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DISSERTATION

Titel der Dissertation

Comparative analysis of high-alpine and subnival vegetation of mountain ecosystems in Iran (Alborz and NW-Iran) and assessing the impacts of climate change and land-use

verfasst von

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List of original publications

The thesis is based on the following publications:

1. **Noroozi, J.**, Pauli, H., Grabherr, G. & Breckle, S.W. (2011) The subnival-nival vascular plant species of Iran: a unique high-mountain flora and its threat from climate warming. Biodiversity and Conservation 20: 1319-1338.

2. **Noroozi, J.**, Willner, W., Pauli, H. & Grabherr, G. (2013) Phytosociology and ecology of the high-alpine to subnival scree vegetation of N and NW Iran (Alborz and Azerbaijan Mts.). Applied Vegetation Science DOI: 10.1111/avsc.12031.

3. **Noroozi, J**., Ajani, Y. (2013) A new alpine species of *Nepeta* sect. *Capituliferae* (Labiatae) from Northwestern Iran. Novon 22: 297–303.

4. **Noroozi, J**., Ajani, Y., Nordenstam, B. (2010) A new annual species of *Senecio* (Compositae-*Senecioneae*) from subnival zone of southern Iran with comments on phytogeographical aspects of the area. Compositae News Letter 48: 43-62.

5. Ajani, Y., **Noroozi, J.** & Levichev, I.G. (2010) *Gagea alexii* (Liliaceae), a new record from subnival zone of southern Iran with key and notes on sect. *Incrustatae.* Pakistan Journal of Botany 42: 67-77.

6. **Noroozi, J.** (In press). High mountain regions of Iran (chapter 7.6), *in* C. Hobohm (editor). Endemism in Vascular Plants. Springer.

Author’s contribution to each publication

Publications	**1**	**2**	**3**	**4**	**5**	**6**
Idea and design	+	+	+	+	-	+
Sampling	+	+	+	+	+	+
Data analysis	+	+	+	+	-	+
Writing	+	+	+	+	+	+

Abstract

Iran is a mountainous country where rather small patches of alpine habitats are scattered across large mountain areas. The diverse flora and vegetation of these habitats have been poorly investigated so far, despite the high rate of narrowly distributed plant species which are expectedly very vulnerable to climate change impacts.

The aim of this thesis is to study the flora and vegetation of the high alpine to subnival-nival elevation belts of Iran with emphasis on N- (Alborz) and NW-Iran (Sahand and Sabalan), its biodiversity in relation to elevation and its vegetation patterns in comparison with neighboring mountain systems, as well as its potential threats through climate warming.

The thesis is divided into two related research foci, the first on high-altitude species, the second on their vegetation patterns.

The first study deals with assessing the plant diversity and phytogeography of vascular plants occurring in the uppermost elevation belts of Iran, and attempts to give a first estimate on the risk of biodiversity losses through effects of climate change. This work was based on an extensive literature research and on additional field observations. All vascular plant species living in the subnival–nival zone of Iranian mountains (151 species) and those restricted to this zone (51) were identified. The elevational and geographical distribution patterns of these species were analyzed and the current distribution patterns are discussed with respect to potential warming-induced species losses. The rate of endemics (endemic to Iran, in most cases however far more restricted distributions) increases sharply with increasing elevation.

The narrow distribution of most of Iran's cold-adapted mountain flora and the low potential of alternative cold habitats render it highly vulnerable to climate change.

Furthermore, Iran's high mountains may host a number of still unknown species, as this study revealed two subnival-nival vascular plant species new to science: *Senecio subnivalis* (on Hezar Mts in south Iran) and *Nepeta sahandica*, (on Sahand, NW Iran), and a highly disjunct occurrence of *Gagea alexii*. The original descriptions of these discoverings and of these species' vegetation ecology are arranged in a separate chapter.

The second main research focus of the thesis was on the vegetation of the alpine and subnival-nival zones of N and NW Iran. In total, about 700 vegetation relevés have been collected from different habitats of the study area during the MSc and PhD theses. This thesis mainly deals with

high-elevation scree vegetation, using 141 relevés for analysis and phytosociological classification. A synoptic table of the most important alliances of scree vegetation in the European Alps, the Balkan Peninsula, the Caucasus, Anatolia, as well as the alliances described in the present paper was prepared to show the floristic and syntaxonomic relationship of these regions. All high-alpine and subnival scree communities of the study area were arranged in one class, two orders, and three alliances which are new for the science. This was the first formal syntaxonomic classification of the high mountain scree vegetation of Iran.

Zusammenfassung

Iran ist ein Gebirgsland. Alpine Habitate sind jedoch über ausgedehnte Gebirgsräume weit zerstreut und stark fragmentiert. Die artenreiche Flora und Vegetation dieser Habitate wurde bislang kaum untersucht. Dies trotz des hohen Anteils engräumig verbreiteter Arten und der dadurch erwarteten hohen Anfälligkeit auf Effekte des Klimawandels.

Ziel dieser Dissertation ist das Studium der Flora und Vegetation der hoch-alpinen bis subnival-nivalen Höhenstufen Irans, mit einem speziellen Fokus auf das Elburs-Gebirge in Nord-Iran und die isolierteren Bergstöcke Sahand und Sabalan im Nordwesten. Im speziellen bezieht sich die Arbeit auf Biodiversitätsmuster entlang des Höhengradienten, auf die Vegetationszusammensetzung im Vergleich mit benachbarten Gebirgsräumen und auf das Gefährdungspotential bezüglich Klimaerwärmung.

Die Arbeit ist in zwei Themenbereiche gegliedert, wobei sich der erste auf die Artenmuster, der zweite auf die Vergesellschaftung der Arten bezieht.

Teil 1 beinhaltet eine detaillierte phytogeographische Erfassung aller in den obersten Höhenstufen vorkommenden Gefäßpflanzenarten und versucht, darauf aufbauend, eine erste Risikoabschätzung von klimawandelinduzierten Biodiversitätsverlusten zu geben. Die Studie basiert auf eingehender Literaturrecherche sowie ergänzenden Felderhebungen. Für die gesamte subnival-nival-Stufe wurden 151 Arten identifiziert, 51 davon sind auf diese Höhenstufe beschränkt. Anhand der Verbreitungsmuster der Arten entlang des Vertikalgradienten und der geographischen Verbreitung wird das Potential für erwärmungsinduzierte Artenverluste diskutiert. Der Endemitenanteil (Iran-Endemiten, meist jedoch sind es sehr lokal verbreitete Arten) zeigte einen sehr deutlichen Anstieg mit der Höhenlage. Sehr engräumig verbreitete Arten zeigen also eine Häufung in der höchsten, nur sehr kleinflächigen Höhenstufe. Diese kälteadaptierten Gebirgsspezialisten sind demnach hochgradig anfällig auf Klimawandeleinflüsse.

Darüber hinaus sind für die iranischen Gebirge noch etliche unbekannte Gefäßpflanzenarten zu erwarten, wie durch die Neufunde im Rahmen dieser Studie angezeigt ist. Zwei Arten, *Senecio subnivalis* (im Hezar-Gebirge Süd-Irans) und *Nepeta sahandica* (im Sahand, NW-Iran), wurden erstmals beschrieben, für eine weitere, *Gagea alexia*, wurde ein sehr disjunktes Vorkommen gefunden. Die Originalbeschreibungen mit vegetationsökologischen Informationen zu diesen Arten sind in einem eigenen Kapitel dargestellt.

Der zweite Haupt-Fokus der Dissertation liegt auf der Vegetation der hoch-alpinen und subnival-nivalen Stufe Nord- und Nordwest-Irans. Aus insgesamt 700 Vegetationsaufnahmen wurden 141 Aufnahmen für die Analyse und phytosoziologische Klassifizierung der Schuttvergesellschaftungen ausgewählt. Anhand einer synoptischen Tabelle wurde der syntaxonomische Bezug mit der Schuttvegetation benachbarter Gebirge in Anatolien, Kaukasus sowie der Gebirge auf der Balkanhalbinsel und der Alpen untersucht. Aufgrund klarer floristischer Differenzierung zu den Nachbargebirgen mussten die iranischen Schuttgesellschaften in eine neue syntaxonomische Klasse mit zwei Ordnungen und drei Verbänden gestellt werden. Die Arbeit stellt die erste formale syntaxonomische Klassifikation der Hochgebirgs-Schuttgesellschaften Irans dar.

Introduction

1 Background

Mountains are hot spots of biodiversity related to the steep elevational gradients and, thus, to a compression of bioclimatic zones, to topographic heterogeneity, and to speciation through isolation (Nagy & Grabherr 2009). The alpine life zone in the plant geographic sense is applied to any low stature vegetation above the climatic treeline worldwide, and alpine vegetation represents the only biogeographic unit on land with a global distribution and is fragmented into many mountain regions (Körner 2003). The alpine floras of the world are nested within a great variety of regional floras, partly explaining the great overall species diversity among alpine vegetation (Körner & Spehn 2002). Different phenomena in high mountains such as geographic isolation, tectonic uplift, climatic changes, glaciation, strong micro habitat differentiation and a varied history of migration and/or evolution cause a high rate of taxonomic richness (Packer 1974; Agakhanyanz & Breckle 1995; Körner 1995). Many alpine regions are biodiversity hotspots and habitat for many endemic species (Körner 2003).

Alpine vegetation and the distribution ranges of plant species are affected by climate change. Studies, however, are mainly available for temperate and boreal mountains (Grabherr et al. 1994; Walther et al. 2005a; Pauli et al. 2007; Vittoz et al. 2008; Klanderud & Birks 2003; Britton et al. 2009). Resurveys in alpine areas of a number of European mountain systems revealed that vascular plants have been migrating upward to higher altitudes (Grabherr et al. 1994, 2001; Pauli et al. 1996, 2007, 2012; Sturm et al. 2001; Moiseev & Shiyatov 2003; Walther et al. 2005a, 2005b; Holzinger et al. 2008; Klanderud & Totland 2005; Parolo & Rossi 2008; Erschbamer et al. 2009; Gottfried et al. 2012). Biota of high mountains around the Mediterranean Basin including Iran must be considered as being exceptionally vulnerable regarding climate warming impacts due to the small and isolated alpine and subnival-nival areas and due to the potential of increasing drought stress through climate change (Pauli et al. 2003). These mountains are characterised by a pronounced seasonality of precipitation patterns, with dry summers and precipitation in winter that falls almost exclusively as snow at high elevations. A precondition for the exploration and the assessment of potential affects of climate change but also for the interpretation of future monitoring data, is a thorough assessment of the flora and vegetation. For the Iranian alpine life zone, climate impact studies are completely lacking and vegetation studies are very scarce. Therefore, alpine and subnival vegetation ecology and phytosociological description was one of the core components of my thesis.

Vegetation ecology, the study of the plant cover and its relationships with the environment, is an intricate scientific work, both due to the overwhelming variation of its object of study in space and time, and its complicated interactions with abiotic and biotic factors (van der Maarel 2005). Phytosociology is a part of vegetation science, with focusing on extant, taxonomic plant assemblages at the scale of vegetation stands, and its essential purpose is the definition and functional characterization of vegetation types based on the total floristic composition of stands (Dengler et al. 2008). A consistent large-scale classification of floristically defined vegetation types is an important tool for ecological research, bioindication, vegetation monitoring, conservation strategies and legislation (Dengler et al. 2008).

2 Alpine habitats of Iran

Iran with a total surface area of c. 1.6 km², is mostly a high plateau in the SW Asia. Almost half of the country is structured with high elevations and interior lowlands are surrounded with high mountains including the Alborz Mountains in the north, Zagros Mountains extending from the the northwest to southeast, Azerbaijan Plateau in the northwest, Kopeh-Dagh Mountains in the northeast and Makran Mountains in southeast (Fig. 1).

Alpine habitats are almost above 3000 m a.s.l. and scattered in different parts of country. In these ecosystems, the summer is arid, hot and sunny, with intense radiation most of the time. Both annual and diurnal amplitudes of temperature can be very high, in particular near the soil surface. The high elevations of Alborz are affected by the north-westerly flow of polar air masses, and annual precipitation reaches almost 1000 mm (Khalili 1973).

In total c. 700 vascular plant species are present in the alpine belt of Iranian mountains, where more than 50% are endemic or subendemic to the country (Noroozi et al. 2008). The alpine flora of Iran is mainly of Irano-Turanian origin (Zohary 1973; Klein 1982, 1991; Frey et al. 1999; Noroozi et al. 2008). It exhibits the strongest floristic relationships with Anatolia, Hindu Kush and Caucasus which have 23%, 20% and 19% species in common with the high mountains of Iran, respectively (Noroozi et al. 2008).

The N- and NW-Iran is known as being particularly rich in species including many endemics, but ecological studies on the region's alpine plants are scarce or almost absent in the scientific literature. Phytosociological studies of the alpine zone of Iran were carried out only in Central Alborz, and the syntaxonomic inventory of Iran is still far from being complete. The studies of Bunge (1960), Kotschy (1861a, b), Buhse (1899a, b) and Gilli (1939, 1941) were the initial vegetation surveys on high altitudes of Central Alborz. Klein (1991) published a paper on endemism of alpine flora of Alborz mountains. An overview of the flora and phytogeography of the alpine zone in the Iranian mountains was provided by Noroozi et al. (2008). The most important phytosociological research in the subalpine, alpine and subnival belt which aimed at establishing a syntaxonomic system was carried out by Klein (1982, 1984, 1987, 1988, 1994) and Klein & Lacoste (1994, 1996, 1998, 2001). Noroozi et al. (2010) presented a new classification of the snowbed and thorn-cushion grasslands of the alpine zone of Central Alborz. A synopsis of plant communities and their elevational patterns in the southern slopes of Central Aborz from the low montane to the high alpine zone are presented in Akhani et al. (2013).

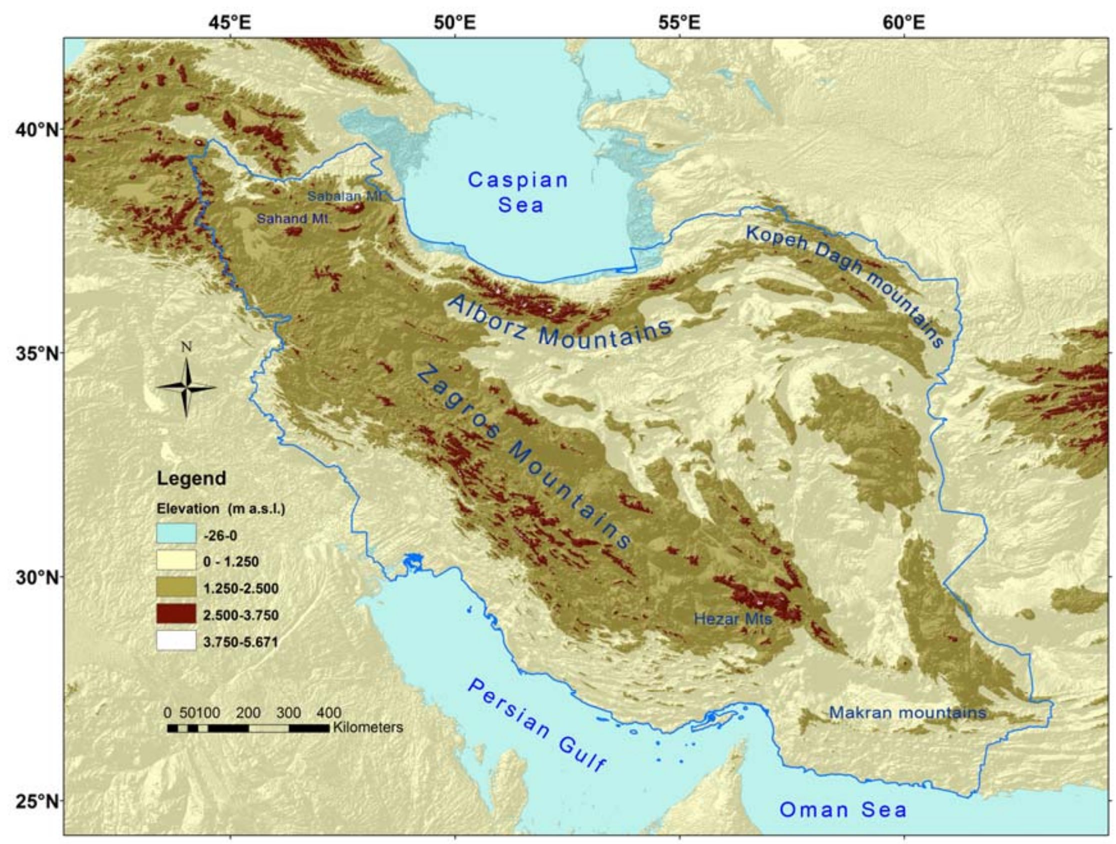

Fig. 1. Mountain ranges of Iran and their altitudinal zonation.

3 Aims of the study

This dissertation thesis focused on the high mountain flora and vegetation of Iran with emphasize on N- (Alborz) and NW-Iran (Sabalan and Sahand), its biodiversity in relation to altitude and to the neighboring mountain systems, and its potential threats through climate warming.

3.1 The research questions

1) How many vascular plant species live in Iran's subnival–nival zone?
2) Are there species being restricted to the subnival–nival zone?
3) What is the relationship between their altitudinal and geographical distribution patterns and are the latter different from species dwelling at lower elevations?
4) Which threats and implications for conservation biology may arise for narrowly distributed cryophilic species?
5) Which major plant community types can be distinguished in high-altitude screes in Central Alborz and the mountains of NW Iran on the basis of their compositional variation, as well as on species' ecological, life-form, and biogeographical characteristics and their habitat preferences?
6) What are the syntaxonomic relationships between these vegetation types at similar habitats of Anatolia, the Caucasus, the Balkan Peninsula and the European Alps?

3.2 Hypotheses

1) Mediterranean high mountains of southern Europe are highly isolated from each other, remained partly ice-free during the Pleistocene and, therefore, show a high rate of endemism, particularly at high elevations (Pauli et al. 2003; Stanisci et al. 2005). Given that the high mountains of Iran share similar geomorphological, glaciation and climatic features, we hypothesize that the majority the vascular plant species in Iranian high mountains are endemics (species restricted to particular mountain ranges or at least to the country) and that their proportion is increasing with elevation.
2) Alpine regions in Iran are scattered over a large area and floristic as well as vegetation studies are largely lacking or only were conducted very sporadically. We, therefore, expect to find new phytogeographic details of known species and probably not yet described species.
3) If the majority of high-altitude species, in fact, are endemics, we hypothesize that plant communities in Iranian mountains belong to different phytosociological units as previously

described communities in similar habitats of the adjacent regions (Anatolia, Caucasus, Balkan and Alps).

4 Results

The result of this thesis is organized into three major chapters:

1) Plant diversity and phytogeography at the upper limit of vascular plants of Iran and potential effect of global warming on these habitats

2) Unknown elements of the subnival-nival flora of Iran

3) Vegetation of the alpine and subnival-nival zones of N and NW Iran

4.1 Chapter 1: Plant diversity and phytogeography at the upper limit of vascular plants of Iran and potential effect of global warming on these habitats

A paper and a book chapter were published for this chapter:

4.1.1 Paper: **Noroozi, J.**, Pauli, H., Grabherr, G. & Breckle, S.W. (2011) The subnival-nival vascular plant species of Iran: a unique high-mountain flora and its threat from climate warming. Biodiversity and Conservation 20: 1319-1338.

This paper provides a first country-wide overview of the vertical distribution patterns and the chorology of vascular plant species that occur in the subnival-nival zone of Iran. After the paper of Noroozi et al. (2008) on alpine habitats of Iran, which represents plant diversity and phyogeography of these ecosystems, it was worthful to focus in detail on phytodiversity of the upper limit of vascular plants which are more cold-adapted and probably more vulnerable to ongoing global warming. In this work we showed how many plant species are living in subnival-nival zone and how many of them are restricted to these habitats. The elevational and geographical distribution patterns of these species were classified and discussed. A total of 151 vascular plant species were identified to occur in the subnival–nival zone of Iran, where 51 of these can be considered as true subnival–nival species. Within the latter, the degree of species endemic to Iran is 68% and clearly decreases to 53 and 20% for species that also occur in the alpine and in the subalpine zones, respectively. The rate of endemism increases very sharply with increasing altitude in Iran. Furthermore, a narrow vertical distribution restricted to high altitudes often corresponds to a constricted geographic range. Vice versa, species with a larger amplitude of their elevational distribution commonly are widespread species. Richness and proportions of endemic species, in fact, were found to be similar to mountains around the Mediterranean Basin, such as the central Apennines (Stanisci et al. 2005), Sierra Nevada (Pauli et al. 2003) or the Atlas mountains (Favarger 1972). The larger alpine areas further north in Europe, such as the Alps, host fewer endemic species, which predominantly occur in the out and lower ranges, where glaciation in the ice ages was weak (Merxmüller 1952; Essl et al. 2011). In the Caucasus mountains the percentage of endemics was reported to be high in the subnival belt (Nakhutsrishvili 1998), but further comparative studies along elevation gradients would be desirable.

In a larger, northern hemisphere view, the outstandingly high degree of high-elevation endemism is not a general feature, but appears to be especially pronounced in the mountain ranges exposed to Mediterranean-type climate west of the Hindu Kush to NW-Africa and SW-Europe. In the large and more connected mountain ranges of the Hindu Kush-Himalaya-Central Asia system endemism is less common. In the Hindu Kush, for example, endemism peaks in the subalpine zone, but species dwelling in the nival zone (above 5000 m) mostly have a wide geographical distribution over the Eurasian mountains and some to the Arctic (Breckle 1974, 2004). Also in most of the large mountain systems of North America, the degree of endemism is rather low (Mills & Schwartz 2005), which seems to be related to the availability of effective migration pathways in these north-south-oriented mountain ranges. The exceptionally high level of high-altitude endemism appears to result mainly from a pronounced current orographic isolation and fragmented cold areas and from the absence of extensive Pleistocene glaciations. The narrow distribution of most of Iran's cold-adapted mountain flora and the low potential of alternative cold habitats render it highly vulnerable to climate change.

4.1.2 Book chapter: **Noroozi, J.** (in press) High mountain regions of Iran (chapter 7.6), in C. Hobohm (editor). Endemism in Vascular Plants. Springer.

In this accepted manuscript the rare and narrow distributed alpine species of Iranian mountains which are known only from one or very few locations are introduced. A total of 110 vascular plant species were considered to be rare and narrow endemic to Iranian alpine habitats. These species were found mainly in Zagros, Alborz, and in the northwestern part of the country. The species were classified according to their geographical distributions. Most of them can be categorized as Endangered (EN) and Critically Endangered (CR) according to IUCN Red List criteria. In this work the relationship of rate of endemism and different habitats in alpine zone is discussed.

4.2. Chapter 2: Unknown elements of the subnival-nival flora of Iran

Due to the low state of research, high-altitude botanical investigations still yield new species for Iran and to science. The following three papers are original descriptions of two new species, and of one species new to Iran, all occurring in the subnival-nival elevation belt of Iran:

4.2.1 Paper 1: **Noroozi, J**., Ajani, Y., Nordenstam, B. (2010) A new annual species of *Senecio* (Compositae- Senecioneae) from subnival zone of southern Iran with comments on phytogeographical aspects of the area. Compositae News Letter 48: 43-62.

In this paper, *Senecio subnivalis* was described as a new species for science from the subnival zone of Hezar mountain (southern Iran). The accompanying species of the new species and some ecological features of its habitat were presented. Moreover, the phytogeographical aspects of the Hezar-Lalehzar Mts. in high elevations were discussed and different distribution patterns of the species were presented.

4.2.2 Paper 2: Ajani, Y., **Noroozi, J.** & Levichev, I.G. (2010) *Gagea alexii* (Liliaceae), a new record from subnival zone of southern Iran with key and notes on sect. *Incrustatae*. Pakistan Journal of Botany 42: 67-77.

In this paper, *Gagea alexii* was recorded for the first time for Iran from subnival zone of Hezar Mt., exactly in the habitat of *Senecio subnivalis.* It has a very long disjunct distribution from Central Asia and northern Hindu Kush mountains, with a large gap to the isolated occurrence in southern Iran. This seems to be the result of post-glacial global warming. The occurrence of this species in the subnival zone of the high mountains of south Iran is a further evidence of the close floristic affinity of the southeastern Zagros with the Hindu Kush and Central Asia, especially at high altitudes. In this paper the taxonomic problems of the genus *Gagea* in Iran is also discussed.

4.2.3 Paper 3: **Noroozi, J**., Ajani, Y. (2013) A new alpine species of *Nepeta* sect. *Capituliferae* (Labiatae) from Northwestern Iran. Novon 22: 297–303.

In this paper *Nepeta sahandica* was described and illustrated from the high elevations of the Sahand Mountains in northwestern Iran. Morphological differences of this species from its closest relatives were discussed. The new species is restricted to the subnival vegetation zone, associated with unstable scree grounds. The associated species of *Nepeta sahandica* and ecological aspects of its habitat were presented in a phytosociological table. This species was classified as Critically Endangered (CR), based on IUCN Red List criteria.

4.3 Chapter 3: Vegetation of the alpine and subnival-nival zones of N and NW Iran

One paper, representing one of the core publications of the thesis, was published for this chapter:

4.3.1 Paper: **Noroozi, J.**, Willner, W., Pauli, H. & Grabherr, G. (2013) Phytosociology and ecology of the high alpine to subnival scree vegetation of N and NW Iran (Alborz and Azerbaijan Mts.). Applied Vegetation Science DOI: 10.1111/avsc.12031.

As discussed in Noroozi et al. (2010), the phytosociological classification of Klein (1982, 1987, 1988) and Klein & Lacoste (2001) from alpine and subnival zones of Iran are not convincing and need to be revised. The paper of Noroozi et al. (2010) mainly focused on the ecology and phytosociology of snowbed and thorn-cushion grassland vegetation types of alpine zone of Central Alborz and described and classified different plant communities. It was a later addition to the master thesis of the author, but major parts of analyses and the writing process were carried out during the PhD thesis in Vienna. After this paper, the priority focus for vegetation analysis was on scree vegetation types of alpine and subnival-nival zones of the study area. A total of 141 phytosociological relevés from 3200 up to 4800 m a.s.l. of Alborz and Azerbaijan mountains have been collected and used in this paper including 14 relevés of Klein & Lacoste (2001) from similar habitats of Central Alborz. This data set was classified using the TWINSPAN algorithm, and the numerical classification was translated into a syntaxonomic system. In this work, we described one class (*Didymophyso aucheri-Dracocephaletea aucheri*), two orders (*Physoptychio gnaphalodis-Brometalia tomentosi, Didymophysetalia aucheri*), three alliances (*Elymo longearistati-Astragalion macrosemii, Erigerontion venusti, Didymophysion aucheri*) and 10 associations. The ecological characters of the all communities were presented and the geographical territory of them discussed. The territory of this class, which is the first valid phytosociological class of the high elevations of Iran, extends from Alborz to NW Iran and probably to E Anatolia, Transcaucasia and to the Zagros mountains. A synoptic table of the most important alliances of scree vegetation in the European Alps, the Balkan Peninsula, the Caucasus, Anatolia, as well as the alliances described in the present paper was prepared to show the floristic and syntaxonomic relationship of these regions.

References

Agakhanjanz, O. & Breckle S-W. (1995) Origin and evolution of the mountain flora in middle Asia and neighboring mountain regions. In: Chapin III FS, Körner C (eds) *Arctic and alpine biodiversity: patterns, causes and ecosystem consequences,* pp. 63–80. Ecological Studies 113, Springer, Berlin, DE.

Akhani, H., Mahdavi, P., Noroozi, J. & Zarrinpour, V. (2013) Vegetation pattern of Irano-Turanian steppes along a 3000 m altitudinal gradient in the Alborz Moutains (Iran). *Folia Geobotanica* 48: 229-255.

Breckle, S-W. (1974) Notes on Alpine and Nival Flora of the Hindu Kush, East Afghanistan. *Botaniska Notiser* (Lund) 127:278–284.

Breckle, S-W. (2004) Flora, Vegetation und Ökologie der alpin–nivalen Stufe des Hindukusch (Afghanistan). In: Breckle, S-W., Schweizer, B. & Fangmeier, A. (eds) *Proceedings of 2nd symposium AFW Schimperfoundation: results of worldwide ecological studies.* Stuttgart-Hohenheim, p 97.

Britton, A.J., Beale, C.M., Towers W. & Hewison R.L. (2009) Biodiversity gains and losses: Evidence for homogenisation of Scottish alpine vegetation. *Biological Conservation* 142: 1728-1739.

Buhse, F. (1899a) Flora des Alburs und der Kaspischen Südküste. Bisherige Forschungsergebnisse aus diesem Gebiet. *Arbeiten des Naturforscher-Vereins zu Riga*. *Neue Folge.* 8. Heft.

Buhse, F. (1899b) Reisebemerkungen aus dem östlichen Albursgebirge in Persien. *Bulletin de la Société Impériale des Naturalistes de Moscou* 34: 363-383.

Bunge, A. (1860) Die Russische Expedition nach Chorassan in den Jahren 1858 und 1859. *Petermanns Geographische Mitteilungen* 6: 205–226.

Dengler, J., Chytrý, M. & Ewald, J. (2008) Phytosociology. In: Jørgensen, S. E. & Fath, B. D. (eds.) *Encyclopedia of ecology*, pp. 2767–2779. Elsevier, Oxford, UK.

Erschbamer, B., Kiebacher, T., Mallaun, M. & Unterluggauer, P. (2009) Short-term signals of climate change along an altitudinal gradient in the South Alps. *Plant Ecology* 202: 79-89.

Essl, F., Dullinger, S., Plutzar, C, Willner, W. & Rabitsch, W. (2011) Imprints of glacial history and current environment on correlations between endemic plant and invertebrate species richness. *Journal of Biogeography* 38: 604–614.

Favarger, C. (1972) Endemism in the montane floras of Europe. In: Valentine DH (ed) *Taxonomy, phytogeography and evolution.* Academic Press, London, pp 191–204.

Frey,W., Kürschner, H. & Probst, W. (1999) Flora and vegetation, including plant species and larger vegetation complexes in Persia. In: Yarshater, E. (ed.) *Encyclopaedia Iranica* 10(1), pp. 43–63. Mazda Publishers, Costa Mesa, CA, US.

Gilli, A. (1939) Die Pflanzengesellschaften der Hochregion des Elbursgebirges in Nordiran. *Beiheft des Botanischen Centralblatts* 59: 317-344.

Gilli, A. (1941) Ein Beitrag zur Flora des Elburs-Gebirges in Nord-Iran. *Feddes Repertorium Specierum Novarum Regni Vegetabilis* 50: 263-283.

Gottfried, M., Pauli, H., Futschik, A., Akhalkatsi, M., Barancok, P., Benito Alonso, J. L., Coldea, G., Dick, J., Erschbamer, B., Fernández Calzado, M. R., Kazakis, G., Krajci,J., Larsson, P., Mallaun, M., Michelsen, O., Moiseev, D., Moiseev, P., Molau, U., Merzouki, A., Nagy, L., Nakhutsrishvili, G., Pedersen, B., Pelino, G., Puscas, M., Rossi, G., Stanisci, A., Theurillat, J.-P., Thomaselli, M., Villar, L., Vittoz, P., Vogiatzakis, I. & Grabherr, G. (2012) Continent-wide response of mountain vegetation to climate change. *Nature climate change* 2: 111-115.

Grabherr, G., Gottfried, M. & Pauli, H., (1994) climate effects on mountain plants. *Nature* 369: 448-448.

Grabherr, G., Gottfried, M. & Pauli, H. (2001) Long-term monitoring of mountain peaks in the Alps. In: Burga, C.A., & Kratochwil, A. (eds.) *Biomonitoring: General and Applied Aspects on Regional and Global Scales,* Vol 35, pp 153-177. Tasks for Vegetation Science, Kluwer, Dordrecht.

Holzinger, B., Hülber, K., Camenisch, M. & Grabherr, G. (2008) Changes in plant species richness over the last century in the eastern Swiss Alps: elevational gradient, bedrock effects and migration rates. *Plant Ecology* 195:179–196.

Khalili, A. (1973) Precipitation patterns of Central Elburz. *Archiv für Meteorologie, Geophysik und Bioklimatologie, Serie* B 21: 215–232.

Klanderud, K. & Birks, H.J.B. (2003) Recent increases in species richness and shifts in altitudinal distributions of Norwegian mountain plants. *The Holocene* 13: 1-6.

Klanderud, K, Totland, Ø (2005) Simulated climate change altered dominance hierarchies and diversity of an alpine biodiversity hotspot. *Ecology* 86: 2047–2054.

Klein, J.C. (1982) Les groupements chionophiles de l'Alborz central (Iran). Comparaison avec leurs homologues d' Asie centrale. *Phytocoenologia* 10: 463–486.

– (1984) Les groupements végétaux d'altitude de l'Alborz central (Iran). – Ecologie des milieux montagnards et de haute altitude. *Documents d'Ecologie Pyrénéenne* 3–5: 199–204.

– (1987) Les pelouses xérophiles d'altitude du flanc sud de l'Alborz central (Iran). *Phytocoenologia* 15: 253–280.

– (1988) Les groupements à grandes ombellifères et à xérophytes orophiles: Essai de synthèse à l'échelle de la région irano-touranienne. *Phytocoenologia* 16: 1–36.

– (1991) Endémisme à l'étage alpin de l'Alborz (Iran). *Flora et Vegetatio Mundi* 9: 247–261.

– (1994) *La végétation altitudinale de L'Alborz central (Iran).* Institut Français de Recherche en Iran (Téhéran).

Klein, J.C. & Lacoste, A. (1994) Les pelouses subalpines (Alchemilletum plicatissimae ass. nov.) de l'Alborz central (Iran): ultime avancée sud-orientale de l'aire des Festuco-Brometea Br.-Bl. et Tx. 1943. *Phytocoenologia* 24: 401–421.

– (1996) Aperçu synthétique sur l'étagement de végétation dans l'Alborz central (Iran). *Annalen des Naturhistorischen Museums in Wien* 98: 67–74.

– (1998) L'étagement de végétation dans le massif de l'Alborz central (Iran): essai de comparison avec celui du systéme alpin et des montagnes méditerranéennes. *Ecologie* 29: 181–186.

– (2001) Observation sur la végétation des éboulis dans les massifs irano-touraniens: le Galietum aucheri ass. nov. de l'Alborz central (N-Iran). *Documents Phytosociologiques N. S.* 19: 219-228.

Kotschy, T. (1861a) Die Vegetation des westlichen Elbrus in Nordpersien. *Österreichische Botanische Zeitschrift* 11: 105-117.

Kotschy, T. (1861b) Der westliche Elbrus bei Teheran. *Mitteilungen der Kaiserlich-Königlichen Oestereichischen Geographischen Gesellschaft Wien* 5: 65–110.

Körner, Ch. (1995) Alpine plant diversity: a global survey and functional interpretations. In: Chapin FS III, Körner Ch (eds.) *Arctic and alpine biodiversity: Patterns, causes and ecosystem consequences,* pp. 45-62. Springer Ecol Studies 113, Berlin, Heidelberg, New York.

Körner, Ch. (2003) *Alpine Plant Life. Functional Plant Ecology of High Mountain Ecosystem.* Springer, Berlin.

Körner, Ch., & Spehn E.M. (eds.) (2002) *Mountain biodiversity. A global assessment*. Parthenon, Boca Raton.

Merxmüller, H. (1952) Untersuchungen zur Sippengliederung und Arealbildung in den Alpen, Teil I. *Jahrb Ver Schutze Alpenpflanzen Tiere* 17:96–133.

Mills, M-H., Schwartz, M-W. (2005) Rare plants at the extremes of distribution: broadly and narrowly distributed rare species. *Biodiversity and Conservation* 14: 1401–1420.

Moiseev, P.A. & Shiyatov S.G. (2003) Vegetation dynamics at the treeline ecotone in the Ural highlands, Russia. In: Nagy, L., Grabherr, G., Körner, C. & Thompson D.B.A. (eds.) *Alpine biodiversity in Europe – A Europe-wide assessment of biological richness and change,* pp 423-435. Springer, Berlin, DE.

Nakhutsrishvili, G. (1998) The vegetation of the subnival belt of the Caucasus Mountains. *Arctic and and Antarctic Alpine Research* 30: 222–226.

Noroozi, J., Akhani, H. & Breckle, S.W. (2008) Biodiversity and phytogeography of the alpine flora of Iran. *Biodiversity and Conservation* 17: 493-521.

Noroozi, J., Akhani, H. & Willner, W. (2010) Phytosociological and ecological study of the high alpine vegetation of Tuchal Mountains (Central Alborz, Iran). *Phytocoenologia* 40: 293-321.

Nagy, L, Grabherr, G. (2009) *The biology of alpine habitats*. Oxford University Press, New York.

Packer, J.G. (1974) Differentiation and dispersal in alpine floras. *Arctic and and Antarctic Alpine Research* 6: 117-128.

Parolo, G. & Rossi, G. (2008) Upward migration of vascular plants following a climate warming trend in the Alps. *Basic Applied Ecology* 9: 100–107.

Pauli, H., Gottfried, M. & Grabherr, G. (1996) Effects of climate change on mountain ecosystems - upward shifting of alpine plants. *World Resource Review* 8: 382-390.

Pauli, H., Gottfried, M., Dirnböck, T., Dullinger, S. & Grabherr, G. (2003). Assessing the long-term dynamics of endemic plants at summit habitats. In: Nagy, L., Grabherr, G., Körner, C. & Thompson D.B.A. (eds.) *Alpine biodiversity in Europe – A Europe-wide assessment of biological richness and change,* pp. 195-207. Springer, Berlin, DE.

Pauli, H., Gottfried, M., Reiter, K., Klettner, C. & Grabherr, G. (2007) Signals of range expansions and contractions of vascular plants in the high Alps: observations (1994-2004) at the GLORIA* master site Schrankogel, Tyrol, Austria. *Global Change Biology* 13: 147-156.

Pauli, H., Gottfried, M., Dullinger, S., Abdaladze, O., Akhalkatsi, M., Benito Alonso, J.L., Coldea, G., Dick, J., Erschbamer, B., Fernández Calzado, R., Ghosn, D., Holten, J.I., Kanka, R., Kazakis, G., Kollár, J., Larsson, P., Moiseev, P., Moiseev, D., Molau, U., Molero Mesa, J., Nagy, L., Pelino, G., Puşcaş, M., Rossi, G., Stanisci, A., Syverhuset, A.O., Theurillat, J.-P., Tomaselli, M., Unterluggauer, P., Villar, L., Vittoz, P. & Grabherr, G. (2012) Recent plant diversity changes on Europe's mountain summits. *Science* 336: 353-355.

Stanisci, A., Pelino, G. & Blasi, C. (2005) Vascular plant diversity and climate change in the alpine belt of the central Apennines (Italy). *Biodiversity and Conservation* 14: 1301–1318.

Sturm, M., Racine, C. & Tape, K. (2001) Climate change – increasing shrub abundance in the Arctic. *Nature* 411: 546-547.

van der Maarel, E. (ed.) (2005) *Vegetation ecology*. Oxford, Blackwell, UK.

Vittoz, P., Bodin, J., Ungricht, S., Burga, C. & Walther, G.R. (2008) One century of vegetation change on Isla Persa, a nunatak in the Bernina massif in the Swiss Alps. *Journal Vegetation Science* 19: 671-680.

Walther, G-R., Beißner, S. & Burga, C.A. (2005a) Trends in the upward shift of alpine plants. *Journal Vegetation Science* 16: 541–548.

Walther, G-R., Berger, S. & Sykes, M.T. (2005b) An ecological 'footprint' of climate change. *Proceedings of the Royal Society of London,* B 272: 1427–1432.

Zohary, M. (1973) *Geobotanical foundations of the Middle East*, vol 2. Fischer, Stuttgart.

Chapter 1:

Plant diversity and phytogeography at the upper limit of vascular plants of Iran and potential effect of global warming on these habitats

A paper and a book chapter were published regarding to this subject:

Paper: The subnival-nival vascular plant species of Iran: a unique high-mountain flora and its threat from climate warming

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ORIGINAL PAPER

The subnival–nival vascular plant species of Iran: a unique high-mountain flora and its threat from climate warming

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Abstract This study provides a first country-wide overview of the vertical distribution patterns and the chorology of vascular plant species that occur in the uppermost elevation zones in Iran. The current distribution patterns are discussed with respect to potential warming-induced species losses. Iran's subnival and nival vegetation zones are found at elevations above 3600–3900 m in a highly fragmented distribution across Alborz, Zagros, and NW-Iran. Based on literature research and on field observations, all vascular plant species living in the subnival–nival zone of Iranian mountains were identified (151 species) and classified into three altitudinal groups: Group A comprises species that occur mainly in subnival–nival habitats (51 species). Group B are species being common in subnival–nival areas but are equally present in the alpine zone (56 species). Group C are species that can reach to subnival areas but also grow in alpine, subalpine and sometimes lower altitudes (44 species). The chorological patterns differ among the three groups. The percentage of species being endemic to Iran decreases from group A, to B and C, with 68, 53 and 20%, respectively. A narrow altitudinal distribution at high elevations is clearly related to a small-scaled geographical distribution range. The outstanding rate of high-altitude endemism appears to result mainly from orographic isolation of the country's highly scattered cold areas and by the absence of extensive Pleistocene glaciations. The narrow distribution of most of Iran's cold-adapted mountain flora and the low potential of alternative cold habitats render it highly vulnerable to climate change.

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Keywords Altitudinal distribution · Climate change · Endemism · High mountains · Phytogeography · Subnival–nival zone · Vascular plants

Introduction

Only the highest mountain peaks of Iran exceed the elevational limits of vascular plant life: Damavand (5671 m), Alamkuh (4850 m), both in the Alborz mountains and Sabalan (4811 m) in the NW of the country. The uppermost zones where vascular plants occur are the subnival and nival vegetation zones. The subnival zone is the transition zone between the alpine grassland and tragacanth heath and the scanty, patchy vegetation of the nival zone (also termed as the alpine–nival ecotone; Nagy and Grabherr 2009). The subnival–nival zone above the alpine zone has a highly scattered distribution over the major mountain systems of Iran. Its flora and vegetation is less known in comparison to that of lower altitudes. Initial vegetation survey on Central Alborz that at least marginally included subnival areas dates back to Kotschy (1861a, b), Buhse (1899a, b) and Gilli (1939, 1941). Further studies on the subnival–nival vegetation of the Central Alborz were published by Klein (1982) and Klein and Lacoste (1999), who made 31 phytosociological relevés in subnival to nival areas above 3900 m up to 4350 m. Due to the low state of research, high-altitude botanical investigation still yield new species for Iran and to science. For example, *Senecio subnivalis* was described most recently from Hezar–Lalehzar Mts. at 4443 m a.s.l. (Noroozi et al. 2010a). In the same place *Gagea alexii* was first recorded for Iran (Ajani et al. 2010).

In this study we attempt to answer the following questions: (1) how many vascular plant species live in Iran's subnival–nival zone?; (2) what is the relationship between their altitudinal and geographical distribution patterns?; (3) are there species being restricted to the subnival–nival zone? (4) Which threats and implications for conservation biology may arise for narrowly distributed cryophilic species?

Methods

Study area

Iran is a mountainous country in Southwest-Asia covering an area of 1.6 million km^2. The Alborz in the north and Zagros from northwest to southeast are the major mountain ranges of Iran. The elevation extends from −26 m a.s.l. on the shore of the Caspian Sea to 5671 m a.s.l. at the highest peak of Alborz (Damavand). The high mountains of Iran exhibit a continental climate with Mediterranean precipitation regime. The growing season is arid and exposed to intensive radiation and strong winds are common. Both annual and diurnal amplitudes of temperature can be high, on the soil surface in particular (Noroozi et al. 2008, 2010b). There are some active glaciers in both Alborz and Zagros mountain ranges (Ferrigno 1991).

Subnival and nival zones have a fragmental and highly scattered distribution over the mountain systems of Alborz, NW-Iran and Zagros. The largest subnival–nival areas are concentrated in Central Alborz with more than 50 mountain peaks exceeding 4000 m. Sabalan and Sahand mountains in the northwest of the country, Zardkuh and Oshtorankuh in Central Zagros and Dena and Hezar–Lalehzar mountains in south and southeastern Zagros are other important mountains which embrace isolated subnival to nival areas (Fig. 1).

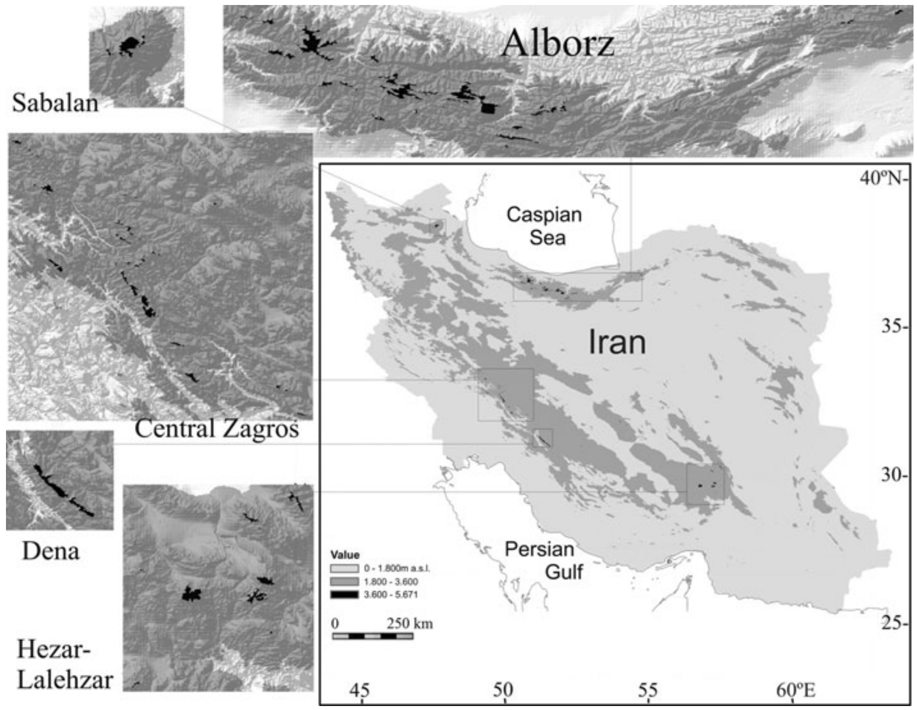

Fig. 1 The mountain areas of Iran (*grey*) and the distribution of the subnival-nival zone (*black* patches)

Vertical species ranges

The documentation of species that reach subnival–nival areas and the characterization of their altitudinal ranges are based on literature, Flora Iranica in particular (Rechinger 1963–2010), and our own field survey. Previous phytosociological survey from Central Alborz (Klein 1982; Klein and Lacoste 1999) includes data on the region's subnival–nival flora. Our botanical surveys were carried out at different mountains of Central Alborz (Tuchal, 3966 m; Alamkuh, 4850 m; Damavand, 5671 m), Azarbayjan mountains in NW-Iran (Sahand, 3707 m; Sabalan, 4811 m), and southeastern Zagros (Hezar Mts., 4465 m). In these mountains we were determining the lower limit of the subnival–nival zone by exploring vegetation patterns and species composition. The subnival–nival zone in Central Alborz, where plants still occur, ranges approximately from 3900 to 4800 m, in NW-Iran approximately from 3600 m to 4400 m, and in Hezar–Lalehzar mountains it commences at approximately 4200 m. In Central Zagros the lower limit of the subnival–nival zone is similar to that of Central Alborz.

Using the above altitudinal limits, we grouped all species that occur within the subnival–nival zone according to their vertical distribution patterns: Group A comprises the predominantly subnival–nival species, group B subnival–nival to alpine species, and group C those with a wider vertical distribution from subnival to subalpine areas. The grouping is on the species level. Different subspecies, e.g., of *Asperula glomerata*, range differently through subalpine to nival zones. In these cases we put the species to group C. Some species, such as *Arenaria balansae,* are restricted to subnival–nival environments in Iranian mountains but in other regions such as Anatolia are common in alpine areas. In these cases we put these species in group A. Biogeographic relationships of the species of groups A, B and C are calculated separately to understand the relationship between vertical and geographical distributions. Distribution maps of all species of group A (except *Luzula spicata*) are given.

The nomenclature and chorology of species is mainly based on Flora Iranica (Rechinger 1963–2010), and also on Flora of Turkey (Davis 1965–1988), Flora of Caucasus (Grossheim 1945–1967), Flora of China (http://www.efloras.org/flora_page.aspx?flora_id=2) and the Flora of Pakistan (http://www.efloras.org/flora_page.aspx?flora_id=5). Endemics are defined as species that are restricted to Iran, including cases having their main distribution within the country, but may extend into neighbor countries for a distance of up to c. 30 km.

Results

Altitudinal distribution

A total of 151 vascular plant species, belonging to 27 families and 80 genera, was found to occur within the subnival–nival zone of Iran. This is around 22% of the alpine to nival flora and 2% of the entire flora of Iran. Plant families and genera with the largest number of species and the proportional share of the main life forms of all 151 species are shown in Table 1.

The species could be divided into three groups of different vertical distribution patterns (Fig. 2, Table 2). Group A consists of 51 true subnival–nival species, being centred within this uppermost zone, but some species may extend downwards into the upper part of the alpine zone. Group B comprises 56 species being equally distributed across the alpine and the subnival–nival zones. Group C comprises 44 subalpine to alpine species that can extend into subnival areas.

Upper climatically determined altitudinal limits of vascular plant life in Iran are reached only in Central Alborz on Damavand (5671 m) and Alamkuh (4850 m), and in the NW of the country on Sabalan (4811 m), the three highest mountain peaks in Iran. In the SE-Zagros range the climatic potential for the upper limit of vascular plant species is estimated to be at around 5000 m, but the highest summit (Hezar mountain) only reaches 4465 m. The altitudinal maximum for flowering plants in Iran according to previous records was

Table 1 The richest plant families and genera and the life forms in the subnival–nival zone of Iran

Families	No. species	Genera	No. species	Life forms	%
Asteraceae	29	*Astragalus*	8	Hemicryptophyte	70
Caryophyllaceae	15	*Potentilla*	8	Graminoid	10
Fabaceae	14	*Silene*	5	Non-cushion chamaephyte	9
Brassicaceae	12	*Oxytropis*	5	Cushion chamaephyte	4
Lamiaceae	12	*Veronica*	5	Geophyte	4
Poaceae	11	*Draba*	4	Annual	3
Scrophulariaceae	9	*Nepeta*	4		
Rosaceae	8	*Senecio*	4		
Apiaceae	6				

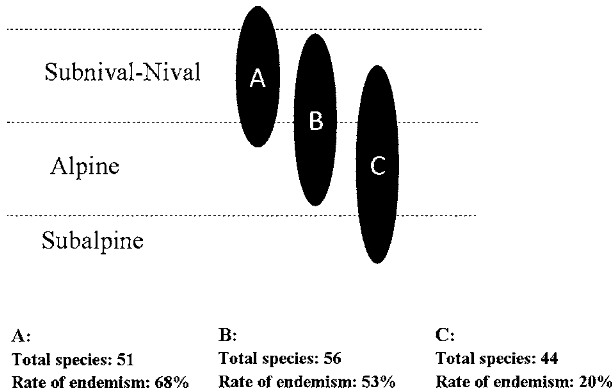

Fig. 2 Vertical distribution groups of vascular plant species that occur in the subnival–nival zone of Iran, and their percentage endemism to Iran

4800 m (Noroozi et al. 2008). Table 3 shows the species growing in the highest altitudes in Iran and their updated uppermost occurrences. The highest plant community was observed at 4460 m on Damavand; above this elevation, vascular plants only occur as scattered, isolated individuals with low frequency and cover in fragmentary colonies.

Phytogeography

Iran extends over three phytogeographical regions, the Irano–Turanian, Euro–Siberian and the Saharo–Arabian (sensu Zohary 1973) or Sudano–Zambezian (sensu Takhtajan 1986). The alpine area of Iran belongs to the Irano–Turanian region, where the rate of endemism is generally high (Klein 1982, 1991; Noroozi et al. 2008, 2010a, b). Figure 3 illustrates the floristic relationship of the three altitudinal species groups with mountainous regions outside of Iran and in a global context and Fig. 4 shows the chorological spectra of species with the degree of local endemism. The vertical distribution of species is related to the geographical distribution patterns. The rate of endemism is highest in the true subnival–nival species of group A (68%). Most of the species of group C are widely distributed and the endemism rate is low (20%). Group B takes an intermediate position. Most of endemics are restricted to Central Alborz and Central Zagros.

Nine groups of different distribution patterns can be distinguished for the true subnival–nival species (group A):

(1) Holarctic distribution: *Luzula spicata* is the only species being widespread across the northern hemisphere in most alpine and arctic areas (see distribution map in Meusel et al. 1964, p. 88). In Iran this species is only known from Sabalan at 3800 m (Snogerup 1971). Species with similar distribution, but from group B, are *Erigeron uniflorus* (Meusel et al. 1992, p. 457) and *Oxyria digyna* (Meusel et al. 1964, p. 129).

