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Four new endemic species of *Nolana* (Solanaceae-Nolaneae) from Arequipa, Peru

Cuatro nuevas especies endémicas de *Nolana* (Solanaceae-Nolaneae) de Arequipa, Perú

Victor Quipuscoa Silvestre
Departamento de Biología, Universidad Nacional de San Agustín,
Arequipa, PERÚ
vquipuscoa@unsa.edu.pe

Michael O. Dillon
The Field Museum, Integrative Research Center
1400 South Lake Shore Drive, Chicago, IL 60605-2496, USA
mdillon@fieldmuseum.org

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Abstract

In preparation of a monographic treatment for *Nolana* L. ex L. f. (Solanaceae-Nolaneae), four new species are described from department of Arequipa, southern Peru: *N. bombonensis* Quip. & M. O. Dillon, prov. Islay, district of Punta de Bombón, Lomas de Alto La Punta; *N. callae* Quip. & M. O. Dillon, prov. Islay, district of Punta de Bombón, Lomas de Jesús; *N. quicachaensis* Quip. & M. O. Dillon, prov. Caravelí, dist. Quicacha; and *N. tricotiflora* Quip. & M. O. Dillon, prov. Camaná, dist. Quilca, Lomas de Quilca. These species are diagnosed, described, illustrated and compared to nearest geographic neighbors in southern Peru. To aid in recognition, a key to *Nolana* species reported from Arequipa is provided.

Keywords: *Nolana*, Nolaneae, new species, department of Arequipa, Peru, Solanaceae.

Resumen

En la preparación para la publicación de la monografía de *Nolana* L. ex L. f. (Solanaceae-Nolaneae), se describen cuatro especies nuevas en departamento de Arequipa del sur de Perú: *N. bombonensis* Quip. & M. O. Dillon, prov. de Islay, distrito de Punta de Bombón, Lomas de Alto La Punta; *N. callae* Quip. & M. O. Dillon, prov. de Islay, distrito de Punta de Bombón; *N. quicachaensis* Quip. & M. O. Dillon de la prov. Caravelí, dist. Quicacha; y *N. tricotiflora* Quip. & M. O. Dillon de la prov. Camaná, dist. Quilca, Lomas de Quilca. Además de las diagnosis y descripciones, se realizan las ilustraciones y se comparan con las especies geográficamente vecinas más cercanas del sur de Perú. Para ayudar al reconocimiento, se proporciona una clave para las especies de *Nolana* reportadas en departamento de Arequipa.

Palabras clave: *Nolana*, Nolaneae, endémicas, especies nuevas, departamento de Arequipa, Perú, Solanaceae.

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Introduction

Nolana L. ex L. f. (Solanaceae-Nolaneae) is a genus consisting of 89 species, including the four described here (Dillon, 2016, Table 1). No fewer than 39 species have been reported from Peru, and another three species which have distributions ranging into northern Chile (*Nolana adansonii* (Roem. & Schult.) I. M. Johnst., *N. gracillima* (I. M. Johnst.) I. M. Johnst. and *N. lycioides* I. M. Johnst.). This brings the total number of *Nolana* potentially encountered in Peru to 42 species. Of this number, 32 species (75%) are recorded from the Department of Arequipa. In Peru, greatest species diversity is confined to near-ocean localities termed *lomas* formations, between 50-800 m elevation and within 50 kms of the Pacific Ocean (Rundel *et al*., 1991; Dillon, 1997; Dillon *et al*., 2003). Only a few species are distributed above 2000 m and/or at a distances of 50-500 kms inland from the coast, e.g., *N. chapiensis* M. O. Dillon & Quip., *N. confinis* I. M. Johnst., *N. laxa* (Miers) I. M. Johnst., *N. lezamae* M. O. Dillon, Leiva, & Quip., *N. urubambae* Vargas, and *N. weberbaueri* I. M. Johnst.). Most species are narrow endemics, with small, restricted geographic ranges and specific ecological requirements, but a few species have larger geographic distributions and occur over wide geographic ranges, e.g., *Nolana humifusa* (Gouan) I. M. Johnst. and *N. gayana* (Gaudich.) Koch.

The area occupied by *Nolana* species in the department of Arequipa is an arid

strip bordering the Pacific Ocean, ca. 500 kms long and ca. 50 kms wide or an area of approximately 25,000 km^2 (Dillon, 1997; Dillon *et al*., 2003). The desert is essentially continuous, but there are changes in physiognomy and discontinuities provided by intervening river valleys. The major rivers to dissect the coast are Río Ocoña, Río Camaná, Río Quilca, Río Tambo, and Río Osmore. The distribution of the 32 species recorded from the department contains some taxa with wide distributions, essentially occurring throughout, for example *Nolana spathulata* Ruiz & Pav., or the aforementioned species recorded from northern Chilean localities (i.e., *N. adansonii*, *N. gracillima*, *N. lycioides*), but most are narrow endemics.

The amazing species diversity in *Nolana* has been stimulated by ecological changes within the study area. Both long-term (glacial cycles, ~15,000 years) and short-term (ENSO events, ~15 years) causational phenomena (Dillon *et al*., 2003). Current-day distributions belie the dynamic history of the coastal region over the last 4 my (Dillon *et al*., 2009). It is assumed that taxa are products of allopatric speciation models, where isolation plays an important role in insuring geographic fidelity in breeding populations. Today, instances of sympatry at a specific localities are deamed to be the result of transport of mericarps downslope by rain and wind. While rare, the periodic coastal rains move mericarps and provide germination opportunities.

Nolana is easy to identify as a genus with its unique mericarp fruits (Knapp 2002); however, species delimitations are open to interpretation and recognition of the number of accepted species has varied widely (Mesa, 1981; Dillon *et al*., 2009). This variation in the number of species recognized is due to widespread homology in easily observed characters and the dramatic loss of discriminant characters only observable in living material. Upon drying, *Nolana* specimens lose characters, i.e., working with herbarium or dried material is much more difficult. In this study and in the preparation of a monograph, virtually all taxa have been examined and photographed in the living state. Recent discoveries during field studies in the Department of Arequipa have led to the recognition of four new species considered morphologically distinct and geographically circumscribed.

As illustrated in Dillon *et al*. (2009), members from three clades are represented in Arequipa, i.e., Clades D, E, and F. It is surmised that the four species described here would all fall within Clade F. Clade F was recovered as a well-supported but poorly resolved group (Dillon *et al*., 2009); 27 species confined to Peru, and one Chilean species, *N. intonsa*. Of the new species proposed here, only one has been included in phylogenetic analyses (Dillon *et al*., 2007; 2009; Tu *et al*., 2008). Comments concerning phylogenetic relationships are largely postulated from comparative morphology.

Materials and methods

Descriptions were made from both living material encountered during field studies and dried herbarium specimens deposited in HSP, F, and USM. All acronyms follow those in Index Herbariorum (http://sweetgum.nybg.org/science/ih/). Conservation status was assigned using IUCN criteria (2017) combined with field observations and geographic distribution based on herbarium specimens.

We utilize the "morphological cluster" concept in recognition of species in *Nolana* (see Mallet, 1995), defined as "assemblages of individuals with morphological features in common and separate from other assemblages by correlated morphological discontinuities in a number of features". In addition to the diagnoses provided for the new species, specific characters useful in recognition of species are detailed in the Key to Species of Arequipa.

Resultads and discussion

Taxonomic treatment

1. *Nolana bombonensis* Quip. & M. O. Dillon, sp. nov. (Fig. 1, 2, 3)

TYPE: PERU. **Arequipa:** Prov. Islay, dist. Punta de Bombón, Lomas de Alto La Punta, 17º09´37.0" S, 71º46´35.5' W, 168 m, 31-X-2017, *V. Quipuscoa S., M. O. Dillon, C. Tejada P., M. Balvin A., S. Huamaní Q., M. Bedoya C., C. Sanz N., & M. Flores M. 6338* (holotype: HSP-007821; isotypes: F-2322991, USM-301275).

Diagnosis

Nolana bombonensis is most similar to N. volcanica and differs from that species in cinereous habit, oblong densely lanuginous leaves, calyx lobes unequal, apically obtuse or blunt, and pale lilac or light lavender corollas lacking prominent dark-purple nectar guides in the inner throat.

