Acta Botanica Brasilica, 2022, 36: e20210318
doi: 10.1590/0102-3306-ABB-2021-0318

Original article

Agalinis marianae (Orobanchaceae), a new endangered species endemic to the Quadrilátero Ferrífero, Minas Gerais, Brazil

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Received: October 25, 2021
Accepted: September 14, 2022

ABSTRACT

The Quadrilátero Ferrífero (Iron Quadrangle [IQ]), in Minas Gerais, Brazil, exhibits high geological and geomorphological diversity, reflected by its high heterogeneity of vegetation. Its rock outcrops, particularly ironstone, harbor endemic-rich plant communities and contribute substantially to the biodiversity of the biomes they are embedded within the Atlantic Rainforest and Cerrado region. The aim of this study was determining the distribution, phenology and state of conservation of one new species for science with occurrence in the Quadrilátero Ferrífero. Random walks were carried out in the areas of potential occurrence of the species and individuals were collected to allow description. The plant species was identified and categorized as being new to science and known only from this location: *Agalinis marianae* (Orobanchaceae). This new species is morphologically similar to *A. itambensis* but can be recognized by the smaller pedicels and the shape of the corolla. The distinct geographic distribution of these species is an additional factor that supports this separation. Here, we describe and illustrate *A. marianae*, and provide notes on its distribution, habitat, phenology, and conservation status. We also present a key to the species of *Agalinis* from Minas Gerais.

Keywords: Mariana municipality, Quadrilátero Ferrífero (Iron Quadrangle [IQ]), Scrophulariaceae, new species, endemic species, Hemiparasitic.

Introduction

Orobanchaceae is represented in Brazil by 11 genera and 44 species, more than half of which are exclusive to this country (Souza 2020). Several new species of Orobanchaceae from Brazil have been described in the last two decades (Souza *et al.* 2001; Souza 2001; Souza & Paula-Souza 2016; Scatigna *et al.* 2017, 2020). *Agalinis* Rafinesque has a predominantly neotropical distribution, with a center of diversity in South America, especially in the Andes and in the Espinhaço Range in Minas Gerais. Consists of approximately 40 species, of which thirteen occur in Brazil and eight in Minas Gerais State. While North American species are predominantly herbaceous, the South American sub-shrub to shrub species are more common. *Agalinis* is

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morphologically similar to *Esterhazya* Mikan, differing mainly in having non–villous anthers (vs. villous) and a predominantly pink corolla (vs. usually yellow, orange, or red in *Esterhazya*) (Souza & Giulietti 2009). *Agalinis* and *Esterhazya* Mikan are both exclusive to the New World. *Agalinis* comprises perennial herbs, sub-shrubs, and shrubs, and is hemiparasitic, with leaves generally opposite, sessile, often linear to lanceolate, and entire or rarely pinnatisect (Souza & Gulietti 2009). Its flowers are axillary, solitary, sessile to long–pedicellate, generally concentrated at the apex of branches, forming a poorly defined raceme, with a tubular, pentamerous calyx. The corolla is cylindrical to campanulate, zygomorphic and generally pink, with four stamens, included or rarely slightly exserted, with parallel or divergent anther thecae. The fruit is a loculicidal capsule, with numerous seeds having a reticulate–inflated testa.

During the ongoing taxonomic work on the Neotropical Orobanchaceae, a new species endemic to the Quadrilátero Ferrífero in the Mariana municipality, state of Minas Gerais, Brazil, was found and is described and illustrated here. *Agalinis marianae* was listed in the Integrated Environmental Impact Study of the Germano Complex and categorized as being new to science. As a result, Samarco Mineração S.A and Amplo Engenharia proposed and developed a program to determine the distribution of this species in the area of influence in the Germano Complex (Samarco) and in other areas with potential for occurrence in Minas Gerais. The field team, led by Mariana Neves Moura and Flávio Gontijo, sent the botanical material to the first author, who performed a detailed analysis of its morphology and identified it as a new species.

