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High altitude flora of Sierra Nevada (Spain)

Abstract

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Spanish Sierra Nevada has one of the richest and most original flora of the western Mediterranean region with a large number of endemic species. The area is considered one of the biodiversity "hotspots" of the Mediterranean Basin. Its high summits are particularly important from a conservation point of view and its flora is extremely vulnerable to the impacts of climate change.

This paper shows a detailed analysis of the flora in the upper vegetation belt (cryoromediterranean zone) of Sierra Nevada, based on an updated delimitation of its area (38.76 km^2). In total, 185 species belonging to 44 families and 116 genera were catalogued. The most relevant families were; *Poaceae* (24 taxa), *Asteraceae* (20) and *Caryophyllaceae* (16). Despite its small territory, the high vegetation belt is prominent in endemic taxa (37.3%), 55 of which do not exceed the range of Sierra Nevada. The number of threatened taxa is 39 and the biological spectrum shows the dominance of hemicryptophytes (63.16%) and chamaephytes (26.31%).

We believe that this high mountain flora data could be a strong indicator of the long-term climatic variations and might therefore be used in the future to observe possible upward movements of the taxa.

Key words: Biodiversity, conservation, climatic change, endemism, high-altitude vegetation.

Introduction

Upper mountain areas are generally isolated zones with high habitat diversity and less human population pressure that have recently been recognized as suitable sites to observe the plant changes provoked by the current global warming (Dullinger & al. 2007; Grabherr & al. 1994, 2001; Pauli & al. 2003). The observations of these high mountain plants in Europe were done in the beginning of 20th century by Klebelsberg (1913) or Braun-Blanquet (1955, 1957) who saw the usefulness of plants as bioindicators of the long-term climatic variation. These species living above the tree line are thought to be particularly sensitive to climatic changes in the long-term due to the following reasons: (1) the climate is a more important habitat factor compared to the biotic one, such as competition; (2) the effects of human activities, which can mask impacts caused by climatic changes, are of inferior relevance, compared to lowland regions; (3) the majority of vascular plants are slow-growing and long-lived perennials, thus, are expected to indicate impacts of a continued climate change rather than effects of short-term climate oscillations (Pauli & al. 1999).

Nowadays, the consequences of climatic change on mountain plants have already been recognised: upward range expansions, increase on species richness, extinctions, etc (Erschbamer & al., 2009; Grabherr & al., 1994, 2010; Holzinger & al., 2008; Klanderud & Birks, 2003; Vittoz & al., 2008). Therefore, in order to protect the flora, it is important to know in detail its current situation in the mountain areas which might be threatened by the effects of global warming. This is the case of Sierra Nevada (southern Spain), an outstanding massif in the Mediterranean region detected as a vulnerable biodiversity hotspot in the Mediterranean basin (Fernández-González & al. 2005; Médail & Quézel 1997, 1999). The importance of the massif, characterised by an exceptional concentration of endemic taxa on its higher summits (Blanca & Molero Mesa 1990; Blanca & al. 1998; Rivas-Martínez & al. 1991), is well documented in the context of national and international biodiversity (Blanca 1996; Molero Mesa & Pérez Raya 1987; Molero Mesa & al. 1996; Myers 2000; Quézel 1953; Rivas Goday & Mayor López 1966). The current projections on changes in temperatures and precipitation conditions on the Iberian Peninsula, where Sierra Nevada is located, threaten its flora and endanger its biodiversity (Fernández-González & al. 2005). Therefore, we consider this study to be a very useful research as it contributes to a current and detailed analysis about the highest mountain flora of Sierra Nevada, information that could be used in the future as a testimony for variations that might be provoked by climatic change.

Methods

Study area.- The Sierra Nevada massif is part of the Baetic Cordillera in the southern part of Spain and stretches over about 90 km in west-east direction (Fig. 1). Its altitude exceeds the rest of Baetic Cordillera by 1100 m, with numerous summits above 3000 m a.s.l., including the highest peak on the Iberian Peninsula (Mulhacen, 3481m).

The study area coincides with the limits of the upper vegetation belt, called the cryo-oromediterranean belt by Rivas-Martínez (1981, 2007). This area only covers 38,8 km^2 with its lower boundaries oscillating between 2750 m, on northern and western slopes and 3290 m on southern and eastern (Fernández Calzado 2007; Molero Mesa & al. 2009). The limit of the lower vegetation belt, oromediterranean, is approximately between 1900-2200 m (Valle & al. 2003).

