



## A new species of *Sedum* (Crassulaceae) from northwest Michoacan, Mexico

IGNACIO GARCÍA-RUIZ<sup>1</sup> & MIHAI COSTEA<sup>2\*</sup>

<sup>1</sup>Instituto Politécnico Nacional (CIIDIR-IPN Michoacán), Justo Sierra 28, Jiquilpan, Michoacán, México C.P. 59510 [igarcia@ipn.mx](mailto:igarcia@ipn.mx)

<sup>2</sup>Wilfrid Laurier University, Waterloo, Canada, 75 University Avenue W, Waterloo, ON, N2L3C5, Canada [mcostea@wlu.ca](mailto:mcostea@wlu.ca) (corresponding author)

### Abstract

A new species of *Sedum*, *S. moniliforme* (Crassulaceae) is described and illustrated from the Canyon La Gloria, Municipio Jiquilpan, State of Michoacan, Mexico. The closest morphological affinities of this taxon are with *Sedum longipes* from which it differs through its moniliform or markedly articulate stems with whorled leaves, 3–4 at each node, sepals that are not imbricated at the base, as well as smaller flowers, pollen grains, and sterile rosettes.

### Resumen

Se describe e ilustra *Sedum moniliforme* como especie nueva para la ciencia a partir de plantas procedentes de la barranca La Gloria del municipio de Jiquilpan, Estado de Michoacán, México. Las afinidades morfológicas más cercanas de este taxón son con *Sedum longipes*, diferenciándose de esta principalmente por tener los tallos moniliformes o articulados, las hojas en verticilios de 3 a 4, sépalos no imbricados en la base, así como flores, granos de polen y rosetas estériles más pequeñas.

**Key words:** morphology, succulent plants, scanning electron microscopy, tropical deciduous forest

### Introduction

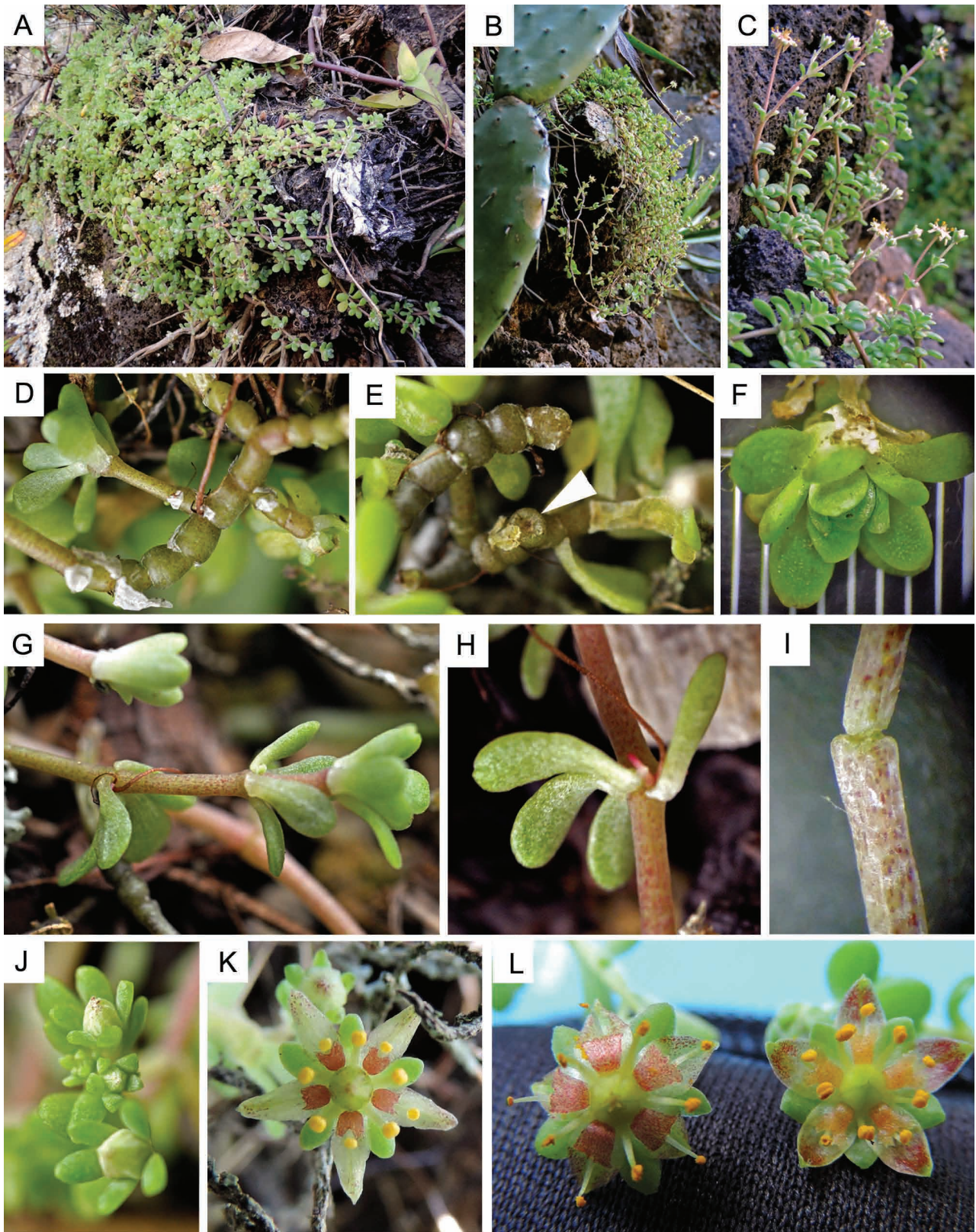
*Sedum* Linnaeus (1753: 430) is the largest genus of Crassulaceae and nearly half of its diversity is centered in the Americas (ca. 170 sp.; Hart & Bleij 2003, Thiede & Egli 2007). Mexico in particular is rich in species (Clausen 1959, Meyrán & López 2003). Recent detailed explorations of the Canyon La Gloria of Municipio Jiquilpan to update a conspectus of vascular plants of northwest Michoacan have revealed a new distinctive *Sedum* species.