Materials and methods

The search process took place initially in the Germano Complex Mine (Samarco Mineração S.A.), in its area of direct influence and in some target points outside the Germano Complex, including in the rock outcrops in the cities of Ouro Preto, Mariana, and around the Serra do Gandarela National Park. The search for the species began in April 2019 and ended in September 2021, with greater sampling effort during the flowering periods of individuals. The rock outcrops in the cities of Ouro Preto and Mariana were considered target regions because their quartzitic rock outcrops provide environments for potential occurrence of the species. In addition, Itambé State Park was visited with the aim of verifying the occurrence of a species of the same genus, named *Agalinis itambensis*, whose morphological characters, already described, resemble that of the new species in question.

The Quadrilátero Ferrífero (Iron Quadrangle [IQ]), where this study took place, exhibits high geological and geomorphological diversity, which reflects a high heterogeneity of vegetation (Azevedo *et al.* 2012; Jacobi & Carmo 2012). Its rock outcrops, particularly ironstone, harbor endemic-rich plant communities and contribute substantially to the biodiversity of the biomes they are embedded within, i.e., the Atlantic Rainforest and Cerrado region (Viana & Lombardi 2007; Jacobi & Carmo 2008; Carmo & Jacobi 2013). The IQ is also one of the most important mineral provinces in the world, being particularly rich in iron ore (Salles *et al.* 2018; Spier *et al.* 2003). It is currently under intense habitat-specific degradation due to mining activities (Sonter *et al.* 2014).

Random walks were carried out in the areas of potential occurrence of the species, taking into consideration the optimal environment and altitude of the locations where the species had already been registered in the Germano Complex (1350 m). Individual plants with an appearance like that of the species of interest were collected. Samples were labeled with a sequential number and location coordinates. In addition, samples were marked in the field with pink biodegradable tape to aid in monitoring the individual during the fertile period.

To allow visual identification in the field, photos of the collected materials (exsiccates) and details of structures that aid in field identification of this new species were collected. After the expeditions, these photos, as well as some of the collected specimens, were sent to the first author for taxonomic analysis. The collected material was dehydrated according to the herborization techniques described by Fidalgo and Bononi (1984) and Mori *et al.* (1989). Herbarium specimens were collected and prepared according to standard procedures (Bridson & Forman 1992). The specimens were deposited in the ESA Herbarium (Herbário da Escola Superior de Agricultura "Luiz de Queiroz" – ESALQ), and the BHCB Herbarium (Herbário da Universidade Federal de Minas Gerais).

Specimens of *Agalinis itambensis* V.C.Souza & S.I.Elias were obtained from the BHCB and through field collection. The collection of all botanical material was supported by the Authorization for Collection and Transport of Exsiccate No. 003/2018–A. Search activities in the Serra do Gandarela National Park area were carried out with authorization from ICMBio, through Direct Authorization No. 16/2018; search activities in Itambé State Park were carried out with authorization from IEF, through the Authorization Term of a research project linked to Environmental Licensing No. 01 / 2019. Sterile plant individuals found near the collected materials had their coordinates recorded in the field. These records could not be used to describe the species but were used to assess conservation status and are present in Supplementary Information (S1).

Conservation status assessment followed the IUCN criteria and its guidelines (IUCN 2022). We estimated the area of occupancy (AOO) and extent of occurrence (EOO) using the Geospatial Conservation Assessment Tool (GeoCAT; Bachman *et al.* 2011) with a cell width of 2 km, based on georeferenced records obtained in field explorations

and provided on herbarium sheet labels. Conservation status was assessed using primarily the IUCN criteria B, geographic range in the form of B1 (extent of occurrence, EOO) and B2 (area of occupancy, AOO) (IUCN 2022).

Results

Taxonomic treatment

Agalinis marianae V.C.Souza, *sp. nov.* Type: BRAZIL. Minas Gerais: Mariana, Alegria Norte, Campo rupestre ferruginoso, 20° 09′ 30″ S, 43° 31′ 00″ W, 1353 m, 23 April 2019 (fl), *C.V.Vidal* s.n. (holotype BHCB 190343! *hic designatus*, isotypes ESA!, RB!) (Figs. 1, 2).

Agalinis marianae is similar to *A. itambensis* with regard to the shrubby habit and the vegetative stage of the plant but differs in having a shorter pedicel (1–1.4 cm long vs. 1.6–2 cm long), and a more inflated, cream–white corolla tube (vs. less inflated and light pink).