Its bedrock composition consists mainly of highly weathered feldspar and graphitic mica schist (Gómez Ortiz & al. 2009). The landscape includes steep slopes, scree and rocky areas that were partly shaped by Pleistocene glaciers.

Biogeographically speaking, the area belongs to the Nevadense sector of the Baetic province of the Mediterranean region (Rivas-Martínez 2007). Unlike elsewhere in Europe, several species of the study area are shared with the High Atlas range (Morocco).

From a bioclimatic point of view, Sierra Nevada is exposed to a Mediterranean bioclimate in its pluviseasonal oceanic variant (Rivas-Martínez 2007). There is a pronounced summer drought at all altitudes and above 2500 m precipitation falls almost exclusively as snow.

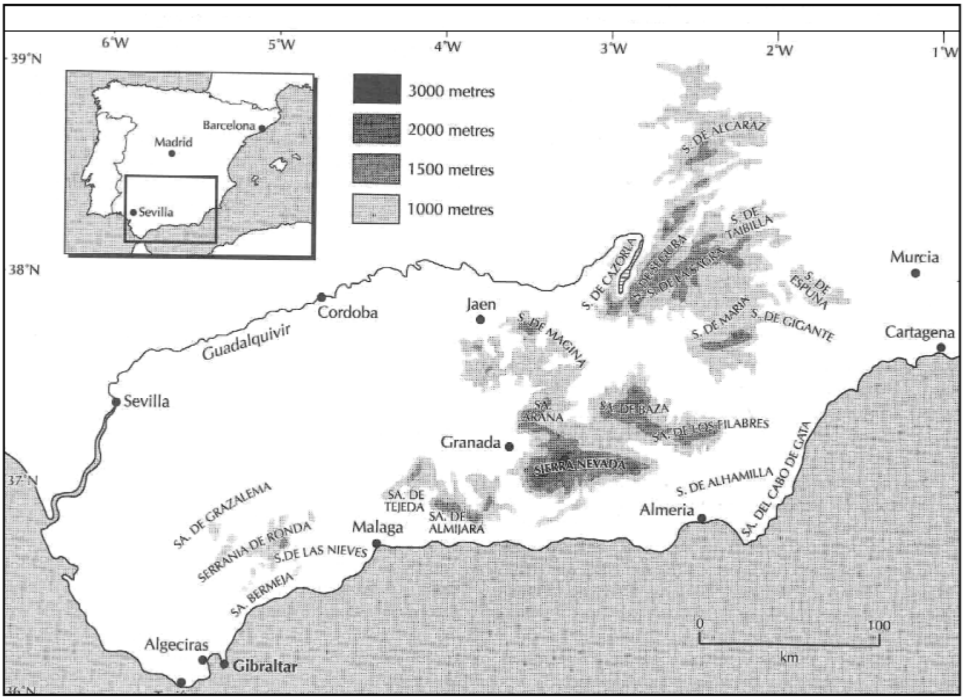

Fig. 1. Location of the study area.

Data sources.- The background of this work is the international monitoring programme GLORIA (Global Observation Research Initiative in Alpine Environments; www.gloria.ac.at), a network with more than 70 research teams distributed over five continents which have been developed during the last decade in order to establish and maintain standardised long-term observation sites for climate change impacts on alpine biota. Specifically in the upper zone of Sierra Nevada eight monitoring summits have been installed (Pauli & al. 2004; Molero Mesa & al. 2009) in the year 2000.

Then, the cited project was the point of departure for a wider and more detailed study about the highest mountain flora on the massif, with the intention to asses its richness and biodiversity. The floristic data is based on the field work carried out over 4 years in the upper zone of Sierra Nevada (Fernández Calzado 2007) and on the literature sources (Blanca & al. 2009; Boissier 1839-1845; Molero Mesa & Pérez Raya 1987; Molero Mesa & al. 1996; Prieto Fernández 1975; Willkomm & Lange 1861-1880).

