

Roadside flora in arid and semi-arid natural areas (Case study: Northern Khorasan province, Iran)

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Received: 15 May 2017; Received in revised form: 12 August 2017; Accepted: 23 August 2017

Abstract

Roads have an important role in plants dispersal on different scales. Various plant species settle on roadsides, but some of them can enter the natural environments and threaten their biodiversity. Worldwide knowledge of roadside flora is necessary for local and global management of natural areas. Accordingly, the roadside flora of Northern Khorasan rangelands was studied along the 600 km of 12 paved roads. Base on a stratified random sampling design, 38 sites were sampled by 100 m² rectangular quadrats established on both roadsides. Totally, 330 plant taxa of 39 spermatophyte families were identified and their life-forms and chorology were determined through botanical resources. The results showed that therophytes and hemicryptophytes were the dominant life-forms of roadside vegetation. The native Irano-Turanian elements were the dominant chorotype of roadside habitats. Number of endemic taxa (3.6%) was notable in comparison with cosmopolitan (1.2%) and alien (0.6%) species. *Agropyron desertorum* (Fisch. ex Link) Schult. and *Agropyron elongatum* (Host) P. Beauv. were the only two introduced alien species in the studied roadsides. Some of the cosmopolitan and pluriregional species such as *Triticum aestivum* L. were cultivated plants, but most of them were common weeds. Native weeds like *Hordeum glaucum* Steud. and *Alhagi persarum* Boiss. & Buhse had the highest frequency on the studied roadsides. The present study, therefore, revealed that the roadside flora in natural areas could have a considerable stock of native and endemic species which would be suitable for the revegetation of roadsides and the disturbed natural areas around the roads.

Keywords: Rangelands; Roadside habitats; Chorology; Alien species; Life-form

1. Introduction

Roadside vegetation has various species of different life-forms and origins. Road construction destroys some parts of the natural habitats and as a result, new man-made habitats are formed. Roadside habitats differ from surrounding natural areas and support various species with different ecological needs (Martinez and wool, 2006; Irl *et al.*, 2014). Whereas roadsides are disturbed habitats, they usually support a ruderal flora (Dogan *et al.*, 2004). Plants which settle on roadsides are a combination of native and exotic species. Roadside species have different life-forms

which vary from annual herbs to shrubs and trees on different roadsides. Domination of a specific life-form type in roadside habitats is dependent on the climate and characteristics of the corresponding roads (Lausi and Nimis, 1985; Szwed and Sykora, 1996; Sera, 2010).

Roads are usually considered as a main agent in the presence of exotic species in new habitats (Fowler *et al.*, 2008). Roadsides not only provide habitats for alien species, but they can also act as corridors for the dispersion of exotic plant species (Gelbard and Belnap, 2003; Pauchard and Alaback, 2006; Sera, 2008; Okimura *et al.*, 2016). New settled species in roadsides can be spread and established in natural habitats. Established species compete with native flora, endangering the biodiversity of the natural habitats (Pickering and Hill, 2007; Nehr *et al.*, 2013; Szymura and Szymura, 2016).

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Roadsides are also disturbed by human through road improvement measurements, resulting in the displacement or extinction of native plant species and invasion of some alien species (Pauchard and Alaback, 2004; Hansen and Clevenger, 2005).

Exploration of roadside flora is valuable from different views. Species dispersion occurs in local, zonal and geographical scales (Pickering and Hill, 2007; Akbar *et al.*, 2008; Kosako *et al.*, 2010; Paiaro *et al.*, 2011; Rentch *et al.*, 2013; Shaltout *et al.*, 2016). Therefore, recognizing the roadside flora in different parts of the world is a necessity for the global management of alien and invasive species. On the other hand, roadside vegetation provides habitats for some wildlife, so it has a conservation value that should be properly sustained and managed (Carthew *et al.*, 2013). Roadside vegetation is a combination of native and alien species from different habitats. The study of roadside flora can provide suitable information regarding restoration and revegetation of roadside habitats with native species (Karim and Mallik, 2008; Spooner and Smallbone, 2009).

