Soil seed bank characteristics in relation to different shrub species in semiarid regions

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Abstract

Little information is available about the effects of different species of shrubs on the composition of the soil seed bank (SSB) and how the SSB could contribute to the restoration of degraded area in semiarid regions. We determined the role of three dominant shrub species on SSB characteristics and evaluated their potential for their possible use in rangeland restoration projects. Fifteen sites, each containing three shrub species (Amygdalus scoparia, Daphne mezereum and Ebenus stellata) and a herbaceous patch (control) in close proximity, were sampled and their SSB density, species richness and diversity at 0-10 cm depth were determined. The results showed that density of the SSB was highest under A. scoparia (1133 seeds per m2) and lowest in herbaceous vegetation (110 seeds per m2). Species richness and diversity of the SSB was significantly greater under E. stellata than under the other shrubs and control. This study revealed that the extent to which vegetation affected SSB characteristics did not only depend on the presence of shrubs, but also on the species of shrub. These different roles of different species of shrubs on SSB are advised to be considered in restoration of degraded areas through conservation of shrubs in semiarid regions.

Introduction

Arid and semi-arid ecosystems occupy 36% of the land area of the globe and shrubs function as foundation species within these ecosystems (Yang and Williams, 2015). A foundation species in ecology was described as species with significant impacts on the structure and functioning of an ecosystem (Lortie et al., 2017). It has been frequently called shrubs as fertile islands, since, they can strongly influence habitat conditions. Shrubs have been shown to affect the quality and quantity of soil microorganisms (Wardle and Zackrisson, 2005), control the soil erosion and runoff amounts (Zuazo and Pleguezuelo, 2008; García Ruiz et al., 2013; Keesstra et al., 2016) and influence the soil seed bank (SSB) (Erfanzadeh et al., 2014; Niknam et al., 2018; Funk et al., 2019). They can be facilitators and alter SSB under their canopies by trapping seeds or enhancing seed production by sub-canopy plants through ameliorating the environment (Li et al., 2011; García-Sánchez et al., 2012; Mussa et al., 2016).

Study on SSB is important, since, it is one of the most important functional parts of any plant community and can be significant components in the process of rehabilitating degraded lands (Mohammed and Denboba, 2020). Bakker (1989) identified SSBs as non-mature seeds buried in soil that can replace existing vegetation when they are degraded.

In semiarid regions, shrubs are able to change SSB characteristics. According to some reports SSB density was much higher under the shrubs than the surrounding areas (Pugnaire and Lázaro, 2000; Marone et al., 2004). In overgrazing sites, particularly, shrubs accumulated large and diverse SSBs beneath their canopy which were different in composition from seed banks of the open matrix (Dreber and Esler, 2011). This significant effect are induced by the ability of shrubs in seed trapping and providing suitable microclimate and conditions for seed production by other plant species (Erfanzadeh et al., 2014). However, different shrubs with different canopy architectures (erect stems or recumbent, open or dense canopy) could have different efficiency in trapping seeds and could affect differently seed production by herbaceous species and therefore, they play different roles in changing the characteristics of SSB (density, species richness and diversity) in semiarid environments. Nevertheless, none of the previous studies has focused on the effect of different species of shrubs on affecting SSB characteristics.

In this study, we selected three dominant shrub species and determined SSB density, species richness and diversity and, similarity between SSB and above-ground vegetation (AGV) in their understory. Since the shrubs were different in their canopy traits, we assumed that they affect SSB characteristics, differently. Moreover, in semiarid areas, shrubs are cleared and damaged by humans for many purposes including agriculture, oil and gas production, and sustainable energy developments (Lortie et al., 2017); we need to know whether these foundation species can recover and consistently facilitate the abundance and diversity of other plants through SSB and whether this effect is different between different species of shrubs with different crown features and architectures. It can be supposed that dwarf and procumbent shrubs have higher ability to trap seeds comparing with erect stem and free canopies. In this study, three dominant shrubs with different features and architectures in the canopy were selected, i.e. *Amygdalus scoparia* and *Daphne mezereum* with single-elongated main stems and, *Ebenus stellata*with procumbent canopy and multiple stems. We hypothesized that the density and species richness and diversity of SSB under the canopy of*E. stellata* would be higher than *A. scoparia* and *D. mezereum* .

Materials and Methods

Introducing the study area

This study was conducted in the rangelands of Chenarnaz, Yazd province, Iran (30° 03' 51" N - 30deg 05' 89" N; 53deg 00' 16" E - 54deg 01' 23" E) (Fig. 1). The average altitude is 2200 m asl. The average annual temperature is 17.5degC and the average rainfall is 250 mm, which has a semiarid climate based on Domarten index.