The floristic nomenclature is in accordance with Flora Iberica for the published families (Castroviejo & al. 1986-2002) and Flora Europaea (Tutin & al. 1964-1980), in some cases, other authors have been considered (Rivas-Martínez & al. 2002). The Appendix contains a checklist of all cryoromediterranean taxa including taxonomic authorship and additional indications such as the thermotype (Rivas-Martínez 2007), life form, threat category and distribution.

Taxa have been classified according to the following life form categories (Raunkiaer 1934): phanerophytes, chamaephytes, hemicryptophytes, geophytes and therophytes.

The list of endemic taxa is done according to Blanca & al. (2002), Castroviejo & al. (1986-2009) and Rivas-Martínez & al. (1991). The terms "Nevadense" and "Betican" refer to taxa being restricted to the Sierra Nevada or in the Baetic Cordillera, respectively.

The information about threat categories was compiled using data of Blanca & al. (1999, 2000, 2002) and Bañares & al. (2003).

Results

There are 185 taxa (species and subspecies) recorded in the upper vegetation zone of Sierra Nevada, which mainly belong to the following families: *Poaceae* (24 taxa), *Asteraceae* (20), *Caryophyllaceae* (16), *Brassicaceae* (12), *Scrophulariaceae* (10) and *Cyperaceae* (7).

These taxa are distributed over a variety of endemic plant communities of dry grassland, scree and cliff communities where hemicryptophytes (61.62 %) and chamaephytes (27.58 %) are dominant, whereas geophytes, therophytes and phanerophytes only account for 10.8 %. The first dominant life form is characteristic in mountainous areas with humidity and low temperatures; however, our percentage is low if we compare it with other high European mountains. On the contrary, the chamaephytes percentage, many of them dwarf chamephytes, is significantly raised possibly due to the Mediterranean character of this mountain.

As far as the taxa altitudinal distributions are concerned, taking into account the five bioclimatic zones distinguished by Rivas-Martínez (2007) in Sierra Nevada (thermomediterranean, mesomediterranean, supramediterranean, oromediterranean and cryoromediterranean), only 18 taxa were found to belong exclusively to the cryoromediterranean zone, representing 9.73% of the total number of taxa considered in this study. Some of these species are just represented by scanty and sparse populations and are considered to be on the edge of the disappearance. This is the case for taxa that had immigrated during the Pleistocene glaciations and they remained as relics, i.e. *Artemisia umbelliformis, Draba dubia* subsp. *laevipes, Papaver lapeyrousianum, Ranunculus glacialis, Sibbaldia procumbens, Valeriana apula* or *Saxifraga oppositifolia.*

The number of taxa that live within the oro and cryoromediterranean zones is 115 (62.16 %). Some have also arrived in Sierra Nevada during the ice ages and have survived here in refugee areas, i.e. *Alchemilla saxatilis, Asplenium septentrionale* or *Gentiana alpine*. This group, however, also includes a large number of endemic plants, i. e. *Agrostis canina* subsp. *granatensis, Arenaria tetraquetra* subsp. *amabilis, Draba hispanica* subsp. *laderoi, Eryngium glaciale, Festuca pseudoeskia, Saxifraga nevadensis, Senecio nevadensis, Sideritis glacialis, Thymus serpylloides, Trisetum glaciale* or *Viola crassiuscula* (see appendix).

The remaining 52 taxa (28.11%) live in more than two bioclimatic zones (Fig. 3).

In relation with the chorology and the degree of endemism, the value of Sierra Nevada is well known. It includes its upper summits where between 30-40 % of ifs flora is exclusive, increasing up to 80 % in certain ecological niches as scree or rocky areas (Blanca

2002). Specifically our data shows that 37.3% (69 taxa) of the cryoromediterranean flora are endemics. Some of them, 29.73% (55 taxa) are considered restricted to Sierra Nevada (Nevadense) but 14 taxa are also present elsewhere in the Baetic Cordillera, although they are usually very rare. The remaining 116 taxa (62.7%) are distributed over different territories: Iberian Peninsula, Europe, etc. Some are particularly interesting, i.e. *Androsace vandelli*, *Artemisia umbelliformis, Draba dubia* subsp. *laevipes, Festuca rivularis* or *Phyteuma charmelii* because they spread from the Alps and other European mountain systems with Sierra Nevada as the southern outpost (Molero Mesa & al. 2009).

