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Biodiversity and phytogeography of the alpine flora of Iran

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Abstract Iran is a mountainous country. Zagros and Alborz mountains reach altitudes of more than 4,000 m. Alpine regions are above timber-line, which is not easy to recognize, since aridity is prominent in most regions. The alpine zone in Alborz lies between 3,000 and 4,000 m, the nival zone is above 4,000 m, locally varying by some hundred meters. A first evaluation of vascular flora shows that 682 species belonging to 193 genera and 39 families are known from the alpine zone of Iran. The alpine zone is commonly characterized by many species of hemicryptophytes and thorny cushions. Species numbers decline very strongly with increasing altitude. In this paper biogeographical patterns of the alpine flora of Iran have been discussed and distribution maps of 44 species are illustrated. New data indicate a transitional situation of the Iranian mountains between Anatolia/Caucasus and the Hindu Kush, but with a strong own element with high endemism and remarkable relict species. Ca. 58% of the alpine flora of Iran are endemic and subendemic. The Zagros Mountains harbor high endemism which justify considering this area as a separate floristic province. Based on the evaluation of published data from 682 known alpine species ca. 160 species have been known only by one record, 110 species by 2–3 records and 87 endemic species have been known only based on the type location. These plants need a strong conservation and protection management since the fragile ecosystems are often very restricted, small and very isolated, nonetheless grazing and overgrazing are still common threats.

Keywords Alborz · Biodiversity · Chorology · Conservation · Endemics · Iran alpine flora · Phytogeography · Zagros

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Introduction

Iran has a total surface area of 1.6×10^6 km^2. Except for the interior deserts and the lowlands along the Caspian Sea, Persian Gulf and Gulf of Oman, ca. half of Iran is composed of high mountains. The main mountain chains are Alborz, Zagros, Kopet Dagh and Khorassan and Makran (Fig. 1). Iran is a typical high mountain country with alpine life zones and a diverse alpine flora. Iran is situated within the dry belt of Asia: Zonobiom III (hot deserts) in the south, Zonobiom VII (rIII) in the north (Breckle 2002). Only the Hyrcanian forests located in the South Caspian Sea characterized a humid climate with a rich vegetation of lowland and montane decidous forests (Akhani 1998).

Mountains play a vital role; Iranians are almost entirely depending on water resources in the form of spring rains or melting snow descending from the mountains or underground water resources. Traditionally, in most parts of the country, the rich underground water resources in the higher altitudes are transferred by the man-made underground water channels systems to the lower and dryer agricultural and settled areas which are known as Qanat or Karez. In contrast to Afghanistan, where the mountains form a 'backbone' of the country [WF1], in Iran the mountains are surrounding the desert lowlands of the central part.

The Iranian alpine areas have been poorly investigated ecologically and botanically. There are still comparatively little in-depth studies, which deal with the alpine flora and biodiversity. The initial vegetation research on Alborz Mountains goes back to Kotschy (1861a, b) and Bunge (1860). Buhse (1899a, b) and Gilli (1939, 1941) have published studies on Alborz Mountains vegetation. Some phytosociological research in the subalpine and alpine belt which aimed to establish of a syntaxonomic system has been done by Klein (1982, 1984, 1987, 1988, 1991, 2001) and Klein and Lacoste (1994, 1996, 1998). The vegetation and flora of Tuchal mountains is under active investigation by the Research Project "Geobotanical studies in different parts of Iran" including some M.Sc. projects in University of Tehran (Zarrinpour 2002; Noroozi 2005; Noroozi and Akhani, in press; Khassanov et al. 2006; Mahdavi 2007).

This paper provides an overview of biodiversity among alpine plants in Iran with special reference to the flora and phytogeography. It discusses threats to the environment and the

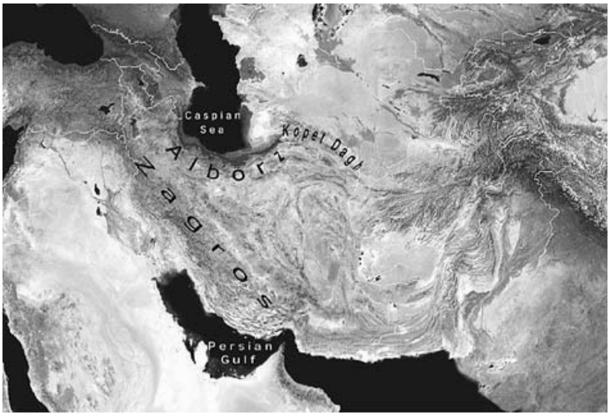

Fig. 1 Main mountain ranges of Iran: the Alborz in central N, The Zagros from NW to SE and the Kopet Dagh in NE

conservation of alpine ecosystems. The paper includes the result of our field studies and literature.

The Flora Iranica is the major taxonomic and nomenclatural reference for the project (Rechinger 1963–2005). Most of the plant families are now treated within edited volumes of this comprehensive flora. Additional distribution data are also added from Floras of neighbouring countries such as Flora of Turkey (Davis 1965–1980), Flora of Iraq (Townsend et al. 1966–1985), and Flora of Caucasus (Grossheim 1967). For some taxa, information of recent monographs has been adopted. In order to find phytogeographical patterns the reported localities in Flora Iranica and surrounding flora have been transferred into coordinates and the distribution maps have been generated using computer programme DMAP (Morton 2001). In most cases the distribution maps have been checked in relevant literatures particularly from Meusel et al. (1964, 1978, 1992).

Physical geography

Geographical distribution

The two largest mountain ranges, the Alborz lies along the northern border of Iran at the southern shore of the Caspian Sea and extends about 650 km from west to east. The Zagros stretches along the Western parts of Iran and extends from northwest to southeast. Besides several other mountains in Khorassan, Baluchestan and Central Iran they provide diverse orophytic ecosystems. Altitude amplitude is from 26 m below sea-level, on the shores of the Caspian Sea to 5,670 m at the summit of Mt. Damavand, which is the highest peak west of the Hindu Kush in whole Eurasia. There are many mountain peaks in Iran with an elevation higher than 4,000 m.

The Iranian high mountains are a rather continuous mountain chain especially at the Alborz and Zagros (Fig. 1). The Alborz interpose between Hindu Kush—Himalaya Mountains in the east and Anatolia and Caucasus Mountains in the west. Therefore, this transition area exhibits some very important historical, evolutionary, phytogeographically and biogeographical aspects.

Geology

The orogeny, stratography and geographical mosaic of the area are very complex and it is not easy to summarize in here. The reader is referred to Stöcklin (1974), Berberian and King (1981), Alavi (1996) and Krinsley (1970). The main orogenic events are mentioned here for background information. The Early Alpine orogenic events lasted from 200 Ma to around 65 Ma. Subsequent Late Cretaceous movements, the extensive volcanism during Eocene and active erosion presumably associated with rapid orogenic uplift occurred in Pliocene time. The convergence of the Arabian-Eurasian plates has continued to present times. The present orographical picture of the area is chiefly determined by high-mountain ranges of Tertiary age. Soils of higher parts of Alborz Mountains are largely derived from Eocene volcanic tuff.

Glaciers occur in the higher elevations of the Alborz mountains, the Zagros Mountains and Kuhhaye Sabalan in the northwest part of Iran. The present snowline in several part of Iran lie between 3,800 and 5,000 m (Bobek 1953; Ehlers 1980). During the Pleistocene, glaciation was much more extensive in Iran. During that time the climatic snowline was

600–1,100 m lower than the present level. The temperature and precipitation pattern was thought to be similar except that the mean temperature was 4–5 K lower and precipitation/ evaporation rate was higher (Ferrigno 1991; Bobek 1937).

Climate

The high mountain areas exhibit a strong continental climate. In the low altitudes of mountains in the south slopes of Alborz there are zones with total precipitation (rain and snow) from 200 to 600 mm a^{-1} (Khalili 1973) (Fig. 2a–c). But at high elevations and also on north slopes of the Alborz (Hyrcanian area) precipitation exceeds 1,000 mm a^{-1} (Alex 1985). Orography plays a very important role in the rain climate of different parts of Iran. The Alborz, Zagros and Makran mountain ranges which enclose Iran from north, west and south, respectively, act as barriers taking away moisture-bearing clouds from the interior parts. Therefore, there are large deserts in the central and eastern parts of Iran. The effect of the topography and exposure on rainfall is well represented in the Alborz mountains by the comparison of South Kandavan (2,900 m a.s.l.) receiving 765 mm a^{-1}, with North Kandavan (2,750 m a.s.l.) receiving 1,175 mm a^{-1} (Khalili 1973). This difference is also exemplified by comparison of Tonekabon (50 m a.s.l. on Caspian Plain) receiving 1,180 mm a^{-1}, with Tehran (1,190 m on southern foot-hill of the Alborz) receiving only 230 mm a^{-1}. The humid conditions on the northern side of Alborz result in a Hyrcanian deciduous closed forest, forming an arc along the southern shore of the Caspian Sea and the adjacent lower zones of the northern slopes of the Alborz Mountains. The climate of this area is mesic and warm, with rainy summers and mild winters (Akhani 1998). In most parts of Alborz the precipitation increases by altitude. However, on the northern slopes of Alborz the influence of hyrcanian moist climate is getting weaker above the timberline, where precipitation decreases towards higher elevations. A large amount of snow falls during the winter season in high mountains. The main period of precipitation is during the late of autumn, winter and early spring. For example the data of two stations at the southern and northern slopes of Kandavan show that the winter rainfall comprise 50%, spring 22%, autumn 25% and the summer only 3% of the annual precipitation. The analytical data show that the higher altitudes of Alborz are affected by the north westerly flow of polar air masses (Khalili 1973).

The summer is arid, hot and sunny with intensive radiation most of the time. Both annual and diurnal amplitudes of temperature can be very high, on the soil surface in particular. The microclimate in the high alpine zone is characterized by a long-persistent

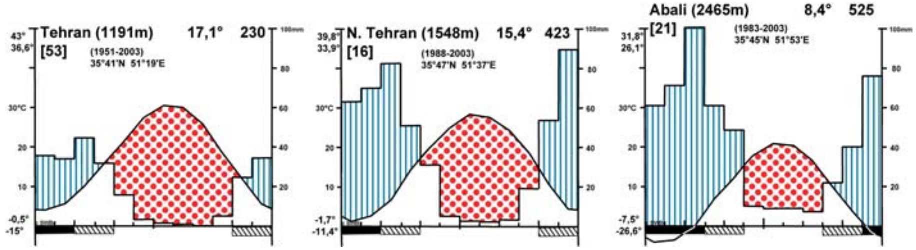

Fig. 2 Ecological climate diagrams of the meteorological stations at different altitudes around Central Alborz, indicating monthly means of temperature and precipitation, and relative humid (hatched) and relative arid (stippled) seasons

snow-cover and a short vegetation period. Water supply during the arid summer is derived mainly from melting snow. The time of snowmelt is the most characteristic factor which determines vegetation patterns and the distribution of plant communities in the alpine zone of these mountains. Figure 2 shows the increase of precipitation and the decrease of temperature and aridity with increasing elevation. Unfortunately there is no meteorological data from higher elevations.