Description

Sprawling, cinereous, suffrutescent *subshrubs*, to 1.5 m in diameter, 25-50 cm tall; stems intricately branched, prostrate to decumbent or spreading, stems to 50 cm long, much-branched, densely lanuginous to arachnoid. *Leaves* alternate, sessile, the blades linear-oblong, 5-8 (-11) mm long, 1-2 (-2.5) mm wide, densely lanuginous pubescent, succulent, entire, apically rounded, the bases cuneate, margins revolute, abaxially canaliculate. *Inflorescences* of solitary flowers in upper leaf axils; pedicels cylindrical, densely pubescent, 2-7 (-10) mm long. *Flowers* 5-merous; calyx narrowly campanulate, 3-4 mm wide at anthesis, densely lanuginous, 5-lobed, the tube ca. 3 mm long, 3-5 mm in diameter, the lobes oblong-lanceolate, unequal, 4-5 (-5.5) mm long, 1.5-2 mm wide, the apices obtuse or rounded; corollas zygomorphic, infundibuliform, 15-20 mm wide at anthesis, 15-20 (-22) mm long, light lavender or lilac, the throat clear, externally and internally glabrous, the trichomes uniseriate; stamens 5, included, the filaments inserted on lower third of corolla, unequal, 8-14 mm long, pilose at the bases; anthers dithecal, purple, the thecae ca. 1.2 mm long, ca. 1 mm wide, glabrous; ovary glabrous, ca. 1 mm long, ca. 1.2-1.5 mm wide, basal nectary ca. 1 mm wide, the carpels 5, the style included, (4-) 7-11 mm long, the stigma lateral, green, ca. 0.5 mm long. *Fruits* mericarps, 5, 1-seriate, polyhedrons, brown to black, rugose, 2-2.5 mm, 3 large, 2 small, included within the expanding calyx, 3-4-seeds.

Phenology

Flowering august-november.

Etymology

The specific epithet is derived from the geographic area of Punta de Bombón, near the town of Cocachacra in southern Department of Arequipa.

Distribution and ecology

Nolana bombonensis has been recorded from several locations south of Punta de Bombón, Department of Arequipa (Figure 4) at the mouth of the Río Tambo. The type locality is the most northwestern population with additional localities

extending about 30 kms to the south along a low strip of land near the ocean.

Putative relationships

Nolana bombonensis is distinctive among its congeners in Peru with its dense, gray, tomentose pubescence and lite lavender corollas. It is apparently a narrow endemic restricted to a small environmentally distinct habitat, and sympatric at some localities with other *Nolana* species, e.g., *N. adansonii*, *N. pilosa*, *N. spathulata*, and *N. thinophila* I. M. Johnst. When this plant was first encountered in 2003, it was mistaken for *N. volcanica*, a species originally described from above Mollendo, i.e., Lomas of Yuta (Quipuscoa *et al*., 2016). When detailed sampling more clearly defined the range of phenotypic variation in *N. volcanica*, the population at Punta de Bombón was deemed distinct.

This species was included in the molecular studies under the name, *N. volcanica* (Quipuscoa *et al. 2930*) and its relationships were with other southern Peruvian species. Utilizing a variety of DNA markers, *N. volcanica* was recovered with congeners, i.e., GBSSI sequences (Dillon *et al*., 2007) found *N. lycioides* as its sister taxon; LEAFY second intron (Tu *et al*., 2008) recovers it in a clade with *N. cerrateana*, *N. intonsa* (Chilean), and *N. lycioides*; and a variety of chloroplast markers recovered it in an unresolved clade with other over a dozen other species from Arequipa (Dillon *et al*., 2009).

The growth form is not unique among *Nolana*, but the gray The character of dense tomentose pubescence is not common in the genus. Among Peruvian taxa, only *Nolana tomentella* Ferreyra shares the character. There are tomentose taxa found in Chile, e.g., *Nolana diffusa* I. M. Johnst., *N. tocopillensis* (I. M. Johnst.) I. M. Johnst. N. *sedifolia* Poepp., and *N. villosa* (Phil.) I. M. Johnst.; however, these species are very different in their floral and vegetative morphology; they have no clear relationships with any Peruvian species (Dillon *et al*., 2009).

Conservation status

Critically Endangered (CR); overall distribution <10 km^2 (CR) and perhaps <250 individuals. See IUCN (2017) for explanation of measurements. Agriculture and poultry farming is expanding rapidly in this area severely impacting coastal ecosystems; the future of this and other plants is very uncertain.

Additional specimens examined

PERU. **Arequipa**: prov. Islay, Punta de Bombón. Carretera Costanera, Aprox. 10 Km al Sur de Punta de Bombón, 17º11'S, 71º43'W, 20 m, 19-XI-2005, *M. O. Dillon, J. Wen, S. Leiva G., V. Quipuscoa S., E. Ortiz, M. Zapata C., M. Corrales M. & J. Castillo 8989* (HSP, HUSA, F-2276597), *8995* (HSP, HUSA, F-2276603); ca. Km 153 carretera Punta de Bombón-Ilo, 17º11´57.6" S, 71º42´08.6' W, 7 m, 28-X-2017, *V. Quipuscoa, M. O. Dillon, M. Balvin A., S. Huamaní Q. & M. Bedoya C. 6226* (HSP).

Notes

Nolana bombonensis was initially confused with *Nolana volcanica* Ferreyra (1960), a species based upon a collection by Ms. Dora B. Stafford (holotype: K000532281) from a locality ca. 40 kms north of the Río Tambo. That collection was gathered from the quebrada above Mollendo at ca. 600 m (2000 ft) from habitats of "sand and volcanic ash" in the Lomas of Yuta. Sampling *N. volcanica* throughout its range and over a period of years illustrated that the density of pubescence is variable with glabrescence typical. The

floral morphology and corolla coloration pattern in *Nolana volcanica* is significantly different from *N. bombonensis*. In contrast to *N. bombonensis*, *N. volcanica* is composed of spreading perennials appearing green, and flowers with attenuate calyx lobes, and shorter, pale blue corollas with a dark purple band and nectar guides within the throat.

2. *Nolana callae* Quip. & M. O. Dillon, sp. nov. (Fig. 5, 6)

TYPE: PERU. **Arequipa**: Prov. Islay, dist. Punta de Bombón, Lomas de Jesús, ca. Km 172 carretera costanera, entre Corío y Yerba Buena, 17º14´39.03" S, 71º32´46.5' W, 265 m, 06-I-2018, *V. Quipuscoa S., M O. Dillon & C. Tejada P. 6857* (holotype, HSP-007823; isotypes, F-2322992, USM-301277).

Diagnosis

Nolana callae most closely resembles N. cerrateana, but differs in characters of the habit, leaves, pedicels, calyx shape, and number of mericarps. The former species has a prostrate habit forming mats to 1.2 m in diameter; slightly larger elliptic-lanceolate leaves 15-30 mm long, 5-12 mm wide, base of petioles with conspicuous sheath, abaxial and adaxial surfaces lanuginous; pedicles to 35 mm long; calyx with narrowly deltoid to linear lobes and five mericarps.

Description

Suffruticose *perennials*, 0.7-1.2 m in diameter; stems decumbent to repent, much-branched, lanuginose, glabrescent, young branches greenish-purple, pubescence of simple trichomes. *Leaves* alternate, petiolate, swollen bases 2-4 mm wide, sclerified; petioles slightly ribbed, 3-7 (-10) mm long, lanuginous, the blades elliptic to lanceolate, 15-30 (-40) mm long, 5-12 (-15) mm wide, laxly lanuginous, glabrescent, succulent, entire, apically acute, basally attenuate, slightly revolute. *Inflorescences* of solitary flowers in upper leaf axles; pedicels 5-30 (-35) mm long, lanuginous. *Flowers* 5-merous; calyx campanulate 4-7 (-8) mm wide, densely lanuginous, 5-lobed, the tube 1.5-2 mm long, 3-5 mm in diameter, the lobes narrowly deltoid to linear, unequal, 5-10 (-12) mm long, 1-2.5 (-3) mm wide, the apices acute to obtuse; corollas zygomorphic, infundibuliform, 15-23 mm wide at anthesis, 17-23 (-25) mm long, lavender, inner throat purple, externally and internally glabrous; stamens 5, included, the filaments 11-15 (-17) mm long, 2 long, 3 short, bases pilose; anthers dithecal, purple, the thecae 2-2.5 mm long, ca. 1 mm wide, glabrous; ovary glabrous, ca. 1 mm long, 1.2-1.5 mm wide; nectary basal, orange, ca. 1 mm wide, the carpels 5, the styles included, 6-9 mm long, the stigma lateral, green, ca. 0.5 mm long. *Fruits* mericarps, 5, 1-seriate, polyhedrons, black, lightly rugose to smooth, 4-3 mm long, 2-3 mm in diameter, equal, included within maturing calyx; 2-3-seeds per mericarp.

