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Manfreda santana-michelii (Asparagaceae subfamily Agavoideae), a Striking New Species from Sierra Madre del Sur in Western Mexico

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Abstract*—*Manfreda santana-michelii is described from ecotone areas between open pine-oak forest and savannoid vegetation in the northern range of the Sierra Madre del Sur, in western Mexico. Morphologically, the new species resembles *M. involuta* and *M. singuliflora*, but differs from both of these by the development of denticulate margins on the leaves, racemose inflorescences, two pedicellate, tubulate, ascending flowers per node, a straight perigone tube, and 0.3–0.5 cm long filaments that are inserted just at the base of the perigone lobes. Illustrations, photographs for the new species and similar taxa, and a key to identify *Manfreda* in western Mexico accompany the description.

***Keywords*—**Agavaceae tribe Poliantheae, Sierra del Cuale.

Resumen*—**Se describe ***Manfreda santana-michelii, una especie presente en la ecotonía entre el bosque de pino-encino y la vegetación sabanoide en el extremo norte de la Sierra Madre del Sur, al oeste de México. Por su morfología, la nueva especie se relaciona a *M. involuta* y *M. singuliflora* pero difiere de ellas en el desarrollo de hojas con márgenes denticulados, inflorescencias racemosas, flores geminadas y pediceladas en cada nodo floral, tubo del perigonio tubular, ascendente y recto, y filamentos del androceo de 0,3–0,5 cm de longitud e incertos justo en la base de los lóbulos del perigonio. Además de ilustraciones y fotografías de la nueva especie y taxones relacionados, se incluye una clave para la identificación de *Manfreda* en el occidente de México.

***Palabras clave*—**Agavaceae tribe Poliantheae, Sierra del Cuale.

The genus *Manfreda* Salisb. (Asparagaceae subfamily Agavoideae) includes 36 species with a natural geographic distribution from southeastern USA, throughout Mexico, and southwards into Honduras and El Salvador (Verhoek-Williams 1975; Castro-Castro et al. 2017). All species, except *M. fusca* Ravenna, occur in Mexico, and western Mexico is one of the most species rich areas, wherein 14 species have been registered. They occupy moist to xeric habitats with cold to mild winters. Commonly, the plants grow in open sun or partial to deep shade, often in oak-pine forests, grasslands, and tropical dry forests, and in an elevation range from sea level to 3050 m.

Manfreda comprises polycarpic perennial herbs. The perenniality is achieved by the development of an upright bulb and globose to cylindrical corm with fleshy and contractile roots. The plants produce thin to succulent leaves, which are accommodated into a basal rosette. The inflorescences are mainly spiciform with solitary and sessile flowers at the nodes, subtended by one bract and one or two bracteoles. However, in some anomalous specimens the flowers grow paired, short-pedicellate or on a common pedicel. *Manfreda paniculata* L.Hern., R.A.Orellana & Carnevali and *M. petskinil* R.A. Orellana, L.Hern. & Carnevali develop paniculate inflorescences and flowers subtended by a single bracteole. Hernández-Sandoval et al. (2008) noticed that these characters in the two above species are intermediate between *Manfreda* and *Agave* L.

During an herbaria revision, as a part of diversity and biogeographic analyses of Agavaceae tribe Poliantheae, we noted some unusual specimens from Sierra del Cuale lowlands, in the northern extreme of the Sierra Madre del Sur in western Mexico, that did not match any known species of *Manfreda* because of their racemose inflorescence with geminate and pedicellate flowers and erect-tubular perigone. These features were reported by Verhoek-Williams (1975) in unusual specimens of *M. scabra* (Ort.) McVaugh, but although the flowers develop in pairs at the nodes, only one is short-pedicellate or the flower pair had a common pedicel. Even the dehydrated plants resemble the genus *Polianthes* L. rather than *Manfreda*.

Hence, after an analysis of the herbarium vouchers and live plants from a recent field collection, review of relevant literature, and critical comments from experts, we demonstrated this to be a *Manfreda* species hitherto unknown to science, which is described and illustrated as a new species in this contribution. The novelty is morphologically compared with the most related taxa in the genus. Illustrations, photographs for the new species and the most similar taxa, and a key to identify *Manfreda* in western Mexico accompany the description.