Discussion

The geographical situation of Sierra Nevada inside the Mediterranean region, as well as its altitude, is reflected in its flora composition which has a high number of taxa from the typical Mediterranean families and logical incorporations from colder times (glaciations and interglacial periods). As far as the first one, it is obvious that numerous taxa undergo an adaptation or go through a specialization process to adapt to the current environmental conditions, i.e. *Trisetum glaciale, Hormathophylla spinosa, Nevadensia purpurea, Thymus serpylloides*. At the same time, the representations of other typical species from other European mountains are minimal here.

A similar thing occurs with the type of climate, the Mediterranean, which mainly means that there is a period with high precipitation during winter (at high elevations most of it falls as snow) and a dry summer (two or more months) reflecting in its flora. The species are snow-covered usually until June and after snow-melt in early summer following two or more months of dry season with almost no precipitation (Rivas-Martínez 2007). Normally, at upper altitudes in Sierra Nevada, this dry period falls in July and August. These harsh climatic conditions coincide with the growing season peak when evapotranspiration is high, therefore, the plants have developed special adaptations such as long tap roots, small leaves, short activity period, etc.

In this context, the current climatic trends predict a drier climate, therefore, the activity period will be wider with the same quantity of water which is expected to be a serious threat for the Sierra Nevada plants (Fernández-González & al. 2005). Adding to it, the cryoromediterranean flora is on a fragile balance surviving in a smaller territory than we had expected at the beginning of our research (Molero Mesa & al. 2009). Among its taxa the high level of endemism and rarity are not unusual phenomena, therefore, any threat or catastrophic event might provoke important consequences as the disappearance of some populations. Currently, we have also realized some flora changes in our study area thanks to the work developed by Boissier 172 years ago (Molero Mesa & Fernández Calzado 2010). Today, the situation has changed to a much shorter snow-cover period, often less than five months, and the number of taxa has increased by 65 in this upper area.

Focussing on the endemism rate topic, a pronounced geographical, orographic and ecological isolation has supported a high degree of endemism in Sierra Nevada (Blanca 1998; Giménez & al. 2004; Mota & al. 2008; Peñas & al. 2005; Pérez-García & al. 2007) where we have observed an inverse relationship between species richness and the percentage of endemism: as we move upwards the number of species decreases and the degree of endemism increases.

Our estimations indicated that 37.3% (69 taxa) is the percentage of endemism on the cryoromediterranean flora, a high number in spite of the small size of the territory. If we compare our observations with the data from Pérez-García & al. (2007), who counted 121 Baetic endemic plants and 56 endemic plants in the siliceous part of Sierra Nevada, they do not exactly coincide. We should clarify that our data has been recorded in a well-delimitated siliceous part (Fernández Calzado 2007, Molero Mesa & al. 2009) with the percentage of restricted endemic flora in our territory being more prominent.

To add, if we extend the concept of endemism considering the taxa that live in the Iberian Peninsula as endemic, we could do other comparisons which reveal the extraordinary originality and rarity of the cryoromediterranean territory. This new percentage in our area would increase up to 47.57 %, comparing it with the percentage of endemic species in the alpine belt of the Aragonese Pyrenees (20 %; Villar & al. 2001) or Gredos Mountain in the Central system (14.77 %; Luceño & Vargas 1991) giving us an idea of the importance of Sierra Nevada cryoromediterranean belt.

Finally, we would like to emphasize the legislative situation of the Sierra Nevada high mountain flora in Spain, protected by the National Park Network, Red List of Spanish Vascular Flora and Red List of Andalusia Vascular Flora. In spite of this protection, many taxa are categorised as endangered (Pérez-García & al. 2007) classifying Sierra Nevada as one of the most important sites in Andalusia with an elevated number of threatened species, specifically in its upper zone. Concretely, 39 taxa are included in the three major risk categories: 33 vulnerable, 4 endangered and 2 critically endangered taxa. The majority of them are distributed in the two upper zones (oro- and cryoromediterranean belts).