Northern Khorasan province is a part of Irano-uranian phytogeographic region. Three main phytochoria including Irano-Turanian, Saharo-Sindian and Euro-Siberian have been recognized in Iran (Eig, 1931; Zohari, 1950; Leonard, 1989; White and Leonard, 1991; Akhani, 2007). Irano-Turanian region covers two-thirds of Iran, but Euro-Siberian and Sahara-Sindian regions are restricted only to the northern and southern parts of Iran, respectively. The Northern Khorasan province is a mountainous-flat area; its mountainous parts belong to Khorasan-Kopet Dagh floristic Province of the Irano-Turanian region (Akhani, 2007; Memariani *et al.*, 2016c). It is also a corridor connecting different phytogeographical units of Irano-Turanian region, serving as a transitional zone between the Irano-Turanian phytochorion and the Hyrcanian province of the Euro-Siberian region (Memariani *et al.*, 2016a).

Flora and vegetation of Iran have been investigated by different botanists and ecologists (Boissier, 1810-1885; Parsa, 1948-1952; Rechinger, 1963-2015; Zohary, 1973; Mobayen, 1975-1995; Ghahreman, 1977-2007; Assadi *et al.*, 1988-2014; Akhani, 1998); however, there is little information regarding the roadside flora of Iran, especially in the natural areas. This research was aimed to provide a clear view of road effects on natural flora in Northeast of Iran, so that the results could be e

used for the proper management of natural areas in local and regional scales.

2. Materials and Methods

2.1. The study area

2.1.1. Coordinates, topography and climate

Northern Khorasan province, with the area of about 2843400 hectares, is located in the northeast of Iran, between 55° 53' to 58° 20' eastern longitude and 36° 37' to 38° 17' northern latitude. (Figure 1). The province is a mountainous-plain area, and its elevation ranges from 400 to 3041 m a.s.l. (Jafari *et al.*, 2015). According to the De Martonne Aridity Index, only arid and semiarid climates can be recognized in this province (Meteorological Administration of Northern Khorasan province, 2016). Annual mean temperature is 13.3 °C. The maximum and minimum temperatures are 24.7 °C and 1.5 °C, respectively, and the annual mean precipitation varies from 124.4 mm in lowlands to 468.5 mm in elevations (Jafari *et al.*, 2015).

2.1.2. Roads and natural areas

Natural ecosystems in Northern Khorasan cover around 2,033,036 hectares. This includes 434,540 hectares of forest and woodland, 1,414,850 hectares of rangeland, and 183,636 hectares of desert and bare land. (Natural Resources and Watershed Administration of Northern Khorasan province, 2016). More than 1000 km asphalt roads stretch all over this province. These roads consist of 81 km of highway, 35 km of broad main road, 392 km of ordinary main road, 325 km of primary by-road, and 175 km of secondary by-road. Most of these roads pass through natural areas, especially rangelands.

2.2. Methodology

2.2.1. Field survey

A stratified random sampling design was used for the floristic study of roadside vegetation in the study area, over 2014-2015 time period. For this purpose, 12 asphalt roads, including five main roads with moderate to heavy traffic and seven secondary roads with light to moderate traffic, were selected. Sampling sites were determined randomly on homogenous physiographic-physiognomic units, which could be regarded as an acceptable

representative of topography, soil, and vegetation type (Kent and Coker, 1992). Totally, 38 sites were selected (Figure 1); by considering the topography and road shape at each site, 2-4 100 m² rectangular quadrats were

established on both sides of the road. In each quadrat, the list of vascular plants was prepared, and herbarium specimens were collected or photographed for identification.