Sheep and goats are the dominant grazers in the region (ca. four heads of sheep and/or goats per ha) during the year. Heavy grazing has led to locally exposed soil. In addition, the previous examination of erosion status in the study area showed that environmental and human factors had a role in the occurrence of soil erosion and vegetation degradation. Human activities such as intensive harvesting of medicinal plants and the use of pharmaceutical products have reduced the density of plant species and created empty gaps in the AGV in some places (Gravand et al., 2016). Therefore, herbaceous revegetating bare soil and restoration of degraded sites using of native plants is a priority. SSB has been considered one of the major natural sources that facilitates the recovery of degraded vegetation (Shang et al., 2016). We carried out this study to quantify the potential of different species of shrubs to increase the SSB associated with them and thus their potential use for restoration. Therefore, it is important to identify firstly shrubs that associated with larger and richer SSB and secondly, consider restoring shrub species which have higher potential as SSB reservoir accompany with higher palatability for grazing. Thereupon, three shrubs together with surrounding herbaceous vegetation (hereafter called control) were selected:

A) *Amygdalus scoparia* Spach (Rosaceae family) is a wild species of almond that occupies large areas in many parts of central Iran and its neighbouring countries. The extraction and use of the oil from the*A. scoparia* is of interest due to their fatty acids composition that is comparable to those of olive oil (Sorkheh et al., 2016). The plant is attractive for grazing animals due to its shade, fruits and high palatability of leaves. It is a deciduous large shrub that grows to a height of up to 6 m, having a single-elongate main stem. It produces numerous long and green branches. Fruits are drupes and are 1 to 1.5 cm long and 0.5 cm wide. They are ripened and dehiscent at the end of July (Mozaffarian, 2012).

B) *Daphne mezereum* L. (Thymelaeaceae family) is a rounded-upright deciduous shrub with an erect and bushy habit that typically grows to 1.5 m tall. All parts of this plant are poisonous to humans if ingested, especially the fruits, sap and bark. Therefore, this shrub is unpalatable for grazing animals. Nevertheless, fruits are attractive to birds with no resulting ill effects (Mozaffarian, 2012). This species is found globally in dry and semi-dry areas and, in the provinces located in the central Iran.

C) *Ebenus stellata* Boiss. (Fabaceae family) is a thorny shrub with a height of 30-120 cm, having short and oblong-leafy branches and ternate leaves that are alternate and covered with dense silk flakes. This species grows in large part of Iran including Kerman, Yazd, Esfahan, Fars and Hormozgan provinces and some dry and semi-dry regions of world (its native range is Oman and Iran to India). The canopy structure is open with compact thorny branches that it is difficult to graze livestock (Mozaffarian, 2012) (Fig. 2).

Soil sampling and greenhouse experiments

Soil sampling was carried out in the early autumn after the end of the growing and seeding season. Thus, the germinable seeds contained transient and persistent components of the SSB. After a field survey, we randomly selected 15 replicate sampling areas, each containing the three shrub species and a herbaceous patch (control) in close proximity to each other (Fig. 2). The distance between any two sampling areas was at least 100 m to exclude spatial autocorrelation. In each sampling area, under each shrub, after removing coarse litter (> 2 cm) 10 soil cores (subsamples) were collected at random, to a depth of 10 cm, with a 5 cm diameter auger and then the subsamples were pooled for each patch (totally 60 soil samples were collected). The soil samples were transported to the laboratory and were stored at ca. 4 oC for cold stratification for a period of one month (Miller and Cummins, 2003). Subsequently, soil samples were transported into the greenhouse and each sample was spread over a mix of (1:1) sterilised potting soil and sand of a thickness of 3 cm in free draining plastic trays of 25 cm x 35 cm (totally 60 trays). Six control trays containing only sterile potting soil and sand, were placed at random with the samples to test for contamination of samples from greenhouse or nearby seed sources. All trays were kept under natural light and temperature conditions and were watered to keep them moist (Niknam et al., 2018). Air temperature varied between 14 degC and 25 degC. Germinated seedlings were identified, counted and removed once they reached an identifiable stage. Seedlings that could not be identified immediately were transplanted to pots to allow further growth until identification was possible. No seeds were germinated in the control trays.

After a germination period of seven months, no further seedlings were observed. Therefore, the trays were left to dry for two weeks and then the samples were rewetted and kept for another one month to encourage seed dormancy breaking.

Soil seed bank characteristics measurements

The density of SSB was expressed as the number of seeds per m^2 and SSB richness was measured as the number of species for each soil sample.

SSB species diversity indices were calculated for each individual under-shrub using greenhouse data. The Shannon index is most frequently used to characterize the diversity of communities; it is sometimes referred to as the Shannon-Wiener index (Equation 1).

Equation 1 $H' = \sum_{i=1}^{s} \mathrm{pi} \log \mathrm{pi}$

Where p_i is the relative abundance of SSB of the ith species in a soil sample, and S is the number of detected species in SSB in that sample (Chernov et al., 2015). Another diversity index frequently used in ecology is the Simpson index, which is frequently determined as the probability of belonging to different taxa for two plant species randomly selected from an indefinitely large community. The Simpson index was calculated from the equation 2 (Chernov et al., 2015).

Equation 2 $S_I = \sum_{i=1}^{s} \frac{ni\ (ni-1)}{N(N-1)}$

Where n_i is the individual number of each plant species in the SSB in a sample, and N is the total number of all germinants of all plant species in SSB in that sample.

The diversity indices were calculated using the Past software.

In addition, during the growth season, we recorded the presence of all plant species within each of the patches sampled for SSB. Species abundance of the AGV was not estimated because it was not possible to place a sampling frame beneath the shrubs and we used presence-absence data for AGV in the analyses. Qualitative similarity between the species composition of the AGV and the SSB was assessed using the Jaccard similarity index (Kent and Coker 1994) in each patch using equation 3.

Equation $3\mathrm{IS}_j = \left[\frac{C}{(C+A+B)}\right] \times 100$

Where C is the number species common between AGV and SSB, A, the number of species found only in the AGV and B, the number of species found only in the SSB.

