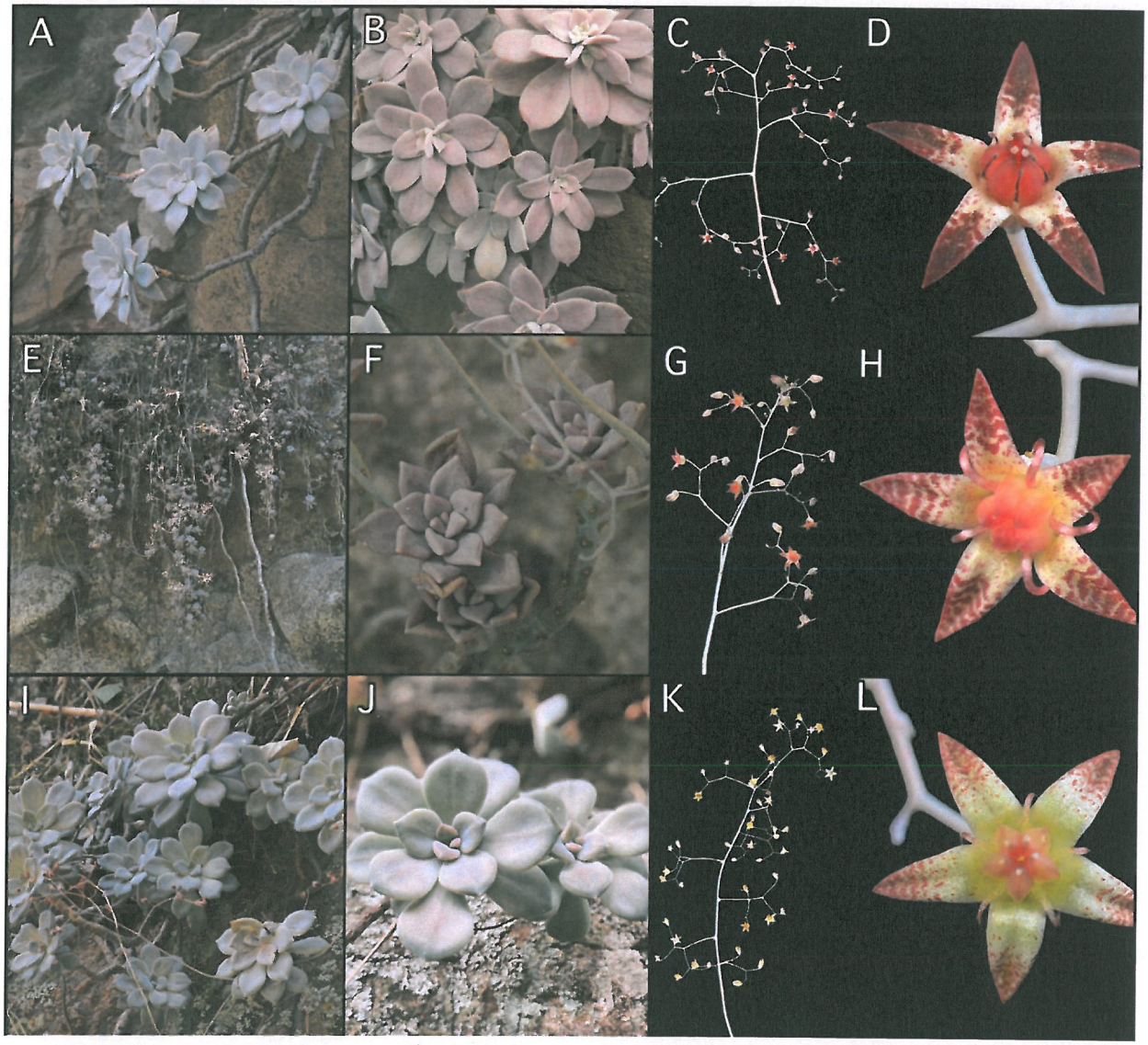

FIGURE 2. Comparison among morphologically close species. *Graptopetalum superbum* A–D, A. Decumbent rosettes, B. Basal leaves wide, C. Inflorescence branches long and bifurcated, D. Flowers with red-wine petal tips. *G. rosanevadoense* E–H, E. Pendant rosettes, F. Basal leaves narrow, *G. Inflorescence* branches of intermediate length, H. Flowers with red striped petal tips. *G. trujilloi*. I–L. I. Prostrate rosettes. J. Subequal basal leaves. K. Inflorescence branches short. L. Greenish flowers with inconspicuous red stripes. Photographs: A–I and K–L by J. Etter & M. Kristen, J by Santiago Rosales.