(2) Irano–Turanian to Euro–Siberian distribution: *Draba siliquosa* (Fig. 5a) and *Alopecurus himalaicus* (Fig. 5b). Within Iran, both are restricted to very small areas at high elevations. *Draba siliquosa* reaches its easternmost limit of distribution in Iran and *Alopecurus himalaicus* has a highly disjunct distribution.
Species with similar distribution in group B is *Koeleria eriostachya.*

(3) Hindu Kush–Himalaya system and Central Asian elements with disjunct distribution in Iran: *Carex melanantha* (Fig. 6a), *Kobresia schoenoides* (Fig. 6b), *K. humilis*

Table 2 Species known to occur within the subnival–nival zone of the mountains of Iran

Family	Species	Life form	Altitudinal group	Chorotype
Alliaceae	*Allium capitellatum*	Ge	B	En(Iran)
Apiaceae	*Carum caucasicum*	He	B	Cau-Atro
	Chaerophyllum nivale	He	A	LEn(Zagos)
	Chamaesciadium acaule	He	C	Cau-Atro
	Heracleum anisactis	He	B	LEn(Alboz)
	Semenovia dichotoma	He	A	En(Zagos)
	Trachydium depressum	He	B	FI
Asteraceae	*Achillea aucheri*	NC	A	En(Atro)
	Artemisia melanolepis	He	A	En(Atro)
	Artemisia persica	NC	C	IT
	Cousinia eburnea	He	A	LEn(Zagros)
	Cousinia fragilis	He	A	LEn(Zagros)
	Cousinia lasiolepis	NC	C	FI
	Crepis heterotricha	He	B	En(Iran)
	Crepis multicaulis	He	C	Hol
	Erigeron caucasicus	He	C	Cau-Atro
	Erigeron hyrcanicus	He	B	En(Alborz)
	Erigeron uniflorus	He	B	Hol
	Iranecio oligolepis	He	A	LEn(Alborz)
	Jurinella frigida	He	B	En(Alborz)
	Myopordon damavandica	He	A	LEn(Alborz)
	Myopordon persicum	He	A	LEn(Zagros)
	Psychrogeton alexeenkoi	He	B	IT
	Psychrogeton amorphoglossus	He	C	IT
	Psychrogeton chionophilus	He	A	LEn(Zagros)
	Scorzonera radicosa	He	B	Ana-Atro
	Senecio iranicus	An	A	LEn(Alborz)
	Senecio subnivalis	An	A	LEn(Zagros)
	Senecio taraxacifolius	He	A	Cau-NWIran
	Senecio vulcanicus	He	B	En(Alborz)
	Tanacetum kotschyi	NC	C	Ana-Cau-Iran
	Tanacetum pamiricum	NC	A	IT
	Taraxacum baltistanicum	He	A	IT
	Taraxacum crepidiforme	He	B	(Cau)IT
	Taraxacum primigenium	He	B	En(Zagros)
	Tripleurospermum caucasicum	He	C	ES(NWIran)
Boraginaceae	*Lepechiniella persica*	He	A	En(Alborz)
	Myosotis asiatica	He	C	Hol
	Myosotis olympica	He	B	En(Atro)
Brassicaceae	*Aethionema trinervium*	He	C	IT
	Aethionema umbellatum	He	A	LEn(Zagros)
	Arabis caucasica	He	C	ES-IT
	Clastopus vestitus	He	B	En(Atro)

Table 2 continued

Family	Species	Life form	Altitudinal group	Chorotype
	Didymophysa aucheri	He	A	Cau-Iran
	Draba aucheri	He	B	Ir-CAsia
	Draba bruniifolia	He	A	Ana-Cau-NWIran
	Draba pulchella	He	B	SEn(Atro)
	Draba siliquosa	He	A	IT-ES
	Erysimum caespitosum	He	C	Ana-Iran
	Erysimum elbrusense	He	A	En(Atro)
	Graellsia saxifragifolia	He	C	FI
Campanulaceae	*Campanula karakuschensis*	He	A	Atro
Caryophylaceae	*Arenaria minutissima*	NC	B	LEn(Zagros)
	Arenaria balansae	NC	A	Ana-Zagros
	Arenaria insignis	CC	C	FI
	Cerastium cerastioides	He	C	Hol
	Cerastium purpurascens	He	A	Ana-Cau-Atro
	Dianthus erythrocoleus	NC	B	Atro
	Herniaria caucasica	He	C	Ana-Cau-Atro
	Minuartia aizoides	CC	B	NAna-Cau-NWIran
	Minuartia lineata	CC	C	SEn(Atro)
	Minuartia recurva	He	C	ES-IT
	Silene daënensis	He	A	En(Zagros)
	Silene nurensis	CC	B	En(Zagros)
	Silene odontopetala	He	C	IT
	Silene persica	He	B	En(Zagros)
	Silene tragacantha	He	A	LEn(Zagros)
Chenopodiaceae	*Chenopodium foliosum*	An	C	PL
Crassulaceae	*Sedum tenellum*	An	B	Cau-Atro
	Sedum kotschyanum	He	B	En(Zagros)
Cyperaceae	*Carex melanantha*	Gr	A	IT
	Kobresia humilis	Gr	A	IT
	Kobresia schoenoides	Gr	A	(Cau)IT
Euphorbiaceae	*Euphorbia aucheri*	He	C	FI
	Euphorbia cheiradenia	He	C	En(Iran)
Fabaceae	*Astragalus atricapillus*	He	A	En(Alborz)
	Astragalus capito	He	B	En(Alborz)
	Astragalus macrosemius	CC	B	En(Alborz)
	Astragalus melanocalyx	He	A	LEn(Zagros)
	Astragalus melanodon	He	C	En(Zagros)
	Astragalus montis-varvashti	He	B	LEn(Alborz)
	Astragalus tenuiscapus	He	C	En(Zagros)
	Astragalus zerdanus	He	B	En(Zagros)
	Cicer stapfianum	He	A	LEn(Zagros)

Table 2 continued

Family	Species	Life form	Altitudinal group	Chorotype
	Oxytropis immersa	He	B	IT
	Oxytropis kermanica	He	A	En(Iran)
	Oxytropis persica	He	B	SEn(Atro)
	Oxytropis savellanica	He	B	IT
	Oxytropis takhti-soleimanii	He	A	LEn(Alborz)
Gentianaceae	*Gentiana pontica*	He	B	EAna-Cau-Alborz
Juncaceae	*Luzula spicata*	Gr	A	Hol
Lamiaceae	*Betonica nivea*	He	B	ES-IT
	Dracocephalum aucheri	NC	A	SEn(Atro)
	Dracocephalum surmandinum	NC	A	LEn(Zagros)
	Lamium tomentosum	He	A	Cau-Atro
	Nepeta allotria	He	B	LEn(Alborz)
	Nepeta archibaldii	He	A	LEn(Zagros)
	Nepeta crispa	He	B	En(Iran)
	Nepeta lasiocephala	He	B	LEn(Zagros)
	Scutellaria glechomoides	He	A	LEn(Alborz)
	Stachys obtusicrena	He	B	En(Zagros)
	Thymus pubescens	NC	C	Atro
	Ziziphora clinopodioides	NC	C	IT
Liliaceae	*Gagea alexii*	Ge	A	FI
	Gagea caroli-kochi	Ge	B	Atro
	Gagea soleimani	Ge	C	En(Atro)
Plantaginaceae	*Plantago atrata*	He	C	ES-IT
Plumbaginaceae	*Acantholimon demawendicum*	CC	B	En(Alborz)
	Acantholimun haesarense	CC	A	LEn(Zagros)
Poaceae	*Alopecurus dasyanthus*	Gr	B	Ana-Cau-NWIran
	Alopecurus himalaicus	Gr	A	ES-IT
	Alopecurus textilis	Gr	C	IT
	Bromus frigidus	Gr	A	En(Zagros)
	Bromus tomentosus	Gr	C	(Cau)IT
	Catabrosella parviflora	Gr	C	(Cau)IT
	Festuca alaica	Gr	C	FI
	Koeleria eriostachya	Gr	B	ES(NWIran)
	Poa alpina	Gr	B	Hol
	Poa araratica	Gr	C	(Cau)IT
	Stipa hohenackeriana	Gr	C	IT
Polygonaceae	*Oxyria digyna*	He	B	Hol
	Polygonum serpyllaceum	He	B	FI
Primulaceae	*Androsace villosa*	He	B	ES-IT
	Primula algida	He	B	(Cau)IT

Table 2 continued

Family	Species	Life form	Altitudinal group	Chorotype
Ranunculaceae	*Paraquilegia caespitosa*	He	A	En(Alborz)
	Ranunculus crymophilus	He	B	SEn(Atro)
	Ranunculus eriorrhizus	He	B	En(Zagros)
Rosaceae	*Potentilla argaea*	He	B	Ana-Cau-NWIran
	Potentilla argyroloma	He	B	En(Iran)
	Potentilla aucheriana	He	B	SEn(Atro)
	Potentilla gelida	He	B	ES-IT
	Potentilla hololeuca	He	B	Iran-CAsia
	Potentilla nuda	He	C	En(Iran)
	Potentilla polyschista	He	A	SEn(Atro)
	Potentilla porphyrantha	He	A	SEn(Atro)
Rubiaceae	*Asperula glomerata*	NC	C	(Cau)IT
	Galium aucheri	He	A	En(Alborz)
	Galium decumbens	He	B	En(Atro)
Saxifragaceae	*Saxifraga exarata*	He	C	ES-IT
	Saxifraga iranica	He	A	LEn(Alborz)
	Saxifraga sibirica	He	C	ES-IT
Scrophulariaceae	*Euphrasia juzepczukii*	An	C	Atro
	Pedicularis caucasica	He	B	Cau-Atro
	Scrophularia olympica	He	B	Ana-Cau-NWIran
	Scrophularia subaphylla	He	C	En(Iran)
	Veronica aucheri	He	A	En(Alborz)
	Veronica biloba	An	C	IT
	Veronica gentianoides	He	C	Ana-Cau-Atro
	Veronica kurdica	He	C	En(Iran)
	Veronica paederotae	He	A	LEn(Alborz)
Woodsiaceae	*Cystopteris fragilis*	He	C	PL

Life forms: *An* annual, *Ge* geophyte, *CC* cushion chamaephyte, *NC* non-cushion chamaephyte, *He* Hemicryptophyte, *Gr* graminoid. Chorology: *Hol* Holarctic, *PL* Pluriregional, *IT* Irano–Turanian, *ES* Euro–Siberian, *Atro* Atropatenian subprovince, *FI* Flora Iranica territory, *Ana* Anatolia, *Cau* Caucasus, *En* endemic, *LEn* local endemic, *SEn* subendemic. Altitudinal groups: *A* true subnival-nival, *B* alpine–subnival, *C* subalpine–subnival

(Fig. 6c), *Taraxacum baltistanicum* (Fig. 6d), *Tanacetum pamiricum* (Fig. 6e) and *Gagea alexii* (Fig. 6f).

Species with similar distribution in group B are *Psychrogeton alexeenkoi* (see distribution map in Noroozi et al. 2010a), *Draba aucheri, Oxytropis immersa, O. savellanica* and *Potentilla hololeuca.*

The distribution of several genera or species groups within genera fit to this pattern. In the genus *Paraquilegia,* consisting of 12 species, 11 species are found in the Hindu Kush, Himalaya and in Central to Middle Asia and one, *P. caespitosa*, is endemic to Iran and grows in subnival–nival rocky habitats of Central Alborz, forming the westernmost outpost of the genus. The Iran-endemic *Dracocephalum aucheri* is a member of a distinctive species group, containing several species that stretch

Table 3 The uppermost records of vascular plants on the four highest mountains of Iran

Central Alborz		NW-Iran	SE-Zagros
Damavand (5671 m)	Alamkuh (4850 m)	Sabalan (4811 m)	Hezar (4465 m)
4820 m	4735 m	4371 m	4450 m
Veronica aucheri	*Saxifraga iranica*	*Draba bruniifolia*	*Artemisia persica*
4799 m	4730 m	*Potentilla porphyrantha*	*Asperula glomerata*
Didymophysa aucheri	*Cerastium purpurascens*	4357 m	*Astragalus melanodon*
Achillea aucheri		*Alopecurus dasyanthus*	*Gagea alexii*
Alopecurus himalaicus	*Veronica aucheri*	*Didymophysa aucheri*	*Nepeta lasiocephala*
4767 m		*Draba siliquosa*	*Potentilla nuda*
Erysimum elbrusense		*Erigeron caucasicus*	*Psychrogeton alexeenkoi*
4600 m		*Saxifraga sibirica*	
Dracocephalum aucheri		*Tripleurospermum caucasicum*	*P. amorphoglosus*
			Ranunculus eriorrhizus
			Scrophularia subaphylla
			Senecio subnivalis
			Silene daënensis

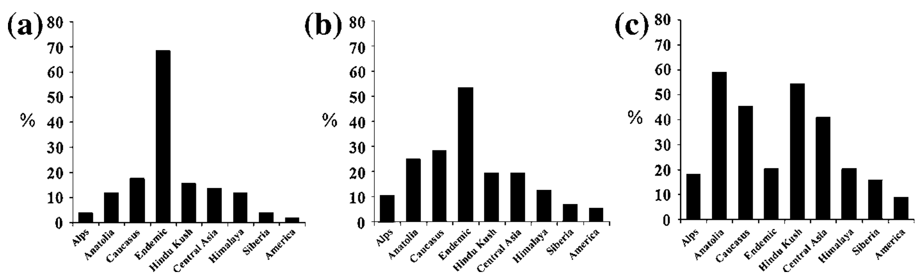

Fig. 3 Global distribution of vascular plants occurring in the subnival–nival zone of Iran: percentages of Iranian endemic species and of other regions where wider-spread species occur; compare text and Fig. 2 for species groups A (**a**), B (**b**) and C (**c**)

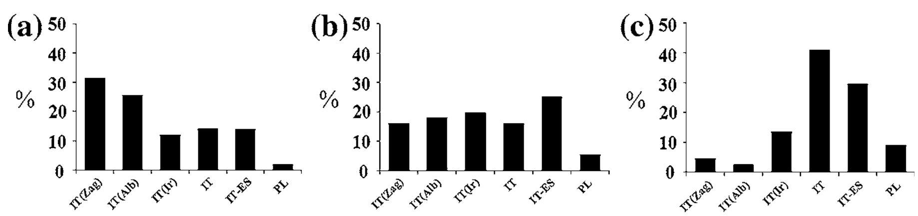

Fig. 4 Chorological spectra of species in groups A (**a**), B (**b**) and C (**c**). *IT(Zag)* endemic of Zagros, *IT(Alb)* endemic of Alborz, *IT(Ir)* endemic of Iran, *IT* Irano–Turanian, *IT-ES*: Irano–Turanian/Euro–Siberian, *PL*: Pluriregional

disjunctly from SE Turkey to the Alborz, E Afghanistan, C Asia and thence to the extreme NE of Russia (Hedge and Wendelbo 1978). *Saxifraga iranica* (also endemic to Iran) is very close to two Himalayan species, *S. imbricata* and *S. namulosa* (Bornmüller 1906 in Klein 1991), belonging to the *Marginatae* group with 19 species,

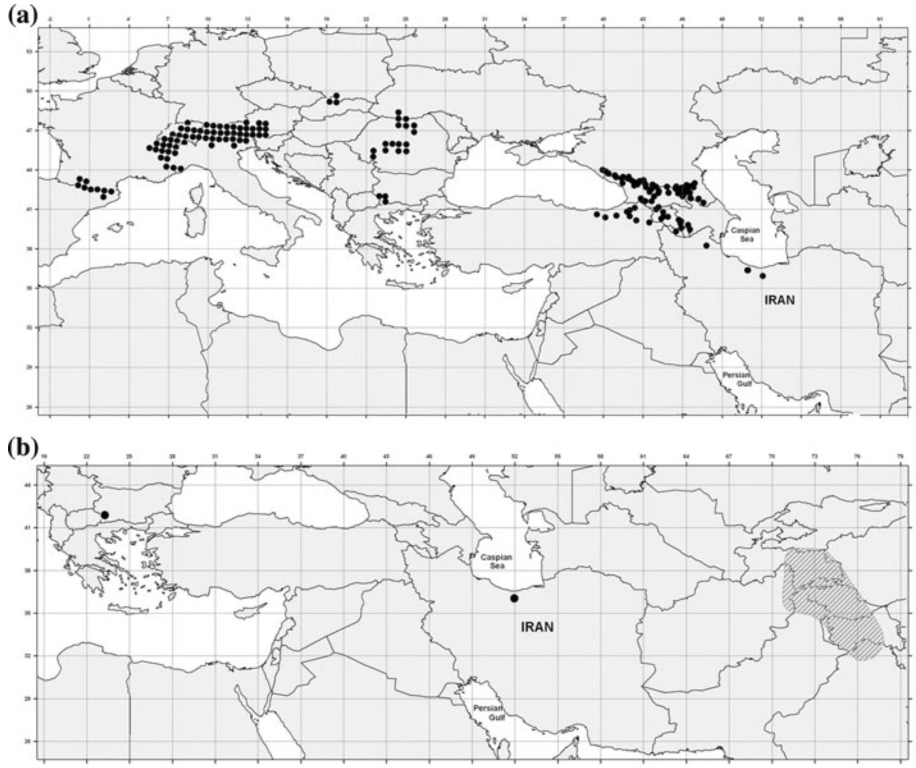

Fig. 5 Irano–Turanian to Euro–Siberian distribution: **a** *Draba siliquosa* and **b** *Alopecurus himalaicus*

where 13 species are distributed in Himalaya and China (Engler and Irmscher 1919 in Klein 1991).

(4) Distributed from Iran to Caucasus and/or Anatolia: *Draba bruniifolia* (Fig. 7a), *Cerastium purpurascens* (Fig. 7b) and *Arenaria balansae* (Fig. 7c).
Species with similar distribution in group B are *Scrophularia olympica, Scorzonera radicosa* (Meusel et al. 1992, p. 532) and *Potentilla argaea.*

(5) Distributed from Iran to the Caucasus and E Anatolia: *Didymophysa aucheri* (Fig. 8a), *Lamium tomentosum* (Fig. 8b), *Senecio taraxacifolius* (Fig. 8c) and *Campanula karakuschensis* (Fig. 8d).
Species with similar distribution in group B are *Carum caucasicum, Gentiana pontica* (Meusel et al. 1964, p. 353)*, Minuartia aizoides* and *Pedicularis caucasica* (Noroozi et al. 2008).

(6) Distributed across the Atropatenian subprovince sensu Takhtajan (1986): *Dracocephalum aucheri* (Fig. 9a), *Potentilla polyschista* (Fig. 9b), *P. porphyrantha* (Fig. 9c), *Achillea aucheri* (Fig. 9d), *Artemisia melanolepis* (Fig. 9e) and *Erysimum elbrusense* (Fig. 9f). The Atropatenian subprovince includes the arid and semiarid parts of Transcaucasia, the east and southeast of Turkey, the southern Armenian highlands, the northwest of Iran, and the Alborz mountains. This subprovince is one of the most active centers of speciation in Western Asia (Takhtajan 1986).
Species with similar distribution in group B are *Myosotis olympica, Dianthus erythrocoleus, Clastopus vestitus* (see distribution map in Hedge and Wendelbo

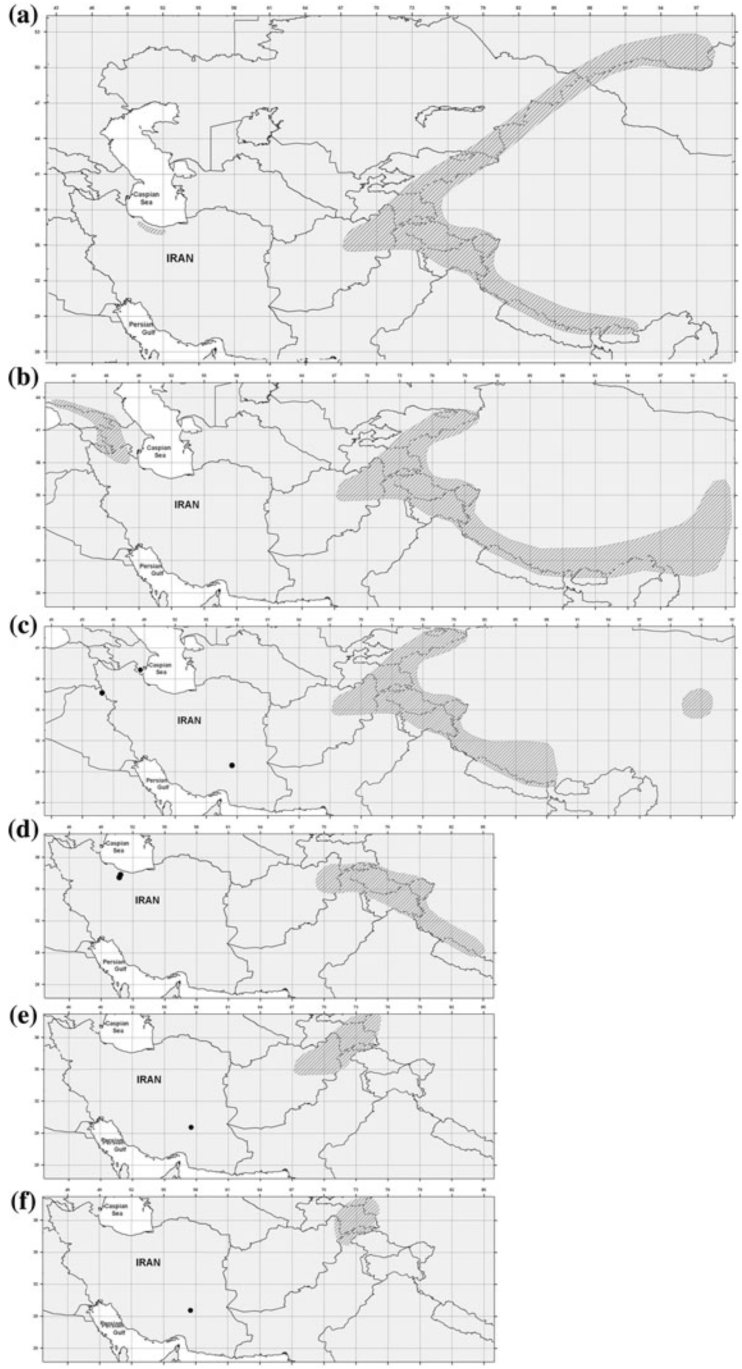

Fig. 6 Hindukush–Himalaya system and Central Asia elements with disjunct distribution. **a** *Carex melanantha,* **b** *Kobresia schoenoides*, **c** *K. humilis,* **d** *Taraxacum baltistanicum*, **e** *Tanacetum pamiricum,* **f** *Gagea alexii*

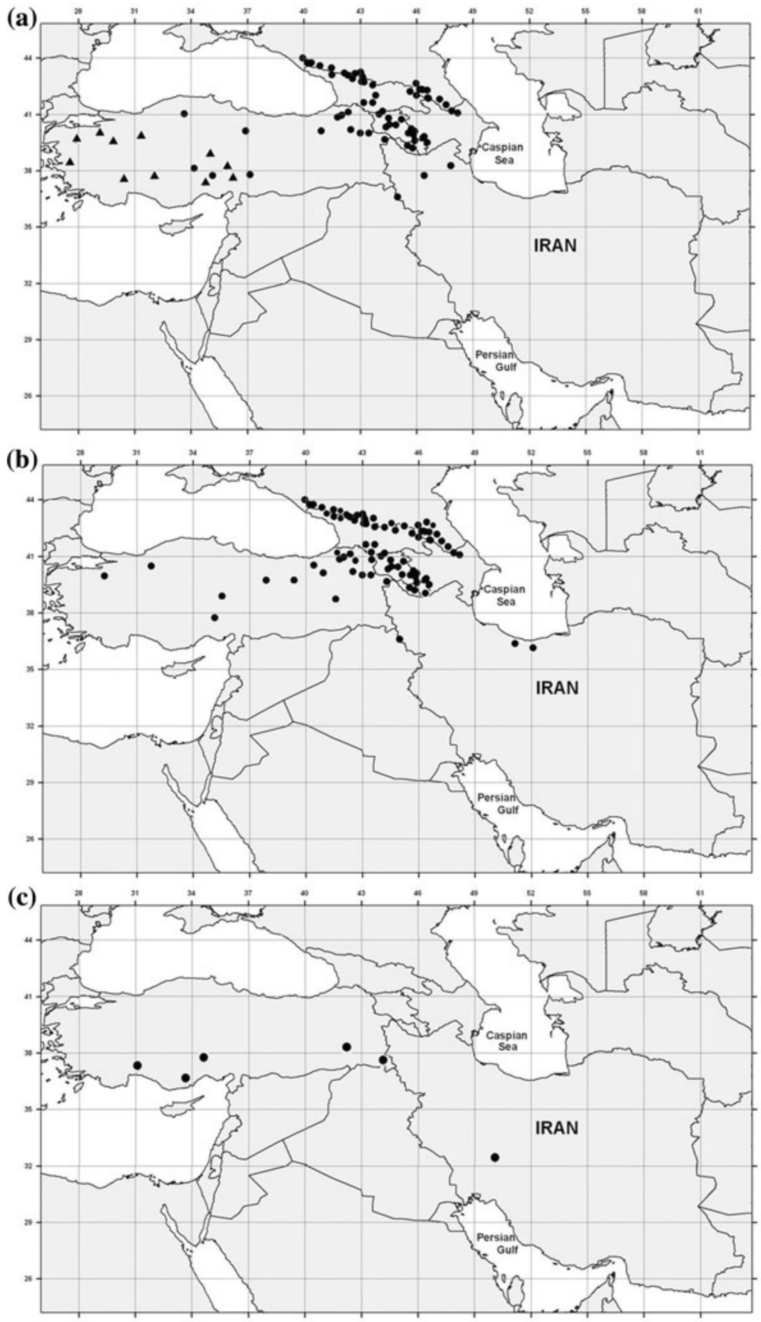

Fig. 7 Distributed from Iran to Caucasus and/or Anatolia. **a** *Draba bruniifolia*; subsp. *bruniifolia* (*circle*), other subspecies (*triangular*), **b** *Cerastium purpurascens,* **c** *Arenaria balansae*

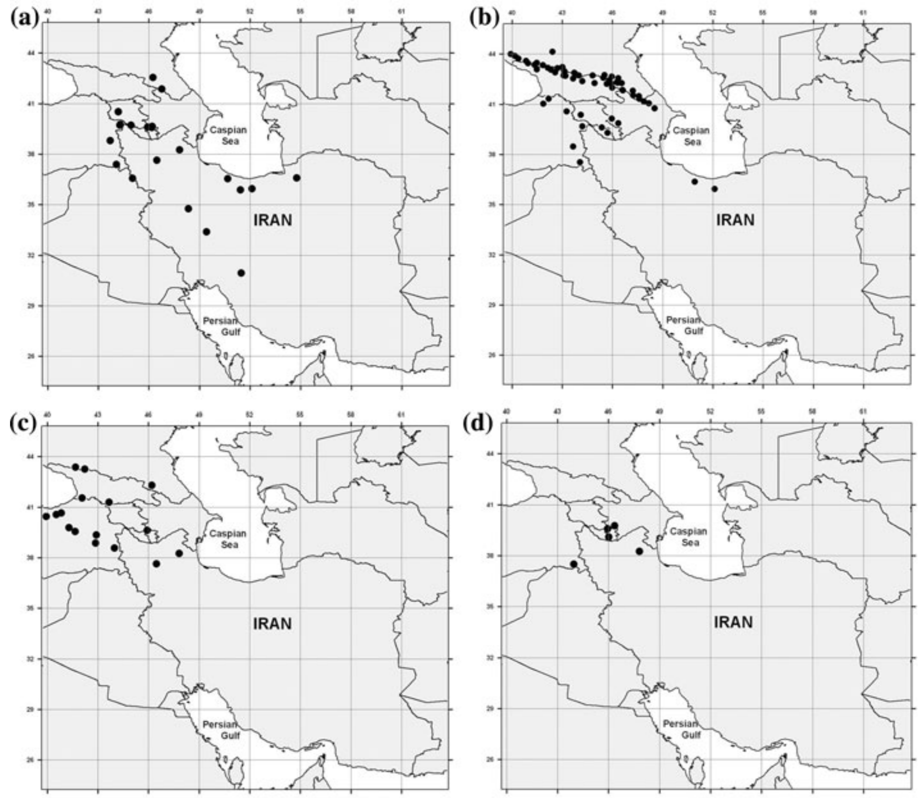

Fig. 8 Distributed from Iran to the Caucasus and E Anatolia. **a** *Didymophysa aucheri*, **b** *Lamium tomentosum*, **c** *Senecio taraxacifolius* and **d** *Campanula karakuschensis*

1978), *Draba pulchella* (Noroozi et al. 2008), *Oxytropis persica* (Noroozi et al. 2008), *Ranunculus crymophilus, Potentilla aucheriana* (Noroozi et al. 2008) and *Gagea caroli-kochii.*

(7) Distributed in Alborz and Zagros: *Oxytropis kermanica* (Fig. 9g).
Species with similar distribution in group B are *Potentilla argyroloma, P. nuda* (Noroozi et al. 2010a), *Scrophularia subaphylla* (Noroozi et al. 2010a), and *Veronica kurdica* (Noroozi et al. 2008).

(8) Alborz endemic species: *Galium aucheri* (Fig. 10a), *Lepechinella persica* (Fig. 10b), *Astragalus atricapillus* (Fig. 10c), *Veronica aucheri* (Fig. 10d), *V. paederotae* (Fig. 10e), *Paraquilegia caespitosa* (Fig. 10f), *Saxifraga iranica* (Fig. 10g), *Iranecio oligolepis* (Fig. 10g), *Scutellaria glechomoides* (Fig. 10h), *Myopordon damavandica* (Fig. 10h), *Oxytropis takhti-solimanii* (Fig. 10i) and *Senecio iranicus* (Fig. 10i).
Species with similar distribution in group B are *Erigeron hyrcanicus* (Meusel et al. 1992, p. 457), *Senecio vulcanicus* (Noroozi et al. 2008), *Jurinella frigida*, *Astragalus capito*, *A. macrosemius*, *A. montis-varvashti*, *Nepeta allotria*, *Acantholimon demawendicum* (Noroozi et al. 2008), *Heracleum anisactis*, *Galium decumbens*, *Erigeron uniflorus* subsp. *elbursensis* and *Asperula glomerata* subsp. *bracteata*.

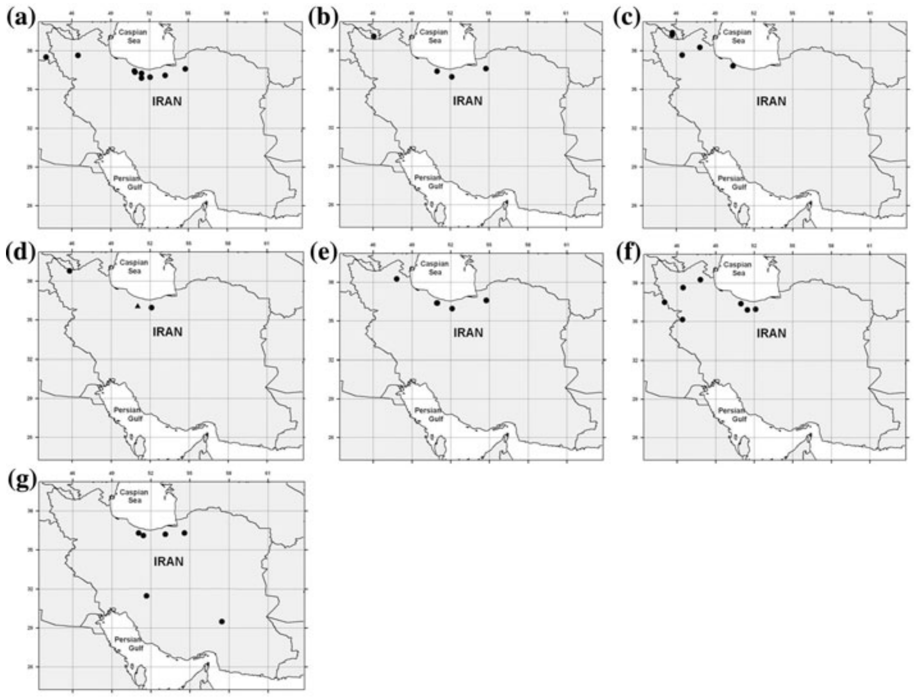

Fig. 9 Distributed across the Atropatenian subprovince. **a** *Dracocephalum aucheri*, **b** *Potentilla polyschista*, **c** *P. porphyrantha*, **d** *Achillea aucheri* [subsp. *aucheri* (*circle*), subsp. *glabra* (*triangle*)], **e** *Artemisia melanolepis*, **f** *Erysimum elbrusense* and distributed in Alborz and Zagros. **g** *Oxytropis kermanica*

(9) Zagros endemic species: *Bromus frigidus* (Fig. 11a), *Chaerophyllum nivale* (Fig. 11a), *Acantholimon haesarense* (Fig. 11a), *Aethionema umbellatum* (Fig. 11b), *Cousinia eburnea* (Fig. 11b), *C. fragilis* (Fig. 11b), *Myopordon persicum* (Fig. 11c), *Dracocephalum surmandicum* (Fig. 11c), *Nepeta archibaldii* (Fig. 11d), *Silene tragacantha* (Fig. 11d), *Semenovia dichotoma* (Fig. 11e), *Silene daënensis* (Fig. 11f), *Astragalus melanocalyx* (Fig. 11f), *Psychrogeton chionophilus* (Fig. 11g), *Cicer stapfianum* (Fig. 11g), *Senecio subnivalis* (Fig. 11g) and *Asperula glomerata* subsp. *condensata* (Fig. 11h).

Species with similar distribution in group B are *Arenaria minutissima*, *Astragalus zerdanus*, *Erigeron uniflorus* subsp. *daënensis*, *Nepeta lasiocephala* (Noroozi et al. 2010a), *Ranunculus eriorrhizus* (Noroozi et al. 2010a), *Silene nurensis* (Noroozi et al. 2010a), *S. persica*, *Stachys obtusicrena* (Noroozi et al. 2008) and *Taraxacum primigenium* (Noroozi et al. 2010a). The degree of endemism appears to be higher in Zagros mountains compared with Alborz (Wendelbo 1971; Akhani 2004, 2007; Noroozi et al. 2008, 2010a).

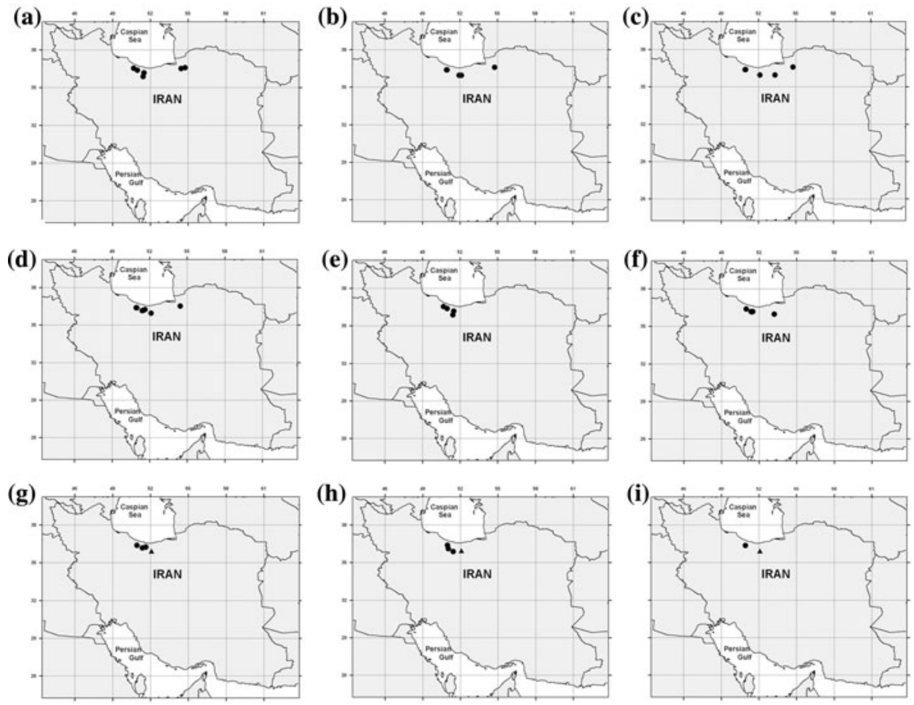

Fig. 10 Alborz endemic species. **a** *Galium aucheri*, **b** *Lepechinella persica*, **c** *Astragalus atricapillus*, **d** *Veronica aucheri*, **e** *V. paederotae*, **f** *Paraquilegia caespitosa*, **g** *Saxifraga iranica* (*circle*), *Iranecio oligolepis* (*triangle*), **h** *Scutellaria glechomoides* (*circle*), *Myopordon damavandica* (*triangle*), **i** *Oxytropis takhti-solimanii* (*circle*) and *Senecio iranicus* (*triangle*)

Discussion

Endemism, species vertical ranges and altitude

The rate of endemism increases very sharply with increasing altitude in Iran, where a narrow vertical distribution restricted to high altitudes often corresponds to constricted geographic range. Vice versa, species with a larger amplitude of their altitudinal distribution commonly are widespread species (see Figs. 2, 3 and 4). Similar patterns were observed in several European mountains, for example in mountains exposed to Mediterranean-type climate such as the Sierra Nevada (Spain) (Pauli et al. 2003) and the central Apennines (Italy) (Stanisci et al. 2005), but also in some mountain ranges in the temperate climate of Central Europe. For example, in the NE Calcareous Alps the highest rate of endemism was observed in the upper elevation zones (subalpine to alpine) of these lower and outer parts of the Alps, whereas the percentage of endemism generally decreases towards the central Alps; the latter having been fully glaciated during the Pleistocene (Pauli et al. 2003; Essl et al. 2009). Also in the Caucasus mountains the percentage of endemics was reported to be highest in the subnival belt (Nakhutsrishvili 1998). In the Hindu Kush mountains, however, the percentage of endemism peaks in the subalpine zone, but species dwelling in the nival zone (above 5000 m) mostly have a wide geographical distribution over the Eurasian mountains and the Arctic (Breckle 1974, 2004). Similar

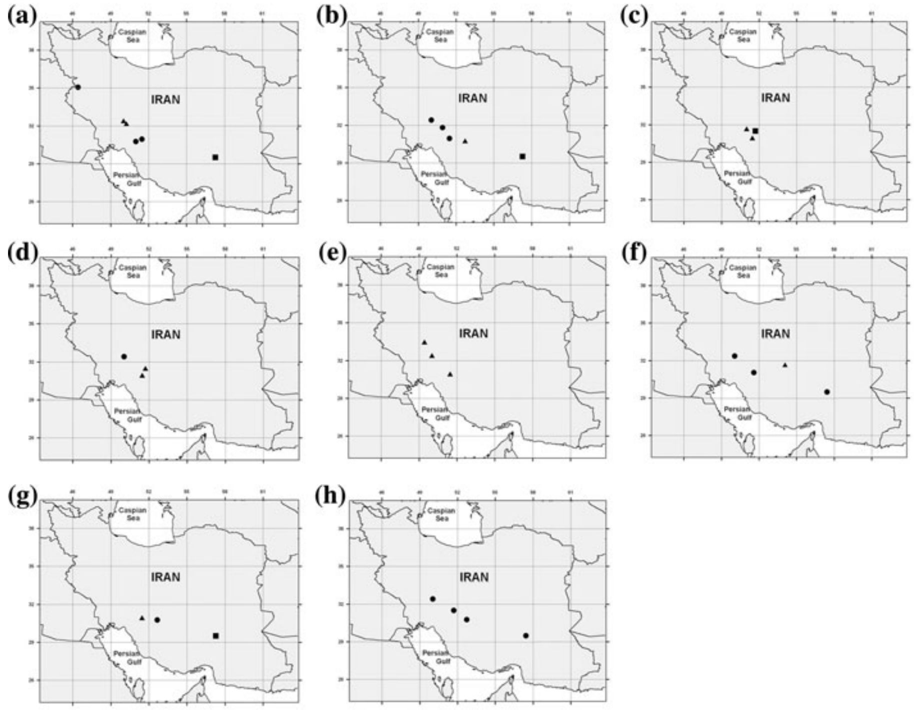

Fig. 11 Zagros endemic species. **a** *Bromus frigidus* (*circle*), *Chaerophyllum nivale* (*triangle*), *Acantholimon haesarense* (*square*), **b** *Aethionema umbellatum* (*circle*), *Cousinia eburnea* (*triangle*), *C. fragilis* (*square*), **c** *Myopordon persicum* (*triangle*), *Dracocephalum surmandicum* (*square*), **d** *Nepeta archibaldii* (*circle*), *Silene tragacantha* (*triangle*), **e** *Semenovia dicotoma*, **f** *Silene daënensis* (*circle*), *Astragalus melanocalyx* (*triangle*), **g** *Psychrogeton chionophilus* (*triangle*), *Cicer stapfianum* (*circle*) and *Senecio subnivalis* (*square*), **h** *Asperula glomerata* subsp. *condensata*

distribution patterns were found in the Himalaya (Vetaas and Grytnes 2002). This contrast may be explained by the lesser orographic isolation of the Hindu Kush and Himalaya in the past and present, compared to the high mountains of Iran.

Orogenesis during the Cenozoic played a major role in the evolution of the alpine flora (Agakhanjanz and Breckle 1995). The high rate and extent of mountain uplift in the Alborz and Zagros and the high degree of fragmentation and isolation of their high-elevation areas from the neighboring mountain ranges (Breckle 2009) are considered as important determinants for the pronounced high-elevation endemism (Noroozi et al. 2008, 2010a). In spite of extensive glaciations in the mountains of Iran and a climatic snowline level lowered by 600–1,100 m during the Pleistocene (Bobek 1937; Ferrigno 1991), the glaciations may have not severely affected the overall distribution patterns of the flora of Alborz and Zagros mountains (Bobek 1937, 1953; Noroozi et al. 2008). Mainly valley glaciations may have occurred (Agakhanjanz and Breckle 1995), thus enabling many high-mountain species to persist on relict stands not far from their current occurrences (Hedge and Wendelbo 1978; Klein 1991; Noroozi et al. 2008, 2010a). A strong orographic isolation and the absence of larger ice-shields during the ice-ages appear to be crucial for the present high-mountain endemism in Iran and other mountain regions where a similar situation occurs, such as the Spanish Sierra Nevada (Blanca et al. 1998) or the Moroccan High Atlas.

A general south–north gradient of decreasing endemism from the Atlas mountains to northern Europe can be found, which coincides with an increasing Pleistocene glaciation and connectivity among cold areas (Favarger 1972). The surprisingly low degree of alpine endemic plants in North America (Mills and Schwartz 2005) may be associated with maintained connections and migration pathways supported by extensive north–south-oriented mountain ranges.

Climatic links during the Pleistocene glacial periods between the Himalaya and Central Asia with the Iranian, Caucasian and some European mountains facilitated a long-distance migration of several cryophilic species. Through the post-glacial climatic amelioration and, thus, the disruption of migration corridors, the distribution of some species became highly disjunct (e.g., *Alopecurus himalaicus,* Fig. 5b). In addition to a high level of endemism, the pronounced orographic isolation in Iran led to an abrupt decrease of plant diversity with altitude (Noroozi et al. 2008). By contrast, the past and contemporary connections of cold areas of Hindu Kush to neighboring ranges (Himalaya, Central and Middle Asia) facilitated species migrations (Breckle 2007).

Global warming and the vulnerability of subnival–nival endemics

In spite of the importance of historic determinants, the temperature component of orographic isolation is the most important factor favouring endemism in high mountain areas at present (Pauli et al. 2003). A changing temperature regime through an ongoing climate warming therefore may increasingly threaten the persistence of the isolated and unique cryophilic flora of Iran, where the potential to escape to suitable cold habitats is highly limited. The narrower the altitudinal distribution, the geographical range and the within-species genetic diversity and plasticity, the more severe is the potential vulnerability to climate change (Dirnböck et al. 2003; Ohlemüller et al. 2008). This particularly accounts for the endemic species of group A and, to a lesser extent, of group B of the Iranian subnival–nival flora.

There is evidence of an ongoing upward migration (e.g., Grabherr et al. 1994; Walther et al. 2005) and of a decline of subnival–nival species at their lower range margins in the Alps (Pauli et al. 2007). No such data are available for the Iranian mountains owing to the lack of permanent observation plots. First sites in the Alborz mountains only were setup in 2008 by the authors as part of the GLORIA network (www.gloria.ac.at).

Unlike the situation in the Alps, but similar to other Mediterranean-type mountains, barriers against invading competitor species from lower elevations, such as closed forest and grassland belts, are absent in Iranian mountains. Instead, open habitats from lower elevations up to the high terrains may support an upward colonization driven by climate change. Hypothetically, climate warming is coupled with an earlier snow-melt and, thus, to an extended low-precipitation period in summer that, in turn, may lead to a reduced vitality of cryophilic plants. A prolonged drought period could also affect invaders from lower elevations, but these species are likely to be well adapted to arid conditions (Pauli et al. 2003).

Conclusions

(1) In Iran, 151 vascular plant species were identified to occur in the subnival–nival zone, where 51 of these can be considered as true subnival–nival species. Within the latter,

the degree of species endemic to Iran is 68% and clearly decreases to 53 and 20% for species that also occur in the alpine and in the subalpine zones, respectively.

(2) The outstanding level of high-altitude endemism appear to result mainly from a pronounced orographic isolation of the country's highly scattered and fragmented cold areas and the absence of extensive Pleistocene glaciations.

(3) Predicted climate warming may seriously threaten the survival of the unique subnival–nival flora of Iran, due to a very low potential of alternative low-temperature habitats at higher elevations. Additional pressure through drought-tolerant competitors from lower altitudes can further increase the risk of biodiversity losses.

(4) An expansion of long-term observation sites, and of ecological, biogeographic and phylogeographic research on Iran's high-altitude flora and vegetation is strongly recommended.

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References

Agakhanjanz O, Breckle S-W (1995) Origin and evolution of the mountain flora in middle Asia and neighboring mountain regions. In: Chapin III FS, Körner C (eds) Arctic and alpine biodiversity: patterns, causes and ecosystem consequences, Ecological Studies. Springer, Berlin, vol 113, pp 63–80

Ajani Y, Noroozi J, Levichev I-G (2010) *Gagea alexii* (Liliaceae), a new record from subnival zone of southern Iran with key and notes on sect. *Incrustatae*. Pak J Bot 42:67–77

Akhani H (2004) A new spiny, cushion-like *Euphorbia* (Euphorbiaceae) from south–west Iran with special reference to the phytogeographic importance of local endemic species. Bot J Linn Soc 146:107–121

Akhani H (2007) Diversity, biogeography, and photosynthetic pathways of *Argusia* and *Heliotropium* (Boraginaceae) in South–West Asia with an analysis of phytogeographical units. Bot J Linn Soc 155:401–425

Blanca G, Cueto M, Martínez Lirola M-J et al (1998) Threatened vascular flora of Sierra Nevada (Southern Spain). Biol Conserv 85:269–285

Bobek H (1937) Die Rolle der Eiszeit in Nordwestiran. Zeitschr Gletscherk 25:130–183

Bobek H (1953) Zur eiszeitlichen Vergletscherung des Alborzgebirges, Nordiran. Carinthia 2:97–104

Bornmüller J (1906) Beiträge zur Flora der Elburzgebirge Nord-Persiens, Bull Herb Boiss, Genève, vol 6, pp 605–620, 765–780

Breckle S-W (1974) Notes on Alpine and Nival Flora of the Hindu Kush, East Afghanistan. Bot Not (Lund) 127:278–284

Breckle S-W (2004) Flora, Vegetation und Ökologie der alpin–nivalen Stufe des Hindukusch (Afghanistan). In: Breckle S-W, Schweizer B, Fangmeier A (eds) Proceedings of 2nd symposium AFW Schimper-foundation: results of worldwide ecological studies. Stuttgart-Hohenheim, p 97

Breckle S-W (2007) Flora and vegetation of Afghanistan. Basic Appl Dryland Res 1(2):155–194

Breckle S-W (2009) Ökologie der Vegetation und der Höhenstufen im Zagros-Gebirge (Iran). In: Gratzl K, Kostka R (eds) Die Bergwelt des Iran. Weishaupt-Verlag Gnas, Austria, pp 48–60

Buhse F (1899a) Flora des Alburs und der Kaspischen Südküste. Bisherige Forschungsergebnisse aus diesem Gebiet. Arbeiten des Naturforscher-Vereins zu Riga. Neue Folge. 8. Heft. WF Häcker, Riga

Buhse F (1899b) Reisebemerkungen aus dem östlichen Albursgebirge in Persien. Bull Soc Imper Natur Moscow 34:363–383

Davis PH (ed) (1965–1988) Flora of Turkey and the East Aegean Islands, vols 1–10. Edinburgh University Press, Edinburgh

Dirnböck T, Dullinger S, Grabherr G (2003) A regional impact assessment of climate and land-use change on alpine vegetation. J Biogeogr 30:401–417

Engler A, Irmscher E (1919) Saxifragaceae: *Saxifraga*. In: Engler A (ed) Das Pflanzenreich 69 (IV.117). Verlag von Wilhelm Engelmann, Leipzig, pp 449–709

Essl F, Staudinger M, Stöhr O et al (2009) Distribution patterns, range size and niche breadth of Austrian endemic plants. Biol Conserv 142:2547–2558
Favarger C (1972) Endemism in the montane floras of Europe. In: Valentine DH (ed) Taxonomy, phytogeography and evolution. Academic Press, London, pp 191–204
Ferrigno JG (1991) Glaciers of the Middle East and Africa—glaciers of Iran. In: Williams RS, Ferrigno JG (eds) Satellite image atlas of glaciers of the world. U.S. Geological Survey Professional Paper 1386-G. United States Government Printing Office, Washington, pp 31–47
Gilli A (1939) Die Pflanzengesellschaften der Hochregion des Elbursgebirges in Nordiran. Beih Bot Cbl 59:317–344
Gilli A (1941) Ein Beitrag zur Flora des Elburs-Gebirges in Nord-Iran. Feddes Repert Spec Regni Veg 50:263–283
Grabherr G, Gottfried M, Pauli H (1994) Climate effects on mountain plants. Nature 369:448
Grossheim AA (1945–1967) Flora Kavkaza (*Flora of Caucasus*), vols 3–7. Nauk, Leningrad
Hedge IC, Wendelbo P (1978) Patterns of distribution and endemism in Iran. Notes Roy Bot Gard Edinb 36:441–464
Klein JC (1982) Les groupements chionophiles de l'Alborz central (Iran). Comparaison avec leurs homologues d' Asie centrale. Phytocoenologia 10(4):463–486
Klein JC (1991) Endemisme à l'etage alpin de l'Alborz (Iran). Flora Veg Mundi 9:247–261
Klein JC, Lacoste A (1999) Observation sur la végétation des éboulis dans les massifs irano-touraniens: le Galietum aucheri ass. nov. de l'Alborz Central (N-Iran). Documents phytosociologiques 19:219–228
Kotschy T (1861a) Die Vegetation des westlichen Elbrus in Nordpersien. Österr Bot Zeitschr 11(4):105–117
Kotschy T (1861b) Der westliche Elbrus bei Teheran. Mitt. der K. K. Oester Geogr Gesell Wien 5:65–110
Meusel H, Jäger E, Weinert E (1964) Vergleichende Chorologie der zentraleuropäischen Flora Band I. Fischer, Jena
Meusel H, Jäger E, Bräutigam S et al (1992) Vergleichende Chorologie der zentraleuropäischen Flora, Band III. Fischer, Jena
Mills MH, Schwartz MW (2005) Rare plants at the extremes of distribution: broadly and narrowly distributed rare species. Biodivers Conserv 14:1401–1420
Nagy L, Grabherr G (2009) The biology of alpine habitats. Oxford University Press, New York
Nakhutsrishvili G (1998) The vegetation of the subnival belt of the Caucasus Mountains. Arct Alp Res 30:222–226
Noroozi J, Akhani H, Breckle S-W (2008) Biodiversity and phytogeography of the Alpine flora of Iran. Biodivers Conserv 17:493–521
Noroozi J, Ajani Y, Nordenstam B (2010a) A new annual species of *Senecio* (Compositae–Senecioneae) from subnival zone of southern Iran with comments on phytogeographical aspects of the area. Comp Newsl 48:4–23
Noroozi J, Akhani H, Willner W (2010b) Phytosociological and ecological study of the high alpine vegetation of Tuchal Mountains (Central Alborz, Iran). Phytocoenologia 40(4):293–321
Ohlemüller R, Anderson BJ, Araujo MB et al (2008) The coincidence of climatic and species rarity: high risk to small-range species from climate change. Biol Let 4:568–572
Pauli H, Gottfried M, Dirnböck T et al (2003) Assessing the long-term dynamics of endemic plants at summit habitats. In: Nagy L, Grabherr G, Körner C et al (eds) Alpine biodiversity in Europe—a Europe-wide assessment of biological richness and change, Ecological Studies. Springer, Berlin, vol 167, pp 195–207
Pauli H, Gottfried M, Reiter K et al (2007) Signals of range expansions and contractions of vascular plants in the high Alps: observations (1994–2004) at the GLORIA master site Schrankogel, Tyrol, Austria. Glob Change Biol 13:147–156
Rechinger KH (ed) (1963–2010) Flora Iranica, vols 1–178. Akad. Druck-u. Verlagsanstalt, Graz
Snogerup S (1971) Juncaceae. In: Rechinger KH (ed) Flora Iranica, No. 75. Akademische Druck u. Verlagsanstalt, Graz
Stanisci A, Pelino G, Blasi C (2005) Vascular plant diversity and climate change in the alpine belt of the central Apennines (Italy). Biodivers Conser 14:1301–1318
Takhtajan A (1986) Floristic regions of the world. University of California Press, California (English translation from Russian)
Vetaas OR, Grytnes JA (2002) Distribution of vascular plant species richness and endemic richness along the Himalayan elevation gradient in Nepal. Glob Ecol Biogeogr 11:291–301
Walther GR, Beißner S, Burga CA (2005) Trends in upward shift of alpine plants. J Veg Sci 16:541–548
Wendelbo P (1971) Some distributional patterns within the Flora Iranica area. In: Davis PH, Harper PC, Hedge IC (eds) Plant life of South–West Asia. Edinburgh, pp 29–41
Zohary M (1973) Geobotanical foundations of the Middle East, vol 2. Fischer, Stuttgart

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7.6 High Mountain Regions in Iran

Jalil Noroozi

7.6.1 Physical Geography of Mountain Ranges in Iran

Iran with a total surface area of c. 1.6 million km² is a typical high mountain country. Almost half the country consists of high elevations, and Alborz and Zagros are the major high mountain chains (Fig. 7.7). The highest mountains are Damavand (5671 m asl.), Alamkuh (4850 m), Sabalan (4810 m), and Hezar (4465 m). More than 100 mountain peaks exceed 4000 m.

There are glaciers in the higher elevations, i.e. Damavand, Alamkuh, Sabalan and Zardkuh (Ferrigno 1991). According to Schweizer (1972) the present snowline in Alborz, north and central Zagros, and the NW Iranian mountains lies between 4000 and 4200 m. In the mountains of central and southern Iran, e.g. Shirkuh, Dena, and Hezar-Lalehzar Mts. it is between 4500 to 5000 m. The higher elevations of Iran have a continental climate with Mediterranean precipitation regime. The annual precipitation in the higher altitudes of Alborz reaches almost 1000 mm (Khalili 1973).

The alpine habitats are almost all above 3000 m, and are found scattered across different parts of the country (see Fig. 7.7).The Iranian alpine flora is of Irano-Turanian origin (Zohary 1973, Klein 1982, 1991, Frey et al. 1999). A conspicuous feature of this flora is the high rates of endemism. A total of 682 vascular plant species are known from alpine habitats of Iranian mountains, and of this total 394 species are endemic or subendemic to Iran (Noroozi et al. 2008). These habitats are less known, and plant species are still being discovered and described as new to science (e.g. Jamzad 2006, Khassanov et al. 2006, Noroozi et al. 2010a, Noroozi & Ajani 2013, Razyfard et al. 2011).