We also estimated the mean canopy surface of our shrubs on ground and the height of each individual shrub using metal tape measure.

Data statistical analysis

Firstly, normality of data (SSB density, species richness, diversity indices and similarity between AGV and SSB) was examined using the Kolmogorov-Smirnov test and homogeneity of variance using Levene's test. Total seed density was transformed toto meet the normal distribution. To evaluate the effect of shrub species on SSB properties one-way ANOVA and LSD mean comparison tests were used. All statistical analyses were performed in the SPSS software ver. 16.

Results

Soil seed bank composition

A total of 118 species were found in the SSB and AGV. 55 species were present in SSB while they were absent in the AGV and 53 species were present in the AGV while absent in the SSB (Appendix 1).

In total, 2316 seedlings of 67 species (22 families) were germinated in soil samples: 910 seedlings belonging to 28 species in *A. scoparia* patch, 661 seedlings belonging to 30 species in *D. mezereum* patch, 637 seedlings belonging to 45 species in *E. stellata* patch and 108 seedlings belonging to 23 species in herbaceous patch (control). There were 12 species, common in four patches. The germinated seeds of *A. scoparia* shrub was observed in the greenhouse while seeds of *D. mezereum* and *E. stellata*shrubs were absent in the SSB. Most observed species in SSB belonged to Asteraceae (12 species, 17.91% of total species), Poaceae (9 species, 13.43% of total species) and Lamiacea (9 species, 13.43% of total species), respectively (Appendix 1).

Variation of soil seed bank characteristics under the shrubs

The ANOVA results showed that the highest and lowest values of SSB densities were found under *A. scoparia* (1133 seeds /m^2) and control (110 seeds /m^2), respectively (df = 3, F = 3.56 and $p<0.05$) (Fig. 3). The highest and lowest species number of SSB were observed under *E. stellata* (8.26 species per samples) and control (3.13 species per samples), respectively (df = 3, F = 6.41 and $P<0.01$) (Fig. 4). In addition, the results showed that the highest and lowest values of Shannon-Wiener diversity index were observed beneath of *E. stellata* and control with 1.06 and 0.83, respectively (df = 3, F = 3.32 and $P<0.05$) (Fig. 5). The highest and lowest values of Simpson diversity indices were found under canopy of *E. stellata* (0.75) and the control (0.44), respectively (df = 3, F = 5.02 and $P<0.01$) (Fig. 5). The highest values of similarity between SSB and AGV were found under three shrubs (18% to 19%) and the lowest was observed in the control (8%) (df = 3, F = 15.11 and $P<0.01$) (Fig. 6).

In addition, the mean surface of shrub canopies on ground was ca. 7.5 m^2, 5.5 m^2 and 4.00 m^2 for *A. scoparia, D. mezerum* and *E. stellata* , respectively, and amongst three shrubs, *A. scoparia*had the highest mean height with ca. 3.5 m comparing with *D. mezerum* and *E. stellata* with ca. 2.60 m and ca. 1.83 m, respectively

Discussion

Our results showed that among 22 plant families in SSB, the highest number of species belonged to Asteraceae. Previous studies showed that these plants were also widely present in the SSB (e.g. Gomaa et al., 2012). One of the possible reasons for the increase of these plants in SSB is the abundant seed production and morphological characteristics of the seeds. Species of Asteraceae with small seed size and wing shape, light and easy dispersal provide conditions for the presence of their seeds in the SSB (Harper, 1977; Hong et al., 2012). Forbs were the most abundant plants in the SSB composition. Our results showed that number of forb species was higher (33, 27, 24 and 17 species beneath *E. stellata* , *D. mezareum* , *A. scoparia* and control, respectively) than grasses (6, 7, 5 and 5 species beneath *E. stellata* , *D. mezareum* , *A. scoparia* and control, respectively) in the study area. In accordance with the results of our study, Bertiller et al. (2011), Parlak et al. (2011) and Tessema et al. (2012) reported that forbs had the highest number of species in SSB. Higher number of forbs in the AGV might be a reason for increasing the seeds of these species in the SSB. In contrast, woody plant species (trees and shrubs) were scarcely found in the greenhouse. Although, Teketay and Granstrom (1997) and Chaideftou et al. (2009) attributed the lack of woody species in the SSB to the lack of mature species in the AGV, in our study, this cannot be the reason because woody species in the AGV were frequent. Many factors are involved in reducing the density and richness of woody species in the SSB in an area. These could include the larger size of the seeds, the higher amount of predations and seed dormancy (Esmailzadeh et al., 2011). Some studies have shown that breaking seed dormancy of woody plants requires special conditions and if these conditions are not provided, these plants will eventually be removed from the SSB (Chaideftou et al., 2009).

