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Fire effects on germination of soil seed bank in a semi-arid rangeland (a case study in Darehshahr, Ilam Province)

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ABSTRACT
The size and longevity of soil seed bank in rangeland ecosystem change continuously due to natural and anthropogenic disturbances such as seed mortality, decomposition, consumption by seedivores, fire, and germination. This study aimed to examine the influence of human-induced fire on seeds germination rate in soil seed bank of a semi-arid rangeland. The study was carried out in Darehshahr, southeast of Ilam Province, western Iran in 2016 with two treatments, i.e. burned and unburned sites, in three replications. Soil samples was randomly taken at two different layers of 0-5 and 5-10 cm. Totally, 30 soil samples were taken in each soil layers at each site. Soils were spread on 15 × 20 cm sterilized sand bed and germinated seed was monitored for 3 months. Seedlings were counted every 10 days and then removed from the trays. Diversity and richness of seedling were calculated using respective indices. The Repeated Measure Analysis of Variance was used to compare the diversity and richness of seedlings. The values of the Margalef and Menhinick richness indices in the burned site were 31.12 and 25.15% greater than that in unburned site. In addition, the values of the Simpson's and also Shannon-Wiener diversity indices in the burned site were 26.6 and 23.27% greater than that in the unburned site, respectively.

Keywords: Burning, Soil seed bank, Plant diversity.

INTRODUCTION
Soil seed bank is a set of viable seeds in terrestrial ecosystems that is mainly produced by the plants in a specific region and is finally completed with the seeds having been introduced from other regions. In fact, soil seed bank is non-germinated seed population available on the surface and sub-surface soil that may be died out by death, destruction and consumption by seedivores, animals and humans and/or provide the ability to alternate mature plants (Sadeghipour & Kamali 2013). The seeds of some species can remain alive for tens or even hundreds of years (Cassie & Waters 2001). The composition of soil seed bank largely depends on the amount and variety of seed production and composition of resources producing seed including past and current vegetation. Therefore, any factor that interferes with the distribution of plant species can affect the composition, density and distribution of soil seed bank. In other words, the presence of plant species in the soil seed bank is associated with the species composition of vegetation on ground, their seed production rate, and duration of viability of seed in the soil (Kellerman 2004). The biomass of plants can increases the richness and diversity of plant community because bare soils cause high temperature on surface and ultimately reduces the richness of the soil seed bank. Therefore, the vegetation should be managed to strengthen the soil seed bank (Erfanzade & Hossieni Kahnoj 2014). The soil seed bank play an important role in maintaining the ecological and genetic diversity of plant communities and in restoring vegetation after degradation (Najafiye-tire-shabankare *et al*. 2012). The soil seed bank makes it possible for the ecosystem to remain alive. Regeneration of the seeds under the soil is an important variable to keep dynamic of ecosystem (Cassie & Waters 2001). In addition to the importance of seed

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banks in survival and dynamics of plant communities, it is also important in restoring endangered species and preserving genetic diversity of plant community as well as the response of plant community to the environmental changes and even climate change (Erfanzade & Hossienikahnoj 2012). Numerous natural and anthropogenic factors such as climate, topography, hydrology, soil, light, fire/burning, grazing and type of plant community affect the density, diversity, survival, amount and type of seeds in the soil seed bank (Asgari *et al*. 2012). Firing is one of the common and important occurrences in terrestrial. Fire can affect various aspects of growth and development of plant communities such as flowering, seed scattering and seedling establishment, biomass of plants and so on. The ecological (controlled) burning is used for removing invader and unfavorable plants, replacing them and changing vegetation type in rangelands. The changes made by fire in vegetation can cause changes in the size of soil seed bank. After burning, some changes occur in the composition of the seed bank of the habitat (Abbasi Moslo *et al*. 2010). The heat coming from fire causes awakening the dormant seeds by influencing on physical structure as well as crust and fetus (Baskin, 1998). The positive effect of fire on seed germination and ultimately increased species diversity is an important method for conserving and restoring plant communities. De Bano (1990) reported that fire intensity has different effects on soil properties. Intense fire can affect the physical, chemical and biological characteristics of soil such as soil permeability, porosity and micro-organisms. Verma & Jaykumar (2012) showed that micronutrients and macronutrients, soil physical properties such as texture, color, acidity and soil organisms alter under the effect of firing. Naghipoor *et al*. (2014) revealed that firing and smoking stimulate the germination of seeds in many species. Heydari & Faramarzi (2014) stated that burning can significantly reduce the density of seeds and their germination abilities due to physiological alterations in the seeds and soil properties, in addition to their direct destruction as the result of high fire temperature shortly after burning. Salimi *et al.* (2012) conducted a study on the effect of flamethrowers on *Sinapis arvensis* seed bank, microorganism population as well as physical and chemical characteristics of the soil, concluding that firing has a negative effect on soil seed bank and reduces species density. Consequently, knowledge on the fire effects on the various aspects of an ecosystem is very important for management. This study aimed to investigate the influence of fire on the diversity of germinated seeds of soil seed bank in a semi-arid rangeland.

