

GEA, FLORA ET FAUNA

A new *Noccaea* (Brassicaceae) species endemic from alpine habitats of the Pyrenees

Pere Aymerich*

* C. Onze de Setembre, 31. E08600 Berga. Catalonia..A/e: pere_aymerich@yahoo.es

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Abstract

Noccaea cadinensis sp. nov. is described here. This species is known from a single locality in Serra del Cadí (Eastern Pyrenees, SW Europe), where it grows in limestone scree and stony meadows of the alpine vegetation belt. It is morphologically close to *N. nevadensis* from Sierra Nevada (S Iberian Peninsula), from which it can be separated by several characters (fruit length, style length, corymb elongation, petiole length, leaves margin, seed size). The new species is assessed as EN (Endangered) according to IUCN Red List Categories and Criteria.

Key words: taxonomy, endemism, mountain, Iberian Peninsula.

Resum

Una nova espècie de *Noccaea* (Brassicaceae) endèmica d'hàbitats alpins dels Pirineus

Es descriu *Noccaea cadinensis* sp. nov. Aquesta espècie es coneix actualment només d'una localitat de la serra del Cadí (Pirineus orientals), on viu en tarteres i prats pedregosos sobre calcària de l'estatge alpí. Morfològicament és similar a *N. nevadensis* de Sierra Nevada (sud de la península Ibèrica), de la qual es diferencia per diversos caràcters (longitud del fruit, longitud de l'estil, elongació del corimb, longitud del pecíol, marge de les fulles, mida de les llavors.). Seguint els criteris i categories de la IUCN, aquesta nova espècie és catalogada com a EN (En perill).

Paraules clau: taxonomia, endemisme, muntanya, península Ibèrica.

Introduction

Noccaea Moench (Brassicaceae) is a genus formerly nested in *Thlaspi* L. until Meyer (1979) split it into 6 genera. The splitting of *Thaspi* is now widely accepted, but there is still controversy over the number of genera into which it should be divided, ranging between 3 (Al-Shehbaz, 2014) and 13 (<https://brassibase.cos.uni-heidelberg.de/>). More recent and comprehensive work supports the acceptance of a low number of genera, but it is recognized that new phylogenetic approaches must be made with new information (Özüdoğru *et al.*, 2019).

In its broadest sense, *Noccaea* has about 136 species (Al-Shehbaz, 2022), some of very recent description (Güzel *et al.*, 2018; Özgişi *et al.*, 2018; Özgişi, 2020; Sefali *et al.*, 2023) while in a more restricted delimitation 92 are accepted (<https://brassibase.cos.uni-heidelberg.de/>). The vast majority are of Eurasian distribution and the greatest diversity is found in the mountains and steppes of C-W Asia (Al-Shehbaz, 2014). Narrow range endemic species are common, especially in the mountains, and the morphological differences between taxa are often subtle. Examples of species restricted to high mountain or alpine habitats in Europe are *Noccaea rotundifolia* (L.) Moench (Alps), *N. corymbosa* (J. Gay) F.K. Mey. (Alps W-C), *N. cepaeifolia* (Wulfen) Rchb. (Alps E),

N. minima (Ard.) F.K. Mey. (Alps E), *N. nevadensis* (Boiss. & Reut.) F.K. Mey. (Sierra Nevada), *N. stylosa* (Ten.) Rchb. (Apennines) and *N. bellidifolia* (Griseb.) F.K. Mey. (Balkans).

To date any *Noccaea* species restricted to alpine habitats was known in the Pyrenees. In this range the known species are *N. brachypetala* (Jord.) F.K. Mey., *N. caerulescens* J. Presl & C. Presl and *N. occitanica* (Jord.) F.K. Mey., which are mostly found in montane and subalpine vegetation belts, while *N. perfoliata* (L.) Al-Shehbaz [*Microthlaspi perfoliatum* (L.) F.K. Mey.] has a wide distribution from the basal belt to the subalpine. The nearest known true high mountain (mainly alpine) *Noccaea* species were 500-600 km away, in the SW Alps and Sierra Nevada.

In 2022, a *Noccaea* population was discovered in the alpine belt at the western end of the Serra del Cadí, a peripheral (Pre-Pyrenean) range of the SE Pyrenees. These plants showed features that clearly distinguished them from the *Noccaea* already known in the area, especially its unwinged fruits and longer petals. This *Noccaea* population could not be identified with the available literature of the flora of Pyrenees or nearby regions, although these plants were fairly similar to *N. nevadensis*. A subsequent analysis revealed a set of characters that justify its description as a new species.