Phenology

Flowering october-january.

Etymology

The specific epithet is dedicated in homage to the professor of Botany of the National University of San Agustin de Arequipa, Abraham Calla Paredes, for his dedication to the teaching of algae and shared friendship for many years.

Distribution and ecology

Nolana callae is considered endemic to Arequipa and is restricted to dry, rocky slopes at the lower part of the Lomas de Jesus, between Punta de Bombón and Ilo (Figure 4). To date, it has only been

recorded from the type locality together with *Nolana adansonii*, *N. bombonensis*, *N. spathulata*, and *Solanum peruvianum* L. It was discovered in disturbed roadside localities and likely, with continued exploration, it is anticipated that the distribution may be expanded upslope.

Putative relationships

Nolana callae has not been included in phylogenetic analysis and its putative relationships are here based upon comparative morphology and distribution. It has similarity with *N. cerrateana*, sharing habit and lanuginous leaves; however, *N. cerrateana* has longer pedicels to 50 mm, more fasciculate leaves, and a calyx with purple coloration, and 10-14 mericarps.

Conservation status

Critically Endangered (CR); overall distribution <10 km^2 (CR) and perhaps <250 individuals. See IUCN (2017) for explanation of measurements.

Additional specimens examined

PERU. **Arequipa**: Prov. Islay, Dist. Punta de Bombón. Punta de Bombón, 17º14.6'S, 71º32.7'W, 27-X-2003, *V. Quipuscoa S., M. O. Dillon, R. Freyre, & M. Benavides 2930* (HSP, HUSA), *2933* (HSP, HUSA); Prov. Islay, Dist. Punta de Bombón, Lomas de Jesús, 17º14´40.7" S, 71º32´46.06' W, 267 m, 29-X-2017, *V. Quipuscoa S., M.O. Dillon, C. Tejada P., M. Balvin A., S. Huamaní Q. & M. Bedoya C. 6309* (HSP, F).

Notes

Nolana callae most closely resembles *N. cerrateana*, a species from the area of Camaná, further north in Arequipa; however, it also shares some superficial similarity to *N. intonsa* I. M. Johnst. from northern Chile. These species also have a prominent dark band and nectar guides in the throat of the corolla (Figure 6B).

3. *Nolana quicachaensis* Quip. & M. O. Dillon sp. nov. (Fig. 7, 8)

TYPE: PERU. **Arequipa**: Prov. Caravelí; Quicacha, entre Caramba y Quicacha, 15º39´24.58" S, 73º48´53.07' W, 1593 m, 30 -XI-2017, *V. Quipuscoa S., M. O. Dillon, M. Balvin A., S. Huamaní Q, M. Bedoya C. & W. Ancalla Ch. 6763* (holotype, HSP-007825; isotypes, F-2322993, USM-301276).

Diagnosis

Nolana quicachaensis most closely resembles N. lycioides, with its woody, much-branched habit and tubular corollas; however, the new species has fasciculate, sessile, terete leaves, pubescent with short glandular trichomes; solitary axillary flowers forming a weak, terminal raceme; calyx lobes narrowly deltoid, long-attenuate, 4-6 mm long; the corollas hypocrateriform with yellow tube and white lobes; 15-18 mericarps.

Description

Shrubs, 0.3-1 m tall, the stems of dense wood, 3-4 cm in diameter, lenticellate, fissured, much-branched, glabrescent. *Leaves* fasciculate, sessile, the blades linear to narrowly spathulate, 5-9 (-11) mm long, 0.5-1.5 (-2) mm wide, sigmoid, glutinous, succulent, entire, apically cuspidate, basally attenuate, terete. *Inflorescences* weakly racemose, the flowers solitary, axillary, pedicles cylindrical, glandular-pubescent, 5-8 (-13) mm long. *Flowers* 5-merous; calyx narrowly campanulate, 3-4 mm wide, glutinous inside and out, 5-lobed, the tube ca. 1 mm long, 2.5-3 mm in diameter, the lobes linear-lancelate, unequal, 4-5 (-6) mm long, 1-1.5 mm wide, apices long-attenuate; corollas zygomorphic, tubular-hypocrateriform, 10-12 mm wide at anthesis, 18-20 (-23)

mm long, the tube yellow, the lobes white, externally glutinous internally glabrous; stamens 5, included, the filaments inserted in the middle of the corolla, unequal, 12-16 (-18) mm long, 2 long and 3 short, bases glabrescent; anthers dithecal, white, the thecae 1.5-2.5 mm long, ca. 1 mm wide, glabrous; ovary glabrous, ca. 1 mm long, 1-1.5 mm wide, nectary basal, orange, ca. 1 mm wide, the carpels 15-18, the styles 14-17 mm de largo, the stigma lateral, ca. 0.5 mm long. *Fruits* mericarps, 15-18, 2-3-seriate, 5 large, 2-2.5 mm long, 1.8-2 mm in diameter; 10 intermediate, 1.5-1.8 mm long, ca. 1 mm in diameter, 1-3 small, 1-1.2 mm long, 0.5-0.8 mm in diameter, pyriform, oblong, black, lightly rugose to smooth, contained within the calyx at maturity, 1 seed per mericarp.

Phenology

Flowering october-december.

Etymology

The specific epithet is derived from the geographic area of Quicacha, near the town of Cháparra in north Department of Arequipa.

Distribution and ecology

Nolana quicachaensis is only known from the type between the towns of Caramba and Quicacha (Figure 4). It was found growing between granitic rocks in the lower part of the south-facing slopes. Associates included members of desert vegetation such as, species of Cactaceae (*Melocactus*, *Cumulopuntia*, *Weberbauerocereus*), Asteraceae (*Helogyne*, *Baccharis*) and annual grasses.

Putative relationships

Nolana quicachaensis has not been included in phylogenetic analysis and its putative relationships are here based upon comparative morphology and distribution. It has similarity with *N. lycioides*, but differs in a range of characters.

Conservation status

Critically Endangered (CR); overall distribution <10 km^2 (CR) and perhaps <250 individuals. Before rational status can be determined, further studies in the area are needed to determine population size and distribution.

4. *Nolana tricotiflora* Quip. & M. O. Dillon. sp. nov. (Fig. 9, 10)

TYPE: PERU. **Arequipa**: Prov. Camaná, Quilca, Lomas de Quilca, Km 62 carretera Costanera, Carrizales, 16º51´18.6" S, 72º12´21.4' W, 622 m, 03-XI-2017, *V. Quipuscoa S., M. O. Dillon, M. Balvin A., S. Huamaní Q. & M. Bedoya C, 6433* (holotype, HSP-007827; isotypes, F2322994, USM-301274). Figure 9

Diagnosis

Nolana tricotiflora differs from all other members of the genus with a unique combination of characters not encountered. Its erect crooked, woody trunks to 50 cm tall; numerous spirally-arranged leaves, and terminal, three-branched, scorpioid cymes.

Description

Shrublets, 30-50 cm tall; stems woody, 1-2 cm in diameter, brown, lenticellate, cracked, slightly branched at the base, pubescent on mature stems, densely villous, young stems greenish-purple, pubescent with crooked glandular trichomes to 2 mm long. *Leaves* whorled, crowded at branch apex, sessile to subsessile, the leaf blades elliptic to linear-lanceolate, 10-14 (-15) mm long, 2-3 (-3.5) mm wide, falcate, distally flexed upwards, both surfaces villous, the trichomes to 1.5 mm long, apically capitate-glandular, succulent, entire, apically acute

to obtuse, basally attenuate. *Inflorescences* of 3 terminal, lax scorpioid cymes, 7-12 cm long, each with ca. 12 flowers; pedicels villous, apically capitate-glandular, 2-3(-4) mm long, subtended by reduced, villous, foliar bracts. *Flowers* 5-merous; calyx campanulate, 8-12 mm wide at anthesis, externally villous, glutinous, internally pubescent, 5-lobed, the tube 3-4 mm long, 3-5 mm in diameter, the lobes deltoid, unequal, 7-10 (-12) mm long, 3-4 mm wide, apically acute to obtuse; corollas zygomorphic, infundibuliform, 17-22 (-25) mm wide at maturity, 17-20 (-25) mm long, purple, the throat with dark nectar guides, externally and internally glabrous; stamens 5, included, the filaments 9-12 (-13) mm long, 2 long, 3 short, bases pilose; anthers dithecal, purple, the thecae 1.5-2.5 mm long, ca. 1 mm wide, glabrous; ovary glabrous, ca. 1.5 mm long, 1.5-2 mm wide, nectary basal, orange, ca. 1 mm wide, the carpels (11-) 12-18, the styles included, flat, 9-12 mm long, ca. 1 mm wide, the stigma apical, ca. 0.5 mm long, 1-1.5 mm wide. *Fruits* mericarps, 12-18, 2-seriate, pyriform, black, 5 large, 2-2.5 mm long, 1.5-2 mm in diameter; 10 medium, 1-3 small, lightly rugose to smooth, included within the expanded calyx as it matures; larger mericarps with 2-3-seeds.