The distribution map of the haplostemonous species of *Graptopetalum* was generated from georeferenced herbarium records and from NaturaLista (2021) with overlays of the shapefile of biogeographic provinces by Morrone (2017) (Fig. 1).

The conservation status was assessed following the guidelines of IUCN Red List Criteria (IUCN 2019). The Area of Occupancy (AOO) and the Extent of Occurrence were calculated using the GeoCat cloud software tool: https://www.kew.org/science/our-science/projects/geocat-geospatial-conservation-assessment-tool (Bachman *et al.* 2001).

Results

The comparative analysis of *in situ* plants from north of San Gabriel, Jalisco, and the closest related morphological species, *Graptopetalum rosanevadoense* and *G. superbum*, allowed us to unveil that these populations belong to a new species of *Graptopetalum* subg. *Glassia*, since the major characters did not match with any other member of the genus. *Graptopetalum* sp. shared with its closest morphological species, *G. rosanevadoense*, similar habit, stem surface and stem diameter, but differed from the latter in plant size (stem and rosette without scape), number of primary branches per inflorescence, number of flowers per basal branch, flower diameter, petal width and mean flower density per 10 cm of the scape. It shared with *G. superbum* a similar habit, rosette diameter and mean flower density per 10 cm of the scape, but differed from the latter in stem surface, stem diameter, inflorescence length, number of primary branches per inflorescence and flower diameter (Table 1).

All five species together were micro endemic to a small area (<100 km of radius) belonging to a specific micro watershed (Table 2). Each one was confined to a single location, except *Graptopetalum pentandrum* reported from two distant localities (85 km apart) in the Michoacán state, one in Los Reyes municipality and the other in the Aguililla municipality (Table 2).

TABLE 1. Morphological differences among species of *Graptopetalum* subg. *Glassia.*

	G. superbum	***G. trujilloi***	*G. rosanevadoense*	*G. glassii*	*G. pentandrum*
Plant habit	Ramose; pendant, decumbent or erect	Ramose; pendant	Ramose; pendant	Cespitose	Cespitose-ramose
Plant size including stem and rosette, without scape (cm)	40–80.0	15.0–35 (–41)	40.0–87.0	16.0–20.0	39.0–41.0
Rosette diameter (cm)	9.0–11.0	9.0–11.0 (–12.0)	10.0–16	2.0–4.0	6.0–8.0
Stem surface	Squamose	Smooth	Smooth	Smooth	Smooth
Stem diameter (mm)	10.0–12.0	6.0–8.0	7.0–8.0	3.0–5.0	3.0–6.0
Leaf length (cm)	4.0–5.5	4.0–7.5	1.5–5.9 (–7.6)	1.3–2.0	2.0–4.0
Leaf form	Oblong-obovate	Obovate	Oblong-obovate	Oblanceolate	Obovate
Leaf colour	Gray-bluish to pink-violet	Glaucous greenish to pinkish	Glaucous to brownish green, pink when young	Blue-greenish to white-greenish	Blue-greenish to white-bluish
Inflorescence length (cm)	30.0–40.0	15.0–32.0	9.8–60*	6.0–12.0	20.0–35.0 cm
Number of primary branches per inflorescence	12–15	8–10	5–7	1–2 (–3)	3–5

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TABLE 1. (Continued)

	G. superbum	***G. trujilloi***	*G. rosanevadoense*	*G. glassii*	*G. pentandrum*
Number of flowers per primary branch	8–15	3–7	2–7	8–20	1– 12
Flower diameter (mm)	15.0–16.0	12.9–13.1	14.9–15.1	12.0–19.0*	17.0–19.0
Petal width (mm)	2.0–2.7	2.7–2.8	2.9–3.0	3.5-3.6	1.7–1.8
Abaxial carpel	Obtuse to rounded	Obtuse	Rounded	Rounded	Obtuse
Number of flowers per basal branch	8–12	3–6	7–8	4–10	1–12
Number of flowers per inflorescence	57–121	30–50	14–34	15–35	6–43*
Mean flower density per 10 cm of the scape	19–30	16–20	6–14	13–29	3–12

* Updated values from additional material (herbarium specimens, living plants and pictures).

TABLE 2. Conservation status and habitat differences among haplostemonous species of *Graptopetalum* in western México.