Flora

The subalpine and alpine flora of Iran consists of a large number of families and genera where many of them are highly showy and attract both professional and amateur botanists (Fig. 4).

A first evaluation of the vascular flora shows that 682 species, belonging to 193 genera and 39 families, are known from the alpine zones of Iran. These figures represent only species without considering the infraspecific taxa. The number of known plant species in whole Iran is nearly 7,300 species (Akhani 2006). Asteraceae (32 genera, 111 species) is the most common angiosperm family in the Iran alpine flora, followed by Fabaceae (6 genera, 106 species), Caryophyllaceae (11, 52), Poaceae (21, 50), Lamiaceae (16, 50), Brassicaceae (19, 38), Rosaceae (7, 38), Apiaceae (16, 30) and Scrophulariaceae (5, 29), respectively (Table 1). The number of plant species, genera and endemic species of the different families, compared with Hindu Kush Mountains, is shown in Table 1. The largest alpine genera in Iran are *Astragalus* with 78, *Nepeta* 21, *Cousinia* 20, *Potentilla* 19, *Silene* 18 and *Oxytropis* 14 species. It is noteworthy that some of these genera have a very high proportion of endemic and subendemic species (occurring in adjacent high altitudes in NE Iraq), such as *Astragalus* with 69 (88%), *Cousinia* 18 (90%) and *Nepeta* 18 (86%), where most of them have a local distribution. *Astragalus* is the largest genus in the area covered by Flora Iranica (sensu Rechinger 1963f) with ca. 1,000 species. which occur further in some adjacent high mountains So far nearly 800 species of *Astragalus* have been reported from Iran with an endemic rate of nearly 65% (Maassoumi 2005). However, this figure seems exaggerated because of the description of so many new species in recent years based on minor differences.

Strict alpine genera include *Myopordon* (Asteraceae) with four species (see also Mozaffarian 1991), *Jurinella* (Asteraceae) with three species, *Diplotaenia* (Apiaceae) with two alpine species, *Lomatogonium* (Gentianaceae) with one species, *Elburzia* (Brassicaceae, monotypic), *Sclerochorton* (Apiaceae, monotypic), *Physoptychis* and *Didymophysa* (Brassicaceae, both with one species in Iran), *Zerdana* (Brassicaceae, monotypic), an endemic alpine species in Zagros and *Anchonium* (Brassicaceae, ditypic), one species in Alborz.

Phytogeography

The phytogeographical pattern in the alpine and nival belt differs from that of the lower regions. The most important aspect of alpine phytogeography is the high level of endemism in comparison with neighboring mountain ranges. Maybe different species concepts have been applied in different areas and this might influence the number of endemics, but the difference is remarkable, anyhow. Approximately 58% of the alpine and nival species are endemic and subendemic for Iran which is a very high rate in comparison with the endemic

Table 1 Number of spermatophytic plant species, genera and endemism in alpine areas of Iran mountains, and in comparison with Hindu Kush Mountains in Afghanistan (Hindu Kush data is derived from Breckle 1974; Rechinger 1963ff)

Plant family	Iran			Hindu Kush
	Genera	Species	Species Endemic–subendemic	Species
Alliaceae	1	13	10	9
Apiaceae	16	30	20	15
Asteraceae	32	111	68	68
Boraginaceae	9	12	7	18
Brassicaceae	19	38	22	73
Campanulaceae	2	6	3	4
Caprifoliaceae	–	–	–	10
Caryophyllaceae	11	52	29	12
Chenopodiaceae	2	2	–	2
Crassulaceae	3	6	2	14
Cupressaceae	1	2	–	1
Cuscutaceae	–	–	–	1
Cyperaceae	3	12	1	20
Dipsacaceae	1	1	–	–
Ephedraceae	–	–	–	2
Ericaceae	–	–	–	1
Euphorbiaceae	1	5	4	4
Fabaceae	6	106	81	47
Fumariaceae	–	–	–	8
Gentianaceae	3	7	1	12
Geraniaceae	2	2	2	5
Grossulariaceae	1	1	–	3
Iridaceae	1	1	1	–
Juncaceae	2	2	–	7
Lamiaceae	16	50	38	33
Liliaceae	4	12	4	11
Onagraceae	1	2	–	5
Papaveraceae	1	2	–	2
Parnassiaceae	1	2	–	1
Plantaginaceae	1	2	–	1
Plumbaginaceae	1	14	12	11
Poaceae	21	50	6	55
Polygonaceae	3	8	3	20
Primulaceae	3	12	9	16
Ranunculaceae	4	19	11	17
Rhamnaceae	1	2	0	1
Rosaceae	7	38	24	31
Rubiaceae	3	13	10	2
Salicaceae	–	–	–	1
Saxifragaceae	1	6	4	12

Table 1 continued

Plant family	Iran			Hindu Kush
	Genera	Species	Species Endemic–subendemic	Species
Scrophulariaceae	5	29	17	9
Solanaceae	1	4	3	–
Tamaricaceae	–	–	–	2
Valerianaceae	1	3	–	2
Violaceae	1	3	2	3
Total	192	680	394	569
Pteridophytes	1	2	–	6
Total	193	682	394	575

Subendemic species refer to those species which their distributions extend in the surrounding mountains of Iranian borders, mainly in NE Iraq

species of whole Iran (24%) (Akhani 2006). Almost 22.5% of Iran endemic species are restricted to alpine life zone.

This result supports the hypothesis that the proportion of endemism increases with increasing altitude (Vetaas and Grytnes 2002; Pauli et al. 2003). Ca. 32% of alpine endemic species are restricted to the Alborz, 46% restricted to the Zagros. The taxonomic relationships of most endemic species show that the origin of alpine flora of Iran is Irano-Turanian (see also Klein 1991).

In contrast to Hindu Kush Mountains where endemism decreases with increasing elevation (Breckle 1974, 2004) in the alpine belts and where there is a maximum of endemism in higher montane and subalpine belts, in Iran mountains endemic species percentage increases with increasing altitude. It would be interesting to look for the distribution ranges of the very high altitude species.

In Fig. 3 it is indicated how many percent of alpine and nival species of Iran are in common with adjacent mountains. The alpine zone in Alborz is ca. between 3,000 and 4,000–4,200 m and nival zone is above 4,000 m with some difference related to geographical position and slope and exposure. The altitudinal maximum record for the flowering plants is 4,800 m and is held by *Paraquilegia caespitosa* (Fig. 4c) (Rechinger 1992), *Veronica aucheri* (Fischer 1981) and *Potentilla gelida* (Schiman-Czeika 1969) on

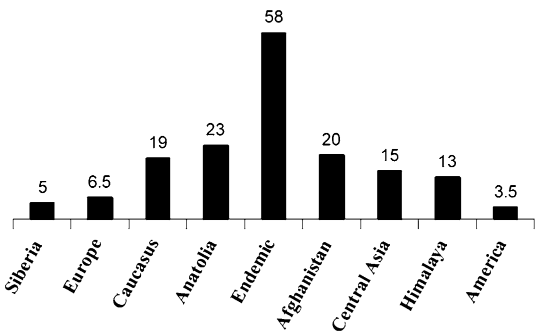

Fig. 3 Floristic relationships of alpine flora in Iran as percentage of species common with other areas and mountain ranges

Fig. 4 A selection of some typical alpine species of Iran. (**a**) *Physoptachys gnaphalodes* (Tuchal, 3,500 m, Tehran). (**b**) *Scutellaria glechomoides* (Tuchal, 3,700 m, Tehran). (**c**) *Paraquilegia caespitosa* (Alamkuh, 4,200 m, Kalardasht), (**d**) *Primula auriculata* (Bozgush, 3,000 m, Mianeh) (photo: **a**, **c**–**d** J.N.; **b**, H.A.)

Alamkuh in Central Alborz (which is second highest peak in Iran with 4,845 m), and *Alopecurus himalaicus* (Bor 1970) on Damavand.

The chorology of alpine and nival species of Iran could be classified into following subgroups.

Boreal species

There are a few species (3.5%) which belong to widespread alpine species distributed in the northern hemisphere in most alpine and arctic areas which are known as boreal species. Examples are *Myosotis alpestris* (Akhani 1999), *M. asiatica* (see distribution map of both species in Meusel et al. 1978: 364), *Sagina saginoides*, *Erigeron acris* (Meusel et al. 1992: 456), *Trichophorum pumilum*, *Luzula spicata* (Meusel et al. 1964: 88), *Poa alpina* (Meusel et al. 1964: 31), *Draba nemorosa* (Meusel et al. 1964: 185), *Agrostis canina* (Meusel et al. 1964: 47), *Parnassia palustris* (Meusel et al. 1964: 207), *Cerastium cerastioides* (Meusel et al. 1964: 144) *Erigeron uniflorus* s. l. (Meusel et al. 1992: 457), *Oxyria digyna* (Meusel et al. 1964: 129), *Potentilla multifida* (Meusel et al. 1964: 215), *Galium boreale* (Meusel et al. 1992: 423), *Epilobium palustre* (Meusel et al. 1978: 299), *Deschampsia caespitosa* (Meusel et al. 1964: 51), *Nardus stricta* (Meusel et al. 1964: 57), *Asplenium viride* (Meusel et al. 1964: 13), *Juniperus communis* (Meusel et al. 1964: 22) and *Phleum alpinum* (Meusel et al. 1964: 55).