Materials and Methods

The morphological description and illustration of the new species are based on traditional taxonomic methods. The terminology used follows Verhoek-Williams (1975). An informal conservation status of the new species was determined based on field observations, using GeoCAT (Bachman et al. 2011) and applying the IUCN red list criteria (IUCN 2012). Finally, the *Manfreda* identification key resulted from the analysis of 320 herbarium specimens deposited in following herbaria: ANSM, CHAPA, CIIDIR, CIMI, CREG, ENCB, FEZA, GUADA, IBUG, IEB, MEXU, QMEX, SLPM, XAL, and ZEA (acronyms according to Thiers 2017).

Taxonomic Treatment

Manfreda santana-michelii Art.Castro, Aarón Rodr. & P.Carrillo sp. nov. Type: Mexico. Jalisco: Cabo Corrientes, km 18.5

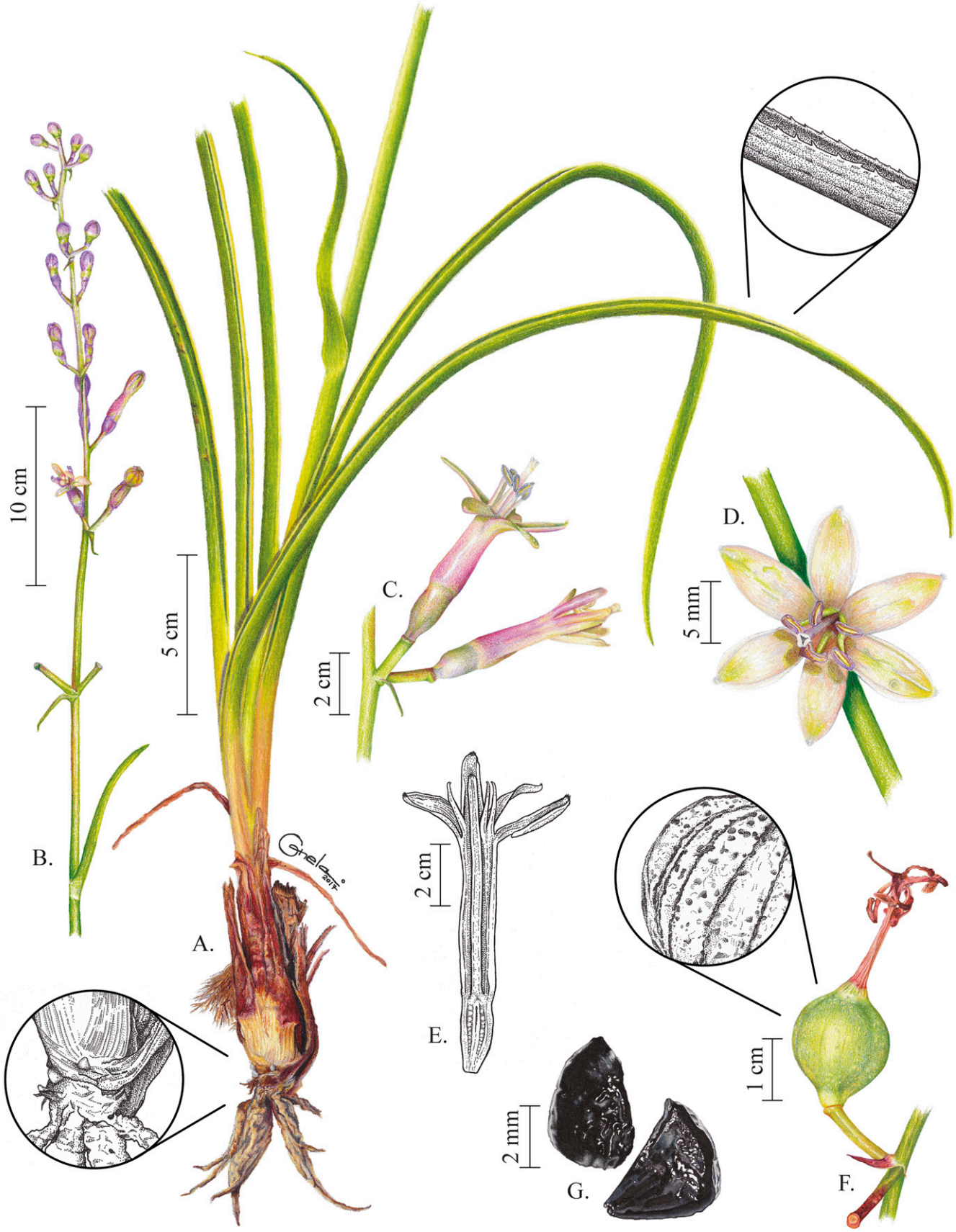

FIG. 1. *Manfreda santana-michelii*. A. Roots, corm with buds detail, leaves with detail of denticulate margins, and peduncle with sterile bract. B. Rachis of the racemose inflorescence. C. Lateral view of geminate and pedicellate flowers. D. Front view of perigone. E. Perigone dissection. F. Fruit and surface detail. G. Seeds. Illustrated by Silvia "Canela" Saucedo Heredia.

del camino de El Tuito a El Cuale, 1060 m, 14 Nov 2015 (fl), *P. Carrillo-Reyes & G. I. Tinoco-Villa 8160* (holotype: IBUG!; Isotypes CIIDIR!, MEXU!).

Manfreda santana-michelii resembles *M. involuta* and *M. singuliflora* but differs from both by the development of denticulate margins on the leaves, racemose inflorescences, geminate and pedicellate flowers, perigone tube tubular, ascending, and straight, and filaments 0.3–0.5 cm long and inserted just at the base of the perigone lobes.

Perennial herb. Corm cylindrical 2–2.8 × 1–1.3 cm, with conspicuous buds and thickened, contractile and fleshy roots. Roots filiform, 2–7.5 cm long. Bulb oblong-ovoid, 3.5–4.8 × 2–2.5 cm, tunicate, reddish brown. Leaves 7–10 in a basal rosette, alternate, linear, 30–45 × 0.2–0.5 cm, erect, falcate, involute, margin hyaline, retrorsely and antrorsely denticulate, thin to leathery, grayish green, concolorous, upper and lower surface papillate, acute and soft apex. Inflorescence racemose, 90–135 cm long, erect, internodes decreasing in length towards the apex; peduncle 90–96 cm long, bracts 6–9,