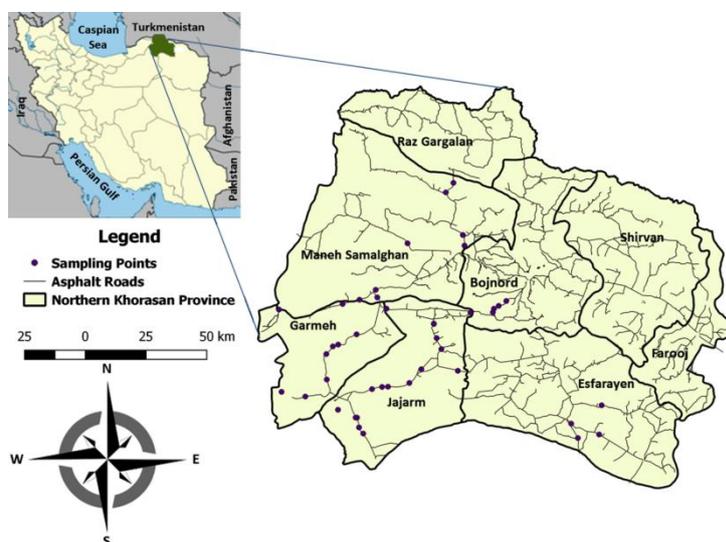


Fig. 1. Location of the study area and sampling sites in the Northeast of Iran

2.2.2. Laboratory and library researches

Plant specimens were taken to the Herbarium of Isfahan University of Technology and identified based on the flora of Iran and bordering areas (Rechinger, 1963-2015; Assadi et al., 1988-2015; Davis, 1965-1988; Komarov, 1934-1964; Nasir and Qaser, 1970-1989; Townsend and Guest, 1966-1986). Life-forms of the identified species were determined according to the Raunkiaer life-form classification (Raunkiaer, 1934). The geographical distribution or chorology of plant species was determined mainly by Flora Iranica (Rechinger, 1963-2015), according to the phytogeographical delimitation of the Middle East by Eig (1931-1932) and Zohary (1950). The endemism of plant species was determined according to *Biodiversity of Plant Species in Iran* (Ghahreman and Attar, 1998) and *Flora Iranica* (Rechinger, 1963-2015).

3. Results

3.1. Floristic diversity

In exploring the roadside flora of Northern Khorasan province, 330 taxa, including 289 species, 21 subspecies and 20 varieties of 39 families, were collected and identified. All of these families, including one gymnosperm and 38 angiosperms, belonged to spermatophytes. The families of Asteraceae, Poaceae, Chenopodiaceae and Brassicaceae, with 56, 41, 36, 34 and 30 taxa, respectively, had the maximum number of species, subspecies, and varieties of the identified plant families. Among the identified genera, *Astragalus* L. with 21 species had the maximum number of species (Table. 1), and many of genera had the minimum or one species.

Table. 1 The largest Plant families and genera in the roadside flora of Northern Khorasan province

Family	Number of taxa	Genus	Number of species
Asteraceae	56	<i>Astragalus</i>	21
Poaceae	41	<i>Alyssum</i>	7
Chenopodiaceae	36	<i>Artemisia</i>	7
Papilionaceae	34	<i>Cousinia</i>	7
Brassicaceae	30	<i>Euphorbia</i>	7
Caryophyllaceae	15	<i>Gallium</i>	7
Boraginaceae	14	<i>Salsola</i>	7
Rubiaceae	12	<i>Acanthophyllum</i>	5
Lamiaceae	10	<i>Atriplex</i>	5
Apiaceae	9	<i>Convolvulus</i>	5
Euphorbiaceae	8	<i>Centaurea</i>	4
Polygonaceae	8	<i>Gallium</i>	4

3.2. Life-forms

According to Raunkiaer classification of life-forms (Raunkiaer 1934), five groups of life-forms were identified in the roadside vegetation

of the study area. Among the identified life-forms, therophytes (53.9%) and hemicryptophytes (24.8%) had the maximum number of the identified species in the study area (Figure 2).

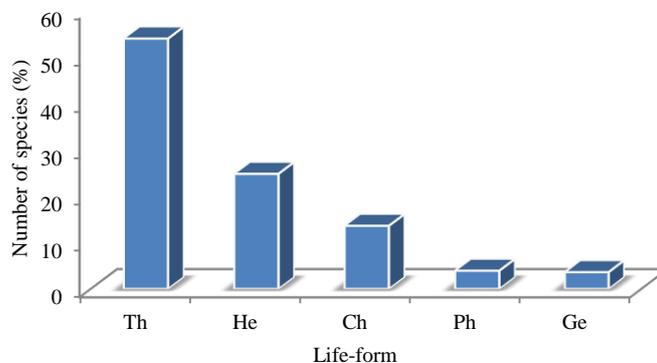


Fig. 2. The life-form spectrum of roadside flora in the study area. Th: therophyte, He: hemicryptophyte, Ch: chamephyte, Ph: phanerophyte, and G: geophyte