Phenology

Flowering october-november.

Etymology

The specific epithet refers to the inflorescence of three terminal, lax scorpioid cymes.

Distribution and ecology

Nolana tricotiflora has only been recorded from the type locality, the Lomas of Quilca, between Matarani and Quilca (Figure 4). It was found growing between 550-800 m on ocean-facing slopes in the Carrizales sector. Vegetative associates include *Heliotropium* (Boraginaceae), *Cryptantha* (Boraginaceae), *Palaua* (Malvaceae), *Spergularia* (Caryophyllaceae), *Senecio* (Asteraceae), *Oenothera* (Onagraceae), *Nasa* (Loasaceae), *Hoffmannseggia* (Fabaceae), *Pasithea*, *Cytharexylum* (Verbenaceae), *Hierobotana* (Verbenaceae), *Loxanthocereus* (Cactaceae) and *Vasconcellea* (Caricaceae).

Putative relationships

Nolana tricotiflora has not been included in phylogenetic analysis and its putative relationships are difficult to establish upon comparative morphology and distribution.

Conservation status

Critically Endangered (CR); overall distribution <10 km^2 (CR) and perhaps <250 individuals. See IUCN (2017) for explanation of measurements.

Notes

Nolana tricotiflora contains a combination of characters not to be met in any other member of the genus. No woody species approach its overall habit with crowded cauline leaves and very long villous pubescence with glandular apical cells. But most unusual, is the inflorescence of three-branched weak scorpioid cymes with large flowers. In the majority of Peruvian *Nolana* species, the flowering stems are unmodified and flowers are borne as solitary in leaf axils. The only exceptions are southern Peruvian species, which have modifications of flowering stems into recognizable inflorescences with modified bracts subtending individual flowers, but arising from a basal rosette of modified leaves, *N. inflata* and *N. weissiana*. In *N. scaposa*, the condition reaches it maximum development where the inflorescence is a modified branch with subtending floral

bracts. None of these species remotely resemble *N. tricotiflora*.

Key to *Nolana* species recorded from Department of Arequipa

1	Plants with persistent basal rosette of petiolate leaves; leaves	**2**
_	Plants without persistent basal rosette of petiolate leaves; if ephemeral central rosette present, then leaves similar to cauline leaves in size and shape	**4**
2	Basal leaves wtih strictly entire blades; flowering shoots with sessile oval to ovate bracts subtending flowers, the flowers congested in dense inflorescence, densely villous pubescence; calyx campanulate, deeply lobed, lobes unequal, obtuse; corollas white	***N. scaposa***
_	Basal leaves with dentate to crenate blades; flowering shoots with petiolate, lanceolate bracts subtending flowers, the inflorescence open, flowers not congested, densely hirsute-glandular to arachnoid or lanuginous; calyx globose or bladder-inflated, lobes equal, triangular, acute; corollas deep purple to lavender	**3**
3	Cauline leaves ovate	***N. inflata***
_	Cauline leaves laneolate	***N. weissiana***
4	Inflorescences well-developed, consisting of three, terminal, weak scorpioid cymes	***N. tricotiflora***
_	Inflorescences not present, flowers usually solitary in upper leaf axles, weaking racemose, but never scorpioid cymes	**5**
5	Calyx appearing zygomorphic	**6**
_	Calyx actinomorphic or simply bilobed, the apices of lobes triangular to attenuate, never expanded apically	**8**
6	Leaf blades lancolate	***N. pallidula***
_	Leaf blades broadly lanceolate, spathulate, ovate	**7**
7	Blades with bases truncate	***N. spathulata***
_	Blades cuneate	***N. arenicola***

8	Leaves clearly petiolate, the bases auriculate, at times connate, the blades cordiform, more rarely reniform to lanceolate or elliptic, glabrous, surface with salt glands that attract atmospheric moisture causing the look and feel of oil	***N. adansonii***
_	Leaves not obviously petiolate, the bases not auriculate nor connate, the blades linear, lanceolate, elliptic to ovate, but never cordiform, surfaces glabrous to glabrescent to lanuginous or tomentose with stellate pubescence, never oily	**9**
9	Leaves linear, oblong, oblanceolate or narrowly spathulate	**10**
_	Leaves laminar, elliptic, lanceolate to ovate, mostly 2.5 mm wide or greater, margins often revolute	**21**
10	Leaves glabrous	**11**
-	Leaves pubescent with stipitate-glandular trichomes, villous, lanuginous or tomentose	**16**
11	Calyx bilobed, cylindrical, 2-4 mm wide, apically with 1-2 deep clefts, the proper calyx lobes reduced, either absent or inconspicuous 2-3 mm wide	**12**
-	Calyx uniformly 5-lobed, campanulate-tubular to globose	**14**
12	Minute erect annuals, 2-5 cm tall; flowers blue (Camaná)	***N. minor***
_	Spreading robust, annuals to perennials, generally 20-30 cm tall; flowers violet, purple, to white	**13**
13	Leaves 10-20 mm long, 2-4 mm wide, obovate to oblanceolate, corollas white, 3-6 mm wide, distributed in inland habitats (100-300 m)	***N. arequipensis***
_	Corollas purple to violet or lavender, 10-40 mm wide. Calyx glabrous to short, stipitate glandular, corolla ca. 1 cm broad (beachside)	***N. thinophila***
14	Calyx globose, 6-10 mm tall, 4-8 mm wide; leaves linear to oblanceolate, 10-40 mm long, 2-6.5 mm wide	***N. chancoana***
-	Calyx cylindrical-tubular to campanulate, 4-9 mm tall, 1.5-3.5 wide; leaves 8-25 mm long, 0.8-1.5 mm wide	**15**
15	Leaves lanuginous and glabrescent; flowers sessile or with short pedicels; mericarps 2	***N . spergularioides***
_	Leaves strictly glabrous; flowers pedicles, 5-13 mm long; mericarps 5	***N. gracillima***

16	Stems, leaves and calyx lobes tomentose, canescent or gray; leaves linear-oblong, mm long, mm wide	***N. bombonensis***
_	Stems, leaves and calyx lobes stipitate-glandular or lanuginous, green; leaves elliptic to ovate	**17**
17	Pubescence of stipitate-glandular trichomes	**18**
_	Pubescence lanuginous	**20**
18	Perennial herbs; corolla 10-15 long, 4.8-9 mm wide; leaves 6-14 mm long, 1.6-1.8 mm wide	***N. confinis***
-	Shrubs, much-branched; corollas infundibularis or salverform, generally longer than 15 mm	**19**
19	Corollas infundibular, 13-27 mm long, purple	***N. lycioides***
-	Corollas salverform, 18-23 mm long, white	***N quicachaensis*** .
20	Leaves linear-lanceolate, 7-10 mm long, 1.2-2.8 mm wide, pubescence lanuginous, sometimes dense	***N. volcanica***
_	Leaves linear, 8-16 mm long, 1-2 mm wide, pubescence laxly pubescent	***N. tovariana***
21	Leaves pubescent with stellate pubescence	***N. pallida***
-	Leaves glabrous or variously pubescent, never stellate	**22**
22	Leaves glabrous	**23**
-	Leaves pubescence	**24**
23	Corolla 20-30 mm long; calyx prominently pleated at the sinus, evenly rounded off beneath it, glabrous	***N. coronata***
-	Corolla 15-20 mm long; calyx lobes deeply cut, strigose	***N latipes***
24	Leaves with short or long stipitate-glandular trichomes	**25**
-	Leaves pubescent of non-stipitate trichomes, tomentose to strigose or sericeous	**28**
25	Pubescent with short stipitate-glandular trichomes	**26**
-	Pubescence villous, trichomes long, terminally stipitate-glandular	**27**
26	Calyx bilabiate, the lobes connate, 2 and 3 fused, 15-26 mm; corollas 28-50 mm long, 25-60 mm wide; mericarps 3-5	***N. aticoana***