Fig. 2. Flower comparison among *Manfreda santana-michelii* and the most similar species. A–B. *M. santana-michelii* (*P. Carrillo-Reyes & G. I. Tinoco-Villa 8160*, IBUG!, IEB!, MEXU!). C–D. M. involuta (A. Rodríguez et al. 4852, IBUG). E–F. *M. singuliflora* (*A. Rodríguez et al. 4527*, IBUG). Photos A–B by P. Carrillo-Reyes, and C–F by A. Rodríguez.

first sterile bracts similar to the leaves, linear-lanceolate, 15–37 × 0.2–0.4 cm, the closest to the rachis 2.5–3.5 × 0.1–0.3 cm, both acute, truncate, thin to leathery, green, concolorous, upper and lower surface smooth, hyaline, diffuse to divaricate; rachis lax, 26–36 cm long, with 12–17 floral nodes, primary floral bracts linear to subulate, 0.3–4.5 × 0.02–0.2 cm, acute, truncate, smooth, persistent, green, reflexed. Bracteoles 2 at each floral node, ensiform to acicular, 0.4–1 × 0.1–0.2 mm, entire, reddish green to black when dry. Pedicels 0.4–2.5 × 0.05–0.07 cm long in anthesis, terete, glaucous. Flowers geminate, actinomorphic, salverform, ascending, green yellowish or pale red yellowish on the outside and yellow pale inside in anthesis, on pedicels 2–2.5 cm long; perigone tube 0.9–1.5 cm long, 0.3–0.4 cm wide at the base of the lobes, tubular but tapering slightly toward the extremes, not curved; lobes 0.7–0.9 × 0.3–0.4 mm, ovate to lanceolate, markedly divergent in anthesis, outer lobes barely noticeably hyaline, apices with a tuft of short white hairs. Stamens epitepalous, antitepalous, phaneranthérous; filaments subulate, 3.7–5.6 mm long from their insertion into the perigone tube, inserted just at the base of the lobes, yellow; anthers elliptic, 4.5–5.5 × 2–2.5 mm, yellow. Ovary 0.5–0.7 × 0.3–0.5 cm, ovate; style filiform, 1.7–2.1 cm long in anthesis, exserted from the perigone tube 0.3–0.5 cm in anthesis; stigma trigonous, trilobed, papillose, clavate. Fruit a loculicidal capsule, 1.2–1.6 × 1–1.5 cm, globose, crowned by the remains of the perigone. Seeds deltoid, 3–3.5 × 2.2–2.5 mm, flat, black, and shiny.