3.3. Chorology

The roadside flora of the study area belonged to different phytogeographic areas. Irano-Turanian elements with 61.8% had the maximum proportion of the identified species. Other species were two or multiregional elements, such as Irano-Turanian/Mediterranean/Euro-Siberian, Irano-Turanian/Mediterranean, and Irano-Turanian/Sahara-Sindian (Figure 3). About 4.6% of the identified taxa were Pluriregional elements; this included *Cichorium intybus* L., *Descurainia Sophia* (L.) Web & Berth.,

Capparis spinosa L., *Arenaria serpyllifolia* L. var. *serpyllifolia*, *Chenopodium album* L. subsp. *striatum* (Krassan) Murr., *Chenopodium botrys* L., *Kochia scoparia* (L.) Schrad., *Salsola Kali* subsp. *ruthenica* (Iljin) Soo in Soo and Jar., *Cucumis melo* L., *Centaurium pulchellum* (Swartz) Druce, *Botriochloa ischaemum* (L.) Kengo., *Bromus japonicas* Thunb., *Bromus tectorum* L., *Cynodon dactylon* (L.) Pers., and *Galium aparine* L.. Cosmopolitan elements such as *Convolvulus arvensis* L., *Phalaris minor* Retz., *Triticum aestivum* L., and *Polygonum aviculare* L. had a little portion (1.2%) of the identified taxa.

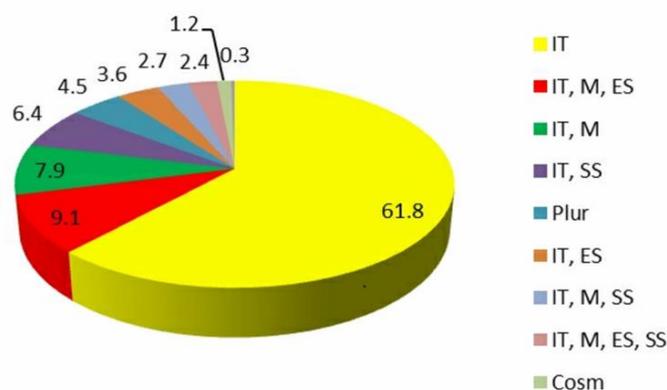


Fig. 3. Chorotypes of roadside flora in the natural areas of Northern Khorasan province, IT Irano-Turanian, M Mediterranean, ES Euro-Siberian, SS Saharo-Sindian, Plur pluriregional, and Cosm cosmopolitan

Among the 204 identified Irano-Turanian elements, 12 taxa including 10 species, one subspecies and one variety were the endemic taxa. These taxa included *Amaranthus blitoides* S. Watson. var. *halophilus*, *Cousinia lasiandra*

Bunge, Mem., *Cousinia lepida* Bunge ex Boiss., *Cousinia qarebilensis* Rech.f., *Echinops leiopolycrooides* Mozaffarian, *Onosma stenosphon* Boiss., *Erysimum crassicaule* (Boiss.) Boiss., *Halothamnus glaucus* (M. B.)

Botsch. subsp. *vestitus*, *Physogeton occultus* (Nge.) Assadi, *Acantholimon quinquelobum* Bge., *Polygonum hyrcanicum* Rech. f.; and

Haplophyllum furfuraceum Bunge ex Boiss., which were only endemic to Iran (Figure 4).