Euro-Siberian/Irano-Turanian species

The second group includes those species which are widely distributed from the European Alps to Iran which may also occur further East to Central Asia, Himalaya, Siberia and East Asian Mountains (omni-Euro-Siberian species). Examples of widespread Euro-Siberian and Irano-Turanian species are such as *Androsace villosa* (Meusel et al. 1978: 340), *Stipa pennata* s. l. (Freitag 1985), *Viola rupestris* (Meusel et al. 1978: 291), *Plantago atrata* s. l. (incl. *P. saxatilis*) (Meusel et al. 1978: 420), *Cerastium dubium*, *Lomatogonium carinthiacum* (Mozaffarian 1988, Meusel et al. 1978: 356), *Hieracium prenanthoides* (Meusel et al. 1992: 554) and *Crepis multicaulis*, *Potentilla bifurca*, *P. gelida* and *Juniperus sabina* (Meusel et al. 1964: 23). Some species such as *Trifolium badium*, *T. spadiceum* (Meusel et al. 1964: 236), *Sesleria phleoides*, *Koeleria eriostachys* and *Saxifraga exarata* (Meusel et al. 1964: 203) are Euro-Siberian species which occur in their easternmost or southernmost range in Iran.

Widespread Irano-Turanian or Omni-Irano-Turanian species

Some are widespread species from Central Anatolia and/or Caucasus to Afghanistan, and sometimes Central Asian mountains and Himalaya such as *Salsola canescens* (Fig. 5a), *Primula auriculata* (Fig. 5b), *P. algida*, *Taraxacum crepidiforme*, *Cirsium rhizocephalum*, *Catabrosella parviflora*, *Aethionema trinervium*, *Swertia longifolia*, *Kobresia humilis*, *K. schoenoides*, *Carex melanantha*, *Gentiana umbellata*, *Poa araratica*, *Bromus biebersteinii*, *B. tomentosus*, *B. variegatus*, *Hordeum violaceum*, *Piptatherum laterale* (see distribution map in Freitag 1975: 384), *Agrostis olympica*, *Psychrogeton amorphoglossus*, *Oxytropis savellanica*, *Veronica biloba*, *V. pusilla* and *V. hispidula.* These two latter species occur also in the Lebanon. Most species in this category belong to omni-Irano-Turanian species or widespread Irano-Turanian species. However, they provide only ca. 3.8% of Iranian alpine flora.

Irano-Anatolian and Irano-Caucaso-Anatolian species

These include sharing species between Caucasus and/or Anatolia and NE Iraq with Iran mountains. This distribution pattern matches well with the Armeno-Kurdic pattern described by Hedge and Wendelbo (1978), and illustrated by the distribution range of *Physoptychis.* There are two distinct subgroups with this pattern. The first group of species have a wide and continuous range from Anatolia and/or Caucasus through NW Iran and further occur in Alborz and/or Zagros such as *Tanacetum kotschyi*, *Artemisia splendens*,

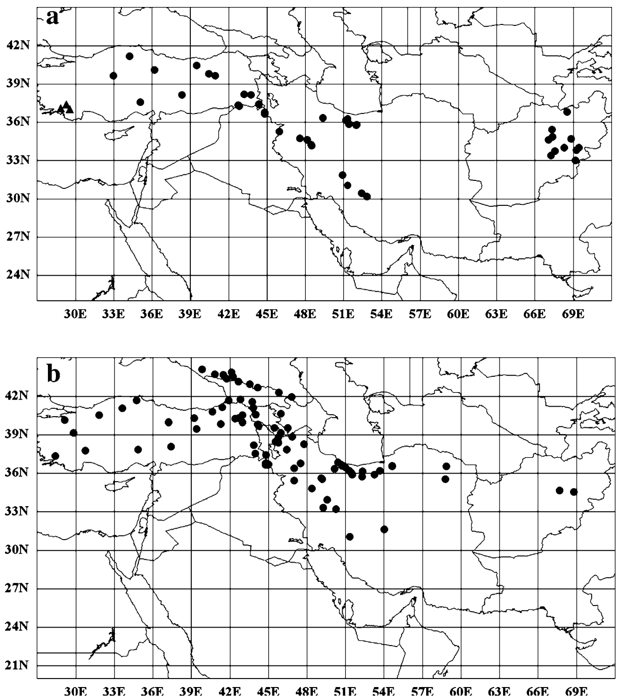

Fig. 5 Examples of distribution maps of species with a widespread range from Anatolia and/or Caucasus, NE Iraq, Afghanistan and Central Asia. (**a**) *Salsola canescens* (compiled from Freitag and Özhatay 1997), subsp. *canescens* (dot), subsp. *serpentinicola* (triangle). (**b**) *Primula auriculata* (from Grossheim 1967)

Helichrysum psychrophilum, *Iranecio pausilobus*, *Scorzonera meyeri*, *Aethionema virgatum*, *Centaurea rhizantha* (Fig. 6a), *Anchonium elichrysifolium* (see distribution map in Jacquemound 1984: 741), *Pedicularis caucasica* (Fig. 6b), *Physoptychis gnaphalodes* (Fig. 4a), *Didymophysa aucheri* (Fig. 6c), *Vicia ciceroidea*, *Campanula stevenii* (Azerbaijan and Alborz only), *Cicer anatolicum*, *Lamium tomentosum*, *Salvia staminea*, *Colpodium versicolor*, *Scrophularia amplexicaulis*, *Xanthogalum purpurascens* and *Festuca skvortsovii*.

The second subgroup of species are endemic species of the mountains in E Anatolia, Caucasus and NW Iran which their easternmost range is high mountains in W and/or E Azerbaijan. Examples showing this pattern are *Marrubium cordatum, Silene lucida*, *Euphorbia iberica*, *Senecio taraxacifolius* (Fig. 6e), *Crepis sahendi* (Fig. 6d) *Draba bruniifolia*, *Allium kunthianum* (Caucasus, NW-Iran)*; Campanula ruprechtii*, *Scrophularia olympica*, *Sedum sempervivoides* (*=Rosularia sempervivoides*, see Eggli 1988), *Ranunculus diversifolius* (Fig. 6f), *Asperula prostrata* and *Centaurea drabifolia.* We can add in this category several local endemic species with their distribution being restricted to mountains in E and W Azerbaijan such as *Astragalus savellanicus*, *A. sahendi* (see map in Zarre-Mobarekeh 2000, Map 14), *A. azizii* and *A. pauperiflorus, Dianthus seidlitzii*, *Thlaspi tenue*, *Erysimum alpestre* and *Campanula savalanica*.

The Sahand and Sabalan are two mountains in this area which are geographically in a transition zone between Alborz, Zagros and mountains in Caucasus and E Anatolia. This transitional character is well illustrated in range of various alpine species. However, the

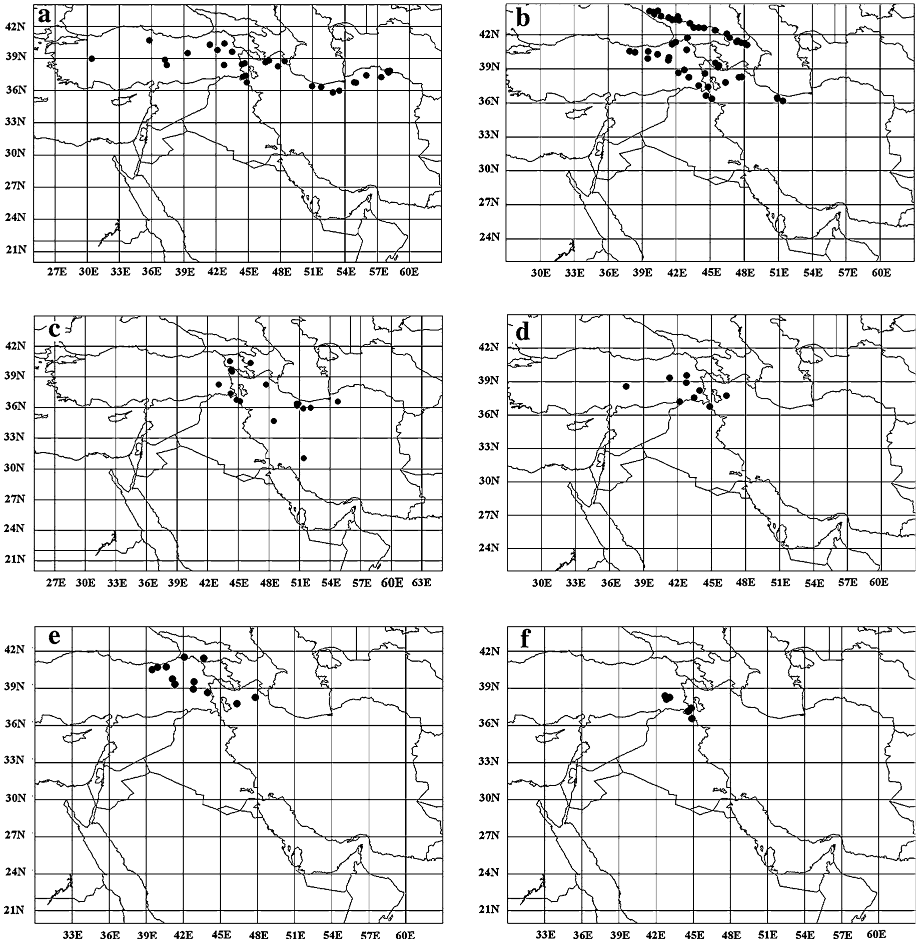

Fig. 6 Examples of distribution pattern of species occuring from Anatolian mountains and/or Caucasus to Iran. (**a**) *Centaurea rhizantha*, (**b**) *Pedicularis caucasica*, (**c**) *Didymophysa aucheri*, (**d**) *Crepis sahendi*, (**e**) *Senecio taraxifolius*, (**f**) *Ranunculus diversifolius*

area in a broader sense (including E. Anatolia and Southern Caucasus) is an autochthonous area and harbours considerable number of endemic species. Similar pattern of distribution have already been found in species of the lower altitudes in halophytes and the genus *Heliotropium* (Akhani 2004a, 2007).