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Appendix: Checklist of cryoromediterranean plant species (185 taxa)

TAXA	Thermotype[a]	Life form[b]	Threaten[c]	Distribution[d]
Acinos alpinus subsp. *meridionalis* (Nyman) P.W.Ball	S,O,C	Ch	NL	Eu-N
Aconitum vulparia subsp. *neapolitanum* (Ten.) Muñoz Garmendia	S,O,C	He	NL	Eu-N
Agrostis canina subsp. *granatensis* Romero García, Blanca & C. Morales	O,C	He	VU	Ne
Agrostis nevadensis Boiss.	O,C	He	NL	Ne
Alchemilla glabra Neygenf.	S,O,C	Ch	NL	Eu
Alchemilla saxatilis Buser	O,C	He	NL	Eu
Alyssum nevadense Willmmott ex P.W.Ball & R. Dudley	O,C	He	VU	Ne
Anarrhinum laxiflorum Boiss.	S,O,C	He	NL	Ib-N
Androsace vandelli (Turra) Chiov.	O,C	Ch	NL	Eu
Androsace vitaliana subsp. *nevadensis* (Chiarugi) Luceño	O,C	Ch	VU	Ne
Antennaria dioica var. *congesta* DC.	C	Ch	VU	Others
Anthericum baeticum (Boiss.) Boiss.	S,O,C	Ge	NL	Ib-N
Anthyllis vulneraria subsp. *pseudoarundana* H.Lindb	O,C	He	NL	Ne
Arabis alpina L.	S,O,C	Ch	NL	Others
Arenaria tetraquetra subsp. *amabilis* (Bory) H. Lindb. fil.	O,C	Ch	NL	Ne
Arenaria armerina Bory	S,O,C	Ch	NL	Ib-N
Arenaria nevadensis Boiss. & Reuter	C	Te	CR	Ne
Arenaria pungens Clemente ex Lag.	O,C	Ch	NL	Be
Armeria filicaulis subsp. *nevadensis* Nieto Feliner, Rosselló & Fuertes.	O,C	He	VU	Ne
Armeria splendens (Lag. & Rodr.) Webb	O,C	He	VU	Ne
Arrhenaterum elatius subsp. *baeticum* Romero Zarco	S,O,C	He	NL	Ib-N
Artemisia granatensis Boiss.	O,C	Ch	CR	Ne
Artemisia umbelliformis Lam.	C	Ch	EN	Eu
Asperula aristata subsp. *scabra* (J. & C.Presl.) Nyman	M,S,O,C	He	NL	Eu-N
Asplenium ruta -muraria L.	S,O,C	He	NL	Others
Asplenium septentrionale (L.) Hoffm.	O,C	He	NL	Others
Asplenium viride Hudson	O,C	He	NL	Others
Astragalus incanus L.	M,S,O,C	Ch	NL	Eu-N
Avenella iberica (Rivas Martínez) Rivas Martínez, Fern-Gonz & Loidi.	O,C	He	NL	Ib
Avenula levis (Hackel) J. Holub	O,C	He	VU	Be
Biscutella glacialis (Boiss. & Reut.) Jordan	O,C	He	NL	Ne
Botrychium lunaria (L.) Swartz	O,C	Ge	VU	Others
Bunium macuca subsp. *nivale* (Boiss.) Mateo & López Udias	O,C	Ge	NL	Ne
Campanula herminii Hoffmm. & Link.	O,C	He	NL	Ib
Campanula rotundifolia L. subsp. *hispanica* (Willk. in Willk. & Lange) O. Bolos & Vigo	O,C	He	NL	Eu
Cardamine resedifolia L.	O,C	He	NL	Eu-N
Carduus carlinoides subsp. *hispanicus* (Kazmi) Franco	O,C	He	NL	Ne
Carex capillaris L.	O,C	He	NL	Others
Carex echinata Murray	O,C	He	NL	Others
Carex furva Webb	O,C	He	NL	Ib
Carex leporina L.	S,O,C	He	NL	Others
Carex nevadensis Boiss. & Reuter	O,C	He	NL	Be
Carex nigra subsp. *intricata* (Tineo) Rivas Martínez	O,C	He	NL	Others
Centranthus nevadensis Boiss.	S,O,C	Ch	VU	Be
Cerastium alpinum subsp. *aquaticum (*Boiss.) Martínez Parra & Molero Mesa	C	Ch	NL	Ne
Cerastium alpinum subsp. *nevadense* (Pau) Martínez Parra & Molero Mesa	C	Ch	NL	Ne
Cerastium cerastoides (L.) Britton	O,C	Ch	NL	Others

