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DIVERSITY AND DISTRIBUTION OF SOIL SEED BANKS AND PLANT LITTER IN AL WADI AL AKHDAR (THE GREEN VALLEY) OF TABUK REGION – SAUDI ARABIA

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Abstract

We explored the species composition, diversity, and spatial distribution of soil seed banks and plant litter at two sites within Al Wadi Al Akhdar 'the green valley' area of Tabuk region, KSA, the main valley, and an adjoining shallow stream which are in essence different in elevation, slope and amount of overflow. The objectives were to evaluate and detect the species diversity and spatial variability in soil seed banks and plant litter. We used the systematic sampling procedure to collect soil samples, and the flotation method to extract seeds and plant litter. We employed Paleontological Statistics (PAST) version 4.03 to achieve summary statistics, diversity indices, and graphs and drive appropriate statistical tests that are crucial to answering research questions. Seed banks and plant litter exhibited abnormal spatial distributions. Differences in the mean number of seeds and plant litter contents between sampling points and between the two sites were not significant ($p \leq 0.05$). The shallow stream was more diverse in seed species with a high evenness of distribution between species compared to the valley. The valley possessed a higher number of seeds with a higher dominance _ D value. Species within the shallow site varied significantly ($p \leq 0.05$) in their mean number of seeds, but the difference between the valley species was not significant. *Senecio* sp. seeds dominated the seed bank of the valley, while *Brassica* sp. seeds dominated the shallow stream seed bank. The seed banks of both sites were made of herbaceous species. The parent plants of seed banks do not belong to the standing vegetation. We concluded that elevation and slope influenced soil seed banks' spatial distribution, diversity, and plant litter.

Key words: Soil, Seed, Banks, Plant, Litter, Distribution, Diversity.

Introduction

The valleys represent one of the unique land formations in Saudi Arabia. They pass through the mountain series widely distributed in different parts of the country. The valleys are of high social, cultural, economic, and environmental values. They afford suitable conditions for seasonal and sustainable agricultural activities, excellent pastures rich in palatable nutritious plant species because of the accumulation of water and minerals, making them favorable sites for plant growth and causing the spatial variability in plant assemblages (Ludwig & Tongway, 1995; Al-Rowaily *et al*., 2012). They also support various medicinal plants with multiple traditional uses which are in the popular legacies of the people of the region. Picturesque areas for recreation and hunting sites are also common in the valleys. They also contain a range of archaeological sites and provide natural habitats rich in species of wildlife. Wadi Al Akhdar (the green valley), Wadi Damm, and Wadi Asafir are the most important valleys in the Tabuk region (City profiles: Tabuk, 2019). The Tabuk region is characterized by appreciable plant diversity, but this natural biodiversity is subject to decline and shift due to human activities, such as agricultural production, woodcutting and overgrazing. It was reported That 40000 hectares of woody vegetation were removed annually, with a considerable reduction of rare plant species (Almutairi *et al*., 2015). Deterioration of rangelands in the KSA is one consequence of overgrazing (Al Rowaily *et al*., 2015) through increasing consumption of plant matter, especially of desirable species, resulting in a low percentage of vegetation cover, reduction in potential regrowth of future generations, and shift in species composition (Ludwig *et al*., 2005). Xerophytic vegetation is the most noticeable feature of the plant lifeforms in the KSA (Zahran, 1982). However, the most dominant plant lifeforms in the Tabuk region are therophyte and chamaephyte and most of the species belong mainly to three groups: charophytes, Sahara-Arabian, and Irano-Turanianands (Al-Mutairi *et al*., 2016). The Green valley represents the most observable land forms of the area. It exhibits physiographic irregularity that causes variation in species distribution (Fakhireh, 2012). The Green Valley provides shelter, food, and medicine (Shehata & Galal, 2014), habitats for a variety of perennial Woody and herbaceous plant species, in addition to wild fauna including birds, reptiles, mammals, and insects. Many of the plant species in the valley are of high traditional herbal medicine values, including *Haloxylon persicum*, *Haloxylon salocornium Artemisia monosperma, Artemisia annua, Artemisia vulgaris, Aaronsohnia factorovskyi, Pulicaria incisa, Fagonia bruguieri, Rumex vesicarius,* and *Malva parviflora*. The green valley also represents a good grazing site where *Acacia seyal, Panicum turgidum*, and *Retama raetam*, among many others, provide feed for grazing and browsing animals. Moreover, this site contains some valuable archaeological sites like Al Akhdar Well and Al-Akhdar Castle.