### Methods

In addition to collecting of herbarium specimens, living plants of both *S. moniliforme* and *S. longipes* Rose in Britton & Rose (1903: 43) (subsp. *longipes* growing in Temascalcingo, Estado de Mexico and subsp. *rosulare* R.T. Clausen 1959: 199 cultivated as ornamental in Abadiano, Michoacan) were transplanted and cultivated in Jiquilpan, Michoacan for further study. Entire plants were fixed in FAA (Ruzin 1999) for morphological studies or dried in silica gel for DNA extraction. For scanning electron microscopy (SEM), we used hexamethyldisilazane (HMDS) as an alternative for critical dry point (Wright *et al.* 2011). Samples were air dried and coated with 20 nm gold using an Emitech K 550 sputter coater. Micromorphological examination, measurements and pictures were taken at 10–15 kV using a Hitachi SU1510 variable pressure scanning electron microscope. Additional images than those provided in the article have been uploaded in Phytoimages (Nickrent *et al.* 2006 onwards).

## Taxonomy

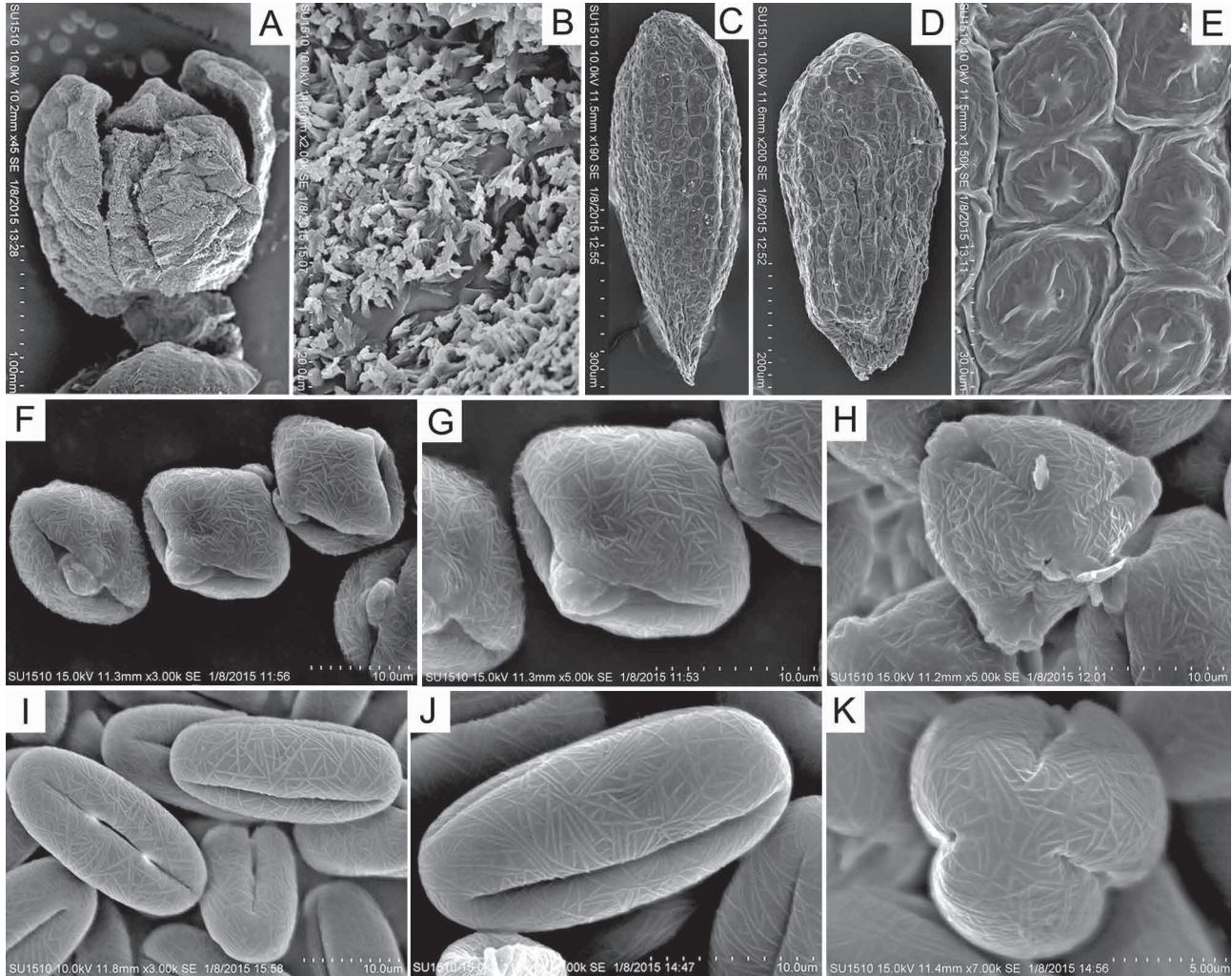
*Sedum moniliforme* I. García & Costea, *sp. nov.*, Figs. 1–2



**FIGURE 1.** *Sedum moniliforme* and flowers of *S. longipes*. A–K. Type specimen(s) prior to conservation. L. A–B. Habit. C. Flowering stems and inflorescences. D–E. Rhizome-like basal stems with moniliform internodes (arrow indicates scar left by previous year's flowering stem). F. Sterile rosette. G–I. Flowering stems. G. General view (note the whorled leaves). H. Internode with four