Irano-Afghanistan or Irano-Afghanistan and Himalayan and Central Asian species

There are ca. 70 species with such a pattern which are divided into three subgroups:

The first group includes common and widespread species between the Zagros/Alborz/Khorassan-Kopet Dagh/Afghanistan and sometimes Himalaya and Central Asia such as *Bromus gracillimus* (Fig. 7a), *Cousinia multiloba* (Fig. 7b), *Euphorbia aucheri*, *Oxytropis pusilloides*, *Ox. hirsutiuscula*, *Polygonum serpyllaceum* (Fig. 7c), *P. molliaeforme*,

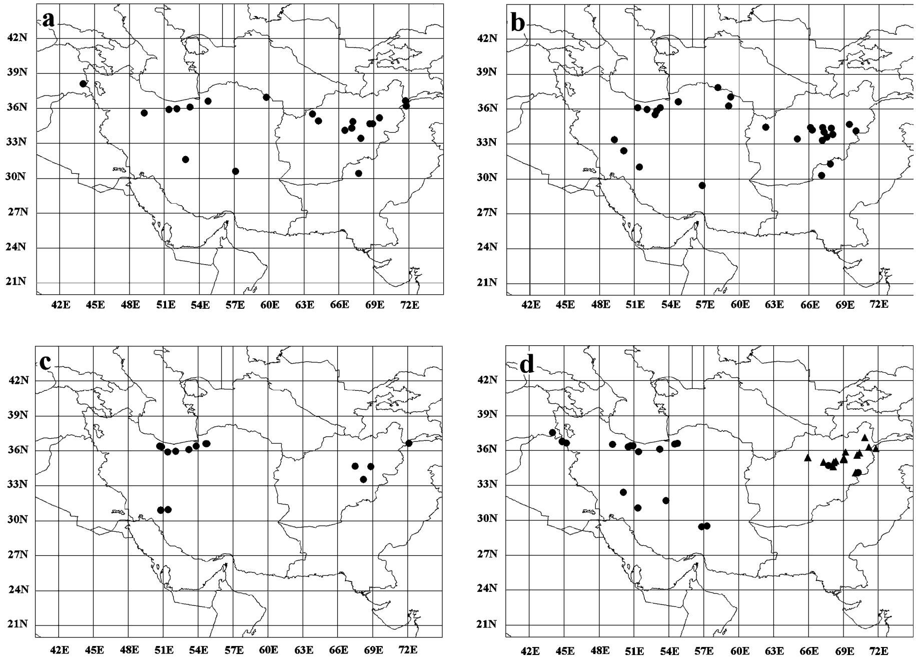

Fig. 7 Examples of distribution maps of plant species with an Irano-Afghanistan range or a distribution pattern from Iran/Afghanistan to Himalaya and Central Asia. (**a**) *Bromus gracillimus*, (**b**) *Cousinia multiloba*, (**c**) *Polygonum serpyllaceum*, (**d**) *Trachydium depressum* ssp. *depressum* (dot), subsp. *chitralicum* (triangle), (**e**) *Arenaria insignis*, (**f**) *Pedicularis pycnantha*, (**g**) *Graellsia saxifragifolia*, (**h**) *Cousinia lasiolepis*, (**i**) *Pedicularis cabulica*, (**j**) *Primula capitellata*

P. thymifolium, *Sagina micrantha*, *Trachydium depressum* (Fig. 7d), *Silene guntensis* subsp. *guntensis*, *Draba aucheri*, *Gagea dshungarica*, *G. exilis*, *Nepeta daënensis*, *Acantholimun erinaceum*, *Ferula ovina*, *Juncus rechingeri* and *Valeriana clarkei.*

Second are linking species between Alborz, Kopet Dagh and Afghanistan and sometimes Central Asia and Himalaya such as *Arenaria insignis* (Fig. 7e), *Bromus stenostachyus*, *B. confinis*, *Alopecurus himalaicus*, *Taraxacum baltistanicum*, *Crepis frigida*, *Alyssum lanceolatum*, *Allium hymenorrhizum*, *Poa aitchisonii*, *Inula rhizocephala*, *Stellaria graminea*, *Silene tachtensis*, *Eremopoa bellula*, *Elymus canaliculatus*, *Geum kokanicum*, *Oxytropis immersa*, *Pterocephalus afghanicus*, *Onobrychis arnacantha* and *Pedicularis rhinanthoides.* Some of the species of this group occur also in NW of Iraq (Alqurd Dag) such as *Pedicularis pycnantha* (Fig. 7f), *Taraxacum brevirostre*, *Alopecurus seravshanicus* and *A. apiatus.* Some of these species are distributed from Alborz to Kopet Dagh and further east to Afghanistan mountains.

The third pattern represents species which are common species between Zagros and mountains in East and SE Iran and Afghanistan and sometimes Himalaya and Central Asia. Some of these species have a wider range in Zagros and extend their distribution through the SE extension of Zagros to the East of Iran such as *Graellsia saxifragifolia* (Fig. 7g, see also distribution map in Hyam and Jury 1990). Some of these species show interesting disjunctions between Zagros and mountains in Afghanistan such as *Silene goniocaula*, *Cousinia lasiolepis* (Fig. 7h). The other species are those which have their center of distribution in Afghanistan and West Himalaya mountains but occur sporadically in high

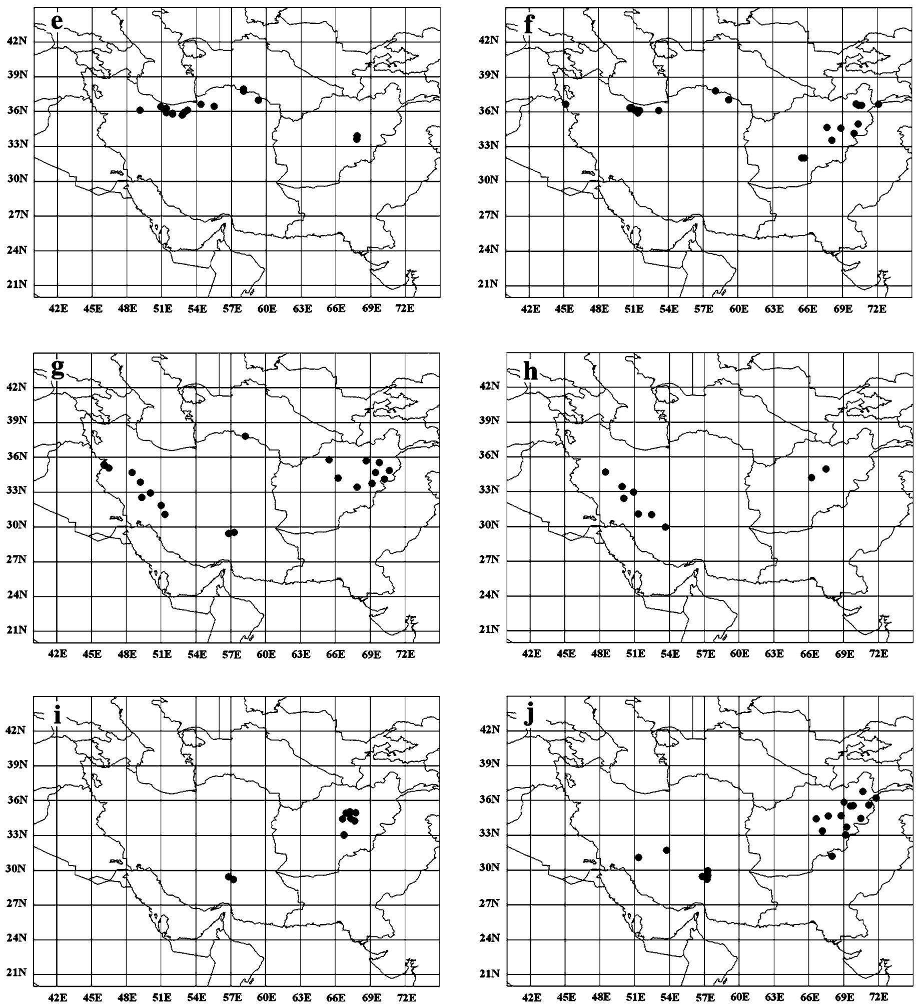

Fig. 7 continued

altitudes of the Southeasternmost of Zagros mountains in Kerman and Fars and isolated mountain peaks in Baluchestan (Taftan) such as *Oxytropis sojakii*, *Pedicularis cabulica* (Fig. 7i), *Primula capitellata* (Fig. 7j), *Tanacetum pamiricum*, *Salvia rhytidea*, *Artemisia persica*, *Inula rhizocephala*, *Brachyactis roylei*, *Artemisia lehmanniana*, *Psychrogeton alexeenkoi*, *Parnassia cabulica*, *Taraxacum chitralense*, *Gagea capillifolia*, *Alopecurus mucronatus*, *Delphinium uncinatum* and *Rhamnus prostratus* (see distribution maps in Browicz 1988). This kind of distribution has been given by Hedge and Wendelbo (1978) for a few species. This link is very striking because there is no continuous mountain chain between the Zagros and Afghanistan mountains. It seems these species remained from last glaciation period where alpine species were distributed in lower altitudes. During post-glacial the elevation of the alpine belt rose and these species became disjuncted. An interesting example of a similar link was shown by the distribution range of the isolated species *Podolotus hosackioides* Royle & Benth. (Rechinger 1984). This monotypic genus with a main range in E Afghanistan, N Pakistan, Kashmir and N India (N Punjab and Kumaon) occurs disjunctly on Genu Mountain peak in S Iran. In some of such species there are morphological and geographical differences which are sometimes treated as subspecies or separate species.

Iranian endemics

The Iranian endemics could be divided into following groups:

(1) *Co-occurring species between the Alborz and Zagros* which sometimes extend to Khorassan-Kopet Dagh mountains such as *Veronica kurdica* (Fig. 8a), *Veronica rubrifolia*, *Buffonia kotschyana* (Fig. 8b), *Dracocephalum kotschyi* (Fig. 8c), *Cicer tragacanthoides* (Fig. 8d), *Allium capitellatum*, *Nonnea persica* (Fig. 8e), *Oxytropis kermanica*, *O. masanderanensis*, *Scrophularia frigida* (Fig. 8f), *Silene gynodioica* (with core distribution in Zagros), *Ranunculus crymophilus*, *R. aucheri*, *Cerastium persicum*, *Scorzonera grossheimii*, *S. stenocephala*, *Aethionema stenopterum*, *Fibigia multicaulis*, *F. umbellata*, *Erysimum elbursense*, *Dielsiocharis kotschyi*, *Thymus pubescens*, *Acantholimon brachystachyum*, *Potentilla argyroloma*, *P. mallota*, *P. nuda*, *P. pannosa*, *Delphinium lanigerum*, *Ferula angulata*, *Leutea petiolaris*, *Asyneuma multicaule* and *Crepis heterotricha. Veronica kurdica* ssp. *kurdica* distributed in the Alborz mountains and ssp. *filicaulis* distributed in the Zagros mountains (Fig. 8a).