MATERIALS AND METHODS

Study area

The study was conducted in the rangelands around the Kolah-Joob village, Darehshahr township, southeast of Ilam Province, West Iran. The study site was located between 33° 9´ N latitude and 47° 24´ E longitude. The climate was semi-arid with annual mean precipitation and temperature of 390 mm and 9.20 °C, respectively.

Experimental design and sampling

This study was defined in a completely randomized design. Treatments comprised soils of burned and unburned (control) sites in three replications. At the end of grazing season and after plants seed dispersal in September 2016, soil sampling in each treatment was performed at 0-5 and 5-10 cm depths. Each soil composite sample was a mix of three sub-samples taken from three different intervals within sampling plot (1 m^2). Soil samples were collected by a soil probe with 5 cm radius. Each composite samples were placed in a separate sampling bag. Finally, 30 samples were taken from each depth in each treatment. Soil samples spread separately out on 15 × 20 cm trays on a bed of sterilized sand. Totally, there were 60 containers containing the samples in each treatment from the two different soil depths. In order to ensure the existence of weed seeds in sand bed, a container without the soil of the study area (control) was placed amongst each 10 trays containing the sample.
Sprinklers irrigation in the form of artificial rain were performed every two days to stimulate germination. At regular intervals, i.e., every 10 days, counting of the germinated seeds was done in each container and the counted seedlings were removed. Counting of germinated seeds in containers continued up to 3 months. After three months, when no seed germination occurred inside the containers irrigation was stopped for two weeks. Then, the soils inside the container were surface scratched and again were irrigated. Irrigation prolonged one month to ensure availability of ungerminated seeds.

Data analysis

The Menhinick and Margalef indices were employed to calculate richness, while the Simpson and Shannon-Wiener diversity indices for calculatin diversity. The GLM Repeated Measure analysis of variance was used to compare the richness and diversity of germinated seed between soil depths as well as treatments.

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RESULTS

Significant difference was found between the values of Margalef richness index between the sites, soil depths and the interaction between them ($p > 0.05$) (Table 1). The Margalef index values in burned site was 12.31 percent higher than that in unburned site.

Table 1. Analysis of variance (ANOVA) of the Margalef richness index values for germinated seeds in soil seed bank.

Source of variation	**Sum of squares**	**Degree of freedom**	**Mean of square**	***F***	***P***
Fire treatment	0.441	1	0.441	383.33	*0.000
Soil depth	0.145	1	0.145	126.26	*0.000
Treatment × Depth	0.016	1	0.016	14.03	*0.006
Error	0.009	1	0.001		
Total	28.786	12			

* significant at the 0.05 level.

Table 2. Mean comparison of the Margalef richness index value in soil seed bank between soil depths in the treatments.

Fire treatment	**Soil depth (cm)**	**Mean**	**Error**	***P***
Burned site	0–5	1.95	0.1151	0.000*
	5–10	1.66		
Unburned site	0–5	1.50	0.1151	0.000*
	5–10	1.35		

* significant at the 0.05 level

The Menhinick richness index values were significantly varied between the treatments, between soil depths and the also in the case of interactions between them ($p < 0.05$) (Tables 3-4). This index in burned site was 10.32% higher than that in unburned one.

Table 3. Analysis of variance (ANOVA) of Menhinnick richness index of soil seed bank.

Source of variation	**Sum of Squares**	**Degree of freedom**	**Mean of squares**	***F***	***P***
Fire treatment	0.827	1	0.827	1340.82	0.000*
Soil depth	0.082	1	0.082	132.44	0.000*
Treatment × Depth	0.052	1	0.052	84.33	0.000*
Error	0.005	8	0.001		
Total	26.167	12			

* significant at 0.05 level; ns: without significant difference.

Table 4. Comparison Menhinick richness index means in soil seed bank between soil depths in the treatments.

Fire treatment	**Soil depth (cm)**	**Mean**	**Error**	***P***
Burned site	0–5	1.8600	0.1207	0.000*
	5–10	1.5633		
Unburned site	0–5	1.2033	0.1207	0.000*
	5–10	1.1700		

* significant at the 0.05 level

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In addition, Simpson diversity index values were significantly varied ($p < 0.05$) between the treatments and between soil depths, but not between their interaction ($p > 0.05$) (Table 5). The Simpson's index values in burned site was 26.6% higher than that in unburned site (Table 6).

Table 5. Analysis of variance (ANOVA) for Simpson's diversity index in soil seed bank.