Several different vegetation types are found in the high regions of Iran. The dry slopes of the subalpine zone are usually covered with tall herbs and umbelliferous vegetation types (Klein 1987, 1988). Small patches of subalpine wetlands are found scattered on dry slopes (Naqinezhad et al. 2010). Thorn-cushion grasslands occur in alpine meadow and windswept areas, and snowbed vegetation types in snow patches or snow melting runnels (Klein 1982, Noroozi et al. 2010b). Scree vegetation types with sparse vegetation cover occupy high alpine and subnival steep slopes with a high percentage of screes and stones on the ground (Klein & Lacoste 2001, Noroozi et al. 2013).

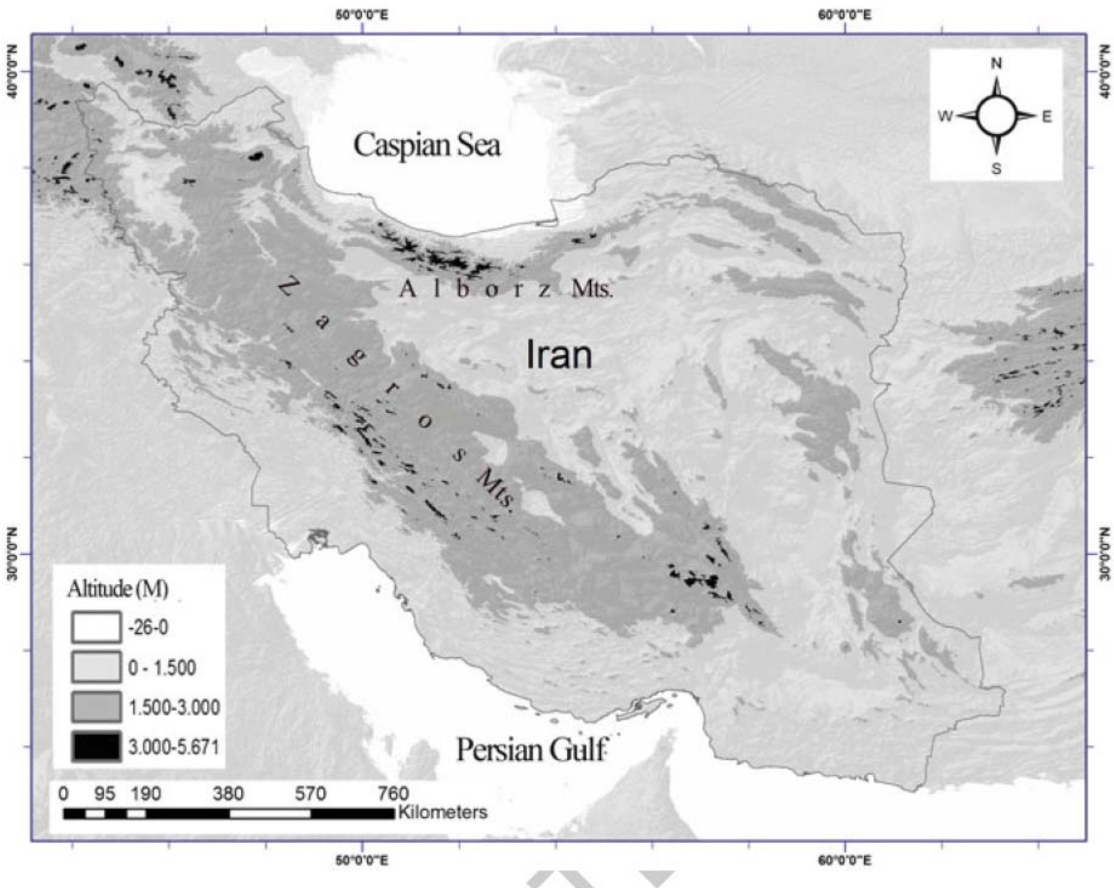

Fig. 7.7 Alborz and Zagros are the major mountain chains of Iran. The alpine habitats (black spots) are scattered around different parts of the country.

7.6.2 Analysis of Floras and Phytosociological Investigation

To select the local endemic species, the Flora Iranica (Rechinger 1963-2012) and Flora of Iran (Assadi et al. 1988-2012) were used as the main sources.

The main data on endemism in alpine habitats of Iran and the percentage of endemism in alpine and subnival-nival zones were extracted from Klein (1991), Hedge & Wendelbo (1978) and Noroozi et al. (2008, 2011).

The rate of endemism in different habitats is based on phytosociological vegetation studies of the author in Central Alborz. This rate is measured from all character species which were recorded for each habitat. Some species which were characteristic for two different habitats were separately calculated for both habitats. For example *Astragalus macrosemius* is a character species for alpine thorn-cushion grasslands and alpine-subnival scree grounds and was thus counted separately for both habitats as a character species.

7.6.3 Endemism in Different High Mountain Areas and Habitats

Three monotypic genera are found exclusively within Iranian alpine habitats, *Elburzia* in Central Alborz (Hedge 1969), *Sclerochorton* in northern Zagros (Rechinger 1987), and *Zerdana* in central, south and southeastern Zagros (Rechinger 1968). There are also some interesting ditypic genera in these habitats, such as *Clastopus* with two species endemic to Iran (Hedge & Wendelbo 1978), *Didymophysa* with one species occurring in Iran and Transcaucasus, and another one in central Asia and Hindukush (Hedge 1968), and *Dielsiocharis* with one endemic species in Iran (Hedge 1968) and one local endemic in central Asia (Al-Shehbaz & Junussov 2003). All the above-mentioned genera belong to the Brassicaceae except *Sclerochorton*, which belongs to Apiaceae. The author has only seen *Zerdana, Clastopus* and *Didymophysa* in the wild, and all of these are restricted to scree habitats.

A total of 110 vascular plant species were considered to be rare and narrow endemic to Iranian alpine habitats and have only been recorded from one or very few locations. These species are found in Zagros, Alborz, and in the northwestern part of the country (Sahand and Sabalan Mts.). They are classified into four mountainous regions as below:

Rare species in Alborz:

Alchemilla amardica, A. rechingeri, Allium tuchalense, Astragalus aestivorum, A. herbertii, A. montis-varvashti, A. nezva-montis, Cousinia decumbens, C. harazensis, *Diplotaenia damavandica, Elburzia fenestrata, Erodium dimorphum, Festuca rechingeri, Galium delicatulum, Iranecio oligolepis, Myopordon damavandica, M. hyrcanum, Nepeta allotria, N. pogonosperma, Oxytropis aellenii, O. cinerea, O. takhti-soleimanii, Paraquilegia caespitosa, Phlomis ghilanensis, Saxifraga koelzii, S. ramsarica, S. iranica, Scorzonera xylobasia, Scutellaria glechomoides, Senecio iranicus, Silene demawendica, Thlaspi maassoumi, Trachydium eriocarpum, Veronica euphrasiifolia, V. paederotae, Vicia aucheri.*

Rare species in the mountains of northwestern Iran:

Astragalus azizii, A. pauperiflorus, A. savellanicus, Dianthus seidlitzii, Euphorbia sahendi, *Festuca sabalanica, Nepeta sahandica, Ranunculus renzii, R. sabalanicus, Thlaspi tenue.*

Rare species in north, central and southern Zagros (from Kordestan to Fars provinces):

Acantholimon eschkerense, Allium mahneshanense, Arenaria minutissima, Astragalus mahneshanensis, A. montis-parrowii, Bufonia micrantha, Chaerophyllum nivale, Cicer stapfianum, Cousinia concinna, C. eburnea, Crepis connexa, *Cyclotrichium straussii, Dianthus elymaiticus, Dionysia aubrietioides, D. iranshahrii, Dracocephalum surmandinum, Erysimum frigidum, Euphorbia plebeia, Festuca iranica, Galium schoenbeck-temesyae, Jurinea viciosoi, Myopordon aucheri, Nepeta archibaldii, N. chionophila, N. iranshahrii, N. monocephala, N. natanzensis, Potentilla flaccida, Psychrogeton chionophilus, Ranunculus dalechanensis, Salvia lachnocalyx, Satureja kallarica, Sclerochorton haussknechtii, Scorzonera nivalis, Scrophularia flava, Senecio kotschyanus, Seratula melanocheila, Silene hirticalyx, Tragopogon erostris, Veronica daranica.*

Rare species in southeastern Zagros (mountains of Yazd, Kerman and Baluchestan provinces):

Acantholimon haesarense, A. kermanense, A. nigricans, A. sirchense, Allium lalesaricum, Astragalus hezarensis, A. melanocalyx, A. pseudojohannis, Chaenorhinum grossecostatum, Cousinia fragilis, Dionysia curviflora, Helichrysum davisianum, Hymenocrater yazdianus, Hyoscyamus malekianus, Nepeta asterotricha, N. bornmulleri, N. rivularis, Polygonum spinosum, Rubia caramanica, *Senecio eligulatus, S. subnivalis*, *Silene dschuparensis, Verbascum carmanicumm.*

Since alpine habitats have been less well investigated than lower elevations, our knowledge about the distribution range of species living in high mountain regions is low. This means that it is more likely that new explorations at these elevations will produce new records and localities for local endemics. Nonetheless, the above mentioned species are rare, with narrow geographical and altitudinal distribution. Most of the above-mentioned species can be categorised as Endangered (EN) and Critically Endangered (CR) according to IUCN Red List criteria. However, more field studies are needed to clarify this. Some of these species are only known from type specimens. For instance, *Sclerochorton haussknechtii* has not been found for 140 years, since it was first collected. This could be because the species has become extinct in the wild or, more likely, because of a lack of information due to a scarcity of field investigations.

Based on the vegetation data of the author from Central Alborz, the highest rate of endemism occurs in alpine-subnival scree grounds (60% taxa), followed by alpine thorn-cushion grasslands (49% taxa), subalpine dry slopes covered with umbelliferous vegetation types (41% taxa), alpine snowbeds (36% taxa) and subalpine wetlands (6% taxa).

Examples for endemics adapted to alpine-subnival scree grounds are: *Asperula glomerata* subsp. *bracteata, Astragalus capito, Cicer tragacanthoides, Clastopus vestitus, Crepis heterotricha, Dracocephalum aucheri, Galium aucheri, Jurinella frigida, Leonurus cardiaca* ssp. *persicus*, *Nepeta racemosa, Scutellaria glechomoides*, *Senecio vulcanicus, Veronica paederotae, Veronica aucheri* and *Ziziphora clinopodioides* subsp. *elbursensis.*

Examples for endemics which occur in alpine thorn-cushion grasslands are: *Acantholimon demawendicum, Allium tuchalense, Astragalus chrysanthus, A. iodotropis, A. macrosemius* (Photo 7.14), *Bufonia kotschyana, Cousinia crispa, Draba pulchella, Minuartia lineata, Oxytropis persicus, Scorzonera meyeri, Silene marschallii, Tragopogon kotschyi* and *Veronica kurdica.*

Photo 7.14 *Astragalus macrosemius* (3700 m) in Central Alborz with Mt. Damavand (5671 m) in the background (photographed by Noroozi)

Examples of endemics which inhabit subalpine dry slopes covered with umbelliferous vegetation are: *Aethionema stenopterum, Allium derderianum, A. elburzense, Astragalus aegobromus, Cousinia adenosticta, C. hypoleuca, Echinops elbursensis, Galium megalanthum, Iris barnumae, Parlatoria rostrata, Ranunculus elbursensis* and *Rumex elbursensis.*

Examples of endemic taxa of alpine snowbeds are: *Cerastium persicum, Erigeron uniflorus* ssp. *elbursensis, Potentilla aucheriana* and *Ranunculus crymophylus.*

An example of endemics of subalpine wetlands is *Ligularia persica.*

According to Naqinezhad et al. (2010), of 323 vascular plant species recorded for the wetland flora on the southern slopes of Alborz, only 7% are endemic and subendemic to Iran, which is consistent with our local findings. This rate of endemism is very low in comparison to other high-elevation habitats in Iranian mountains.

The percentage of endemic species for the true subnival-nival flora is 68% (Noroozi et al. 2011), and for alpine habitats (including the subnival-nival zone) 58% (Noroozi et al. 2008). This rate is much higher than that for the entire Iranian flora (24%, Akhani 2006). It means that c. 23% of Iranian endemics are concentrated in alpine habitats, suggesting that the alpine zone can be considered one of the centres of endemism. Most studies on plant biodiversity of Iranian mountains demonstrate that the proportion of narrowly distributed plant species increases consistently from low to high elevations (Klein 1991, Noroozi et al. 2008, 2011, Naqinezhad et al. 2009, 2010, Kamrani et al. 2011).

The major factors increasing the extinction risk for geographically restricted alpine species of Iran could be climate change and overgrazing. The evidence of global warming impacts on the upward shift of plant species has been demonstrated for European mountains (e.g., Grabherr et al. 1994, Walther et al. 2005, Gottfried et al. 2012, Pauli et al. 2012). The persistence of the unique cryophilic flora of Iran would be seriously threatened under the impact of ongoing global warming where the potential to migrate to appropriate habitats is very limited (Noroozi et al. 2011).

High elevations in Iran have been used as summer pastures, and overgrazing is very severe in these habitats. Thus, the high mountain flora and vegetation are seriously disturbed (personal observation).

Since alpine habitats are floristically less well researched, we have insufficient knowledge about the habitats of rare species in the various mountain ranges. We thus strongly recommend more field exploration of high mountain areas to determine the ecology, biology and conservation status of local endemics according to IUCN criteria, and to improve the protection status of the country's high mountain flora and vegetation.

References

Akhani H 2006. Flora Iranica: facts and figures and a list of publications by K. H. Rechinger on Iran and adjacent areas. - Rostaniha 7/2: 19–61.

Al-Shehbaz I & Junussov SJ 2003. *Arabidopsis bactriana* belongs to *Dielsiocharis* (Brassicaceae). - *Novon* 13: 171-172.

Assadi M, Massoumi AA, Khatamsaz M & Mozaffarian V (eds) 1988-2012. Flora of Iran, No. 1-74. - Research Institute of Forest and Rangelands. Tehran. (in Persian).

Ferrigno JG 1991. Glaciers of the Middle East and Africa – glaciers of Iran. - In: Williams RS & Ferrigno JG (eds.) Satellite image atlas of glaciers of the world. - U.S. Geological Survey Professional Paper 1386-G, United States Government Printing Office, Washington: 31-47.

Frey W, Kürschner H & Probst W 1999. Flora and vegetation, including plant species and larger vegetation complexes in Persia. - In: Yarshater E (ed.) Encyclopaedia Iranica 10/1: 43-63. Costa Mesa, California, Mazda Publishers.

Gottfried M, Pauli H, Futschik A, Akhalkatsi M, Barančok P, Benito Alonso JL, Coldea G, Dick J, Erschbamer B, Fernández Calzado MR, Kazakis G, Krajči J, Larsson P, Mallaun M, Michelsen O, Moiseev D, Molau U, Merzouki A, Nagy L, Nakhutsrishvili G, Pedersen B, Pelino G, Puscas M, Rossi G, Stanisci A, Theurillat JP, Tomaselli M, Villar L, Vittoz P, Vogiatzakis I & Grabherr G 2012. Continent-wide response of mountain vegetation to climate change. - Nature Climate Change 2/2: 111-115.

Grabherr G, Gottfried M & Pauli H 1994. Climate effects on mountain plants. - Nature 369: 448–448.

Hedge IC & Wendelbo P 1978. Patterns of distribution and endemism in Iran. - Notes from the Royal Botanic Garden, Edinburgh 36: 441–464.

Hedge IC 1968. *Dielsiocharis* (pp. 320-321), *Didymophysa* (pp. 87-98) [Cruciferae]. - In: Rechinger KH (ed.) Flora Iranica 57. - Akademische Druck u. Verlagsanstalt, Graz.

Hedge IC 1969. *Elburzia*, a new genus of Cruciferae from Iran. - Notes from the Royal Botanic Garden, Edinburgh 29: 181-184.

Jamzad Z 2006. A new species and a new record from Iran. - Iranian Journal of Botany 11/2: 143-148.

Kamrani A, Jalili A, Naqinezhad A, Attar F, Maassoumi AA & Shaw SC 2011. Relationships between environmental variables and vegetation across mountain wetland sites, N Iran. - Biologia 66: 76-87.

Khalili A 1973. Precipitation patterns of Central Elburz. - Arch Met Geoph Biokl Ser B 21: 215-232.

Khassanov F, Noroozi J & Akhani H 2006. Two new species of *Allium* genus from Iran. - Rostaniha 7(2): 119-130.

Klein JC & Lacoste A 1999. Observation sur la végétation des éboulis dans les massifs irano-touraniens: le Galietum aucheri ass. nov. de l'Alborz central (N-Iran). - Documents Phytosociologiques N. S. 19: 219-228.

Klein JC 1982. Les groupements chionophiles de l'Alborz central (Iran). Comparaison avec leurs homolegues d' Asie centrale. - Phytocoenologia 10: 463-486.

Klein JC 1987. Les pelouses xérophiles d'altitude du franc sud de l'Alborz central (Iran). - Phytocoenologia 15: 253-280.

Klein JC 1988. Les groupements grandes ombellifères et a xerophytes orophiles: Essai de synthèse à l'échelle de la région irano-iouranienne. - Phytocoenologia 16: 1-36.

Klein JC 1991. Endémisme à l'étage alpin de l'Alborz (Iran). - Flora et Vegetatio Mundi 9: 247-261.

Naqinezhad A, Attar F, Jalili A & Mehdigholi K 2010. Plant biodiversity of wetland habitats in dry steppes of Central Alborz. - Australian Journal of Basic and Applied Sciences 4/2: 321-333.

Naqinezhad A, Jalili A, Attar F, Ghahreman A,Wheeler BD, Hodgson JG, Shaw SC & Maassoumi AA 2009. Floristic characteristics of the wetland sites on dry southern slopes of the Alborz Mts., N. Iran: The role of altitude in floristic composition. - Flora 204: 254–269.

Noroozi J & Ajani Y 2013. A new alpine species of *Nepeta* sect. *Capituliflorae* (Labiatae) from Northwestern Iran. - *Novon* DOI: 10.3417/2012022.

Noroozi J, Ajani Y & Nordenstam B 2010a. A new annual species of Senecio (Compositae-Senecioneae) from subnival zone of southern Iran with comments on phytogeographical aspects of the area. - Compositae Newsletter 48: 4–23.

Noroozi J, Akhani H & Breckle SW 2008. Biodiversity and phytogeography of alpine flora of Iran. - Biodiversity and Conservation 17: 493-521.

Noroozi J, Akhani H & Willner W 2010b. Phytosociological and ecological study of the high alpine vegetation of Tuchal Mountains (Central Alborz, Iran). - Phytocoenologia 40: 293-321.

Noroozi J, Pauli H, Grabherr G & Breckle WS 2011. The subnival-nival vascular plant species of Iran: a unique high-mountain flora and its threat from climate warming. - Biodiversity and Conservation 20: 1319-1338.

Noroozi J, Willner W, Pauli H & Grabherr G 2013. Phytosociology and ecology of the high alpine to subnival scree vegetations of N and NW Iran (Alborz and Azerbaijan Mts.). - Applied Vegetation Science DOI: 10.1111/avsc.12031.

Pauli H, Gottfried M, Dullinger S, Abdaladze O, Akhalkatsi M, Benito Alonso, JL, Coldea G, Dick J, Erschbamer B, Fernández Calzado R, Ghosn D, Holten JI, Kanka R, Kazakis G, Kollár J, Larsson P, Moiseev P, Moiseev D, Molau U, Molero Mesa J, Nagy L, Pelino G, Puşcaş M, Rossi G, Stanisci A, Syverhuset AO, Theurillat J-P, Tomaselli M, Unterluggauer P, Villar L, Vittoz P & Grabherr G 2012. Recent plant diversity changes on Europe’s mountain summits. - Science 336: 353-355.

Razyfard H, Zarre S & Fritsch RM 2011. Four new species of *Allium* (Alliacea) from Iran. - Ann. Bot. Fenn. 48/4: 352-360.

Rechinger KH (ed.) 1963-2012. Flora Iranica 1-179. - Akademische Druck- u. Verlagsanstalt und Naturhistorisches Museum Wien. Graz & Wien.

Rechinger KH 1968. *Zerdana* (pp. 307-308) [Cruciferae]. - In: Rechinger KH (ed.). Flora Iranica 57. Akademische Druck u. Verlagsanstalt. Graz.

Rechinger KH 1987. *Sclerochorton* (pp. 366-366) [Umbelliferae]. In: Rechinger, K.H. (ed.) *Flora Iranica*, No. 162. Akademische Druck u. Verlagsanstalt. Graz.

Schweizer G 1972. Klimatisch bedingte geomorphologische und glaziologische Züge der Hochregion vorderasiatischer Gebirge (Iran und Ostanatolien). - In: Troll C (ed.) Landschaftökologie der Hochgebirge Eurasiens. - Franz Steiner Verlag GMBH, Wiesbaden: 221-236.

Walther GR, Beißner S, Burga CA 2005. Trends in upward shift of alpine plants. - Journal of Vegetation Science16: 541–548.

Zohary M 1973. Geobotanical foundations of the Middle East 2. - Fischer, Stuttgart.

Chapter 2:

Unknown elements of the subnival-nival flora of Iran

Three papers were published regarding to this subject:

Paper 1: A new annual species of *Senecio* (Compositae- Senecioneae) from subnival zone of southern Iran with comments on phytogeographical aspects of the area

Paper 2: *Gagea alexii* (Liliaceae), a new record from subnival zone of southern Iran with key and notes on sect. *Incrustatae*

Paper 3: A new alpine species of *Nepeta* sect. *Capituliferae* (Labiatae) from Northwestern Iran

Title of paper:

A new annual species of *Senecio* (Compositae- Senecioneae) from subnival zone of southern Iran with comments on phytogeographical aspects of the area

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A new annual species of *Senecio* (Compositae-Senecioneae) from subnival zone of southern Iran with comments on phytogeographical aspects of the area

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Abstract

A new species of *Senecio* sect. *Senecio* (Compositae-Senecioneae), viz. *Senecio subnivalis* Y. AJANI, J. NOROOZI & B. NORD. sp. nov., from subnival zone of Hezar mountain (Kerman Province), in the south of Iran, is described and illustrated. Distribution map and morphological comparisons of the species with its close relatives, *Senecio eligulatus* B. NORD., MOUSSAVI & DJAVADI, *S. iranicus* B. NORD., *S. kotschyanus* BOISS., and *S. dubitabilis* C. JEFFREY & Y. L. CHEN (syn. *S. dubius* LEDEB.) are given. The new species differs from these species mainly in size and shape of ligulate florets, leaf morphology, and pubescence of cypsela and vegetative parts. The accompanying species of *Senecio subnivalis* and some ecological features of its habitat are mentioned. The phytogeographical aspects of Hezar-Lalehzar mountains are discussed and distribution maps of 15 species are presented.

Keywords: Iran, new species, *Senecio*, subnival zone, phytogeography, endemism.

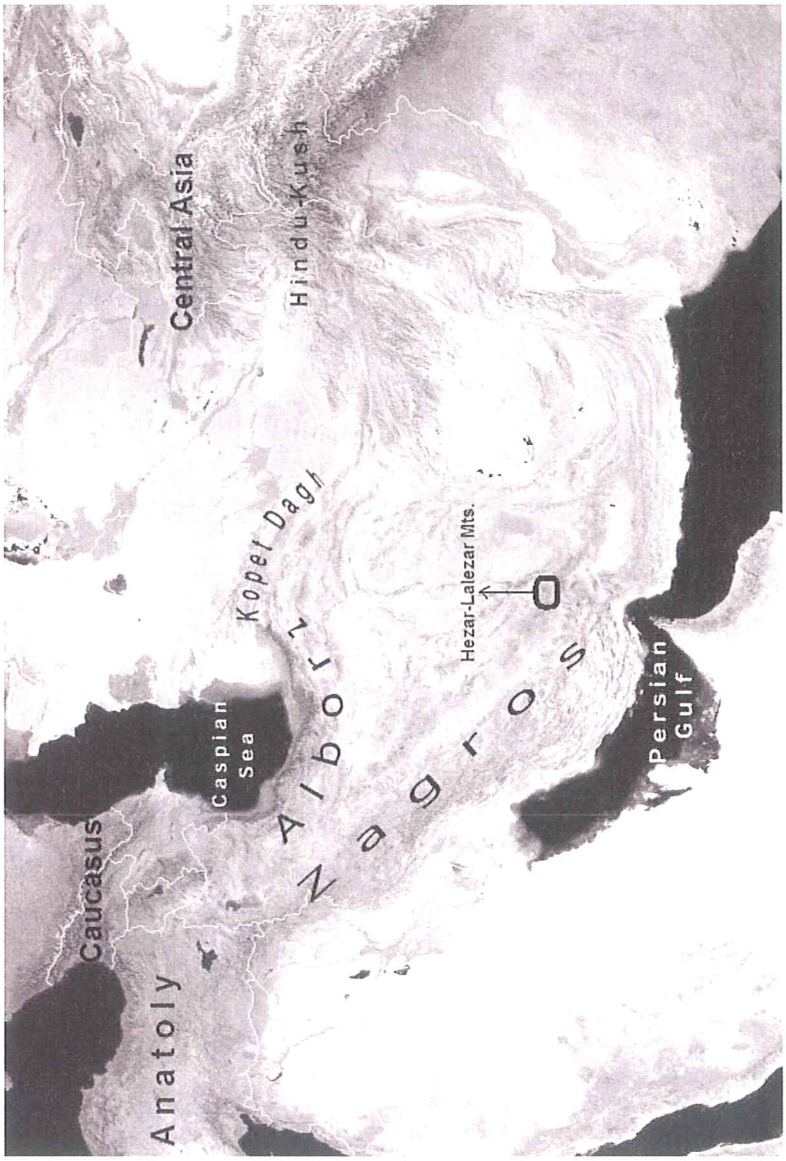

Fig. 1. Position of the Hezar-Lalehzar Mountains and adjacent mountain ranges.

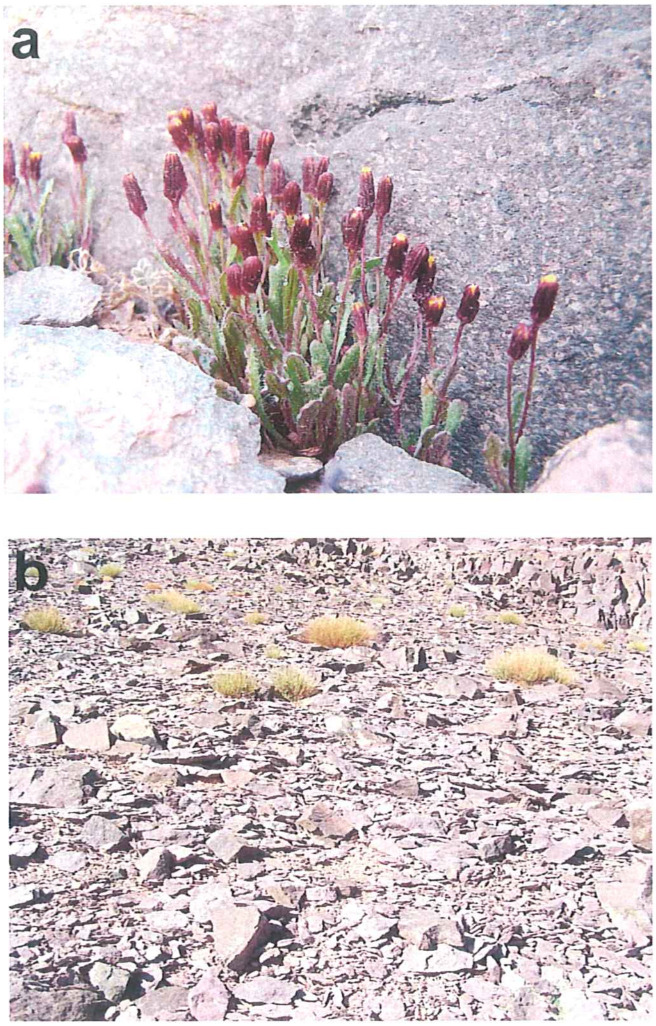

Fig. 2. (a) *Senecio subnivalis.*
(b) *Artemisia persica* community, the habitat of the new species at 4443m (photos J. NOROOZI).

Introduction

Compositae (Asteraceae) is the largest plant family in the flora of Iran (RECHINGER 1963–2007, GHAHREMAN & ATTAR 1999, JALILI & JAMZAD 1999). In the tribe Senecioneae the largest genus is *Senecio* L. with an almost cosmopolitan distribution and well over 1,000 species (NORDENSTAM 2007, PELSER et al. 2007, NORDENSTAM et al. 2009). In *Flora Iranica* (NORDENSTAM 1989) 25 species of *Senecio* were recorded. After transfers to the segregated genera *Jacobaea* MILL. and *Iranecio* B. NORD. and the description of one new species, twelve Iranian species of *Senecio* s.str. remain. Among those, six species are distributed in alpine and subnival mountain areas. Four of these species are local endemics, viz. *S. vulcanicus* BOISS., *S. iranicus* B. NORD., *S. kotschyanus* BOISS. and *S. eligulatus* B. NORD., MOUSSAVI & DJAVADI (NORDENSTAM 1989, ASSADI 1992, MOUSSAVI et al. 2001, NORDENSTAM et al. 2002).

This paper is based on a field expedition in 2009 to the poorly investigated alpine and subnival zone of Hezar-Lalehzar Mountains. These mountains with a highest elevation of 4465 m a.s.l. are isolated and located in the south of the country (Kerman Province) and surrounded by semi-desert lowlands (Fig. 1). The alpine and subnival plants of these mountains were first collected by BORNMÜLLER in 1892. FREITAG & KUHLE (1980) published a list of woody elements with ecological remarks of Jupar Mountain, which is located in the northern part of the range. The rate of endemism is high in these mountains especially at high altitudes. In recent years, *Senecio eligulatus* B. NORD., MOUSSAVI & DJAVADI (NORDENSTAM et al. 2002) and *Ferula hezarlalehzarica* Y. AJANI (AJANI & AJANI 2008) were described from this region.

Of the twelve Iranian *Senecio* species, seven species are annual, viz., *S. vulgaris* L., *S. vernalis* WALDST. & KIT., *S. glaucus* L., *S. kotschyanus*, *S. flavus* (DECNE.) SCH. BIP., *S. eligulatus* and *S. iranicus* (NORDENSTAM 1989, NORDENSTAM et al. 2002, MOUSSAVI et al. 2001). Since the new species showed some similarities especially to *S. iranicus* and *S. kotschyanus* and also somewhat to *S. eligulatus* and *S. dubitabilis* C. JEFFREY & Y. L. CHEN (1984) we compared it with the mentioned taxa (Table 1). The latter species was included in the *Flora Iranica* (NORDENSTAM 1989) in the key but without any description, since it has not yet been recorded from Iran. It has been treated (as *S. dubius* LEDEB.) in the *Flora USSR* (SCHISCHKIN 1961), *Flora of West Pakistan* (NASIR & ALI 1972), and *Flora of Kazakhstan* (PAVLOV 1966).

Material and Methods

The new species was discovered during a botanical excursion of first and second authors in the alpine to subnival zones of Hezar-Lalehzar mountains in late July 2009. A phytosociological relevé (size 100m^2) according to BRAUN-BLANQUET method (BRAUN-BLANQUET 1964) was sampled from the habitat of the new species (altitude 4443 m) to identify associated species. The ecological characteristics of the habitat were recorded. For distribution ranges of the relevant species, *Flora Iranica* (RECHINGER 1963–2007) and other recent monographs and revisions have been used.

Herbarium abbreviations follow THIERS, with the addition of the new acronym ACECR for Central Herbarium of Medicinal Plants, Iranian Academic Centre for Education, Culture and Research, Karaj, Iran.

Results and Discussion

Senecio subnivalis **Y. AJANI, J. NOROOZI & B. NORD., sp. nov.** (Figs. 2a, 3).

TYPE: Iran, Kerman Province, Rayen, Mt. Hezar, on the north side of summit, 29°30′44″N, 57°16′20″E, 4443 m, Y. AJANI & J. NOROOZI 396 (IRAN, holotype; ACECR, S, TARI, TUH, isotypes).

Herba annua erecta parva 1.5–5 cm alta laxe albolanata vel subglabra. Folia caulina sessilia integra vel paucidentata aut breviter lobata, spathulata–oblanceolata vel oblonga, apice obtusa–rotundata. Capitula solitaria vel pauca, pedunculata, heterogama. Involucrum anguste campanulatum–subcylindricum; involucri bracteae uniseriatae 8–9 lineares purpurascentes. Flosculi radii pauci inconspicui, corolla breviter ligulata, lamina 0.5–1.5 mm longa. Flosculi disci hermaphroditi; corolla tubulosa superne anguste campanulata 5-loba; lobi triangulari-ovati apice papillati. Antherae appendice anguste ovata obtusa incluso c. 1 mm longae, basi breviter sagittatae ecaudatae. Styli rami apice truncati pilis everrentibus breves. Cypselae anguste elliptico-oblongae 8–10-costatae puberulae. Pappi setae numerosae albae caducae.

Dwarf annual herb. Stems erect, 1.5–5 cm high, simple or branched, green or purplish, subglabrous or sparsely pubescent with lax, long white hairs. Leaves alternate, sessile, usually spathulate–oblanceolate or sometimes linear, 7–22×2–4 mm, entire or with few teeth or lobes, sparsely thinly pubescent, apex obtuse to rounded. Upper leaves similar to basal leaves but smaller, 4–7 mm long, ± lanceolate. Capitula heterogamous, single or 2–3 in lax corymb; peduncles 7–12 mm, laxly pubescent with long white hairs. Involucre narrowly campanulate–subcylindrical, 6–7 mm high, 3–4 mm wide; phyllaries uniseriate, 8–9, narrowly oblong-lanceolate, 5.5–6×1 mm, herbaceous, with narrow membranous margins, glabrous or with a few scattered hairs, 1–3-nerved, distinctly purplish, apically acute and puberulous; calyculus bracts few (2–3), 1–2 mm long, narrowly lanceolate. Receptacle flat, glabrous, minutely alveolate. Ray-florets 1–5, female, shortly ligulate; tube cylindric, 1–1.5 mm long, greenish-yellow, glabrous; lamina narrowly elliptic-oblong, 0.5–1.5 mm long, 0.5–0.7 mm wide, yellow, indistinctly veined, apically entire or bifid; style overtopping lamina, style branches 0.7–1 mm long, obtuse; disc-florets 10–15, hermaphroditic; corolla yellow, 3.5–4 mm, tubular and only gradually somewhat widening upwards, 5-lobed; lobes narrowly ovate, ca. 0.5 mm, midlined, apically papillate. Anthers 1 mm long, ecaudate, shortly sagittate; apical appendage narrowly ovate, obtuse; endothecium radial (cells elongate with thickenings on vertical walls); filament collar balusterform. Style branches linear-oblong, 0.5–0.8 mm long, apically truncate with short sweeping-hairs, stigmatic surfaces separated. Cypselas narrowly elliptic-oblong, 3–4 mm long, 1–1.5 mm wide, faintly 8–10-ribbed, sparsely puberulous with short obtuse duplex hairs. Pappus bristles numerous, white, 2.5–3.5 mm long, slender, minutely barbellate, caducous.

General distribution: Endemic to southern Iran (Fig. 5n).

Phenology: Flowering in mid–late July.

The morphological differences among *S. subnivalis, S. iranicus, S. eligulatus, S. dubitabilis* and *S. kotschyanus* are summarized in Table 1.

The new species might be confused with *S. dubitabilis* (which is not yet recorded from Iran; cf. above), but is distinguished by its ligulate though inconspicuous ray-florets. In the latter species the capitulum is truly discoid with all florets hermaphroditic and tubulate. Further examination of the species indicated perhaps more affinities with *S. eligulatus, S. kotschyanus* and *S. iranicus*. All of these have heterogamous capitula. The new species differs from *S. eligulatus* by its smaller size and by having single or few capitula, entire or paucilobate smaller leaves, and ray-florets glabrous with a short but distinct lamina. In *S. eligulatus*, capitula are more numerous, involucres broader with more numerous phyllaries, the leaves are pinnately lobate and larger, and the plant is taller, viz., 10–25 cm. Furthermore, the rayflorets of *S eligulatus* are reduced to a short puberulous tube without a lamina (NORDENSTAM et al. 2002 Fig. 1C).

S. subnivalis is also close to *S. iranicus* which is likewise a dwarf annual of subnival zone, but locally endemic to Damavand on the Alborz (Elburz) Mountains (NORDENSTAM 1989). The significant differences between these species are cypsela pubescence, present in the new species but absent in *S. iranicus*, and the usually eight ray-florets with well-developed lamina in the latter species. The differences from *S. kotschyanus*, which is locally endemic to alpine areas of Dena Mts. (south of Zagros), are also mainly in pubescence. In the new species the pubescence consists of lax and long hairs while *S. kotschyanus* has a more dense, partly copious hair-cover. For further differences, see Table 1.

Ecological aspects: *S. subnivalis* grows in real subnival zone with harsh climatic conditions. The ground is covered with large and small scree (ca. 85%). The vegetation cover is around 10% (Fig. 2b, Table 2).

Accompanying species: *Artemisia persica*, *Scrophularia subaphylla*, *Asperula glomerata* subsp. *condensata*, *Potentilla nuda*, *Ranunculus eriorrhizus*, *Astragalus melanodon*, *Nepeta lasiocephala*, *Veronica kurdica* subsp. *filicaulis*, *Psychrogeton alexeenkoi* and *Silene daenensis*.

Phytogeography and Conservation

Hezar-Lalehzar Mts. are biogeographically situated on the border between two important vegetation units, viz. the Irano-Turanian semi-desert *Artemisia* steppes and the northern Saharo-Arabian regions (ZOHARY 1973). The vegetation of these mountains from the lowlands to the summit of Hezar (4465 m) is dominated by *Artemisia* steppe, and the dominant species in the alpine and subnival zones is *Artemisia persica* (Fig. 2b). The phytogeographical patterns and relations in the high altitude areas of Iran differ from those of the lower regions (NOROOZI et al. 2008). Whereas the lowland flora of the region is influenced by Saharo-Arabian elements (ZOHARY 1973, WHITE & LÉONARD 1991, AKHANI 1994, 1997), the high altitude flora, especially of the alpine and subnival zones, is completely composed of Irano-Turanian elements. According to previous records and our own field work in this area, at least 28 taxa reach the subnival zone of these mountains, viz., *Senecio subnivalis*, *Arenaria minutissima*, *Tanacetum pamiricum*, *Artemisia persica*, *Cousinia fragilis*, *Psychrogeton amorphoglossus*, *P. alexeenkoi*, *Taraxacum primigenium*, *Crepis heterotricha* subsp. *heterotricha*, *Draba aucheri*, *Arabis caucasica*, *Kobresia humilis*, *Oxytropis kermanica*, *Astragalus tenuiscapus*, *A. melanodon*, *Acantholimon haesarense*, *Primula algida*, *Scrophularia subaphylla*, *Veronica kurdica* subsp. *filicaulis*, *Potentilla nuda*, *Ranunculus eriorrhizus*, *Trachydium depressum* subsp. *depressum*, *Asperula glomerata* subsp. *condensata*, *Veronica biloba*, *Nepeta lasiocephala*, *Silene nurensis*, *Silene daenensis* and *Gagea* sp.

All species mentioned are Irano-Turanian elements. 11% of them are endemic to Hezar-Lalehzar Mts., 27% to south-east Zagros, 50% to Zagros and 62% to Iran. Fig. 4 shows biogeographical relationships of vascular plants occurring in the subnival belts of Hezar-Lalehzar mountains and adjacent ranges. In spite of the high rate of species endemic of Iran (62%), the floristic relationships with

Hindu-Kush and Central Asia are remarkable (ca. 30% for both).

Six main distribution patterns for the subnival species of these mountains can be recognized:

1- Wide distribution from Zagros and Alborz to Hindu-Kush and/or Central Asia and Himalaya. Some examples are *Trachydium depressum* (see distribution map in NOROOZI et al 2008: Fig. 7d), *Draba aucheri*, *Primula algida* and *Kobresia humilis*. The importance of Central Asia as a source for the flora of the whole Irano-Turanian region was stressed by WENDELBO (1971).

2- Close floristic and phytogeographical relationship of Zagros and especially the mountains of southern Iran with Hindu-Kush and Central Asia. This pattern was demonstrated by WENDELBO (1971), HEDGE & WENDELBO (1978) and NOROOZI et al. (2008). The recently described *Ferula hezarlalehzarica* (Apiaceae) from Hezar-Lalehzar mountains, e.g. has close affinity to *F. koso-poljanskyi* and *F. hindukushensis* in Central Asia and Hindu-Kush mountains (AJANI & AJANI 2008). In the subnival zone of these mountains some species are Central Asian and Hindu-Kush elements with a disjunct distribution in Iran and reach their westernmost extension in central and northern Zagros (e.g., *Artemisia persica* [Fig. 5a]), south-east Zagros (e.g., *Psychrogeton alexeenkoi* [Fig. 5b]), or Hezar-Lalehzar Mts. (e.g., *Tanacetum pamiricum*).

3- Distribution across Iranian mountains. Several taxa are distributed in Zagros and Alborz and sometimes Kopet Dagh, such as *Potentilla nuda* (Fig. 5c), *Scrophularia subaphylla* (Fig. 5d) and *Oxytropis kermanica*.

4- Distribution across Zagros. The phytogeographical importance of such patterns was noted by HEDGE & WENDELBO (1978), AKHANI (2004, 2007) and NOROOZI et al. (2008). Some taxa of the subnival zone are distributed from Hezar-Lalehzar and adjacent mountains to central and/or northern Zagros, such as *Crepis heterotricha* subsp. *heterotricha* (Fig. 5e), *Taraxacum primigenium* (Fig. 5f), *Silene daenensis*, *S. nurensis* (Fig. 5g), *Veronica kurdica* subsp. *filicaulis* (see distribution map in NOROOZI et al. 2008: Fig. 8a), *Astragalus melanodon* and *Asperula glomerata* subsp. *condensata*, which well justifies the Zagros as a separate province as suggested by AKHANI (2007) and NOROOZI et al. (2008).

5- Distribution in the southern mountains of Iran (south-east Zagros). There is a strong link between Kerman, Shiraz and Yazd mountains in south Iran. In the subnival flora some species show this link, e.g., *Nepeta lasiocephala* (Fig. 5i), *Ranunculus eriorrhizus* (Fig. 5j), *Astragalus tenuiscapus* (Fig. 5k) and *Arenaria minutissima* (Fig. 5l). In addition to the mentioned species, some others, which belong to the alpine flora, have similar distribution patterns, e.g., *Astragalus rufescens* (Fig. 5h), *Arenaria bulica*, *Silene caroli-henrici*, *Cousinia longifolia* (see distribution map in NOROOZI et al. 2008: Fig. 11e), *C. sicigera, Chamaegeron asterellus, Scorzonera intricata* (see distribution map in NOROOZI et al. 2008: Fig. 11g), *Stachys obtusicrena* (see distribution map in NOROOZI et al. 2008: Fig. 11h), *Nepeta dschuparensis, N. glomerulosa* subsp. *carmanica, Cotoneaster persica, Potentilla poteriifolia, Ranunculus papyrocarpus, Onobrychis plantago, Astragalus abditus, A. confertiformis, A. heterodoxus* and *A. pseudoshebarensis*. The rate of local endemism in mountains of this area is remarkable too. The southern mountains of Iran (south-east of Zagros), which are strongly influenced by the aridity of central and southern Iranian and Arabian climate, are therefore suggested as a subunit of Zagros province.

6- Local endemics of Hezar-Lalehzar mountains (i.e., within the range of *Rubia caramanica*, Fig. 5m). The most important phytogeographical aspect of these mountains is the high rate of local endemism. Some subnival species which are local endemics of these mountains are *Cousinia fragilis, Acantholimon haesarense* and *Senecio subnivalis* (Fig. 5n). There are also many locally endemic species restricted to the subalpine and alpine zones of these mountains, such as *Allium cathodicarpum, A. lalesaricum, Nepeta rivularis, N. bornmuelleri, Dracocephalum polychaetum, Polygonum spinosum, Dionysia oroedoxa, D. rhaptodes, Leucopoa pseudosclerophylla, Acantholimon cupreo-olivascens, A. albocalycinum, A. kermanense, A. sirchense, Verbascum carmanicum, Semenovia suffruticosa, Rubia caramanica, Senecio eligulatus, Astragalus carmanicus, A. hezarensis* and *A. lalesarensis*. Most of these species are known only from their type location. The high rate of endemism indicates that these mountains could be recognized as a local center of endemism. The area is botanically less known and we strongly recommend detailed floristic and vegetation studies which may result in further taxa new to science or to Iran and which will clarify the biogeography of the region.

Mountains are hotspots for biodiversity and priority regions for conservation, because a single mountain may host a series of climatically different life zones over short elevational distances (KÖRNER 2004). The distribution and ecology of endemics differ considerably from overall biodiversity patterns and must be addressed appropriately in conservation strategies (ESSL et al. 2009). The southern Zagros has a very long history of land use (DJAMALI et al. 2009). In spite of a high rate of local endemism, especially in high altitudes of these mountains the protection of nature is very poor. The most important threat to the flora and vegetation of the region is high pressure of overgrazing, particularly by sheep and goat herds. Like other mountains of the country, these mountains are used as spring and summer pastures. Every year in the warm season, overcrowded herds are moved from adjacent lowland and deserts to high altitudes of these mountains with very poor control, resulting in threats to the narrowly distributed species and the natural vegetation, particularly in the fragile subalpine and alpine zones. The pressure of grazing is lower in subnival habitats. However, the smaller altitudinal distribution and the limited number of colonized habitats of very narrowly distributed endemics make these species especially vulnerable to climate change (Ohlemüller et al. 2008, Dirnböck et al. 2003). Especially in mountains like Hezar-Lalehzar where local endemic species cannot migrate to a nival zone (because of altitudinal limit of these mountains) or to other mountain ranges (because of the isolated situation), the risk of extinction increases by global warming. We strongly recommend the conservation of Hezar and Lalehzar mountains as protected area or National Park in order to protect the locally endemic species and vulnerable plant communities.

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References

Ajani, Y. & M. Ajani 2008. A new species of *Ferula* (Umbelliferae) from southern Iran. *Edinburgh J. Bot.* 65: 425–431.

Akhani, H. 2004. A new spiny, cushion-like *Euphorbia* (Euphorbiaceae) from south-west Iran with special reference to the phytogeographic importance of local endemic species. *Bot. J. Linn. Soc.* 146: 107–121.

Akhani, H. 2007. Diversity, biogeography, and photosynthetic pathways of *Argusia* and *Heliotropium* (Boraginaceae) in South-West Asia with an analysis of phytogeographical units. *Bot. J. Linn. Soc.* 155: 401–425.

Assadi, M. 1992. New species and new plant records from Iran. *Iranian J. Bot.* 5(2): 57–63.

Braun-Blanquet, J. 1964. *Pflanzensoziologie. Grundzüge der Vegetationskunde.* Springer-Verlag, Wien.

DIRNBÖCK, T., DULLINGER, S. & G. GRABHERR 2003. A regional impact assessment of climate and land-use change on alpine vegetation. *J. Biogeography* 30: 401–417.

DJAMALI M., DE BEAULIEU, J.-L., MILLER, N. F., ANDRIEU-PONEL, V., PONEL, P., LAK, R., SADEDDIN, N., AKHANI, H. & H. FAZELI 2009. Vegetation history of the SE section of the Zagros Mountains during the last five millennia; a pollen record from the Maharlou Lake, Fars Province, Iran. *Veget. Hist. Archaeobot.*18: 123–136.

ESSL, F., STAUDINGER, M., STÖHR, O., SCHRATT-EHRENDORFER, L., RABITSCH, W. & H. NIHLFELD 2009. Distribution patterns, range size and niche breadth of Austrian endemic plants. *Biol. Conservation* 142: 2547–2558.

FREITAG, H. & M. KUHLE 1980. A plant list from the Kuh-e-Jupar (S.E. Iran), with some ecological remarks. *Willdenowia* 10: 161–169.

GHAHREMAN, A. & F. ATTAR 1999. *Biodiversity of Plant Species in Iran.* Tehran: Tehran University Publication (In French & Persian).

HEDGE, I. C. & P. WENDELBO 1978. Patterns of distribution and endemism in Iran. *Notes Roy. Bot. Gard. Edinb.* 36: 441–464.

JALILI, A. & Z. JAMZAD 1999. *Red Data Book of Iran.* Tehran: Research Institute of Forests and Rangelands.

JEFFREY C. & Y.-L. CHEN 1984. Taxonomic studies on the tribe Senecioneae (Compositae) of Eastern Asia. *Kew Bulletin* 39: 205–446.

KÖRNER, C. 2004. Mountain biodiversity, its causes and function. *Ambio, Special Report* 3: 11–17.

MOUSSAVI, M., DJAVADI, B. & B. NORDENSTAM 2001. Rediscovery of *Senecio kotschyanus* in Iran. *Compositae Newsl.* 36: 77–80.

NASIR, E. & S. I. ALI 1972. *Senecio dubius. In*: NASIR, E. & S. I. ALI (eds.), *Flora of West Pakistan* 782. Rawalpindi: Stewart Herbarium, Gordon College.

NORDENSTAM, B. 1989. *Senecio. In*: RECHINGER, K. H. (ed.), *Flora Iranica* 164: 59–95. Akad. Druck- u. Verlagsanst., Graz.

NORDENSTAM, B. 2007. Tribe Senecioneae. *In*: KADEREIT, J. W. & C. JEFFREY, (eds.), *The Families and Genera of Vascular Plants* (KUBITZKI, K., ed.), vol. VIII, Flowering Plants, Eudicots, Asterales, pp. 208–241. Springer, Berlin.

NORDENSTAM, B., MOUSSAVI, M. & B. DJAVADI 2002. A new annual species of *Senecio* from Iran. *Compositae Newsl.* 38: 42–46.

NORDENSTAM, B., PELSER, P. B., KADEREIT, J. W. & L. E. WATSON 2009. Chapter 34. Senecioneae. *In:* FUNK, V.A., SUSANNA, A., STUESSY, T. F. & R. J. BAYER (eds.), *Systematics, evolution, and biogeography of Compositae*, pp. 503–525. IAPT, Vienna, Austria.

NOROOZI, J., AKHANI, H. & S. W. BRECKLE 2008. Biodiversity and phytogeography of the alpine flora of Iran. *Biodiversity and conservation* 17(3): 493–521.

OHLEMÜLLER, R., ANDERSON, B. J., ARAÚJO, M. B., BUTCHART, S. H. M., KUDRNA, O., RIDGELY, R. S. & C. D. THOMAS 2008. The coincidence of climatic and species rarity: high risk to small-range species from climate change. *Biology Letters* 4: 568–572.

PAVLOV, N. B. (ed.) 1966. *Senecio dubius*. *In*: *Flora of Kazakhstan* Vol. 9: 148, 161. Izdatelstovo Nauk USSR.

PELSER, P. B., NORDENSTAM, B., KADEREIT, J. W. & L. E. WATSON 2007. An ITS phylogeny of tribe Senecioneae (Asteraceae) and a new delimitation of *Senecio* L. *Taxon* 56: 1077–1104.

RECHINGER K. H. (ed.) 1963–2007. *Flora Iranica*, Vols. 1–177. Akad. Druck- u. Verlagsanst., Graz.

SCHISCHKIN, B. K. 1961. *Senecio* L. *In*: KOMAROV, V. L. et al. (eds.), *Flora of the U.S.S.R.* 26: 699–788. Academiae Scientarum URSS.

THIERS, B. [continuously updated]. *Index Herbariorum*: A global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. http://sweetgum.nybg.org/ih.

WENDELBO, P. 1971. Some distributional patterns within the Flora Iranica area. *In*: DAVIS, P. H., HARPER, P. C. & I. C. HEDGE (eds.), *Plant Life of South-West Asia*, pp. 29–41. Edinburgh.

WHITE, F. & J. LÉONARD 1991. Phytogeographical links between Africa and Southwest Asia. *Flora et Vegetatio Mundi* 9: 229–246.

ZOHARY, M. 1973. *Geobotanical Foundation of the Middle East*, Vol. 1–2. G. Fischer Verlag, Stuttgart (Geobot. Sel. 3).

Table 1. Morphological comparison between *Senecio subnivalis, S. eligulatus, S. iranicus* and *S. dubitabilis.*

Characters	*Senecio subnivalis*	*S. iranicus**[1]	*S. eligulatus**[2]	*S. dubitabilis**[3]	*S. kotschyanus**[4]
Height (cm)	1.5–5.5	1–4	10–25	5–30	1–5(–10)
Plant pubescence	Lax with scattered long hairs	Sparsely araneose to lanate	Lax pubescence esp. on peduncles and involucre	Glabrous or pubescent with white long hairs	Densely white-villous
Leaves (shape; margin; dimension)	Spathulate; entire or 2–3-lobate; 0.7–2.2×0.2–0.4 cm	Linear-oblanceolate; entire or dentate to pinnatilobate; 0.3–2 ×0.1–0.3 cm	Oblong, oblanceolate; pinnatilobate with dentate lobes: 2–5×1–2 cm	Spathulate, oblong–lanceolate-linear; entire or shortly pinnatilobed; 3–7×0.3–2 cm	Spathulate, oblanceolate; subentire, dentate or lobate; 1–3×0.1–0.8 cm
Capitula (number; sexuality)	Single or few; heterogamous	Single or few; heterogamous	Several–numerous; heterogamous	Few; homogamous	Single or few (rarely many); heterogamous
Phyllaries (number; shape; dimension; venation)	8–9; linear; 5–5.5×0.8–1 mm; with 3 distinct lines	11–15, oblong or linear-oblanceolate; 4–4.4×0.7–2 mm; 1(–3) indistinct lines	11–13, linear-lanceolate, 5–8×1 mm, with 2–3 distinct lines	15, linear-oblong–lanceolate, 5–10 mm, with 3 distinct lines	8–14; oblong or oblong–lanceolate; 5–7.5×0.7–1.2; with single distinct line

Marginal female florets (number; shape)	1–5; lamina narrowly elliptic-oblong–linear, 1.5×0.5 mm, entire or bifid, indistinctly veined	8; lamina oblong or elliptic-oblong, 3.5–6×1.4–3 mm, 4-veined, minutely 3-fid	Few (1–5?); lamina absent; corolla reduced to a narrow puberulous tube 1.5 mm long	Absent	5–6; lamina oblong, 1.5–3×1–2 mm, distinctly 3-lobed
Cypselas (length; pubescence)	3 mm; sparsely appressed villous with short duplex hairs	2.4–2.8 mm; glabrous	2 mm; puberulous with appressed short hairs	3–3.5 mm; Densely shortly villous	3.5 mm; appressed villous between ribs with short setiform hairs

*[1] data from NORDENSTAM (1989).

*[2] data from NORDENSTAM et al. (2002).