Cerastium ramosissimum Boiss.	S,O,C	Te	NL	Others
Chaenorrhinum glareosum (Boiss.) Willk	O,C	He	NL	Ne
Cirsium gregarium Boiss. ex. Willk.	O,C	He	NL	Be
Coincya monensis subsp. *nevadensis* (Willk.) Leadlay	O,C	He	NL	Ne
Comastoma tenellum (Rottb.)Toyok.	O,C	Te	VU	Others
Conopodium bunioides (Boiss.) Calestani	O,C	Ge	NL	Ib
Crepis oporinoides Boiss.	O,C	Ch	NL	Be
Cryptogramma crispa (L.) R. Br. ex Hooker	O,C	Ge	NL	Others
Cuscuta planiflora Ten.	O,C	Te	NL	Others
Cystopteris fragilis (L.) Bernh subsp. *fragilis*	M,S,O,C	He	NL	Others
Cystopteris fragilis subsp. *alpina* (Lam.) Hartman	S,O,C	He	NL	Eu
Cystopteris fragilis subsp. *huteri* (Hausm. ex Milde) Prada & Salvo	C	He	NL	Eu
Dactylis juncinella Bory	O,C	He	NL	Ne
Dianthus pungens L. subsp. *brachyanthus* (Boiss.) Bernal, Fern. Casas, G. López,M. Lainz & Muñoz Garm.	S,O,C	Ch	NL	Ib-N
Draba dubia Suter subsp. *laevipes* (DC) B- Blanq. In Trav.	C	Ch	VU	Eu
Draba hispanica Boiss. subsp. *laderoi* Rivas Martínez, M.E. García & Penas	O,C	Ch	NL	Ne
Dryopteris filix-max (L.) Schott	M,S,O,C	He	NL	Others
Eleocharis quinqueflora (F.X.Hartmann) O.Schwartz	O,C	He	NL	Others
Epilobium alsinifolium Vill.	O,C	He	NL	Eu
Epilobium anagallidifolium Lam.	O,C	He	NL	Others
Epilobium atlanticum Litard. & Maire	S,O,C	He	VU	Ib-N
Erigeron frigidus Boiss. ex DC	C	He	VU	Ne
Erigeron major (Boiss.) Viehr	O,C	He	NL	Be
Erodium cheilanthifolium Boiss.	S,O,C	Ch	NL	Be
Eryngium glaciale Boiss	O,C	He	NL	Ib-N
Euphorbia esula L.	S,O,C	He	NL	Others
Euphorbia nevadensis Boiss. & Reut.	O,C	Ch	NL	Ib
Euphrasia willkommii Freyn	O,C	Te	NL	Ib-N
Festuca clementei Boiss.	C	He	VU	Ne
Festuca frigida (Hackel) K. Richter	O,C	He	VU	Ne
Festuca iberica (Hackel) K. Richter	O,C	He	NL	Ib-N
Festuca indigesta Boiss.	S,O,C	He	NL	Ib-N
Festuca pseudoeskia Boiss.	O,C	He	NL	Ne
Festuca rivularis Boiss.	O,C	He	NL	Eu
Fritillaria lusitanica Wikstr.	M,S,O,C	Ge	NL	Ib-N
Gagea nevadensis Boiss.	M,S,O,C	Ge	NL	Ib-N
Galium nevadense Boiss. & Reuter	O,C	He	NL	Ib-N
Galium pyrenaicum Gouan	O,C	Ch	NL	Ib
Galium rosellum (Boiss.) Boiss. & Reuter	O,C	He	NL	Be
Gentiana alpina Vill.	O,C	He	VU	Eu
Gentiana boryi Boiss.	O,C	He	VU	Ib
Gentiana pneumonante L. subsp. *depressa* (Boiss.) Malag.	O,C	He	VU	Ne
Gentiana sierrae Briquet (*Gentiana verna* L.)	O,C	He	VU	Ne
Helictotrichon filifolium (Lag.) Henrad subsp. *velutinum* (Boiss.) Romero Zarco	S,O,C	He	NL	Ib-N
Helictotrichon sedenense (Clarion ex DC.) J. Holub	S,O,C	He	NL	Eu-N
Herniaria boissieri Gay	O,C	Ch	NL	Be
Hieracium pilosella L. subsp *melanops* Peter	S,O,C	He	NL	Eu
Holcus caespitosus Boiss.	O,C	He	NL	Ne
Hormathophylla spinosa (L.)Kupfer	M,S,O,C	Ch	NL	Eu-N
Hypericum undulatum Schousboe ex Willd.	M,S,O,C	He	NL	Eu-N