(2) *Alborz endemic species*: Klein (1991) has provided a list of 76 alpine species in Alborz where 36 species (50.5%) are endemic. Based on updated data available at this time the number of endemic species in Alborz is about 126 species. Examples are *Paraquilegia caespitosa* (Fig. 4c), *Acantholimon demavandicum* (Fig. 9a), *Oxytropis cinerea*, *Cousinia adenosticta*, *Ligularia persica* (Fig. 9b), *Minuartia lineata* (Fig. 9c), *Potentilla aucheriana* (Fig. 9d), *Scutellaria glechomoides* (Fig. 9e), *Veronica paederotae*, *V. mirabilis*, *Silene demawendica*, *Cousinia xiphiolepis*, *Tanacetum hololeucum*, *Scorzonera xylobasis*, *Iranecio oligolepis*, *Senecio vulcanicus* (Fig. 9f), *Cousinia decumbens*, *C. gmelinii* (see distribution map in Rechinger 1987), *Sempervivum iranicum*, *Galium decumbens* (with one report in Sabalan Mountain), *Oxytropis aellenii*, *Erodium dimorphum*, *Astragalus rubrolineatus*, *A. iodotropis*, *A. macrosemius* (Zarre-Mobarakeh 2000, Maps, 14, 15), the newly described species *Allium tuchalense* (Khassanov et al. 2006), and the monotypic subalpine to alpine endemic genus *Elburzia* (*E. fenstrata* (Boiss.) Hedge. This interesting monotypic genus has its next relative with *Petrocallis* and *Pseudovesicaria* from Europe and Caucasus, respectively (Hedge 1969). The taxonomic status of described local endemic *Stellaria scaturiginella* from Tuchal mountains (Rechinger 1988) is doubtful and is more likely a synonym of *Cerastium persicum.*

(3) *Subendemic species* with a distribution range extending from Alborz Mountains through mountains in Iranian Azerbaijan to NE of Iraq (Alqurd Dag) or SE Anatolia such as *Ranunculus trichocarpus*, *Erysimum nanum*, *Taraxacum neo-spurium* and *Cousinia pterocaulos*. Among this group there are some species with their center of distribution is in Alborz mountains but occur disjunctly in NE of Iraq and E/C Anatolia such as *Nepeta racemosa* (Fig. 10a), *N. menthoides*, *Draba pulchella* (Fig. 10b), *Dracocephalum aucheri* (Fig. 10c), *Lagochilus kotschyanus* (Fig. 10d),

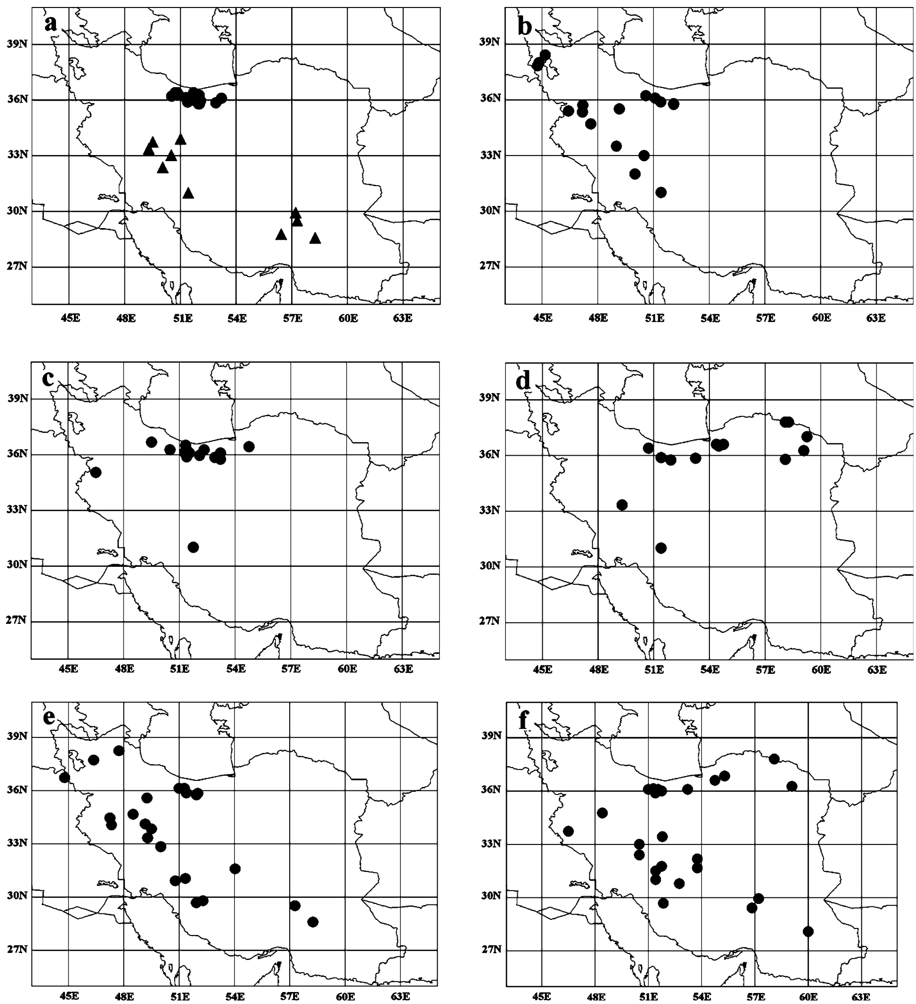

Fig. 8 Examples of distribution maps of Iranian alpine plant species with co-occurrence in Alborz and Zagros mountains. (**a**) *Veronica kurdica* subsp. kurdica (dot), subsp. *filicaulis* (triangle), (**b**) *Buffonia kotschyana*, (**c**) *Dracocephalum kotschyi*, (**d**) *Cicer tragacanthoides*, (**e**) *Nonnea persica*, (**e**) *Scrophularia frigida*

Ranunculus bulbilliferus (Fig. 10e), *Oxytropis persica* (Fig. 10f), *Trifolium radicosum*, *Crepis elbrusensis* and *Tanacetum nivale*, *Calamagrostis parsana* (=*Deyeuxia parsana*). *Diplotaenia cachrydifolia* has a similar range in Central Alborz but recently a disjunct locality from Antalya in the southern parts of Middle Anatolia is found (H. Duman, pers. comm.).

(4) *Zagros endemic species*: Zagros Mountains are richer than Alborz in endemic species according to our results. Around 185 alpine species are restricted to Zagros. Several species are true Zagros elements which are distributed rather continuously from the Northern to the Southern extension of Zagros such as *Euphorbia hebecarpa* (Fig. 11a), *Rhamnus cornifolia* (see distribution map in Browicz 1984, map 41), *Tetrataenium lasiopetalum* (Fig. 11b), *Colpodium violaceum* (Fig. 11c), *Hyoscyamus*

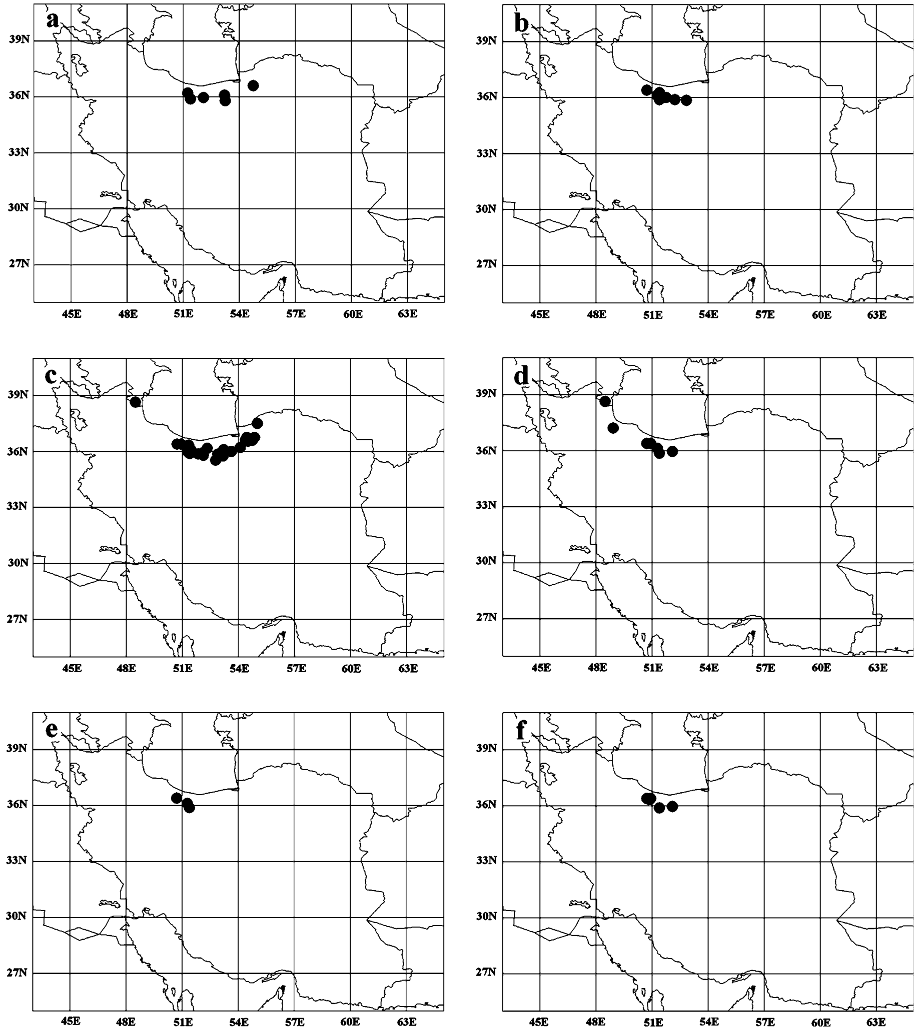

Fig. 9 Examples of distribution pattern of Alborz endemic species. (**a**) *Acantholimon damavandicum*, (**b**) *Ligularia persica*, (**c**) *Minuartia lineata*, (**d**) *Potentilla aucheriana*, (**e**) *Scutellaria glechomoides*, (f) *Senecio vulcanicus*

kotschyanus, *Trachydium kotschyi*, *Rubia pauciflora*, *Galium pseudokurdicum* and *Stachys acerosa* (Fig. 11d). Some species are distributed in several mountain peaks such as *Cousinia longifolia* (Fig. 11e), *C. sicigera*, *Euphorbia erythradenia* (Fig. 11f), *Scorzonera intricata* (Fig. 11g), *Stachys obtusicrena* (Fig. 11h), *Sedum kotschyanum*, *Semenovia frigida*, *Astragalus fragiferus*, *A. ghashghaicus* and *Taraxacum primigenium.* But most of species are local endemics and have been recorded as very rare such as *Silene hirticalyx*, *Sclerochorton haussknechtii* (a monotypic genus of Apiaceae), *Astragalus zagrosicus*, *Myopordon persicum*, *Cousinia concinna*, *Scorzonera nivalis*, *Crepis connexa*, *Serratula melanocheila* which are endemic in the mountains in Kurdistan. Furthermore *Nepeta iranshahrii*, *N.*