***Additional Specimens Examined*—Mexico**. Jalisco: Cabo Corrientes, El Tuito, km 18.5 del camino de El Tuito a El Cuale, 1060 m, 14 Nov 2015 (fl), *P. Carrillo-Reyes & G. I. Tinoco-Villa 8160* (IBUG, IEB, MEXU); km 18 brecha Mina Zimapán-Cuale, 1050 m, 25 Jan 2015 (fr), *F. J. Santana-Michel 6215* (ZEA); km 17 de la brecha a El Cuale, a partir del km 175 de la carretera Méx. 200, 920 m, 13 Sep 2015 (infertile), *A. Rodríguez & A. Castro-Castro 7611* (IBUG); km 18.5 de la brecha a El Cuale, a partir del km 175 de la carretera Méx. 200, 920 m, 13 Sep 2015 (infertile), *A. Rodríguez & A. Castro-Castro 7613a* (IBUG).

Distribution and Habitat*—Manfreda santana-michelii* is endemic to western Mexico, where it occurs on the Pacific slopes of the north extreme of Sierra Madre del Sur, Cabo Corrientes municipality, Jalisco, Mexico. It inhabits the ecotone between open *Quercus* L. and *Pinus* L. forest, and savannoid vegetation. The plants are found in areas with deep and acidic soils at 920–1060 m elevation. *Manfreda santana-michelii* is associated with *Bejaria mexicana* Benth., *Bessera tuitensis* R.Delgad., *Bletia ensifolia* L.O.Williams, *Byrsonima crassifolia* (L.) Kunth, *Clethra rosei* Britton., *Manfreda involuta, Muhlenbergia cualensis* Y.Herrera & P.M.Peterson, *Nolina* sp., *Pinus jaliscana* Pérez de la Rosa, *P. oocarpa* Schiede ex Schltdl., *Prochnyanthes mexicana* (Zucc.) Rose, *Quercus aristata* Hook. & Arn., *Q. cualensis* L.M.González, *Q. resinosa* Liebm., *Salvia cualensis* J.G.González, *Schoenocaulon jaliscense* Greenm., *Vaccinium stenophyllum* Steud., *Verbesina* sp., and *Wedelia talpana* B.L.Turner.

Table 1. Differences and similarities in morphological, phenological and geographical traits among *Manfreda santana-michelii* and related species.