*[3] data from SCHISCHKIN (1961); PAVLOV (1961); JEFFREY & CHEN (1984); NASIR & ALI (1972).

*[4] data from NORDENSTAM (1989) and MOUSSAVI et al. (2001).

Table 2. Species composition of the *Artemisia persica* community (habitat of *Senecio subnivalis*) based on one phytosociological relevé from subnival zone of Hezar mountains, north slope of the highest peak. The symbols show cover-abundance of each species according to the method of Braun-Blanquet (1964), where 1= <5% [or over 50 small plants or 1–5 large plants], += <1% [1–5 small plants].

Relevé	**1**
Coordinates:	29°30'44"N 57°16'20"E
Sample area (m^2)	100
Inclination(°)	20
Altitude (m)	4443
Aspect	NE
Vascular plants (%)	10
Scree (%)	85
Solid rock (%)	3
Bare ground (%)	2
Litter (%)	0.5
Richness	11
Species	**cover-abundance**
Artemisia persica	1
Asperula glomerata subsp. *condensata*	1
Nepeta lasiocephala	1
Astragalus melanodon	1
Ranunculus eriorrhizus	1
Senecio subnivalis	+
Potentilla nuda	+
Scrophularia subaphylla	+
Veronica kurdica subsp. *filicaulis*	+
Psychrogeton alexeenkoi	+
Silene daenensis	+

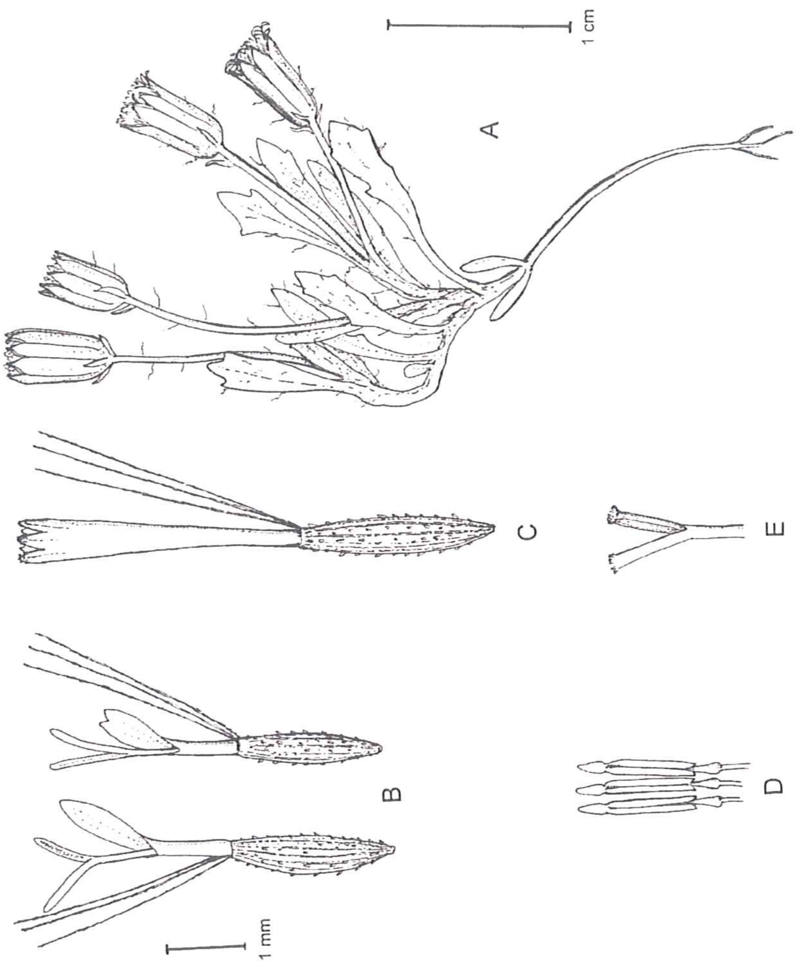


Fig. 3. *Senecio subnivalis*, drawn from isotype in S.
A Habit. B Ray-florets. C Disc-floret. D Stamens. E Style branches from disc-floret. Del. B. NORDENSTAM.

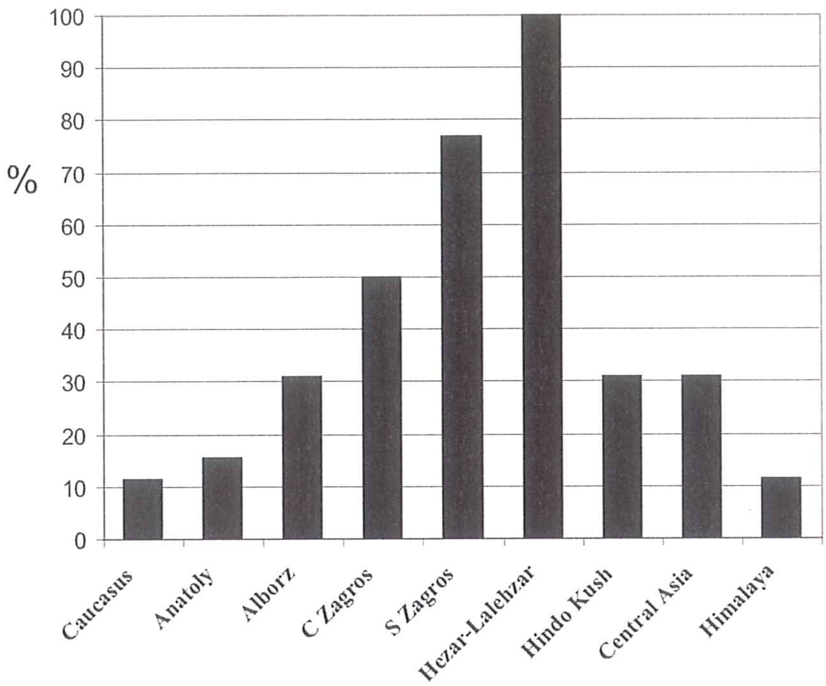
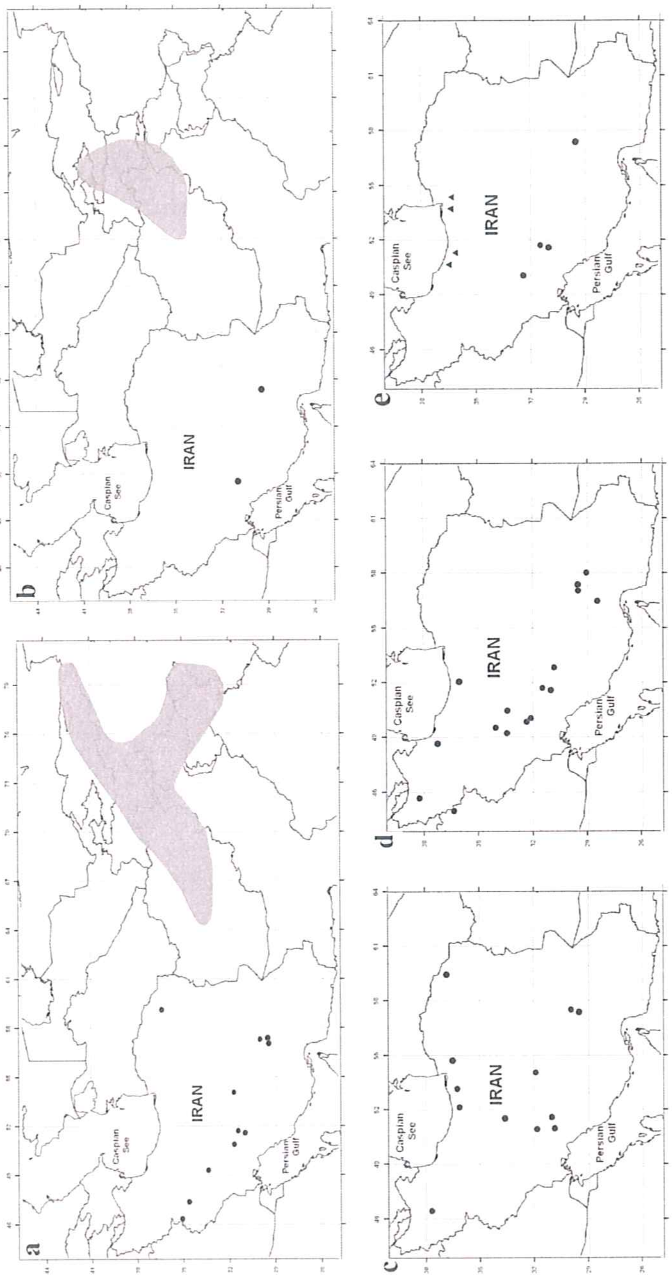
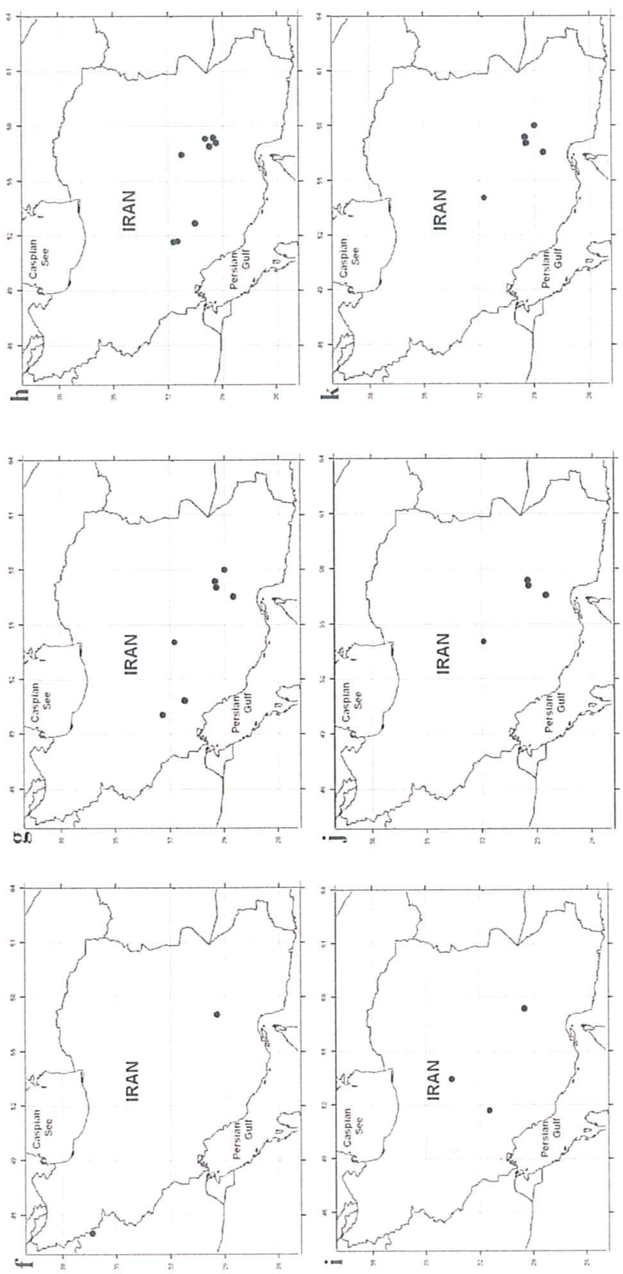


Fig. 4. Biogeographical relationships of vascular plants occurring in the subnival belts of Hezar-Lalehzar mountains with adjacent mountain ranges. (C Zagros= central and north of Zagros; S Zagros= south-east of Zagros except Hezar-Lalehzar Mts.).


a
b
c
d
e
IRAN
Caspian See
Persian Gulf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IRAN
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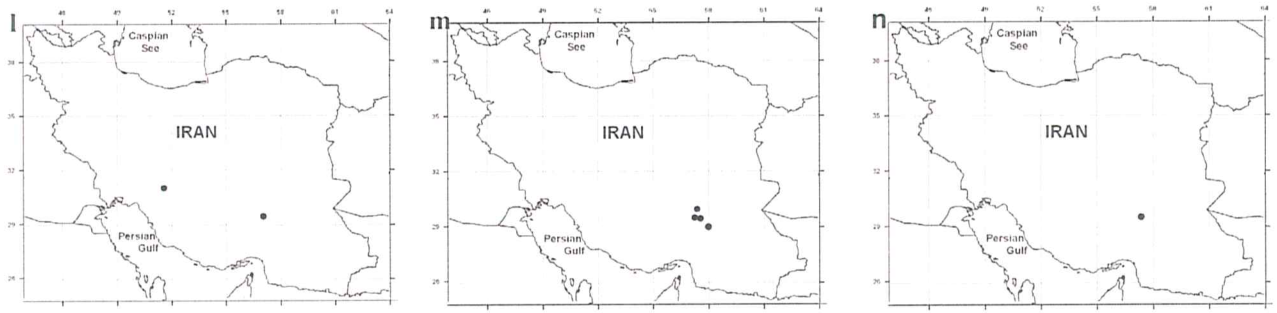

Fig. 5. Different distribution patterns of species occurring in subnival zone of Hezar-Lalehzar mountains: (a) *Artemisa persica*, (b) *Psychrogeton alexeenkoi*, (c) *Potentilla nuda*, (d) *Scrophularia subaphylla*, (e) *Crepis heterotricha* subsp. *heterotricha* (circle) subsp. *lobata* (triangle), (f) *Taraxacum primigenium*, (g) *Silene nurensis*, (h) *Astragalus rufescens*, (i) *Nepeta lasiocephala*, (j) *Ranunculus eriorrhizus*, (k) *Astragalus tenuiscapus*, (l) *Arenaria minutissima*, (m) *Rubia caramanica* (n) *Senecio subnivalis*.

Title of paper:
Gagea alexii (Liliaceae), a new record from subnival zone of southern Iran with key and notes on sect. *Incrustatae*

Authors: Yousef Ajani, Jalil Noroozi, Igor G. Levichev

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GAGEA ALEXII (LILIACEAE), A NEW RECORD FROM SUBNIVAL ZONE OF SOUTHERN IRAN WITH KEY AND NOTES ON SECT. *INCRUSTATAE*

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Abstract

Gagea alexii Ali & Levichev (*G.* sect. *Incrustatae* Levichev) is recorded from the subnival zone of the southern mountains of Iran, the Hezar Mts. (Kerman province). Plant associates and some ecological aspects of the habitat of the species are discussed. A distribution map and expanded description of the *G. alexii,* including a cross-section of the peduncle is given. The morphological comparison of this species with its close relatives is also provided. The characters of the *G.*sect. *Incrustatae* and a key for specific identification are presented. The occurrence of this species in the subnival zone of the Hezar Mts. is a further evidence of the close floristic affinity of the southeastern Zagros with the Hindu Kush and Central Asia especially at high altitudes.

Introduction

Gagea Salisb. (Liliaceae) is a fairly large genus in Iran and its members show much variations in morphology. Several new species and records have been documented by various authors, therefore the number of species belonging to *Gagea* is increased to 35 in Iran (Assadi, 1988; Wendelbo & Rechinger, 1990; Akhani, 1999; Levichev, 1999a; Zarrei & Zarre, 2005). However, Zarrei *et al*., (2007), after some modifications, recognized only 26 species. We have strong grounds to believe that, there are many more taxa (± up to 40) in Iran, some of which are not yet correctly named. According to Levichev (1999b) and Peterson *et al*., (2008) the existence of any undescribed species of this genus in the southwest and Mediterranean region is almost certain.

Gagea alexii Ali & Levichev was described from northern Pakistan (Chitral, including boundary area with Afghanistan) and eastern Tajikistan (Ali & Levichev, 2007). This species was recently collected for the first time from the subnival zone of the Hezar-Lalehzar mountains, southern Iran (Kerman province) along with *Senecio subnivalis* Y. Ajani, J. Noroozi & B. Nord (Noroozi *et al*., 2010).

G. alexii belongs to the *G.* sect. *Incrustatae* Levichev (Ali & Levichev, 2007). According to Wendelbo & Rechinger (1990), *G. circumplexa* Vved is the only species of this section present in Iran. However, recently Zarrei *et al*., (2007) mentioned that it should be treated as synonym of *G. setifolia* Baker., but, *G. setifolia* is placed in the sect. *Platyspermum* Boiss. In this article, the separation and correct interpretation of *G. alexii* from widely distributed *G. setifolia* at low altitudes is discussed.

Material and Methods

Population of *G. alexii* has been surveyed in the summer 2009 in Hezar-Lalehzar Mts.: Iran, Kerman province, Rayen, at summit of Hezar mountain, on scree beds, 29°30′41″N, 57°16′23″E, 4455 m, 19 VII 2009, Y. Ajani, J. Noroozi 395. Morphological studies have been conducted on living plants. Vouchers are deposited in ACECR Herbarium- Acronym for the Central Herbarium of Medicinal Plants (Iranian Academic Centre for Education, Culture and Research. This herbarium is not indexed in Index Herbariorum). Morphological characters within the limits of *G.* sect. *Incrustatae* were repeatedly studied on living specimens in the nature and culture (Levichev, 1999b, 2002).

Result and Discussion

For the "Flora Iranica", the account of the genus *Gagea* was primarily prepared by P. Wendelbo (1927-1981), however, after the death of Wendelbo, it was finalized by Karl Heinz Rechinger (Wendelbo & Rechinger, 1990). Analysis of the texts and images clearly showed incorrect nomenclature of some taxa (expert's opinion I.G. Levichev); particularly concerning *G. setifolia*. In Kew (K), one of the syntypes bear the label: "Pakistan, Kurrum valley, Ally Khel, [17 IV 1879] J.E.T. Aitchison n104", the label, is also signed by P. Wendelbo (04.1958), which he designates as lectotype of *G. setifolia*. However, this choice of the lectotype had never been published and consequently it was only indicated recently (Ali & Levichev, 2007: 54).

The specimen of lectotype *G. setifolia* (Aitchison n104, K) and the image published on Tab. 10 under name *G. setifolia* (Wendelbo & Rechinger, 1990), is of two different species from two different subdivisions of the genus, i.e.: for *G.* sect. *Platyspermum* and for *G.* sect. *Incrustatae* respectively. Features of the last taxon (mixed with attributes of *G. aitchisoniana* A.Terracc.) under name *G. setifolia,* appear in text on page 28 Flora Iranica: "... planta in sicco atroviridis.. ", "... folium basale... glabrum... ", "... tepala 3-4.5 mm lata... ". Such characteristics don't correspond with the specimen of *G. setifolia* in the specified lectotype. The plants of the lectotypus (Aitchison n104) are in a stage of flowering, but already have a yellow shade, all leaves and peduncle are incrusted along the longitudinal edges by a hard superficial collenchymas, narrow tepals of the perianthium are long pointed. Rigidity and a characteristic ribbing of all parts of a plant, sharp perianthium tepals, as well as fast loss of a green shade are all characteristic features of *G.* sect. *Platyspermum*.

Associations of *G. aitchisoniana* (and indirectly *G. alexii*) with *G. setifolia* begin with a combination of *G. setifolia* var. *aitchisoniana* (A.Terracc.) Pascher. Subsequently, *G. setifolia* has been considered having a restricted distribution to alpine mountains of the Pamir (Ikonnikov, 1963; Vvedensky, 1963: 222). Later on inaccurate information has increased because of its inclusion in *G. iliensis* M.Pop. (Vvedensky, 1971: 33). The diagram of this last species (Goloskokov, 1958, Tab. 11, fig. 9) does not correspond at all with the specimen "Aitchison n104". All of the above-stated facts compelled us to describe the high-altitude plants from Pamir and Pakistan under the name *G. alexii.*

The distribution of the species of *G.* sect. *Incrustatae* are disjunctive among the plains and mountains of the Irano-Turanian region, from Lake Balkhash up to Persian Gulf, and from Anatolia up to the Western Himalayas.

In view of the morphological features, *G.* sect. *Incrustatae* have a special position in the genus. In some representatives of this section, separate features of other genera of lily are present. For example in the genus *Tulipa,* there are a sharp crest in the bottom of a bulb, vertical stolons which are deepening, a grey, easily erased wax covering of an epidermis etc. are percent From this section 9 taxa are known, one of which (from range, Pamir-Alaj) to be studied in detail and for this reason it has not been included in the key (given below).

All representatives of the genus including this section the ontogeny consists of annually replaced shoots. Each shoot develops in two years and forms cyclic annual roots (Levichev, 1999a, 2001a; 2001b). In the first cycle from the bottom scale, roots and one bud are formed from which the shoot in the second cycle develops. Roots of the first cycle usually have species-specific value. Quite often, these roots are ageotropically focused, strongly incrassate and also are very rigid. It is highlighted by scalarified roots especially in *G. circumplexa*. After dying off scalrified roots remain intact for several years. Besides mechanical protection of a bulb, empty, thick-walled cells of these roots (Levichev, 1999a, fig. 5), keep an additional stock of moisture. In other species, roots of the first cycle, are also focused geotropically and neither they differ in thickness nor from the roots of second cycle.

Features of the basal leaf and peduncle, also possess an interesting specificity. An illustration of the cross-section forms in the genus *Gagea* has been used for the first time for a basal leaf in *G. lutea* (L.) Ker Gawl. (Oeder, 1768, Tab. 378) and for a peduncle in *G. spathacea* (Hayne) Salisb. (Müller, 1775. Tab. 612), and also, as an evident distinctive indication that there are other species of *Gagea* in Sicily (Lojacono, 1909, Tab. 7, 8, 10). The form and anatomical characters of the leaf and peduncle are recognized as important and reliable taxonomic criteria for the differentiation of sections of the genus (Davlianidze, 1976: 23-24; Levichev, 1982a: 18). For this reason, images showing the features of epidermis, collenchyma, bundles, fistulas etc. may indicate a new species (Levichev, 1981, 1982b, 2001, etc.; Krasovskaya & Levichev, 1986; Peruzzi *et al*, 2007; Ali and Levichev, 2007; Hamzaoğlu *et al.*, 2008; 2010, etc.). With similar analytical species diagram (Levichev, 2002: 232) it is preferable to refer as well publications of surveys (Levichev, 1997; Peruzzi *et al.*, 2008, etc.). The form of a peduncle is especially specific. As it is established, that the second basal leaf (as well all others leaves in an inflorescence) accretes with a peduncle from the basis up to an inflorescence and functions as the lower floral leaf (Levichev, 2001a: 8, 32, Tab. 8, fig. 8, 16-20; 2001b). Accretion forms a dissymmetric and the specific configuration of the transverse section of the peduncle.

In addition to what has already been published (Levichev, 1990; Peterson *et al.*, 2008) herewith a detailed description of sect. *Incrustatae* is presented.

Plants are smooth, elastic, soft, dark and blue-green, often with wax for a short time (bloom). The vegetative reproduction is known only in *G. balchaschensis* M.Pop. Deepening of a bulb during seed reproduction occurs by means of geotropic stolon which at a young age annually lowers a replacement bulb to a greater depth (*G. incrustata* Vved., *G. iliensis*). Basal leaf always one, unifacial type, on cross-section roundish, often fistulose, with a ring arrangement of vascular bundles, *G. incrustata* and *G. iliensis* have it in 1/4 - 1/2 accretes with a peduncle, in other species it is free. Second basal leaf always accretes with a peduncle, resulting in a partially or completely enveloped peduncle in a circle, and is separated by means of the lower floral leaf. Peduncle smooth, in cross-section roundish or unsymmetrically roundish with a ring arrangement of vascular bundles. Inflorescence 1-3 (-4) flowered, umbrella-shaped, leaves and pedicles are collected in a verticil. Sometimes for old and large specimens, the lower floral leaf is located below a common verticil, the smallest leaves may be present on pedicles. Pedicles often shorter than a perianth and straight. Capsule spherical; seeds thin-flat, with a small arillus on the chalazal end, easily dispersed by the wind.

Key for the Identification of species belonging *G.* sect. *Incrustatae*

1 + Tunics of the bulb continue to a well pronounced long neck..........................2
- Tunics of the bulb without or with a very short neck..................................5

2 + Neck coriaceous, parchment-like, in the form of the whole or disruptate tube; a basal leaf in cross-section roundish, with lateral flattening along the top...........3
- Neck fiber-like, splitting in the filament; plants very small, 1-2 flowered; a vegetative bulbil semi teardrop-like with its own short sclerified roots; the internal tepal widely rounded..................... ***G. balchaschensis*** M.Pop. 1936, in sched.

3 + Tunics of bulb not hidden under roots; pedicles shorter than a perianth; the base of the bulb with downwards focused crest.. 4
- Tunics of bulb hidden under a dense braiding from the thick, ageotropicly focused sclerified roots; basal leaf with a small central fistula and the poorly-concave ventral surface; tepals elliptic; pedicles 1.5-2 times longer than tepals............... ....***G. circumplexa*** Vved. 1952, Not. Syst. (Tashkent), 13: 28.

4 + Tunics of bulb thickly coriaceous, covered by the comb-type ledges; the first basal leaf without a fistula, accretes with a peduncle up to level of soil.................... ....***G. incrustata*** Vved. 1941, Fl. Uzbekist. 1: 542, 416.
- Tunics of bulb smooth, thickly coriaceous, splits longitudinall; tepals widely elliptic; first basal leaf with a small fistula in the center, on 1/4 accretes with the peduncle. ....***G. iliensis*** M.Pop. 1936, Bull. Kazakh. Gosud. Univ. 1: 93, fig.

5 + Flowers narrowly bell-shaped; tepals narrowly-lanceolate;4-5leaves at the base of the inflorescence...6
- Flowers widely bell-shaped on short pedicles; tepals widely elliptic, rounded at top (in the end of flowering their tips are convolute and seem acute, 2 -3 leaves at the base of the in florescence. The bulb with very plentiful thin roots and is often greatly disproportianate. ***G. aitchisoniana*** A.Terracc., 1904, Boll. Soc. Ort. Palermo, II, fasc. 4: 5. (*G. setifolia var. aitchisoniana* (A.Terracc.) Pascher, 1905. Repert. Sp. Nov. Regni Veg., 1: 193.....................***G. setifolia*** sensu Wendelbo et Rech.f. 1990, p. p.)

6 + Basal leaf long, in 1.5-2 times exceeding the inflorescence; alpine plants..........7
- Basal leaf does not exceed inflorescence; pedicles are in different length, the longest are 2-3 times longer than a perianth, tepals linearly extended; plants of lower altitude............***G. luteoides*** Stapf, 1885, Denkschr. Acad. Wien, 50, 2: 80.

7 + Tepals elongated-lanceolate, pointed at top; pedicles of different lengths, shorter or are equal to tepals; lower leaf present at the base of inflorescence is lanceolate and proportional to an inflorescence......................***G. alexii*** Ali et Levichev, 2007. Fl. Pakist. 215: 57, fig. 17, C-H (*G. setifolia* sensu Wendelbo et Rech.f. 1990, p. p.)
- Tepals (especially internal) rounded at top; pedicles in 1.5-2 times longer than perianth; the lower leaf of the inflorescence narrow, exceeding the inflorescence ....***G. kopetdagensis*** Vved. 1932, in Fl. Turkmen. 1, 2: 260.

The original description of the *G. alexii* in Flora of Pakistan is deficient in the features of fruits (Ali & Levichev, 2007). In this paper, additional characters are given, including the dimension, texture and shape of peduncle, seed, and fruitcase, which are described and illustrated (Figs. 1 & 2).

Gagea alexii Ali et Levichev

Holotype: Chitral, N Pakistan., *J.D.A . Stainton* 2847(BM)

Plants single, (8-)10-15 cm, smooth, blue-green. Bulb 8-10 (-13) mm in diameter, oviform, covered by greyish-brown, thin-coriaceous, continued in a fiber-like neck (0.5-1 cm long) tunics, without thickened *sclerified* roots. Generative specimens without bulbils. Peduncle 3-11 cm long, in cross-section pressed-roundish, about 2-3 mm in diameter (Fig. 2A & B). Basal leaf single, up to 13 (-17 cm), curved, linear (circular in fresh, pressed in dried), almost twice exceeding the inflorescence, 1-2 mm broad, in cross-section roundish, with little concave ventral surface (Fig. 1A). Leaves on peduncle 2-3(-5), in whorl; lower are equal or are longer inflorescence, narrowly-lanceolate, 2-3 (-4) mm broad, gradually pointed, in cross-section keel-shaped, upper diminishing (Fig. 1A & B). Inflorescence 1-3 (-5)-flowered; umbrella-shaped, pedicles equal or unequal, extended, 0.5-20 mm long. Tepals narrowly-lanceolate, 8-15 mm long, elongating at anthesis, 0.9-1.7 (-3) mm broad, inside pale yellow, outside green, internal palea-bordered, little shorter and already than external, at apical parts pointed at hooded tip. Anthers brownish (yellow), linear (3 mm long), dehiscence oblong (about 1.7 mm long). Ovary narrowly-oval. Capsule in fruiting spherical, 9-10 mm, glabrous, green or greenish magenta. Seeds thin-flat, triangular, 3 × 2.5 mm, yellow, glossy, rugo-faveolate (Fig. 1C).

General distribution: E Tajikistan, N Pakistan and S Iran. Presence in E Afghanistan is probable (Fig. 3A).

In drawing 2A the cross-section of a peduncle at 4 cm above a bulb is represented. Epidermis I- layered, covered by cuticle. Followed by 3-4 layered hypodermis. Vascular bundles 13, on the periphery forming an incorrect ring, phloem usually roundish, conic xylem, both are surrounded by sclerenchyma. Central parts including only spongy with sclerenchyma. Cross-section of a peduncle 2-3 mm above a bulb. Epidermis 2 layered, covered by cuticle. Vascular bundles completely 11, a ventral surface (concerning a dorsal rib accreting with a peduncle of the second basal leaf) a little concave (Fig.2B).

The close relatives of *G. alexii* are *G. aitchisoniana*, *G. luteoides* and *G. circumplexa.* All these species are placed in *G.* sect. *Incrustatae*. Two later species are distributed in Iran (Assadi, 1988; Wendelbo & Rechinger, 1990). Although, *G. luteoides* has been recorded from northwest Iran, Arasbaran protected area, but it has been reduced to the synonymy of *G. liotardii* (Sternb.) Schult. et Schult. f. (Assadi 1988; Zarrei *et al.*, 2007)[2]. These problems demand special and separate studies. In this paper, we have accepted *G. luteoides* and *G. circumplexa* as distinct species for flora of Iran.

G. alexii differs from *G. aitchisoniana* in having narrow and pointed tepals. In this species the breadth of tepals is 0.9-1.7 mm and apical parts are pointed, but in *G. aitchisoniana* they are broader and seem to be pointed. *G. alexii* differs from *G. circumplexa* by the absence of thick sclerified roots. This species differs from *G. luteoides* by the short pedicels and a long basal leaf, which are 0.5-2 mm, 10-15 cm in *G. alexii* and 15-30 mm, 6-12 cm in *G. luteoides*, respectively.

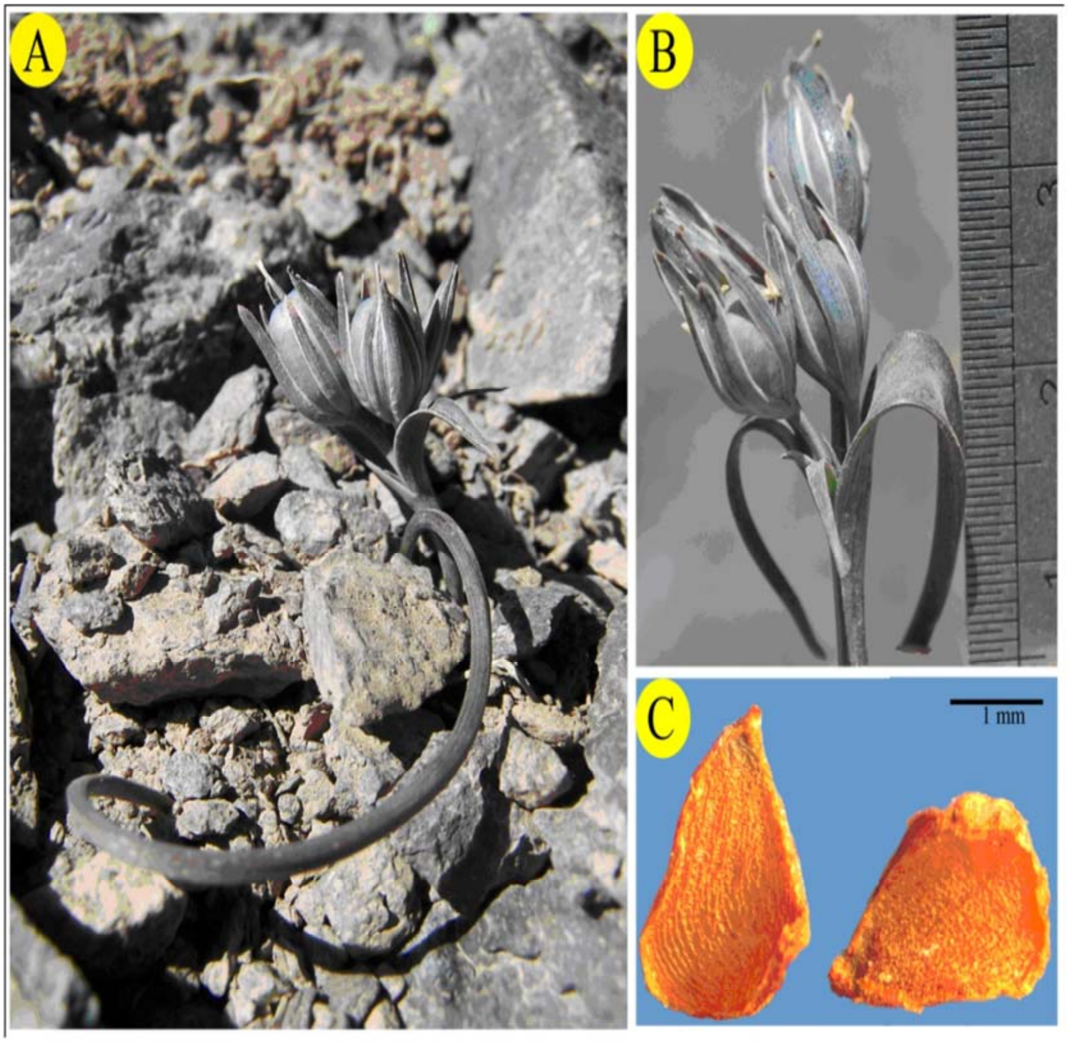
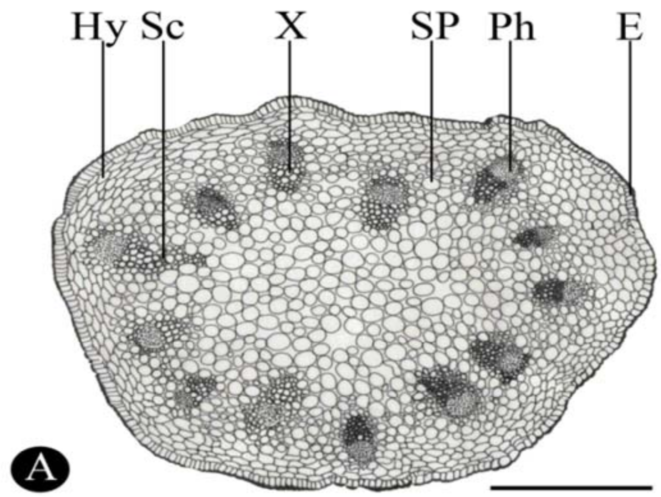


Fig.1. *Gagea alexia:* at 4455 m a.s.l. on 20 July 2009. B. Umbel-like inflorescence with capsules and upper leaves. C. Seeds.

According to the approach of Braun-Blanquet (1964), a phytosociological r relevé site (100 m²) was sampled in the habitat of *G. alexii* and some ecological characters of the habitat were also recorded (Table 1)

Hezar-Lalehzar Mts. are isolated mountains in southern Iran, Kerman province. These mountains are botanically less known with a high rate of endemic species especially in high altitudes (Noroozi *et al*., 2010). Recently, some local endemic species like *Senecio eligulatus* B. Nord., Moussavi & Djavadi, Ferula hezarlalehzarica Ajani and *S. subnivalis* Y. Ajani, J. Noroozi & B. Nord., are described from high altitudes of these mountains (Nordenstam *et al*., 2002; Ajani & Ajani, 2008; Noroozi *et al*., 2010).



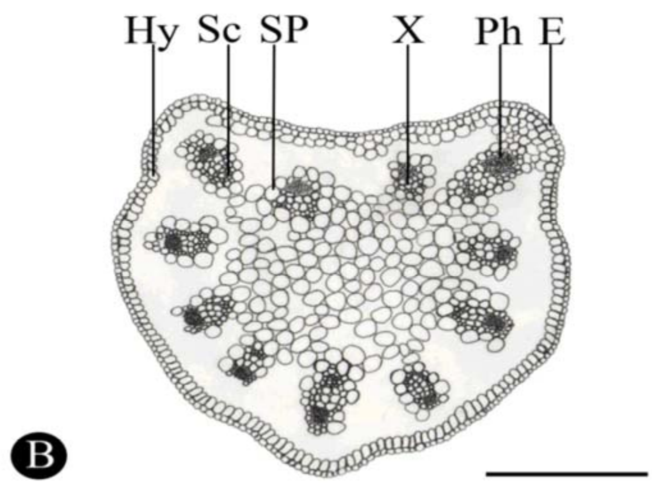
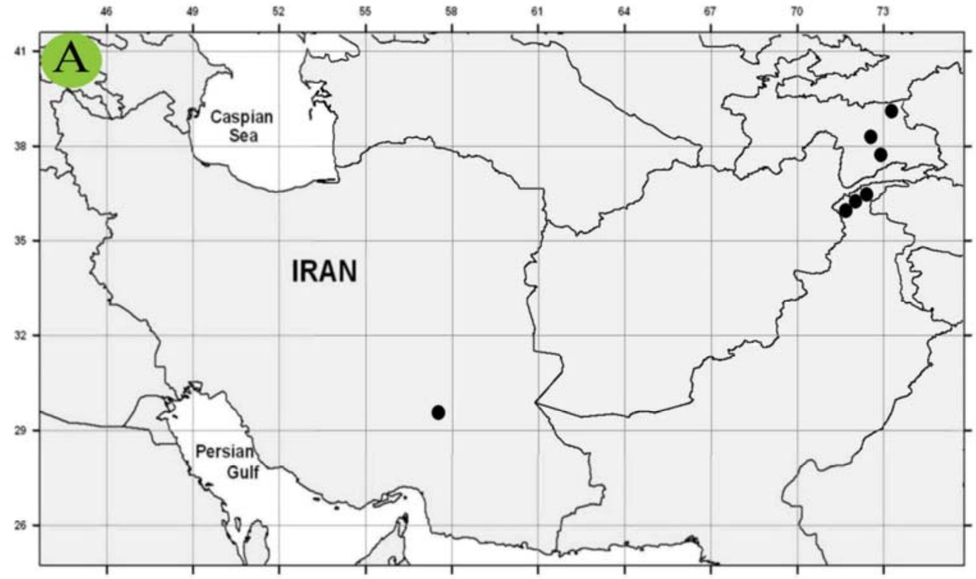


Fig. 2. Gagea alexia: Diagrammatic transvers sections of peduncle.A. 4 cm above bulb; B. 2-3 mm above bulb; Sc - sclerenchyma; SP - spongy pare nchyma; X - xylem; Ph - phloem; BS - vascular sheath, E - epidermis; Hy - hypodermis. (Scale bars - 1 mm).

Assadi 1988; Zarrei *et al*., 2007, accepted the *G. fistulosa* (Ramond ex DC. in Lam. et DC.) Ker Gawl. which according to Articles 34.1a, c and 52.1 ICBN is incorrect in relation to name *G. liotardii* (Sternb.) Schult. et Schult. f. See Levichev, 2006: 942.



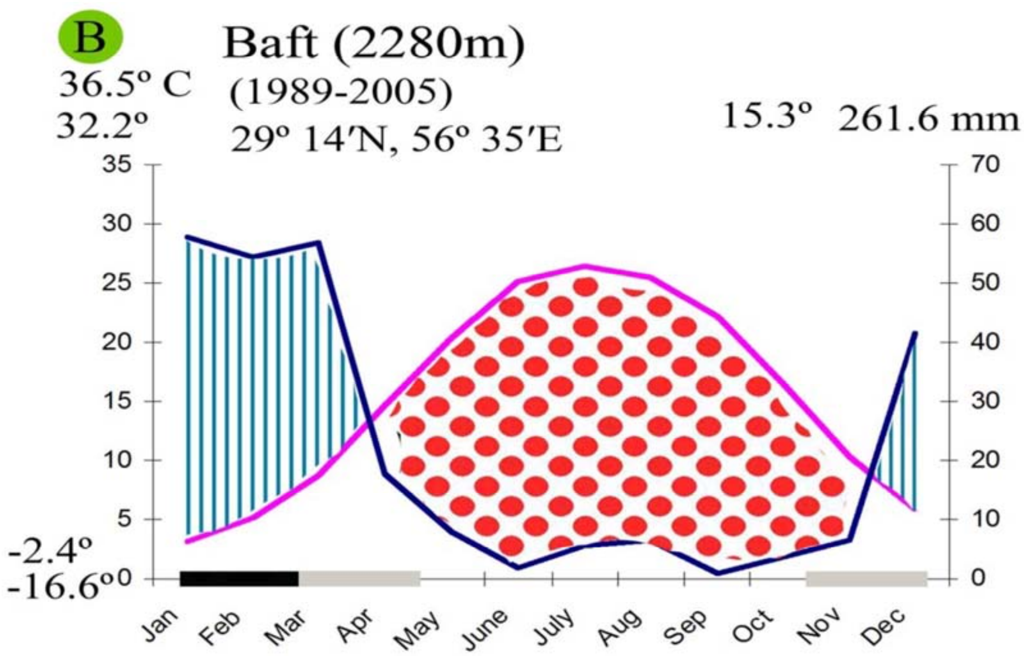


Fig. 3. A. Distribution map of Gagea alexii; B. The climate diagram of Baft meteorological station for 1989-2005: 29° 14′N, 56° 35′E, 2280 m Mean annual precipitation261.6 mm, Mean annual temperature= 15.3°C, Absolute maximum temperature= 36.5°C, Mean daily maximum of the hottest month= 32.2°C, Monthly means of precipitation= dark blue line, Monthly means of temperature= pink line, Humid period= blue shading, Arid period= red circles, Mean daily minimum temperature of the coldest month= -2.4°C, Absolute minimum temperature= -16.6°C, Months with a mean daily minimum temperature below 0°C= black line, Months with an absolute minimum below 0°C= grey line.

Table 1. Species composition of the *Artemisia persica* community (habitat of *Gagea alexii*) based on one phytosociological relevé from subnival zone of Hezar mountains, northern slope of the highest peak. The symbols show cover-abundance of each species according to the method of Braun-Blanquet (1964), where 1= <5% [or over 50 small plants or 1-5 large plants], += <1% [1-5 small plants).

Relevé	**1**
Coordinates:	29°30′41″N 57°16′23″E
Sample area (m²)	100
Inclination (°)	20
Altitude (m)	4455
Aspect	NE
Vascular plants (%)	5
Scree (%)	92
Solid rock (%)	2
Bare ground (%)	1
Litter (%)	-
Species	
Artemisia persica	+
Asperula glomerata subsp. condensata	+
Nepeta lasiocephala	1
Astragalus melanodon	1
Potentilla nuda	1
Scrophularia subaphylla	+
Gagea alexia	+

Associate species: *Artemisia persica* Boiss., *Asperula glomerata* (M. B.) Griseb.

Subsp *condensata*, *Nepeta lasiocephala* Benth., *Astragalus melanodon* Boiss., *Potentilla nuda* Boiss. and *Scrophularia subaphylla* Boiss. The main percentage of ground is covered with scree (ca. 92%) and vegetation cover is low (ca. 5%). The dominant species of this zone in Hezar-Lalehzar mountains is *Artemisia persica* (Fig. 1A; Table 1).

The floristic relationship and close affinity of the southeastern Zagros with Hindu Kush and Central Asia especially in high altitudes was discussed previously (Hedge & Wendelbo, 1978; Noroozi *et al*., 2008 & 2010). Disjunct distribution of *G. alexii* in upper limit of vascular plants in Hezar mountains (above 4455m) is another evidence of this type of distribution pattern (Fig. 3). The occurrence of *G. alexii* in Hezar mountains above 4455m is the highest known record of this genus, Since the habitat of this species is too narrow and is limited to upper zone of this mountain and also because it is endangered by several factors due to the occurrence of many local endemics (Noroozi *et al*., 2010), therefore serious efforts for conservation and protection of these endangered by several factors mountains are strongly suggested.

Conclusions

Both the descriptions and the images of *G. setifolia* in Flora Iranica are incorrect. The description is attributed to *G. aitchisoniana* (et p.p. *G. alexii*), image - *G. alexii*. The type of specimen (Aitchison n104, Lectotype, K) determined by Per Wendelbo as *G. setifolia* belongs to *G.* sect. *Platyspermum*. Our field expeditions to the Hezar mountain 5 revealed the occurrence of *G. alexii* (*G.* sect. *Incrustatae*) at the higher altitudes of Iran. This record is the highest altitude known today for this genus. The presence of this species in the subnival zones of the Hezar Mts. is further valid evidence of the close floristic affinities of Hezar-Lalehzar Mts, isolated mountains in southeastern Zagros, with the Hindu Kush and Central Asia especially in high altitudes. The habitat of *G. alexii* is so narrow, and endangered by several factors, that the serious conservation efforts of this area is strongly suggested.

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References

Ajani, Y. and M. Ajani. 2008. A new species of *Ferula* (*Umbelliferae*) from southern Iran. *Edin. J. Bot.*, 65: 425-431.

Akhani, H. 1999. Studies on the flora and vegetation of the Golestan National Park, NE Iran III. Three new species, one new subspecies and fifteen records for Iran. *Edin. J. Bot.*, 56: 1–31.

Ali, S.I and I.G. Levichev. 2007. *Gagea*. In: Ali, S.I. and Qaiser M. (Ed.) *Flora of Pakistan*, vol. 215. Karachi University Press. p. 17-81.

Assadi, M. 1988. Plants of Arasbaran protected area, NW Iran (Part II). *Iranian J. Bot.*, 49: 1–59.

Braun-Blanquet, J. 1964. *Pflanzensoziologie, Grundzüge der Vegetationskunde*. Wien, Springer-Verlag.

Davlianidze, M.T. 1976.Caucasian representatives of the genus Gagea Salisb. Tbilisi. Pub. Co.: Metsniereba. 160 p. (In Russian)

Gagea calcicola (*Liliaceae*), a new species from southwestern Iran. *Kew Bulletin* 65: 89-96.

Goloskokov, V.P. 1958. Genus *Gagea*. *Flora of Kazakhstan. Alma-Ata.* T. 2: 118-134 (In Russian).

Hamzaoğlu, E., Budak Ü. Budak and A. Aksoy 2008. A new species of *Gagea* Salisb. (Liliaceae) from Sivas (Central Anatolia, Turkey) *Turk. J. Bot.*, 32: 261-264.

Hedge, I.C. and P. Wendelbo. 1978. Patterns of distribution and endemism in Iran. *Notes Roy. Bot. Gard. Edinb.*, 36: 441-464.

Ikonnikov, S.S. 1963. *Determinant of plants of Pamir. Dushanbe,* Publishing Academy of Sciences of the Tajik SSR. 282 p. (In Russian).

Krasovskaya, L.S., I. G. Levichev 1986. *The Flora of the Chatkal Nature Reserve*. Pub. Co.: Fan, Tashkent.,Tashkent. 173 p. (In Russian).

Levichev, I.G. 1981. The new species of the genus *Gagea* (Liliaceae) from Western Tien Shan. *Bot. J. (Leningrad)*. 66, 11: 1635-1645. (In Russian).

Levichev, I.G. 1982a. *The new species of the genus Gagea from Middle Asia*. Botanical materials of a herbarium of institute botanists of an Academy of sciences *Uzbek SSR. Tashkent*. Vol. 20. P. 17-28. (In Russian).

Levichev, I.G. 1982b. The new species of *Gagea* Salisb. (Liliaceae) from relationship *Gagea capusii* Terr. *Novitates systematicae plantarum vascularium (Leningrad)*. 19: 62-67. (In Russian).

Levichev, I.G. 1990. The synopsis of the genus *Gagea* (*Liliaceae*) from the Western Tien-Shan. *Bot. J., (Leningrad)*. 75(2): 225-234. (In Russian).

Levichev, I.G. 1997. The review of the genus *Gagea* Salisb. (Liliaceae) in the flora of the Far East. *Bot. J. (St. Petersburg)*. 82(12): 77-92. (In Russian).

Levichev, I.G. 1999a. Zur Morphologie in der Gattung *Gagea* Salisb. (Liliaceae). I. Die unterirdischen Organe. *Flora*, 194: 379-392.

Levichev, I.G. 1999b. Phytogeographical analysis of the genus *Gagea* Salisb. (Liliaceae). *Komarovia,* 1: 45-57.

Levichev, I.G. 2001a. New species of the genus *Gagea* Salisb. (Liliaceae) from western districts of Asia. – *Turczaninowia*. 4(1–2): 5–35. (In Russian).

Levichev, I.G. 2001b. Dicyclism and age variability of homologous the foliar structures of the shoot of *Gagea* (*Liliaceae*) as indicators of neotenization. Homologies in Botany: Experience and Reflections. Proceedings of IX Workshop on Theoretical Plant Morphology "*Types of Similarities and Principles of Homologies Revealed in Plant Morphology*". Saint-Petersburg. P. 280-283. (In Russian).

Levichev, I.G. 2002. Collection of the genus *Gagea*. *The platns of outdoor of the Botanical Institute. Collections, Expositions.* St. Petersburg. P. 228-236.

Levichev, I.G. 2006. A review of the *Gagea* (*Liliaceae*) species in the flora of Caucasus. *Bot. J., (St. Petersburg)*. 91(6): 917-951. (In Russian).

Lojacono, P. 1909. Flora Sicula. 3: 129-136.

Müller, O.F. 1775. Icones plantarum.... *Florae danicae*. Copenhagen, Vol. 4, Fasc. 11.

Nordenstam, B., M. Moussavi and B. Djavadi. 2002. A new annual species of *Senecio* from Iran. *Comp. Newsl.*, 38: 42-46.

Noroozi, J., H. Akhani and S.W. Breckle. 2008. Biodiversity and phytogeography of the alpine flora of Iran. *Biodivers. Conserve.*, 17(3): 493-521.

Noroozi, J., Y. Ajani and B. Nordenstam. 2010. A new annual species of *Senecio* (*Compositae-Senecioneae*) from subnival zone of southern Iran with comments on phytogeographical aspects of the area. *Comp. Newsl.*, 48: 43-62.

Oeder, G.C. 1768. *Icones plantarum... Florae danicae*. Copenhagen, Vol. 3. Fasc. 7.

Peruzzi, L, A. Peterson, J-M.Tison and J. Peterson. On the phylogenetic position and taxonomic value of *Gagea trinervia* (Viv.) Greuter and *G.* sect. *Anthericoides A. Terracc.* (*Liliaceae*). *Taxon*, 57: 1201–1214.

Peruzzi, L., Bartolucci F., Frignani F. and Minutillo F. 2007. *Gagea tisoniana*, a new species of *Gagea* Salisb. sect. *Gagea* (*Liliaceae*) from central Italy *Bot. J. Linn. Soc.*155: 337-347.

Peterson, A., I.G. Levichev and J. Peterson. 2008. Systematics of *Gagea* and *Lloydia* (*Liliaceae*) and infrageneric classification of *Gagea* based on molecular and morphological data. *Mol. Phyl. Evol.,* 46: 446-465.

Vvedensky, A.I. 1963. *Gagea*. *Flora of the Tajik SSR*. Moscow-Leningrad, Publishing Academy of Sciences USSR. T.2: 212-239. (In Russian).

Vvedensky, A.I. 1971. *Gagea*. *Conspectus florae Asiae Mediae*. Taschkent, Editio Academiae Scientiarum UzSSR. T.2: 27-39. (In Russian).

Wendelbo, P. and K.H. Rechinger. 1990. *Gagea*. In: K.H. Rechinger. (Ed.), *Flora Iranica, vol.* 165. Graz, Akademische Druck-und Verlagsanstalt P. 13–57.

Zarrei, M. and S. Zarre 2005. A new species of *Gagea* (Liliaceae) from Iran. *Nord. J. of Bot.*, 23: 269-274.

Zarrei, M., Sh. Zarre, P. Wilkin and M. Rix. 2007. Systematic revision of the genus *Gagea* Salisb. (*Liliaceae*) in Iran. *Bot. J. Linn.* Soc., 154: 559–588.

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A New Alpine Species of *Nepeta* sect. *Capituliferae* (Labiatae) from Northwestern Iran

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Abstract. A new species, *Nepeta sahandica* Noroozi & Ajani (Labiatae), is described and illustrated from the high altitudes of the Sahand Mountains in northwestern Iran. Morphological differences of this species from its closest relatives in *Nepeta* L. sect. *Capituliferae* (Benth.) Pojark., *N. lasiocephala* Benth. and *N. monocephala* Rech.f., are discussed. These species differ mainly in their respective habit, basal and stem leaves, indumentum, and character of bract and calyx. The new species is restricted to the subnival vegetation zone, associated with unstable scree grounds. *Nepeta sahandica* is classified as Critically Endangered (CR), based on IUCN Red List criteria.

Key words: Iran, IUCN Red List, Labiatae, *Nepeta*, Sahand Mountains.

The genus *Nepeta* L. (Labiatae) is an Irano-Turanian element and one of the largest genera in Iran with ca. 80 species, of which almost 60% are endemic or subendemic (Rechinger, 1982; Jamzad, 2009). It is the second most numerous genus represented in the alpine habitats of Iran (21 species) with an 86% endemic or subendemic rate (Noroozi et al., 2008). Four *Nepeta* species have been previously recorded for the subnival-nival flora of Iran (Noroozi et al., 2011). The high rate of endemism of *Nepeta* in Iranian mountains might represent evidence of active speciation in the region.

In the *Flora Iranica*, the genus *Nepeta* was divided into 13 sections, with *Nepeta* sect. *Capituliferae* (Benth.) Pojark. characterized by its capitate, terminal or axillary inflorescences (Rechinger, 1982). Since the publication of *Flora Iranica*, two new species of *Nepeta* sect. *Capituliferae*, *N. minuticephala* Jamzad and *N. natanzensis* Jamzad, have been described (Jamzad, 1999, 2006), increasing the number of species in this section to eight (Jamzad, 2009). With the inclusion of the new species here described, the number of species in the section reaches nine. All species in this section are either endemics or localized endemics at high altitudes of the Zagros and Alborz mountain ranges (Rechinger, 1982; Jamzad & Assadi, 1984; Jamzad, 1992, 1998, 1999, 2006; Delghandi, 1993; Jamzad et al., 2003), but none have extended to the high altitudes of the Azerbaijan region in northwestern Iran, with the exception of the new species described in this paper.