	G. superbum	***G. trujilloi***	*G. rosanevadoense*	*G. glassii*	*G. pentandrum*
Physiography	Sierra de Amula, Jalisco	Sierra de Tapalpa, SE low valleys, Jalisco	Nevado de Colima Low valleys southwest, Jalisco	Cordillera Costera, Colima	Sierra de Coalcomán & Barranca del Río Itzicuaro, Michoacán
Biogeographic province	Pacific Lowlands	Transmexican Volcanic Belt	Transmexican Volcanic Belt	Pacific Lowlands	Balsas Basin
Micro watershed / Subwatershed /Watershed	Juchitlán Río Ayuquila Río Armería	Tapalpa Río Tuxcacuesco Río Armería	Alseseca - Río Armería	La Salada - Río Armería	Itzícuaro, Aguililla Tepalcatepec Río Balsas
Elevation (m)/ Mean annual precipitation (mm)	1200 852	1400 819	1400 700	410 380	1280, 920 922, 1000
Flowering	Late March to early June	Early March to April	April to May & perhaps in November	Late February to April or early May	April & May
Threats	Over-collected	Deforestation, flooding, landslide, recreation	Over-collected	Gypsum mining	Tourism
Conservation status (IUCN 2019)	Critically endangered A3d, B1,2a,biii	Critically endangered A3d, B1,2a,biii	Critically endangered A3d, B1,2a,biii	Endangered B1, B2, a, b	Critically endangered A3d, B1,2,biii
Ex-situ collections	IBUG	IBUG, Rosales-Martínez	IBUG	Etter & Kristen	Etter & Kristen

Two species, *Graptopetalum rosanevadoense* and *G. trujilloi*, occurred in the Transversal Volcanic Belt province, two more, *G. superbum* and *G. glassii*, thrived in the Pacific Lowland province and one, *G. pentandrum* in the Balsas Basin province (Table 2). Most of the species inhabited elevations ranging from 900 to 1400 m, except *G. glassii*, which thrived at a low elevation of 500 m. The geographically closest species to *G. trujilloi* were *G. rosanevadoense* and *G. superbum*, the three species inhabited deep ravines ("barrancas"), on different subwatersheds (Tapalpa-Tuxcacuesco,

Alseseca, and Juchitlán-Ayuquila, respectively). In terms of geology, *Graptopetalum glassii* and one population of *G. pentandrum* were confined to limestone, while the other three species inhabited soils derived from igneous substrates. *Graptopetalum glassii* is the only species of the genus endemic to gypseous soils in Colima state. Most species thrived under rainfall regimes between 700–1000 mm MAP, except *G. glassii* that thrived under more xeric conditions, at 380 mm MAP (Table 2).

Four of the five species occurred in a single watershed, the Armería river, each on a particular micro watershed (Table 2). Two of them, *Graptopetalum rosanevadoense* and *G. trujilloi*, were associated with permanent streams, one, *G. superbum,* was on a rocky ravine, while *G. glassii* faced moist winds from the Pacific Ocean, located 28–45 km away. The fifth species, *G. pentandrum,* inhabited rocky outcrops near waterfalls, in Michoacán.

Rosette habit was variable throughout the year; they tended to be larger and turgent during summer, small in the winter and somewhat dehydrated in late spring. All the species had a flowering peak in spring and fruits dehisced late May to early June. (Table 2).

All five haplostemonous species met the IUCN (2019) criterion A3, implying inferred or suspected population reduction, based on current or potential levels of exploitation. We assessed four of them, including *Graptopetalum trujilloi*, as critically endangered, each under a particular set of threats: natural disasters (flooding and landslides) or anthropic pressures (tourism, overcollection, deforestation). *G. superbum*, *G. trujilloi* and *G. rosanevadoense*, met the criteria Ba,2a,b,iii implying the reduced extent of occurrence (EOO) and area of occupancy (AOO), while *G. pentandrum* met a slightly different criteria Ba,2b,iii, being in more than one location. We confirmed the existence of living plants of these species on ex situ collections including HNT, IBUG or in private collections (Table 2). Private collections hosted three critically endangered species (Table 2). We assessed only one species, *Graptopetalum glassii,* as endangered, meeting the following criteria: B1, EOO is less than <5000 km^2; B2, AOO <500 km^2, (a) severely fragmented; and (b) inferred decline of quality of habitat through land-use change, from mining and agricultural expansion. Private living collections included this species, and several nurseries had plants of this species for sale (Table 2).

Discussion

Graptopetalum trujilloi morphologically belongs to a very small subgroup within *Graptopetalum* subg. *Glassia* (Byalt 2012) that is defined by a synapomorphy, the haplostemony state (Acevedo-Rosas *et al.* 2004a, 2004b), a distinctive character consisting of a single whorl of stamens (5 stamens alternate to the petals), instead of two whorls (10 stamens), typical of the family Crassulaceae.