Material and methods

The new species is identified on the basis of macromorphological characters. In a first approach, samples collected in the only known population the years 2022 and 2023, in various phenological stages, were compared with the information provided by the regional floras (Bolòs & Vigo, 1990; Pujadas, 1993; Tison & Foucault, 2014; Tison *et al.*, 2014; Pignatti, 2017) for the *Noccaea* taxa known in SW Europe. In this bibliography the descriptions of these taxa are often partial and in some cases not coincident between different works. This bibliographic search pointed towards a morphological affinity between the plants of the Pyrenees and *Noccaea nevadensis* of Sierra Nevada (SE Iberian Peninsula). Also the use of the dichotomous keys provided by the synopsis of the genus *Noccaea* by Al-Shehbaz (2014) led to *N. nevadensis*. For this reason, later the effort was focused on analyzing the differences between *N. nevadensis* and the Pyrenean plants.

For the subsequent comparison, we used bibliographic information on *N. nevadensis* -based on Pujadas (1993), Blanca *et al.* (2009) and Al-Shehbaz (2014)- and *N. nevadensis* vouchers from the herbaria MA, GRA and BC. A list of revised vouchers is shown in Appendix 1.

Considering that the main characters that separate *N. cadinensis* and *N. nevadensis* are quantitative and that there is some overlap between these characters, a statistical analysis of the fruit characters has been made. Student's T-test was used to test whether the measurements of two characters (fruit length, style length) are statistically significant or not. The sample analyzed was 36 ripe fruits of *N. cadinensis* and 32 of *N. nevadensis* (vouchers MA304335, MA306154, MA45048, MA304551, MA306154).

Results

Noccaea cadinensis Aymerich sp. nov.

Holotype

Spain, Catalonia, Serra del Cadí, between Torreta de Cadí and Cap de la Costa Verda peaks, 42°16'60" N, 1°34'22" E, 2335 m, limestone scree, 18 July 2022, P. Aymerich (BCN170324).

Diagnosis

Noccaea cadinensis is morphologically close to *N. nevadensis*, but differs from it by the fruit usually 4-8 mm long (versus 7-12 mm in *N. nevadensis*), style usually 1-1.5 mm long (versus usually 1.5-3 mm), seeds 1.8-2.5 mm long (versus 1.4-1.8 mm), corymb not or weakly elongate in fructification to 25 mm (versus usually elongated, to 55 mm) and basal leaves with petiole usually shorter or equal to leaf blade (versus petiole usually longer than blade in *N. nevadensis*). Also the rosette leaves are usually marginally toothed in *Noccaea cadinensis* but usually non-dentate in *N. nevadensis* and ratio fruit body length / style length is usually higher in *N. cadinensis*.

A comparative table of the characters of *Noccaea cadinensis* and *N. nevadensis* is shown (Table 1). The characters of *N. nevadensis* are a compilation of bibliographical data and own observations.

Etymology

The specific name *cadinensis* is derived from an ancient name of Serra del Cadí range, *Cadino*.

Description

Perennial herb, 5-10 cm tall, glabrous, stoloniferous and caespitose (Fig. 1a,b). Basal leaves (Fig. 2) arranged in rosettes (10)15-22(31) mm diameter; deep green, glossy; thick and somewhat fleshy; petiole 2-7(12) mm long, usually shorter than leaf blade (sometimes equal, exceptionally long-



Figure 1. Plant habit. a): In nature (some stones have been removed to show the ramification). b): Herbarium sample, flowering plant.



Figure 2. Basal leaves. a): *N. cadinensis* and, to compare, b): *N. nevadensis* (MA45047).

er); blade 3-11 x 2-5 mm, obovate, elliptic or rhombic, with weakly marked veins, apex obtuse, base tapering, margins usually with some coarse and obtuse teeth or rarely entire (0-5 teeth per leaf side). Stem ascending, simple, usually one per rosette, c. 1 mm diameter, with 4-8 leaves. Cauline leaves sessile, oblong, auriculate at base; 5-10 mm long; margins entire or with inconspicuous teeth (0-4 per leaf side); apex obtuse to subacute; auricles with obtuse to subacute apices. Inflorescence, a corymb with 11-20 flowers (Fig 1b, 3); 10-17 (25) mm diameter, 12-17 (20) mm height, diameter-height ratio 1.3-2.4; only weakly elongated in fruit, to 25 mm height (Fig. 4a). Flowers pedicels ascending, 2-5 mm long in anthesis (3-6 mm in fructification); sepals 2.5-4 × 1.5-2 mm, oblong-obovate, deep green and often partially purple tinged, but paler green and translucent in a wide marginal strip; petals oblong-obovate, 5-8 × c. 2 mm, colour initially