The Sahand refers to a complex of inactive volcanic mountain peaks in northwestern Iran, east of Lake Urumiyeh (Urmia) and south of Tabriz City, reaching 3707 m.s.m. at its highest summit (Fig. 1). The Sahand is surrounded by the Alborz, Zagros, Anatolia, and Caucasus mountain ranges and is located in the southernmost corner of the Caucasian region, one of the world's 25 biodiversity hotspots (Myers et al., 2000). Snow remains on the northern slopes as snowbeds until mid- to late summer, and the subnival zone in this region begins ca. 3500 m.s.m.

The new species was discovered during fieldwork by the first author in the high altitudes of the Sahand in early August 2010. To identify associated species and ecological characters of the habitat, several phytosociological relevés (100 m^2) were sampled from the habitat of the new species, following the methodology of Braun-Blanquet (1964). Morphological characters of this species, such as the plant habit, root system, and the fresh color of the corolla, were investigated directly in the field.

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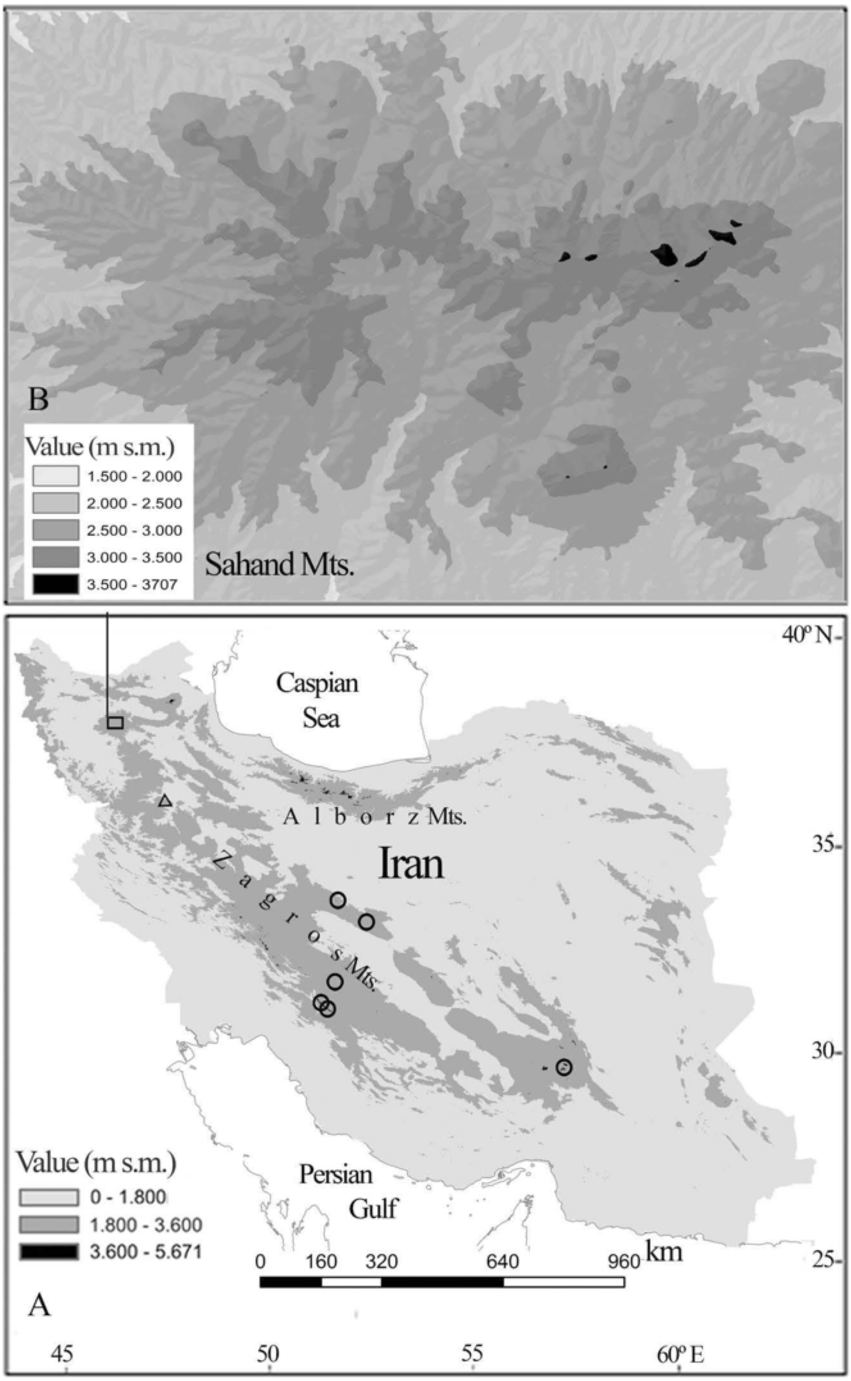

Figure 1. —A. Topographic map of Iran, indicating the known distribution of *Nepeta sahandica* Noroozi & Ajani (box), *N. monocephala* Rech.f. (triangle), and *N. lasiocephala* Benth. (circle). —B. Topographic close-up of the Sahand Mountains, where the new species *N. sahandica* is restricted to altitudes above 3500 m.s.m. (darkest shading).

Nepeta sahandica Noroozi & Ajani, sp. nov. TYPE: Iran. East Azerbaijan: Sahand Mtns., 37°44 03 N, 46°29 59 E, 3500–3630 m.s.m., on scree grounds, 31 July 2011, *J. Noroozi 2598* (holotype, TARI; isotype, W, WU). Figure 2A–F.

Diagnosis. The new species *Nepeta sahandica* Noroozi & Ajani differs from *N. monocephala* Rech.f. and *N. lasiocephala* Benth. by the stem leaves restricted mostly to the lower half of the stem and by the velutinous calyces and leaves. The calyces (6–8 mm) are shorter than those of *N. lasiocephala* (8.5–9 mm), and the lower tooth of the calyx is shorter (2–2.5 mm) than those of both species (ca. 3 and ca. 5 mm in *N. monocephala* and *N. lasiocephala*, respectively). In *N. sahandica*, the bracts are only ciliate and larger (7–8 × 1.5–2 mm) versus villous and smaller (3–4 × 0.5–1 mm) in *N. monocephala*.

Perennial, lignified at the base, with multiple, ascendent stems that are densely glandular; root extended, to 30 cm or more; stems 15–24 cm tall, 1.5–2 mm wide at base, not branched or with thin and short branches 4.5–6 cm, all stem parts densely covered with capitate glandular trichomes intermixed with a few simple, nonglandular, multicelluar trichomes; stems green shading to violet in upper portions of the stem close to the flower heads; stem internodes associated with the lowermost leaves 1–3 cm, uppermost internodes 4.5–9.5 cm. Leaves mostly restricted to the lower half of the stems; basal leaves petiolate, petioles 9–18 mm; blades 6–13 × 7–13 mm, widely ovate to triangular, bases truncate to cordate, margin crenate, apex obtuse; abaxial lamina surfaces with prominent veins, covered with capitate glandular trichomes intermixed with sparse to moderate simple, nonglandular, multicellular trichomes, velutinous, adaxial lamina surfaces with few capitate, glandular trichomes, but with dense, simple, nonglandular, multicellular trichomes; stem leaves subsessile, blades 6–14 × 4–8 mm, ovate to oblong, bases cuneate, margin denticulate, apex acute. Inflorescences capitate and terminal, 14–18 × 14–18 mm; pedicels ca. 1 mm long; bracts linear, 7–8 × 1.5–2 mm, violet in middle portion, 1 vein evident dorsally, with sparse, simple, nonglandular, multicellular trichomes, velutinous, margin ciliate. Flowers with the calyx 6–8 × 1 mm, tubular, throat oblique, with capitate glandular and dense, simple, nonglandular trichomes, velutinous thoughout, violet in at the least upper and middle portions; calyx teeth lanceolate, acuminate or acute, with the lower tooth 2–2.5 mm long, the upper tooth 1.5–2 mm long; corolla tubular, blue-violet, 12–13 mm, the corolla tube exerted from the calyx, the outer surface covered by short, simple, nonglandular trichomes, dorsal portions of the upper lip densely covered with capitate glandular and simple nonglandular trichomes. Fruit as nutlets 2–2.5 × 0.9 mm, brown, oblong to elliptic, with 1 prominent median keel.

Distribution and habitat. *Nepeta sahandica* is known only from the subnival zone of the northern slopes of the Sahand in northwestern Iran, ranging from altitudes of 3500–3630 m.s.m. The new species is adapted to unstable scree grounds with a high percentage of scree cover (ca. 65%) and steep slope inclination, ca. 30°–45°. This species thus belongs to the subnival-nival flora of Iran, a zone with a very high rate of endemism and with narrow geographical distributions (Noroozi et al., 2011). A selection of seven phytosociological relevés from the plant community of the new species, following the methodology of Braun-Blanquet (1964), is given in Table 1. The vegetation cover of the relevés was ca. 15%, and species richness was ca. 10 species per relevé. For more information about the phytosociological aspects of this plant community, see Noroozi et al. (2013).

IUCN Red List category. Vegetation studies in the high alpine and subnival zones of the Sahand Mountains show that the new species is restricted to the highest altitudes, above 3500 m.s.m., and that *Nepeta sahandica* may be very sensitive to global warming as there is no alternative low-temperature habitats for upward migration. The Sahand Range is also under high pressure from summer overgrazing by goats and sheep, whose milk is used to produce the region's famous cheese. In spite of the known high rate of local endemism in these mountains, there are no appropriate control and protection plans. Therefore, *N. sahandica* is assessed as Critically Endangered (CR), according to IUCN Red List criteria (IUCN, 2001).

Phenology. The new species has been seen in flower from mid-July to mid-August.

Etymology. The epithet of the new species refers to its type locality in the Sahand Mountains.

Taxonomic affinities. The presumed closest relatives of the new species include *Nepeta monocephala* and *N. lasiocephala*, and both are recorded from the Zagros mountain ranges, extending to the south and southeast of the Sahand (Fig. 1). *Nepeta monocephala* is known only from the type collection in northern Zagros, collected in 1968 from the Chang Almas Mountain at altitudes between 2200 and 2500 m.s.m. (Rechinger, 1982); it has not been recorded or collected since then. The description of *N. mono-*

Figure 2. A–F. *Nepeta sahandica* Noroozi & Ajani. —A. Inflorescence. —B, C. Entire plant. —D. Calyx. —E. Corolla. —F. Nutlet. G–J. *Nepeta lasiocephala* Benth. —G. Inflorescence. —H, J. Entire plant. Photos A–C taken by J. Noroozi in the Sahand, 3550 m.s.m.; photos D–F taken by Y. Ajani from the TARI holotype, *J. Noroozi 2598* (TARI); photos G–J taken by J. Noroozi and Y. Ajani in the Hezar Mountains, 4450 m.s.m.

Table 1. Species composition of the habitat for *Nepeta sahandica*, based on seven phytosociological relevés from the subnival zone of the Sahand, at the northern slope of its highest peak, on Kamal Daghi (3707 m.s.m.), and for *N. lasiocephala*, based on two relevés from the subnival zone of the Hezar Mountains, on the northern slope of its highest peak (4465 m.s.m.). The symbols show the cover-abundance of each species, according to the method of Braun-Blanquet (1964), where 2 = 5%–25%; 1 = 1%–5%; + = < 1%; and r = < 5 cm². Each relevé area is 100 m².

	Sahand							Hezar	
Relevé number	1088	1089	1090	1091	1092	1093	1095	938	939
Altitude (m.s.m.)	3538	3550	3553	3567	3571	3592	3622	4455	4443
Slope aspect	N	N	N	N	N	N	NE	NE	NE
Slope inclination (degrees)	40	45	40	45	45	35	30	20	20
Plant cover (%)	20	15	15	10	10	15	30	5	10
Scree coverage (%)	45	40	40	85	80	60	75	92	85
Solid rock (%)	30	35	40	0	0	15	0	2	3
Bare ground (%)	5	10	5	5	10	10	5	1	2
Species richness	16	9	11	8	9	8	13	7	11
Nepeta sahandica	**1**	**1**	**1**	**2**	**1**	**1**	**1**		
Didymophysa aucheri Boiss.	1	1	1	1	1	1	1		
Bromus tomentosus Trin.	1	1	1	1	1	2	2		
Ziziphora clinopodioides Lam.	1	1	1	1	1	1	1		
Senecio taraxacifolius (M. Bieb.) DC.	1	1	1	+	1	—	1		
Poa araratica Trautv.	1	1	1	1	—	+	+		
Festuca alaica Drobow	1	—	1	+	1	1	1		
Dracocephalum aucheri Boiss.	1	2	1	—	+	1	—		
Arabis caucasica Willd.	+	—	+	—	—	+	1		
Galium hyrcanicum C. A. Mey.	—	—	+	+	1	—	2		
Saxifraga sibirica L.	+	+	—	—	1	—	—		
Pedicularis caucasica M. Bieb.	+	—	—	—	—	—	+		
Erysimum gelidum Bunge	+	—	—	—	—	—	1		
Erigeron caucasicus Steven	+	—	—	—	—	—	1		
Helichrysum psychrophilum Boiss.	—	—	—	—	—	—	+		
Crepis frigida (Boiss. & Balansa) Babc.	+	—	+	—	—	—	—		
Nepeta menthoides Boiss. & Buhse	1	—	—	—	—	—	—		
Thymus kotschyanus Boiss. & Hohen. ex Boiss.	+	—	—	—	—	—	—		
Artemisia L., sp. indet.	—	r	—	—	—	—	—		
Nepeta lasiocephala								**1**	**1**
Astragalus melanodon Boiss.								1	1
Artemisia persica Boss.								+	1
Asperula glomerata (M. Bieb.) Griseb. subsp. *condensata* (Ehrend.) Ehrend.								+	1
Potentilla nuda Boiss.								1	+
Scrophularia subaphylla Boiss.								+	+
Gagea alexii Ali & Levichev								+	—
Ranunculus eriorrhizus Boiss. & Buhse								—	1
Senecio subnivalis Y. Ajani, J. Noroozi & B. Nord.								—	+
Veronica kurdica Benth. subsp. *filicaulis* (Freyn) M. A. Fisch.								—	+
Psychrogeton alexeenkoi Krasch.								—	+
Silene daenensis Melzh.								—	+

cephala is thus based only on the type specimens in the W and IRAN herbaria. We have seen live plants of *N. lasiocephala* (Fig. 2G–J) on the highest summit of the Hezar Mountains (4465 m.s.m.) in southern Iran, and we have also examined the type specimens of both *N. lasiocephala* and *N. monocephala* in the W herbarium. These three species share several morphological characters. The basal leaves of these species are identical in shape, margin, apex, and basal parts. The major morphological differences between these species include the plant habit, stem trichome types and indumentum, leaf sizes and indumentum, bract sizes, and calyx sizes and indumentum, as well as the corolla shape and length

Table 2. Morphological differences among *Nepeta sahandica*, *N. monocephala*, and *N. lasiocephala*.

Characters	*N. sahandica*	*N. monocephala*[1]	*N. lasiocephala*[2]
Habit	ascendant	straight	ascendant or deflexed
Stem trichome types; indumentum	dense capitate glandular trichomes intermixed with a few simple nonglandular multicellular ones; densely glandular	subsessile glandular trichomes intermixed with simple nonglandular multicellular ones; basally villous, glabrescent above	dense capitate glandular trichomes intermixed with simple nonglandular multicellular ones; villous
Basal leaf sizes (mm)	6–13 × 7–13	15–20 × 15–20	5–10 × 5–10
Stem leaf sizes (mm), position, shape, margin	6–14 × 4–8, mostly in lower half, but some also in upper half of the stem, leaves ovate to oblong, denticulate	2–4 × 0.5–1, stems nearly naked (subnude), leaves basal, lanceolate, denticulate, or entire	5–10 × 5–10, leaves equally distributed, ovate, crenate
Leaf indumentum	velutinous, denser adaxially than abaxially	densely villous, more so abaxially than adaxially	densely lanate, more so abaxially than adaxially
Bract size (mm), indumentum at margin	7–8 × 1.5–2, glabrate, ciliate	3–4 × 0.5–1, villous	8 × 2.5–3, villous in upper portions
Calyx indumentum	velutinous	villous	villous in upper portions
Calyx size (mm)	6–8 × 1	7–8 × 1.5–2	8.5–9 × 1
Calyx lower tooth size (mm)	2–2.5	3	5
Calyx upper tooth size (mm)	1.5–2	1.5–2	2.5–3
Corolla shape	tubular	tubular	funneliform
Corolla length (mm)	12–13	12–13	11
Nutlet shape	oblong to elliptic	ovate to elliptic	oblong
Nutlet size (mm)	2–2.5 × 0.9	1.3 × 0.8	1.9 × 0.9

[1] Data according to Rechinger (1982) and isotype *Iranshahr & Dezfoulin E13207* (W).
[2] Data according to Rechinger (1982), isotype *Kotschy 757* (W), and field studies.

(see Table 2). Nutlet shape and size are also significant characters for the taxonomy of the tribe Nepeteae (Budantsev, 1993; Budantsev & Lobova, 1997). Distributional and ecological characters of the three similar species are compared in Table 3. *Nepeta natanzensis* is another member of *Nepeta* sect. *Capituliferae*, but it differs greatly from the discussed species in its clearly lignified caudex and basal parts of the stem and its spine-shaped calyx.

The habitat of *Nepeta lasiocephala* was studied in the Hezar Mountains, in southern Iran, with sampling of two phytosociological relevés. Table 1 compares the ecology and species composition of this species with *N. sahandica*, showing the data of relevés. There is no information available for the habitat of *N. monocephala* because this species is known only from the type collection and has not been recorded since, despite some general, although not detailed, botanical surveys by local botanists (H. Maroofi, pers. comm.). The type locale for *N. monocephala* on the Chang Almas Mountain has not been botanically well explored, and its precise location is not known. It is likely that this species may be found again with botanical investigation. There is no doubt that this species is very rare and locally endemic, and further botanical exploration of its distribution, habitat, and ecology is highly recommended.

Table 3. Distributional and ecological characters associated with *Nepeta sahandica*, *N. monocephala*, and *N. lasiocephala*.

Characters	*N. sahandica*	*N. monocephala*	*N. lasiocephala*
Geographical distribution	Sahand Mtns.	northern Zagros (Chang Almas Mtn.)	central, south, and southeastern Zagros
Altitudinal distribution (m.s.m.)	3500–3630	2200–2500	2000–4465
Habitat	scree grounds of subnival zone	no data	scree grounds of subalpine to subnival zones
Threat status (IUCN Red List criteria)	Critically Endangered (CR)	Data Deficient (DD) (its presence has not been recorded for 44 years)	Near Threatened (NT)

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Literature Cited

Braun-Blanquet, J. 1964. Pflanzensoziologie: Grundzüge der Vegetationskunde. Springer-Verlag, Vienna.

Budantsev, A. L. 1993. Ultrastructural features of fruit surface in some genera of the tribe Nepeteae (Lamiaceae). Bot. Zhurn. 78: 100–108.

Budantsev, A. L. & T. A. Lobova. 1997. Fruit morphology, anatomy and taxonomy of tribe Nepeteae (Labiatae). Edinburgh J. Bot. 54(2): 217–229.

Delghandi, M. 1993. *Nepeta leucostegia* (Labiatae), a new record for the flora of Iran. Iranian J. Bot. 6(1): 149–151.

IUCN. 2001. IUCN Red List Categories and Criteria, Version 3.1. Prepared by the IUCN Species Survival Commission. IUCN, Gland, Switzerland, and Cambridge, United Kingdom.

Jamzad, Z. 1992. Two new species from Labiatae in Iran. Iranian J. Bot. 5(2): 69–74.

Jamzad, Z. 1998. A new species of *Nepeta* L. (Labiatae) from Iran. Iranian J. Bot. 7(2): 249–253.

Jamzad, Z. 1999. Two new species of *Nepeta* L. (Labiatae) from Iran. Iranian J. Bot. 8(1): 43–48.

Jamzad, Z. 2006. A new species and a new record from Iran. Iranian J. Bot. 11(2): 143–148.

Jamzad, Z. 2009. Notes on the genus *Nepeta* L. (Lamiaceae-Nepetoideae). Iranian J. Bot. 15(2): 141–145.

Jamzad, Z. & M. Assadi. 1984. New species of the genera *Nepeta* and *Ajuga* (Labiatae) from Iran. Iranian J. Bot. 2(2): 95–102.

Jamzad, Z., M. Ingrouille & M. S. J. Simmonds. 2003. Three new species of *Nepeta* (Lamiaceae) from Iran. Taxon 52: 93–98.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. Fonseca & J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853–858.

Noroozi, J., H. Akhani & S. W. Breckle. 2008. Biodiversity and phytogeography of the alpine flora of Iran. Biodivers. & Conservation 17(2): 493–521.

Noroozi, J., H. Pauli, G. Grabherr & S. W. Breckle. 2011. The subnival-nival vascular plant species of Iran: A unique high-mountain flora and its threat from climate warming. Biodivers. & Conservation 20(6): 1319–1338.

Noroozi, J., W. Willner, H. Pauli & G. Grabherr. 2013. Phytosociology and ecology study of the high-alpine to subnival scree vegetation of N and NW Iran (Alborz and Azerbaijan Mts.). Appl. Veg. Sci. DOI: 10.111/avsc.12031.

Rechinger, K. H. 1982. *Nepeta*. Pp. 108–216 *in* K. H. Rechinger (editor), Flora Iranica, Vol. 150. Akademische Druck-u. Verlagsanstalt, Graz.

Chapter 3:

Vegetation of the alpine and subnival-nival zones of N and NW Iran

One paper was published regarding to this subject:

Paper: Phytosociology and ecology of the high alpine to subnival scree vegetation of N and NW Iran (Alborz and Azerbaijan Mts.)

Title of paper:
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Authors: Jalil Noroozi, Wolfgang Willner, Harald Pauli & Georg Grabherr

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Phytosociology and ecology of the high-alpine to subnival scree vegetation of N and NW Iran (Alborz and Azerbaijan Mts.)

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Abstract

Questions: The vegetation of high-alpine and subnival scree habitats in Iranian mountains has been poorly investigated so far despite the large variety of narrowly distributed vascular plant species and the expected vulnerability of these ecosystems to global warming. Which plant communities occupy these ecosystems and what is their syntaxonomic position? Which environmental factors determine the species composition of these habitats?

Location: Alborz and Azerbaijan Mountains in N and NW Iran.

Methods: A total of 141 phytosociological relevés were collected from 3200 to 4800 m a.s.l. This data set was classified using TWINSPAN, and the numerical classification was translated into a syntaxonomic system. Floristic differences between vegetation types were evaluated with detrended correspondence analysis (DCA). We determined the means and SD of measured environmental and vegetation parameters for all associations. Differences in the major environmental parameters among associations and alliances were analysed using ANOVA and *post-hoc* tests. Moreover, we determined the mean cover percentage of life forms in all associations.

Results: All high-alpine and subnival scree communities are arranged in one class (*Didymophyso aucheri-Dracocephaletea aucheri*), two orders (*Physoptychio gnaphalodis-Brometalia tomentosi*, *Didymophysetalia aucheri*), three alliances (*Elymo longearistati-Astragalion macrosemii*, *Erigerontion venusti*, *Didymophysion aucheri*) and ten associations, which are new to science, except for one association. The territory of the class extends from Alborz to NW Iran and probably to E Anatolia, Transcaucasia and the Zagros Mountains. Altitude, aspect and edaphic qualities are the major ecological factors influencing the species composition and vegetation mosaic.

Conclusions: Our study introduces a formal syntaxonomic classification of the scree vegetation at high altitudes in Iran, thus providing a scheme for ongoing ecological surveys and monitoring programmes to assess the impacts of climate warming and of human land use on these unique ecosystems.

Introduction

In spite of the vast and diverse mountain areas of Iran, the high-alpine and subnival–nival areas have a highly scattered distribution throughout the country, and the rate of endemic vascular plants with narrow geographic distribution is very high in comparison to lower altitudes (Noroozi et al. 2011). Of the ca. 700 vascular plant species present in the alpine belt of the Iranian mountains, more than 50% are endemic or sub-endemic to the country (Noroozi et al. 2008). A total of 151 species reach the subnival–nival belt, and of the 51 species with mainly subnival–nival distribution, 68% are endemic to Iran, most of them being found in only one or a few mountain ranges (Noroozi et al. 2011). The alpine flora of Iran has Irano-Turanian origin (Zohary 1973; Klein 1982, 1991;

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Frey et al. 1999; Noroozi et al. 2008, 2011). It exhibits the strongest floristic relationships with Anatolia, the Hindu Kush and the Caucasus, which have 23%, 20% and 19% of species in common with the high mountains of Iran, respectively (Noroozi et al. 2008).

A consistent large-scale classification of floristically defined vegetation types is an important tool for ecological research, bioindication, vegetation monitoring, conservation strategies and legislation (Dengler et al. 2008). The first vegetation survey on high elevations of Central Alborz dates back to Kotschy (1861a,b), Buhse (1899a,b) and Gilli (1939, 1941). An overview of the flora and phytogeography of the alpine and subnival–nival zone in the Iranian mountains was provided by Noroozi et al. (2008, 2011). Phytosociological studies of the alpine zone of Iran were carried out only in Central Alborz, and the syntaxonomic inventory of Iran is still far from complete. A first syntaxonomic treatment of the sub-alpine and alpine vegetation of Central Alborz was published by Klein (1982, 1987, 1988), who introduced three classes, which are, however, not validly published: '*Prangetea ulopterae*' (sub-alpine heaths and tall herb vegetation), '*Onobrychidetea cornutae*' (lower alpine thorn cushion vegetation) and '*Oxytropidetea persicae*' (higher alpine dwarf shrub vegetation). Noroozi et al. (2010) presented a new classification of the snowbed and thorn cushion grasslands of the alpine zone of Central Alborz and suggested that the above-mentioned classes should be reconsidered. A synopsis of plant communities and their elevational patterns on the southern slopes of Central Aborz from the low-montane to the high-alpine zone, is presented in Akhani et al. (2013). The only phytosociological work on scree vegetation of subnival areas of Iran was published by Klein & Lacoste (2001), describing one association (*Galietum aucheri*) based on 14 phytosociological relevés from Central Alborz. The high mountains of NW Iran are even less known, and our study presents the first vegetation data for this area.

We describe the alpine and subnival–nival scree vegetation of the Central Alborz and the mountains of Azerbaijan (NW Iran), based on 141 of our own relevés plus the afore-mentioned 14 relevés of Klein & Lacoste (2001). The purpose of this research was to address the following questions: (1) which major plant community types can be distinguished in high-altitude screes in Central Alborz and the mountains of NW Iran, and how can their compositional variation be adequately represented in a syntaxonomic classification; (2) what are the ecological, life-form and biogeographical characteristics of these syntaxa; and (3) what is the syntaxonomic relationship between these vegetation types and similar habitats of Anatolia, the Caucasus, the Balkan Peninsula and the European Alps?

Study area

Alborz is a W–E ranging mountain chain, located in N Iran, along the southern shore of the Caspian Sea, with Mt. Damavand, at 5671 m a.s.l., being the highest peak in the country. In NW Iran there are two isolated high volcanic mountains: Sabalan, which is the third highest peak in Iran, at 4811 m a.s.l. and having an active glacier near its peak, and Sahand, a complex of several volcanic summits with a maximum elevation of 3707 m a.s.l. (Fig. 1). These two mountains in the NW part of Iran are located between four main mountain ranges: Alborz in the east, Zagros in the south, the Caucasus in the north and Anatolia in the west.

All study sites are located on volcanic and volcaniclastic formations with acidic soils. The main body of the Damavand volcano, remarkably around the summit including the sampling area, is composed of trachyandesitic lava flows and pyroclastic sediments of Quaternary age (Davidson et al. 2004). Tuchal summit and its S and N flanks are constructed of Eocene acidic volcanic tuffs and tuffaceous siltstones/shales (Jamshidi & Afsharian Zadeh 1993). Sabalan is a Plio-Quaternary volcano, mainly composed of potassium-rich calc-alkaline andesitic rocks (Innocenti et al. 1982). Sahand volcano is a volcanic complex that has formed through two major episodes of volcanic activity: during Middle-Upper Miocene and Plio-Quaternary. The studied plots are localized over the Plio-Quaternary rocks mostly comprised of calc-alkaline dacitic and andesitic rocks (Innocenti et al. 1982; Behrouzi et al. 1997). The soil of all these volcanic areas is constituted of lithosols (igneous rocks) (Dewan et al. 1961).

There are glaciers in the higher elevations of the three highest mountains of Iran, i.e. Damavand, Alamkuh and Sabalan (Ferrigno 1991; Fig. 1). The present snowline in Alborz and NW Iranian mountains lies between 4000 and 4200 m a.s.l. (Schweizer 1972), and the upper limit of vascular plants in Central Alborz and Sabalan is 4800 and 4500 m a.s.l., respectively (Noroozi et al. 2011). It is assumed that during the Pleistocene the climatic snowline in the Iranian mountains was 1200–1800 m lower than at present (Wright 1962). Therefore, the upper limit of vascular plants might have been around 1500 m below its present level.

The higher altitudes of Alborz are affected by the north-westerly flow of polar air masses, and annual precipitation reaches almost 1000 mm (Khalili 1973). The summer is arid, hot and sunny, with intense radiation most of the time. Both annual and diurnal amplitudes of temperature can be very high, in particular near the soil surface. Although the duration of snow cover might be an important factor determining vegetation patterns, there are no data available to discuss this factor for the

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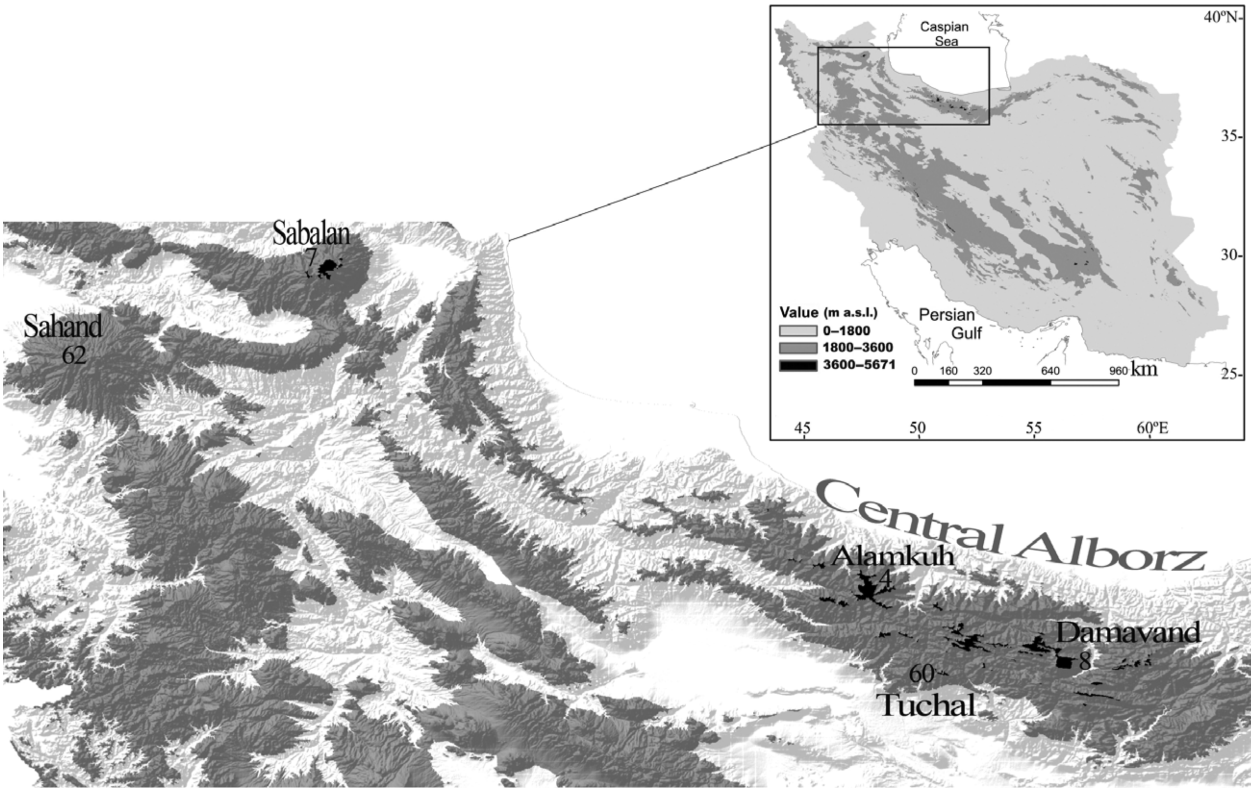

Fig. 1. The study areas in N and NW Iran and the number of relevés recorded by the first author in each mountain area. Damavand (5671 m a.s.l., highest peak of Iran), Alamkuh (4850 m a.s.l., second highest peak of Iran), Sabalan (4811 m a.s.l., third highest peak of Iran), Tuchal (3966 m a.s.l.), Sahand (3707 m a.s.l.). The 14 relevés of Klein & Lacoste (2001) are from Central Alborz [Alamkuh, Azadkuh and Damavand, with 11, 2 and 1 relevés, respectively].

communities of this study. Based on the Global Bioclimatic Classification System (GBC) developed by Rivas-Martínez et al. (1997, 1999), the high plateaus of NW Iran and most of Alborz (except the Hyrcanian region) belong to the mediterranean macrobioclimate, with long summer droughts, but colder winters compared to the mediterranean region (Djamali et al. 2011). Sahand has the driest climate among the studied mountains (mediterranean xeric-continental), Central Alborz has a more humid climate (mediterranean pluviseasonal continental), and Sabalan has the least continental bioclimate (mediterranean pluviseasonal-oceanic).

Methods

From 2003 to 2011, a total of 141 relevés were collected in the scree vegetation of the Central Alborz and NW Iran, focusing on altitudes between 3200 and 4800 m a.s.l., and following the traditional sampling strategy in the Braun–Blanquet approach (Dengler et al. 2008). The relevés were taken in open plant communities growing on unstable or stable stony and scree substrates. Usually, these vegetation types are easily distinguished from alpine snowbeds and thorn cushion grasslands (Noroozi et al. 2010) by their low vegetation cover, high percentage of scree on the ground and distinct species composition. It was decided at the outset of the field sampling to record scree vegetation with plot sizes of 10 m × 10 m, thorn cushion grasslands at 5 m × 5 m, and snowbeds at 2 m × 2 m. However, after a preliminary analysis of the data, we found that some of the communities on scree ground rather belong to snowbed vegetation in terms of species composition, while some stands initially classified as thorn cushion grassland have a closer floristic relationship to scree vegetation (data not shown). Therefore, the relevés selected for the present study vary in plot size between 25 and 100 m². This is, however, still within the extremes of the plots of Klein & Lacoste (2001), which vary from 5 to 400 m². Our target vegetation types do not extend to lower altitudes because the scree grounds of the sub-alpine zone are almost fully occupied by communities of the class *Prangetea ulopterae* Klein 1987 nom. inval., i.e. tall herb vegetation dominated by umbelliferous plants, which have a totally different physiognomy and floristic composition (Klein 1987, 1988). For each plot, elevation, geographic coordinates, aspect, slope inclination, as well as percentage of open scree (gravel or larger stones), solid rock, bare ground (open soil) and vegetation cover were recorded.

Species cover was recorded using a modified Braun–Blanquet scale (*r*: <5 cm², +: <1%, 1: 1–5%, 2: 5–25%, 3: 25–50%, 4: 50–75%, 5: 75–100%). Due to the low relevance of bryophytes and lichens in the studied vegetation types (see Photo S1–S17), which is probably caused by the dryness of the growing season, only vascular plants were recorded.

For data storage and table work, the programs TURBOVEG and JUICE were used. The relevés were first classified using the TWINSPAN algorithm, using percentage cover values of 0, 5, 25 and 50 as cut-off levels. Associations were delimited following the proposals of Willner (2006). The final delimitation included the re-arrangement of a single relevé according to the summarized cover of the diagnostic species (see Willner 2011). Floristic differences between vegetation types were also evaluated with detrended correspondence analysis (DCA) using Canoco for Windows v. 4.5. Associations were arranged into higher units (alliances, orders) by taking into account the TWINSPAN and DCA result, but the TWINSPAN hierarchy was not strictly followed. Instead, we aimed at achieving a classification that maximizes the number and fidelity of absolute character species for the higher units, although a strict statistical evaluation of this criterion is hardly possible with the available data (see Willner et al. 2009; Luther-Mosebach et al. 2012). The distinction between differential and character species was met subjectively by taking into account all available information about the habitat and geographical distribution of the species. A species was considered as diagnostic for a syntaxon if its constancy ratio (CR) was ≥ 2, i.e. if the constancy of the species in a unit was at least twice as high as in any other unit of the same rank within the next higher hierarchical level (Dengler 2003). A species with CR < 2 was considered diagnostic if its total cover (=average cover taking also into account zero values) was >15% and its total cover ratio (TCR) was ≥ 2, i.e. if its total cover in this unit was at least twice as high as in any other unit of the same rank within the next higher hierarchical level. Species cover in individual relevés was approximated by taking the average cover corresponding to each value of the Braun–Blanquet scale. We preferred the TCR over other fidelity measures, such as the Phi coefficient of association, because it includes information on species cover, and provides a simple criterion for distinguishing non-diagnostic, diagnostic and strongly diagnostic species (Willner et al. 2009). However, because of the unavoidable inaccuracy of the calculated total cover values, we used a combination of CR and TCR for the definition of diagnostic species. Species with a total cover <1% were only exceptionally considered as diagnostic. If a species reached the threshold for a diagnostic species at several hierarchical levels, it was only considered at the lowest level, except (1) if it was a differential species at the lower but a character species at the higher level, or (2) if it was diagnostic at a low and a high level but not at the intermediate level (e.g. at the association and order level but not at the alliance level), or (3) if it was considered as a transgressive character species. For the last, various definitions exist (e.g. Dengler 2003: 97; Luther-Mosebach et al. 2012: 406). We considered a species as a transgressive character species of a syntaxon if its fidelity for this syntaxon was lower than for the next higher level. Note that following the proposal of Willner et al. (2009), total cover values <0.1% were set to 0.1 for the calculation of TCR.

We determined the means and SD of measured environmental and vegetation parameters (altitude, aspect, inclination, species richness per plot, Shannon diversity index and Smith–Wilson evenness index (Smith & Wilson 1996), vegetation cover, open scree cover, bare ground cover, solid rock cover) for all associations. Differences in the major environmental parameters among associations and alliances were analysed using ANOVA and Games–Howell *post-hoc* tests and illustrated with box plots. We also determined the mean cover percentage of life forms in all associations using the average cover percentage corresponding to each value of the modified Braun–Blanquet scale. We assigned all taxa to six categories of life forms: therophyte, small hemicryptophyte (<ca. 30 cm), tall hemicryptophyte (>ca. 30 cm), graminoid, cushion chamaephyte and non-cushion chamaephyte.

Flora Iranica (Rechinger 1963–2012) was used as the main source for identification and nomenclature of plants. Furthermore, several other monographs were used to identify some taxa such as *Elymus longearistatus* (Davis 1985), *Erysimum* (Polatschek 2011) and *Festuca alaica* (Alexeev 1979). Information on the phytogeography of diagnostic species was obtained from various literature sources. Specimens are preserved at the personal herbarium of the first author. For nomenclature of syntaxa, the International Code of Phytosociological Nomenclature (Weber et al. 2000) was applied.

Results and discussion

General floristic and physiognomic features

The number of species recorded in all plots totalled 101, where ca. 70% of the species belong to six families (Asteraceae: 19 species, Poaceae: 13, Brassicaceae: 11, Labiatae: ten, Scrophulariaceae: eight, Fabaceae: seven species). Constancy above 1% (i.e. at least two occurrences) was reached for 77 species. The highest constancies within the whole data set were (values in brackets): *Bromus tomentosus* (65%), *Poa araratica* (37%), *Dracocephalum aucheri* (35%), *Festuca alaica* (35%), *Ziziphora clinopodioides* (32%) and *Didymophysa aucheri* (28%).

Almost 80% of the plant species in our data set are hemicryptophytes, followed by chamaephytes (14%) and therophytes (6%). In comparison to the alpine thorn cushion grasslands of the Central Alborz (Noroozi et al. 2010), the percentage of hemicryptophytes is higher while the percentage of chamaephytes and therophytes is lower, and there are no geophytes in our plots. Thus, our result is similar to previous observations that the percentage of hemicryptophytes increases from lowlands to high elevations in Iranian mountains (Noroozi et al. 2008, 2010; Naqinezhad et al. 2009), as also found in the Hindu Kush (Agakhanjanz & Breckle 1995) and in Mediterranean mountains (Kazakis et al. 2007; Fernández Calzado & Molero Mesa 2011). Hemicryptophytes can be classified into three groups: rosettes/small hemicryptophytes (54%), tall hemicryptophytes (12%) and graminoids (14%).

Numerical classification and DCA ordination

The alliances described below correspond with the first and second level of division in the TWINSPAN classification (Table 1). Cluster 1-1 comprises the communities of the upper limit of vascular plants in Central Alborz, with low vegetation cover and low species richness. They are classified as alliance *Didymophysion aucheri*. The relevés of Klein & Lacoste (2001) are all accommodated within this cluster. Cluster 1-0 comprises scree vegetation in the high-alpine belt of Central Alborz and communities interposing alpine thorn cushion grasslands with subnival scree habitats in the same region. This cluster represents the alliance *Elymo longearistati-Astragalion macrosemii*. Cluster 0 includes the scree communities of the Sahand and Sabalan Mts. It is classified as alliance *Erigerontion venusti*. Although this alliance was separated from the others at the first TWINSPAN level, the communities of NW Iran have a considerable floristic, physiognomical and ecological similarity to the communities of the *Elymo-Astragalion* (cluster 1-0), including high cover and constancy of *Bromus tomentosus*, *Ziziphora clinopodioides* and *Poa araratica*. Therefore, we propose to join these two alliances into one order (see below). The associations described in this study are separated at the third or fourth level of the TWINSPAN classification (Table 1).

In the DCA diagram (Fig. 2), the communities of NW Iran (*Erigerontion venusti*) are clustered on the left and the communities of the high-alpine and lower subnival zone of Central Alborz (*Elymo-Astragalion*) on the right. Within both alliances, the communities with high cover of grasses are concentrated in the centre of the diagram. The communities of the higher subnival–nival zone of Central Alborz (*Didymophysion*) are clustered in the upper part of the diagram.

Syntaxonomic assignment to a class

Klein & Lacoste (2001) classified the subnival–nival scree vegetation of Central Alborz as provisional class '*Didymophysetea aucheri*'. A synoptic table of the most important alliances of scree vegetation in the European Alps, the Balkan Peninsula, the Caucasus, Anatolia, as well as the alliances described in the present paper, supports this proposal (Table 2, Appendix S1): the only scree species present in all five regions is *Oxyria digyna,* which occurs in two associations of our study area (Table 1). Other species with a wide geographic distribution are *Arabis alpina* agg. (including *A. caucasica*), which is recorded in all regions except the Caucasus (*sic*!), *Cerastium cerastoides,* which is rather a snowbed species and not present in our relevés, and *Draba siliquosa*. *Sedum tenellum* is a frequent species of scree vegetation in the Caucasus (Onipchenko 2002) but rarely occurs in Anatolia and Iran. Seven more species are common to Iran and the Caucasus (*Alopecurus dasyanthus*, *Carum caucasicum*, *Lamium tomentosum*, *Minuartia recurva*, *Saxifraga sibirica*, *Scrophularia variegata*, *Senecio taraxacifolius*), and two species are common to Iran and Anatolia (*Jurinella moschus*, *Pisum formosum*). In contrast, 32 species are unique to Iranian scree vegetation. Of 55 character species of the *Thlaspietea rotundifolii* or subordinate syntaxa (according to Valachovič et al. 1997) present in the Alps and the Balkan, only four species occur in the Caucasus, three reach Anatolia, and two the Iranian mountains. A single class comprising the scree vegetation of Europe as well as of W Asia seems rather ill defined. There is some floristic relationship between the Caucasus and NW Iran, but uniting these two regions into one class would neglect the long list of common differential species between the Caucasus and the European mountains (see Appendix S1). The scree vegetation of Iranian mountains can certainly not be accommodated within the *Heldreichietea* Quézel ex Parolly 1995 of Anatolia (Parolly 1995, 1998), and therefore the description of a new class seems unavoidable. The distribution patterns of its character species (which are described in the next sections) suggest that the territory of this class covers the whole Atropatenian subprovince (*sensu* Takhtajan 1986), which includes the arid and semi-arid parts of Transcaucasia, E and SE Turkey, S Armenian highlands, NW Iran and the Alborz mountains. This subprovince is one of the most active centres of speciation in W Asia (Takhtajan 1986). Thus, the concept of the class as outlined by Klein & Lacoste (2001) can be confirmed. The class may also extend to the Zagros Mountains, but more data from this region are required to confirm this assumption.

Table 1. Synoptic table of the scree communities in N and NW Iran. Values are percentage constancies. The constancy values of diagnostic species are shaded, character species are additionally framed. A dashed frame indicates that the character species are only present in certain sub-associations. In the case of transgressive character species, the higher level is indicated with light shading. If a species has a total cover of >15%, the constancy value is in bold. Companion species that occur in less than ten plots are not shown. Association numbers are the same as in Tables 3 and 4, and Fig. 2. For the association names, see Table 4.

Class	*Didymophyso-Dracocephaletea aucheri*									
Order	*Physoptychio-Brometalia tomentosi*								*Didymophysetalia*	
Alliance	*Erigerontion venusti*				*Elymo-Astragalion*				*Didymophysion*	
Association	1	2	3	4	5	6	7	8	9	10
Number of relevés	8	19	35	7	6	21	33	3	12	11
TWINSPAN level 1	0	0	0	0	1	1	1	1	1	1
TWINSPAN level 2	0	0	1	1	0	0	0	0	1	1
TWINSPAN level 3	0	1	0	1	0	0	1	1	0	1
TWINSPAN level 4					0	1	0	1		
Nepeta menthoides	**100**	42	3	.	.	.	.	.	.	.
Alopecurus aucheri	100	37	.	.	.	.	.	.	.	.
Carum caucasicum	50	5	.	.	.	.	.	.	.	.
Sedum tenellum	38	5	.	.	.	.	.	.	.	.
Taraxacum crepidiforme	38	11	.	.	.	.	.	.	.	.
Senecio taraxacifolius	75	**95**	26	.	.	.	.	.	.	.
Myosotis asiatica	.	58	.	.	.	.	.	.	.	9
Oxyria digyna	.	47	.	.	.	.	.	.	.	9
Astragalus beckii	.	.	26	.	.	.	.	.	.	.
Nepeta sahandica	.	.	23	.	.	.	.	.	.	.
Potentilla porphyrantha	.	.	17	100	.	.	.	.	.	.
Alopecurus dasyanthus	.	.	.	57	.	.	.	.	.	.
Potentilla argaea	.	.	.	29	.	.	.	.	.	.
Erigeron caucasicus subsp. *venustus*	.	89	63	57	.	.	.	.	.	.
Tripleurospermum caucasicum	25	74	3	86	.	.	.	.	.	.
Festuca alaica	88	79	86				6			9
Koeleria eriostachya	75	26	43	.	.	.	.	.	.	.
Galium hyrcanicum	.	63	46	.	.	.	.	.	.	.
Draba bruniifolia subsp. *bruniifolia*	.	.	40	86	.	.	.	.	.	.
Sesleria phleoides	.	26	29	.	.	.	.	.	.	.
Minuartia glandulosa	63	37	17	.	.	.	.	.	.	.
Saxifraga sibirica	25	47	9	57	.	.	.	.	.	.
Pedicularis caucasica	.	16	40	.	.	.	.	.	.	.
Erysimum gelidum	.	21	17	.	.	.	.	.	.	.
Euphorbia aucheri	.	.	.	.	100	38	3	.	8	.
Scutellaria glechomoides	.	.	.	.	67	.	18	.	33	.
Nepeta racemosa	.	.	.	.	.	**71**	.	.	.	.
Cicer tragacanthoides	.	.	.	.	.	**57**	.	.	.	.
Leonurus cardiaca subsp. *persicus*	.	.	.	.	.	43	.	.	.	.
Asperula glomerata subsp. *bracteata*	.	.	.	.	.	19	64	.	58	.
Senecio iranicus	.	.	.	.	.	.	.	100	.	.
Artemisia melanolepis	.	.	.	.	.	.	.	100	.	.
Catabrosella parviflora	.	16	.	14	.	.	.	100	.	.
Carex oreophila	.	.	.	14	.	.	.	67	.	.
Draba siliquosa	.	.	.	14	.	.	.	100	.	9
Veronica biloba	25	.	.	.	.	.	.	100	.	.
Potentilla argyroloma	.	.	.	.	.	.	.	67	.	27
Astragalus macrosemius	.	.	.	.	33	29	76	**100**	.	.
Elymus longearistatus	.	.	.	.	17	95	52	.	.	.
Bromus tomentosus	50	47	100	.	.	67	**100**	67	25	.
Ziziphora clinopodioides	.	.	97	.	.	5	45	.	.	.
Physoptychis gnaphalodes	.	.	31	.	17	29	12	.	8	.

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Table 1. (*Continued*)

Class	*Didymophyso-Dracocephaletea aucheri*									
Order	*Physoptychio-Brometalia tomentosi*								*Didymophysetalia*	
Alliance	*Erigerontion venusti*				*Elymo-Astragalion*				*Didymophysion*	
Association	1	2	3	4	5	6	7	8	9	10
Poa araratica	.	5	91	14	.	43	33	100	.	9
Galium aucheri	.	.	.	.	.	.	.	.	92	9
Veronica paederotae	.	.	.	.	.	.	.	.	58	.
Senecio vulcanicus	.	.	.	.	.	.	.	.	42	.
Lamium tomentosum	.	.	.	.	.	.	.	.	58	9
Pseudocamelina glaucophylla	.	.	.	.	.	.	.	.	33	.
Achillea aucheri	.	.	.	.	.	.	.	33	25	55
Veronica aucheri	.	.	.	.	.	.	.	33	.	55
Didymophysa aucheri	.	.	49	71	.	.	.	.	92	100
Dracocephalum aucheri	.	5	66	.	.	.	52	100	8	91
Cerastium purpurascens var. *elbursensis*	.	.	.	.	.	.	.	100	33	45
Erysimum elbrusense	.	.	.	.	.	.	.	100	33	27
Alopecurus textilis	.	37	43	.	.	.	.	.	25	18
Helichrysum psychrophilum	50	63	17	.	.	14	6	.	.	.
Arabis caucasica	.	.	17	14	.	.	.	.	17	36
Campanula stevenii subsp. *beauverdiana*	13	16	14	.	.	5	9	.	.	.

Description of vegetation units

The plant communities are arranged in two orders, three alliances and ten associations. From these associations, one was previously described in Klein & Lacoste (2001), eight are formally described as new, and one is only presented as a provisional association. The mean and SD of the measured ecological factors and vegetation parameters for all associations and alliances, as well as the result of the ANOVA and *post-hoc* tests, are given in Appendix S2, and the differences among the units are illustrated in Fig. 3. Mean proportional cover of life forms in the ten associations is shown in Fig. 4. The character and differential species are listed in alphabetical order in the text by decreasing constancy in Table 1. A synoptic table with the total cover and fidelity degree of all species is given in Appendix S3. For type relevés, see Table 3.

1- Didymophyso aucheri-Dracocephaletea aucheri cl. nov. hoc loco

Syn.: *Didymophysetea aucheri* Klein & Lacoste 2001 nom. inval. (Art. 3b).
Typus: *Didymophysetalia aucheri* ord. nov. (see below)
Character species: *Didymophysa aucheri*, *Dracocephalum aucheri*
Differential species (against *Heldreichietea* and *Thlaspietea rotundifolii*): *Alopecurus textilis*

This class comprises open plant communities on unstable or stable screes in the alpine and subnival–nival zones of the Atropatenian subprovince (*sensu* Takhtajan 1986) and probably also of Zagros. The communities of this class are distinguished from alpine snowbed and thorn cushion grasslands (Noroozi et al. 2010) by low vegetation cover, high proportion of open scree cover and different species composition. The character species of the class are *Didymophysa aucheri* and *Dracocephalum aucheri*. Both species typically dwell on scree fields and are indicator species of the subnival–nival zone. *Didymophysa aucheri* (Photo S1) is distributed in E Anatolia, Transcaucasia, NW Iran, Zagros and Alborz (Hedge 1968), and *Dracocephalum aucheri* (Photo S1) from SE Anatolia to NW Iran and Alborz (Rechinger 1982b). The distribution of these two species (especially *Didymophysa aucheri*) probably also determines the geographical borders of the class. *Alopecurus textilis* is equally common in alpine thorn cushion grasslands of the *Acantholimion demawendici* (Noroozi et al. 2010) and occurs from Lebanon, Anatolia, Iraq, Iran to Turkmenistan (Bor 1970).

1-1 Physoptychio gnaphalodis-Brometalia tomentosi ord. nov. hoc loco

Typus: *Elymo longearistati-Astragalion macrosemii* all. nov. (see below)
Character species: *Bromus tomentosus*, *Physoptychis gnaphalodes*, *Ziziphora clinopodioides*
Differential species: *Poa araratica*

This order covers the high-alpine and lower subnival scree vegetation of Alborz and NW Iran and includes mobile and stabilized scree grounds. *Bromus tomentosus*,

Table 2. Abbreviated synoptic table of 18 alliances of scree vegetation in five regions of Europe and W Asia. C, character species; D, differential species. Only species with higher constancy are shown. For a longer version of this table, data sources and details on the calculation of constancy values, see Appendix S1.