whorled leaves and adventitious roots. I. Stem node after the removal of leaves to show the markedly articulate internodes. J. Flower buds. K. Flower. L. Flower of *S. longipes* subsp. *longipes* (right) and subsp. *rosulare* (left).

Like *Sedum longipes* but differing in the moniliform rhizome-like basal stems and markedly articulate regular stems; whorled leaves, 2–3.5 mm long, 3–4 at each node; flowers 6–8 mm in diameter, with sepals that are not imbricated at the base, 1–1.2 mm wide, petals 3–5 × 1–1.5 mm, pollen grains subspheroidal, 14–17 μm long, and nectaries 1 mm long.

**Type**.—MÉXICO. Michoacán: Municipio Jiquilpan, Barranca La Gloria, lado oeste del “Medio Sitio” y al nor-noroeste de la localidad El Fresno, sobre paredes de rocas basálticas con orientación oeste y oeste-noroeste. Ubicación aproximada 20°01'15"N, 102°48'54"W, 1790 m, 25 November 2014, *I. García et al.* 8994 (holotype CIMI! Isotypes IEB! MEXU!, WLU!).



**FIGURE 2.** Micromorphological features of *Sedum moniliforme* (from holotype material fixed in FAA prior to pressing/drying) and pollen comparison with *S. longipes*. A. Young leaves of a sterile rosette. B. Cristalloid epicuticular wax deposits on young rosette leaf. C–E. Seed morphology. C–D. Shape variation. E. Surface of testa cells. F–H. Pollen grains of *S. moniliforme*. I–K. Pollen grains of *S. longipes*. Note the marked difference in shape and length of pollen grains between the two species. Scale bars and SEM data are embedded in the images.