Source of variation	Sum of squares	Degree of freedom	Mean of square	*F*	*P*
Fire treatment	0.27	1	0.827	394.71	*0.000
Soil depth	0.73	1	0.082	1062.75	*0.000
Treatment × Depth	7.50	1	0.052	0.11	0.750ns
Error	0.006	8	0.001		
Total	14.39	12			

* significant at the 0.05 level and ns means non-significant

Table 6. Comparing Simpson's index means in soil seed bank between soil depths in the treatments.

Fire treatment	Soil depth (cm)	Mean	Error	p
Burned site	0–5	1.45	0.1326	0.000*
	5–10	0.96		
Unburned site	0–5	1.15	0.1326	0.000*
	5–10	0.65		

* significant at the 0.01 level.

The values of Shannon-Wiener diversity index were significantly different between treatments, soil depths and the interaction between them ($p < 0.05$) (Tables 7-8). The Shannon-Wiener index values in burned site was 27.23% higher than that in unburned site.

Table 7. Analysis of variance (ANOVA) of Shannon-Wiener diversity index in soil seed bank.

Source of variation	Sum of squares	Degree of freedom	Mean of square	*F*	*P*
Fire treatment	0.41	1	0.41	553.753	0.000*
Soil depth	0.06	1	0.06	83.101	0.000*
Treatment × Depth	0.02	1	0.02	19.820	0.002*
Error	0.006	8	0.001		
Total	32.05	12			

* significant at the 0.05 level.

Table 8. Comparing Shannon-Wiener index means in soil seed bank between soil depths in the treatments.

Fire treatment	Soil depth (cm)	Mean	Error	p
Burned site	0–5	18433	0.1102	0.000*
	5–10	1.7700		
Unburned site	0–5	1.5433	0.1102	0.000*
	5–10	1.3300		

* significant at the 0.05 level.

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DISCUSSION

Soil seed bank of studied rangeland reacted to burning. Fires had a significant impact on all aspects of diversity and richness of soil seed bank. Germinated seeds density in the soil seed bank varied under fire treatments. The influence rate and species change of seeds in the first and second soil depths in the burned and unburned sites were not similar. Species composition within treatment were not changed, but there was a significant difference between treatments. These findings are consistent with the results of Elsaforia Wills & Read (2011) and Abbasi Moselo (2008). However, Sarabi *et al.* (2014) concluded that the species richness in the first depth of both burned and unburned sites was higher than that in the second depth. In addition, Bekole (2000), stated that if the seeds are not placed in the enough depth, they will be lost in a fire.

Increased ambient temperature due to fire can cause stimulation of biological activity of soil and nutrients availability to plants. Also, releasing mineral nutrients through the ash will enrich the soil. Firing stimulates the germination of seeds of some range plants by creating thermal stress, smoke and ash. The effect of fire on seed germination can be internal (chemical) or external (physical). The heat produced by fire can split impermeable coat of seed and thus enables water entering into seed and as a result, seed germination increases. Mansouri *et al.* (2008) and Ghorbani *et al*. (2011) reported that firing can play an important role in breaking of seed bank of the available species and can increase diversity. Also, it can be said that firing has provided a ground for germination of new species that can be a result of damage or direct elimination of most dominant species due to intense heat or alterations in physico-chemical properties of soil. In such circumstances, the presence of new species becomes possible and the monotony of the dominant species disappears resulting increase in plant diversity and richness (Brodstock & Gill 2002).

Increased ambient temperature can cause stimulation of biologic activity of soil and nutrients availability to plants. Also, releasing mineral nutrients through the ashes will enrich the soil and the plants and the soil seeds. Firing stimulates the germination of seeds of some range plants by creating thermal stress, smoke and ash. The influences of fire products on seed germination can be internal (chemical) or external (physical). The heat produced by fire splits impermeable crust of seed, thus enables water entering into seed and subsequently elevate in its germination. Fire can induce a positive and also negative impacts on presence or absence of germination in soil seed bank respectively. This problem has also been reported by Mansouri *et al.* (2008) and Ghorbani *et al.* (2011) who pointed out that fire can play an important role in breaking seed bank of the available species. They also stated that species richness and diversity arise as a result of firing. Fire provides a ground for germination of new species, which may be a result of damage or direct elimination of most dominant species due to intense heat or alterations in physico-chemical properties of soil. the presence of new species becomes possible and the monotony of the dominant species disappears resulting increase in plant diversity and richness (Brodstockand Gill 2002).