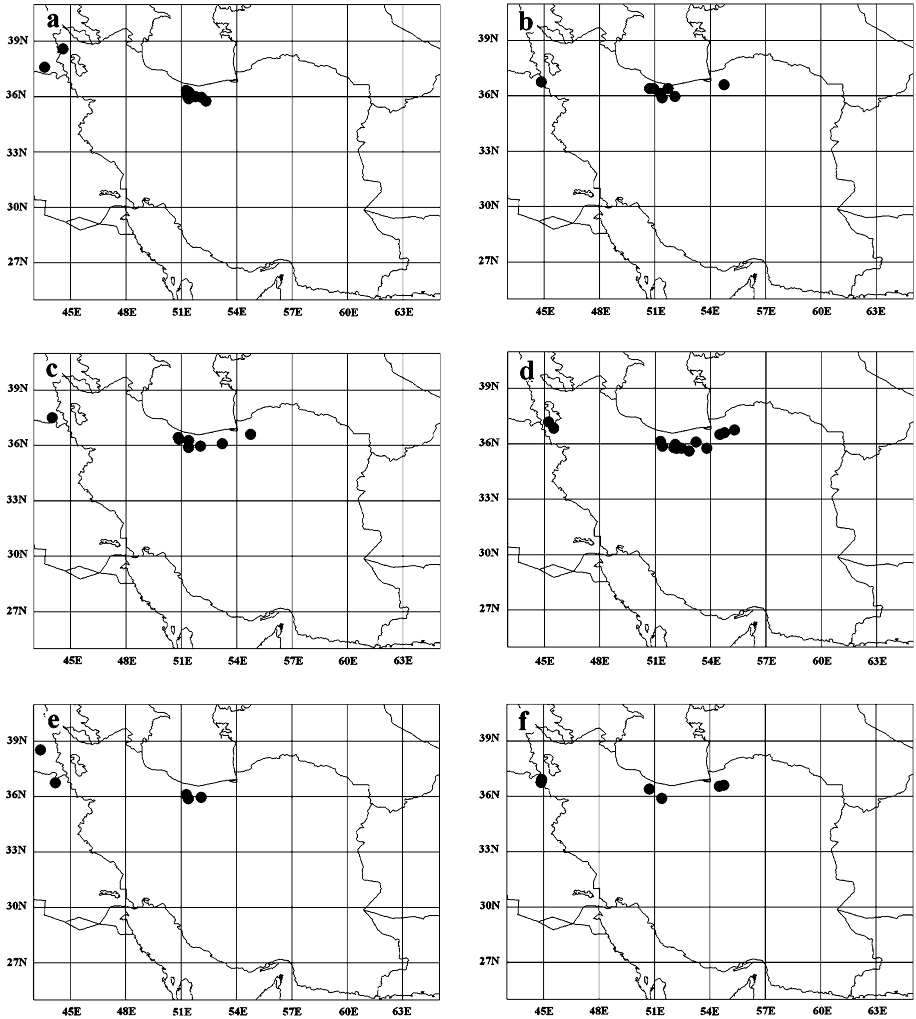

Fig. 10 Examples of plant species distribution in the Alborz mountains and with disjunct occurence in NE Iraq and E Anatolia. (**a**) *Nepeta racemosa*, (**b**) *Draba pulchella*, (**c**) *Dracocephalum aucheri*, (**d**) *Lagochilus kotschyanus*, (**e**) *Ranunculus bulbillifera*, (**f**) *Oxytropis persica*

archibaldii, *Chaerophyllum nivale*, *Arenaria balansae* are endemic in the Bakhtiari Mountains, *Cicer stapfianum*, *Salvia lachnocalyx*, *Acantholimon tomentellum* are endemic in the Fars Mountains, *Nepeta rivularis*, *Dionysia oreodoxa*, *D. rhaptodes*, *Astragalus carmanicus*, *A. hezarensis*, *Acantholimon modestum*, *Polygonum spinosum* are endemic in the Kerman Mountains and *Dionysia curviflora*, *Helichrysum davisianum*, *Hymenocrater yazdianus*, *Astragalus melanocalyx* and *Acantholimon nigricans* are examples of local alpine endemics in the Yazd Mountains.

From various distribution patterns described in this paper and comparative data in lowland flora and the patterns described by Hedge and Wendelbo (1978), Zohary (1973),

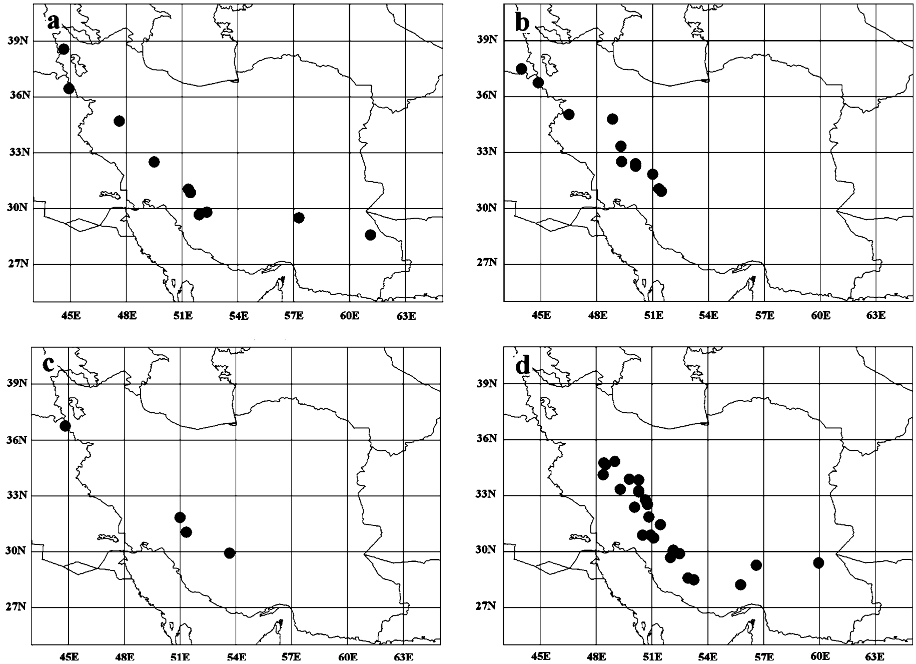

Fig. 11 Examples of distribution pattern of Zagros endemic species. (**a**) *Euphorbia hebecarpa*, (**b**) *Tetrataenium lasiopetalum*, (**c**) *Colpodium violaceum*, (**d**) *Stachys acerosa*, (**e**) *Cousinia longifolia*, (**f**) *Euphorbia erythrandenia*, (**g**) *Scorzonera intricata*, (**h**) *Stachys obtusicrena*

Takhtajan (1986) and Akhani (2007) we can conclude that in spite of some differences and peculiarities of species occurring in alpine areas there is consensus in several distribution patterns of alpine species with species of the lower altitudes. Some general conclusions are given here:

(1) The alpine flora of Iranian plateau belongs to the Irano-Turanian area where only a few species are widespread northern hemisphere species or species of the Euro-Siberian area. The northern slopes of Alborz mountains have a higher proportion Euro-Siberian flora (Boreal sensu Meusel et al. 1964–1992), but towards the timberline and in the alpine zone the Irano-Turanian elements replace the Euro-Siberian species. This could be interpreted with the different floristic history of the Alps and the Iranian mountains and support previous evidences that the glaciations have not been much affected the flora of Alborz and Zagros mountains (Bobek 1937, 1953).

(2) A reassessment of floristic provinces suggested by Zohary (1973) and Takhtajan (1986) for SW Asia is necessary. The broadly defined floristic province Irano-Anatolian by Zohary (l.c., p. 81, Map 6) which extends from Central Anatolia to Afghanistan should be reconsidered. Only 1% (7 species) of Iranian alpine species have a distribution range from central Anatolia to central Afghanistan. The range of most central Anatolian species ends in the mountains in Azerbaijan or extends at most in Alborz and Zagros.

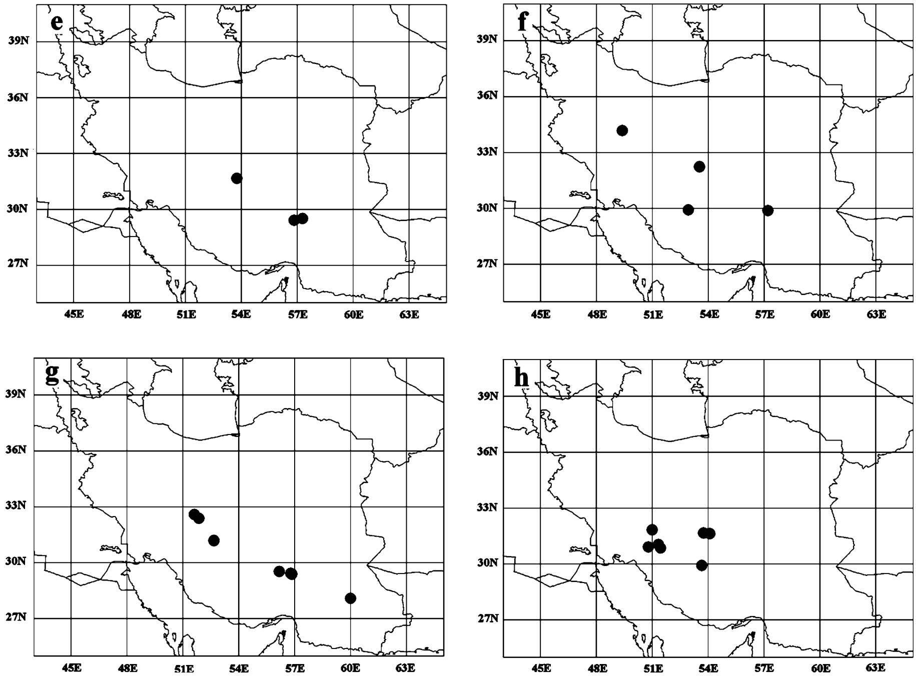

Fig. 11 continued

(3) In spite of presence of a rather considerable number of endemic species in Alborz mountains, but, there are very few species which distribute all parts of Alborz in contrary to the range of many Hyrcanian elements in the forested zone. This is more likely because of climatic, geologic, and topographic heterogeneity in the Northern and Southern slopes in one side and Eastern and Western slopes in other side. Alborz Mountains have been more subject to present and past climatic fluctuations because of the proximity and the influence of humid climates of the northern slopes, and dry conditions of the Southern zone. The eastern, western and central parts of Alborz are linked with the highlands of mountains in Azerbaijan and Caucasus, Khorassan-Kopet Dagh mountains and Zagros. Therefore the Alborz chain acts as a corridor of floristic migration of the flora of East, West and Southwest and therefore is very rich in terms of species. Two well distinguished patterns are represented by the species in Central Alborz and species distributed from the Central Alborz to the Eastern Alborz (Fig. 9a–f).