Description: Sub-shrubs to shrubs, 0.6 –1.1 m tall, upright, profusely branched. Stems and branches erect, glabrous, quadrangular. Leaves decussate, sessile, glabrous, linear, arched upwards, acute at apex and base, margin entire, 1.6–3.7 cm long, 0.1–0.2 cm wide. Internodes 0.2–0.6 cm long. Flowers axillary, solitary, concentrated at the ends of the branches; pedicel erect to sub-erect, glabrous, 1.0–1.4 cm long; calyx tubular, 0.4–0.5 cm long, glabrous, teeth triangular–subulate, 0.05–0.1 cm long; corolla sub-bilabiate, tube cream–white, 1.7–2.0 cm long, covered with a villous indumentum on the outer surface, lobes light–pinkish, orbicular to suborbicular, 0.4–0.6 cm long; stamens very slightly exserted, reaching the corolla mouth. Capsule ellipsoid to ovate–ellipsoid, 0.8–1.0 cm long.

Distribution, habitat, and phenology: *Agalinis marianae* is restricted to the Mariana and Ouro Preto municipalities, Minas Gerais, Southeast Brazil; this region is included in the biogeographic district known as the Quadrilátero Ferrífero (Colli-Silva *et al.* 2019) and corresponds to a transition between the domain of the Atlantic Forest and Cerrado region (semi-deciduous wooded grassland). The species grows on rocky outcrops formed by ironstone, known as "canga", and occupies an elevational range between 1180 and 1500 meters above sea level. It flowers from April to June, corresponding to the beginning of the dry season. Fruiting and seed dispersal occur between July and September.

According to the Map of Biomes and Marine Coastal System of Brazil (IBGE 2019), the area in question is located within the limits of the Atlantic Forest, and the use and protection of the native vegetation of this biome are regulated by federal law. However, it is a transition area with another large Brazilian phytogeographic domain: the Cerrado region. The Atlantic Rainforest and the Cerrado region are the most threatened ecosystems in the world and are both considered biodiversity hotspots due to high rates of endemism and degradation (Myers *et al.* 2000; Mittermeier *et al.* 2004).

Preliminary conservation status: *Agalinis marianae* is currently known based on 26 individuals from Ouro Preto and Mariana, and nearby a natural protected area, the Serra do Gandarela National Park. In addition, the region is a mining complex with historically intense iron ore extraction activity (Carmo & Kamino 2015) and a recent episode of flooding due to the collapse of a waste containment dam (Lopes 2016). The extent of occurrence (EOO) is 3.41 km² and area of occupancy (AOO) calculated is 20km². Following the IUCN Red List Criteria (IUCN 2022), the species would qualify as critically endangered (CR) B1 a, b (i, iv) (Fig. 3).

Etymology: The epithet of this species honors the municipality of Mariana, where the species was first known.

Additional specimens examined (Paratypes): BRAZIL. Minas Gerais, Mariana: Mina Samarco, Cava Norte de Alegria 1 e 6, Campo rupestre sobre minério de ferro, 20° 09′ 17″ S, 43° 30′ 53″ W, 1250 m, 28 July 2009 (fr), S.G.Rezende BHCB 145984 (BHCB!); Mina Samarco, Norte de Alegria 1 e 6, Campo rupestre sobre minério de ferro, 20° 09′ 17″ S, 43° 30′ 53″ W, 1250 elev., 28 July 2009 (fr), S.G.Rezende BHZB 8301 (BHZB!); Cava Alegria, Campo rupestre sobre canga, 20° 09′ 32″ S, 43° 31′ 02″ W, 1352 elev., 01 August 2019 (fl), M.N.Moura s.n. BHCB 1901261 (BHCB!); Complexo Germano, Alegria Sul/Conta História Norte, Campo rupestre sobre minério de ferro, 20° 13′ 14″ S, 43° 30′ 57″ W, 1360 elev., 14 March 2021 (fl.), N.R.Campos s.n. and M.N.Moura 74 (ESA!).