Comparative morphology illustrated relevant differences of our population samples from all four published species in this subgenus (Moran 1971, Kimnach 1987, Acevedo-Rosas & Cházaro 2013, Vázquez-García *et al.* 2021a), deserving to be considered as a new species. *Graptopetalum rosanevadoense* and *G. superbum* are considered as the morphological and geographical closest species to *Graptopetalum trujilloi* (Table 1 & 2 Fig. 2).

Morphological and molecular data of subg. *Glassia* display a moderate to well-supported subclade within the genus and a strong geographic structure in the phylogeny (Acevedo-Rosas *et al.* 2004a, 2004b). However, relationships remain to be focused within *Graptopetalum* subg. *Glassia*, with the inclusion of the recently discovered taxa, *G. rosanevadonse* (Vázquez-García *et al.* 2021a) and *G. trujilloi* (here described), and the clonotype of *G. pentandrum* (in Huntington Botanical Gardens) and the population from the Aguililla municipality (Kimnach 1987).

Phylogenetic analyses in Crassulaceae (Mort *et al.* 2001, Mayuzumi & Ohba 2004) indicate that haplostemony is an exclusive feature of the "Crassula clade" and the "Telephium clade". But these five haplostemonous species of *Graptopetalum* subg. *Glassia* seem to demonstrate that this character independently arose more than twice in the family, i.e., in the African *Crassula* Linnaeus (1753: 282), the Asian *Sinocrassula* Berger (1930: 462) and the American genera *Graptopetalum* and *Sedum* ("Acre clade"). However, the evolutionary process that gave rise to pentandrous flowers (haplostemony) within the family remains uncertain and needs to be investigated, especially since we have witnessed the occurrence of heptameric and tetramerous flowers in *G. glassii* and *G. trujilloi* in ex situ collections, respectively.

Most likely, the recently described pentandrous species, *G. rosanevadoense* and *G. trujilloi*, belong to the haplostemonous clade, a derived group within the caulescent *Graptopetalum* (Acevedo-Rosas *et al.* 2004a, 2004b). Sharing a common ancestor that may have had a wide distribution promoted diversification after the emergence of geographic barriers such as mountains and ravines, preventing genetic flow, thus resulting in the observed pattern of allopatric speciation, similar to that reported for *Magnolia* on a regional scale in western Mexico (Vázquez-García *et*

*a*l. 2021b). The newly formed orogeny and geology of the Trans Mexican Volcanic Belt generated a great diversity of microclimates in a variety of soil substrates (igneous and limestone) (Greeland 2015), imposing for each population different selective pressures resulting in morpho-ecological radiation of *Graptopetalum* subg. *Glassia* within a small area (<100 km of radius) in Western Mexico, without any parallel in the genus.

Despite the short distance among the species (<100 km of radius) they occur on a remarkable gradient involving three different biogeographic provinces (Morrone 2017) and three different geologic substrates: igneous, limestone and gypsum (Secretaría de Programación y Presupuesto 1981a, 1981b).

The occurrence of four of the five species in a single hydrographic region, the Armeria watershed, illustrates the effective role of deep ravines ("barrancas") in isolating populations, preventing dispersal and genetic flow and promoting diversification (Vázquez-García *et al.* 2021a). *Graptopetalum glassii* is an ecological outlier among the haplostemonous species of *Graptopetalum*, inhabiting in gypsum soils where rainfall quickly infiltrates to the underground phreatic layers, but may instead benefit from horizontal precipitation of incoming moisture from the relatively close (28–45 km) Pacific Ocean such as that observed in the Atlantic slopes (Vogelmann 1973).

The spring flowering provides sufficient time for seed development to mature before the start of the rainy season, usually starting in mid-June, a similar phenological strategy to that of other CAM plants in western Mexico, such as the "pitayo" *Stenocereus* spp. (Cactaceae), and in *Agave* (Asparagaceae) of the Gypsophila complex, Marmoratae group (Vázquez-García *et al.* 2013).