Region	Alps						Balkans		Caucasus			Anatolia				Iran		
Column number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Number of relevés	219	265	62	273	289	34	89	7	24	22	12	156	114	143	157	69	63	23
Widespread species																		
Oxyria digyna	6	.	19	1	43	.	.	43	5	90	.	1	1	4	1	13	.	4
Arabis alpina agg. (incl. *A. caucasica*)	42	17	32	20	16	6	32	.	.	.	.	11	32	4	14	10	.	26
Cerastium cerastoides	.	.	3	3	2	.	.	.	10	43	.	.	.	.	25	.	.	.
Draba siliquosa	.	.	.	1	.	.	.	.	27	.	.	.	.	.	.	1	5	4
C *Thlaspietea rotundifolii*																		
Cerastium uniflorum	1	.	66	6	75	.	.	.	.	.	.	.	.	.	.	.	.	.
Linaria alpina	51	25	34	2	18	12	30	.	.	.	.	.	.	.	.	.	.	.
Poa cenisia s.lat.	2	3	.	.	.	.	24	86	.	.	.	.	1	10	3	.	.	.
Ranunculus alpestris	23	7	5	64	7	6		.	.	.	.	.	.	.	.	.	.	.
Rumex scutatus	22	49	.	.	1	65	36	.	.	.	.	.	.	.	.	.	.	.
Saxifraga oppositifolia	6	.	79	8	9	3	.	.	.	.	.	.	.	.	.	.	.	.
Silene vulgaris subsp. *glareosa* et *prostrata*	18	47	.	1	14	56	34	.	.	.	.	.	.	.	.	.	.	.
Achillea atrata	40	7	16	45	7	12	.	.	.	.	.	.	.	.	.	.	.	.
Campanula cochleariifolia	37	46	15	6	1	18	.	.	.	.	.	.	.	.	.	.	.	.
Pritzelago alpina	64	12	42	51	4	15	.	.	.	.	.	.	.	.	.	.	.	.
Ranunculus montanus agg.	20	17	5	25	1	21	6	57	10	35	15	.	.	.	.	.	.	.
Moehringia ciliata	53	18	3	36	.	6	10	.	.	.	.	.	.	.	.	.	.	.
Poa minor	43	17	23	18	.	18	4	.	.	.	.	.	.	.	.	.	.	.
Thlaspi rotundifolium	46	6	.	1	.	9	.	.	.	.	.	.	.	.	.	.	.	.
Adenostyles glabra	26	43	.	5	.	15	.	.	.	.	.	.	.	.	.	.	.	.
Petasites paradoxus	1	40	.	.	.	18	2	.	.	.	.	.	.	.	.	.	.	.
Saxifraga rudolphiana	.	.	55	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.
Salix retusa	7	1	11	53	24	3	4	.	.	.	.	.	.	.	.	.	.	.
Poa laxa	1	.	5	.	44	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga androsacea	10	.	40	42	18	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga bryoides	1	.	29	3	76	.	.	14	.	.	.	.	.	.	.	.	.	.
Achnatherum calamagrostis	.	4	.	.	.	26	2	.	.	.	.	.	.	.	.	.	.	.
Epilobium dodonaei	.	.	.	.	.	12	.	.	.	59	.	.	.	.	.	.	.	.
Cardamine glauca	.	.	.	.	.	.	40	43	.	.	.	.	.	.	.	.	.	.
Saxifraga pedemontana subsp. *cymosa*	.	.	.	.	.	.	.	57	.	.	.	.	.	.	.	.	.	.
D Alps																		
Viola biflora	40	22	.	30	3	21	.	.	.	.	.	.	.	.	.	.	.	.
Minuartia gerardii	11	1	45	11	10	3	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga moschata	11	1	45	11	21	3	.	.	.	.	.	.	.	.	.	.	.	.
Persicaria vivipara	15	2	32	69	26	3	.	.	.	.	.	.	.	.	.	.	.	.
Silene acaulis subsp. *exscapa*	.	.	15	2	63	.	.	.	.	.	.	.	.	.	.	.	.	.
Leucanthemopsis alpina	3	.	15	3	56	.	.	.	.	.	.	.	.	.	.	.	.	.
D Alps and Balkans																		
Juncus trifidus	1	.	.	1	30	.	.	100	.	.	.	.	.	.	.	.	.	.
Arenaria biflora	.	2	3	.	3	.	2	86	.	.	.	.	.	.	.	.	.	.
Festuca violacea agg.	5	2	2	4	36	.	.	71	.	.	.	.	.	.	.	.	.	.
D Alps–Balkans–Caucasus																		
Carex atrata agg.	1	.	11	42	3	3	.	.	.	39	15	.	.	.	.	.	.	.
Phleum alpinum agg.	2	.	2	2	34	.	.	.	.	45	.	.	.	.	.	.	.	.
Dicranoweisia crispula	.	.	.	.	5		.	57	.	20	70	.	.	.	.	.	.	.
Dryopteris filix-mas	.	1	.	.	2	3	.	43	.	15	90	.	.	.	.	.	.	.
Poa alpina s.lat. (incl. *P. badensis*)	35	14	69	66	61	3	.	.	.	38	15	.	.	.	.	.	.	.

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Table 2. *(Continued).*

Region	Alps						Balkans		Caucasus			Anatolia				Iran		
Column number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Number of relevés	219	265	62	273	289	34	89	7	24	22	12	156	114	143	157	69	63	23
D Balkans																		
Senecio glaberrimus	.	.	.	.	.	.	.	71	.	.	.	.	.	.	.	.	.	.
Doronicum columnae	.	1	.	.	.	.	15	57	.	.	.	.	.	.	.	.	.	.
C and D scree vegetation of Caucasus																		
Sedum tenellum	.	.	.	.	.	.	.	.	27	70	70	.	.	2	6	6	.	.
Carum caucasicum	.	.	.	.	.	.	.	.	50	40	.	.	.	.	.	7	.	.
Alopecurus ponticus	.	.	.	.	.	.	.	.	5	52	.	.	.	.	.	.	.	.
Veronica minuta	.	.	.	.	.	.	.	.	50	52	.	.	.	.	.	.	.	.
Matricaria caucasica	.	.	.	.	.	.	.	.	23	78	.	.	.	.	.	.	.	.
Murbeckiella huetii	.	.	.	.	.	.	.	.	15	45	70	.	.	.	.	.	.	.
Alopecurus dasyanthus	.	.	.	.	.	.	.	.	45	.	.	.	.	.	.	6	.	.
Potentilla gelida	.	.	.	.	.	.	.	.	45	.	.	.	.	.	.	.	.	.
Chaerophyllum humile	.	.	.	.	.	.	.	.	63	.	.	.	.	.	.	.	.	.
Corydalis alpestris	.	.	.	.	.	.	.	.	45	.	.	.	.	.	.	.	.	.
Dentaria bipinnata	.	.	.	.	.	.	.	.	43	.	.	.	.	.	.	.	.	.
Hyalopoa pontica	.	.	.	.	.	.	.	.	23	52	15	.	.	.	.	.	.	.
Lascuraea saxicola	.	.	.	.	.	.	.	.	5	10	50	.	.	.	.	.	.	.
Common scree species Caucasus–Iran																		
Saxifraga sibirica	.	.	.	.	.	.	.	.	15	63	30	.	.	.	.	26	.	.
Lamium tomentosum	.	.	.	.	.	.	.	.	30	5	.	.	.	.	.	.	.	35
Senecio taraxacifolius	.	.	.	.	.	.	.	.	.	27	.	.	.	.	.	48	.	.
C and D Heldreichietea																		
Heldreichia spp.	.	.	.	.	.	.	.	.	.	.	.	17	33	19	31	.	.	.
Euphorbia herniariifolia	.	.	.	.	.	.	.	.	.	.	.	62	.	45	31	.	.	.
Bunium microcarpum subsp. *microcarpum*	.	.	.	.	.	.	.	.	.	.	.	43	27	13	20	.	.	.
Elymus tauri	.	.	.	.	.	.	.	.	.	.	.	.	41	13	12	.	.	.
Fritillaria crassifolia	.	.	.	.	.	.	.	.	.	.	.	57	.	.	.	.	.	.
Scrophularia myriophylla	.	.	.	.	.	.	.	.	.	.	.	.	50	.	.	.	.	.
Anthriscus kotschyi	.	.	.	.	.	.	.	.	.	.	.	.	.	42	9	.	.	.
Arenaria balansae	.	.	.	.	.	.	.	.	.	.	.	.	.	48	48	.	.	.
Lamium eriocephalum	.	.	.	.	.	.	.	.	.	.	.	.	.	25	50	.	.	.
C and D Didymophyso-Dracocephaletea																		
Didymophysa aucheri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	32	.	96
Dracocephalum aucheri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	35	32	48
Bromus tomentosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	70	78	13
Ziziphora clinopodioides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	49	25	.
Poa araratica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	49	37	4
Erigeron caucasicus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	62	.	.
Festuca alaica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	75	3	4
Astragalus macrosemius	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	57	.
Elymus longearistatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	.
Galium aucheri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	52

Physoptychis gnaphalodes and *Ziziphora clinopodioides* prefer scree fields but can also be found scattered and with low frequency in alpine thorn cushion grasslands. *Bromus tomentosus* plays an important role in plant communities of this order, reaching especially high cover in almost stabilized screes. It is distributed in Transcaucasia and the whole territory of Flora Iranica (Bor 1970). *Physoptychis gnaphalodes* is a scree species of Transcaucasia, Anatolia, NW Iran, Zagros and Alborz (Rechinger 1968). *Ziziphora clinopodioides* is an Irano-Turanian element with nine subspecies in the Flora Iranica territory, where some of them reach the alpine and subnival screes (e.g. subsp. *elbursensis*, *filicaulis* and *pseudodasyantha*), but most of them are rather common in sub-alpine and montane regions (Rechinger 1982b). *Poa araratica* is not exclusively confined to scree fields but is also dominant in alpine thorn

Table 3. Typus relevés. Association numbers are the same as in Table 1. For the association names, see Table 4. Letters after the association number refer to sub-associations.

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12
Association number	1	2	3a	3b	3c	3d	4	5	6a	6b	7	10
Turboveg relevé number	1066	1072	1040	1035	1100	1088	950	760	832	718	888	916
Geographic coordinates	37°44′ 17.2″N 46°29′ 53.3″E	37°44′ 14.3″N 46°30′ 09.5″E	37°43′ 58.6″N 46°31′ 08.6″E	37°44′ 00.0″N 46°31′ 09.3″E	37°43′ 56.0″N 46°29′ 58.5″E	37°44′ 06.2″N 46°29′ 59.7″E	38°16′ 24.6″N 47°51′ 15.0″E	35°53′ 38.0″N 51°24′ 32.0″E	35°52′ 44.0″N 51°24′ 35.0″E	35°54′ 08.0″N 51°24′ 40.0″E	35°53′ 07.0″N 51°24′ 54.0″E	36°21′ 55.0″N 50°57′ 44.0″E
Nepeta menthoides	4	1	.	.	.	1	.	.	.	.	.	.
Alopecurus aucheri	2	.	.	.	.	.	.	.	.	.	.	.
Senecio taraxacifolius	+	2	.	.	.	1	.	.	.	.	.	.
Myosotis asiatica	.	+	.	.	.	.	.	.	.	.	.	.
Oxyria digyna	.	1	.	.	.	.	.	.	.	.	.	.
Jurinella moschus	.	.	1	.	.	.	.	.	.	.	.	.
Potentilla porphyrantha	.	.	2	.	+	.	1	.	.	.	.	.
Minuartia recurva subsp. *oreina*	.	.	+	.	.	.	.	.	.	.	.	.
Astragalus beckii	.	.	.	.	1	.	.	.	.	.	.	.
Draba bruniifolia subsp. *bruniifolia*	.	.	.	.	2	.	+	.	.	.	.	.
Nepeta sahandica	.	.	.	.	.	1	.	.	.	.	.	.
Thymus kotschyanus	.	.	.	.	.	+	.	.	.	.	.	.
Crepis frigida	.	.	.	.	.	+	.	.	.	.	.	.
Erysimum gelidum	.	.	.	.	.	+	.	.	.	.	.	.
Alopecurus dasyanthus	.	.	.	.	.	.	+	.	.	.	.	.
Tripleurospermum caucasicum	.	1	.	.	.	.	1	.	.	.	.	.
Saxifraga sibirica	.	.	.	.	.	+	+	.	.	.	.	.
Erigeron caucasicus subsp. *venustus*	.	1	1	+	1	+	+	.	.	.	.	.
Sesleria phleoides	.	.	2	.	.	.	.	.	.	.	.	.
Galium hyrcanicum	.	1	1	.	+	.	.	.	.	.	.	.
Pedicularis caucasica	.	.	+	.	+	+	.	.	.	.	.	.
Minuartia glandulosa	.	1	.	+	.	.	.	.	.	.	.	.
Koeleria eriostachya	+	.	1	.	1	.	.	.	.	.	.	.
Scutellaria glechomoides	.	.	.	.	.	.	.	2	.	.	.	.
Euphorbia aucheri	.	.	.	.	.	.	.	2	1	+	.	.
Nepeta racemosa	.	.	.	.	.	.	.	.	3	3	.	.
Cicer tragacanthoides	.	.	.	.	.	.	.	.	3	.	.	.
Leonurus cardiaca subsp. *persicus*	.	.	.	.	.	.	.	.	+	.	.	.
Polygonum serpyllaceum	.	.	.	.	.	.	.	.	.	1	.	.
Asperula glomerata subsp. *bracteata*	.	.	.	.	.	.	.	.	.	.	1	.
Draba siliquosa	.	.	.	.	.	.	+	.	.	.	.	.
Astragalus macrosemius	.	.	.	.	.	.	.	.	.	.	2	.
Elymus longearistatus	.	.	.	.	.	.	.	.	1	2	1	.
Bromus tomentosus	+	1	1	1	2	1	.	.	1	.	2	.
Ziziphora clinopodioides	.	.	1	1	2	1	.	.	.	.	1	.
Physoptychis gnaphalodes	.	.	.	1	1	.	.	.	.	.	.	.

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Table 3. *(Continued).*

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12
Association number	1	2	3a	3b	3c	3d	4	5	6a	6b	7	10
Turboveg relevé number	1066	1072	1040	1035	1100	1088	950	760	832	718	888	916
Geographic coordinates	37°44′	37°44′	37°43′	37°44′	37°43′	37°44′	38°16′	35°53′	35°52′	35°54′	35°53′	36°21′
	17.2″N	14.3″N	58.6″N	00.0″N	56.0″N	06.2″N	24.6″N	38.0″N	44.0″N	08.0″N	07.0″N	55.0″N
	46°29′	46°30′	46°31′	46°31′	46°29′	46°29′	47°51′	51°24′	51°24′	51°24′	51°24′	50°57′
	53.3″E	09.5″E	08.6″E	09.3″E	58.5″E	59.7″E	15.0″E	32.0″E	35.0″E	40.0″E	54.0″E	44.0″E
Poa araratica	.	.	+	.	2	1	.	.	.	+	2	.
Festuca alaica	1	1	1	1	1	1	.	.	.	.	.	.
Campanula stevenii subsp. *beauverdiana*	.	+	1	.	.	.	.	.	.	.	1	.
Helichrysum psychrophilum	1	.	.	.	.	.	.	.	.	.	.	.
Cerastium purpurascens	.	.	.	.	.	.	.	.	.	.	.	1
Didymophysa aucheri	.	.	.	.	1	1	+	.	.	.	.	1
Dracocephalum aucheri	.	+	.	1	1	1	.	.	.	.	1	2
Alopecurus textilis	.	+	.	.	+	.	.	.	.	.	.	.
Arabis caucasica	.	.	.	.	.	+	+	.	.	.	.	1
Acantholimon demawendicum	.	.	.	.	.	.	.	.	.	.	1	.
Arenaria insignis	.	.	.	.	.	.	.	.	.	.	1	.
Veronica orientalis	1	.	.	.	.	.	.	.	.	.	.	.
Linaria lineolata	.	.	.	.	.	.	.	.	1	.	.	.

cushion grasslands (Noroozi et al. 2010). It is distributed from Anatolia and the Caucasus to the Hindu Kush (Bor 1970).

Two alliances are distinguished within the order. One alliance is distributed in Alborz and the other in Sahand and Sabalan (NW Iran).

1-1-1 Erigerontion venusti all. nov. hoc loco (Appendix S4)

Typus: *Dracocephalo aucheri-Brometum tomentosi* ass. nov. (see below)
Character taxa: *Erigeron caucasicus* subsp. *venustus*, *Nepeta menthoides*, *Senecio taraxacifolius*, *Tripleurospermum caucasicum* var. *caucasicum*, *Tripleurospermum caucasicum* var. *melanolepis*

Differential species: *Alopecurus textilis*, *Draba bruniifolia* subsp. *bruniifolia*, *Erysimum gelidum*, *Festuca alaica*, *Galium hyrcanicum*, *Koeleria eriostachya*, *Minuartia glandulosa*, *Pedicularis caucasica*, *Saxifraga sibirica*, *Sesleria phleoides*

This alliance covers the scree vegetation of Sahand and Sabalan. *Erigeron caucasicum* subsp. *venustus* is an alpine–subnival species distributed from NE and E Anatolia to N Iran (Grierson 1975; Rechinger 1982a). It is common in Sahand and Sabalan but very rare in Alborz. *Nepeta menthoides* is recorded from NE Iraq and NW Iran (Rechinger 1982b). *Senecio taraxacifolius* is distributed in NE Anatolia, Caucasus and NW Iran (Nordenstam 1989). In Iran, it is restricted to the high-alpine–subnival scree habitats of Sahand and Sabalan. *Tripleurospermum caucasicum* occurs on the Balkan Peninsula, in Lebanon, Anatolia, NE Iraq, the Caucasus and NW Iran (Podlech 1986). There are two varieties of this species in Iran, var. *caucasicum* and var. *melanolepis*, which are both distributed in the alpine–subnival zone of E Anatolia, the Caucasus and NW Iran (Podlech 1986). The diagnostic species include several differential species that are equally common in thorn cushion grasslands. *Festuca alaica* is distributed from NW Iran to the Hindu Kush and Central Asia (Alexeev 1979). *Saxifraga sibirica*, which also grows on rocky habitats, is a widespread species in Eurasia, occurring from mountains of the Balkan Peninsula to Russia (including Siberia), in the Caucasus, NW Iran and Central Asia (Schönbeck-Temesy 1967).

1-1-1-1 Nepetetum menthoidis ass. nov. hoc loco (Table 1: 1, Appendix S4, Photo S2)

Typus: relevé 1 (field nr. 1066) in Table 3.
Character species (transgressive): *Nepeta menthoides*
Differential species: *Alopecurus aucheri*, *Carum caucasicum*, *Sedum tenellum*, *Taraxacum crepidiforme*

This association is found on wet scree ground with high cover of *Nepeta menthoides*, which is a large perennial herb

Table 4. Syntaxonomic survey of the study area.

Class	*Didymophyso aucheri-Dracocephaletea aucheri* cl. nov.
Order 1	*Physoptychio gnaphalodis-Brometalia tomentosi* ord. nov.
Alliance 1	*Erigerontion venusti* all. nov.
Ass. 1	*Nepetetum menthoidis* ass. nov.
Ass. 2	*Senecionetum taraxacifolii* ass. nov.
Ass. 3	*Dracocephalo aucheri-Brometum tomentosi* ass. nov.
Ass. 4	*Potentilletum porphyranthae* ass. nov.
Alliance 2	*Elymo longearistati-Astragalion macrosemii* all. nov.
Ass. 5	*Scutellario glechomoidis-Euphorbietum aucheri* ass. nov.
Ass. 6	*Cicero tragacanthoidis-Nepetetum racemosae* ass. nov.
Ass. 7	*Asperulo bracteatae-Brometum tomentosi* ass. nov.
Ass. 8	*Senecioni iranici-Astragaletum macrosemii* ass. prov.
Order 2	*Didymophysetalia aucheri* ord. nov.
Alliance 3	*Didymophysion aucheri* all. nov.
Ass. 9	*Galietum aucheri* Klein & Lacoste 2001
Ass. 10	*Dracocephaletum aucheri* ass. nov.

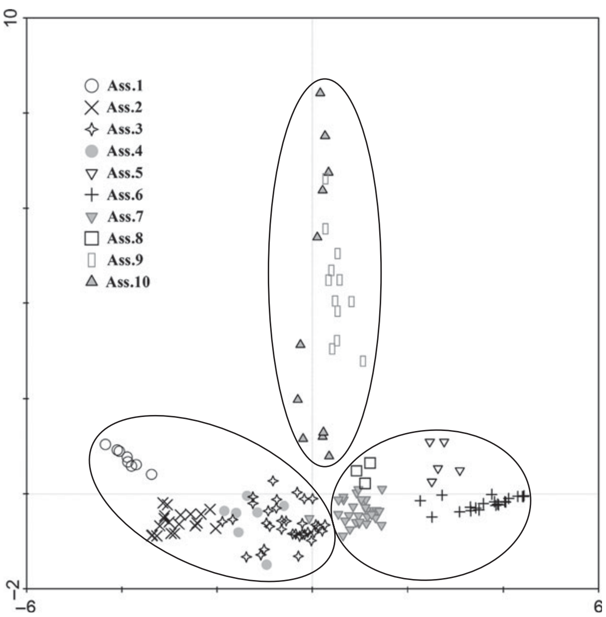

Fig. 2. Detrended correspondence analysis diagram of the sample plots. Association numbers are the same as in Table 1. 1: *Nepetetum menthoidis*, 2: *Senecionetum taraxacifolii*, 3: *Dracocephalo aucheri-Brometum tomentosi*, 4: *Potentilletum porphyranthae*, 5: *Scutellario glechomoidis-Euphorbietum aucheri*, 6: *Cicero tragacanthoidis-Nepetetum racemosae*, 7: *Asperulo bracteatae-Brometum tomentosi*, 8: *Senecioni iranici-Astragaletum macrosemii*, 9: *Galietum aucheri*, 10: *Dracocephaletum aucheri*. Left circle: *Erigerontion venusti* (Ass. 1–4), right circle: *Elymo-Astragalion macrosemii* (Ass. 5–8), upper circle: *Didymophysion aucheri* (Ass. 9–10).

of up to 60 cm. The stands are located in E and NE aspects between alpine thorn cushion grasslands and steep scree slopes. The high moisture of the soil is due to heavy snow accumulation during winter. In the DCA, the association is clearly separated at the left side of the diagram (Fig. 2). It is a transition between scree and snowbed communities, which is also indicated by the presence of snowbed species such as *Carum caucasicum, Alopecurus aucheri* and *Taraxacum crepidiforme*

1-1-1-2 Senecionetum taraxacifolii ass. nov. hoc loco (Table 1: 2, Appendix S4, Photo S3)

Typus: relevé 2 (field nr. 1072) in Table 3.
Character species (transgressive): *Senecio taraxacifolius*
Differential species: *Myosotis asiatica, Oxyria digyna*

This association is widespread in the high-alpine and subnival belt of Sahand in N aspects with steep inclination (ca. 30–45°). It occurs at altitudes from ca. 3300 m up to the highest peak, 3707 m a.s.l. The ground is covered with big and small mobile and stabilized stones. *Senecio taraxacifolius* is the most dominant species of this association, and its yellow flowers make the stands showy and attractive in July. *Myosotis asiatica* and *Oxyria digyna* are widespread scree species in the northern hemisphere (Meusel et al. 1964).

1-1-1-3 Dracocephalo aucheri-Brometum tomentosi ass. nov. hoc loco (Table 1: 3, Appendix S4, Photos S4, 5, 6)

Typus: relevé 5 (field nr. 1100) in Table 3.
Central association of the alliance.
Character species (only present in certain sub-associations): *Astragalus beckii, Nepeta sahandica*

This is one of the most widespread associations of the highest altitudes of Sahand, growing in SW, W and NW aspects with ca. 20–30° inclinations and an altitudinal range of ca. 3500–3707 m a.s.l.

Four sub-associations can be recognized:

1 *Dracocephalo-Brometum jurinelletosum moschi* subass. nov. hoc loco [Typus: relevé 3 (field nr. 1040) in Table 3] (Photo S4) with *Jurinella moschus, Potentilla porphyrantha* and *Minuartia recurva* subsp. *oreina* as differential taxa. This community is recorded from W slopes near ridges at altitudes of around 3500–3550 m a.s.l. The ground is often covered with small-grained scree. *J. moschus* is typical for scree vegetation near the top of mounds and ridges of the alpine and subnival areas of Anatolia, Transcaucasia, NE Iraq and NW Iran (Rechinger 1979). The alliance *Jurinellion moschi* Parolly 1995 was described from scree habitats of the Taurus Mts. in Central Anatolia, which is classified within the *Heldreichietalia* Quézel ex Parolly 1995 and *Heldreichietea* Quézel ex Parolly 1995 (Parolly 1995).

2 *Dracocephalo-Brometum minuartietosum glandulosae* subass. nov. hoc loco [Typus: relevé 4 (field nr. 1035) in Table 3] (Photo S5) with *Minuartia glandulosa* as differential species. This unit is recorded from W aspects with ca. 30° inclination at ca. 3510–3540 m a.s.l. The ground is covered with big stones (30–50 cm) and smaller scree

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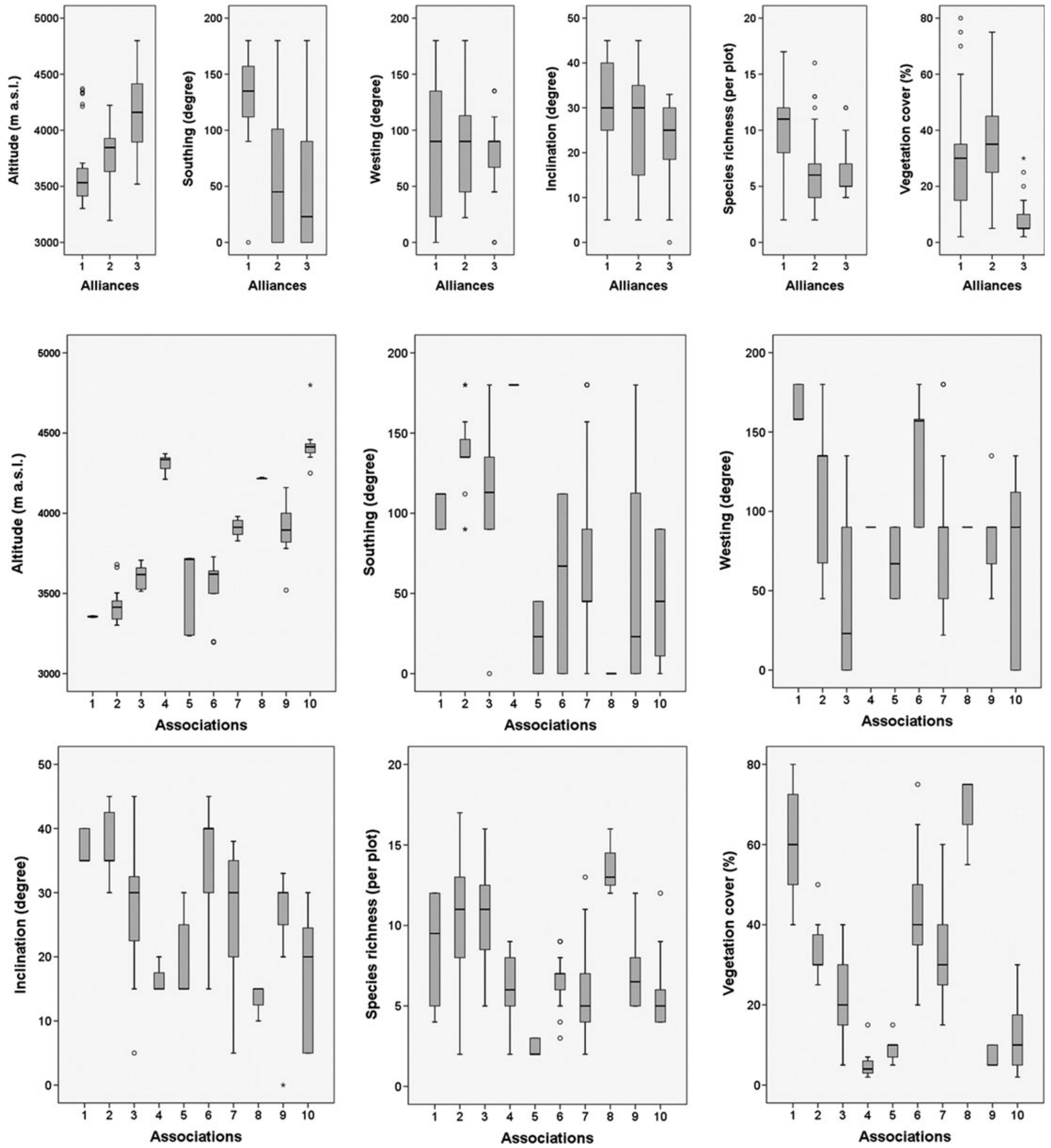

Fig. 3. Box plots for altitude, 'southness' of aspect, 'westness' of aspect, inclination, species number per plot and vegetation cover for all three alliances and ten associations. The boxes represent the interquartile range (IQR), horizontal lines the median values and points the outliers (>1.5 IQR outside the box). Alliance 1 (Ass. 1–4): *Erigerontion venusti*, Alliance 2 (Ass. 5–8): *Elymo-Astragalion macrosemii*, Alliance 3 (Ass. 9–10): *Didymophysion aucheri*. The association numbers are the same as in Table 1 and Fig. 2. For the association names, see Table 4.

material. *Minuartia glandulosa* is a cushion plant and more dominant in the alpine thorn cushion grasslands of Sahand. It is distributed in E Anatolia, Armenia, Republic of Azerbaijan and NW Iran (Rechinger 1988).

3 *Dracocephalo-Brometum typicum* subass. nov. hoc loco [Typus = typus of the association] (Photo S6) is more widespread than the two previous sub-associations and occurs at the highest elevations of Sahand (ca. 3600–3707 m a.s.l.) in SW, W and NW aspects. The character species *Astragalus beckii* seems to be restricted to this sub-association. Differential taxa are *Draba bruniifolia* subsp. *bruniifolia*, *Alyssum condensatum* and *Alopecurus textilis*. This unit has a higher vegetation cover, and *Bromus tomentosus*, *Poa araratica* and *Ziziphora clinopodioides* are more dominant than in the other three sub-associations. *Astragalus beckii* is distributed in Alborz and NW Iran as well as in Talysh (Podlech et al. 2010). *Draba bruniifolia* subsp. *bruniifolia* and *Alyssum condensatum* are common dominant species in alpine thorn cushion grassland. The first is distributed in NW Iran, SE Anatolia and NE Iraq (Hedge 1968), and the second in Lebanon, Syria, Anatolia and NE Iraq (Rechinger 1968).

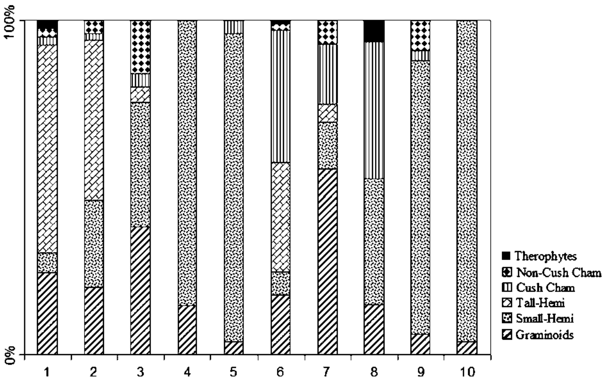

Fig. 4. Mean proportional cover of life forms over all relevés of each association. Ass. 1–4: *Erigerontion venusti*, Ass. 5–8: *Elymo-Astragalion macrosemii*, Ass. 9–10: *Didymophysion aucheri*. The association numbers are the same as in Table 1 and Fig. 2. For the association names, see Table 4. Non-Cush Cham: non-cushion chamaephyte, Cush Cham: cushion chamaephyte, Tall-Hemi: tall hemicryptophyte (>ca. 30 cm), Small-Hemi: small hemicryptophyte (<ca. 30 cm).

4 *Dracocephalo-Brometum nepetetosum sahandicae* subass. nov. hoc loco [Typus: relevé 6 (field nr. 1088) in Table 3] (Photo S7) with *Arabis caucasica* and *Senecio taraxacifolius* as differential species. *Nepeta sahandica* is almost restricted to this sub-association. This unit occurs on moving scree fields with poor soil material and very steep inclination (30–45°) of N slopes at altitudes between 3500 and 3630 m a.s.l. of Sahand. Due to steep inclination and unstable scree and soil material, the vegetation cover is sparse. *Nepeta sahandica* is a local endemic of Sahand and a new species to science (Noroozi & Ajani in press). *Arabis caucasica* is distributed in the mountains of SW Asia and S Europe, with a wide altitudinal range from the montane to the nival belt (Hedge 1968). It is a close relative of *A. alpina* and often treated as a subspecies of the latter.

1-1-1-4 Potentilletum porphyranthae ass. nov. hoc loco (Table 1: 4, Appendix S4, Photo S8)

Typus: relevé 7 (field nr. 950) in Table 3.
Character species: *Alopecurus dasyanthus, Potentilla argaea, Potentilla porphyrantha*

This association represents the plant assemblages at the upper limit of vascular plants in the subnival–nival zone of Sabalan at altitudes around 4200–4400 m a.s.l., where the ground is usually covered with solid rocks and smaller scree material. The syntaxonomic position of this unit is unclear because the character species of the order *Physoptychio-Brometalia tomentosi* are totally absent. Perhaps it should be classified within a separate alliance belonging to the order *Didymophysetalia*, but more material from the subnival–nival zone of NW Iran is required to solve this question. The association is only recorded from N aspects. The plant cover and species richness are very low. *Potentilla porphyrantha* is a narrowly ranged species of the subnival zones of S Armenia and NW Iran (see distribution map in Noroozi et al. 2011). *Potentilla argaea* is distributed in Anatolia and NW Iran (Schiman-Czeika 1969). *Alopecurus dasyanthus* occurs in NE Anatolia, the Caucasus and NW Iran (Bor 1970).

1-1-2 Elymo longearistati-Astragalion macrosemii all. nov. hoc loco (Appendix S5)

Typus: *Asperulo bracteatae-Brometum tomentosi* ass. nov. (see below)
Character species: *Euphorbia aucheri, Scutellaria glechomoides*
Differential species: *Astragalus macrosemius, Elymus longearistatus*

This alliance includes the high-alpine to lower subnival scree vegetation of Central Alborz. *Euphorbia aucheri* and *Scutellaria glechomoides* have their optimum in the *Scutellario glechomoidis-Euphorbietum aucheri* (see below). *Astragalus macrosemius* is a compact thorn cushion species common in this alliance but also in alpine thorn cushion grasslands of the *Acantholimion demawendici* (Noroozi et al. 2010). The species is restricted to Central Alborz (Zarre et al. 2008) and is the only tragacanthic species in Alborz that can reach altitudes above 4200 m a.s.l. *Elymus longearistatus* is a polymorphic species, which prefers scree habitats from sub-alpine to subnival zones. It is not considered a character species of this alliance, as it is also a dominant in sub-alpine umbelliferous vegetation (*'Prangetea ulopterae'*). The species has a wide distribution in the Irano-Turanian region and comprises six subspecies (Davis 1985). The character species of this alliance have a rather low constancy and even the differential species are absent from some stands, so the unit should be regarded as the central alliance of the order.

1-1-2-1 Scutellario glechomoidis-Euphorbietum aucheri ass. nov. hoc loco (Table 1: 5, Appendix S5, Photo S9)

Typus: relevé 8 (field nr. 760) in Table 3.
Character species (transgressive): *Euphorbia aucheri, Scutellaria glechomoides*

This community occurs on moving scree fields lacking any soil except in the deeper parts (below ca. 50 cm). It is floristically one of the poorest communities of the class. *Euphorbia aucheri* and *Scutellaria glechomoides*, which mainly constitute this community, are characteristic moving scree plants and scree pioneers. They are well adapted to such conditions by their very long and flexible rhizomes (50–100 cm; Photo S9c). The above-ground stems are very short and so the plants look like rosettes. *Euphorbia aucheri* is distributed in the alpine and subnival zones of Iran and

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the Hindu Kush (Rechinger & Schiman-Czeika 1964). *Scutellaria glechomoides* is restricted to Central Alborz (Rechinger 1982b). The community is known from 3230 to 3800 m a.s.l. on S slopes but may extend up to the subnival–nival zone.

1-1-2-2 Cicero tragacanthoidis-Nepetetum racemosae ass. nov. hoc loco (Table 1: 6, Appendix S5, Photo S9A, 10,11)

Typus: relevé 9 (field nr. 832) in Table 3.
Character species: *Cicer tragacanthoides*, *Leonurus cardiaca* subsp. *persicus*, *Nepeta racemosa*

This association occurs on recently stabilized scree fields, and sometimes is surrounding stands of the *Scutellario-Euphorbietum* (see Photo S9a). According to field observations of the first author, it is the most frequent association in the alpine scree slopes of Central Alborz. The altitudinal range of the community is ca. 3200–3730 m a.s.l., and it usually covers S slopes with inclinations of 15–45°. *Nepeta racemosa* is distributed in Alborz, with a single record from SE Turkey near the border with Iran (Rechinger 1982b). *Cicer tragacanthoides*, which has a tragacanthic habit, is restricted to the alpine zone of Iran (van der Maesen 1979). It crawls over the scree and thus stabilizes it (Photo S3). *Leonurus cardiaca* subsp. *persicus* is endemic in Central Alborz (Rechinger 1982b).

Besides the typical sub-association (1) *Cicero tragacanthoidis-Nepetetum racemosae typicum* subass. nov. hoc loco [Typus = typus of the association] (Photo S10), a deviating subunit (2) *Cicero tragacanthoidis-Nepetetum racemosae polygonetosum serpyllacei* subass. nov. hoc loco [Typus: relevé 10 (field nr. 718) in Table 3] (Photo S11), can be distinguished on NE slopes with steep inclination (ca. 40–45°), where the ground is covered with coarse scree and boulders (ca. 0.5–1.0-m diameter). This sub-association is differentiated by *Polygonum serpyllaceum*, a character species of snowbed communities (*Taraxaco brevirostre-Polygonion serpyllacei* Noroozi et al. 2010). Its presence in this community is due to long snow cover and high soil moisture. *Nepeta racemosa* has high cover in this sub-association but the other two character species of the association are absent. There is some ecological similarity between this sub-association and the *Nepetetum menthoidis* of Sahand. In both communities, there are snowbed species, and both occur in NE and E aspects. The two *Nepeta* species (*N. racemosa* and *N. menthoides*) play a similar ecological role in the two different geographic regions.

1-1-2-3 Asperulo bracteatae-Brometum tomentosi ass. nov. hoc loco (Table 1: 7, Appendix S5, Photo S12, 13)

Typus: relevé 11 (field nr. 888) in Table 3.
Central association of the alliance.

This association mostly occurs on SW slopes mostly of 20–35° inclination at the highest altitudes of the Tuchal (3800–3960 m a.s.l.) N of Tehran. The structure and ecology of this association is very close to the *Dracocephalo-Brometum tomentosi* that covers the highest altitudes of Sahand, mostly in W aspects. The most remarkable physiognomic difference between the two associations is the absence of thorn cushions in *Dracocephalo-Brometum*. In the DCA diagram these two associations are located very close to each other near the centre of the diagram.

Three provisional sub-associations have been distinguished:
1 The typical sub-association with *Asperula glomerata* subsp. *bracteata* as differential species (Photo S12). *A. glomerata* is an altitudinally widespread species ranging from ca. 700 to 4200 m a.s.l., with many subspecies. *A. glomerata* subsp. *bracteata* is a strongly compact cushion restricted to Central Alborz (Ehrendorfer et al. 2005) and concentrated in high-alpine and subnival scree habitats.
2 On N aspects with moderate slope, stabilized scree and more developed soil, transitions to snowbed communities can be found that are differentiated by *Ranunculus crymophilus* and *Polygonum serpyllaceum*. Both of these are character species of snowbed communities (Noroozi et al. 2010).
3 On steep slopes with large volcanic stony ground and undeveloped soils on N and W slopes, *Asperula glomerata* disappears and the dominance of *Dracocephalum aucheri* increases (Photo S13). The ecology and physiognomy of this sub-association is very similar to *Dracocephalo-Brometum minuartietosum glandulosae* of Sahand (compare Photos S5 and S13).

1-1-2-4 Senecioni iranici-Astragaletum macrosemii ass. prov. (Table 1: 8, Appendix S5, Photo S14)

Character species: *Senecio iranicus*
Differential species: *Artemisia melanolepis*, *Carex oreophila*, *Catabrosella parviflora*, *Cerastium purpurascens* var. *elbursensis*, *Draba siliquosa*, *Erysimum elbrusense*, *Potentilla argyroloma*, *Veronica biloba*

This community reaches the highest elevation within this alliance and probably harbours the highest occurrences of the spiny cushions in in the study area. In spite of the high altitude of the stands (ca. 4200–4230 m a.s.l.), finer material with appropriate moisture, moderate inclination (ca. 10–15°) and stabilized scree make this community one of the richest of the class (ca. 14 species on 25 m²) with high vegetation cover (ca. 70%). This community is located on the S slopes of Mt. Damavand. *Senecio iranicus* is an annual and local endemic species for Damavand (Nordenstam 1989) and recorded only from this community. *Artemisia melanolepis* is an endemic species in the subnival zone of NW and N Iran (Podlech 1986). *Carex oreophila* occurs in the Caucasus, Turkey, Iraq and Iran (Kukkonen 1998). *Catabrosella parviflora* is a dominant species of snowbed and thorn cushion grasslands of Iranian high-alpine regions (Noroozi et al. 2010). *Draba siliquosa* is a widespread species in European and Caucasian alpine and subnival zones, and Damavand is the easternmost limit of this species (see distribution map in Noroozi et al. 2011). *Potentilla argyroloma* is an endemic species of Iran and occurs in Zagros and Alborz (Schiman-Czeika 1969). *Veronica biloba* is an annual species with a wide altitudinal (ca. 1200–4220 m a.s.l.) and geographical distribution from the Caucasus and W Asia to Central Asia, Mongolia and the Himalaya (Fischer 1981). *Cerastium purpurascens* var. *elbursensis* and *Erysimum elbrusense* are diagnostic taxa of the *Didymophysion aucheri* (see below).

1-2 Didymophysetalia aucheri ord. nov. hoc loco

Typus: *Didymophysion aucheri* all. nov. (see below)
Character species (transgressive): *Didymophysa aucheri*, *Dracocephalum aucheri*
Differential species: *Erysimum elbrusense*

This order is monotypic, with a single alliance so far (but see *Potentilletum porphyranthae* above). *Erysimum elbrusense* is common in Alborz but is also known with a few records from NW Iran (Polatschek 2011).

1-2-1 Didymophysion aucheri all. nov. hoc loco (Appendix S6)

Typus: *Dracocephaletum aucheri* ass. nov. (see below)
Character species: *Achillea aucheri*, *Cerastium purpurascens* var. *elbursensis*

This alliance includes open communities at the upper limit of vascular plant species in the subnival–nival zone of Central Alborz. Very low cover–abundance of grasses, absence of thorn cushions, low species richness, sparse plant cover and a high percentage of open scree are the main features of this alliance. *Achillea aucheri* is a true subnival–nival species in Central Alborz, with a few records from NW Iran (Huber-Morath 1986). *Cerastium purpurascens* is an alpine and subnival–nival species of Anatolia, the Caucasus, NE Iraq and Central Alborz. In Iran it is confined to the subnival–nival zone of Central Alborz, a taxon known as var. *elbursensis* (Möschl 1988).

1-2-1-1 Galietum aucheri Klein & Lacoste 2001 ['1999'] (Table 1: 9, Appendix S6, Photo S15)

Typus: relevé 99 in Klein & Lacoste 2001 (see Appendix S6, relevé no. 1170)
Character species: *Galium aucheri*, *Senecio vulcanicus*, *Veronica paederotae*
Differential species: *Asperula glomerata* subsp. *bracteata*, *Lamium tomentosum*, *Pseudocamelina glaucophylla*

This association is concentrated at altitudes between 3800–4200 m a.s.l., with ca. 20–35° inclination. It was recorded by Klein & Lacoste (2001) from Alamkuh and Azadkuh. In the DCA diagram, it is located in the centre of the alliance (Fig. 2). *Galium aucheri*, *Senecio vulcanicus* and *Veronica paederotae* are subnival–nival species and restricted to Alborz (see distribution maps in Fischer 1981; Nordenstam 1989; Ehrendorfer et al. 2005; Noroozi et al. 2011). The main distribution of *Lamium tomentosum* is Caucasus and Transcaucasus mountains, with disjunct distribution in Central Alborz (Mennema 1989; see distribution map in Noroozi et al. 2011). *Pseudocamelina glaucophylla* is an endemic species of Iran but widespread in the alpine zone of Zagros, NW Iran and Alborz mountains (Rechinger 1968). Klein & Lacoste (2001) indicated also *Achillea aucheri* and *Scutellaria glechomoides* as character species of this association. According to our data, however, these two species clearly have their optimum in other communities.

1-2-1-2 Dracocephaletum aucheri ass. nov. hoc loco (Table 1: 10, Appendix S6, Photo S16, 17)

Typus: relevé 12 (field nr. 916) in Table 3.
Central association of the alliance.

This association represents the upper limit of vascular plants in Central Alborz. It is the highest plant community of the Iranian mountains, concentrated between 4300 and 4600 m a.s.l., but in some special places reaches even higher altitudes. The ground is completely covered with scree.

Two subunits can be distinguished which, due to the small number of relevés, are treated as provisional subassociations. With more material, however, the first unit might become a good association, with *Achillea aucheri* and *Veronica aucheri* as character species.

1 *Dracocephaletum aucheri achilleetosum aucheri* subass. prov. (Photo S16) with the diagnostic species *Achillea aucheri* and *Veronica aucheri.* This community grows at very high altitudes of Damavand on S slopes from 4300 to 4800 m a.s.l., and future studies may lead to the conclusion that it should be treated as a separate association. *Veronica aucheri* is a true subnival–nival species and endemic for Alborz (Fischer 1981). It is the most common species at altitudes from 4500 to 4800 m a.s.l. of Damavand, and has the highest altitudinal record for vascular plants in Iran (4820 m a.s.l.). In one plot of this association (4799 m a.s.l.), *Alopecurus himalaicus* was found, which has an extremely disjunct distribution in Bulgaria, Iran and the W Hindu Kush

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–Himalaya system (Noroozi et al. 2011). This is probably the same location from which the species was previously recorded (Bor 1970), and so far the only known population of this species in Iran.

2 *Dracocephaletum aucheri typicum* (Photo S17) with *Arabis caucasica* and *Potentilla argyroloma* as differential species. It is recorded from the nival zone of Mt. Alamkuh at altitudes from 4350 to 4450 m a.s.l. on gentle to steep slopes without special aspect preference.

Concluding remarks

Floristically defined vegetation types are suitable reference entities for ecological research, bioindication and nature conservation (Dengler et al. 2008). Our study extends knowledge of alpine scree vegetation into a previously almost unknown area, and therefore represents an important building block for a future synopsis of the scree vegetation of the northern hemisphere. The alpine and subnival scree communities in our study area show a high degree of local endemism, and many endemic taxa of Iran are restricted to high altitudes (Klein 1991; Frey et al. 1999; Noroozi et al. 2008, 2011). We therefore consider our study as an important assessment tool for nature conservation that will improve knowledge of phytodiversity in alpine habitats of Iran. It is also a basis for monitoring of future changes and for assessing endangered vegetation types.

The direct human impact on the described scree communities is not very strong due to their low productivity. However, there are large herds grazing neighbouring alpine grasslands. Therefore, in spite of the low attraction for sheep and goats to feed on scree vegetation, effects of pastoralism should not be neglected, especially the impact of trampling on unstable scree habitats. As the herds in these mountains are usually very large, the substrate movement is strongly intensified by trampling, plants are uprooted and thus the vegetation is sometimes completely destroyed. The most important threat to the flora and vegetation of the study habitats, however, may be the acceleration of climate warming. The high rate of narrowly distributed species in the alpine and subnival–nival zones and the absence of alternative low-temperature habitats in Iranian mountains increase this threat (Noroozi et al. 2011). The highest growing vascular plant in Iran was found at ca. 4800 m a.s.l. on Damavand, and only three mountain peaks exceed the upper limit of vascular plants (Damavand and Alamkuh in Central Alborz and Sabalan in NW Iran). Therefore, global warming will threaten the very fragmented and small-scale habitats of the cryophilous flora and vegetation of the Iranian mountains (Noroozi et al. 2011). A decline of high-altitude habitats through climate warming and reduced water availability is expected to be similar to that on Mediterranean mountains of S Europe, where species richness has decreased during the past particularly warm decade (Pauli et al. 2012). Climate change models predict increasing temperature and decreasing precipitation for our study region during the 21st century (Christensen et al. 2007; Zarghami et al. 2011). Hence, we have to presume a very high risk of biodiversity losses in the hig-altitude vegetation of N and NW Iran. Detailed knowledge of these plant assemblages appears to be essential for tracing the expected changes in their species composition and the possible shrinkage of cryophilic, narrowly distributed species.

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References

Agakhanjanz, O. & Breckle, S.-W. 1995. Origin and evolution of the mountain flora in middle Asia and neighboring mountain regions. In: Chapin, F.S. & Körner, C. (eds.) *Arctic and alpine biodiversity: patterns, causes and ecosystem consequences*, pp. 63–80. Ecological Studies 113, Springer, Berlin, DE.

Akhani, H., Mahdavi, P., Noroozi, J. & Zarrinpour, V. 2013. Vegetation pattern of Irano-Turanian steppes along a 3000 m altitudinal gradient in the Alborz Moutains (Iran). *Folia Geobotanica*. doi:10.1007/s12224-012-9147-8.

Alexeev, E. 1979. Genus *Festuca* L. Florae Iranicae et territorium confinium. *Novitates systematicae Plantarum vascularium* 16: 7–35.

Behrouzi, A., Amini Fazl, A., Amini Azar, A. & Emami, M.H. 1997. *Geological map of Bostan Abad (1: 100,000)*. Geological Survey of Iran, Tehran, IR.

Bor, N.L. 1970. Gramineae. In: Rechinger, K.H. (ed.) *Flora iranica, 70*, pp. 1–573. Akademische Druck u. Verlagsanstalt, Graz, AT.

Buhse, F. 1899a. Flora des Alburs und der Kaspischen Südküste. Bisherige Forschungsergebnisse aus diesem Gebiet. *Arbeiten des Naturforscher-Vereins zu Riga. Neue Folge*. 8. Heft.

Buhse, F 1899b. Reisebemerkungen aus dem östlichen Albursgebirge in Persien. *Bulletin de la Société Impériale des Naturalistes de Moscou* 34: 363–383.

Christensen, J. H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., Jones, R., Kolli, R. K., Kwon, W.-T., Laprise, R., Magaña Rueda, V., Mearns, L., Menéndez, C. G., Räisänen, J., Rinke, A., Sarr, A. & Whetton, P. (2007) Regional climate projections. In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. & Miller, H. L. (eds.) *Climate change 2007: the physical science basis. Contribution of working group I to the fourth assessment report of the Intergovernmental Panel on Climate Change*, pp. 847–940. Cambridge University Press, Cambridge, UK.

Davidson, J., Hassanzadeh, J., Berzins, R., Stockli, D.F., Bashukooh, B., Turrin, B. & Pandamouz, A. 2004. The geology of Damavand volcano, Alborz Mountains, northern Iran. *Geological Society of America Bulletin* 116: 16–29.

Davis, P.H. (ed.) 1985. *Flora of Turkey and the East Aegean Islands, 9*. Edinburgh University Press, Edinburgh, UK.

Dengler, J. 2003. *Entwicklung und Bewertung neuer Ansätze in der Pflanzensoziologie unter besonderer Berücksichtigung der Vegetationsklassifikation*. Martina Galunder, Nümbrecht, DE.

Dengler, J., Chytrý, M. & Ewald, J. 2008. Phytosociology. In: Jørgensen, S. E. & Fath, B. D. (eds.) *Encyclopedia of ecology*, pp. 2767–2779. Elsevier, Oxford, UK.

Dewan, M.L., Famouri, J., Farmanara, M., Mahjoori, R., Pirooz, N., Samadi, M., Vakilian, M. & Verot, P. 1961. *Soil map of Iran*. Iranian Ministry of Agriculture and Food and Agriculture Organization of the United Nations (FAO), Tehran, IR.

Djamali, M., Akhani, H., Khoshravesh, R., Andrieu-Ponel, V., Ponel, P. & Brewer, S. 2011. Application of the global bioclimatic classification to Iran: implications for understanding the modern vegetation and biogeography. *Ecologia Mediterranea* 37: 91–114.

Ehrendorfer, F., Schönbeck-Temesy, E., Puff, C. & Rechinger, W. 2005. Rubiaceae. In: Rechinger, K.H. (ed.) *Flora Iranica, 176*, pp. 1–287. Naturhistorisches Museum Wien, Wien, AT.

Fernández Calzado, M.R. & Molero Mesa, J. 2011. High altitude flora of Sierra Nevada (Spain). *Flora Mediterranea* 21: 247–259.

Ferrigno, J.G. 1991. Glaciers of the Middle East and Africa – glaciers of Iran. In: Williams, R.S. & Ferrigno, J.G. (eds.) *Satellite image atlas of glaciers of the world*, pp. 31–47. U.S. Geological Survey Professional Paper 1386-G, United States Government Printing Office, Washington, DC, US.

Fischer, M. A. 1981. *Veronica* [Scrophulariaceae I]. In: Rechinger, K.H. (ed.) *Flora Iranica, 147*, pp. 52–165. Akademische Druck u. Verlagsanstalt, Graz, AT.

Frey, W., Kürschner, H. & Probst, W. 1999. Flora and vegetation, including plant species and larger vegetation complexes in Persia. In: Yarshater, E. (ed.) *Encyclopaedia Iranica* 10(1), pp. 43–63. Mazda Publishers, Costa Mesa, CA, US.

Gilli, A. 1939. Die Pflanzengesellschaften der Hochregion des Elbursgebirges in Nordiran. *Beiheft des Botanischen Centralblatt* 59: 317–344.

Gilli, A. 1941. Ein Beitrag zur Flora des Elburs-Gebirges in Nord-Iran. *Feddes Repertorium Specierum Novarum Regni Vegetabilis* 50: 263–283.

Grierson, A.J.C. 1975. *Erigeron* [Compositae]. In: Davis, P.H. (ed.) *Flora of Turkey and the East Aegean Islands*, Vol. 5, pp. 124–130. Edinburgh University Press, Edinburgh, UK.

Hedge, I. 1968. *Didymophysa*, *Draba*, Arabis [Cruciferae]. In: Rechinger, K.H. (ed.) *Flora Iranica, 57*, pp. 87–98, 176–186, 201–210. Akademische Druck u. Verlagsanstalt, Graz, AT.

Huber-Morath, A. 1986. *Achillea* [Compositae VI-Anthemideae]. In: Rechinger, K.H. (ed.) *Flora Iranica, 158*, pp. 49–73. Akademische Druck u. Verlagsanstalt, Graz, AT.

Innocenti, F., Manetti, P., Mazzuoli, R., Pasquaré, G. & Villari, L. 1982. Anatolia and north-western Iran. In: Thorpe, R.S. (ed.) *Andesites*, pp. 327–349. John Wiley & Sons, Chichester, UK.

Jamshidi, K. & Afsharian Zadeh, A.M. 1993. *Geological map of Tehran (1:100,000)*. Geological Survey of Iran, Tehran, IR.