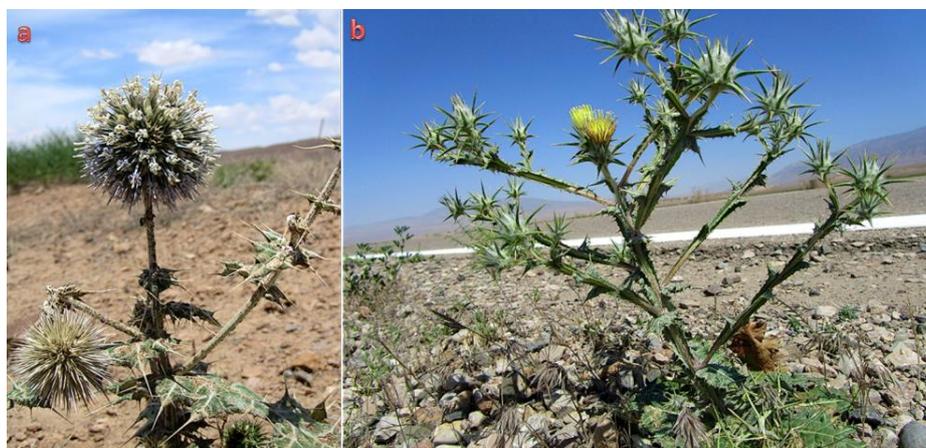


Fig. 4. Two endemic taxa, a: *Echinops leiopolycyroides* and b: *Cousinia lasiandra*

3.4. Species frequency

Frequency of different species changed along the studied roadsides. Most of the species with high frequency were weed species and some were rangeland and cultivated plants (Table 2). *Hordeum glaucum* Stend. and *Alhagi persarum* Boiss. & Buhse., from Irano-Turanian elements, and *Bromus tectorum* L., from pluriregional taxa, were the most frequent species in the studied roads. The presence of the

species with high frequency was not limited to a specific road type. Some of these species had more frequency on some road types, but they occurred both on main and secondary roads. *Medicago sativa* L. and *Artemisia sieberi* Besser, were the two important non-weed species in the group of species with high frequency on roadsides. *M. sativa* L. was the main cultivated forage species in the study area and *A. sieberi* Besser, was the dominant species of some plain rangelands.

Table 2. Plant species with high frequency in the roadside habitats of studied roads

Scientific name	NR	TR		Scientific name	NR	TR	
		S	M			S	M
<i>Hordeum glaucum</i>	12	7	5	<i>Erodium cicutarium</i>	7	5	2
<i>Alhagi persarum</i>	11	7	4	<i>Heliotropium europaeum</i>	7	5	2
<i>Bromus tectorum</i>	11	7	4	<i>Koelpinia linearis</i>	7	5	2
<i>Boissiera squarrosa</i>	10	6	4	<i>Malkolmia africana</i> var. <i>africana</i>	7	6	1
<i>Bromus Danthoniae</i>	10	7	3	<i>Schismus arabicus</i>	7	5	2
<i>Eremopyrum Bonaepartis</i> var. <i>Bonaepartis</i>	9	6	3	<i>Astragalus argyroides</i>	6	4	2
<i>Scariola orientalis</i>	9	6	3	<i>Euphorbia turcomanica</i>	6	3	3
<i>Acroptilon repens</i>	8	4	4	<i>Filago pyramidata</i>	6	4	2
<i>Launea acanthodes</i>	8	6	2	<i>Lactuca serriola</i>	6	4	2
<i>Medicago sativa</i>	8	5	3	<i>Lactuca undulata</i>	6	4	2
<i>Aegilops triuncialis</i>	7	4	3	<i>Peganum harmala</i>	6	5	1
<i>Artemisia sieberi</i>	7	4	3	<i>Roemeria hybrid</i>	6	4	2
<i>Cardaria draba</i>	7	5	2	<i>Scabiosa olivieri</i>	6	5	1
<i>Chondrilla juncea</i>	7	4	3	<i>Sophora alopecuroides</i>	6	4	2
<i>Convolvulus arvensis</i>	7	5	2	<i>Ziziphora tenuir</i>	6	4	2

NR: number of roads, TR: type of road, M: main road, and S: secondary road

4. Discussion

In exploring the roadside flora of Northern Khorasan rangelands, 330 taxa including 39 families were identified. The families of Asteraceae, Poaceae, Chenopodiaceae and Brassicaceae had the maximum number of taxa among the identified families. *Astragalus* L. with 21 species also had the maximum number

of species among the recorded genera. Irano-Turanian elements with 61.8% had the maximum proportion of the identified species in the study area. The number of endemic taxa was noticeable, as compared with cosmopolitan and alien species. Native Irano-Turanian weeds had the highest frequency in roadside habitats and only two introduced alien species were present in the studied roadsides.