*Plants* saxicole, perennial, glabrous, with prostrate to ascending stems, pendent to climbing; basal stems are horizontal, rhizome-like, with short and swollen, moniliform internodes, 4–10 mm long and 3–5 mm in diameter; remaining stems are ascending, 10–20 (30) cm long with internodes markedly articulate, 10–30 mm long and 1–2 mm in diameter; all stems are green to pale chestnut brown, maculate with reddish dots or lines. Sterile shoots form lax rosettes, 0.8–12 mm in diameter, farinose on the young leaves. *Roots* fibrose; particularly basal stems generate brown-reddish adventitious roots at the nodes, 2–3 cm long. *Leaves* whorled, 3–4 at each node, obovate to spatulate, 4–9 × 2–3.5 mm, short petiolate, somewhat clasping, spurred, apex rounded; bracts similar to leaves, opposite or 3–4 whorled. *Inflorescences* cymes terminal or lateral, erect or nutant, lax, 1–2(3)-flowered; pedicels 5–17 mm long and 0.8–1 mm in diameter. *Flowers* 5-merous, 6–8 mm in diameter; sepals oblong-ob lanceolate, not adpressed in bud, 2–3.5 × 1–1.2 mm, free basally, not imbricate at the base, spurred, unequal, green, farinose; petals 3–5 × 1–1.5 mm, basally free, lanceolate-elliptical, acute and somewhat mucronate, white to pale greenish with reddish spots or lines, reflexed as the

flowers age and ultimately caducous. Stamens 10; antesealous filaments 5, 2.2–2.5 mm long; episealous filaments 5, 2 mm long; anthers orange or yellow; pollen tricolpate, subspheroidal, 14–17 × 11–13 µm, sexine rugulate; nectaries bilobed, 1 mm long and 0.7 mm wide, reddish, with 1–3 teeth on each side. Carpels greenish to reddish, 3 mm long and 2 mm wide at the base. *Fruit* aggregate of 5 erect or spreading follicles. *Seeds* 0.5–0.6 × 0.2–0.25 mm long, ellipsoidal to obovoidal, brown-yellowish, reticulate, each seed coat cell with an umbo.

**Taxonomic affinities:**—Following the classification of Berger (1930: 352–485) emended by Meyrán & López (2003: 21–22), *S. moniliforme* belongs to Sect. *Sedum*, “Group” *Americana*, characterized by flat, broader in the upper half leaves, sterile rosettes, and white flowers. However, as suggested by Clausen (1942) and Clausen & Uhl (1943) “Group” *Americana* includes a heterogeneous assemblage of taxa. The latter authors transferred the American species to subgenus *Gormanina* (Britton in Britton & Rose 1903: 29) R.T. Clausen (1942: 29) or section *Cockerellia* R.T. Clausen & Uhl (1943: 34–35), while the remaining Mexican species require more study for their appropriate placement. Among these Mexican species, *S. longipes* is closest to *S. moniliforme*, both biogeographically and morphologically. In its currently accepted delimitation (Clausen 1959), *S. longipes* includes two subspecies differentiated morphologically mainly by the compactness of their rosettes (less compact with divergent leaves in subsp. *rosulare*) and the ratio between their sepals and petals (petals shorter or equaling sepals in subsp. *rosulare* versus petals longer than sepals in subsp. *longipes*; Figs. 1K–L). *Sedum longipes* subsp. *rosulare* is known only from cultivation in the States of Michoacán (I. García, unpublished), Puebla, and Veracruz (Clausen 1959). In contrast, *S. longipes* subsp. *longipes* is relatively common in tropical deciduous or oak-pine forest along the Trans-Mexican Volcanic Belt in the States of Mexico, Morelos, Puebla (Clausen 1959); Chihuahua, Jalisco, Michoacán (Cházaro & Thiede 1995), and Guanajuato (Pérez-Calix 2008). As indicated in the diagnose, *S. moniliforme* and *S. longipes* are easily differentiated morphologically, and a complete comparison is provided in Table 1.