-	Calyx zygomorphic with all lobes on one side, 18-30 mm long; corollas 32-38 mm long, 24-30 mm wide; mericarps 15-19	***N. mariarosae***
27	Leaves elliptic, 8-15 mm long, 2-3.5 mm wide	***N. chapiensis***
-	Densely pubescent with long, stipitate-glandular, trichomes; calyx flat, corolla 13-22 mm broad; leaves 10-27 mm long, 1-6 (-8) mm wide; stems and leaves pilose	***N. pilosa***
28	Pubescence stiff	**29**
-	Pubescence tomentose to lanuginous	**30**
29	Leaves Leaves lanceolate to oblanceolate or spathulate, 15-30 mm long, 10-20 cm wide, strigose	***N. johnstonii***
-	Leaves lanceolate to narrowly ovate, 10-65 mm long, 13 mm wide; trichomes stiff (shaggy) erect sericeous	***N. plicata***
30	Leaves canescent, pubescence tomentose, trichomes inter-tangled and arachnoid	***N. tomentella***
-	Leaves appearing green, pubescence lanuginous, the hairs not inter-tangled, never arachnoid	**31**
31	Leaves 15-30(-40) mm, 5-12 (-15) mm wide; corollas 15-23 mm wide; mericarps 5	***N. callae***
-	Leaves 11-26 mm long, 2-5.5 mm wide; corolla 12-20 mm wide; mericarps 10-14	***N. cerrateana***

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Contribution of the authors

V.Q.: Principal investigator, co-ordinator of the fieldwork in the data collection for the taxa, ecological data, photography and botanical collection; responsible of the descriptions and the first script, making corrections until the final version. M.O.D.: Co-investigator, contributed in the data collection at the field trips for describing the taxa, redaction, geographical data collection, photography, botanical collection, making of the figures, taxonomic key and manuscript correction.

Conflict of interests

The authors declare not to have conflicts of interests.

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Table 1. Alphabetical List of Accepted Names and Authorities, Distribution, and phylogenetic position as suggested by membership in clades of *Nolana* in South America. Membership in clades is adapted from Dillon et al 2019. [* designates distribution recorded from Department of Arequipa]

	Species	**Distribution**	**Clade**
1	*N. acuminata* (Miers) Miers ex Dunal	Chile	B
2	*N. adansonii* (Roem & Schult.) I.M.Johnst.	Chile-Peru*	F
3	*N. aenigma* M.O.Dillon & Quip.	Peru	F
4	*N. albescens* (Phil.) I.M.Johnst.	Chile	G
5	*N. aplocaryoides* (Gaudich.) I.M.Johnst.	Chile	G
6	*N. arenicola* I.M.Johnst.	Peru*	D
7	*N. arequipensis* M.O.Dillon & Quip.	Peru*	F
8	*N. aticoana* Ferreyra	Peru*	F
9	*N. baccata* (Lindl.) Dunal	Chile	B
10	*N. balsamiflua* (Gaudich.) Mesa	Chile	C
11	*N. bombonensis* Quip. & M.O.Dillon	Peru*	F
12	*N. callae* Quip. & M.O.Dillon	Peru*	F
13	*N. carnosa* (Lindl.) Miers ex Dunal	Chile	C
14	*N. cerrateana* Ferreyra	Peru*	F
15	*N. chancoana* M.O.Dillon & Quip.	Peru*	D
16	*N. chapiensis* M.O.Dillon & Quip.	Peru*	D
17	*N. clivicola* (I.M.Johnst.) I.M.Johnst.	Chile	E
18	*N. coelestis* (Lindl.) Miers ex Dunal	Chile	C
19	*N. confinis* I.M.Johnst.	Peru*	F
20	*N. coronata* Ruiz & Pav.	Peru*	F
21	*N. crassulifolia* Poepp.	Chile	G
22	*N. dianae* M.O.Dillon	Chile	G
23	*N. diffusa* I.M.Johnst.	Chile	G
24	*N. divaricata* (Lindl.) I.M.Johnst.	Chile	G
25	*N. elegans* (Phil.) Reiche	Chile	B
26	*N. filifolia* (Hook. & Arn.) I.M.Johnst.	Chile	C
27	*N. foliosa* (Phil.) I.M.Johnst.	Chile	E
28	*N. galapagensis* (Christoph.) I.M.Johnst.	Ecuador	D
29	*N. gayana* (Gaudich.) Koch	Peru	F

30	*N. glauca* (I.M.Johnst.) I.M.Johnst.	Chile	G
31	*N. gracillima* (I.M.Johnst.) I.M.Johnst.	Chile–Peru*	E
32	*N. humifusa* (Gouan) I.M.Johnst.	Peru	F
33	*N. incana* (Phil.) I.M.Johnst.	Chile	G
34	*N. inconspicua* (I.M.Johnst.) I.M.Johnst.	Chile	G
35	*N. inflata* Ruiz & Pav.	Peru*	D
36	*N. insularis* (I.M.Johnst.) I.M.Johnst.	Peru	D
37	*N. intonsa* I.M.Johnst.	Chile	F
38	*N. jaffuelii* I.M.Johnst.	Chile (no modern Peruvian records)	B
39	*N. johnstonii* Ferreyra	Peru*	F
40	*N. lachimbensis* M.O.Dillon & Luebert	Chile	G
41	*N. latipes* I.M.Johnst.	Peru*	D
42	*N. laxa* (Miers) I.M.Johnst.	Peru	D
43	*N. leptophylla* (Miers) I.M.Johnst.	Chile	G
44	*N. lezamae* M.O.Dillon, S.Leiva & Quip.	Peru	F
45	*N. linearifolia* Phil.	Chile	G
46	*N. lycioides* I.M.Johnst.	Chile-Peru*	D
47	*N. mariarosa* Ferreyra	Peru*	F
48	*N. minor* Ferreyra	Peru*	F
49	*N. mollis* (Phil.) I.M.Johnst.	Chile	G
50	*N. onoana* M.O.Dillon & Nakazawa	Chile	G
51	*N. pallida* I.M.Johnst.	Peru*	F
52	*N. pallidula* I.M.Johnst.	Peru*	D
53	*N. paradoxa* Lindl.	Chile	B
54	*N. parviflora* (Phil.) Phil.	Chile	B
55	*N. patula* (Phil.) Mesa ex M.O.Dillon	Chile	G
56	*N. pearcei* I.M.Johnst.	Peru	F
57	*N. peruviana* (Gaudich.) I.M.Johnst.	Chile	G
58	*N. philippiana* M.O.Dillon & Luebert	Chile	G
59	*N. pilosa* I.M.Johnst.	Peru*	F
60	*N. platyphylla* (I.M.Johnst.) I.M.Johnst.	Peru	D

61	*N. plicata* I.M.Johnst.	Peru*	D
62	*N. pterocarpa* Phil. ex Wettst.	Chile	B
63	*N. quicachaensis* Quip. & M.O.Dillon	Peru*	F
64	*N. ramosissima* I.M.Johnst.	Chile	G
65	*N. reichei* M.O. Dillon & Arancio	Chile	B
66	*N. rhombifolia* Marti. & Quez.	Chile	D
67	*N. rostrata* (Lindl.) Miers ex Dunal	Chile	C
68	*N. rupicola* Gaudich.	Chile	B
69	*N. salsoloides* (Lindl.) I.M. Johnst.	Chile	G
70	*N. scaposa* Ferreyra	Peru*	D
71	*N. sedifolia* Poepp.	Chile	G
72	*N. sessiliflora* Phil.	Chile	A
73	*N. spathulata* Ruiz & Pav.	Peru*	D
74	*N. spergularioides* Ferreyra	Peru*	E
75	*N. sphaerophylla* (Phil.) Mesa ex M.O.Dillon	Chile	G
76	*N. stenophylla* I.M. Johnst.	Chile	C
77	*N. tarapacana* (Phil.) I.M.Johnst.	Chile	E
78	*N. thinophila* I.M.Johnst.	Peru*	F
79	*N. tocopillensis* (I.M.Johnst.) I.M. Johnst.	Chile	G
80	*N. tomentella* Ferreyra	Peru*	F
81	*N. tovariana* Ferreyra	Peru*	F
82	*N. tricotiflora* Quip. & M.O.Dillon	Peru*	F
83	*N. urubambae* Vargas	Peru	F
84	*N. villosa* (Phil.) I.M.Johnst.	Chile	G
85	*N. volcanica* Ferreyra	Peru*	F
86	*N. weberbaueri* I.M.Johnst.	Peru	D
87	*N. weissiana* Ferreyra	Peru*	D
88	*N. werdermannii* I.M.Johnst.	Chile	G
89	*N. willeana* Ferreyra	Peru	D