white, turning mauve with age; stamens 3-4 mm long, anthers yellow, 0.8-1.2 mm; Fruits an obovate silicula (Fig. 4a), 4-9 × 2-3.5 mm, glabrous, margin not winged, base cuneate, emarginate at apex, fruiting style 0.5-2.1 mm, exerted from the apex sinus. Seeds 1-3 per loculus, 1.8-2.5 × 0.7-1.5 mm, oblong, elliptic or obovate, smooth, light brown.

Relationships

The new species is morphologically close to *Noccaea nevadensis*. Although the morphological differences between the two are quantitative and overlap, they are considered sufficient to separate both taxa at species level. Differences in inflorescence elongation and fruits measurements are notorious at fruiting stage (Fig. 4a, b). The fruit and the style in Sierra Nevada plants are significantly longer ($P < 0.01$; t-test) than those of the Serra del Cadí plants. Table 2 summarizes the differences in fruit and style length of the populations from



Figure 3. Inflorescences. The stems and leaves are often hidden among grasses and are hardly visible.

Table 1. Comparative table of *Noccaea cadinensis* and *N. nevadensis* characters. In bold type, most useful characters to discriminate these species.

Character	<i>Noccaea cadinensis</i>	<i>Noccaea nevadensis</i>
Height	5-10 cm	4-15 cm
Basal leaves shape	Obovate, rhomboid or elliptic	Obovate to elliptic
Basal leaves dimensions	3-11 × 2-5 mm	5-32 × 2-12 mm
Basal leaves margin	Usually with coarse teeth, rarely entire	Usually entire, sometimes with coarse teeth
Basal leaves petiole	Usually shorter (or equal) than leaf blade, exceptionally longer	Usually longer than leaf blade, exceptionally shorter
Cauline leaves	Oblong, 4-10 mm long, base auriculate	Oblong, 5-15 mm long, base auriculate
Inflorescence	Corymb not or weakly elongate in fructification, to 2.5 cm	Corymb usually elongate in fructification, to 5.5 cm
Pedicels	2-5 mm long in flowers, 3-6 mm in fruits	1-6 mm in flowers, 3-6 mm in fruits
Sepals	2.5-4 mm long, often purple tinged	2-3.7 mm long, often purple tinged
Petals	5-8 mm long, white to mauve	5-7 mm long, white or pinkish
Stamens	3-4 mm long; anthers yellow 0.8-1.2 mm	3-4 mm; anthers yellow 0.7-1 mm
Style	0.5-2.1 mm long, in fruit exerted from apical notch	1.2-3.2 mm long, in fruit exerted from apical notch
Fruit	Unwinged; obovate, 4-9 × 2-3.5 mm; tapering at base; apex emarginate	Unwinged; obovate-oblong, 6-12 × 2.3-3.5 mm; tapering at base; apex emarginate
Ratio L fruit body / L style (in ripe fruit)	3.0-8.0	1.9-6.0
Seeds number	1-3	(1)2-3(4)
Seeds shape and colour	Oblong-obovate, light brown	Oblong-obovate, brown
Seeds size	1.8-2.5 × 0.7-1.4 mm	1.4-1.8 × 1.0-1.2 mm

Table 2. Comparison of fruits and style length in *N. cadinensis* and *N. nevadensis*. Mean ± standard deviation, and minimum and maximum values (in brackets) are shown, all of them in mm.

Character	<i>Noccaea cadinensis</i>	<i>Noccaea nevadensis</i>
Fruit length	6.2 ± 1.6 (4.0-9.0)	8.8 ± 1.7 (6.0-12.0)
Style length	1.3 ± 0.4 (0.5-1.6)	2.3 ± 0.5 (1.3-3.2)

Figure 4. Fructing corymbs of *N. cadinensis* (a) and *N. nevadensis* (b), MA45047. The differences in the elongation and density of the corymbs and in the lengths of the fruits and styles are visible.