In general, this study showed that the SSB density and species richness and diversity under the shrubs was higher than control and this differentiation was more pronounced for forbs. Previous studies (e.g. Marone et al., 2004) showed that the seed density of forbs were often higher under woody plants and positively correlated with the cover of woody vegetation, whereas the seed density of grasses were less associated by woody vegetation. Our results are consistent with some previous studies (e.g. Erfanzadeh et al., 2014) and disagree with others (e.g. Mndela et al., 2020). Positive effects of shrubs on SSB are exerted through direct and indirect ways. They increase buried seeds in soil by directly trapping seeds or by indirect mechanisms through an intermediary animal or plant species (Bullock and Moy, 2004; Giladi et al., 2013). Shrubs significantly influence the movement wind or water around their canopy (Hoffman et al., 2013) and thus can trap seeds or act as barrier for movement (Giladi et al., 2013). Shrubs can indirectly facilitate seed arrival by acting as a perching site for seed-carrying birds (Debussche and Isenmann, 1994) or as cache for granivorous rodents (Beck and van der Wall, 2010) and ants (Vergara-Torres et al., 2018). Additionally, shrubs can indirectly increase SSB by facilitating the plants that are able to increase seed production or viability and vigority of produced seeds (Pugnaire and Lazaro, 2000). Shrubs provide a suitable conditions for growing, flowering and seeding of herbaceous plants under their canopies through modifying the physical and chemical properties of soil with litter and root exudation, improving soil micro-relief, decreasing direct sunlight, increasing soil moisture, protecting the surface soil from erosion and adding organic matter into the soil (Ruiz et al., 2008; Barness et al., 2009; Olvera-Carrillo et al., 2009; Li et al., 2011; Sylvain and Wall, 2011; Garcia-Sanchez et al., 2012).

However, different effects of different shrubs on SSB characteristics were observed in increasing SSB density under the canopy of *A. scoparia* and species richness and diversity under the canopy of*E. stellata.* Previous studies showed that the size of a shrub could impact the arrival of seeds (Pugnaire and Lazaro, 2000) because larger shrubs can provide greater facilitative effects. Larger shrubs can intercept more solar radiation (Maestre and Cortina, 2005), have higher soil nutrients (Zhang et al., 2015), or lower evapotranspiration (Kidron and Gutschick, 2013) creating a favourable microclimate for seed production, particularly by annuals (Filazzola et al., 2019). As a result, comparing to the other shrubs, taller and larger canopy in*A. scoparia* might increase SSB density through higher seed production by plants. The seeds of some annuals were found at strong frequent under *A. scoparia* , i.e. *Bromus tectorum* ,*Galium aparine* and *Veronica anagalis* . However, procumbent canopy in *E. stellata* might increase species diversity and richness of SSB. It might be that attached crown cover to the ground in*E. stellata* physically obstruct more seeds and enhance species diversity and richness in SSB. Our results showed that the seeds of many species were found under *E.*

stellata , while they were absent in control or under other shrubs, e.g. *Polygonum dumosum* , *Poa sinaica* , *Tragopogon jezdianus* and *Dianthus orientalis* ,*Tianthus crinitus* . Briefly, indirect effect of *A. scoparia*on seed production of few plant species (some annuals) and direct effect of *E. stellata* on seed trapping of many species resulted these significant differences of SSB density, species richness and diversity between shrubs.

Similarity between the seed bank and the AGV was generally low in three shrubs and control. The low similarity between the AGV and the SSB in our and other studies is usually due to the fact that some species were present in the vegetation, while they were absent from the seed bank, and vice versa (e.g. Valkoa et al., 2014; Erfanzadeh et al., 2016). However, the similarity between the AGV and the SSB was lowest in the control. In this area, many species, such as *Acantholimon scorpius* and *Ebenus stellata* , were absent from the seed bank while they were present in the AGV. Most of these species were perennial, and these, especially shrubby ones, are well-known for their transient seed bank (Thompson et al., 1997). Moreover some annuals such as *Bromus tectorum* and *Galium aparine* were found in the SSB in control and under three shrubs. These species were present in the AGV under the shrubs while absent in the AGV of control. At the sampling time, some annuals in the AGV might be grazed or dried and ended their phenological stages in the control due to higher availability to grazers or solar radiation, temperature and wind speed comparing with under the canopies of shrubs.

Conclusions

AGV in the present study area suffers from human activities as over grazing and collection of plants for medicinal purposes. This may lead to habitat degradation and vegetation destruction in some part of the area. Knowledge of the SSB and its temporal and spatial variation is a useful tool for conservation and restoration efforts. This study showed that shrubs played an important role in restoring of herbaceous seeds under their canopies. However, the extent to which shrubs affects SSB characteristics is dependent on the species of shrub and the type of SSB characteristics. These different roles of shrubs on SSB are advised to be considered in restoration of areas through conservation of native shrubs in the semiarid regions. Highest SSB density under the canopy of*A. scoparia* with its potential in medical and grazing uses increase the priority of using for degraded site restoration by this shrub species. In addition, although *E. stellata* has a low or intermediate palatability for grazers, it can be of priority for rangeland improvement if plant diversity conservation is of priority for the manager.

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Figures Captions

Fig. 1. Geographical location of the study area and fifteen sites in which all three shrub species were found closed to each other in each site.

Fig. 2. Sampling areas had three shrub species of *Amygdalus scoparia* (A), *Daphne mezereum* (B) and *Ebenus stellata* (C) that formed woody patches in the surrounding herbaceous vegetation, used as control (D) for comparing soil seed bank density and composition, Chenarnaz rangelands, Yazd province, Iran (30deg 03' 51" N - 30deg 05' 89" N; 53deg 00' 16" E - 54deg 01' 23" E).

Fig. 3. Mean densities (+-SE) of seeds that germinated under three shrubs (*Amygdalus scoparia* , *Daphne mezereum* and *Ebenus stellata*) and herbaceous vegetation, Chenarnaz Rangelands, Yazd province, Iran. Lower case letters indicate statistically significant differences (P <0.05) among patch types.