(4) Zagros Mountains are characterized by a very autochthonous rich flora with high number of endemic species. This is because of the geographical isolation of this mountain system. The distribution patterns of alpine flora are in consensus with the distribution of lowland and montane species. A number of species were already listed and mapped in the Western foothills of Zagros such as *Allium olivieri*, *Ergocarpon cryptanthum*, *Oliveria decumbens*, *Cousinia stenocephala*, *Rhanteriopsis puberula*, *Brassica aucheri*, *Scabiosa leucactis*, and *Phlomis bruguieri* Akhani (2004b; Figs. 14–25) as well as the distribution range of *Heliotropium noeanum* (Akhani 2007; Fig. 43). Several Iranian endemic genera are restricted to the Zagros Mountains

> such as seven Umbelliferous genera (*Sclerochorton, Azilia*, *Haussknechtia*, *Rhabdosciadium*, *Rhopalosciadium*, *Oliveria* and *Mozaffariania*), five genera in Brassicaceae (*Brossardia*, *Straussiella*, *Zerdana*, *Heldreichia*, *Acanthocardamum*), *Rhanteriopsis* (Asteraceae), *Zeugandra* (Campanulaceae) and *Alrawia* (Liliaceae, ditypic). Therefore considering this area as a biogeographic unit as a province is well justified.

The formation of species in the upper altitudinal belts originated from the rich ancestral flora during the ongoing tectonic uplift. In some mountains, the oreophytic belt is very high, and the elimination of many species by cold stress on the long run cannot be compensated by the local formation of new species (Agakhanjanz and Breckle 1995). This is obvious from the low number of species of that belt in Iran mountains, where the number of species decreases from 682 species (center of distribution is above 3,000 m) to 4 species (above 4,800 m) (Fig. 12). Thus, the decrease of species numbers is slightly more pronounced than in neighboring countries (Fig. 12). The high rate and extent of mountain uplift in the Alborz and Zagros and the high degree of fragmentation and isolation of them from neighboring mountain ranges, especially in the upper belts, caused high level of alpine endemism. Also, during the Pleistocene only valley glaciation (Agakhanjanz and Breckle 1995) took place in these mountains thus enabling many taxa to withstand and to develop a high degree of endemism, mainly on relict stands. These phenomena could be the most important reasons of the high level of endemism in Iran mountains. During middle Pleistocene, when mountains glaciation seemed to have been at a maximum (Agakhanjanz and Breckle 1995), vegetation belts migrated down. Refugial stands and other isolated areas opened. In the postglacial movement of the flora to higher mountain areas was possible, by adaptation and by the changing temperature regime.

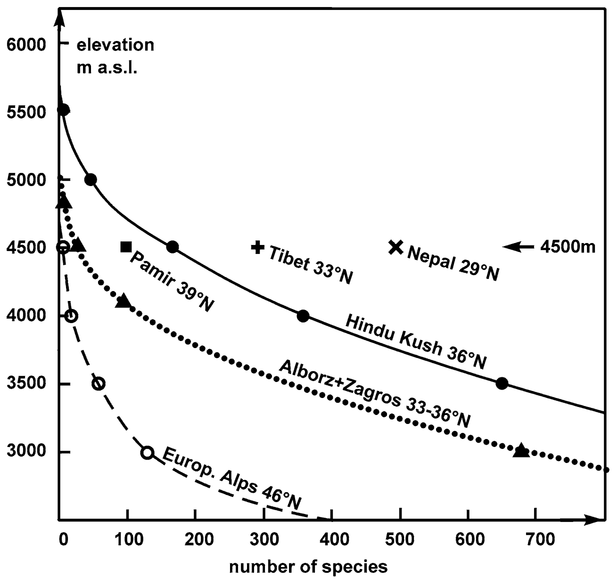

Fig. 12 The decreasing number of vascular plant species along the elevation gradient for three mountain systems of Eurasia. For comparison with other mountains three additional numbers of species are given at the 4,500 m a.s.l. altitude (partly from Breckle 1974; Agakhanjanz and Breckle 2002)

Vegetation

According to Bobek (1952) in several mountains of Iran, Klein (2001) of Central Alborz and own studies in Tuchal mountains, Jahan Nama Protected Area (near Gorgan) and Golestan National Park in the Eastern Alborz and West of Kopet Dagh the upper timberline and shrubline at Alborz and Zagros is varying considerably from 2,200 to 3,600 m. The timberline as a typical ecological marker in mountains, makes the various altitudinal belts of different mountains comparable (Agakhanjanz and Breckle 1995). Under natural conditions potential timberline in Iran should be—according to climate—always above 3,000 m; if below, it is certainly because of longlasting (hundreds of years) anthropogenic influence, deforestation, grazing etc. Actual timberline in Iran lies at lower altitudes ranging from 2,200 to 3,600 m a.s.l., compared to eastern neighbouring mountain systems: Hindu Kush 3,500 m (Breckle 1971, 1975); N and W Pamir mountains 4,000 m (Breckle and Wucherer 2006); Jammu-Kashmir 3,600 m, W-C Nepal 3,700 m, E Nepal 3,800 m and Chitral 3,850 m (Schickhoff 2005). Some of the mentioned mountain ranges are located at slightly higher or similar latitudes; in spite this timberline is located at higher elevations, if aridity is very strong. In parts, where the monsoon climate is effective a higher timberline can be observed, too (S Karakorum, E Hindu Kush).

Timberline in Iran mountains is not dense at all places. In northern slopes of Alborz Mountains and easternmost extension of Caspian forest the timberline ends usually at the uppermost limits of *Quercus macranthera* forests. In most places there is a transition between oak forest and true alpine vegetation consisted of *Juniperus communis* subsp. *nana* in lower limit, mixed sometimes with shrubs like *Acer hyrcanum*, *Carpinus orientalis*, *Crataegus* spp. and *Lonicera* spp. In upper limit this transition zone ends to *Juniperus sabina* (Akhani 1998, 2005) (Fig. 13a). In some parts of southern slopes of Alborz and Kopet Dagh and Khorassan Mountains the timberline is composed of *Juniperus excelsa*. This transition zone with shrubs could also be called a subalpine belt. However, in most parts of Central Alborz there is no tree or shrubby vegetation apparently due to long-term land use and degradation of original vegetation. In some places there are still scattered remnants of *Amygdalus* spp., *Rosa* spp., *Cotoneaster* spp. and *Crataegus* spp. shrubs. Our knowledge on the alpine vegetation of Zagros mountains is very poor. In general, altitude of timberline decreases from south to north in the Zagros. The timberline in Zagros in many parts is formed by scattered *Quercus brantii.* Several shrubby species belonging to *Pistacia*, *Amygdalus*, *Acer*, *Crataegus* and *Lonicera* consists of the upper shrubby limits, forming the subalpine belt. Dense tragacanthic *Astragalus* communities, other thorn-cushion formations, and tall umbelliferous plants above the timberline and the subalpine zone of Zagros (Zohary 1973 and pers. obser.) are part of the lower alpine and alpine belt.

Based on our ongoing research on the alpine vegetation of Tuchal Mountain at Central Alborz (Noroozi and Akhani, in press) and Klein (1982, 1984, 1987, 1988, 1991, 2001) an overview of major vegetation units is shown here. Some major phytosociological units have been distinguished by Klein including Prangetea ulopterae, Onobrychydetea cornutae, Oxytropidetea persicae, Trachydietalia depressae, Catabrosetalia parviflorae. Here we refer to main plant communities without using phytosociological nomenclature, since species-composition in our work is different from the syntaxa described by Klein.

Large parts are covered by *Prangos uloptera* communities (2,800–3,500 m a.s.l.) (Fig. 13b). The physiognomy of these communities is governed by the large herbs and the

Fig. 13 Some representative images of vegetation types in the Iranian alpine area. (**a**) Jahan Nama Protected area in Eastern parts of Alborz (2,300 m), in the background showing timberline followed by a transition of prostrate shrub vegetation with *Juniperus sabina* and in the foreground the transition to thorn-cushion subalpine formation, (**b**) Giant umbellifer vegetation (*Prangos ulopterae* community) in the Tuchal mountains (3,200 m a.s.l.), (**c**) High alpine meadow in Tuchal mountains (3,600 m), foreground short snow free habitats covered by grasses and rosette-like hemicryptophytes, background long snow free habitats covered by traganthic *Astragalus* (photo **a**: H. A., **b**, **c**: J.N.)

umbelliferous species (ca. 1 m) e.g. *Prangos uloptera* as the dominant species with high cover-abundance. These vegetation types which may be composed of different tall umbelliferous genera like *Prangos*, *Ferula* and *Leutea* are very conspicuous in the subalpine zone of Alborz, Zagros and Kopet Dagh mountains (Klein 1988). Also, homogenous groupings so far have been identified and described as formations in the mountains of Middle Asia (Klein 1988; Ahmadov et al. 2006). Other dominant species of these vegetation types in Tuchal mountains are *Hypericum scabrum*, *Piptatherum laterale*, *Polygonum molliaeforme*, *Echinops elbursensis*, *Cruciata taurica*, *Lappula microcarpa*, *Asperula setosa*, *Astragalus aegobromus*, *Elymus longearistatus*, *Fibigia suffruticosa*, *Rumex elbursensis* and *Mesostemma kotschyana*. Vegetation cover is ca. 55–65%. Windswept areas of the subalpine–alpine zone (3,300–3,600 m) are occupied by *Onobrychis cornuta* communities just above *Prangos uloptera* communities. Their physiognomy is formed by large thorn-cushion plants, mainly with tragacanth growth form. The important species of these communities are from *Astragalus*, *Acantholimon*, *Onobrychis*, *Cousinia* and some other genera. These areas are free of snow for a longer period than the surrounding vegetation. Slopes are often steep with ca. 25–30° and are often dominated by screes. Vegetation cover is ca. 45–60%.

The rocky habitats of subalpine–alpine areas are covered by chasmophytic species such as *Silene odontopetala*, *Arabis caucasica*, *Eriocycla olivieri*, *Graellsia stylosa* and *Erigeron hyrcanicus*. Life forms of species are restricted to chamaephytes and hemicryptophytes. Plant cover and richness is low.