4.1. Floristic diversity

Recording of 330 taxa from 39 plant families in the studied roadsides showed a rather high species diversity in these habitats. Khorasan-Kopet Dagh floristic province is one of the important centers of plant endemism in the Irano-Turanian region (Memariani *et al.*, 2016b). The mountainous area of Northern Khorasan is a part of this floristic province, so it is expected that some signs of this phenomenon could be mirrored on roadside vegetation in the natural areas. Rotholz and Mandelik (2013) have stated the proportion of the endemic species is lower than that of the ruderal taxa in the roadside vegetation. In the current study, the proportion of endemic taxa (3.6%) was notable in comparison with the cosmopolitan (1.2%) and the pluriregional taxa (4.6%). Despite the susceptibility of roadsides to the species invasion, they can support various native species (Vasconcelos *et al.*, 2014). Dispersal facilities on roads may be suitable for some endemic species and increase the species turnover (Irl *et al.*, 2014). Most of the recorded endemic species belonged to arid and semiarid plain areas. In arid and semiarid areas, roadside habitats could provide a better moisture condition for plant growth than the surrounding areas, thereby increasing the probability of endemic taxa in these habitats.

4.3. Life-forms

Roadsides usually have a better moisture condition for the plant growth than the adjacent landscapes. On the other hand, the shallow and compacted soil of the roadsides is not suitable for deep roots (Bengough and Mullins, 1990); so annual plants have a better chance for establishment and growth in these habitats. According to Dogan *et al.* (2004), therophytes are the dominant life-form of the roadside vegetation in many regions, due to the periodic road improvements such as grading road edges and traffic-trampling. In the present research, the therophytes with 53.9% had the maximum portion of the identified life-forms, similar to findings obtained by Frenkel (1970) and Dogan *et al.* (2004). According to Hayasaka *et al.* (2012), ephemeral species are less dependent on a specific land-use, so their occurrence on roadsides usually happens regardless of the surrounding habitats. The hemicryptophytes with 24.8% were found to be the second dominant life-form, but in some genera like *Astragalus* L., the therophytic and hemicryptophytic species were nearly equal.

Perennial species of *Astragalus* L. are much more than those of annuals in the flora of Iran, but as annuals are ephemeral species (Taeb *et al.*, 2007), roadside habitats are suitable for their growth in early spring.

4.4. Chorology

Northern Khorasan province is located in the Irano-Turanian phytogeographic region; therefore, dominance of the mono-regional elements of Irano-Turanian in the study area (61.8%), was natural. The study area was next to the Hyrcanian zone in Euro-Siberian phytochorion, but common elements of Irano-Turanian and Euro-Siberian phytochorion (3.6%) were less than those with more distant phytochoria. Climatic and edaphic variations in the Hyrcanian zone not only caused structural differences in this ecosystem (Jafari *et al.*, 2013), but also distinguished it from the drier adjacent phytochorion. Most of the Euro-Siberian elements in the Hyrcanian zone preferred higher moisture and precipitation and also, deep nutrient soil, which was not available in many parts of the study area. On the other hand, many of the Hyrcanian elements were woody species, like trees and shrubs, that had little chance to settle under roadside habitat conditions in the study area. As the study area had arid and semiarid climates, it was more similar to the Mediterranean and Sahara-Arabian regions, so it had more common elements with these phytochoria.

4.5. Weeds and cultivated species

Some cultivated taxa of different chorology were recorded on the studied roadsides. *Triticum aestivum* L. and *Cucumis melo* L. were two cultivated species, which occurred on 4 and 2 roads of 12 studied roads, respectively. *Triticum aestivum* L. is a cosmopolitan species and *Cucumis melo* L. represents the pluriregional taxa. *Medicago sativa* L. is another cultivated species, which was recorded on two-thirds of the studied roads. This species, which is a common element of Irano-Turanian, Mediterranean, and Euro-Siberian phytochoria, is the main forage species in the study area. As studied roadsides were far from farmlands, transportation may be the main reason for the presence of these species on roadside habitats. Cultivated species such as *Triticum aestivum* L., *Hordeum vulgare* Vill. and *Helianthus annuus* L. have been reported in some bordering countries (Dogan *et al.*, 2004).