Identification key to Agalinis *species from Minas Gerais, Brazil*

1. Calyx lobes up to 0.1 (–0.15 cm) long. 2
1'. Calyx lobes 0.3–0.7 cm long. 7
2. Corolla tube 0.8–1.4 cm long. 3
2'. Corolla tube 1.7–3.3 cm long. 4
3. Pedicels 0.4–0.8 cm long; corolla tube 0.8–0.9 cm long. *Agalinis ramulifera* Barringer
3'. Pedicels 1.2–1.8 cm long; corolla tube 1.2–1.4 cm long. ..... *Agalinis schwackeana* (Diels) V.C.Souza & Giul.

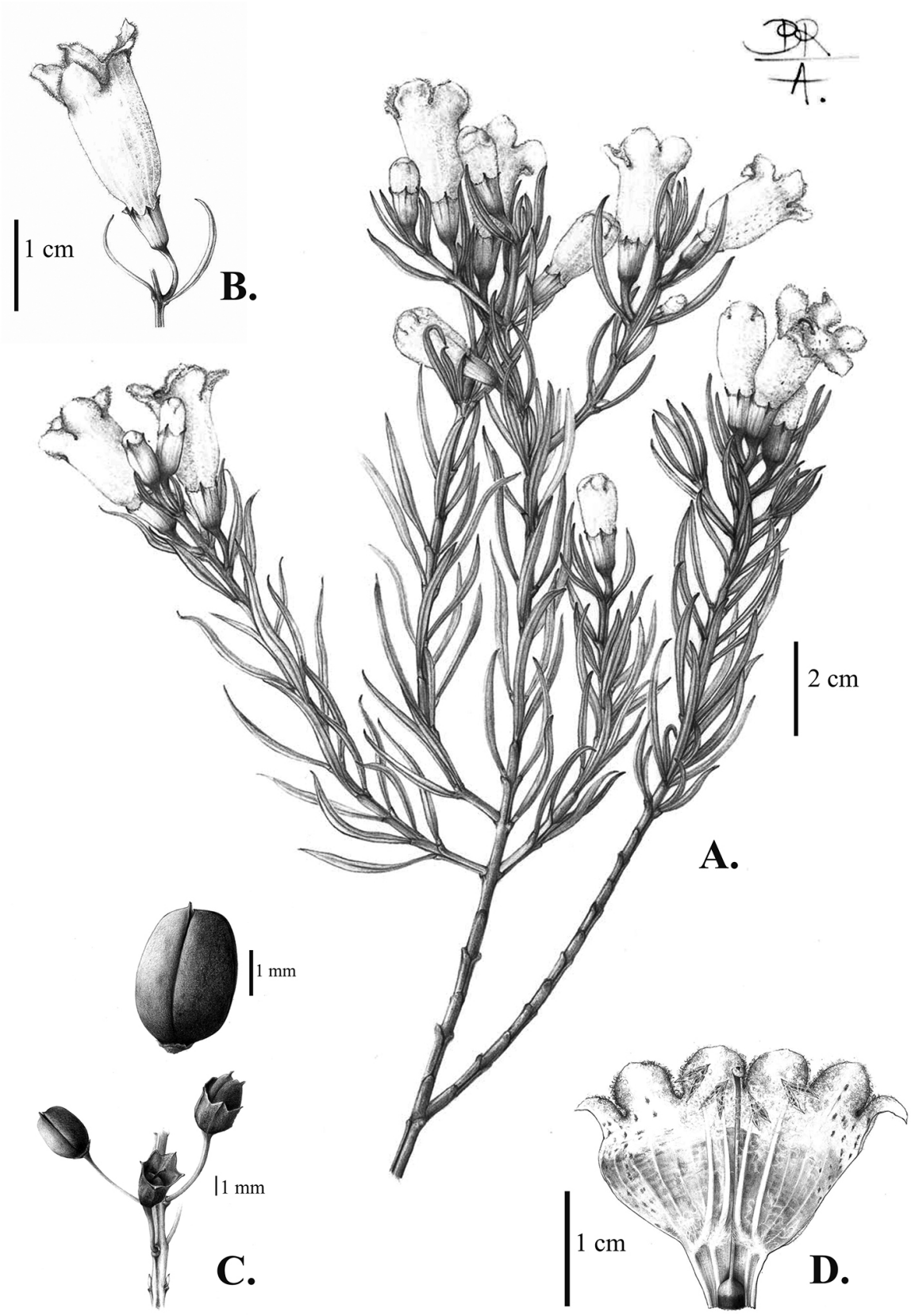

Figure 1. Line drawing of ***Agalinis marianae*** V.C.Souza, *spec. nov.* A. stems and branches erect and glabrous with sessile leaves B. lateral detail of the flower C. detail of the process of fruit development and details of the fruit enclosed by the fruiting calyces D. detail of a dissected flower from Moura s.n. BHCB 1901261. Drawing by Belkiss Radicchi Alméri.

4. Leaves 0.7–1.0 cm long. ..... *Agalinis brachyphylla* (Cham. & Schltdl.) D'Arcy
4'. Leaves 1.4–3.4 cm long. 5
5. Corolla with dark pinkish to lilac tube, 2.9–3.3 cm long. .....
..... *Agalinis angustifolia* (Mart.) D'Arcy