Fig. 4. Mean species richness (+- SE) of germinants under three shrubs (*Amygdalus scoparia* , *Daphne mezereum* and *Ebenus stellata*) and herbaceous vegetation, Chenarnaz Rangelands, Yazd province, Iran. Lower case letters indicate statistically significant differences (P <0.05) among patch types.

Fig. 5 . Mean (+- SE) Shannon and Simpson diversity indices under three shrubs (*Amygdalus scoparia* , *Daphne mezereum* and *Ebenus stellata*) and herbaceous vegetation, Chenarnaz Rangelands, Yazd province, Iran. Lower case letters indicate statistically significant differences (P <0.05) among patch types.

Fig. 6. Mean (+- SE) Jaccard similarity index between soil seed bank and above-ground vegetation under three shrubs (*Amygdalus scoparia* , *Daphne mezereum* and *Ebenus stellata*) and herbaceous vegetation, Chenarnaz Rangelands, Yazd province, Iran. Lower case letters indicate statistically significant differences (P <0.05) among patch types.

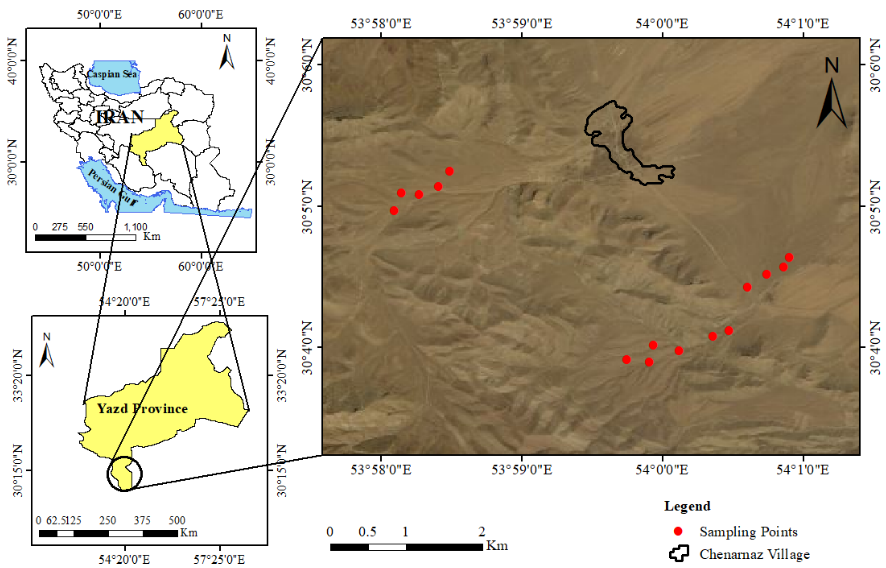
Appendix. 1. Average soil seed bank density of each species under the canopy of each shrub (the digits). *presence of the species in the above-ground vegetation.

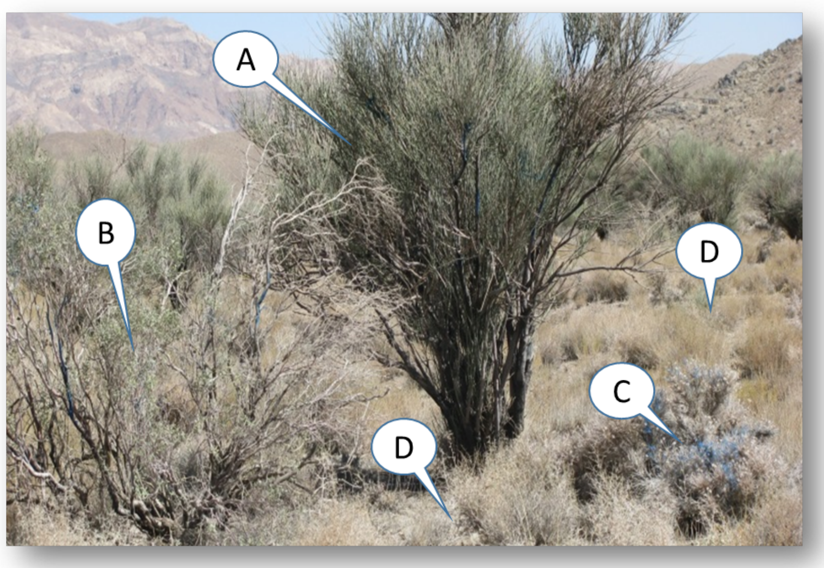
Species	Family	Growth habit	Seed density (seeds per m^2)	Seed density (
			Amygdalus Scoparia	*Daphne Meze*
Acantholimon sp.	Plumbaginaceae	Shrub	0*	0*
Acantholimon scorpius L.	Plumbaginaceae	Shrub	0*	0*
Acanthophyllum spinosum C. A. *May*	Caryophyllaceae	Shrub	0*	0*
Aegopordon berardioides Boiss.	Asteraceae	Forb	0*	0*
Allium inutiflorum Regel.	Liliaceae	Forb	0	0*
Allium sp.	Liliaceae	Forb	74.71*	93.39*
Alkanna sp.	Boraginaceae	Forb	0	0
Alyssum marginatum L.	Brassicaceae	Forb	0*	0*
Alyssum minus (L.) Rothm.	Brassicaceae	Forb	0*	18.67*
Alyssum sp.	Brassicaceae	Forb	0*	0