Character	*M. involuta*	*M. santana-michelii*	*M. singuliflora*
Corm	Oblong or ovate, 1–5 × 0.8–2 cm	Oblong, 2–2.8 × 1–1.3 cm	Oblong, (2–)5.5–9 × 0.8–1 cm
Bulb	Oblong, 5–7.5 × 2–3.5 cm	Oblong-ovoid, 3.5–4.8 × 2–2.5 cm	Ovoid, 4–5.5 × 2–4 cm
Leaves	6–18, linear, 18–80 × 0.2–0.9 cm, erect, involute, smooth	7–10, linear, 30–45 × 0.2–0.5 cm, erect, falcate, involute, retrorsely and antrorsely denticulate, upper and lower surface papillate	6–14, linear-lanceolate, 17–38 × 0.4–1.5 cm, erect, channeled, smooth
Inflorescence	Spiciform, 60–180 cm long	Racemose, 90–135 cm long	Spiciform, 45–116 cm long
Peduncle	50–130 cm long	90–96 cm long	90–96 cm long
Rachis	10–35 cm long, 3–18 floral nodes	26–36 cm long, 12–17 floral nodes	6–28(–36) cm long, 3–8 floral nodes
Floral bracts	Lanceolate-ovate, 0.4–1 × 0.2–0.4 cm, acute, truncate, smooth, persistent, scariose, ascending	Linear to subulate, 0.3–4.5 × 0.02–0.2 cm, acute, green, reflexed	Deltoid to subulate, 0.5–1.3 × 0.2–0.4 cm, scariose, ascending
Pedicels	Sessile	0.4–2.5 × 0.05–0.07 cm long	Sessile or unusually the lower shortly pedicellate
Flowers	Solitary, funnel-shaped, divaricate, green-purplish in anthesis	Geminate, salverform, ascending, green yellowish or red yellowish outside and yellow pale inside in anthesis	Solitary, funnel-shaped, divaricate, green-brownish outside and yellow pale inside in anthesis
Perigone tube	1.2–1.5 cm long, 0.5–0.7 cm wide at the base of the lobes, narrowly funnelform, not curved	0.9–1.5 cm long, 0.3–0.4 cm wide at the base of the lobes, tubular but tapering slightly toward the extremes, not curved	1.5–4 cm long, 0.4–0.9 cm wide at the base of the lobes, narrowly funnelform, curved so that the mouth of the tube faces downwards
Lobes	0.7–0.8 × 0.3–0.5 mm, lanceolate, diffuse in anthesis	0.7–0.9 × 0.3–0.4 mm, ovate to lanceolate, markedly divergent in anthesis	0.7–1.5 × 0.3–0.4 mm, oblong-lanceolate, markedly revolute in anthesis
Filament	Linear, purple, 1.2–2.5 cm long, inserted 0.3–0.7 cm above the ovary tip	Subulate, yellow, 0.3–0.5 cm long, inserted just at the base of the lobes	Linear, purple, 1.0–1.2 cm long, inserted 0.7–2 cm above the ovary tip
Anthers	Lanceolate, 7–8 × 1–1.2 mm	Elliptic, 4–6 × 2–3 mm	Lanceolate, 8–12 × 2–2.5 mm
Style	2.8–3.5 cm long, exserted from the perigone tube 1.8–3 cm in anthesis	1.7–2.1 cm long in anthesis, exserted from the perigone tube 0.3–0.5 cm in anthesis	2–5.5 cm long in anthesis, exserted from the perigone tube 0.5–1.2 cm in anthesis
Fruit	1.5–2 × 0.7–1.3 cm, globose to oblong, crowned by the remains of the perigone and acute ovarian protrusion	1.2–1.6 × 1–1.5 cm, globose, crowned by the remains of the perigone and acute ovarian protrusion	1.5–2.3 × 1.3–1.7 cm, globose to oblong, crowned by the remains of the perigone and acute ovarian protrusion
Seeds	Lunulate to ovate	Deltoid	Deltoid
Habitat	Oak-pine forest	Ecotone between oak-pine forest and savannoid vegetation	Oak-pine forest
Phenology	Flowering and fruiting from March to July	Flowering and fruiting from November to December	Flowering and fruiting from late June to October
Distribution in Mexico	Southeast Nayarit, north-northwestern Jalisco, and southern Zacatecas	Western Jalisco	From Chihuahua and Sinaloa to Durango, Jalisco and Zacatecas
Elevation range	400–2000 m	920–1060 m	1990–2750 m

Phenology—The new species flowers in November and fruits in December.

Conservation Status—*Manfreda santana-michelii* is represented by four collections in close proximity. Using GeoCAT (Bachman et al. 2011) the extent of occurrence (EOO) is 0.67 km^2, and the size of the area of occupancy (AOO) is 4 km^2, based on cells of 2 × 2 km. Based on EOO and AOO area results, and following the IUCN (2012) criteria (extent of occurrence estimated to be less than 100 km^2 and known to exist at only a single location), a preliminary category of critically endangered is suggested (CR/B1a).

Etymology—The specific epithet honors Francisco Javier Santana Michel (1958–2015), the first collector of the species, an outstanding botanist and expert of the western Mexico flora, and promoter for the declaration of the Sierra de Manantlán Biosphere Reserve in Jalisco, Mexico.

Relationship and Systematic Position—Although *Manfreda santana-michelii* is difficult to relate with conspecifics, the most comparable species are *M. involuta* McVaugh and *M. singuliflora* (S.Watson) Rose. However, *M. santana-michelii* differs from both by the development of leaves with denticulate margins (vs. smooth), racemose inflorescences (vs. spiciform), geminate flowers (vs. single), pedicels that are 2–2.5 cm long (vs. sessile flowers), a tubular, ascending, and straight perigone tube (vs. funnel-shaped, divaricate, and curved so that the mouth of the tube faces downwards in *M. singuliflora*), and filaments that are 0.3–0.5 cm long and inserted just at the base of the perigone lobes (vs. 1–2.5 cm long and inserted 0.3–0.7 cm above the ovary tip; Figs. 1–2). The differences and similarities in morphological, phenological, and geographical traits among them are highlighted in Table 1 and in the key for *Manfreda* in western Mexico provided below and modified from Castro-Castro et al. (2017).