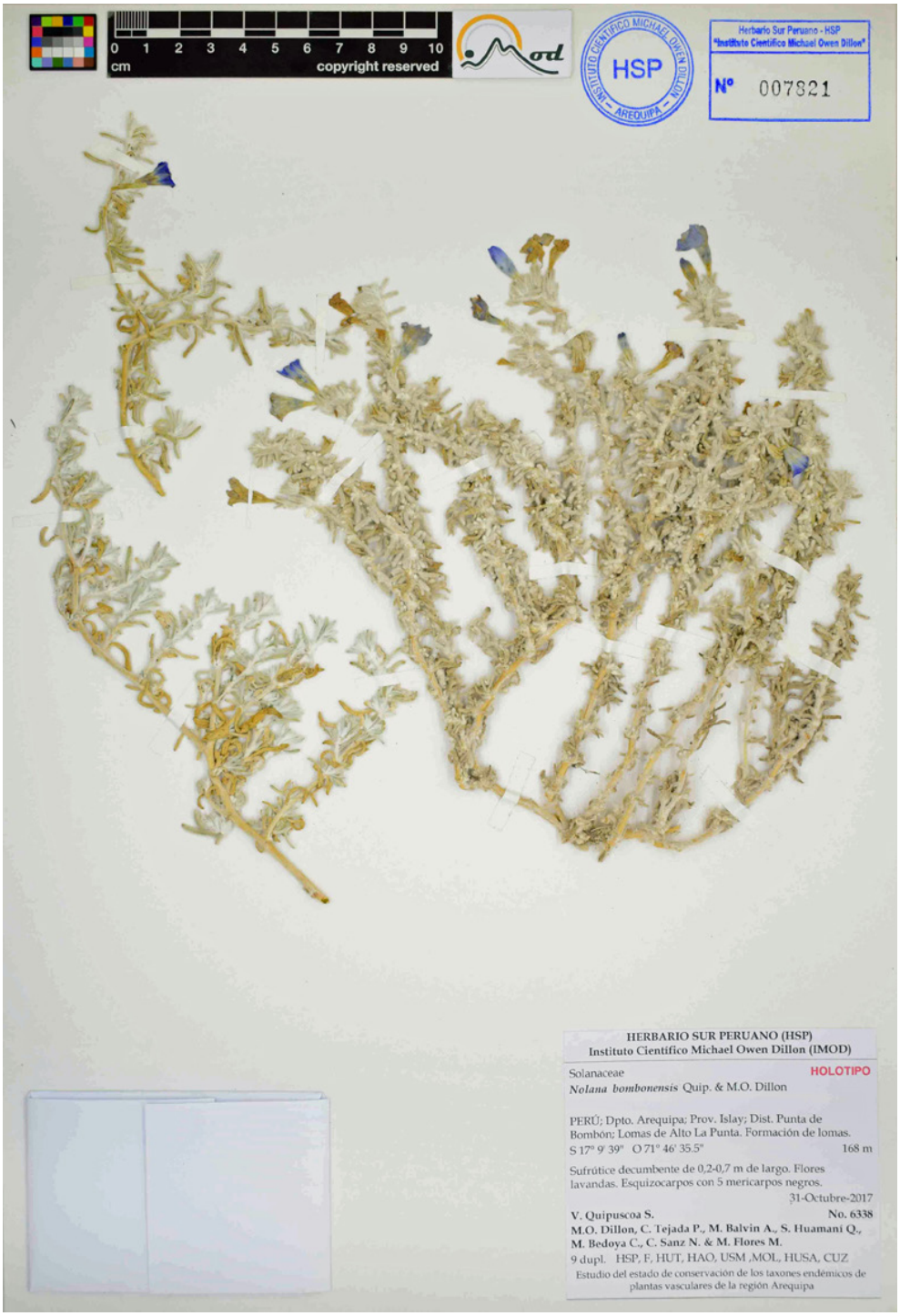

Fig. 1. Holotype of *Nolana bombonensis*, *Quipuscoa et al. 6338* (HSP-007822).

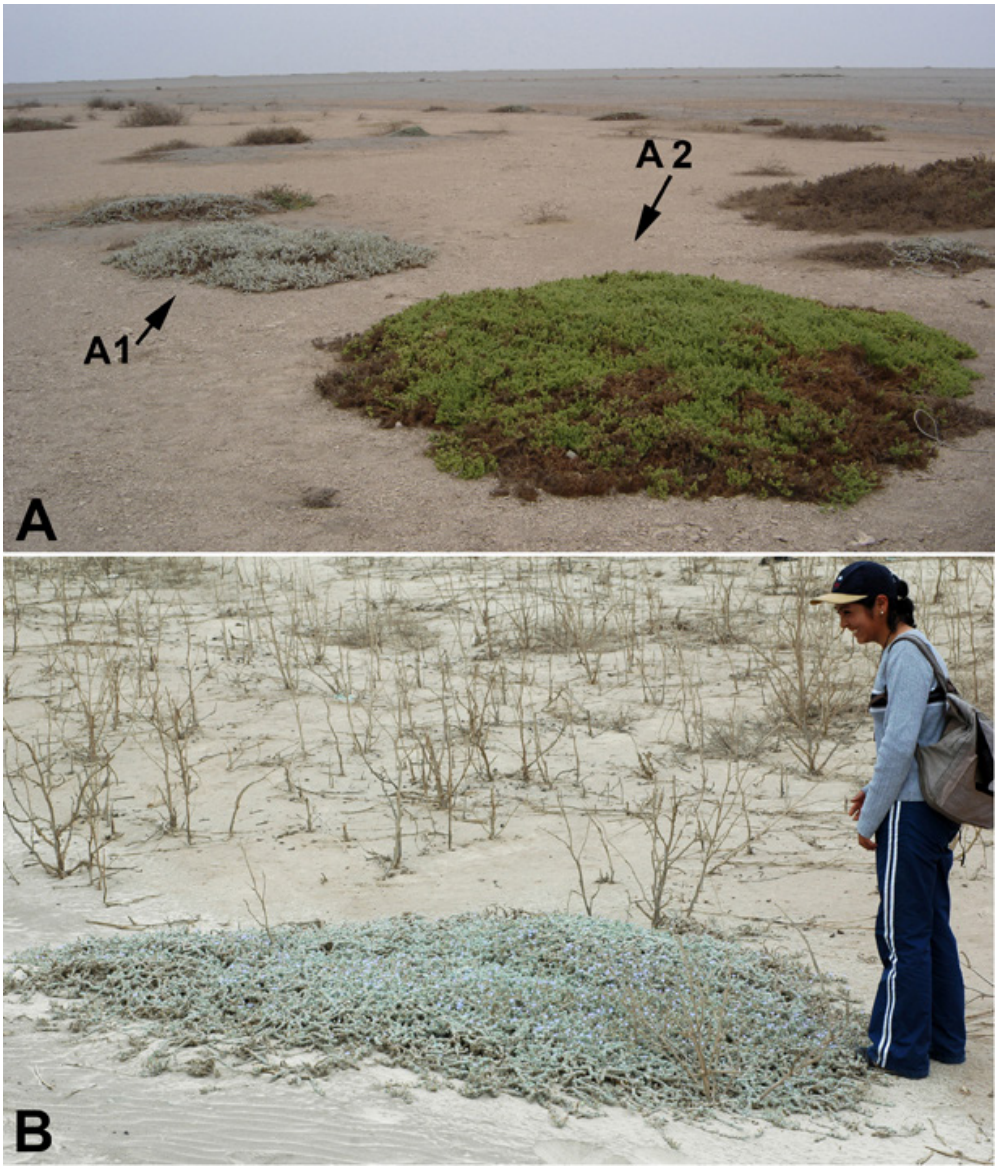

Fig. 2. *Nolana* in the beaches of Punta de Bombón. A1. *N. bombonensis* and A2. *N. pilosa*.B. Individual of *N. bombonensis* growing in sand near the ocean with Massiel Nataly Corrales Medina.