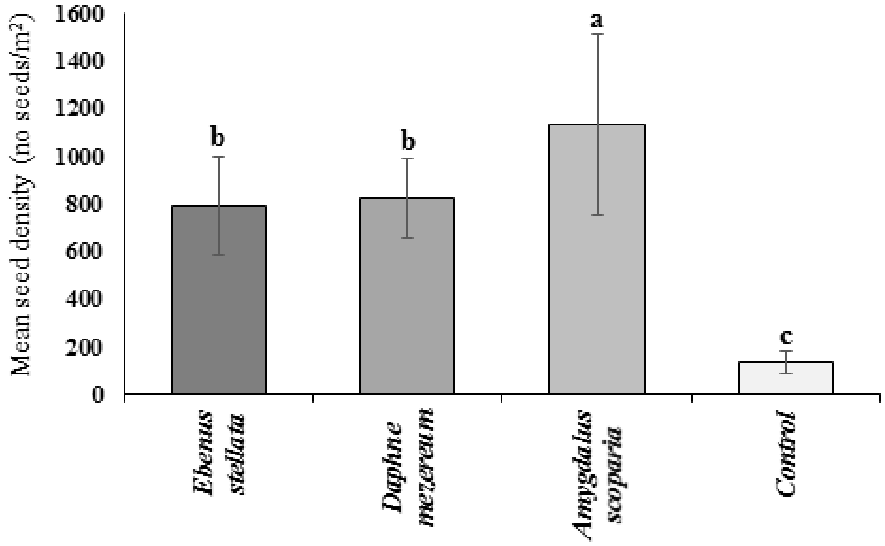
Species	Family	Growth habit	Seed density (seeds per m^2)	Seed density (
Amygdalus lycioides Spach.	Rosaceae	Shrub	0*	0*
Amygdalus scoparia Spach.	Rosaceae	Tree	149.42*	18.67*
Angelonia sp.	Plantaginaceae	Forb	0	0*
Arrhenathrum kotschyi Boiss	Poaceae	Grass	0	18.67
Artemisia aucheri Boiss.	Asteraceae	Shrub	74.71*	74.71*
Astragalus albispinus Sirj & Born.	Papilionaceae	Forb	0*	0*
Astragalus sp.	Papilionaceae	Forb	0*	37.35*
Astragalus spachianus Boiss.	Papilionaceae	Forb	0*	0*
Astragalus terrestris Kitam.	Papilionaceae	Forb	0*	0*
Asperula orientalis Boiss. & Hohen.	Rubiaceae	Grass	56.03	18.67
Brassica sp.	Bracicaceae	Forb	0	0*
Bromus danthonia (L.) DC.	Poaceae	Grass	0	0*
Bromus tectorum L.	Poaceae	Grass	11057.77*	5360.77*
Bromus scoparius L.	Poaceae	Grass	0*	0*
Carex sp.	Cyperaceae	Forb	56.03	18.67
Carthamus glaucus M.Bieb.	Asteraceae	Forb	74.71	224.144
Centaurea virgate Lamarck.	Asteraceae	Forb	0*	0*
Crepis sp.	Asteraceae	Forb	0	0
Cicer oxyodon Boiss & Hohen.	Fabaceae	Forb	0	18.67
Clypeola aspera (Grauer) Turrill.	Brassicaceae	Forb	0	0
Convolvulus fruticosus L.	Convolvulaceae	Forb	0	0*
Crepis sancta L.	Astaraceae	Forb	0*	0
Daphne mezereum L.	Thymelaeaceae	Shrub	0*	0*
Dianthus crinitus Sm.	Caryophyllaceae	Forb	0	0
Dianthus orientalis Beitr.	Caryophyllaceae	Forb	0	0
Dichanthiu mannulatum (Forssk.) Stapf.	Poaceae	Grass	0	280.18
Ebenus stellata Bioss.	Fabaceae	Shrub	0*	0*
Echinophora platyloba DC.	Thymelaeacea	Forb	0*	0*
Erymopyrum distans (Ledeb) Jaub	Poaceae	Grass	653.75	541.68
Erysimum sp.	Brassicaceae	Forb	74.71	0
Erodium cicutarium L.	Geraniaceae	Forb	0*	0
Erodium sp.	Geraniaceae	Forb	0*	0*
Eryngium sp.	Umbelliferae	Forb	0*	0
Eryngium bangai Bioss.	Umbelliferae	Forb	0*	0*
Festuca ovina L.	Poaceae	Grass	597.71	280.18
Galium aparine L.	Rubiaceae	Forb	859.21*	1064.68*
Hertia angustifolia (DC.) Kuntze	Asteraceae	Forb	0*	0*
Geranium sp.	Geraniaceae	Forb	0*	0*
Isatis sp.	Brassicaceae	Forb	0	0
Juncus inflexus L.	Juncaceae	Forb	37.35	0
kochia prostrata (L.) Schrad	Chenopodiaceae	Forb	0	18.67
Lactuca glaucifolia Boiss.	Asteraceae	Forb	0	37.35
Lappula microcarpa (Ledebour) En & Pr	Boraginaceae	Forb	0	0
Linum sp.	Linaceae	Forb	37.35	18.67
Lactuca lanceolate L.	Asteraceae	Forb	0*	0*
Lactuca orientalis Boiss.	Asteraceae	Forb	0*	0
Lactuca serriola L.	Asteraceae	Forb	0	0
Lolium perenne L.	Poaceae	Grass	0*	0
Lolium sp.	Poaceae	Grass	0*	0
Loranthus grewinkii Boiss & Buhse	Loranthaceae	Forb	0	0*