Iberis carnosa Wild subsp. *embergeri* (Serve) Moreno	C	He	EN	Ne
Jasione crispa (Pourr.) Samp. subsp. *tristis (*Bory) G. López	O,C	Ch	NL	Ne
Juncus alpinoarticulatus Chaix	O,C	He	NL	Eu
Juncus tenageia Ehrh. ex L. fil.	O,C	Te	NL	Others
Juniperus communis L. subsp. *hemisphaerica* (K.Presl) Nyman	S,O,C	Fa	NL	Others
Leontodon boryi Boiss.	O,C	He	NL	Be
Leontodon microcephalus (Boiss.) Boiss.	O,C	He	VU	Ne
Lepidium stylatum Lag.& Rodr.	O,C	He	NL	Ne
Leucanthemopsis pectinata (L.) G. López & Ch. E. Jarvis.	O,C	Ch	NL	Ne
Linaria glacialis Boiss.	C	He	VU	Ne
Linaria nevadensis (Boiss.) Boiss & Reut.	O,C	He	NL	Ne
Logfia arvensis (L.) J.Holub	M,S,O,C	Te	NL	Eu
Lotus corniculatus L. subsp. *glacialis* (Boiss.) Valdés	O,C	Ch	NL	Ne
Luzula hispanica Chrtek & Krisa	O,C	He	NL	Ib
Meum athamanticum Jacq.	O,C	He	NL	Eu-N
Montia fontana L. (N)(S-O-C)	S,O,C	He	NL	Others
Murbeckiella boryi (Boiss.) Rothm.	O,C	He	NL	Ib-N
Myosotis minutiflora Boiss. & Reuter	M,S,O,C	Te	NL	Others
Nardus stricta L.	O,C	He	NL	Eu-N
Nepeta nepetella L. subsp. *laciniata* (Willk.) Aedo.	S,O,C	Ch	NL	Ne
Nevadensia purpurea (Lag. & Rodr.) Rivas Martínez	O,C	He	NL	Ne
Omalotheca supina (L.) DC. var. *pusilla* (Haenke) Amich, Rico & Sánchez	O,C	He	NL	Eu
Papaver lapeyrousianum Guterm.	C	He	EN	Ib
Parnassia palustris L.	S,O,C	He	NL	Others
Paronychia polygonifolia (Vill.) DC	S,O,C	Ch	NL	Others
Pedicularis verticillata L. subsp. *caespitosa* (Webb) I. Soriano	C	He	VU	Ne
Phleum abbreviatum (Boiss.) Rivas Martínez, Asensi, Molero Mesa & Valle	O,C	He	VU	Ne
Phyteuma charmelii Vill.	O,C	He	VU	Eu
Pimpinella procumbens (Boiss.) Pau	O,C	He	VU	Ne
Pinguicula nevadensis (Lindb.) Casper	O,C	He	VU	Ne
Plantago holosteum Scop.	S,O,C	Ch	NL	Eu
Plantago nivalis Boiss.	O,C	He	NL	Ne
Poa laxa Haenke	O,C	He	NL	Eu
Poa ligulata Boiss	S,O,C	He	NL	Ib-N
Poa minor Gaudin subsp. *nevadensis* Nannfeldt	O,C	He	NL	Ne
Poa nemoralis subsp. *glauca* (Gaudin) Rouy	S,O,C	He	NL	Eu
Poa supina Schrader	S,O,C	He	NL	Others
Polygonum aviculare L.	O,C	Te	NL	Others
Polystichum lonchitis (L.) Roth	O,C	He	NL	Others
Potentilla nevadensis Boiss.	O,C	Ch	NL	Ne
Ranunculus acetosellifolius Boiss.	O,C	He	NL	Ne
Ranunculus angustifolius subsp. *alismoides* (Bory) Malagarriga	O,C	He	NL	Ne
Ranunculus demissus DC	O,C	He	NL	Others
Ranunculus glacialis L.	C	He	VU	Eu
Reseda complicata Bory	O,C	Ch	NL	Ne
Rhamnus pumila Turra	O,C	Ch	NL	Others
Ribes alpinum L.	O,C	Fa	VU	Eu-N
Sagina saginoides subsp. *nevadensis* (Boiss. & Reut.) Greuter & Burdet	O,C	He	NL	Ib
Sagina procumbens L.	S,O,C	He	NL	Others
Saxifraga granulata L.	M,S,O,C	He	NL	Others
Saxifraga nevadensis Boiss.	O,C	Ch	NL	Ne