The history of ecosystem is stored in seed bank in some ways after destruction by fire, grazing, and drought. This can play an important role in the secondary succession. Heydari *et al.* (2014) reported that fire has negative effects on soil because it can reduce nutrients in the soil and soil fertility; and at last, reduces density, richness and diversity of plant. In Norway, Maren & Vandvik (2009) stated that fire changed the stages of succession and composition of surface vegetation as well as soil seed bank. Stark *et al.* (2008) studied the similarities of sampled groups in the condition of fire disturbance and found increase in species frequency, exhibiting that the masses without disturbance had a unique seed bank, while those with low disturbance (less intense fires) displayed more similarity to the control area in terms of seed bank composition. The seed bank is thought to be less affected from weak disturbance. Brooks & Matchett (2003) pointed out that fire elevates richness while reduces species diversity which are not consistent with our results. The researchers believe that 6 to 14 years is needed after intense fire, as enough time for traveling through the succession stages and elevating the vegetation of burned areas. Turna & Biligili (2006) reported that the difference of soil seed bank rate in the fired region can be caused by high fire heat. So, 110-150 °C exhibits a negatively impact on germination in some plants. On the other hand, Ne mean *et al.* (2009), stated that the ashes left by the fire elevate soil pH, which may reduce seed germination. Brooks *et.al*. (2013) and also Tahmasbi (2013) concluded that short-term firing may hurt the seed bank of one-year old plants in pastures. Once assessing soil seed bank in the northeast America, reported that in degraded habitat, the apparent decline in annual species in association with the region is less disturbed which

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may be due to alterations in the soil physical and chemical properties. Heidari & Faramarzi (2011) reported that higher seed density in control areas play a basic role in increasing species richness. Results of Mamedea & Araujob (2008) exhibited that intense fires can reduce the Shanon diversity and species richness by reducing the density of seeds of different species. In the present study, intense fire declined the possibility of receiving and establishing seed of adjacent areas, while elevating diversity and richness by alterations in soil characteristics such as reducing its permeability (DeFalco *et al.* 2009).
Low-intensity fires arises the monotony and this factor affects marginal increase in its diversity compared to control, which it is due to creating heterogeneity in habitat conditions one or two years after fire (Brooks *et al*. 2013). Generally, based on the results of the present study, it can be stated that growing alterations after fire are evident markedly in terms of the composition of soil seed bank. Firing leads to favorable influences on the habitat diversity and richness of the seed bank and its future. So, the various impacts of fire with different intensities are recommended to be examined in the studied area to determine the revived potential of these areas based on soil seed bank.

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اثر آتش‌سوزی بر جوانه‌زنی بانک بذر خاک در مراتع نیمه‌خشک (مطالعه موردی مراتع دره‌شهر، استان ایلام)

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چکیده

اندازه و طول عمر بانک بذر خاک در اکوسیستم مرتع به دلیل اختلالات ناشی از عوامل طبیعی و انسانی مانند مرگ و میر بذور، تجزیه، مصرف توسط دانه‌خواران، آتش‌شوزی و جوانه‌زنی دائماً در حال تغییر است. هدف این مطالعه، آزمایش اثر آتش‌سوزی انجام شده در اثر انسان بر نرخ جوانه‌زنی بذور بانک بذر خاک در مراتع نیمه خشک بود. این مطالعه در مراتع اطراف شهرستان دره‌شهر در جنوب شرق استان ایلام در سال ۱۳۹۵ با دو تیمار، یعنی منطقه آتش‌سوزی شده و منطقه بدون آتش‌سوزی با سه تکرار انجام شد. نمونه‌های خاک به روش تصادفی در دو عمق صفر تا ۵ و ۵ تا ۱۰ سانتی‌متری خاک برداشت شدند. جمعاً، تعداد ۳۰ نمونه خاک در هر عمق در هر منطقه برداشت شد. نمونه‌های خاک در بسترهای ماسه‌ای ضدعفونی شده به ابعاد ۱۵ در ۲۰ سانتی‌متر گسترانیده شدند و جوانه‌زنی بذرها به مدت سه ماه پایش شد. جوانه‌های خارج شده از خاک هر ۱۰ روز یکبار شمارش و سپس از بستر حذف شدند. تنوع و غنای بذرهای جوانه‌زده با استفاده از شاخص‌های مربوطه محاسبه شدند. تحلیل واریانس به روش اندازه‌گیری تکرار شونده برای مقایسه تنوع و غنای بذرهای جوانه‌زده استفاده شد. مقادیر شاخص‌های غنای مارگالف و منهینیک در منطقه آتش‌سوزی به ترتیب شده ۳۱/۱۲ و ۲۵/۱۵٪ بیش از منطقه بدون آتش‌سوزی بود. به علاوه، شاخص‌های تنوع سیمپسون و شانون-وینر در منطقه آتش سوزی‌شده به ترتیب ۲۶/۶ و ۲۳/۲۷٪ بیش از منطقه بدون آتش‌سوزی بود.

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