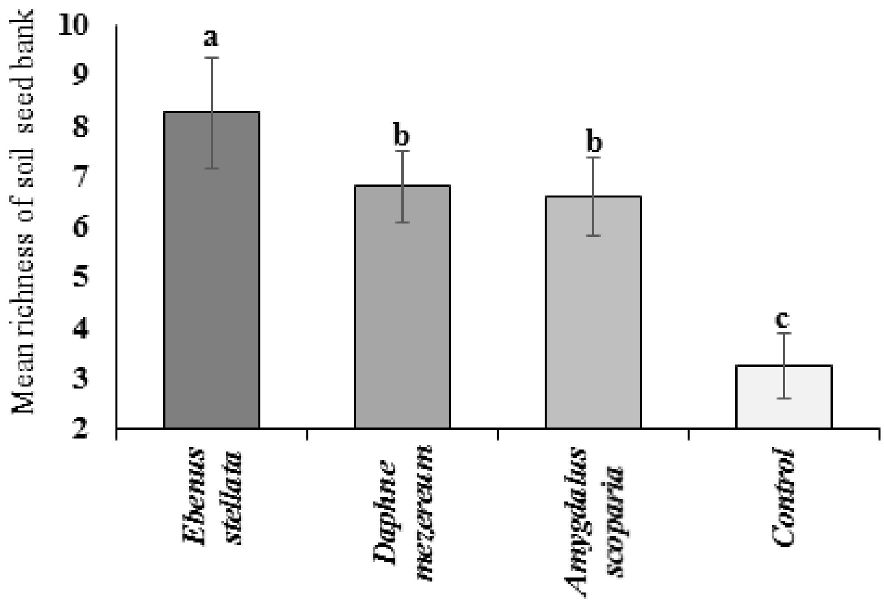
Species	Family	Growth habit	Seed density (seeds per m^2)	Seed density (
Medicago radiata L.	Fabaceae	Forb	0*	0*
Micropus sp.	Asteraceae	Forb	0*	0*
Myosotis sp.	Boraginaceae	Forb	0	0*
Mentha longifolia (L.) Huds.	Lamiaceae	Forb	0	18.67
Minuartia decipienc (Fenzl) Bornm.	Caryophyllaceae	Forb	18.67	0
Marrubium vulgare L.	Lamiaceae	Forb	18.67*	0
Marrubium sp.	Lamiaceae	Forb	0	0
Medicago sativa L.	Fabaceae	Forb	0	0
Medicago sp.	Fabaceae	Forb	18.67	0
Nepeta pungens (Bunge)Benth., Lab.Gen.	Lamiaceae	Forb	0	56.03
Nonea mucronata Forssk.	Chenopodiaceae	Shrub	18.67*	0
Onopordon sp.	Asterace	Forb	0*	56.03*
Papaver sp.	Papaveraceae	Forb	0*	0
Paracaryum sp.	Boraginaceae	Forb	0*	0
Peganum harmala L.	Zygophyllaceae	Forb	56.03	0
Pistacia atlantica Desf.	Anacardiaceae	Tree	0	112.07
Pimpinella affinis L.	Apiaceae	Forb	93.39	0
Phlomis olivieri Benth.	Lamiaceae	Forb	37.35	37.35
Phlomis aucheri Boiss.	Lamiaceae	Forb	0	0
Polygonum erectum L.	Polygonaceae	Forb	18.67	18.67
Polygonum sp.	Polygonaceae	Forb	18.67	0
Polygonum dumosum Boiss	Polygonaceae	Forb	0	0
Poa annual L.	Poaceae	Grass	0*	0
Poa sinaica Steud.	Poaceae	Grass	0	0
Psathyrostachys sp.	Poaceae	Grass	0*	0*
Ribes iebersteinii Berland.exDC.	Grossulariace	Tree	18.67	0
Scariola paradoxa L.	Asteraceae	Forb	0	18.67
Scoriola orientalis (Boiss.) Sojak.	Asteraceae	Forb	0	18.67
Scandix aucheri Boiss.	Apiaceae	Forb	18.67	37.35
Scorzonera mucida L.	Asteraceae	Forb	37.35	18.67
Senecio destontainei L.	Asteraceae	Forb	18.67	0
Saussurea heteromalla DC.	Asteraceae	Forb	0	18.67
Silene spergulifolia (Willd.) M.Bieb.	Caryophyllaceae	Forb	224.14	448.28
Silene sp.	Caryophyllaceae	Forb	149.42	242.82
Sinapis sp.	Brassicaceae	Forb	0	18.67
Solanum nigrum L.	Solanaceae	Forb	168.10	0
Scabiosa olivieri L.	Caprifoliaceae	Forb	0*	0
Schismus arabicus Ness.	Poaceae	Forb	0	0*
Scirpoides holoschoenus L.	Cyperaceae	Forb	0*	0
Scorzonera sp.	Asteraceae	Forb	0	0*
Senecio sp.	Asteraceae	Forb	0*	0
Stachys inflata Benth.	Lamiaceae	Forb	0*	18. 67
Stellaria blatteri Mattf.	Caryophyllaceae	Forb	0	0
Stipagrostis plumose (Linn.)	Poaceae	Forb	0	298.85
Stipa arabica Trin&Ru.	Poaceae	Grass	933.93	2110.69
Sterigmostemum longistylum	Brassicaceae	Forb	0*	0
Stipa barbata Desf.	Poaceae	Grass	0*	0*
Stipa parviflora Desf.	Poaceae	Grass	0*	0
Taraxacum montanum (C.A. Mey.)	Asteraceae	Forb	242.82	485.64
Thymus trnascaucasicus Ronniger.	Lamiaceae	Shrub	112.07	149.42