Clausen (1959: 201) also described from Mexico State, *S. pentastamineum*, which he considered “closely related” to *S. longipes* and possibly derived from the latter through the reduction of one stamen whorl. *Sedum moniliforme* differs from *S. pentastamineum* in the same way it does from *S. longipes* (e.g., moniliform/markedly articulate stems and whorled leaves); in addition, *S. pentastamineum* has elliptical, suborbicular or orbicular leaves; flowers have 5 stamens; sepals are nearly equal, and nectaries are obovate-subquadrate, lacinate (for a complete comparison of the three species see Table 1). Likewise, *S. botterii* Hemsley (1878: 10) and *S. clavifolium* Rose (1911: 297), the only other species indicated by Clausen (1959) to share possible affinities with *S. longipes*, are easily differentiated morphologically from *S. moniliforme* (Clausen 1959). As stated by the latter author, this small group of species restricted to the Trans-Mexican Volcanic Belt is quite unique morphologically and comparisons with other species are not feasible (Clausen 1959). *Sedum longipes* is the only species of this group sampled in a broader molecular phylogeny of the *Sedum* clade in Crassulaceae (Carrillo-Reyes *et al.* 2009). Its closest phylogenetic relationships were with *S. oxypetalum* Kunth (Kunth in Humboldt *et al.* 1823: 45), a woody species that is also endemic to the Trans-Mexican Volcanic Belt (Clausen 1959). However, both the evolutionary relationships among the species of *S. longipes* complex, as well as of this group with other Mexican and American *Sedum* species require a molecular study with more extensive sampling.

**Morphology:**—In general, the leaf arrangement of Crassulaceae is alternate or opposite-decussate; only in *Sedum* leaves can be rarely whorled (Thiede & Eggli 2007). In Mexico, only one species, *S. rhodocarpum* Rose (1911: 300) has whorled leaves but this taxon has entirely different morphological characteristics and taxonomic affinities (“Group” *Ternata*; Berger 1930; Meyrán & López 2003). The short, moniliform internodes of the basal stems and the markedly articulate internodes of the remaining stems are remarkably distinctive, unknown in other *Sedum* species, at least from Mexico (Fig. 1). The basal moniliform stems resemble rhizomes in that they are perennial and exhibit scars of previous inflorescence stems; however, they develop aboveground and they have chlorophyll (Figs. 1D–E). *Sedum moniliforme* plants observed in the field have the ability to grow and expand not only following a pendent habit, but also lateral and vertical (Figs. 1A–B) through the adventitious roots formed by the rhizome-like stems and the basal nodes of the “normal” stems (Figs. 1D–E; G–H). The elevated ability to form adventitious roots indicates both a good anchoring capacity (if a suitable rock support is present), and an excellent potential for vegetative propagation and cultivation.

With regard to micromorphology, young sterile rosette leaves of both *S. moniliforme* (Figs. 1D,F) and *S. longipes* are covered with a layer of epicuticular wax that gives them a farinose appearance (Figs. 2A–B). Considering the relatively high degree of pollen similarity among other *Sedum* species in Mexico (Pérez-Calix 2004), the pollen grains of *S. moniliforme* and *S. longipes* are quite dissimilar in size and shape, the latter being 50–60% longer and perprolate (Figs. 2F–K; Table 1).

**TABLE 1.** Comparison of *Sedum moniliforme*, *S. pentastamineum*, and *S. longipes*. Data for *Sedum longipes* is based on Clausen (1959) and personal observations; *S. pentastamineum* characteristics were provided by Clausen (1959). Missing data is indicated with “—”.