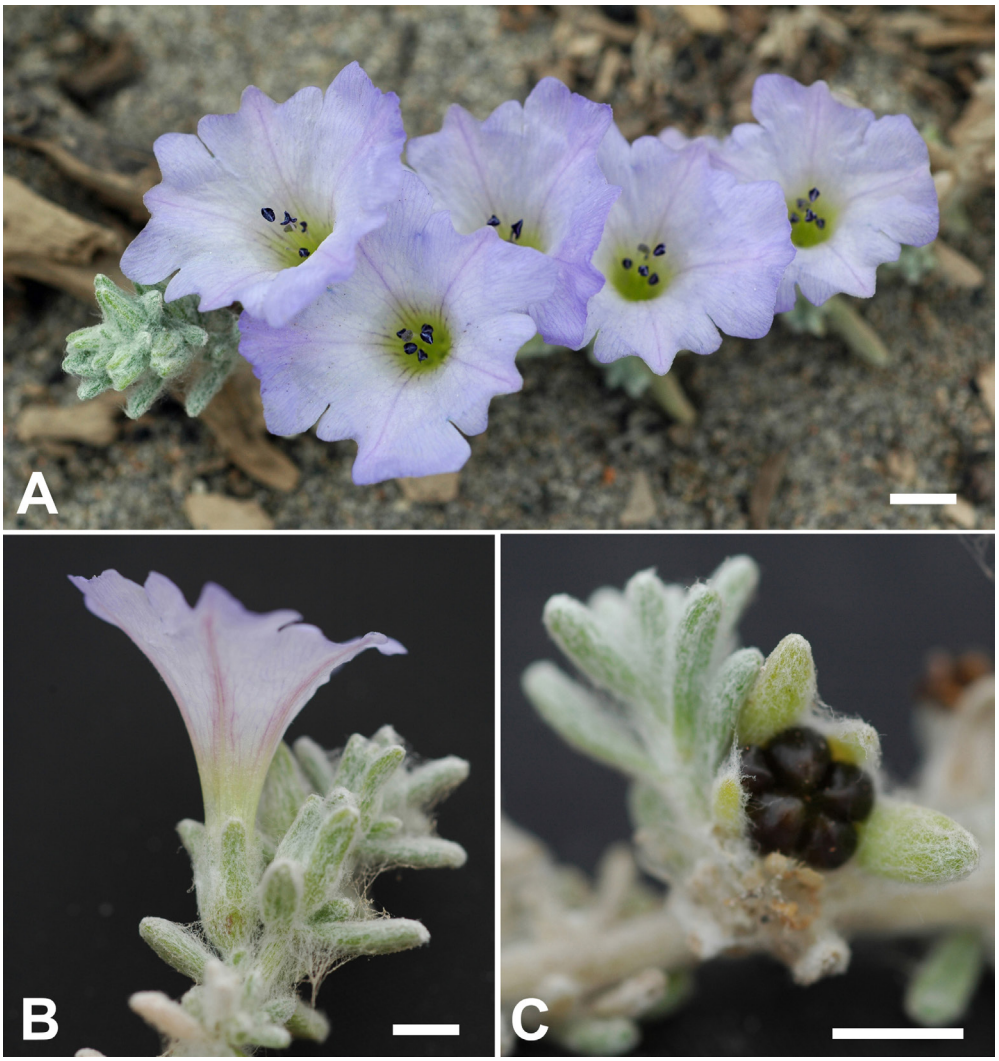

Fig. 3. *Nolana bombonensis*. A. Flowering branch, scale bar = 5 mm (*Dillon et al. 8989,* 19 Nov 2005); B. Flowering stem with corolla, scale bar = 8 mm; C. Mericarps, scale bar = 5 mm.

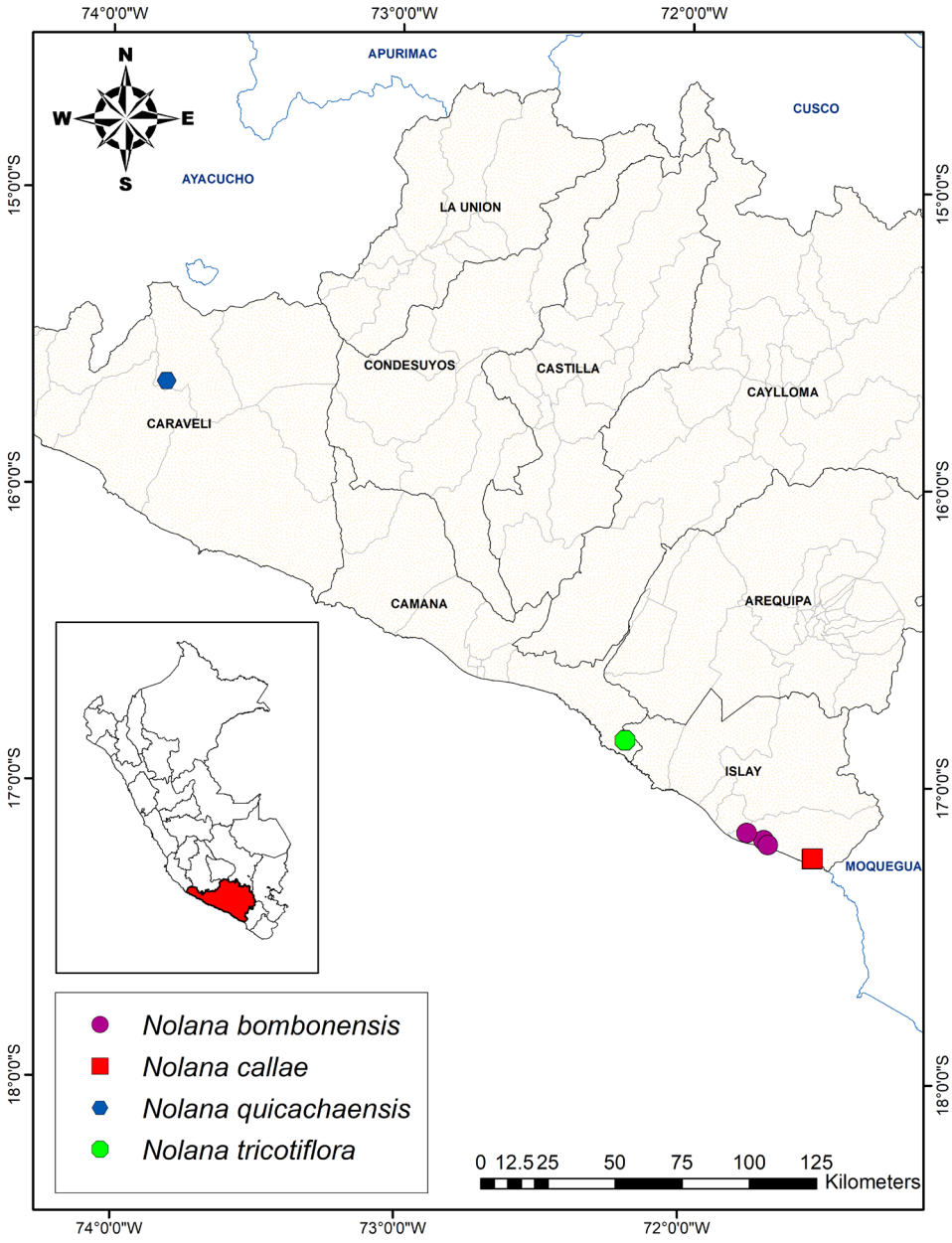

Fig. 4. Distribution map for southern Peruvian species of *Nolana*, *N. bombonensis* (purple circle), *N. callae* (red square), *N. quicachaensis* (blue hexagon), and *N. tricotiflora* (green polygon).

Fig. 5. Holotype of *Nolana callae*, *Quipuscoa et al. 6657* (HSP-007823).

Fig. 6. *Nolana callae* A Flowering individual with Cristian Tejeda-Perez; B. Corollas, scale bar = 5 mm; C. Mericarps, scale bar = 10 mm (*Quipuscoa et al. 6857*, 6 Jan 2018).