Key to *Manfreda* in Western Mexico

1. Geminate and pedicellate flowers at the nodes . . . *M. santana-michelli*
1. Solitary and sessile flowers at the nodes . . . 2
  2. Leaves succulent, 4–8 mm thick, with deltoid teeth on the margins . . . *M. brunnea*
  2. Leaves chartaceous, 0.5–2 mm thick, with erose margins . . . 3
    3. Fruit protruding into the perigone tube as a dome or cone up to 3–5 mm long . . . 4
    3. Fruit not protruding into the perigone tube or hardly so as a cone, to 1 mm long . . . 9
      4. Corm 1.7–2 × 1–1.5 cm; perigone tube funnelform and curved 180° . . . *M. singuliflora*
      4. Corm 2.9–13.5 × 1.4–5 cm; perigone tube cylindrical and straight or curved 20–45° . . . 5
        5. Leaves lanceolate-elliptic, frequently variegate; inflorescence rachis 2.3–14 cm long . . . *M. guttata*
        5. Leaves lanceolate, linear-lanceolate to oblong, concolorous; inflorescence rachis 10–33 cm long . . . 6
          6. Perigone tube 0.3–1.1 cm long; leaves lanceolate to oblong . . . 7
            7. Leaves papillate on both surfaces; perigone 1.8–2.5 cm long, funnel-shaped, yellowish and light purple striped; perigone tube 0.3–0.7 × 0.2–0.4 cm; filaments inserted 0.3–0.7 cm above the ovary tip; style 2.1–3.5 cm long, exceeding the perigone tube by 1.8–3 cm at anthesis . . . *M. occidentalis*
            7. Leaves smooth on both surfaces; perigone 2.8–3.5 cm long, salverform, yellowish; perigone tube 0.9–1.1 × 0.1–0.3 cm; filaments inserted 0.9–1 cm above the ovary tip; style 4.5–5 cm long, exceeding the perigone tube by 3.5–4.2 cm at anthesis . . . *M. planifolia*
          6. Perigone tube 1.3–1.8 cm long; leaves linear-lanceolate . . . 8
            8. Corm 3–4.5 cm long; leaves 24–45(–60) × 0.8–2.8 cm, flat; inflorescence rachis 10–25(–33) cm long . . . *M. pringlei*
            8. Corm 6–10 cm long; leaves (40–)50–95 × 2.5–5 cm, channeled; inflorescence rachis 20–40(–70) cm long . . . *M. elongata*
              9. Perigone tube 15–25 mm long, about as long as or longer than the lobes; flowering from July to September, during the rainy season . . . 10
                10. Floral bracts (1.7–)4.5–6.5 cm long; perigone (3–)4–7 cm long; perigone tube 2.7–3.3 cm long . . . *M. longibracteata*
                10. Floral bracts 1–3.2(–4) cm long; perigone 3–3.5 cm long; perigone tube 1.5–2 cm long . . . *M. scabra*
              9. Perigone tube 4–13 mm long, about as long as the lobes; flowering from January to May, during the dry season . . . 11
                11. Leaves reclined on the ground; perigone yellow-green; filaments exceeding the perigone tube by 4–8.5 cm . . . 12
                12. Perigone tube 0.4–0.6(–1) cm long, shorter than the lobes; style 6–9 cm long . . . *M. jaliscana*
                12. Perigone tube 0.6–1.3 cm long, as long as the lobes; style 4.2–5(–6) cm long . . . *M. chamelensis*
                11. Leaves erect; perigone reddish-green; filaments exceeding the perigone tube by 1–4 cm . . . 13
                13. Leaves 30–50 × 0.2–0.5 cm, involute and often appearing tubular, then 2–3 mm in diameter, wanting during the flowering time . . . *M. involuta*
                13. Leaves 17–30(–38) × 0.6–1.4 cm, flat to channeled, present during the flowering time . . . *M. rubescens*

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