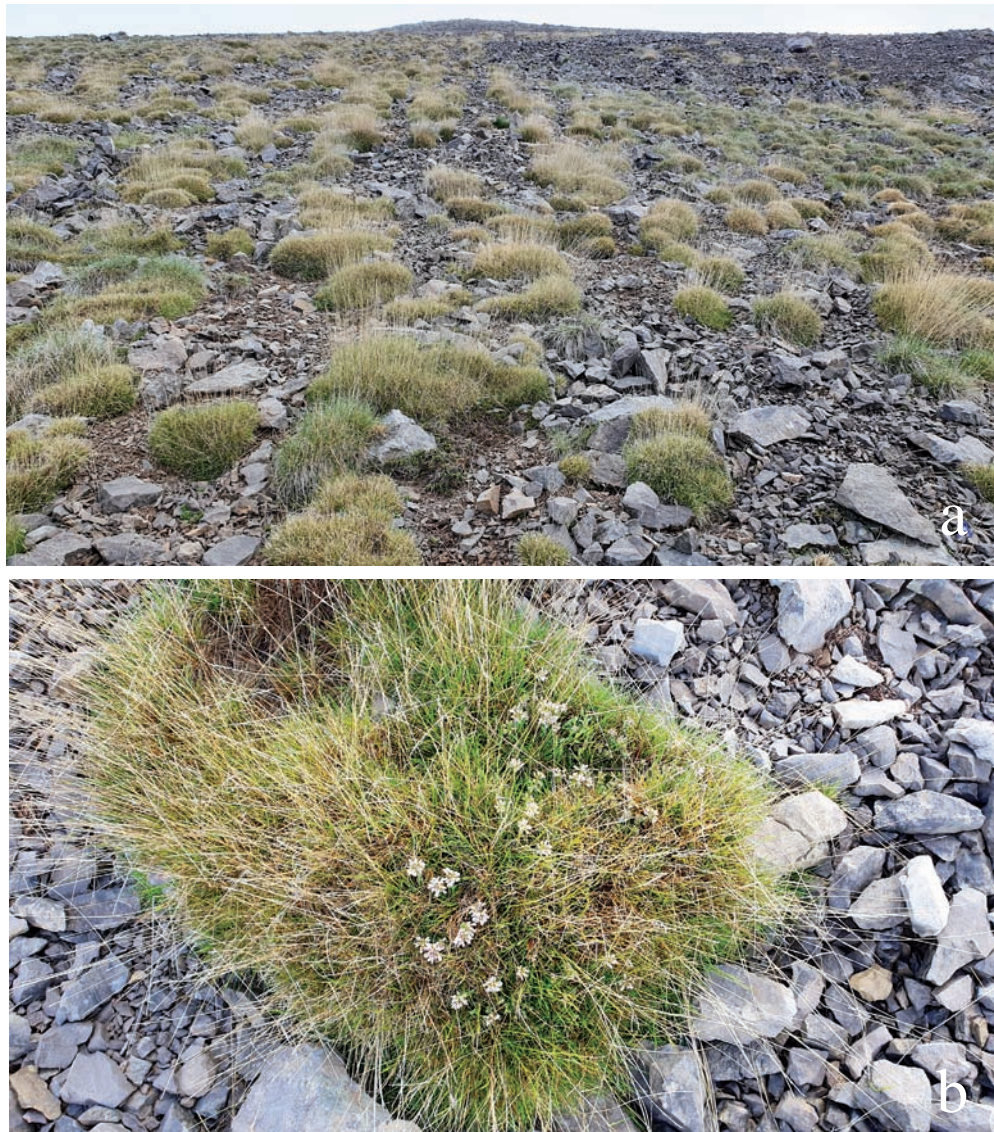


Figure 5. Habitat. a): Macrohabitat of stony meadows and scree. b): Usual microhabitat in cushions of *Festuca gautieri*.

Sierra Nevada and the Pyrenees. The two taxa are geographically separated and the floristic affinities between the Pyrenees and Sierra Nevada are limited, the former more closely related to the Alps and the latter to the mountains of North Africa. In addition *N. nevadensis* is reported as attached to siliceous rocks, while *N. cadinensis* thrives in limestone.