Kazakis, G., Ghosn, D., Vogiatzakis, I.N. & Papanastasis, V. P. 2007. Vascular plant diversity and climate change in the alpine zone of the Lefka Ori, Crete. *Biodiversity and Conservation* 16: 1603–1615.

Khalili, A. 1973. Precipitation patterns of Central Elburz. *Archiv für Meteorologie, Geophysik und Bioklimatologie, Serie B* 21: 215–232.

Klein, J.C. 1982. Les groupements chionophiles de l'Alborz central (Iran). Comparaison avec leurs homologues d'Asie centrale. *Phytocoenologia* 10: 463–486.

Klein, J.C. 1987. Les pelouses xérophiles d'altitude du flanc sud de l'Alborz central (Iran). *Phytocoenologia* 15: 253–280.

Klein, J.C. 1988. Les groupements à grandes ombellifères et à xérophytes orophiles: Essai de synthèse à l'échelle de la région irano-touranienne. *Phytocoenologia* 16: 1–36.

Klein, J.C. 1991. Endémisme à l'étage alpin de l'Alborz (Iran). *Flora et Vegetatio Mundi* 9: 247–261.

Klein, J.C. & Lacoste, A. 2001. (1999). Observation sur la végétation des éboulis dans les massifs irano-touraniens: le Galietum aucheri ass. nov. de l'Alborz central (N-Iran). *Documents Phytosociologiques N. S.* 19: 219–228.

Kotschy, T. 1861a. Die Vegetation des westlichen Elbrus in Nordpersien. *Österreichische Botanische Zeitschrift* 11: 105–117.

Kotschy, T. 1861b. Der westliche Elbrus bei Teheran. *Mitteilungen der Kaiserlich-Königlichen Oestereichischen Geographischen Gesellschaft Wien* 5: 65–110.

Kukkonen, I. 1998. Cyperaceae. In: Rechinger, K.H. (ed.) *Flora Iranica, 164*, pp. 1–307. Akademische Druck u. Verlagsanstalt, Graz, AT.

Luther-Mosebach, J., Dengler, J., Schmiedel, U., Röwer, I-U., Labitzky, T. & Gröngröft, A. 2012. A first formal classification of the Hardeveld vegetation in Namaqualand, South Africa. *Applied Vegetation Science* 15: 401–431.

Mennema, J. 1989. *Lamium* [Labiatae]. In: Rechinger, K.H. (ed.) *Flora Iranica, 150*, pp. 321–333. Akademische Druck u. Verlagsanstalt, Graz, AT.

Meusel, H., Jäger, E. & Weinert, E. 1964. *Vergleichende Chorologie der zentraleuropäischen Flora. Band I*. Gustav Fischer, Jena, DE.

Möschl, W. 1988. *Cerastium* [Caryophyllaceae II]. In: Rechinger, K.H. (ed.) *Flora Iranica, 163*, pp. 85–109. Akademische Druck u. Verlagsanstalt, Graz, AT.

Naqinezhad, A., Jalili, A., Attar, F., Ghahraman, A., Wheeler, B.D., Hodgson, J.G., Shaw, S.C. & Maassoumi, A. 2009. Floristic characteristics of the wetland sites on dry southern slopes of the Alborz Mts., N. Iran: The role of altitude in floristic composition. *Flora* 204: 254–269.

Nordenstam, B. 1989. *Senecio* [Compositae VII -Senecioneae]. In: Rechinger, K.H. (ed.) *Flora Iranica, 164*, pp. 59–95. Akademische Druck u. Verlagsanstalt, Graz, AT.

Noroozi, J. & Ajani, Y. (in press) A new alpine species of *Nepeta* sect. *Capituliflorae* (Labiatae) from Northwestern Iran, *Novon*.

Noroozi, J., Akhani, H. & Breckle, S.W. 2008. Biodiversity and phytogeography of the alpine flora of Iran. *Biodiversity and Conservation* 17: 493–521.

Noroozi, J., Akhani, H. & Willner, W. 2010. Phytosociological and ecological study of the high alpine vegetation of Tuchal Mountains (Central Alborz, Iran). *Phytocoenologia* 40: 293–321.

Noroozi, J., Pauli, H., Grabherr, G. & Breckle, W.S. 2011. The subnival–nival vascular plant species of Iran: a unique high-mountain flora and its threat from climate warming. *Biodiversity and Conservation* 20: 1319–1338.

Onipchenko, V.G. 2002. Alpine vegetation of the Teberda Reserve, the Northwestern Caucasus. *Veröffentlichungen des Geobotanischen Institutes der ETH*, 130.

Parolly, G. 1995. Die Steinschuttfluren (*Heldreichietea*) des Westlichen und Mittleren Taurus (Türkei). Pflanzensoziologische, floristische und ökologische Untersuchungen. *Dissertationes Botanicae* 247: 1–374.

Parolly, G. 1998. Phytosociological studies on high mountain plant communities of the South Anatolian Taurus mountains. 1. Scree plant communities (Heldreichietea): A Synopsis. *Phytocoenologia* 28: 233–284.

Pauli, H., Gottfried, M., Dullinger, S., Abdaladze, O., Akhalkatsi, M., Benito Alonso, J.L., Coldea, G., Dick, J., Erschbamer, B., Fernández Calzado, R., Ghosn, D., Holten, J.I., Kanka, R., Kazakis, G., Kollár, J., Larsson, P., Moiseev, P., Moiseev, D., Molau, U., Molero Mesa, J., Nagy, L., Pelino, G., Puşcaş, M., Rossi, G., Stanisci, A., Syverhuset, A.O., Theurillat, J.-P., Tomaselli, M., Unterluggauer, P., Villar, L., Vittoz, P. & Grabherr, G. 2012. Recent plant diversity changes on Europe's mountain summits. *Science* 336: 353–355.

Podlech, D. 1986. *Tripleurospermum*, *Artemisia* [Compositae VI-Anthemideae]. In: Rechinger, K.H. (ed.) *Flora Iranica, 158*, pp. 73–80, 159–223. Akademische Druck u. Verlagsanstalt, Graz, AT.

Podlech, D., Zarre, S., Massoumi, A.A., Ekici, M. & Sytin, A. 2010. Papilionaceae VI, *Astragalus* IV. In: Rechinger, K.H. (ed.) *Flora Iranica, 178*, pp. 1–430. Naturhistorisches Museum Wien, Wien, AT.

Polatschek, A. 2011. Revision der Gattung *Erysimum* (Cruciferae), Teil 2: Georgien, Armenien, Azerbaidzan, Türkei, Syrien, Libanon, Israel, Jordanien, Irak, Iran, Afghanistan. *Annalen des Naturhistorischen Museums in Wien. B* 112: 369–497.

Rechinger, K.H. (ed.) 1963–2012. Flora Iranica*, 1-179*. Akademische Druck- u. Verlagsanstalt und Naturhistorisches Museum Wien, Graz & Wien, AT.

Rechinger, K.H. 1968. *Physoptychis*, *Alyssum*, *Pseudocamelina* [Cruciferae]. In: Rechinger, K.H. (ed.) *Flora Iranica, 57*, pp. 140–141, 146–170, 220–223. Akademische Druck u. Verlagsanstalt, Graz, AT.

Rechinger, K.H. 1979. *Jurinella* [Compositae III, Cynareae]. In: Rechinger, K.H. (ed.) *Flora Iranica, 139a*, pp. 212–215. Akademische Druck u. Verlagsanstalt, Graz, AT.

Rechinger, K.H. 1982a. *Erigeron* [Compositae V, Astereae]. In: Rechinger, K.H. (ed.) *Flora Iranica, 154*, pp. 14–33. Akademische Druck u. Verlagsanstalt, Graz, AT.

Rechinger, K.H. 1982b. *Scutellaria*, *Nepeta*, *Dracocephalum*, *Leonurus*, *Lagochilus*, *Ziziphora* [Labiatae]. In: Rechinger, K.H. (ed.) *Flora Iranica, 150*, pp. 44–84, 108–216, 218–230, 334–337, 377–344, 480–493. Akademische Druck u. Verlagsanstalt, Graz, AT.

Rechinger, K.H. 1988. *Minuartia* (Caryophyllaceae II). In: Rechinger, K.H. (ed.) *Flora Iranica, 163*, pp. 28–53. Akademische Druck u. Verlagsanstalt, Graz, AT.

Rechinger, K.H. & Schiman-Czeika, H. 1964. Euphorbiaceae. In: Rechinger, K.H. (ed.) *Flora Iranica, 6*, pp. 1–48. Akademische Druck u. Verlagsanstalt, Graz, AT.

Rivas-Martínez, S., Sánchez-Mata, D. & Costa, M. 1997. Syntaxonomical synopsis of the potential natural plant communities of North America I. *Itinera Geobotanica* 10: 5–148.

Rivas-Martínez, S., Sánchez-Mata, D. & Costa, M. 1999. Boreal and western temperate forest vegetation (syntaxonomical synopsis of the potential natural plant communities of North America II). *Itinera Geobotanica* 12: 3–311.

Schiman-Czeika, H. 1969: *Potentilla*. In: Rechinger, K.H. (ed.) *Flora Iranica, 66*, pp. 78–114. Akademische Druck u. Verlagsanstalt, Graz, AT.

Schönbeck-Temesy, E. 1967. Saxifragaceae. In: Rechinger, K.H. (ed.) *Flora Iranica, 42*, pp. 1–17. Akademische Druck u. Verlagsanstalt, Graz, AT.

Schweizer, G. 1972. Klimatisch bedingte geomorphologische und glaziologische Züge der Hochregion vorderasiatischer Gebirge (Iran und Ostanatolien). In: Troll, C. (ed.) *Landschaftökologie der Hochgebirge Eurasiens*, pp. 221–236. Franz Steiner, Wiesbaden, DE.

Smith, B. & Wilson, J.B. 1996. A consumer's guide to evenness indices. *Oikos* 76: 70–82.

Takhtajan, A. 1986. *Floristic regions of the world*. University of California Press, CA, US (English translation from Russian).

Valachovič, M., Dierssen, K., Dimopoulos, P., Hadač, E., Loidi, J., Mucina, L., Rossi, G., Valle Tendero, F. & Tomaselli, M. 1997. The vegetation on screes – a synopsis of higher syntaxa in Europe. *Folia Geobotanica & Phytotaxonomica* 32: 173–192.

van der Maesen, L.J.G. 1979. *Cicer* [Papilionaceae I- Vicieae]. In: Rechinger, K.H. (ed.) *Flora Iranica, 140*, pp. 1–15. Akademische Druck u. Verlagsanstalt, Graz, AT.

Weber, H.E., Moravec, J. & Theurillat, J.P. 2000. International Code of Phytosociological Nomenclature. 3rd ed. *Journal of Vegetation Science* 11: 739–768.

Willner, W. 2006. The association concept revisited. *Phytocoenologia* 36: 67–76.

Willner, W. 2011. Unambiguous assignment of relevés to vegetation units: the example of the *Festuco-Brometea* and *Trifolio-Geranietea sanguinei*. *Tuexenia* 31: 271–282.
Willner, W., Tichý, L. & Chytrý, M. 2009. Effects of different fidelity measures and contexts on the determination of diagnostic species. *Journal of Vegetation Science* 20: 130–137.
Wright, H. 1962. Pleistocene glaciation in Kurdistan. *Eiszeitalter und Gegenwart* 12: 131–164.
Zarghami, M., Abdi, A., Babaeian, I., Hassanzadeh, Y. & Kanani, R. 2011. Impacts of climate change on runoffs in East Azerbaijan, Iran. *Global and Planetary Change* 78: 137–146.
Zarre, S., Massoumi, A.A. & Podlech, D. 2008. Papilionaceae V, *Astragalus* III. In: Rechinger, K.H. (ed.) *Flora Iranica, 177*, pp. 1–124. Naturhistorisches Museum Wien, Wien, AT.
Zohary, M. 1973. *Geobotanical foundations of the Middle East*, Vol. 2. Gustav Fischer, Stuttgart, DE.

Supporting Information

Additional supporting information may be found in the online version of this article:

Appendix S1. Synoptic table of the scree vegetation in five regions of Europe and western Asia.

Appendix S2. The mean and SD of the environmental and vegetation parameters in all associations.

Appendix S3. Synoptic table showing the total cover and diagnostic value of species in all vegetation units.

Appendix S4. Phytosociological table of the alliance *Erigerontion venusti.*

Appendix S5. Phytosociological table of the alliance *Elymo longearistati-Astragalion macrosemii.*

Appendix S6. Phytosociological table of the alliance *Didymophysion aucheri.*

Photos S1–S17. Typical stands of the associations described in this study.

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Appendix S1. **Synoptic table of the scree vegetation in five regions of Europe and western Asia.** Constancy for alliances were calculated either from single relevés (for the Alps and for Iran) or by averaging the constancy values of the synthetic tables (for all other regions). In the latter case, constancy values of associations were averaged without weighting for different number of relevés. If an association was divided into several subassociations in the source table, the constancy values were averaged among these subassociations first. Only species reaching 10% in at least one column (20% if they occur in only one region) are shown. Species given as character species for the class *Thlaspietea rotundifolii* or subordinated syntaxa by Valachovic et al. (1997) are marked with *. Data sources are given at the bottom of the table. The taxonomy and nomenclature of species was unified, mostly following the Euro+Med Plantbase. C: character species, D: Differential species.

Region		Alps						Balkan		Caucasus			Anatolia				Iran		
Column number		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Number of relevés		219	265	62	273	289	34	89	7	24	22	12	156	114	143	157	69	63	23
Widespread species																			
Oxyria digyna	*	6	.	19	1	43	.	.	43	5	90	.	1	1	4	1	13	.	4
Arabis alpina agg. (incl. *A. caucasica*)	*	42	17	32	20	16	6	32	.	.	.	.	11	32	4	14	10	.	26
Cerastium cerastoides		.	.	3	3	2	.	.	.	10	43	.	.	.	.	25	.	.	.
Draba siliquosa		.	.	.	1	.	.	.	.	27	.	.	.	.	.	.	1	5	4
C Thlaspietea rotundifolii																			
Cerastium uniflorum	*	1	.	66	6	75	.	.	.	.	.	.	.	.	.	.	.	.	.
Linaria alpina	*	51	25	34	2	18	12	30	.	.	.	.	.	.	.	.	.	.	.
Poa cenisia s.lat.	*	2	3	.	.	.	.	24	86	.	.	.	.	1	10	3	.	.	.
Ranunculus alpestris	*	23	7	5	64	7	6		.	.	.	.	.	.	.	.	.	.	.
Rumex scutatus	*	22	49	.	.	1	65	36	.	.	.	.	.	.	.	.	.	.	.
Saxifraga oppositifolia	*	6	.	79	8	9	3	.	.	.	.	.	.	.	.	.	.	.	.
Silene vulgaris subsp. *glareosa* et *prostrata*	*	18	47	.	1	14	56	34	.	.	.	.	.	.	.	.	.	.	.
Achillea atrata	*	40	7	16	45	7	12	.	.	.	.	.	.	.	.	.	.	.	.
Campanula cochleariifolia	*	37	46	15	6	1	18	.	.	.	.	.	.	.	.	.	.	.	.
Cerastium carinthiacum	*	34	26	.	11	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pritzelago alpina	*	64	12	42	51	4	15	.	.	.	.	.	.	.	.	.	.	.	.
Ranunculus montanus agg. (mostly *R. oreophilus*)	*	20	17	5	25	1	21	6	57	10	35	15	.	.	.	.	.	.	.
Sedum atratum	*	19	10	18	20	3	3	.	.	.	.	.	.	.	.	.	.	.	.
Minuartia austriaca	*	25	12	.	1	.	15	.	.	.	.	.	.	.	.	.	.	.	.
Moehringia ciliata	*	53	18	3	36	.	6	10	.	.	.	.	.	.	.	.	.	.	.
Papaver alpinum s.lat.	*	18	6	.	1	.		4	.	.	.	.	.	.	.	.	.	.	.
Poa minor	*	43	17	23	18	.	18	4	.	.	.	.	.	.	.	.	.	.	.
Thlaspi rotundifolium	*	46	6	.	1	.	9	.	.	.	.	.	.	.	.	.	.	.	.
Adenostyles glabra	*	26	43	.	5		15	.	.	.	.	.	.	.	.	.	.	.	.
Chlorocrepis staticifolia	*	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Petasites paradoxus	*	1	40	.	.	.	18	2	.	.	.	.	.	.	.	.	.	.	.
Campanula pulla	*	16	6	.	38	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dryopteris villarii	*	3	9	.	1	.	.	15	.	.	.	.	.	.	.	.	.	.	.
Moehringia muscosa	*	1	11	.	.	.	15	13	.	.	.	.	.	.	.	.	.	.	.
Artemisia genipi	*	.	.	31	1	18	.	.	.	.	.	.	.	.	.	.	.	.	.
Doronicum glaciale	*	1	1	21	6	19	.	.	.	.	.	.	.	.	.	.	.	.	.
Draba hoppeana	*	.	.	35	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pedicularis aspleniifolia	*	.	.	37	1	6	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga biflora	*	.	.	31	.	8	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga rudolphiana	*	.	.	55	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.
Sesleria ovata	*	1	1	39	7	11	.	.	.	.	.	.	.	.	.	.	.	.	.
Achillea clusiana	*	3	1	.	23	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arabis caerulea	*	1	.	23	8	2	.	.	.	.	.	.	.	.	.	.	.	.	.
Galium noricum	*	5	1	.	35	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Salix retusa	*	7	1	11	53	24	3	4	.	.	.	.	.	.	.	.	.	.	.
Androsace alpina	*	.	.	13	1	9	.	.	.	.	.	.	.	.	.	.	.	.	.
Cardamine resedifolia	*	1	.	2	1	24	6	.	.	.	.	.	.	.	.	.	.	.	.
Cryptogramma crispa	*	.	.	.	.	1	.	.	.	.	.	30	.	.	.	.	.	.	.
Geum reptans	*	5	.	11	.	37	.	2	29	.	.	.	.	.	.	.	.	.	.
Poa laxa	*	1	.	5	.	44	.	.	.	.	.	.	.	.	.	.	.	.	.
Ranunculus glacialis	*	.	.	19	.	27	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga androsacea	*	10	.	40	42	18	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga bryoides	*	1	.	29	3	76	.	.	14	.	.	.	.	.	.	.	.	.	.
Senecio carniolicus	*	.	.	2		20		.	.	.	.	.	.	.	.	.	.	.	.
Achnatherum calamagrostis	*	.	4	.	.	.	26	2		.	.	.	.	.	.	.	.	.	.
Vincetoxicum hirundinaria	*	.	5	.	.	.	26	.	.	.	.	.	.	.	.	.	.	.	.
Gymnocarpium robertianum	*	4	28	.	.	.	15	.	.	.	.	.	.	.	.	.	.	.	.
Epilobium dodonaei	*	.	.	.	.	.	12	.	.	.	59	.	.	.	.	.	.	.	.
Cardamine glauca	*	.	.	.	.	.	.	40	43	.	.	.	.	.	.	.	.	.	.
Bunium alpinum	*	.	.	.	.	.	.	22	.	.	.	.	.	.	.	.	.	.	.
Drypis spinosa	*	.	.	.	.	.	.	30	.	.	.	.	.	.	.	.	.	.	.
Senecio rupestris	*	.	.	.	.	.	.	30	.	.	.	.	.	.	.	.	.	.	.
Saxifraga pedemontana subsp. *cymosa*	*	.	.	.	.	.	.	.	57	.	.	.	.	.	.	.	.	.	.
D Alps																			
Minuartia gerardii		11	1	45	11	10	3	.	.	.	.	.	.	.	.	.	.	.	.
Erigeron uniflorus		.	.	40	1	4	.	.	.	.	.	.	.	.	.	.	.	.	.
Arenaria ciliata s.str.		1	.	23	4	6	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex firma		14	9	2	26	.	3	.	.	.	.	.	.	.	.	.	.	.	.
Potentilla brauneana		2	1	5	26	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Aster bellidiastrum		14	14	2	26	1	12	.	.	.	.	.	.	.	.	.	.	.	.
Salix reticulata		.	.	13	25	7	.	.	.	.	.	.	.	.	.	.	.	.	.
Euphrasia salisburgensis		5	7	.	21	.	12	.	.	.	.	.	.	.	.	.	.	.	.
Soldanella austriaca		5	1	.	21	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bartsia alpina		3	.	5	20	6	.	.	.	.	.	.	.	.	.	.	.	.	.
Soldanella alpina		4	1	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Silene acaulis subsp. *exscapa*		.	.	15	2	63	.	.	.	.	.	.	.	.	.	.	.	.	.

Region	Alps						Balkan		Caucasus			Anatolia				Iran		
Column number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Number of relevés	219	265	62	273	289	34	89	7	24	22	12	156	114	143	157	69	63	23
Leucanthemopsis alpina	3	.	15	3	56	.	.	.	.	.	.	.	.	.	.	.	.	.
Luzula alpinopilosa	1	.	8	3	42	.	.	.	.	.	.	.	.	.	.	.	.	.
Oreochloa disticha	.	.	3	3	42	.	.	.	.	.	.	.	.	.	.	.	.	.
Cetraria islandica	1	.	3	7	31	3	.	.	.	.	.	.	.	.	.	.	.	.
Leontodon helveticus	.	.	.	2	29	.	.	.	.	.	.	.	.	.	.	.	.	.
Thamnolia vermicularis	1	.	11	3	27	.	.	.	.	.	.	.	.	.	.	.	.	.
Solidago virgaurea	.	3	.	.	26	6	.	.	.	.	.	.	.	.	.	.	.	.
Stereocaulon alpinum	.	.	5		26	.	.	.	.	.	.	.	.	.	.	.	.	.
Salix herbacea	.	.	15	6	26	.	.	.	.	.	.	.	.	.	.	.	.	.
Agrostis rupestris	.	1	.	5	26	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga blepharophylla	.	.	2	.	21	.	.	.	.	.	.	.	.	.	.	.	.	.
Cirsium spinosissimum	7	1	.	2	20	3	.	.	.	.	.	.	.	.	.	.	.	.
Cetraria nivalis	.	.	2	1	20	.	.	.	.	.	.	.	.	.	.	.	.	.
Sedum album	1	6	.	1	.	29	.	.	.	.	.	.	.	.	.	.	.	.
Buphthalmum salicifolium	.	13	.	1	.	24	.	.	.	.	.	.	.	.	.	.	.	.
Calamintha nepeta	.	.	.	.	.	21	.	.	.	.	.	.	.	.	.	.	.	.
Leontodon hispidus	8	15	2	5	3	21	.	.	.	.	.	.	.	.	.	.	.	.
Myosotis alpestris	26	17	16	28	8	6	.	.	.	.	.	.	.	.	.	.	.	.
Sesleria albicans	11	28	13	28	1	15	.	.	.	.	.	.	.	.	.	.	.	.
Acer pseudoplatanus	1	22	.	.	.	9	.	.	.	.	.	.	.	.	.	.	.	.
Picea abies	.	21	.	1	1	18	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga moschata	11	1	45	11	21	3	.	.	.	.	.	.	.	.	.	.	.	.
Minuartia sedoides	4	1	44	18	30	.	.	.	.	.	.	.	.	.	.	.	.	.
Silene acaulis subsp. *longiscapa*	10	1	39	40	.	3	.	.	.	.	.	.	.	.	.	.	.	.
Primula minima	.	.	27	10	33	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga aizoides	15	7	24	18	26	6	.	.	.	.	.	.	.	.	.	.	.	.
Phyteuma globulariifolium	.	.	23	1	21	.	.	.	.	.	.	.	.	.	.	.	.	.
Festuca pumila	15	3	23	31	2	3	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga stellaris	21	3	21	42	14	.	.	.	.	.	.	.	.	.	.	.	.	.
Taraxacum sect. *alpina*	11	1	21	11	21	6	.	.	.	.	.	.	.	.	.	.	.	.
Campanula scheuchzeri	13	6	10	36	29	15	.	.	.	.	.	.	.	.	.	.	.	.
Veronica alpina	7	1	16	29	32	3	.	.	.	.	.	.	.	.	.	.	.	.
Deschampsia cespitosa	1	8	2	7	32	.	.	.	.	.	.	.	.	.	.	.	.	.
Geranium robertianum	1	15	.	.	.	41	.	.	.	.	.	.	.	.	.	.	.	.
Origanum vulgare	.	2	.	.	.	26	.	.	.	.	.	.	.	.	.	.	.	.
Galium anisophyllon	24	29	2	17	3	21	.	.	.	.	.	.	.	.	.	.	.	.
Calamagrostis varia	.	39	.	1	.	24	.	.	.	.	.	.	.	.	.	.	.	.
Persicaria vivipara	15	2	32	69	26	3	.	.	.	.	.	.	.	.	.	.	.	.
Viola biflora	40	22	.	30	3	21	.	.	.	.	.	.	.	.	.	.	.	.
Arabis bellidifolia s.lat.	21	6	6	31	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Carduus defloratus s.lat.	11	33	.	8	.	30	.	.	.	.	.	.	.	.	.	.	.	.
D Alps & Balkan																		
Valeriana montana	7	15	.	1	.	12	34	.	.	.	.	.	.	.	.	.	.	.
Stachys recta	.	1	.	.	.	3	11	.	.	.	.	.	.	.	.	.	.	.
Galium lucidum	.	5	.	.	.	18	6	.	.	.	.	.	.	.	.	.	.	.
Arenaria biflora	.	2	3	.	3	.	2	86	.	.	.	.	.	.	.	.	.	.
Georgia pellucida (= *Mnium pellucidum*)	.	.	.	.	.	.	.	29	.	.	.	.	.	.	.	.	.	.
Pedicularis verticillata	1	.	3	5	3	.	.	29	.	.	.	.	.	.	.	.	.	.
Armeria alpina	1	.	.	5	2	.	.	29	.	.	.	.	.	.	.	.	.	.
Luzula spicata	1	.	13	1	30	.	.	29	.	.	.	.	.	.	.	.	.	.
Poa violacea (= *P. variegata*)	.	.	.	.	.	.	.	29	.	.	.	.	.	.	.	.	.	.
Gentiana punctata	.	.	.	1	3		.	29	.	.	.	.	.	.	.	.	.	.
Anthoxanthum odoratum agg.	.	2	.	3	25	3	.	14	.	.	.	.	.	.	.	.	.	.
Juncus trifidus	1	.	.	1	30	.	.	100	.	.	.	.	.	.	.	.	.	.
Geum montanum	.	.	.	3	1	.	.	71	.	.	.	.	.	.	.	.	.	.
Veronica bellidioides	.	.	.	.	1	.	.	57	.	.	.	.	.	.	.	.	.	.
Gnaphalium hoppeanum	2	.	2	24	7	.	2	.	.	.	.	.	.	.	.	.	.	.
Veronica aphylla	12	2	10	21	.	3	7	.	.	.	.	.	.	.	.	.	.	.
Festuca violacea agg.	5	2	2	4	36	.	.	71	.	.	.	.	.	.	.	.	.	.
Sedum alpestre	.	.	3	1	29	.	.	29	.	.	.	.	.	.	.	.	.	.
Acinos alpinus	5	18	.	2	.	32	.	29	.	.	.	.	.	.	.	.	.	.
Heracleum sphondylium	2	2	.	.	.	.	37	.	.	.	.	.	.	.	.	.	.	.
D Alps-Balkan-Caucasus																		
Carex atrata agg.	1	.	11	42	3	3	.	.	.	39	15	.	.	.	.	.	.	.
Cladonia pyxidata	.	1	3	1	3	.	.	.	5	40	90	.	.	.	.	.	.	.
Poa nemoralis	1	2	.	.	1	3	.	.	5	23	90	.	.	.	.	.	.	.
Rubus idaeus	.	1	.	.	.	3	.	.	.	5	90	.	.	.	.	.	.	.
Calamagrostis arundinacea	.	.	.	.	.	.	.	.	.	5	90	.	.	.	.	.	.	.
Dicranum scoparium	1	.	.	1	3	.	.	.	.	.	50	.	.	.	.	.	.	.
Juniperus communis	.	2	.	.	1	6	.	.	.	.	50	.	.	.	.	.	.	.
Hypnum cupresiforme	.	.	.	.	1	.	.	.	5	.	30	.	.	.	.	.	.	.
Cladonia mitis	.	.	.	.	6	.	.	.	.	.	30	.	.	.	.	.	.	.
Agrostis stolonifera	.	5	.	1	.	3	.	.	.	10	.	.	.	.	.	.	.	.
Pinus silvestris	.	3	.	.	.	15	.	.	.	.	15	.	.	.	.	.	.	.
Phleum alpinum agg.	2	.	2	2	34	.	.	.	.	45	.	.	.	.	.	.	.	.
Sibbaldia procumbens	.	.	.	1	7	.	.	.	.	23	.	.	.	.	.	.	.	.
Calamagrostis epigeios	.	1	.	.	.	.	.	.	.	23	15	.	.	.	.	.	.	.
Dicranoweisia crispula	.	.	.	.	5		.	57	.	20	70	.	.	.	.	.	.	.
Dryopteris filix-mas	.	1	.	.	2	3	.	43	.	15	90	.	.	.	.	.	.	.
Gnaphalium supinum	1	.	3	3	18		.	29	.	28	15	.	.	.	.	.	.	.

Region	Alps						Balkan		Caucasus			Anatolia				Iran		
Column number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Number of relevés	219	265	62	273	289	34	89	7	24	22	12	156	114	143	157	69	63	23
Polygonum alpinum (= *Persicaria alpina*)	.	.	.	.	.	.	.	43	5	.	30	.	.	.	.	.	.	.
Avenella flexuosa	.	.	.	1	8	.	.	43	.	15	50	.	.	.	.	.	.	.
Racomitrium canescens	.	.	5	1	36	3	.	.	.	38	30	.	.	.	.	.	.	.
Lotus corniculatus	3	12	.	4	1	24	.	.	.	5	.	.	.	.	.	.	.	.
Poa alpina s.lat. (incl. *P. badensis*)	35	14	69	66	61	3	.	.	.	38	15	.	.	.	.	.	.	.
Sagina saginoides	2	.	5	14	13	.	.	.	.	10	.	.	.	.	.	.	.	.
Pohlia filum	.	.	5	.	15	.	.	.	.	17	.	.	.	.	.	.	.	.
Salix purpurea	.	8	.	.	.	15	.	.	.	5	.	.	.	.	.	.	.	.
D Balkan																		
Festuca pungens	.	.	.	.	.	.	23	.	.	.	.	.	.	.	.	.	.	.
Sesleria nitida	.	.	.	.	.	.	28	.	.	.	.	.	.	.	.	.	.	.
Senecio glaberrimus	.	.	.	.	.	.	.	71	.	.	.	.	.	.	.	.	.	.
Doronicum columnae	.	1	.	.	.	.	15	57	.	.	.	.	.	.	.	.	.	.
C & D Scree vegetation of Caucasus																		
Sedum tenellum	.	.	.	.	.	.	.	.	27	70	70	.	.	2	6	6	.	.
Minuartia recurva	.	.	.	.	.	.	.	.	17	10	15	.	.	.	.	4	.	.
Carum caucasicum	.	.	.	.	.	.	.	.	50	40	.	.	.	.	.	7	.	.
Scrophularia variegata	.	.	.	.	.	.	.	.	15	27	.	.	.	.	.	4	3	.
Alopecurus ponticus	.	.	.	.	.	.	.	.	5	52	.	.	.	.	.	.	.	.
Veronica minuta	.	.	.	.	.	.	.	.	50	52	.	.	.	.	.	.	.	.
Cerastium polymorphum	.	.	.	.	.	.	.	.	15	37	.	.	.	.	.	.	.	.
Matricaria caucasica	.	.	.	.	.	.	.	.	23	78	.	.	.	.	.	.	.	.
Murbeckiella huetii	.	.	.	.	.	.	.	.	15	45	70	.	.	.	.	.	.	.
Minuartia imbricata	.	.	.	.	.	.	.	.	20	38	.	.	.	.	.	.	.	.
Alopecurus dasyanthus	.	.	.	.	.	.	.	.	45	.	.	.	.	.	.	6	.	.
Potentilla gelida	.	.	.	.	.	.	.	.	45	.	.	.	.	.	.	.	.	.
Chaerophyllum humile	.	.	.	.	.	.	.	.	63	.	.	.	.	.	.	.	.	.
Delphinium caucasicum	.	.	.	.	.	.	.	.	39	.	.	.	.	.	.	.	.	.
Corydalis alpestris	.	.	.	.	.	.	.	.	45	.	.	.	.	.	.	.	.	.
Dentaria bipinnata	.	.	.	.	.	.	.	.	43	.	.	.	.	.	.	.	.	.
Eunomia rotundifolia	.	.	.	.	.	.	.	.	25	.	.	.	.	.	.	.	.	.
Thlaspi pumilum	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.
Draba scabra	.	.	.	.	.	.	.	.	33	.	.	.	.	.	.	.	.	.
Cruciata valentinae	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.
Alopecurus glacialis	.	.	.	.	.	.	.	.	20	5	.	.	.	.	.	.	.	.
Saxifraga flagellaris	.	.	.	.	.	.	.	.	30	.	.	.	.	.	.	.	.	.
Hyalopoa pontica	.	.	.	.	.	.	.	.	23	52	15	.	.	.	.	.	.	.
Primula meyeri	.	.	.	.	.	.	.	.	10	27	.	.	.	.	.	.	.	.
Carex pyrenaica	.	.	.	.	.	.	.	.	.	23	.	.	.	.	.	.	.	.
Sanionia uncinata	.	.	.	.	.	.	.	.	.	30	30	.	.	.	.	.	.	.
Valeriana alpestris	.	.	.	.	.	.	.	.	5	35	.	.	.	.	.	.	.	.
Ranunculus caucasicus	.	.	.	.	.	.	.	.	.	23	.	.	.	.	.	.	.	.
Trifolium spadiceum	.	.	.	.	.	.	.	.	.	23	.	.	.	.	.	.	.	.
Lascuraea saxicola	.	.	.	.	.	.	.	.	5	10	50	.	.	.	.	.	.	.
Sempervivum caucasicum	.	.	.	.	.	.	.	.	.	.	30	.	.	.	.	.	.	.
Common scree species Caucasus-Iran																		
Saxifraga sibirica	.	.	.	.	.	.	.	.	15	63	30	.	.	.	.	26	.	.
Lamium tomentosum	.	.	.	.	.	.	.	.	30	5	.	.	.	.	.	.	.	35
Senecio taraxacifolius	.	.	.	.	.	.	.	.	.	27	.	.	.	.	.	48	.	.
C & D Heldreichietea																		
Heldreichia spp.	.	.	.	.	.	.	.	.	.	.	.	17	33	19	31	.	.	.
Euphorbia herniariifolia	.	.	.	.	.	.	.	.	.	.	.	62	.	45	31	.	.	.
Galium cilicicum	.	.	.	.	.	.	.	.	.	.	.	30	.	26	40	.	.	.
Pisum formosum	.	.	.	.	.	.	.	.	.	.	.	30	.	40	21	.	.	9
Bunium microcarpum subsp. *microcarpum*	.	.	.	.	.	.	.	.	.	.	.	43	27	13	20	.	.	.
Alyssum argyrophyllum	.	.	.	.	.	.	.	.	.	.	.	17	3	30	40	.	.	.
Laserpitium petrophilum	.	.	.	.	.	.	.	.	.	.	.	21	.	4	.	.	.	.
Ranunculus brevifolius	.	.	.	.	.	.	.	.	.	.	.	31	3	1	.	.	.	.
Elymus tauri	.	.	.	.	.	.	.	.	.	.	.	.	41	13	12	.	.	.
Heracleum humile	.	.	.	.	.	.	.	.	.	.	.	.	.	25	3	.	.	.
Linaria corifolia	.	.	.	.	.	.	.	.	.	.	.	.	20	8	.	.	.	.
Thlaspi sintenisii subsp. *sintenisii*	.	.	.	.	.	.	.	.	.	.	.	30	.	.	.	.	.	.
Lamium cymbalariifolium	.	.	.	.	.	.	.	.	.	.	.	35	.	.	.	.	.	.
Fritillaria crassifolia	.	.	.	.	.	.	.	.	.	.	.	57	.	.	.	.	.	.
Scrophularia depauperata	.	.	.	.	.	.	.	.	.	.	.	32	.	.	.	.	.	.
Ormoselenia alpina	.	.	.	.	.	.	.	.	.	.	.	25	.	.	.	.	.	.
Ranunculus cadmicus	.	.	.	.	.	.	.	.	.	.	.	33	.	.	.	.	.	.
Elymus lasicus	.	.	.	.	.	.	.	.	.	.	.	27	.	.	.	.	.	.
Euphorbia macroclada	.	.	.	.	.	.	.	.	.	.	.	.	33	.	.	.	.	.
Nepeta nuda	.	.	.	.	.	.	.	.	.	.	.	.	23	.	.	.	.	.
Scrophularia myriophylla	.	.	.	.	.	.	.	.	.	.	.	.	50	.	.	.	.	.
Ferulago trachycarpa	.	.	.	.	.	.	.	.	.	.	.	.	27	.	.	.	.	.
Vicia canescens subsp. *gregaria*	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.
Scrophularia rimarum	.	.	.	.	.	.	.	.	.	.	.	.	.	34	7	.	.	.
Anthriscus kotschyi	.	.	.	.	.	.	.	.	.	.	.	.	.	42	9	.	.	.
Arenaria kotschyana subsp. *kotschyana*	.	.	.	.	.	.	.	.	.	.	.	.	.	24	.	.	.	.
Arenaria balansae	.	.	.	.	.	.	.	.	.	.	.	.	.	48	48	.	.	.
Cerastium gnaphalodes	.	.	.	.	.	.	.	.	.	.	.	.	.	40	17	.	.	.

Region	Alps						Balkan		Caucasus			Anatolia				Iran		
Column number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Number of relevés	219	265	62	273	289	34	89	7	24	22	12	156	114	143	157	69	63	23
Aethionema oppositifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	5	23	.	.	.
Allium tauricola	.	.	.	.	.	.	.	.	.	.	.	.	.	15	22	.	.	.
Vicia alpestris subsp. *hypoleuca*	.	.	.	.	.	.	.	.	.	.	.	.	.	20	12	.	.	.
Prenanthes glareosa	.	.	.	.	.	.	.	.	.	.	.	.	.	23	8	.	.	.
Lamium eriocephalum	.	.	.	.	.	.	.	.	.	.	.	.	.	25	50	.	.	.
Jurinella moschus	.	.	.	.	.	.	.	.	.	.	.	.	.	2	28	7	.	.
Thymus leucotricus	.	.	.	.	.	.	.	.	.	.	.	.	.	3	22	.	.	.
Silene supina subsp. *pruinosa*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	29	.	.	.
Scutellaria orientalis s. lat.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	28	.	.	.
C & D Didymophyso-Dracocephaletea cl. nov.																		
Didymophysa aucheri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	32	.	96
Dracocephalum aucheri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	35	32	48
Alopecurus textilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	32	.	22
Bromus tomentosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	70	78	13
Ziziphora clinopodioides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	49	25	.
Poa araratica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	49	37	4
Helichrysum psychrophilum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	32	8	.
Draba bruniifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	29	.	.
Alopecurus aucheri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.
Nepeta menthoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	.	.
Tripleurospermum caucasicum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33	.	.
Sesleria phleoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.
Galium hyrcanicum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	41	.	.
Erigeron caucasicus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	62	.	.
Pedicularis caucasica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	.	.
Minuartia glandulosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	26	.	.
Koeleria eriostachya	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	38	.	.
Festuca alaica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	75	3	4
Nepeta racemosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	24	.
Euphorbia aucheri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	24	4
Astragalus macrosemius	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	57	.
Elymus longearistatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	.
Asperula glomerata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	30
Achillea aucheri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	39
Veronica aucheri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	26
Galium aucheri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	52
Veronica paederotae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30
Senecio vulcanicus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22
Erysimum elbrusense	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	30
Cerastium purpurascens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	39

Sources:

1 Thlaspion rotundifolii - Thlaspietea rotundifolii; Austrian Vegetation Database (GIVD-ID EU-AT-001).
2 Petasition paradoxi - Thlaspietea rotundifolii; Austrian Vegetation Database (GIVD-ID EU-AT-001).
3 Drabion hoppeanae - Thlaspietea rotundifolii; Austrian Vegetation Database (GIVD-ID EU-AT-001).
4 Arabidion caeruleae - Thlaspietea rotundifolii; Austrian Vegetation Database (GIVD-ID EU-AT-001).
5 Androsacion alpinae - Thlaspietea rotundifolii; Austrian Vegetation Database (GIVD-ID EU-AT-001).
6 Stipion calamagrostis - Thlaspietea rotundifolii; Austrian Vegetation Database (GIVD-ID EU-AT-001).
7 Bunion alpini - Thlaspietea rotundifolii; Horvat et al. (1974): Tab. 141.
8 Androsacion alpinae - Thlaspietea rotundifolii; Horvat et al. (1974): Tab. 142.
9 Chaerophyllion humilis - Thlaspietea rotundifolii (?); Onipchenko (2002).
10 Murbeckiellion huetii - Thlaspietea rotundifolii (?); Onipchenko (2002).
11 Allosuro-Athyrion alpestris - Thlaspietea rotundifolii (?); Onipchenko (2002).
12 Scrophularion depauperatae - Heldreichietea; Parolly (1998).
13 Scrophularion myriophyllae - Heldreichietea; Parolly (1998).
14 Scrophularion rimarum - Heldreichietea; Parolly (1998).
15 Jurinellion moschus - Heldreichietea; Parolly (1998).
16 Erigerontion venusti - Didymophyso-Dracocephaletea; this paper.
17 Elymo-Astragalion macrosemii - Didymophyso-Dracocephaletea; this paper.
18 Didymophysion aucheri - Didymophyso-Dracocephaletea; this paper.

Appendix 2a.

The mean and standard deviation of the environmental and vegetation parameters in all associations. Different superscript letters after the mean of variables indicate significant differences between the associations ($p < 0.05$; Games-Howell post hoc test). A “-“ indicates that the post hoc test was not possible because of zero variance. The *p*-value of the ANOVA was highly significant for all variables ($p < 0.001$). Note that for ass. 9 (plots of Klein & Lacoste 1999) no data of scree, bare ground and solid rock covers are available. Ass. 1-4: *Erigerontion venusti*, Ass. 5-8: *Elymo-Astragalion macrosemii,* Ass. 9-10 : *Didymophysion aucheri*. For association names see Fig. 2 or Table 4.

Association		No. of relevés	Relevé size (m²)	Altitude (m a.s.l.)	Southing (degree)	Westing (degree)	Inclination (degree)	Species richness	Shannon Index	Evenness Index	Vegetation cover (%)	Scree cover (%)	Bareground cover (%)	Solidrock cover (%)
1	Mean	8	25	3356^{a}	104^{a}	166^{a}	37^{a}	9^{a}	1.28^{a}	0.46^{a}	61^{a}	34^{a}	6^{a}	0^{a}
	SD		0	4	11	11	3	4	0.46	0.09	14	14	3	0
2	Mean	19	100	3420^{a}	137^{b}	109^{b}	38^{a}	10^{a}	1.80^{ab}	0.68^{b}	34^{b}	40^{a}	12^{a}	15^{b}
	SD		0	107	25	46	5	4	0.75	0.2	6	12	8	14
3	Mean	35	94	3599^{b}	123^{ab}	49^{c}	28^{b}	11^{a}	2.10^{bc}	0.78^{b}	22^{c}	64^{b}	6^{a}	7^{bc}
	SD		21	69	38	48	9	3	0.31	0.13	11	17	4	11
4	Mean	7	100	4310^{c}	180^{-}	90^{-}	14^{c}	6^{ab}	1.70^{ac}	0.98^{c}	6^{d}	13^{a}	6^{a}	74
	SD		0	62	0	0	2	3	0.53	0.01	4	7	2	9
5	Mean	6	25	3556^{abd}	23^{c}	67^{bc}	19^{bc}	2^{b}	0.75^{a}	0.90^{bc}	10^{de}	89^{c}	1^{ab}	0^{a}
	SD		0	246	20	20	7	1	0.21	0.15	3	4	2	0
6	Mean	21	25	3574^{b}	55^{c}	127^{b}	35^{ab}	7^{a}	1.38^{a}	0.59^{ab}	42^{ab}	45^{a}	1^{bc}	8^{ab}
	SD		0	151	55	36	9	1	0.33	0.13	13	17	3	13
7	Mean	33	41	3906^{d}	63^{c}	77^{bc}	24^{b}	6^{a}	1.37^{ac}	0.69^{b}	34^{b}	62^{b}	3^{ac}	2^{ac}
	SD		31	48	57	40	11	2	0.41	0.15	11	13	3	3
8	Mean	3	25	4218^{c}	0^{-}	90^{-}	13^{c}	14^{a}	1.98^{ac}	0.58^{ab}	68^{abcef}	17^{a}	8^{ac}	7^{ab}
	SD		0	4	0	0	3	2	0.23	0.01	12	3	6	3
9	Mean	12	114	3900^{d}	58^{abc}	84^{b}	26^{b}	7^{a}	1.89^{ac}	0.98^{c}	7^{dfg}	-	-	-
	SD		152	166	75	22	9	2	0.3	0.01	2	-	-	-
10	Mean	11	65	4429^{c}	45^{c}	69^{bc}	16^{bc}	6^{a}	1.44^{a}	0.78^{bc}	12^{cdg}	60^{ab}	3^{ac}	21^{ab}
	SD		40	135	39	57	10	3	0.51	0.18	10	20	3	24
Total	Mean	155	66	3754	88	86	28	8	1.63	0.73	28	49	5	10
	SD		56	319	61	50	11	4	0.55	0.19	18	25	5	19

Appendix 2b.

The mean and standard deviation of the environmental and vegetation parameters in the three alliances. Different superscript letters after the mean of variables indicate significant differences between the alliances ($p < 0.05$; Games-Howell post hoc test). The *p*-value of the ANOVA is given at the bottom of the table. All. 1: *Erigerontion venusti*, All. 2: *Elymo-Astragalion macrosemii*, All. 3: *Didymophysion aucheri*.

Alliances		No. of relevés	Relevé size (m^2)	Altitude (m a.s.l.)	Southing (degree)	Westing (degree)	Inclination (degree)	Species richness	Shannon Index	Evenness Index	Vegetation cover (%)	Scree cover (%)	Bareground cover (%)	Solidrock cover (%)
1	Mean	69	88	3594^{a}	130^{a}	83	31^{a}	10^{a}	1.88^{a}	0.73^{a}	28^{a}	48^{a}	8^{a}	15^{a}
	SD		28	271	36	58	10	3	0.56	0.19	17	22	6	23
2	Mean	63	33	3777^{b}	54^{b}	93	27^{ab}	6^{b}	1.35^{b}	0.67^{a}	36^{b}	57^{a}	2^{b}	4^{b}
	SD		24	225	54	43	12	3	0.42	0.16	16	21	3	8
3	Mean	23	91	4153^{c}	52^{b}	77	21^{b}	6^{b}	1.67^{a}	0.89^{b}	9^{c}	28^{b}	1^{b}	10^{ab}
	SD		114	308	60	42	10	2	0.46	0.16	7	33	2	19
Total	Mean	155	66	3752	88	86	28	8	1.63	0.73	28	49	5	10
	SD		56	320	61	50	11	4	0.55	0.19	18	25	5	19
***p* (ANOVA)**		-	-	0	0	0.329	0.002	0	0	0	0	0	0	0.001

Appendix S3. Synoptic table showing the total cover and diagnostic value of species in all vegetation units.

Values are total cover (TC), i.e., average cover taking also into account zero values. Species cover in individual relevés was approximated by taking the average cover corresponding to each value of the "Braun-Blanquet scale". TC values of higher syntaxa are averages of the respective values in the subordinated units. The values in ass. 8 (given in red) were downweighted by a factor of 10 because of the low number of relevés and the marginal position of the association in the alliance. Fidelity of species was calculated using the Total Cover Ratio (TCR), i.e., the ratio between the highest and second highest TC among the units of the same rank within a higher syntaxon. TC values of diagnostic species are shaded in yellow (if TCR > 2) or green (if TCR > 10). See text for details on the determination of diagnostic species. C: character species, tC: transgressive character species, D: differential species. Association numbers are the same as in Table 1. For the association names, see Table 4.

	Associations										Alliances			Orders	
Order	P-B	P-B	P-B	P-B	P-B	P-B	P-B	P-B	Da	Da	P-B	P-B	Da	**P-B**	**Da**
Alliance	Ev	Ev	Ev	Ev	E-Am	E-Am	E-Am	E-Am	Da	Da	**Ev**	**E-Am**	**Da**		
Association	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**					
Number of relevés	8	19	35	7	6	21	33	3	12	11	69	63	23	132	23
C & D Ass. 1-4															
Nepeta menthoides (tC Ass. 1)	49.3	2.8	0.1	.	.	.	.	.	.	.	13.1	.	.	6.5	.
Alopecurus aucheri	6.8	1.5	.	.	.	.	.	.	.	.	2.1	.	.	1.0	.
Carum caucasicum	1.1	0.1	.	.	.	.	.	.	.	.	0.3	.	.	0.2	.
Sedum tenellum	0.9	0.2	.	.	.	.	.	.	.	.	0.3	.	.	0.1	.
Taraxacum crepidiforme	0.8	0.2	.	.	.	.	.	.	.	.	0.3	.	.	0.1	.
Senecio taraxacifolius (tC Ass. 2)	1.6	21.5	1.3	.	.	.	.	.	.	.	6.1	.	.	3.1	.
Myosotis asiatica	.	1.5	.	.	.	.	.	.	.	0.2	0.4	.	0.1	0.2	0.1
Oxyria digyna	.	1.3	.	.	.	.	.	.	.	0.2	0.3	.	0.1	0.2	0.1
Astragalus beckii (C Ass. 3)	.	.	1.6	.	.	.	.	.	.	.	0.4	.	.	0.2	.
Nepeta sahandica (C Ass. 3)	.	.	0.9	.	.	.	.	.	.	.	0.2	.	.	0.1	.
Potentilla porphyrantha (C Ass. 4)	.	.	1.1	2.9	.	.	.	.	.	.	1.0	.	.	0.5	.
Alopecurus dasyanthus (C Ass. 4)	.	.	.	1.1	.	.	.	.	.	.	0.3	.	.	0.1	.
Potentilla argaea (C Ass. 4)	.	.	.	0.6	.	.	.	.	.	.	0.2	.	.	0.1	.
C & D Erigerontion venusti (Ev)															
Erigeron caucasicus subsp. *venustus* (C)	.	2.4	1.6	1.1	.	.	.	.	.	.	1.3	.	.	0.6	.
Tripleurospermum caucasicum (C)	0.6	2	0.1	1.9	.	.	.	.	.	.	1.2	.	.	0.6	.
Festuca alaica	8.9	3.8	2.7	.	.	.	0.2	.	.	0.2	3.9	0.1	0.1	2.0	0.1
Koeleria eriostachya	3.3	0.7	1.6	.	.	.	.	.	.	.	1.4	.	.	0.7	.
Galium hyrcanicum	.	2.2	1.5	.	.	.	.	.	.	.	0.9	.	.	0.5	.
Draba bruniifolia subsp. *bruniifolia*	.	.	2.2	2.1	.	.	.	.	.	.	1.1	.	.	0.5	.
Sesleria phleoides	.	0.7	1.7	.	.	.	.	.	.	.	0.6	.	.	0.3	.
Minuartia glandulosa	1.5	0.8	0.4	.	.	.	.	.	.	.	0.7	.	.	0.3	.
Saxifraga sibirica	0.5	1.2	0.2	1.1	.	.	.	.	.	.	0.8	.	.	0.4	.
Pedicularis caucasica	.	0.4	0.9	.	.	.	.	.	.	.	0.3	.	.	0.2	.
Erysimum gelidum	.	0.5	0.5	.	.	.	.	.	.	.	0.3	.	.	0.1	.