Most of the cosmopolitan and pluriregional taxa and some native Irano-Turanian elements, as recorded in roadsides, were common farm and rangeland weeds (Karimi 1995, Asghari and Mahmoudi 1999; Mirkarimi, 2000; Hassannejad and Ghafarbi, 2013). *Convolvulus arvensis* L., *Phalaris minor* Retz., and *Polygonum avicular* L. were the only three cosmopolitan weeds on the studied roadsides; also *Hordeum glaucum* Stend., *Alhagi persarum* Boiss. & Buhse., *Acroptilon repens* (L.) DC., and *Sophora alopecuroide* L. were important Irano-Turanian weeds. On the other hand, *Chenopodium album* L., *Salsola kali* L., *Bromus tectorum* L.,

Cynodon dactylon (L.) Pers., *Galium aparine* L., *Descurainia Sophia* (L.) Web & Berth., *Capparis spinose* (Dc.) Stapf., *Aegilops cylindrical* Host., and *Silene conoidea* L., were some of the important bi-regional to pluriregional weeds. *Salsola dendroides* Pall. is a halophytic Irano-Turanian element which usually grows in salty plain areas in farmlands, fallows, and along irrigation channels with fresh or brackish water. In the study area, this species was recorded in semi-alpine roadsides at snowy places, where salt usually was used for deicing in winters (Figure 5).



Fig. 5. *Salsola dendroides*; a: in saline semi-alpine roadsides at snowy places, and b: in fallows of farmlands

4.6. Alien taxa

Two regional exotic grass species including *Agropyron elongatum* (Host) P. Beauv. and *Agropyron desertorum* (fisch.) Schultes. were recorded on the studied roadsides. The presence of these species along the studied roadsides was due to their application in rangeland reclamation programs. *Agropyron elongatum* (Host) P. Beauv. has been used more in rangeland reclamation programs in Iran and because of its proportionate resistance to drought, it has more dispersal than *Agropyron desertorum* (fisch.) Schultes.. Some populations of *Agropyron desertorum* (fisch.) have been recorded in Ghorkhod, Salook, and Aladagh Mountain ranges of Northern Khorassan Province (Memariani et al., 2016c); so its recording on roadsides can support the idea that this species might have been introduced to the natural areas through roads. These two species have been considered as weeds in Iran by some authors (Karimi, 1995).

5. Conclusion

Road construction, by creating roadside habitats, provides a new bed for the presence and growth of different plant species. Plant species establishing on roadsides may be native or exotic, but in arid and semi-arid areas, most of them are annual herbs. Exploring the roadside flora and identifying their native and exotic species can be the first step in environmental management programs. This type of excavation provides important information regarding restoration and revegetation of roadside habitats and the surrounding natural areas (Spooner and Smallbone, 2009; Karim and Mallik, 2008). The present investigation disclosed that the roadside flora in natural areas like rangelands could be relatively rich in the view of native species. The number of endemic taxa (3.6%) was notable in comparison with the cosmopolitan (1.2%) and alien (0.6%) species. This showed that roadside habitats in natural areas could be valuable like their surrounding landscapes, and they should be kept and

managed properly. As the roadsides are disturbed habitats, plant species thriving at such areas are more or less resistant to road disturbances. Therefore, these habitats can be considered as worthwhile sources for revegetation and reclamation of roadsides and disturbed natural areas around the roads.

Acknowledgements

The authors appreciate Dr. Morteza Behzadfar, Administrations of "Natural Resources and Watershed" and "Roads and Urban Development" of Northern Khorasan province, for providing the basic maps and information of roads and rangelands of the study area. The authors are also grateful to Mr. Abol Hasan Pourali Fard for supporting accommodation and providing all facilities for data gathering during the field excavation.

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