5'. Corolla with cream–white to light pinkish tube, 1.7–2.0 cm long. 6
6. Corolla with cream–white tube, inflated; pedicel 1.0–1.4 cm long. .....
..... *Agalinis marianae* V.C.Souza
6'. Corolla with light pink tube, not inflated; pedicel 1.6–2.0 cm long. .....
..... *Agalinis itambensis* V.C.Souza & S.I.Elias
7. Pedicels 0.1–0.4 cm long. ..... *Agalinis nana* S.I.Elias & V.C.Souza
7'. Pedicels (0.5–) 0.6–1.8 (–2.5cm) long. 8
8. Calyx lobes deltate, almost as long as wide ..... *Agalinis bandeirensis* Barringer
8'. Calyx lobes elongate–deltate, about 2 times longer than wide .....
..... *Agalinis ramosissima* (Benth.) D'Arcy

Figure 2. ***Agalinis marianae*** V.C.Souza, *spec. nov.* photographs. A. plant habit B. detail of stem C. spots in the internal part of the corolla D. open corolla showing anthers, reaching the corolla mouth E–G. Details of the flower, calyx tubular, corolla sub–bilabiate, tube cream–white, covered with a villous indument on the outer surface and lobes light–pinkish. Photographs by Flávio Dayrell Gontijo in type–locality (paratype).