The five species of *Graptopetalum* subg. *Glassia,* here assessed following IUCN criteria, should be listed in the IUCN Red List (IUCN 2019). A MER analysis is needed to support the proposal to include all haplostemonous species in the Mexican endangered species act, NOM-ECOL-059 (SEMARNAT 2010). Additionally, further exploration is highly recommended and urgent actions are needed to legally protect their vulnerable habitat and promote environmental law enforcement by the municipality and the state authorities; not only for the preservation of this extremely narrow endemic species but also for the varied flora harboured in these relictual habitats (Rebiomex https://www.rebiomex.org/cgi-bin/ibug_list.cgi). In the last decade deforestation in the Tapalpa watershed (Benavides-Solorio *et al.* 2008), mostly due to agriculture expansion and recreation, has become a major threat for the habitat of *G. trujilloi*; a similar disturbance regime is affecting the other four species (Table 2). Additionally, future increasing demands of freshwater from population growth and agriculture threaten to dry up these water sources valuable for these fragile ecosystems. Also, over-collecting from tourist visitors and plant hunters could become a serious problem. Each species is exposed to different threats, for instance, a mining project at La Salada (SEMARNAT 2005) is a big threat to *G. glassii* thriving on gypsic mountains valued for the concrete industry. Thus, we urge their inclusion in both the IUCN Red list and the Mexican endangered species act NOM-ECOL-059 (SEMARNAT). Joint institutional efforts among public and private stakeholders are fundamental to achieve in situ and ex situ successful conservation of these critically endangered or endangered haplostemonous species of *Graptopetalum*.

Conclusions

1. We discovered a new haplostemonous species of *Graptopetalum* subg. *Glassia*, endemic to the Tapalpa micro watershed in Jalisco, México. The morphological analysis allowed us to ascertain that specimens from the lower valleys of the Tapalpa micro watershed constitute a new species that we named *Graptopetalum trujilloi*. The distribution and ecological data for all five species comply with sufficient IUCN criteria to assess four of them as critically endangered species and one as endangered, all in need of urgent protection. 2. The discovery is part of a small-scale pattern of allopatric speciation (morphological radiation) that unveiled four of the five haplostemonous species diversified along a latitudinal gradient of deep ravines with permanent stream tributaries within a single watershed: the Armería River. 3. *Graptopetalum trujilloi*, as a novelty, with its unusual synapomorphic pentandry, is expected to be part of the well-supported subclade including all other haplostemonous species, however, biogeographic and evolutionary processes giving rise to haplostemony and allopatric morphological radiation deserve further attention, particularly using the molecular evidence. 4. As a critically endangered species, *G. trujilloi* is in urgent need of protection from both the state and the San Gabriel Municipality authorities.

Taxonomic treatment

Graptopetalum trujilloi A. Vázquez & Rosales *sp. nov.* (Figs. 3–5).

Diagnosis:—*Graptopetalum trujilloi* is similar to *G. rosanevadoense* in sharing a ramose habit, smooth stem surface and stem diameter, but it differs from the latter in having a smaller habit 15.0–35.0 (–41.0) vs. 40.0–87.0 cm, more numerous primary branches per inflorescence 8–10 vs. 5–7, larger mean flower density per 10.0 cm of the scape 16–20 vs. 6–14, fewer flowers per basal branch 3–6 vs. 7–8, smaller flower diameter 12.9–13.1 vs. 14.9–15.1, petals greenish with transversal inconspicuous red stripes vs. yellowish with transversal conspicuous red stripes, petal width 2.7–2.8 vs. 2.9–3.0 mm, filaments greenish to distally red vs. red and carpels abaxially obtuse vs. rounded. It is also similar to *G. superbum* in sharing a ramose habit, similar rosette diameter and similar mean flower density per 10 cm of the scape, but it differs from the latter in having a smaller habit 15.0–35.0 (–41.0) cm vs. 40.0–80.0 cm, stem surface smooth vs. squamose, smaller stem diameter 6.0–8.0 mm vs. 10.0–12.0 mm, less numerous primary branches per inflorescence 8–10 vs. 12–15, and smaller flower diameter 12.9–13.1 vs. 15.0–16.0 mm.

Type:—MEXICO, Jalisco: Municipio de San Gabriel, 4 km north of San Gabriel, Bosque de galería con *Pittocaulon*, *Ficus*, *Salix*. Abundante sobre laderas rocosas, 1350-1400 m, 19 April 2011, *P. Carrillo-Reyes & J.M. Carrillo-García 6335* (holotype: IBUG!, Isotypes: CIMI!, ZEA!).