In fact, to elucidate the affinities between the taxa of *Noccaea* is often difficult, because between groups of evolutionarily related taxa the morphological differences may be weak or subtle (Al-Shehbaz, 2014). The molecular techniques has improved the knowledge of the relationships between *Noccaea* taxa, but there are also groups of taxa that appear genetically close, with a weak divergence (Özüdoğru *et al.*, 2109). For example, most of the European mountain taxa related to *N. rotundifolia* (*N. corymbosa*, *N. cepaeifolia*, *N. stilosa*), which are now recognized as species, had previously been treated with varietal or subspecific ranks under *N. rotundifolia*. Morphologically they are very similar, with a few dis-

criminating characters and these often overlap. The current criterion is to treat them as species, on the basis of this weak differentiation and their allopatric distribution. *Noccaea cadinensis* also shows similarities with plants in this group, as a short style usually up to 1.5 mm (with the exception of *N. stilosa*), but these species have distinctly pink flowers and typically more seeds per locule.

Without genetic information it is uncertain to assess the true relationships of *N. cadinensis* with *N. nevadensis* or other *Noccaea*. But the morphological similarity suggests that it may be evolutionarily more related to *N. nevadensis* than to the alpine taxa. Even a more widely distributed Iberian ancestor is possible, since the general shape of *N. cadinensis* is also reminiscent of *Noccaea stenoptera* (Boiss. & Reut.) F.K. Mey., an endemic species of the NW quadrant of the Iberian Peninsula with a wider ecology, not clearly linked to the high mountains. *N. stenoptera* was first considered silicicolous (Pujadas, 1993) but later is proved that it is indif-

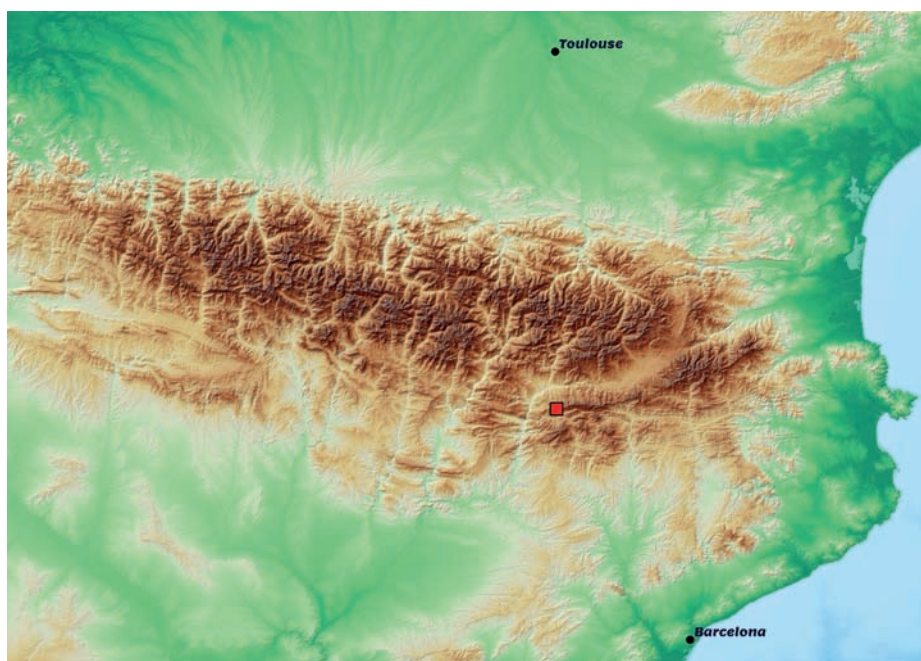


Figure 6. Distribution. The red square shows the only known location on a map of the Pyrenees. (OSM - OpenStreetMap)

ferent to the rock substrate, since in the Cantabrian and Burgos mountains it is found on calcareous ridges reminiscent of *N. cadinensis* habitat, but at a lower altitude (Alejandre *et al.*, 2006; Carlón *et al.*, 2014). These three species have in common the pinkish-white (or with turning pink) colour. *Noccaea nevadensis* and *N. stenoptera* have a lax and elongate fruiting corymb, unlike *N. cadinensis*. *Noccaea stenoptera* clearly differs from *N. cadinensis* and *N. nevadensis* in having winged fruit valves, a character that is usually given taxonomic importance, but interestingly *N. stenoptera* and *N. nevadensis* are very close genetically despite this difference (Özüdođru *et al.*, 2109).

Phenology

Flowering time second half May to first half June. Fruits ripening and seeds dispersal July.

