

Mediterranean Botany

ISSNe 2603-9109

<https://doi.org/mbot.77925>

Sierra Nevada (Spain), the southernmost European locality for the polar-alpine *Umbilicaria aprina* and *U. virginis*

 Leopoldo G. Sancho¹ , Ana Aramburu¹ , Ana Pintado¹ , Manuel Casares² , José Raggio¹  & David Sánchez-Pescador¹ 

Received: 14 September 2021 / Accepted: 21 January 2022 / Published online: 26 April 2022

Abstract: Two strict polar-alpine *Umbilicaria* species (*U. aprina* and *U. virginis*) are reported growing together in Los Peñones de San Francisco. Other localities known on the highest summits of the Alps and Pyrenees are considered. We discussed the meaning of these isolated populations as glacial relicts.

Keywords: Lichens, Polar-alpine, Biogeography, Umbilicaria, Sierra Nevada.

How to cite: Sancho, L.G., Aramburu, A., Pintado, A., Casares, M., Raggio, J. & Sánchez-Pescador, D. 2022. Sierra Nevada (Spain), the southernmost European locality for the polar-alpine *Umbilicaria aprina* and *U. virginis*. *Mediterr. Bot.* 43, e77925. <https://doi.org/mbot.77925>

Umbilicaria aprina and *U. virginis* could be considered as extremist due to their distribution, with a clear preference for the coldest areas of the world. *U. aprina* was described firstly in the high mountains of Ethiopia (Nylander, 1860). Later it was found in Scandinavia (Santesson, 1993), the Alps (Frey, 1933; Hasenhüttl & Poelt, 1978; Codogno, 1995; Hafellner & Türk, 2001), the Tatra Mountains (Krzewicka & Osyczka, 2002; Lisická, 2005) and Central Asia (Poelt, 1977; Wei & Jiang, 1993; Kudratov, 2004). In the Arctic it is known from Greenland (Ryvarden, 1968; Hansen, 2003), Svalbard Islands (Øvstedal *et al.*, 2009) and to Baffin Island (Hale, 1954) and Iceland (Kristinsson, 1974). Recently *U. aprina* has been reported from the French Pyrenees by Hestmark (Hestmark, 2015), in what was the southernmost European locality for this species until now. This author highlights the remarkable inverse correlation between latitude and altitude for this species, from a minimum of c. 1100 m asl in southern Norway, to c. 2100 m asl in Poland, to 3100 m asl in the Alps and the Pyrenees, and to 4400 m asl in equatorial Africa and South America (Crespo & Sancho, 1982; Krog & Swinscow, 1986; Hestmark, 2009). Therefore, Los Peñones de San Francisco (Sierra Nevada, Spain), where both *U. aprina* and *U. virginis* species coexist at an altitude of only 2500 m asl and a latitude of 37°N, is a particularly unique spot (Figure 1a).

However, it is in Antarctica where *U. aprina* reaches its maximum abundance and biomass (Filson, 1975; Øvstedal & Lewis-Smith, 2001; Sancho *et al.*, 2003). This is arguably the most abundant of all macrolichens in many localities on the Antarctic continent. It can be

found from the coast (Seppelt *et al.*, 2010) to the inland, including the slopes of the inhospitable McMurdo Dry Valleys (Green *et al.*, 2007; Cannone & Seppelt, 2008). In some areas, extraordinary thalli, easily exceeding 10 cm in diameter, can be considered an example of gigantism, a term frequently associated with some Antarctic organisms (Øvstedal & Lewis Smith, 2001). Also, morphological variations in colour and thallus anatomy related to environmental gradients have been discovered and studied (Sancho *et al.*, 2003). Sexual reproduction of this species has never been found in Antarctica so far.

In Los Peñones de San Francisco *U. aprina* does not exhibit apothecia either and thalli are much smaller reaching a maximum of 2.5 cm in diameter. It grows on west-south-west facing rock walls, occupying small ledges, not far from the abundant populations of *U. virginis*, but without mixing with it.

U. aprina had not yet been reported in the checklist of Spanish lichens (Llimona & Hladun, 2001), nor in the very recent checklist of Sierra Nevada lichens (Gómez-Bolea *et al.*, 2021). However, it is mentioned from the highest summit of Sierra Nevada (Mulhacén 3420 m asl) by Codogno (Codogno, 1995) who found it immixed with *U. virginis* in old herbarium samples.

In contrast, *Umbilicaria virginis* is a well-known species from Los Peñones de San Francisco and the summits of Sierra Nevada (Werner, 1975; Casares & Llimona, 1982; Egea *et al.*, 1982; Gómez-Bolea *et al.*, 2021). In Los Peñones de San Francisco it is relatively frequent, colonising more or less vertical runoffs, with a clear preference for western or south-western aspects.

¹ Department of Pharmacology, Pharmacognosy and Botany, Faculty of Pharmacy, Complutense University. E-28040 Madrid, Spain. Email: sancholg@ucm.es

² Botany Department, University of Granada. E-18071 Granada, Spain.

Although *U. virginis* usually appears in small groups in the studied locality, on one occasion we counted more than a hundred thalli in a single runoff. It is common to find thalli with numerous apothecia (Figure 1b), which are of the omphalodiscus type, sometimes apparently degenerated, with the central sterile button and excipulum becoming invisible. The spores of our specimens do not always properly develop, and malformed asci often appear.