Plants perennial, ramose, 15.0–35.0 (–41.0) cm tall without scape, branching basally; stems decumbent to pendant, surface smooth, brownish, 6.0–8.0 mm in diam. at the base, with oval to circular, bumped and dark greenish scars, 1.0–2.0 mm in diameter, the tip soon dried; each *stem* bearing a sparse terminal rosette 9.0–11.0 (–12.0) cm in diam.; leaves 15–32 per rosette, to 52 in cultivation, 4.0–7.5 × 2.3–2.8 cm, 6.0–9.0 mm thick, on an apical 4.0–7.0 cm stem, obovate, glabrous, base cuneate, adaxially slightly concave, abaxially convex, an apical mucro 1.0–3.0 × 1.0–3.0 mm, glaucous greenish to pinkish; scape 2.0–3.0 mm thick at the base, 1.0 mm thick on the upper part, gray-bluish to pinkish, mean flower density per 10 cm of the scape 16–20; panicle 15.0–32.0 cm long, dense, with 8–10 simple or bifurcate primary branches, with 30–50 flowers per inflorescence; bracts 1.0–3.0 mm long, lanceolate to elliptic; panicle primary branches 2.0–6.0 cm, simple or bifurcate, with 3–7 flowers each, 3–6 in the basal branch; pedicels 9.0–11.0 mm long; flowers 12.9–13.1 mm in diameter; petals (4–) 5, 2.7–2.8 mm wide, triangular, subequal, greenish with inconspicuous transversal red stripes, longitudinally with a shallow groove; stamens (4–) 5, erect in early stage of anthesis, later reflexed, filaments greenish to distally red; gynoecium yellow greenish to pinkish orange, carpels abaxially obtuse; fruits costate oblongoid, 5.0–6.0 × 2.0–3.0 mm; seeds unknown.

Distribution, habitat and phenology:—*Graptopetalum trujilloi* is known only from populations at the type locality, on the canyon of the Rio Tapalpa at an elevation of 1350-1410 m. The vegetation corresponds to the tropical deciduous forest with *Bursera* sp., *Heliocarpus* sp., *Isolatocereus dumortierii*, *Lysiloma* sp., *Pithecellobium dulce*, *Plumeria rubra*, *Pseudobombax* sp., *Verbesina oligantha*, *V. tecolotlana*, and *Vitex* sp., among others. Plants form rock-dwelling dense colonies in North exposure vertical slopes along with *Agave attenuata* subsp. *dentata*, *Astrolepis sinuata*, *Dioscorea* sp., *Epidendrum examinis*, *Euphorbia* sp., *Peperomia* sp., *Pitcairnia* sp., *Pittocaulon velatum* *Sedum chazaroi* and *Tillandsia* aff. *capitata* (Fig. 5). Flowering in early March. Fruiting in early June.

Eponymy and ethnobotany:—The specific epithet honours Jesús Trujillo Lara, an outstanding explorer of the Gran Barranca de Guadalajara and expert in succulent cultivation who contributed to the discovery of this species.

Additional specimens examined:—MÉXICO, Jalisco: 4 km north of San Gabriel, 1390 m, 7 September 2008, *J. A. Vázquez-García 8835*, with *J. Trujillo*, *J. Etter*, *M. Kristen* and *M. Cházaro* (IBUG). Same location as previous, 4 km north of San Gabriel, 1410 m, 27 June 2021 (sterile), *S. Rosales w/ C. Rosales* and *E. Martínez 1* (IBUG), same location as previous, 27 June 2021 (infructescence), *S. Rosales w/ C. Rosales* and *E. Martínez 2* (IBUG).

Key to the haplostemonous species of *Graptopetalum*

1. Rosettes 2.0–8.0 cm in diameter, cespitose 2
- Rosettes 9.0–16.0 cm in diameter, non cespitose 3
2. Inflorescence 6.0–12.0 cm long, rosettes 2.0–4.0 cm in diameter, endemic to Colima ..... *G. glassii*
- Inflorescence 20.0–35.0 cm long, rosettes 6.0–8.0 cm in diameter, endemic to Michoacán ..... *G. pentandrum*
3. Stems more than 10.0 mm in diameter, squamose stem surface ..... *G. superbum*
- Stems less than 8.0 mm in diameter, smooth stem surface 4
4. Plants 40.0–87.0 cm tall, inflorescence primary branches 5–7, mean flower density per 10 cm of the scape 6–14, flowers per basal branch 7–8, flower diameter 14.9–15.9 mm, petals yellowish with conspicuous transversal red stripes, petal width 2.9–3.0 mm, filaments red, carpels abaxially rounded ..... *G. rosanevadoense*