Habitat

Shallow soils on limestone rocks, in stabilized screes and stony meadows of the alpine zone, at an altitude of 2330-2350 m (Fig. 5a). Most *Noccaea cadinensis* individuals grow within or on the margins of cushions of *Festuca gautieri* (Hack.) K. Richt., which is the most common species (Fig. 5b). Other taxa observed in these places are *Arenaria grandiflora* L. subsp. *grandiflora*, *Anthyllis vulneraria* subsp. *vulnerarioides* (All.) Arcang., *Botrychium lunaria* (L.) Swartz, *Carduus carlinoides* Gouan subsp. *carlinoides*, *Crepis pygmaea* L., *Helictotrihon sedenense* (DC.) Holub subsp. *sedenense*, *Iberis saxatilis* L., *Iberis spathulata* DC. subsp. *spathulata*, *Jasione crispa* (Pourr.) Samp., *Petrocallis pyrenaica* (L.) R. Br. and *Thymus nervosus* Willk. Taxa nomenclature is based in the Catalonia flora Checklist (Sáez & Aymerich, 2021).

Distribution

Currently, this species is known only from the type locality. It is located at the foot of a west-facing slope between the peaks of Torreta de Cadí and Cap de la Costa Verda, in the western Cadí mountain range, SE Pyrenees (Figure 6). This mountain runs from west to east along about 30 km and has maximum altitudes around 2600 m a.s.l.

Conservation status assessment

To date, *N. cadinensis* is known only from an area of less than 0.5 ha. A detailed census of the population is not available, but it has been estimated at tens or a few hundred individuals. A survey of nearby areas with suitable habitats has not allowed to locate other populations. Although the Serra del Cadí flora is fairly well-known (Vigo *et al.*, 2003) it is possible that this species exists in other places and has been unnoticed, due to its early flowering and the weaker botanical knowledge of the western part of the mountain.

No current risk factors are known, because this area is rarely visited by people, is not used as pasture for domestic livestock and wild ungulates have low densities. Only climate warming is a potential threat, although it appears to be a relatively xeromorphic plant, which would probably not be among the most affected in a scenario of reduced rainfall and snow cover.

With the available data and the application of the IUCN (2012) methodology, the risk category of *N. cadinensis* is assessed as Endangered EN D. Only criterion D (Population size estimated to number fewer than 250 mature individuals) is applicable, as there are no signs of population or area decline, and extreme fluctuations seem unlikely.

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- Appendix 1. *Noccaea nevadensis* vouchers used for the comparative study
- Spain: Sierra Nevada, Peñón de Jerez, ad 3000 m, supra Jerez del Marquesado, in lapidosis, 19-VII-1923, leg. Font Quer (BC109110). Sierra Nevada, puerto de Trevélez, in schistosis, ad 3000 m, 23-VII-1923, leg. P. Font Quer (BC109111). Granada, Sierra Nevada, carretera que sube al Mulhacén, ladera pr. a la Laguna del Peñón Negro, undated, leg. A.B. Robles & P. Sánchez, (GDA19851). Granada, Sierra Nevada, Peñones de San Francisco, 14-V-1944, leg. Muñoz Medina (GDA3389). Sierra Nevada, Hoya de la Mora, pedregales esquistosos, leg. A. Segura, 30-5-1967 (MA301963). Granada, subida a Sierra Nevada, cerca del refugio de la Mora, alt. 2550 m, 18-VII-1976, leg. A. Barra & al. (MA304535). Granada, subida a Sierra Nevada, alt. 2200-2550 m, sobre esquisto, 17-VII-1976, leg. A. Barra & al. (MA304551). Granada, Sierra Nevada, Pico Veleta, leg. P. Cubas, 1-VII-1978, G. López & M. Moreno (MA306154). Granada, Sierra Nevada, Hoya de San Juan, 2600 m, 5-VII-1971, leg. Fernández Casas (MA409192). Sierra Nevada, región nival, 1-VII-1866, leg. P. del Campo (MA45047). Granada, Sierra Nevada, Cueva de los Panderos, 23-VI-1858, leg. V. López Seoane, (MA45048). Granada, Sierra Nevada, undated, leg. P. Sáinz Gutiérrez (MA45049). Granada, Sierra Nevada, entre enebros rastreros, 5-VIII-1976, leg. M. Pascual (MA620006). Granada, Cauchiles del Monachil, 2800 m, 25-VI-1970, leg.?, (MA753103). Granada, Sierra Nevada, faldas del pico Veleta cerca del viejo observatorio astronómico, matorrales y pastos psicroxerófilos, en sustrato ácido, esquistos, 4-VII-2010, leg. E. Glazkova & A. Quintanar (MA836384). Almería, puerto de la Ragua, 2100 m, pas-tizal, 18-IV-2014, leg. C. Aedo (MA89290).