<b>Character</b>	<i>Sedum pentastamineum</i>	<i>S. longipes</i>	<i>S. moniliforme</i>
<b>Habit</b>	Pendent	Pendent to ascending	pendent to ascending
<b>Leaf Rosettes</b>			
Number of leaves	—	12–15	10–12
Diameter (mm)	—	13–15	8–12
Color	—	Dark-green	Light-green
Papillose	—	Yes	Yes
Young leaves farinose	—	Yes	Yes
<b>Rhizome-like</b>	Absent	Absent	Present
<b>moniliform stems</b>			
<b>“Regular” stems</b>			
Markedly articulate	No	No	Yes
Length (cm)	15–33	12–25	10–20 (30)
Diameter (mm)	0.6–1 mm check	1.5–1.9	1–2
Internode length (mm)	—	15–42	10–30
Color	Pale pink	Green	Green, reddish-maculate
<b>Leaves</b>			
Arrangement	Alternate, subopposite, opposite	Alternate	Whorled, 3–4 per node
Shape	Elliptical, suborbicular or orbicular	Elliptical, oblanceolate to obovate	Obovate to spatulate
Length (mm)	2.1–7.9	9	4–9
Width (mm)	1.2–3.6	4.6	2–3.5
Margin	Papillose	Papillose	Not papillose
<b>Inflorescence</b>			
Number of flowers	1–5	1–3	1–2(3)
<b>Pedicel length (mm)</b>	5–27	12–17	5–17
<b>Sepals</b>			
Imbricate at the base	No	Yes	No
Shape	Elliptical, elliptical-oblong, lanceolate	Lanceolate, elliptical-oblong, ovate-elliptical or elliptical	Linear lanceolate
Length (mm)	1.3–3	4–5	2–3.5
Width (mm)	0.7–1.4	1.4–1.7	1–1.5
<b>Petals</b>			
Color	Pale green or yellowish white, streaked with purple or red above middle	Greenish, pale-green, streaked or speckled with red especially above middle	White, slightly red-maculate
Shape	Lanceolate or elliptical-lanceolate	Lanceolate, ovate to elliptical-oblong	Lanceolate-elliptical
Length (mm)	3.1–4.4	5–5.5	3–5
Width (mm)	0.9–1.5	2.5	1–1.5
<b>Stamens</b>	5	5 + 5	5 + 5
<b>Nectaries</b>			
Color	Dark-red	Red	Red
Shape	Obovate-subquadrate, laciniate	Bilobate, dentate	Bilobate, dentate
Length (mm)	0.7–1.6	2	1
Width (mm)	0.4–1.3	1.7	0.7
<b>Pollen</b>			
Shape	—	Perprolate	Subspheroidal
Length (µm)	—	22–26	15–17
<b>Carpels</b>			
Carpel length (mm)	1.6–2	2.9	3
Width at base (mm)	—	2	2
<b>Flowering</b>	?–Jan–?	Oct–Feb	Oct–Nov
Vegetation type	Pine forest	Tropical deciduous forest or oak-pine forest (subsp. <i>longipes</i> )	Tropical deciduous forest
<b>Elevation (m)</b>	2300–2310	1800–2890 (subsp. <i>longipes</i> )	1780–1830

**Distribution, ecology and phenology:**—*Sedum moniliforme* is currently known only from the type locality where it is represented by one population with ca. 150–200 plants. Its habitat corresponds to tropical deciduous forests with some cloud forest elements. It occurs together with other Crassulaceae and succulents (García & Nava 1996, García *et al.* 1999). The species grows on rock ledges and semivertical volcanic rocks with north-northwest exposition, in places with sufficient run-off water. During the dry season (winter-spring), leaf-rosettes gradually shrink, but at the end of June, after the first rains, they begin to develop and will form inflorescences. Flowering takes place from October to mid-November. In general, the ecology of *S. moniliforme* is very similar to that of *S. longipes* subsp. *longipes* (Table 1) but the latter species flowers for a much longer time, from October to February (Table 1).

**Conservation status:** Based on the area of occupancy and the small population size, we assess *S. moniliforme* as Vulnerable (VU) (IUCN 2001) based on criteria D. A more exhaustive survey will be undertaken in the future to search for additional populations in the area.

**Etymology:**—From Latin “monil” (necklace) and “formis” (shape), necklace shaped, alluding to the moniliform internodes of the basal, rhizome-like stems.

**Additional specimens examined (paratypes):**—MÉXICO. Michoacán: Municipio Jiquilpan: Barranca La Gloria, lado oeste del “Medio Sitio” al nor-noroeste de El Fresno, paredes de rocas basálticas con orientación oeste y oeste-noroeste, 20°01'14"N, 102°48'54", 1830 m., 21 October 2014, *I. García et al.* 8960-bis (CIMI!); 29 October 2014, *I. García et al.* 8964 (CIMI!, IEB!, WLU!); 25 November 2014, *I. García et al.* 8994 (CIMI!, IEB!, MEXU!, WLU!).

## Acknowledgements

We would like thank to Mr. Juan Manuel Figueroa for allowing access on his private property, and to Dennis Ochoa and Alfonso Fuentes for their help in the field. One anonymous reviewer provided comments that improved this manuscript. Last but not least we are grateful to COFAA and EDI of the Instituto Politécnico Nacional, Mexico for supporting this type of research.