Although the two species can be confused with one another when only the upper side is observed, the lower side is very distinctive. While *U. virginis* has a pale, even pinkish, underside with concolor rhizinomorphs, *U. aprina* has a carbonaceous-black underside, due to the thick layer of thalloconidia produced from the lower cortex. On this black surface, the white rhizinomorphs stand out for most of their length, as they have thalloconidia only at the base (Figure 1c, 1d).

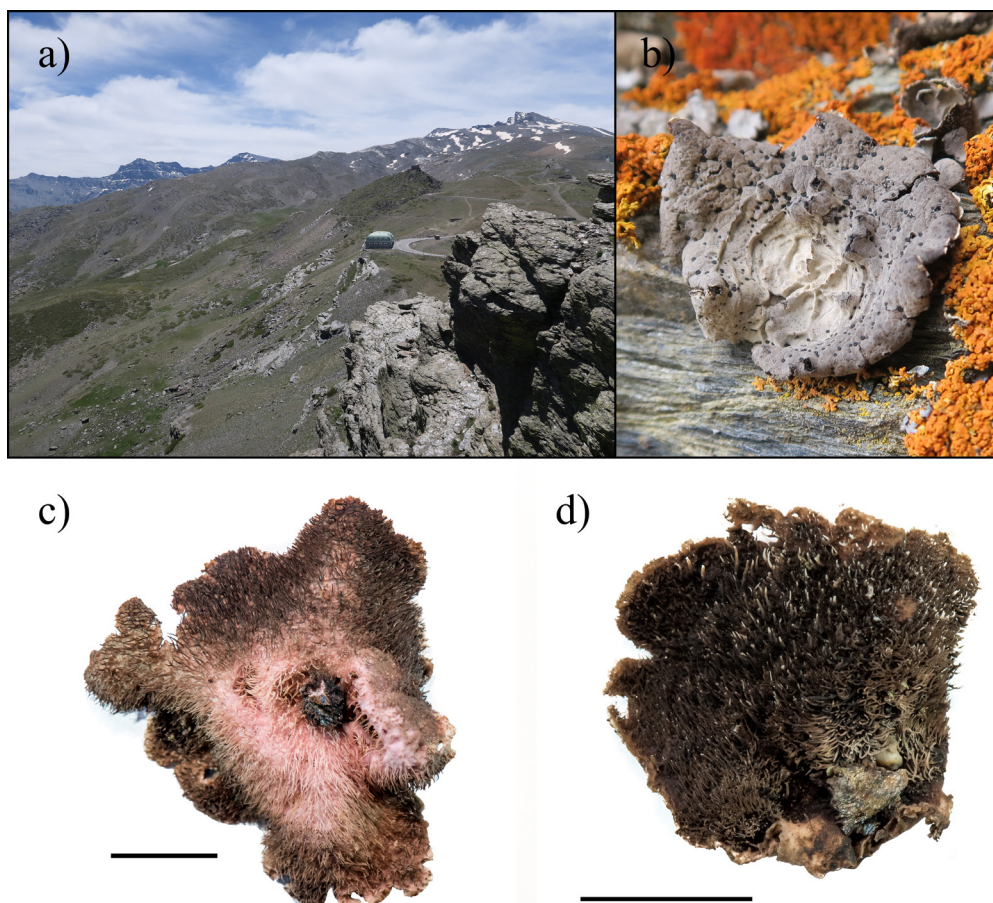


Figure 1. Study area: a, view of Pico Veleta from Los Peñones de San Francisco; b, habitus of *Umbilicaria virginis*; c, lower surface of *Umbilicaria virginis*; d, lower surface of *U. aprina*. Bar = 1 cm.

In the northern hemisphere the distribution of *U. virginis* is quite similar to that of *U. aprina*, although, in mid-latitudes, it is even more restricted to very high altitudes and therefore absent from mountains such as the Tatra. Remarkably, *U. virginis*, described from the Jungfrau (4158 m asl), has never been found in the Alps below 3000 m asl, being the only macrolichen restricted to the nival belt (Hafellner & Türk, 2001; Scheidegger, 2021). However, it seems to be a relatively common species in northern North America and along the western mountains (Brodo *et al.*, 2001). In the southern hemisphere this species is only known from New Zealand Alps (specimens studied by the first author together with David Galloway in New Zealand herbarium OTA).

How and when both species reached such an isolated locality as Los Peñones de San Francisco and how they have survived at such a moderate altitude are still open questions. However, we can argue that their presence at this locality is probably related to

its geomorphological history. This prominent rocky outcrop was a nunatak close to the Veleta glacier front during the last ice age maximum (Palma *et al.*, 2017; Oliva *et al.*, 2020; Palacios *et al.*, 2020). We hypothesize that both species have survived the last glacial maximum in Los Peñones de San Francisco and should be considered as relicts from at least the last ice age.

In Los Peñones de San Francisco, together with *U. aprina* and *U. virginis*, appear other *Umbilicaria* species with a wider distribution in the mountains of the Iberian Peninsula and Europe. Namely: *U. cinerascens*, *U. cylindrica*, *U. decussata*, *U. nylanderiana*, *U. polyphylla*, *U. proboscidea*, *U. subglabra* and *U. vellea*. At the same time, a rich alpine lichen flora, with more than one hundred species (Gómez-Bolea *et al.*, 2021), further increases the interest of this locality, right on the border of the Sierra Nevada National Park, as a lichen hot spot, which requires adequate conservation and dissemination strategy.

Localities of sampling

Spain, Sierra Nevada, Granada, Los Peñones de San Francisco, 37° 05' N, 3° 23' W; alt. 2500–2530 m asl.

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