- Plants 15.0–35.0 (–41.0) cm tall, inflorescence primary branches 8–10, mean flower density per 10 cm of the scape 16–20, flowers per basal branch 3–6, flower diameter 12.9–13.1 mm, petals greenish with inconspicuous transversal red stripes, petal width 2.7–2.8 mm, filaments greenish to distally red, carpels abaxially obtuse ..... ***G. trujilloi***

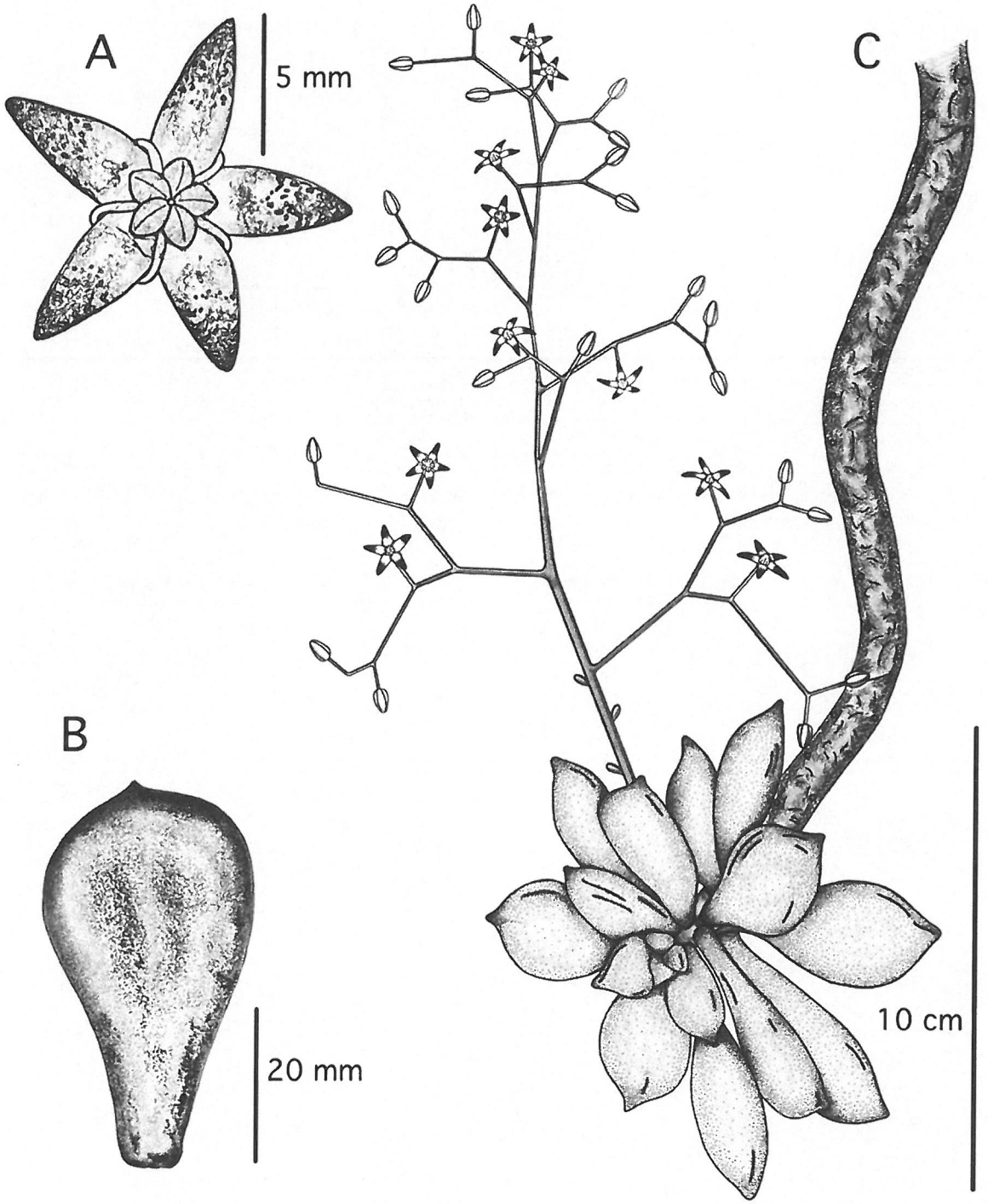

FIGURE 3. *Graptopetalum trujilloi.* A. Flower with reflexed stamens. B. Leaf. C. Plant showing pendant habit and full panicle with flowers and buds. Illustration by Santiago Rosales.