## References

- Berger, A. (1930) Crassulaceae. In: Engler, A. & Prantl, K. (Eds.) *Die natürlichen Pflanzenfamilien*, ed. 2, 18a. W. Engelmann, Leipzig, pp. 352–485.
- Britton, N.L. & Rose, J.N. (1903) New or noteworthy North American Crassulaceae. *Bulletin of the New York Botanical Garden* 3: 1–45.
- Carrillo-Reyes, P., Sosa, V. & Mort, M.E. (2009) Molecular phylogeny of the *Acre* clade (Crassulaceae): Dealing with the lack of definitions for *Echeveria* and *Sedum*. *Molecular Phylogenetics and Evolution* 53: 267–276.  
<http://dx.doi.org/10.1016/j.ympev.2009.05.022>
- Cházaro, B.M.J & Thiede, J. (1995) Floristic and phytogeographical studies on the Crassulaceae of Jalisco (Mexico). In: Hart, H. & Egli, U. (Eds.) *Evolution and systematics of the Crassulaceae*, Backhuys, Leiden, pp. 124–125.
- Clausen, R.T. & Uhl, C.H. (1943) Revision of *Sedum cockerellii* and related species. *Brittonia* 5: 33–46.  
<http://dx.doi.org/10.2307/2804873>
- Clausen, R.T. (1959) *Sedum of the Trans-Mexican volcanic belt: An exposition of taxonomic methods*. Cornell Univ. Press. Ithaca, New York, 380 pp.
- García, R.I., & Nava, J.V. (1996) *Ferocactus histrix* (DC.) Lindsay, un nuevo registro para Michoacán. *Cactáceas y Suculentas Mexicanas* 61: 93–95.
- García, R.I., Nava, V.J., Cházaro, B.M.J. & Machuca, J.A. (1999) Suculentas de la Barranca La Gloria, Michoacán, México. *Cactáceas y Suculentas Mexicanas* 64: 37–40.
- Hart, H. & Bleij, B. (2003) *Sedum*. In: Egli, U. (Ed.) *Illustrated handbook of succulent plants Crassulaceae*, Springer, Berlin, pp. 235–332.
- Hemsley, W.B. (1878) *Diagnoses plantarum novarum vel minus cognitarum Mexicanarum et Centrali-Americanarum. Part 1*. Taylor and Francis, London, pp. 1–16.  
<http://dx.doi.org/10.5962/bhl.title.60211>
- IUCN (2001) The World Conservation Union. *IUCN Red List Categories and Criteria*. Version 3.1. Gland (Switzerland).
- Linnaeus, C. (1753) *Species Plantarum*. Tomus I. Imp. Laurentii Salvii, Holmiae, 560 pp.

<http://dx.doi.org/10.5962/bhl.title.669>

- Meyrán, G.J. & López, L. (2003) *Las crasuláceas de México*. Sociedad Mexicana de Cactología, México, 234 pp.
- Nickrent, D.L., Costea, M., Barcelona, J.F., Pelsner, P.B. & Nixon, K. (2006) *Phytoimages*. Available from: <http://www.phytoimages.siu.edu> (accessed 14 January 2015)
- Pérez-Calix, E. (2004) *La familia Crassulaceae en el Bajío y Regiones adyacentes*. PhD thesis, Universidad Nacional Autónoma de México, 199 pp.
- Pérez-Calix, E. (2008) *Familia Crassulaceae*. Flora del Bajío y de Regiones Adyacentes, Fascículo 156. Instituto de Ecología, A.C. Centro Regional del Bajío. Pátzcuaro, Michoacán, 143 pp.
- Rose, J.N. (1911) Studies of Mexican and Central American plants. No. 7. *Contributions from the United States National Herbarium* 13: 291–312.
- Ruzin, S.E. (1999) *Plant microtechnique and microscopy*. Oxford University Press, Oxford, 332 pp.
- Thiede, J. & Egli, U. (2007) *Crassulaceae*. In: Kubitzki, K. (Ed.) *Flowering Plants. Eudicots, Vol. 9*. Springer, Berlin, pp. 83–118.  
[http://dx.doi.org/10.1007/978-3-540-32219-1\\_12](http://dx.doi.org/10.1007/978-3-540-32219-1_12)
- Wright, M.A., Welsh, M. & Costea, M. (2011) Diversity and evolution of the gynoeceium in *Cuscuta* (dodders, Convolvulaceae) in relation to their reproductive biology: two styles are better than one. *Plant Systematics and Evolution* 296: 51–76.  
<http://dx.doi.org/10.1007/s00606-011-0476-5>