Saxifraga oppositifolia L.	C	Ch	NL	Others
Saxifraga gredensis Rivas Mateos	O,C	Ch	VU	Ib
Scutellaria jabalambrensis Pau	O,C	He	NL	Ib
Sedum amplexicaule DC	M,S,O,C	Ch	NL	Others
Sedum annuum L.	O,C	Te	NL	Eu
Sedum brevifolium DC	O,C	Ch	NL	Eu-N
Sedum candollei Raym.-Hamet	O,C	Te	NL	Ib
Sedum dasyphyllum L.	O,C	Ch	NL	Eu-N
Sedum melanantherum DC	O,C	Ch	NL	Ib-N
Sempervivum minutum (Kunze ex Willk.) Nyman ex Pau	S,O,C	Ch	NL	Be
Senecio boissieri DC.	O,C	Ch	NL	Ib
Senecio nebrodensis L.	S,O,C	He	NL	Ib
Senecio nevadensis Boiss. & Reut.	O,C	Ch	VU	Ne
Senecio pyrenaicus subsp. *granatensis* (Boiss. ex DC) Rivas Martínez	O,C	Ch	NL	Be
Sesamoides prostrata (Boiss.) G. López.	S,O,C	Ch	NL	Be
Sibbaldia procumbens L.	C	He	VU	Others
Sideritis glacialis Boiss.	O,C	Ch	NL	Ne
Silene boryi Boiss.	S,O,C	He	NL	Ib
Silene rupestris L.	O,C	He	NL	Eu
Silene saxifraga L.	S,O,C	Ch	NL	Eu
Solidago virgaurea subsp. *minuta* (L.) Arcangeli	O,C	He	NL	Others
Taraxacum nevadense H. Lind. fil.	O,C	He	NL	Ne
Thymus serpylloides Bory	O,C	Ch	NL	Ne
Trifolium pratense L.	M,S,O,C	He	NL	Others
Trifolium repens subsp. *nevadense* (Boiss.) D.E. Coombe	S,O,C	He	NL	Ib
Trisetum antonii-josephii Font Quer & Muñoz Medina	O,C	He	EN	Ne
Trisetum glaciale (Bory) Boiss. (*Trisetum glacile* Boiss.)	C	He	VU	Ne
Vaccinium uliginosum subsp.*nanum* (Boiss.) Rivas Martínez, Asensi, Molero Mesa & Valle	O,C	Ch	NL	Ne
Valeriana apula Pourret	C	He	VU	Ib-N
Veronica alpina L.	O,C	He	NL	Others
Veronica fruticans Jacq	O,C	Ch	NL	Others
Veronica nevadensis (Pau) Pau	O,C	He	NL	Ib
Veronica ponae Gouan	O,C	He	NL	Ib
Vicia pyrenaica Pourret	S,O,C	He	NL	Eu
Viola crassiuscula Bory	O,C	He	NL	Ne
Viola hirta L.	S,O,C	He	NL	Others
Viola palustris L.	O,C	He	NL	Others

a M = mesoditerranean, S = supramediterranean, O = oromediterranean, C = cryoromediterranean

b Fa = phanerophytes, Ch = chamaephytes, He = hemicryptophytes, Ge = geophytes, Te = therophytes

c CR = critically endangered, EN = endangered, VU = vulnerable, NL = not list

d Ne = nevadense, Be = betican, Ib = iberian, Ib-N = iberian-northern Africa, Eu = european, Eu-N = european-northern Africa, Others = widely distributed