High alpine xerophytic areas which are located at hill tops, ridges, and windswept areas are covered by graminoides such as *Bromus tomentosus*, *Poa araratica*, *Alopecurus textilis*, and cushion forming species such as *Asperula glomerata*, *Arenaria insignis*, *Ziziphora clinopodioides*, *Acantholimon demavendicum*, *Astragalus macrosemius*, *Trachydium depressum* and *Jurinella frigida*.

Alpine meadow communities with additional water supply can be divided into two habitat types. Firstly, long snow free habitats which are covered by *Astragalus jodotropis* communities (Fig. 13c). The physiognomy is characterised by incompact cushion forms and *Astragalus iodotropis* is the dominant species of these communities. Other species which are common in these habitats are *Astragalus chrysanthus*, *Cousinia crispa*, *Helichrysum psychrophilum*, *Tragopogon kotschyi*, *Erigeron uniflorus* ssp. *elbursensis*, *Scorzonera meyeri*, *Veronica kurdica* ssp. *kurdica*, *Silene marschallii* and *S. aucheriana.* Plant cover is ca. 60–80%.

Secondly, short snow free habitats occur on depressed places where snow cover remains to mid summer and growth period is very short. The life forms of most of the species here are rosettes such as *Taraxacum brevirostre*, *Trifolium radicosum*, *Polygonum serpyllaceum*, *Ranunculus crymophilus*, *Potentilla* sp. and short gramineae as *Catabrosella parviflora.* The species richness is poor (ca. 4–5 species) and vegetation cover is between 50 and 100% (Fig. 13c).

Scree habitats govern steep high alpine and subnival areas. Some species occur on mobile screes with very low cover (less than 5%) such as *Didymophysa aucheri*, *Scutellaria glechomoides* (Fig. 4b), *Euphorbia aucheri* and *Galium aucheri*. *Didymophysa* is a typical mobile scree genus with inflated siliculae and two species. *Didymophysa aucheri* is distributed in Iran, NE Iraq, N Anatolia and Transcaucasus (Fig. 6c) (Hedge 1968); *Didymophysa fedtschenkoana* is distributed in the Afghanistan and Pamir-Alai mountains (Breckle 1971). The species richness of these habitats is very low. These species also can be found in the nival zone (above 4,000 m). They are creeping hemicryptophytes with very long below-ground rhizomes (sometimes longer than 50 cm). This life form was described as is the best adaptation to moving and nutrient poor slopes (Parolly 1998).

In stabilized screes size of stones is larger, steepness is lower and soil is more developed than mobile screes. Dominant species of these habitats are *Cicer tragacanthoides* (which has very important role for stabilizing mobile scree), *Dracocephalum aucheri*, *Asperula glomerata*, *Senecio vulcanicus*, *Leonurus cardiaca* ssp. *persicus*, *Nepeta racemosa* and *Astragalus macrosemius.*

Life forms

As expected, hemicryptophytes dominate in the alpine belt (76%). The hemicryptophytes fall into three subgroups:

- Rosettes and small stemmed plant forms mostly occur in highest altitudes on scree and habitats with snowmelt. This is one of the most advantageous life forms in alpine area represented by species such as *Taraxacum brevirostre*, *Ranunculus crymophilus*, *Trifolium radicosum*, *Polygonum serpyllaceum*, *Scutellaria glechomoides*, *Scorzonera meyeri*, *Potentilla argyroloma*, *Lamium tomentosum*, *Euphorbia aucheri* and *Tragopogon kotschyi* and *Didymophysa aucheri.*
- Graminoids: It comprises species belonging to Poaceae and Cyperaceae and Juncaceae. This life form occurs in several vegetation types in alpine ecosystems and in the subnival zone forming clonal cluster and garlands such as *Catabrosella parviflora*, *Bromus tomentosus*, *Alopecurus textilis*, *Stipa atriseta*, *Piptatherum molinioides* and *Carex pseudofoetida.*
- Tall herbs and Umbellifereae-like herbs: They are tall herbaceous plants ca. 50–100 cm height belonging to Apiaceae, Polygonaceae and some other families which often grow in subalpine zone. Some examples for this kind of life form are *Prangos uloptera*, *Prangos tuberculata*, *Ferula angulata*, *Heracleum anisactis*, *Solenanthus circinnatus*, *S. stamineus*, *Cousinia hypoleuca*, *Rheum ribes* and *Rumex elbursensis.*
- Approximately 14.5% of the flora consists of chamaephytes, most of them are thorny cushions. In spite of low frequency, cover of these forms is high in most of the habitats. The cushion growth form occurs in various types in alpine and subalpine areas. They may be thorny (like *Astragalus* subg. *Tragacantha*, *Onobrychis* and *Acantholimon*) or not spiny like (like *Physoptychis gnaphalodes* (Fig. 4a), *Gypsophila aretioides*, *Cicer tragacanthoides*). Such growth forms are known from Irano-Afghanian mountains and Mediterranean mountain regions, as well as from wind-swept areas of southern South America. This formation is adapted to the intensive radiation, to dry and windswept sites (Rauh 1939; Gams 1956; Breckle 1983; Hager 1984; Hager and Breckle 1985; Kürschner 1986; Klein 1987). Additionally they are rather resistant to grazing.
- Only a few species are shrubby in Iranian alpine and subalpine areas. The shrubby species in the Iranian alpine area are mostly prostrate and ascending or dwarf shrubs and form sometimes very dense patches adapted to strong winds long lasting snow cover in such habitats. Species like *Juniperus communis* subsp. *hemisphaerica* and subsp. *nana*, *J. sabina*, *Acer monspessulanum* subsp. *turcomanicum*, *Ephedra major* subsp. *procera*, *Rhamnus cathartica*, *Lonicera iberica* and *Ribes melananthum* have been reported from alpine zone of Golestan National Park (Akhani 1998).
- Geophytes (bulbous and rhizomatous) mainly belong to Liliaceae, Alliaceae, and Iridaceae and comprise ca. 6% of the Iranian alpine flora. Geophytic species that are restricted to the alpine area are: *Allium capitellatum*, *A. tuchalense*, *A. elburzense*, *Gagea alexeenkoana*, *G. glacialis*, *Tulipa humilis* and *Iris barnumae*. *Allium capitellatum* and *A. tuchalense* can reach to subnival and nival zone.
- Annual species decrease with increasing altitude and become quite rare in high altitude (Körner 1999). In Iranian alpine area there are only 2.5% annuals and 1% biennials of total alpine flora. Some examples of alpine and subalpine annuals in Iran are *Chenopodium foliosum*, *Lomatogonium carinthiacum, Polygonum molliaeforme*, *Cerastium dubium*, *C. persicum* and *C. purpurascens* var. *elbursense* (this var. can grow in subnival and nival areas), *Brachyactis roylei*, *Senecio kotschyanus*, *S. iranicus*,

Nepeta bornmülleri, *Bromus gracillimus*, *Veronica pusilla*, *V. hispidula*, *V. rubrifolia*, *V. biloba*, *Euphorbia juzepczukii* and *Astragalus laricus*.
- *Silene viscosa*, *Cousinia elwendensis*, *Gentiana pontica*, *Rosularia sempervivum*, *Artemisia biennis*, *Senecio vulcanicus*, *Verbascum bornmüllerianum* and *V. carmanicum* are biennial.

Threat and nature conservation

The alpine zones in Iran have been less affected by humans in comparison to the lowland ecosystems. The harsh conditions and physical barrier limit human settlements and intensive agricultural activities. Many of the protected areas of Iran include high altitude mountains such as Central Alborz (Tehran and Mazandaran Provinces), Oshtorankuh area (Lorestan), Haftadgholeh (Arak), Korkhod and Golgulsarani (Khorassan) and Dena (Fars) protected areas and the national parks of Golestan (Golestan and Khorassan provinces) and Lar (Tehran).

However, in recent years strong grazing impact is increasingly threatening the fragile subalpine and alpine ecosystems in Iran (Fig. 14), even in legally protected areas (Akhani 1998, 2004b, own observations in many parts of Iran and several newspaper and interviews of authorities in Iranian media). The mountains meadows, steppes, and xerophytic plant communities represent sufficient food potential for cattle. They are used as summer pastures. The overgrazing leads to the destruction of the vegetation, loss of biological diversity and erosion of soil. The dominance of thorn-cushion formations is obviously one of the consequences of long-term overgrazing and land use in Iranian plateau. The severe overgrazing in most parts of high altitudes in recent years resulted in a spread of poisonous species as e.g. *Euphorbia* as have been seen in Alborz, Binalud and Sahand Mountains.

Most of the endemic species with a narrow distribution (as mentioned for the Alborz and Zagros) are severely threatened. Therefore, the protection and management of rangelands in this zone—as in all other vegetation types in Iran—needs to be considered. The high percentage of endemism and rare species in the alpine zone and the fragile ecosystems are good arguments for particular attention to stop future loss of biodiversity in

Fig. 14 Overgrazing around water supplies in the Tuchal mountains (3,700 m a.s.l.) (photo J.N.)

high mountain regions. Based on the evaluation of published data from 682 known alpine species, ca. 160 species have been known only based on one record and 110 species based on 2–3 records. From 394 endemic species, 87 species have been known only based on type location. Many of these plants are potentially endangered and vulnerable species. It is strongly necessary to assess the threatened status of Iranian alpine plants according to IUCN categories and criteria.

An important threat to the alpine ecosystems of Iran in recent years is road construction in many mountain areas. Such roads not only destroy large parts of the area but also ease access to the high altitudes both for mass climber and grazing animals. Littering and man made fires are two damages in many high mountains in Iran.

There are many literature references from recent years that evidence increasing temperature could force alpine plants to migrate upwards until they reach the highest elevations. Therefore many mountain ranges which host a large number of endemic plants are very likely to suffer critical species losses (Grabherr et al. 1994; Körner 1999; Theurillat and Guisan 2001; Pauli et al. 2003, 2007).

According to climatic data from meteorological stations around Central Alborz we can see increasing temperature in this area during the recent decades. We strongly recommend the establishment of long-term climate and vegetation monitoring programmes in several representative sites in Alborz and Zagros integrated with the GLORIA network (Global Observation Research Initiative in Alpine Environments: http://www.gloria.ac.at).

In general, the high mountain systems in Iran also provide valuable resources (e.g. water during hot season) for the lowlands; the lowland-highland interaction is here very vulnerable and needs strong management plans in future.

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