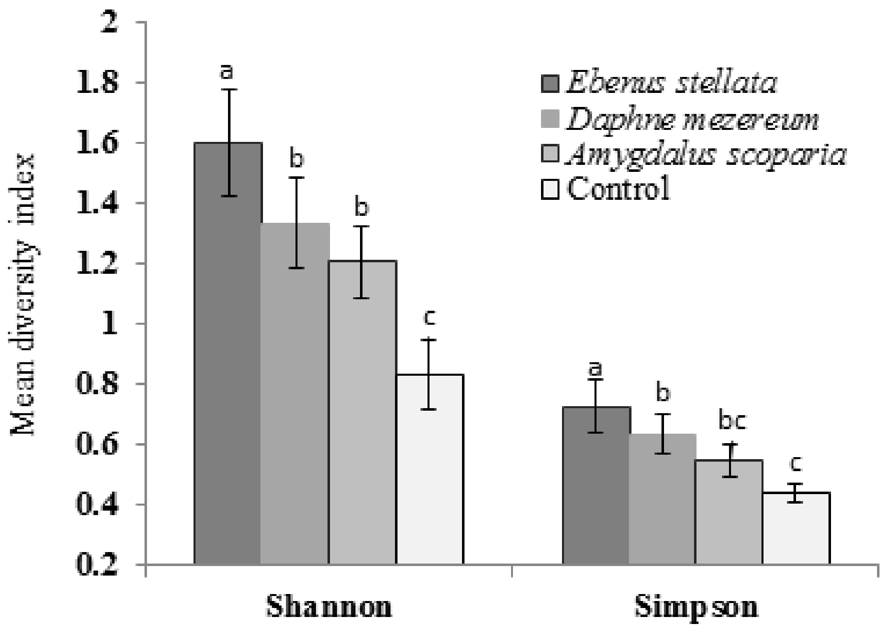
Species	Family	Growth habit	Seed density (seeds per m^2)	Seed density
Tragopogon jezdianus L.	Asteraceae	Forb	0	0
Valerianella oxyrhynchus	Valerianaceae	Forb	0*	0*
Veronica anagallis L.	Plantaginaceae	Forb	971.29	0
Ziziphora clinopodioids Lam.	Lamiaceae	Shrub	18.67	0
Ziziphora tenuior L.	Lamiaceae	Forb	0*	0*

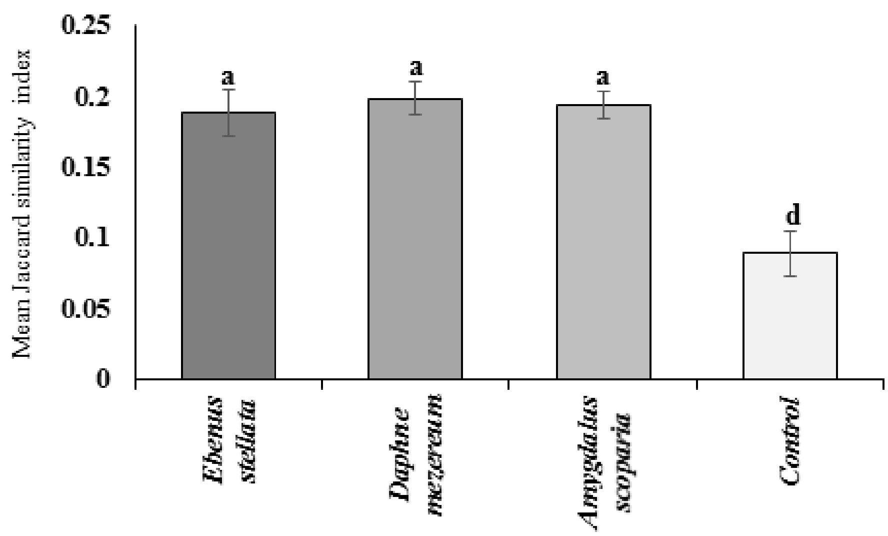





Mean seed density (no seeds/m²)
1600
1400
1200
1000
800
600
400
200
0
a
b
b
c
Ebenus stellata
Daphne mezereum
Amygdalus scoparia
Control


Mean richness of soil seed bank
10
9
8
7
6
5
4
3
2
a
b
b
c
Ebenus stellata
Daphne mezereum
Amygdalus scoparia
Control


2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
Mean diversity index
a
b
b
c
a
b
bc
c
Ebenus stellata
Daphne mezereum
Amygdalus scoparia
Control
Shannon
Simpson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0.15
0.1
0.05
0
Mean Jaccard similarity index
a
a
a
d
Ebenus stellata
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Amygdalus scoparia
Control