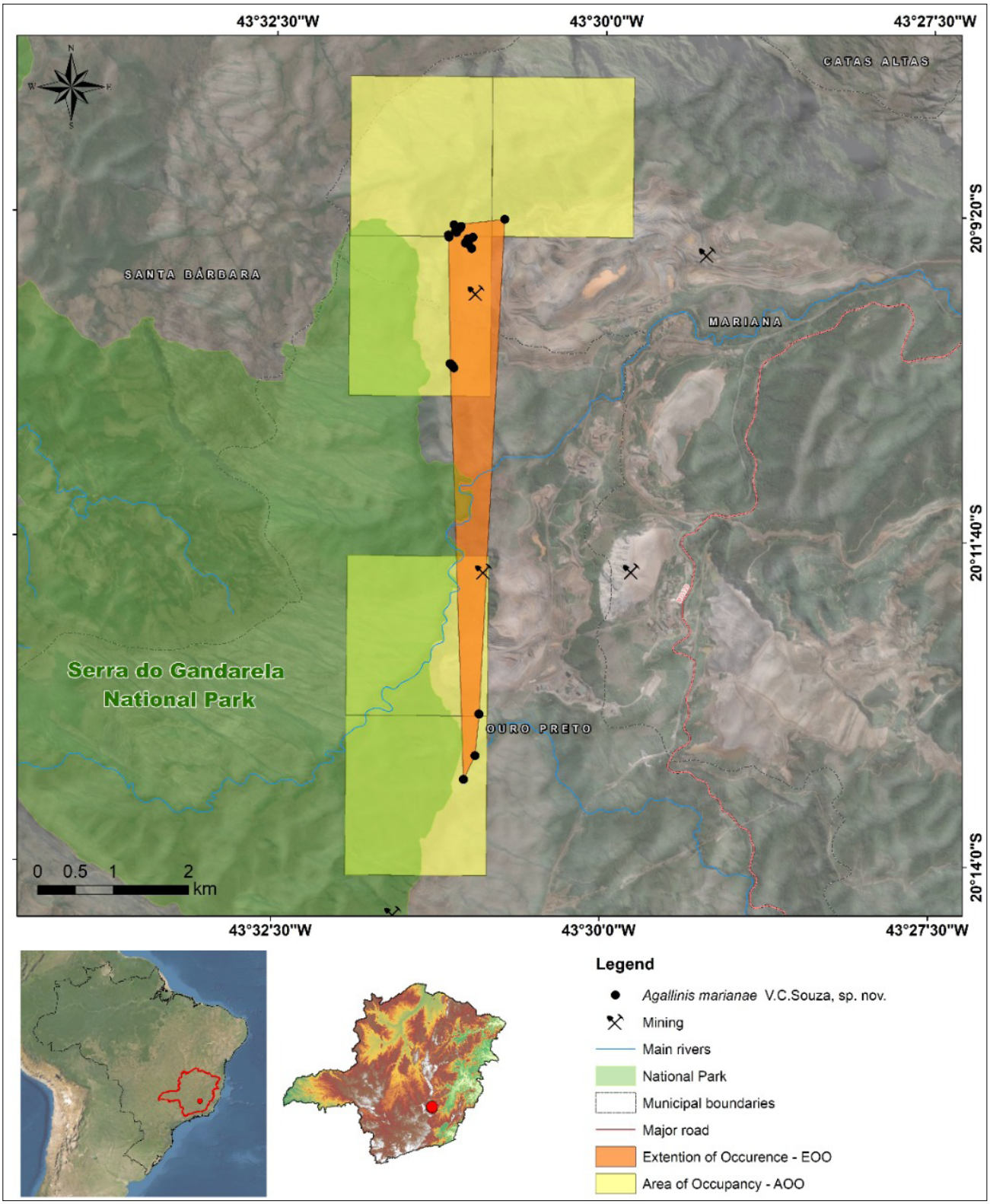

Figure 3. Records points of this study of ***Agalinis marianae*** V.C.Souza, *spec. nov.*, in the rocky outcrops of Quadrilátero Ferrífero (Iron Quadrangle–IQ) environments and anthropized areas, in Mariana and Ouro Preto.

Discussion

Agalinis marianae is part of a group of species characterized by geographic distribution concentrated in the Espinhaço Range in Minas Gerais and its surroundings, and which have in common the fact that they are shrubs or sub-shrubs, with narrow leaves. They are differentiated mainly by characteristics such as dimensions of the pedicel, calyx lobes, corolla, and leaves, as well as the color and shape of the corolla. This new species is characterized by a calyx with short lobes, pedicel, and corolla of medium size, with inflated cream–white corolla tube and light pink lobes, characteristics not found together in any other species. Another particularity of this group is the very restricted geographical distribution of most of its species, with some endemic to certain mountain ranges and their associated national parks, such as *Agalinis bandeirensis* (Serra do Caparaó), *Agalinis itambensis* (Serra do Itambé), *Agalinis nana* (Serra da Canastra), and *Agalinis marianae*, the only one not included in any protected area. Due to the species' very restricted geographic distribution and environmental threats, especially related to iron mining activities, it is recommended to expand the knowledge about the species in order to delineate adequate conservation projects.

Supplementary material

The following online material is available for this article:

Supplementary Information (S1) - Additional specimens use to access the conservation status of the species.

Acknowledgements

We thank Alexandre Salino of the BHCB herbarium; Samarco Mineração S.A., in the names of Gilciana Milagres and Ana Paula Correa, and Amplo Engenharia for financial support; Belkiss Radicchi Alméri for drawings; Cristiano Vidal and Núbia Campos for field expeditions to find new individuals. Thanks to Instituto Estadual de Florestas (IEF) and Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) for authorizations and Itambé State Park for authorization to collect. We also thank Editage for English language editing.

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