C & D Ass. 5-8															
Euphorbia aucheri (tC Ass. 5)	.	.	.	.	6.3	2.4	0.1	.	0.2	.	.	2.2	0.1	1.1	0.1
Scutellaria glechomoides (tC Ass. 5)	.	.	.	.	5.3	.	0.8	.	0.7	.	.	1.5	0.4	0.8	0.4
Nepeta racemosa (C Ass. 6)	.	.	.	.	.	14.8	.	.	.	.	.	3.7	.	1.9	.
Cicer tragacanthoides (C Ass. 6)	.	.	.	.	.	14.6	.	.	.	.	.	3.7	.	1.8	.
Leonurus cardiaca subsp. *persicus* (C Ass. 6)	.	.	.	.	.	1.2	.	.	.	.	.	0.3	.	0.2	.
Asperula glomerata subsp. *bracteata*	.	.	.	.	.	0.5	3	.	1.4	.	.	0.9	0.7	0.4	0.7
Senecio iranicus (C Ass. 8)	.	.	.	.	.	.	.	3	.	.	.	0.1	.	0.0	.
Artemisia melanolepis	.	.	.	.	.	.	.	13	.	.	.	0.3	.	0.2	.
Catabrosella parviflora	.	0.3	.	0.3	.	.	.	6.3	.	.	0.2	0.2	.	0.2	.
Carex oreophila	.	.	.	.	.	.	.	5.3	.	.	.	0.1	.	0.1	.
Draba siliquosa	.	.	.	0.3	.	.	.	2.7	.	0.2	0.1	0.1	0.1	0.1	0.1
Veronica biloba	0.5	.	.	.	.	.	.	2.3	.	.	0.1	0.1	.	0.1	.
Potentilla argyroloma	.	.	.	.	.	.	.	2	.	0.6	.	0.1	0.3	0.0	0.3
D Elymo-Astragalion macrosemii (E-Am)															
Astragalus macrosemius	.	.	.	.	1	1.3	6	48	.	.	.	3.3	.	1.6	.
Elymus longearistatus	.	.	.	.	0.5	4.1	1.8	.	.	.	.	1.6	.	0.8	.
C & D Physoptychio-Brometalia (P-B)															
Bromus tomentosus (C), (D Ass. 3 & 7)	1.1	1.7	7.2	.	.	3.4	15.4	8.7	0.5	.	2.5	4.9	0.3	3.7	0.3
Ziziphora clinopodioides (C), (D Ass. 3 & 7)	.	.	5.9	.	.	0.1	2.2	.	.	.	1.5	0.6	.	1.0	.
Physoptychis gnaphalodes (C)	.	.	0.8	.	0.5	2.8	0.3	.	0.3	.	0.2	0.9	0.2	0.6	0.2
Poa araratica (D Ass. 3)	.	0.1	5	0.3	.	1.1	2.5	2.7	.	0.2	1.4	1.0	0.1	1.2	0.1
C & D Ass. 9-10															
Galium aucheri (C Ass. 9)	.	.	.	.	.	.	.	.	2.2	0.2	.	.	1.2	.	1.2
Veronica paederotae (C Ass. 9)	.	.	.	.	.	.	.	.	1.2	.	.	.	0.6	.	0.6
Senecio vulcanicus (C Ass. 9)	.	.	.	.	.	.	.	.	0.8	.	.	.	0.4	.	0.4
Lamium tomentosum	.	.	.	.	.	.	.	.	1.3	0.2	.	.	0.8	.	0.8
Pseudocamelina glaucophylla	.	.	.	.	.	.	.	.	0.7	.	.	.	0.4	.	0.4
Achillea aucheri (tC Ass. 10)	.	.	.	.	.	.	.	1	0.5	4.4	.	0.0	2.5	0.0	2.5
Veronica aucheri (C Ass. 10)	.	.	.	.	.	.	.	0.7	.	1.2	.	0.0	0.6	0.0	0.6
C & D Didymophysion/-etalia (Da)															
Didymophysa aucheri (tC)	.	.	1.7	1.4	.	.	.	.	2.4	3	0.8	.	2.7	0.4	2.7
Dracocephalum aucheri (tC), (D Ass. 3 & 10)	.	0.1	2.7	.	.	.	3.6	9.7	0.3	8.3	0.7	0.3	4.3	0.5	4.3
Cerastium purpurascens (C)	.	.	.	.	.	.	.	6.3	0.8	1.3	.	0.2	1.1	0.1	1.1
Erysimum elbrusense	.	.	.	.	.	.	.	3	0.7	0.5	.	0.1	0.6	0.0	0.6
D Didymophyso-Dracocephaletea															
Alopecurus textilis (D Ev)	.	1.3	2.7	.	.	.	.	.	0.5	0.4	1.0	.	0.5	0.5	0.5

Other species															
Arabis caucasica	.	.	0.4	0.3	.	.	.	.	0.4	1.9	0.2	.	1.2	0.1	1.2
Helichrysum psychrophilum	1.4	1.6	0.4	.	.	0.4	0.1	.	.	.	0.9	0.1	.	0.5	.
Campanula stevenii subsp. *beauverdiana*	0.3	0.3	0.3	.	.	0.1	0.2	.	.	.	0.2	0.1	.	0.2	.
Minuartia recurva subsp. *oreina*	.	.	0.2	.	.	.	.	.	.	.	0.1	.	.	0.0	.
Jurinella moschus	.	.	1.6	.	.	.	.	.	.	.	0.4	.	.	0.2	.
Alyssum condensatum	.	.	0.3	.	.	.	.	.	.	.	0.1	.	.	0.0	.
Polygonum serpyllaceum	.	.	.	.	.	1	0.2	.	.	.	.	0.3	.	0.2	.
Ranunculus crymophilus	.	.	.	.	.	.	0.7	.	.	0.2	.	0.2	0.1	0.1	0.1
Erigeron uniflorus subsp. *elbursensis*	.	.	.	.	.	.	0.5	.	.	0.5	.	0.1	0.3	0.1	0.3
Oxytropis persica	.	.	.	.	.	.	0.2	.	0.2	.	.	0.1	0.1	0.0	0.1
Draba pulchella	.	.	.	.	.	0.2	0.4	.	.	.	.	0.2	.	0.1	.
Senecio glaucus	.	.	.	.	.	0.3	0.1	.	.	.	.	0.1	.	0.1	.
Pisum formosum	.	.	.	.	.	.	.	.	0.5	.	.	.	0.3	.	0.3
Alopecurus himalaicus	.	.	.	.	.	.	.	.	.	0.2	.	.	0.1	.	0.1
Lepechiniella persica	.	.	.	.	.	.	.	.	0.2	0.2	.	.	0.2	.	0.2
Veronica kurdica	.	.	.	.	.	.	.	0.7	.	0.2	.	0.2	0.1	0.1	0.1
Piptatherum laterale	.	.	.	.	.	0.6	.	.	.	.	.	0.2	.	0.1	.
Acantholimon demawendicum	.	.	.	.	.	0.1	0.6	.	.	.	.	0.2	.	0.1	.
Silene marschallii subsp. *sahendica*	.	0.5	.	.	.	.	.	.	.	.	0.1	.	.	0.1	.
Thymus kotschyanus	.	0.4	0.1	.	.	.	.	.	.	.	0.1	.	.	0.1	.
Scrophularia variegata subsp. *variegata*	.	0.4	.	.	.	0.3	.	.	.	.	0.1	0.1	.	0.1	.
Crepis elbursensis	.	.	0.2	.	.	.	.	.	.	.	0.1	.	.	0.0	.
Vicia ciceroidea	.	.	.	.	.	0.3	.	.	.	.	.	0.1	.	0.0	.
Arenaria insignis	.	.	.	.	.	.	0.2	.	.	.	.	0.1	.	0.0	.
Tanacetum polycephalum	.	0.1	.	.	.	.	0.3	.	.	.	0.0	0.1	.	0.1	.
Veronica orientalis	0.4	0.2	.	.	.	.	.	.	.	.	0.2	.	.	0.1	.
Asperula prostrata	0.3	.	.	.	.	.	.	.	.	.	0.1	.	.	0.0	.
Solenanthus circinnatus	.	.	.	.	.	0.1	.	.	.	.	.	0.0	.	0.0	.
Astragalus sp.	.	.	.	.	.	0.1	.	.	.	.	.	0.0	.	0.0	.
Thymus pubescens	.	.	.	.	.	0.1	.	.	.	.	.	0.0	.	0.0	.
Semenovia frigida	.	.	.	.	.	.	0.1	.	.	.	.	0.0	.	0.0	.
Linaria lineolata	.	.	.	.	.	0.1	.	.	.	.	.	0.0	.	0.0	.
Cousinia crispa	.	.	.	.	.	0.1	.	.	.	.	.	0.0	.	0.0	.
Minuartia lineata	.	.	.	.	.	0.1	.	.	.	.	.	0.0	.	0.0	.
Taraxacum sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crepis sahendi	.	0.1	.	.	.	.	.	.	.	.	0.0	.	.	0.0	.
Euphorbia sahendi	.	.	0.1	.	.	.	.	.	.	.	0.0	.	.	0.0	.
Tragopogon kotschyi	0.3	.	.	.	.	.	.	.	.	.	0.1	.	.	0.0	.
Poa bulbosa	0.3	.	.	.	.	.	.	.	.	.	0.1	.	.	0.0	.

Sibbaldia parviflora	.	0.1	.	.	.	.	.	.	.	.	0.0	.	.	0.0	.
Artemisia sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trachydium depressum	.	.	.	.	.	.	.	.	0.2	.	.	.	0.1	.	0.1
Draba aucheri	.	.	.	.	.	.	.	.	0.3	.	.	.	0.2	.	0.2
Potentilla sp.	.	.	0.1	.	.	.	.	.	.	.	0.0	.	.	0.0	.
Kobresia schoenoides	.	.	.	0.3	.	.	.	.	.	.	0.1	.	.	0.0	.
Chenopodium foliosum subsp. *montanum*	.	.	.	.	.	0.2	.	2	.	.	.	0.6	.	0.3	.

Appendix S4. Phytosociological table of the alliance *Erigerontion venusti*.

Differential species (D) are shaded, character species (C) are additionally framed. Association numbers refer to Table 4.

Class	*Didymophyso aucheri-Dracocephaletea aucheri*																																																																				
Order	*Physoptychio gnaphalodis-Brometalia tomentosi*																																																																				
Alliance	*Erigerontion venusti*																																																																				
Association	1								2																			3																																						4						
Subassociation																												a	a	a	a	a	b	b	b	b	b	b	c	c	c	c	c	c	c	c	c	c	c	c	c	d	d	d	d	d	d	d	d	d	d	d							
Typus of ass. (*) and subass. (°)	*																			*									°						°											*						°												*					
Relevé number	1066	1063	1064	1065	1062	1061	1060	1059	1031	1029	1027	1028	1030	1084	1083	1082	1109	1081	1073	1072	1108	1076	1075	1074	1085	1086	1087	1033	1040	1041	1039	1042	1034	1036	1035	1032	1037	1038	940	1106	1105	1099	1107	941	1096	1100	1097	1103	942	1102	1101	1088	1095	1093	1104	1090	1091	1089	1092	1098	943	1094	949	950	946	951	945	947	948
Geographical position of the plots	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sahand	Sabalan	Sabalan	Sabalan	Sabalan	Sabalan	Sabalan	Sabalan
Altitude (m a.s.l.)	3353	3359	3360	3360	3358	3354	3352	3350	3451	3433	3414	3424	3476	3395	3360	3331	3663	3302	3312	3305	3680	3379	3350	3330	3450	3456	3503	3533	3519	3519	3518	3519	3520	3515	3515	3534	3513	3515	3658	3704	3703	3660	3707	3658	3624	3660	3636	3670	3658	3667	3664	3538	3622	3592	3700	3553	3567	3550	3571	3629	3709	3618	4326	4232	4350	4212	4335	4371	4357
Aspect	ENE	ENE	ENE	ENE	ENE	E	E	E	NW	NW	NW	NW	NW	NE	NE	NE	E	ENE	NE	NNE	E	NE	NE	NE	N	N	N	W	WNW	WNW	WNW	WNW	W	WNW	WNW	W	WNW	WNW	W	W	W	NW	W	W	NE	NW	NE	NW	W	NW	NW	N	NE	N	W	N	N	N	N	NNE	NE	NNE	N	N	N	N	N	N	N
Slope (degrees)	35	40	40	40	35	35	35	35	40	35	30	35	40	40	35	35	45	30	35	35	35	45	40	40	45	45	45	20	30	30	35	30	25	30	30	25	30	30	15	35	30	25	25	15	30	20	30	20	15	20	20	40	30	35	30	40	45	45	45	25	20	30	15	20	15	10	15	15	15
Cover total (%)	75	50	40	80	60	70	50	60	50	30	40	30	40	35	35	35	40	25	30	25	35	30	40	30	30	30	30	20	20	20	20	20	5	10	10	10	10	20	25	30	35	40	40	25	30	40	35	35	20	35	40	20	30	15	10	15	10	15	10	15	15	20	4	7	4	15	5	2	2
Species richness	8	5	5	4	12	12	11	12	16	17	13	12	16	10	13	10	8	8	11	13	8	11	12	12	3	3	2	12	13	13	13	11	7	10	7	6	10	11	8	7	8	12	10	10	12	15	14	12	12	12	11	16	13	8	5	11	8	9	9	11	13	13	7	9	6	9	4	2	6
Relevé area (m²)	25	25	25	25	25	25	25	25	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	25	100	100	100	100	25	100	100	100	100	25	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
TWINSPAN classification	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
																												1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0							
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C & D Associations (and subassoc.)																																																																					
Nepeta menthoides	4	3	3	4	3	4	3	3	.	.	.	.	.	.	2	2	.	2	1	1	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Alopecurus aucheri	2	1	1	2	2	1	1	1	1	1	2	1	1	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Taraxacum crepidiforme	.	.	.	.	.	+	+	+	.	+	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sedum tenellum	.	.	.	.	+	1	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio taraxacifolius	+	1	+	+	+	.	+	.	.	2	3	2	2	3	2	2	3	2	2	2	2	2	3	2	3	3	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	1	+	1	1	2	2	1	.	.	.	.	.	.	.
Myosotis asiatica	.	.	.	.	.	.	.	.	1	1	1	1	1	+	.	.	.	.	+	+	.	1	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oxyria digyna	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	1	.	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Jurinella moschus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Minuartia recurva subsp. *oreina*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Astragalus beckii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	2	1	1	1	2	+	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Alyssum condensatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	.	+	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.
Nepeta sahandica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	1	1	1	.	1	2	1	1	.	.	.	.	.	.	.	.	.	.
Arabis caucasica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	.	+	.	.	.	1	.	1	.	+	.	.	.	.	.
Potentilla porphyrantha	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	1	1	1	1
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Potentilla argaea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.
C & D *Erigerontion venusti*																																																																					
Erigeron caucasicus subsp. *venustus*	.	.	.	.	.	.	.	.	+	+	1	+	1	+	1	1	+	1	1	1	1	1	1	1	1	.	.	+	1	1	1	1	+	+	+	.	1	+	.	.	.	.	.	.	1	1	1	+	+	+	+	1	.	.	.	.	.	.	.	1	1	+	+	+	.	+	.	.	+
Tripleurospermum caucasicum	.	.	.	.	+	.	1	.	+	1	1	1	1	+	+	+	1	.	1	1	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	1	+	+	+	.	+
Festuca alaica	1	2	.	1	2	2	2	2	+	+	1	2	.	1	2	1	1	1	1	1	2	1	1	1	.	.	.	.	1	+	1	1	+	1	1	1	1	1	.	.	1	+	1	+	.	1	1	1	+	1	1	1	1	1	+	1	+	.	1	1	2	1	.	.	.	.	.	.	.
Koeleria eriostachya	+	.	+	.	2	1	1	1	1	1	.	.	1	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	1	1	+	+	.	.	+	+	.	.	.	+	+	.	+	1	1	.	.	+	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Galium hyrcanicum	.	.	.	.	.	.	.	.	+	+	.	.	1	1	2	1	.	1	1	1	.	+	+	1	.	.	.	+	1	1	1	+	.	+	.	.	.	.	.	.	.	.	.	.	1	+	1	.	.	+	.	.	2	.	.	+	+	.	1	1	.	1	.	.	.	.	.	.	.
Draba bruniifolia subsp. *bruniifolia* **[D Subass. 3c]**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	.	+	1	+	1	.	2	r	2	1	2	2	.	.	.	.	.	.	.	.	.	.	+	1	+	+	1	1	+	.
Sesleria phleoides	.	.	.	.	.	.	.	.	1	1	.	1	1	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	2	1	2	.	.	+	.	.	1	2	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Minuartia glandulosa **[D Subass. 3b]**	.	1	.	.	+	+	+	1	+	.	.	+	+	.	1	+	.	.	.	1	.	+	.	.	.	.	.	.	.	.	.	1	.	+	+	+	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga sibirica	.	.	.	.	.	+	+	.	.	.	+	.	+	.	.	.	.	.	1	.	.	+	1	1	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	1	.	.	.	+	+	+	.	.	.	+
Pedicularis caucasica	.	.	.	.	.	.	.	.	1	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	1	.	.	.	.	.	.	.	.	.	+	+	.	1	+	1	1	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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C & D *Physoptychio-Brometalia tomentosi*																																																																					
Bromus tomentosus **[D Ass. 3]**	+	.	+	.	1	+	.	.	.	.	.	.	+	+	2	1	+	+	.	1	1	.	.	+	.	.	.	2	1	1	1	1	1	1	1	+	1	2	2	2	1	2	1	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1	1	1	+	1	.	.	.	.	.	.	.
Ziziphora clinopodioides **[D Ass. 3]**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	+	1	.	+	+	1	+	1	2	2	2	2	2	1	1	1	2	2	2	2	2	2	1	1	1	+	1	1	1	1	1	+	1	.	.	.	.	.	.	.
Physoptychis gnaphalodes	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	+	.	.	.	.	.	.	.	.	1	1	.	.	+	+	1	+	1	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.
Poa araratica **[D Ass. 3]**	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	+	.	+	+	+	1	+	+	2	1	1	2	2	2	1	2	1	2	2	2	2	1	+	+	.	1	1	1	.	1	+	+	.	.	.	+	.	.	.
C & D *Didymophyso-Dracocephaletea aucheri*																																																																					
Dracocephalum aucheri **[D Ass. 3]**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	2	1	1	1	1	1	2	+	.	.	1	+	1	1	+	1	1	.	1	1	1	.	2	+	.	.	.	.	.	.	.	.	.	.
Didymophysa aucheri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	1	1	1	1	1	.	.	.	.	.	1	1	1	2	1	1	1	1	.	+	1	.	+	+	+	+	.	+
Alopecurus textilis **[D Subass. 3c]**	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	+	.	+	2	.	.	+	.	.	.	1	.	.	.	1	.	+	.	.	.	.	+	2	2	+	3	+	1	+	1	1	+	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.
Companion species																																																																					
Scrophularia variegata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helichrysum psychrophilum	1	.	.	.	+	1	.	1	1	1	+	+	1	+	1	1	+	.	+	.	1	.	1	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	+	+	1	.	.	.	.	.	.	.
Campanula stevenii subsp. *beauverdiana*	.	.	.	.	.	.	.	+	+	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	1	+	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Draba siliquosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Thymus kotschyanus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	+	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Silene marschallii subsp. *sahendica*	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Tanacetum polycephalum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Asperula prostrata	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Colpodium parviflorum	.	.	.	.	.	.	.	.	+	+	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Veronica orientalis	1	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potentilla argaea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Tragopogon kotschyi	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Poa bulbosa	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crepis sahendi	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sibbaldia parviflora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crepis elbursensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Taraxacum sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.
Artemisia sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.

Appendix S5. Phytosociological table of the alliance *Elymo longearistati-Astragalion macrosemii*.
Differential species (D) are shaded, character species (C) are additionally framed. Association numbers refer to Table 4.

Class	*Didymophyso aucheri-Dracocephaletea aucheri*																																																													
Order	*Physoptychio gnaphalodis-Brometalia tomentosi*																																																													
Alliance	*Elymo longearistati-Astragalion macrosemii*																																																														
Association	5						6																					7																																		8		
Subassociation							a	a	a	a	a	a	a	a	a	a	a	a	a	a	b	b	b	b	b	b	b	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	b	b	b	b	c	c	c	c	c			
Typus of ass. (*) and subass. (°)			*				*															°										*																															
Relevé number	869	868	760	763	809	761	832	871	830	831	765	766	870	767	768	769	833	834	882	881	880	718	719	716	717	714	715	935	612	883	889	888	607	620	619	614	605	606	609	610	611	613	616	617	618	615	819	818	820	817	822	885	886	887	884	821	890	851	852	608	926	932	933
Geographical position of the plots	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Tuchal	Damavand	Damavand	Damavand
Altitude (m a.s.l.)	3235	3240	3710	3718	3718	3712	3620	3195	3619	3620	3726	3726	3200	3727	3728	3728	3625	3630	3630	3635	3640	3500	3500	3500	3500	3500	3500	3871	3900	3840	3922	3925	3967	3912	3960	3893	3965	3965	3930	3920	3904	3885	3955	3957	3950	3957	3845	3844	3868	3828	3868	3848	3850	3849	3842	3868	3930	3978	3980	3930	4223	4215	4216
Aspect	S	S	SSW	SW	SW	SSW	S	S	S	E	S	S	S	ESE	S	S	S	S	ENE	ENE	ENE	ENE	ENE	ENE	ENE	ENE	ENE	S	SW	NNE	E	E	SW	S	S	SW	SW	SW	SW	SW	SW	SW	S	S	S	S	SW	SW	SW	SW	WSW	N	NE	NE	NNE	SW	S	N	N	SW	S	S	S
Slope (degrees)	15	15	15	25	30	15	40	15	40	40	25	25	15	25	30	30	40	35	40	45	45	40	40	40	40	40	40	5	35	5	7	5	20	20	30	30	20	20	30	30	35	35	30	30	30	30	38	35	35	33	38	7	10	10	5	35	35	27	25	25	10	15	15
Cover total (%)	7	10	15	10	10	5	75	65	50	50	50	30	50	40	45	35	50	40	30	40	50	20	35	35	30	35	25	35	30	60	40	45	45	30	25	35	40	40	35	35	30	35	25	30	30	35	25	25	30	15	20	60	40	40	60	25	20	20	20	30	55	75	75
Species richness	2	2	2	3	3	2	7	6	7	6	8	7	4	7	7	3	7	6	9	9	7	5	6	8	5	7	8	6	6	8	9	10	7	8	5	5	5	4	4	4	5	5	4	5	6	3	6	5	7	4	5	13	8	7	11	4	4	2	2	3	13	12	16
Relevé area (m²)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	100	100	100	100	100	25	25	25	25	100	100	25	25	25	25	25	25
TWINSPAN classification	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
							1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1			
																												1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1			
C & D Associations (and subassoc.)																																																															
Euphorbia aucheri	1	2	2	1	1	1	1	.	+	+	.	.	.	.	1	.	.	.	2	2	2	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Scutellaria glechomoides	.	.	2	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	2	.	1	.	.	.	.	1	1	.	.	.	.	.	.
Nepeta racemosa	.	.	.	.	.	.	3	2	2	2	.	.	.	.	.	.	2	2	1	2	3	3	2	3	2	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cicer tragacanthoides	.	.	.	.	.	.	3	3	3	2	3	2	3	2	3	2	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Leonurus cardiaca subsp. *persicus*	.	.	.	.	.	.	+	1	1	1	1	1	1	.	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Polygonum serpyllaceum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	+	.	.	.	.	.	.	.	.
Asperula glomerata subsp. *bracteata*	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	+	.	.	.	.	.	.	.	+	.	1	+	1	1	+	1	1	1	1	1	1	1	1	1	2	2	1	2	2	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ranunculus crymophilus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	1	1	.	.	.	.	.	.	.	.
Festuca alaica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	2	.	.	.	.	.	.	.	.	.
Senecio iranicus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1
Artemisia melanolepis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2
Catabrosella parviflora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	1
Cerastium purpurascens var. *elbursensis*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	1
Erysimum elbrusense	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1
Draba siliquosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	1
Veronica biloba	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+
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Potentilla argyroloma	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
D *Elymo longearistati-Astragalion macrosemii*																																																															
Astragalus macrosemius	1	1	.	.	.	.	.	1	.	.	1	+	1	.	.	.	.	.	1	2	.	.	.	.	.	.	.	2	1	3	2	2	+	1	1	1	1	1	1	2	2	2	1	2	1	1	.	+	.	.	+	2	1	.	2	.	.	.	.	1	3	3	4
Elymus longearistatus	.	.	.	1	.	.	1	1	1	1	1	1	+	1	1	1	2	1	1	.	1	2	2	+	1	1	+	2	.	1	1	1	1	1	1	1	1	1	+	1	1	+	.	.	.	.	.	.	1	.	.	.	.	1	1	.	.	.	.	.	.	.	.
C & D *Physoptychio-Brometalia tomentosi*																																																															
Bromus tomentosus **[D Ass. 7]**	.	.	.	.	.	.	1	.	1	1	1	2	.	.	1	.	1	2	1	2	1	.	.	1	.	1	+	1	2	2	2	2	2	2	2	2	3	3	3	2	2	2	2	2	2	2	2	2	2	2	1	3	2	2	2	2	2	2	2	2	2	2	.
Ziziphora clinopodioides **[D Ass. 7]**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	2	.	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	+	.	1	2	1	2	1	1	.	.	1	1	.	.	.	.	.	.	.
Physoptychis gnaphalodes	.	.	.	.	1	.	.	.	.	.	1	2	.	2	2	2	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	1	+	.	+	.	.	.	.	.	.	.	.	.	.	.
Poa araratica	.	.	.	.	.	.	.	.	.	.	1	.	.	1	1	.	.	.	.	.	.	+	+	1	+	1	+	.	+	2	1	2	2	1	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	1	2	.	2	.	.	.	.	.	1	1	+
C *Didymophyso-Dracocephaletea aucheri*																																																															
Dracocephalum aucheri **[D Subass. 7c]**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	2	1	1	.	.	1	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	1	1	2	1	1	2	2	2	2	2	2	2	1
Companion species																																																															
Scrophularia variegata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helichrysum psychrophilum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.
Campanula stevenii subsp. *beauverdiana*	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arenaria insignis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tanacetum polycephalum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Piptatherum laterale	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	1	1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Acantholimon demawendicum	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	1	1	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.
Achillea aucheri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Veronica aucheri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Veronica kurdica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Senecio glaucus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	r	r	+	.	.	r	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.
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Vicia ciceroidea	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Solenanthus circinnatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Astragalus sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Thymus pubescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Linaria lineolata	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cousinia crispa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Erigeron uniflorus subsp. *elbursensis*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	1	.	.	.	.	.	.	.	.
Oxytropis persicus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.
Draba pulchella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1	+	.	1	.	.	.	.	.	.	.	.
Chenopodium foliosum subsp. *montanum*	.	.	.	.	.	.	.	.	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1

Appendix S6. Phytosociological table of the alliance *Didymophysion aucheri*.
Differential species (D) are shaded, character species (C) are additionally framed. Association numbers refer to Table 4. Relevés from Klein & Lacoste (2001) are marked in green.

Class	*Didymophyso aucheri-Dracocephaletea aucheri*																						
Order	*Didymophysetalia aucheri*																						
Alliance	*Didymophysion aucheri*																						
Association	9												10										
Subassociation (prov.)													a	a	a	a	a	a	b	b	b	b	b
Typus of associations									*											*			
Relevé number	1167	1166	1171	1169	1165	1164	1168	1172	1170	1174	1173	1175	1176	928	927	931	930	929	917	916	915	918	1177
Geographical position of the plots	Alamkuh	Alamkuh	Azadkuh	Alamkuh	Alamkuh	Azadkuh	Alamkuh	Alamkuh	Alamkuh	Alamkuh	Alamkuh	Alamkuh	Damavand	Damavand	Damavand	Damavand	Damavand	Damavand	Alamkuh	Alamkuh	Alamkuh	Alamkuh	Alamkuh
Altitude (m a.s.l.)	3850	3790	3930	3890	3780	3520	3890	3960	3900	4090	4040	4160	4250	4459	4799	4360	4395	4450	4455	4455	4455	4455	4350
Aspect	S	S	SSW	S	SSW	SSW	S	SW	N	N	SE	0	S	S	SSE	SSE	SE	S	W	W	W	W	SE
Slope (degrees)	30	30	25	30	33	25	30	30	30	27	20	0	20	25	30	17	20	25	5	5	5	5	24
Cover total (%)	10	5	5	5	5	5	5	5	5	10	10	10	5	2	2	10	15	5	30	25	15	20	5
Species richness	9	7	7	5	5	7	5	12	10	5	6	6	9	5	4	7	5	4	4	4	5	4	12
Relevé area (m²)	10	5	200	10	400	100	10	400	200	10	10	10	100	100	100	100	100	100	25	25	25	25	20
TWINSPAN classification	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
													0	0	0	0	0	0	1	1	1	1	1
C & D Associations (and subassoc.)																							
Galium aucheri	1	+	+	+	+	+	.	+	1	1	+	1	.	.	.	.	.	.	.	.	.	.	+
Veronica paederotae	+	.	+	+	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio vulcanicus	+	+	.	+	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lamium tomentosum	.	.	.	.	+	+	+	+	+	1	+	.	+	.	.	.	.	.	.	.	.	.	.
Asperula glomerata subsp. *bracteata*	.	1	+	.	+	1	+	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Pseudocamelina glaucophylla	+	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Achillea aucheri	+	.	.	+	.	.	.	.	.	.	+	.	1	1	1	2	2	2	.	.	.	.	.
Veronica aucheri	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	+	+	.	.	.	.	+
Potentilla argyroloma	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1	.	+
Arabis caucasica	.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	1	1	2	+
C *Didymophysion aucheri*																							
Cerastium purpurascens var. *elbursensis*	.	.	+	.	.	+	.	.	+	.	.	1	.	.	.	+	.	.	1	1	1	.	1
C & D *Didymophysetalia aucheri*																							
Didymophysa aucheri	+	.	1	1	+	1	1	1	1	+	1	+	1	1	1	1	1	1	1	1	1	1	1
Dracocephalum aucheri	.	.	.	.	.	.	.	1	.	.	.	.	+	+	.	+	1	1	3	2	2	2	+
Erysimum elbrusense	.	.	.	.	.	.	.	+	+	.	+	+	+	r	.	1	.	.	.	.	.	.	.
C & D *Physoptychio-Brometalia tomentosi*																							
Bromus tomentosus	+	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Physoptychis gnaphalodes	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Poa araratica	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Festuca alaica	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Scutellaria glechomoides	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.
Euphorbia aucheri	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
D *Didymophyso-Dracocephaletea aucheri*																							
Alopecurus textilis	.	+	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	+
Companion species																							
Pisum formosum	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trachydium depressum	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Draba aucheri	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lepechiniella persica	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Oxytropis persicus	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Alopecurus cf. *himalaicus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Draba siliquosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Erigeron uniflorus subsp. *elbursensis*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	+
Veronica kurdica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Myosotis asiatica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Oxyria digyna	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Ranunculus crymophilus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+

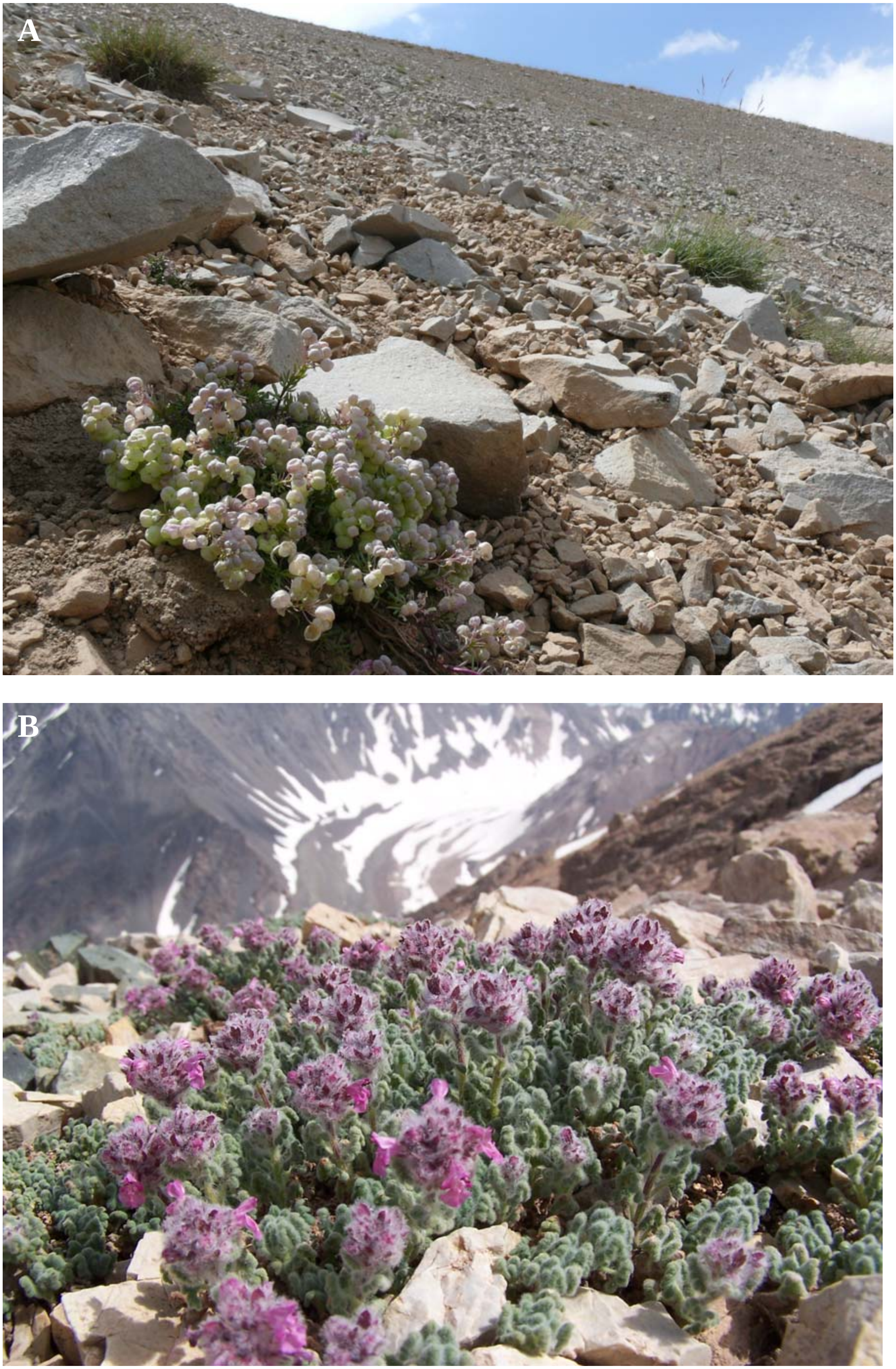

Photo S1. Character species of the class: **A)** *Didymophysa aucheri* in association of *Dracocephalo-Brometum tomentosi* (Sahand Mt. 3570 m a.s.l., photo: J. Noroozi), **B)** *Dracocephalum aucheri* (Alamkuh Mt. 4200 m a.s.l., photo: J. Noroozi).

Photo S2. *Nepetetum menthoidis* (Sahand Mt. 3360 m a.s.l., photo: J. Noroozi): *Nepeta menthoides.*

Photo S3. *Senecionetum taraxacifolii* (Sahand Mt. 3550 m a.s.l., photo: J. Noroozi): *Senecio taraxacifolius.*

Photo S4. *Dracocephalo aucheri-Brometum tomentosi jurinelletosum moschi* (Sahand Mt. 3520 m a.s.l., photo: J. Noroozi): *Jurinella moschus.*

Photo S5. *Dracocephalo aucheri-Brometum tomentosi minuartietosum glandulosae* (Sahand Mt. 3515 m a.s.l., photo: J. Noroozi): *Dracocephalum aucheri.*

Photo S6. *Dracocephalo aucheri-Brometum tomentosi typicum* (Sahand Mt. 3630 m a.s.l., photo: J. Noroozi): *Dracocephalum aucheri, Bromus tomentosus, Festuca alaica.*

Photo S7. *Dracocephalo aucheri-Brometum tomentosi nepetosum sahandicae* (Sahand Mt. 3590 m a.s.l., photo: J. Noroozi), *Nepeta sahandica.*

Photo S8. *Potentilletum porphyranthae* (Sabalan Mt. 4300 m a.s.l., photo: J. Noroozi): *Erigeron caucasicus* subsp. *venustus, Potentilla porphyrantha, Draba bruniifolia* subsp. *bruniifolia*.

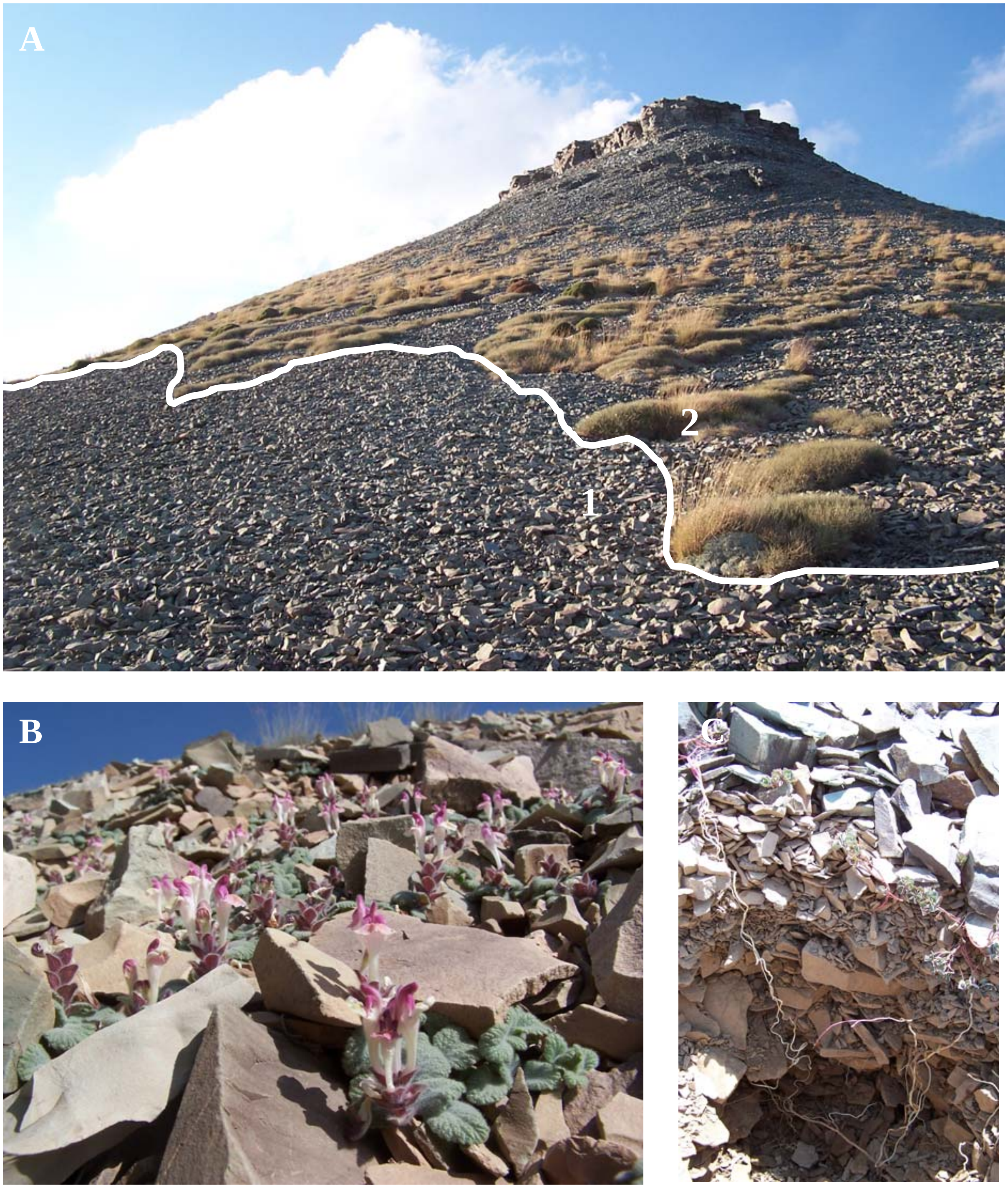

Photo S9. A) *Scutellario glechomoidis-Euphorbietum aucheri* [**1**] is surrounded with *Cicero tragacanthoidis-Nepetetum racemosae* [**2**] (Tuchal Mt. 3710 m a.s.l., photo: J. Noroozi), **B)** *Scutellaria glechomoides* (photo: J. Noroozi), **C)** *Euphorbia aucheri* with long and flexible rhizomes between the screes (photo: J. Noroozi).

Photo S10. *Cicero tragacanthoidis-Nepetetum racemosae typicum* (Tuchal Mt. 3600 m a.s.l., photo: J. Noroozi): *Cicer tragacanthoides*, *Nepeta racemosa*, *Leonurus cardiaca* subsp. *persicus.*

Photo S11. *Cicero tragacanthoidis-Nepetetum racemosae polygonetosum serpyllacei* (Tuchal Mt. 3640 m a.s.l., photo: J. Noroozi): *Nepeta racemosa*.

Photo S12. *Asperulo bracteatae-Brometum tomentosi typicum* (Tuchal Mt. 3900 m a.s.l., photo: J. Noroozi): *Bromus tomentosus, Astragalus macrosemius*.

Photo S13. *Asperulo bracteatae-Brometum tomentosi* (Tuchal Mt. 3880 m a.s.l., photo: J. Noroozi): *Dracocephalum aucheri, Bromus tomentosus.*

Photo S14. *Senecio iranici-Astragaletum macrosemii* (Damavand Mt. 4210 m a.s.l., photo: J. Noroozi): *Astragalus macrocemius, Dracocephalum aucheri, Senecio iranicus.*

Photo S15. *Galietum aucheri* Klein & Lacoste 1999 (Alamkuh Mt. 4200 m a.s.l., photo: J. Noroozi): *Veronica paederotae.*

Photo S16. *Dracocephaletum aucheri achileetosum aucheri* (Damavand Mt. 4470 m a.s.l., photo: J. Noroozi): *Achillea aucheri.*

Photo S17. *Dracocephaletum aucheri typicum* (Alamkuh Mt. 4455 m a.s.l., photo: J. Noroozi): *Cerastium purpurascens* var. *elbursensis, Dracocephalum aucheri.*

Conclusions

With this thesis, our knowledge about the phytodiversity, phytogeography, ecology and phytosociology of the high elevations of Iran markedly increased, and data of high-elevation vegetation in Iran has multiplied and are available as basic references for the future studies. For the first time, the papers presented in this thesis provide a country-wide overview of the vertical and geographical distribution patterns of vascular plant species living in the uppermost elevation zones in Iran and the the syntaxonomic position of the scree vegetation of the high elevations of Iran has been clarified and compared with the vegetation of similar habitats in neighboring mountain regions and in the Alps.

The main conclusions are summarized as follows:

1) The vascular plant flora of subnival-nival habitats of Iran is not outstandingly rich in species, however, the rate of endemism and narrowly distributed species are very high. The outstanding level of high-altitude endemism appears to result mainly from a pronounced orographic isolation of the country's highly scattered and fragmented cold areas and from the absence of extensive Pleistocene glaciations. Glaciers were present mainly in the uppers valleys, whereas high-elevation mountain slopes commonly remained ice-free therefore could have functioned as long-term refugia of cold-adapted plant species.

2) Several vascular plant species, restricted to the subnival-nival belt, were thus far unknown to science and other species were previously only known from mountains outside of Iran. This led to new original descriptions of species and the revision of disjunct distribution patterns of some species. We, hence, expect that the upper elevation zones of Iranian mountains are underexplored and that further unknown species occur. Furthermore, our knowledge about the habitats of rare species in different mountains is low. Therefore, we highly recommend more field exploration in high mountains to determine the ecology, biology and threatened rank of local endemics according to IUCN criteria, and improve the protection status of the high mountain flora and vegetation.

3) Our vegetation study extends knowledge of alpine and subnival scree vegetation into a previously almost unknown area, and therefore represents an important building block for a future synopsis of the scree vegetation of the northern hemisphere. It is a basis for monitoring of future

changes and for assessing endangered vegetation types and for assessing nature conservation needs.

4) One of the most important threats to the flora and vegetation of the study habitats can be the predicted climate change, which may seriously shrink the size of suitable habitats of the unique subnival–nival flora of Iran. The potential of alternative low-temperature habitats at higher elevations is very limited and, therefore, the survival of high-elevation species is uncertain. Decreasing water availability during the growing season and land use pressure (Kousari et al. 2011; Zarghami et al. 2011) may further exacerbate the situation. Additional pressure through drought-tolerant competitors from lower altitudes can increase the risk of biodiversity losses. A decline of high-altitude habitats through climate warming and reduced water availability is expected to be similar to that on Mediterranean mountains of S Europe, where species richness has decreased during the past particularly warm decade (Pauli et al. 2012). Hence, we have to expect a very high risk of biodiversity losses in the high-altitude vegetation of N and NW Iran. Detailed knowledge of these plant assemblages appears to be essential for tracing the expected changes in their species composition and the possible shrinkage of cryophilic, narrowly distributed species.

5) One of the major aims of this PhD thesis was assessing the effects of climate changes on alpine habitats of Iran. Two monitoring stations, therefore, were established in Central Alborz and in Sahand (NW Iran) according to the GLORIA approach. The duration of my PhD studies, however, was too short to allow for a resurvey of the vegetation recorded in the permanent plots. The collected permanent plot data are uploaded to the central GLORIA database and further field recording in the next years is planned to complete the Sahand site. Both Iranian GLORIA sites are planned to be resurveyed at intervals of 5 to 10 years.

6) Overgrazing is another major threat to the flora and vegetation of high elevations in Iran. The alpine grasslands are frequently used for mountain pasturing with large herds of sheep and goats during the summer growing season, when grazing grounds at lower elevations fall dry. Overgrazing and trampling of the herds threat the fragile communities of alpine and even subnival zones. In spite of the low attraction of subnival zones for sheep and goats to feed, effects of pastoralism should not be neglected, especially the impact of trampling on unstable scree habitats. Large herds cause substrate movement, plants can be uprooted and thus the vegetation may be completely destroyed at some sites.

7) As my thesis mainly focuses on the alpine to subnival-nival vegetation of Alborz and NW Iran, large high-altitude areas still remain unstudied. For a comprehensive description of the country's alpine and subnival-nival vegetation types, studies in vegetation ecology and phytosociology in the extensive Zagros mountain range appear to be indispensable.

References

Pauli, H., Gottfried, M., Dullinger, S., Abdaladze, O., Akhalkatsi, M., Benito Alonso, J.L., Coldea, G., Dick, J., Erschbamer, B., Fernández Calzado, R., Ghosn, D., Holten, J.I., Kanka, R., Kazakis, G., Kollár, J., Larsson, P., Moiseev, P., Moiseev, D., Molau, U., Molero Mesa, J., Nagy, L., Pelino, G., Puşcaş, M., Rossi, G., Stanisci, A., Syverhuset, A.O., Theurillat, J.-P., Tomaselli, M., Unterluggauer, P., Villar, L., Vittoz, P. & Grabherr, G. (2012) Recent plant diversity changes on Europe's mountain summits. *Science* 336: 353-355.

Kousari, M.R., Ekhtesasi M.R., Tazeh M., Saremi Naeini, M.A. & Asadi Zarch, M.A. (2011) An investigation of the Iranian climatic changes by considering the precipitation, temperature, and relative humidity parameters. *Theoretical Applied Climatology* 103:321–335.

Zarghami, M., Abdi, A., Babaeian, I., Hassanzadeh, Y. & Kanani, R. (2011) Impacts of climate change on runoffs in East Azerbaijan, Iran. *Global and Planetary Change* 78: 137–146.

Curriculum Vitae

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- 1998-2002: BSc in Plant Biology, Department of Plant Science, Faculty of Natural Science, University of Tabriz, Tabriz, IRAN.

- 2002-2005: MSc in Plant Biology (Ecology and Systematic), Department of Biology, Faculty of Science, University of Tehran, Tehran, IRAN.

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Main Research Interests:

- Ecology of alpine habitats
- Biogeography and evolution of alpine plants
- Alpine plant communities in Iran and the Caucasus region
- Alpine plant diversity and climate change
- Land use impacts and conservation biology in alpine environments

MSc Thesis Subject:

Phytosociological study of alpine zone of Tuchal Mountains, N. Tehran. University of Tehran, Iran.

PhD Thesis Subject:

Comparative analysis of high-alpine and subnival vegetation of mountain ecosystems in Iran (Alborz and NW-Iran) and assessing the impacts of climate change and land-use

Publications:

Book:

- **Noroozi, J.** (2010) A glance at the wild flowers of Iranian mountains. Karimkhaneh Zand Publication, Tehran, IR.

Book Chapters:

- **Noroozi, J.** (In press). High mountain regions of Iran (chapter 7.6), *in* C. Hobohm (editor). Endemism in Vascular plants. Springer.

- **Noroozi, J.** (In press). Iran (chapter 2), *in* J. Solomon, T. Shulkina & G. Schatz (editors). Red Book of endemic plants of the Caucasus Region. Missouri Botanical Garden Press, Saint Louis.

International Peer-reviewed Journals:

- **Noroozi, J.**, Willner, W., Pauli, H. & Grabherr, G. (2013) Phytosociology and ecology of the high-alpine to subnival scree vegetation of N and NW Iran (Alborz and Azerbaijan Mts.). Applied Vegetation Science DOI: 10.1111/avsc.12031.

- Butterfield, B.J., Cavieres, L.A., Callaway, R.M., Cook, B.J., Kikvidze, Z., Lortie, C.J., Michalet, R., Pugnaire, F.I., Schöb, C., Xiao, S., Anthelme, F., Björk, R.G., Dickinson, K., Gavilán, R., Kanka, R., Maalouf, J.-P., **Noroozi, J.**, Parajuli, R., Phoenix, G.K., Reid, A., Ridenour, W., Rixen, C., Wipf, S., Zhao, L., Brooker, R.W. (2013) Alpine cushion plants inhibit the loss of phylogenetic diversity in severe environments. Ecology Letters DOI: 10.1111/ele.12070.

- **Noroozi, J**., Ajani, Y. (2013) A new alpine species of *Nepeta* sect. *Capituliferae* (Labiatae) from Northwestern Iran. Novon 22: 297–303.

- Akhani, H., Mahdavi, P., **Noroozi**, J. & Zarrinpour, V. (2013) Vegetation patterns of the Irano-Turanian steppe along a 3,000 m altitudinal gradient in the Alborz Mountains of Northern Iran. Folia Geobotanica 48: 229-255.

- **Noroozi, J.**, Pauli, H., Grabherr, G. & Breckle, S.W. (2011) The subnival-nival vascular plant species of Iran: a unique high-mountain flora and its threat from climate warming. Biodiversity and Conservation 20: 1319-1338.

- **Noroozi, J.**, Akhani, H. & Willner, W. (2010) Phytosociological and ecological study of the high alpine vegetation of Tuchal Mountains (Central Alborz, Iran). Phytocoenologia 40: 293-321.

- Ajani, Y., **Noroozi, J.** & Levichev, I.G. (2010) *Gagea alexii* (Liliaceae), a new record from subnival zone of southern Iran with key and notes on sect. *Incrustatae.* Pakistan Journal of Botany 42: 67-77.

- **Noroozi, J**., Ajani, Y., Nordenstam, B. (2010) A new annual species of *Senecio* (Compositae-*Senecioneae*) from subnival zone of southern Iran with comments on phytogeographical aspects of the area. Compositae News Letter 48: 43-62.

- **Noroozi, J.** (2009) Understanding the effects of climate change on alpine biodiversity of Alborz mountains. BC Grasslands, Temperate Grasslands of the World, winter 2008/2009. 15-17.

- **Noroozi, J.**, Akhani, H. & Breckle, S.W. (2008) Biodiversity and phytogeography of the alpine flora of Iran. Biodiversity and Conservation 17: 493-521.

- Khassanov F., **Noroozi J.** & Akhani H. (2006) Two new species of *Allium* genus from Iran. Rostaniha 7(2): 119-130.

Participation at scientific meetings:

- **Noroozi, J.** Alpine flora and vegetation of Iranian mountains and their sensitivity to global warming. Plant Life of SW Asia 8 conference at the Royal Botanic Garden Edinburgh. Edinburgh, Scotland/UK, 1-5th July 2013. (oral presentation)

- **Noroozi, J.**, Willner, W., Pauli, H., Grabherr, G. Phytosociology and ecology of the high alpine to subnival scree vegetation of N and NW Iran (Alborz and Azerbaijan Mts.), 56th

Symposium of the International Association for Vegetation Science (IAVS). Tartu, Estonia, 26-30th June 2013. (poster presentation)

- **Noroozi, J.** Alpine flora and vegetation of Iranian mountains and their sensitivity to global warming. Plant Life of SW Asia 8 conference at the Royal Botanic Garden Edinburgh. Edinburgh, UK, 1-5th July 2013. (oral presentation)

- **Noroozi, J.**, Willner, W., Pauli, H., Grabherr, G. Phytosociology and ecology of the high alpine to subnival scree vegetation of N and NW Iran (Alborz and Azerbaijan Mts.). 7th Annual Meeting of the Specialist Group on Macroecology of the Gesellschaft für Ökologie. Göttingen, Germany, 13-15th March 2013. (oral presentation)

- Noroozi, J. The alpine flora of Iranian mountains and its sensitivity to climate change. International Conference on Managing Protected Areas under Climate Change – IMPACT. Dresden, Germany, 24-26 th September 2012. (oral presentation)

- **Noroozi, J.** An overview of alpine vegetation of Iranian mountains. 21st Workshop of European Vegetation Survey. Vienna, Austria, 24-27th May 2012. (oral presentation)

- **Noroozi, J.**, Pauli, H., Grabherr, G. & Breckle S.W. Refugia for coldadapted species in the highly fragmented subnival –nival habitats of Iran. Annual Conference of the Society for Tropical Ecology (gtoe) "Islands in lands- and sea-scape: the challenge of fragmentation". Erlangen, Germany, 22-25th February 2012. (oral presentation)

- Noroozi, J., Willner, W., Pauli, H. & Grabherr, G. Phytosociological and ecological studies of high alpine to subnival scree vegetations of N and NW of Iran (Alborz and Azarbayjan Mts.). 20st Workshop of European Vegetation Survey. Rome, Italy, 06-09th April 2011. (oral presentation)

- **Noroozi, J.**, Pauli, H. & Grabherr, G. Potential effects of climate warming on a unique cryo-flora: the endemic high alpine to subnival plants in the mountains of Iran. International conference of global change and the world's mountains. Perth, Scotland/UK, 26-30th September 2010. (oral presentation)

- **Noroozi, J.**, Pauli, H. & Grabherr, G. Potential effects of climate warming on a unique high-altitude flora. 5th International GLORIA conference. Perth, Scotland/UK, 23-25th September 2010. (oral presentation)

- **Noroozi, J.**, Pauli, H. & Grabherr, G. Potential effects of climate warming on a unique cryo-flora: the endemic high alpine to subnival plants in the mountains of Iran. International GMBA-DIVERSITAS Conference on "Functional Significance of Mountain Biodiversity". Chandolin (Valais), Switzerland, 27-30th July 2010. (oral presentation)

- Noroozi, J. Caucasian Part of Iran. 3th Workshop of Coordination and Development of Plant Red List Assessments for the Caucasus Biodiversity Hotspot, CEPF-IUCN. Tbilisi, Georgia. 25-28th May 2009. (oral presentation)

- Noroozi, J. Endemic species of Caucasian territory of Iran. International Symposium for Plant Conservation in the Caucasus Region. 2-8th October 2009. Missouri Botanical Garden, Missouri, USA. (oral presentation)

- **Noroozi, J.** Alpine Grasslands of Iran. World Temperate Grasslands Conservation Initiative Workshop: Planning for a Decade of Progress. Hohhot, China, 28-29th June 2008. (oral presentation)

- **Noroozi, J.** XXI International Grasslands Congress/ VIII International Rangelands Congress (IGC/IRC). Hohhot, China, 29th June -5 July 2008. (oral presentation)

- **Noroozi, J.** & Akhani, H. Biodiversity of Alpine Flora of Iran. XVII International Botanical Congress. Vienna, Austria, 17-23 th July 2005. (poster presentation)

Invited Talks:

- Flora and vegetation of alpine habitats of Iran. Institut für Pflanzenwissenschaften -Botanischer Garten-, Karl-Franzens-Universität Graz, Graz, Austria. 27th March 2012.

- Flora und Vegetation der alpinen Stufe im Iran. Botanical Society of Regensburg, University of Regensburg, Germany. 7th November 2011.

- Flora und Vegetation der alpinen Stufe im Iran. Institute of Botany, University of Basel, Switzerland. 29th October 2010.

- Mountain vegetation types of Caucasus region of Iran. Faculty of Natural Sceince, University of Tabriz, Iran. 15th December 2009.

- Alpine habitats of Iranian mountains. Faculty Centre of Biodiversity, University of Vienna, Austria. 25th September 2009.

Memberships of scientific networks and societies:

- Global Observation Research Initiative in Alpine Environments (GLORIA)

- Temperate Grasslands Conservation Initiative (TGCI)_IUCN-WCPA

- Alpine Garden Society (AGS)

- International Association for Vegetation Science (IAVS)

- European Vegetation Survey (EVS)

Language Skills:

Farsi (Persian): native
Turkish: native
English: fluently (orally and written)
German: good (orally), moderate (written)
Arabic: basic