Fig. 7. Holotype of *Nolana quicachaensis, Quipuscoa et al. 6763* (HSP-007825).

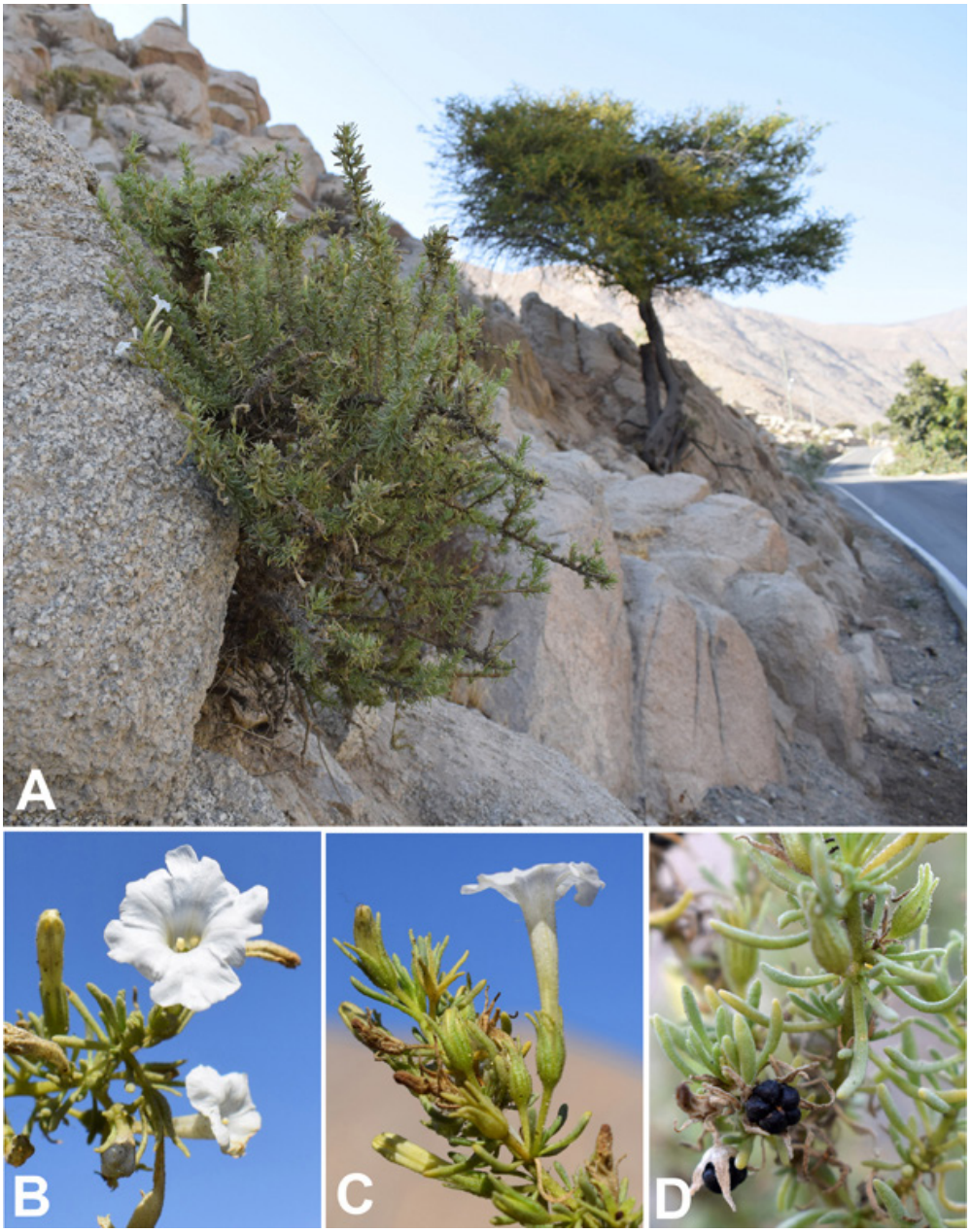

Fig. 8. *Nolana quicachaensis*. A. Flowering shrub; B. Frontal view of corollas, scale bar = 8 mm; C. Lateral view of apex, scale bar = 8 mm; D. Mericarps, scale bar = 5 mm.

Fig. 9. Holotype of *Nolana tricotiflora, Quipuscoa et al. 6433* (HPS-007827).

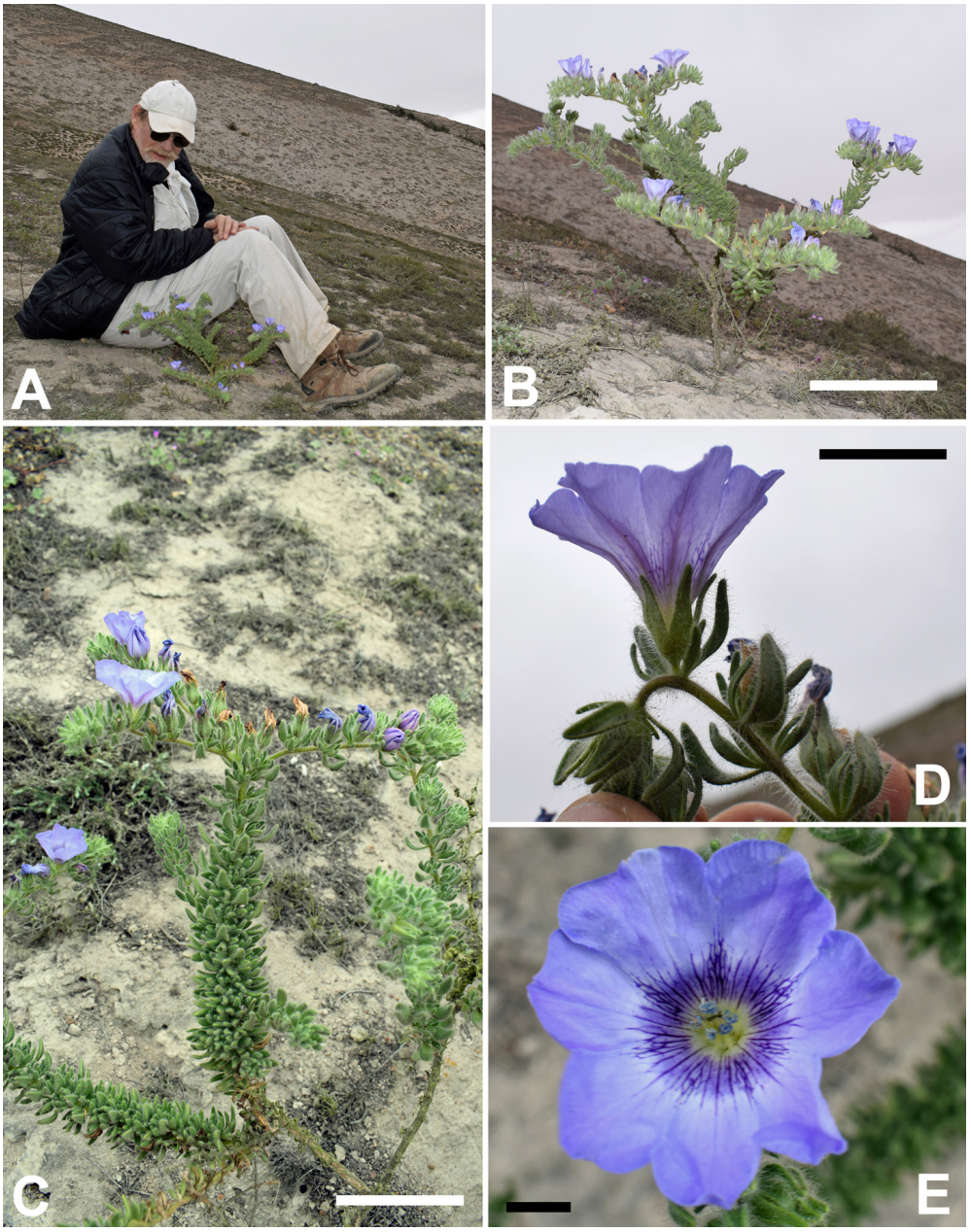

Fig. 10. *Nolana tricotiflora.* A. Flowering shrub next to MOD; B .Close-up of shrubby habit, scale bar = 10 cm; C. Close-up of leafy stem, scale bar = 5 cm; D. Lateral view of flower, scale bar = 10 mm; E. Frontal view of corolla, scale bar = 5 mm.