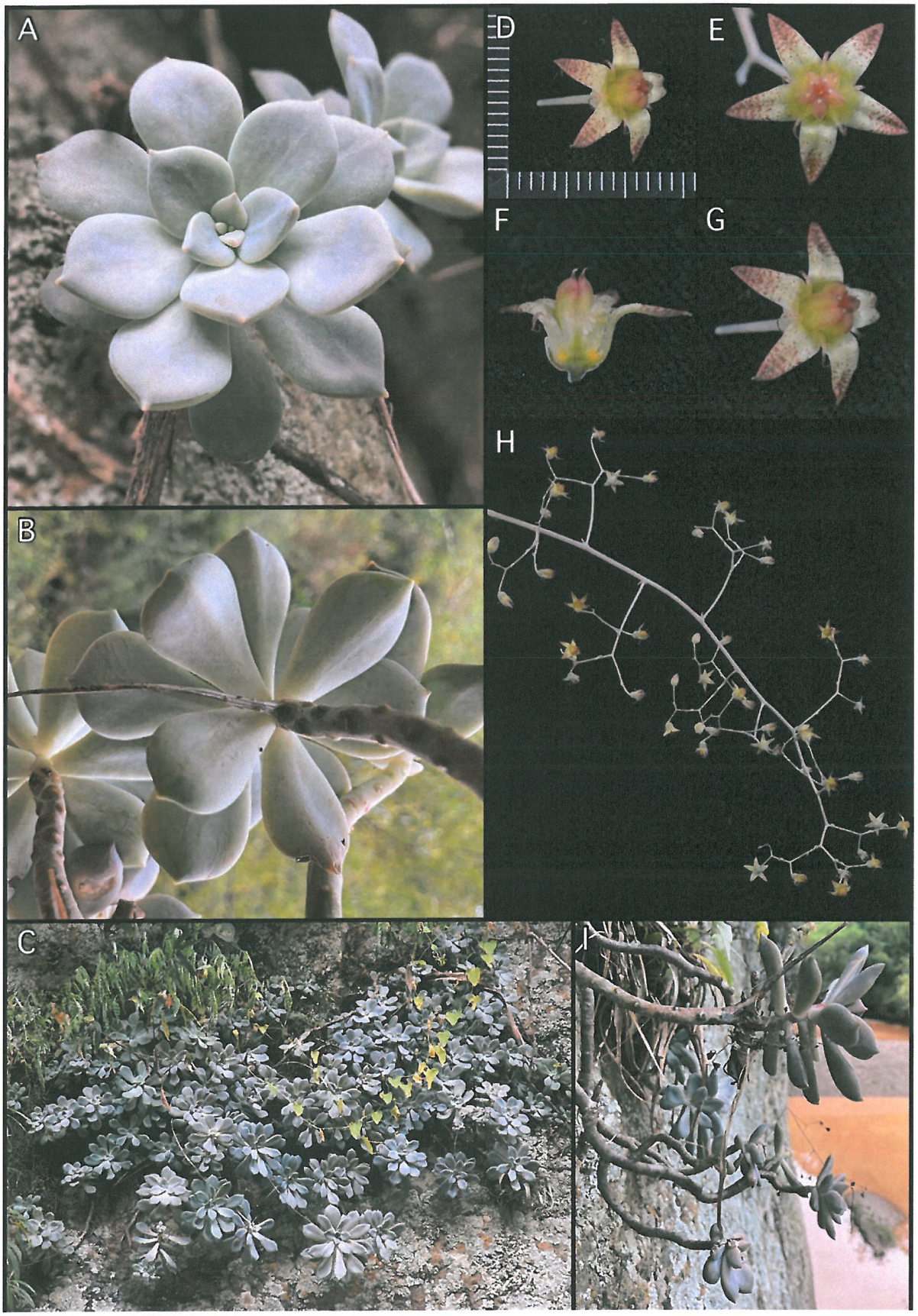

FIGURE 4. *Graptopetalum trujilloi.* A–B. Rosette adaxial and abaxial sides. C. Pendant crowded rosettes. D–E and G. Flowers with reflexed stamens (side and upright views). F. Dissected flower showing nectaries, and shape of carpels. H. Full panicle. I. Pendant ramose habit with distally curved stems. Photographs: A–B and I by Santiago Rosales, C–H by J. Etter & M. Kristen.

FIGURE 5. Habit and habitat of *Graptopetalum trujilloi*. A–B, D. Pendant rock-dwelling rosettes. C. Tropical dry forest in the Tapalpa micro watershed, San Gabriel, Jalisco. E. Santiago and Carlos Rosales reaching pendant rosettes. Photographs: A by Julia Etter & M. Kristen, B–D by Santiago Rosales and E by Endy Martínez.

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