Soil seed banks are composed of all living seeds (Saatkamp *et al*., 2014), seeds in the soil associated with litter/humus (Mekonnen, 2016), and seeds that remain attached to the parent plant. Depending on longevity, transient seed banks are seeds that live for a short period and persistent seed banks are seeds that can survive in the soil for long periods (Gulden & Shirtliffe, 2009). A wide range of values provided by seed banks have been recorded, including offering the plants the ability to migrate to new sites, contributing to the stability of plant populations and conservation of biodiversity (Chesson & Huntly 1997, Faist *et al*., 2013, Plue & Cousins, 2013; Cabin *et al*., 2000, Ayre *et al*., 2009, Lundemo *et al*., 2009, Mandak *et al.*, 2012). Also, increasing the lifespan of plant populations and thus influencing the rate and direction of evolution (Brown & Venable, 1986, Evans & Cabin, 1995, Evans & Dennehy, 2005), gives the plant populations the ability to cope with environmental change. In addition, they allow species to survive harsh environmental conditions (Gulden & Shirtliffe, 2009). Knowledge and studies on different aspects of seed banks are of great importance for predicting potential restoration of sites and managing the structure of standing plant populations (Herrier *et al.*, 2005; van der Valk & Pederson, 1989; Richter & Stromberg, 2005; Hui & Keqin, 2006); understanding the impacts of climate (Paul *et al.*, 1995) and the secondary succession (Lang, 2006). Moreover, the spatial relations of seed bank assemblages are important elements of biodiversity within agroecosystems (Alignier & Petit, 2012; Benvenuti, 2007). Soil erosion and accumulation of sediments are essential for the structure and distribution of soil seed banks, but this field of research has not received the coverage that it deserves (Timothy *et al.*, 2013).

Plant litter is defined as the dead plant material of small size lying loose on the ground, and its production depends basically on the productivity of the plant community at a site (Facelli *et al.*, 1991). Plant litter is rearranged and removed from open areas and higher points to depressions and lower areas by wind and runoff water (MacMahon & Wagner, 1985; Noy-Meir, 1985; West, 1979; Whitford *et al.*, 1982) and moves mostly down slopes, and fallen logs and branches may retain litter and create marked patchiness in the distribution of litter (Orndorff & Lang, 1981). Facelli *et al.*, (1991) reviewed the effects, significance, and values of litter in the availability of mineral nutrients, soil light environment, soil temperature, water dynamics, as a physical barrier of seeds and plants, in addition to its effects on plant community structure and dynamics. Litterfall is a basic component of the biogeochemical cycles. Its biomass and chemical composition are required to quantify the annual return of elements and organic matter to the soil. Moreover, litterfall provides temporal and quantitative information about the phenological development of the stand. The quantification of litter facilitates measurements of annual variation in phenology in response to short-term weather patterns and long-term climate (Pitman *et al.*, 2010). 10 to 20% of decaying plant material will contribute to soil organic matter (Sylvia *et al.*, 2005), meaning that 80-90% of plant litter may persist for long periods and can provide an insight into dynamics, diversity, and abundance of vegetation cover of an area allows comparisons between sites in primary biomass productivity and can be useful in succession studies.

Many studies have been carried out to investigate the floristic composition and diversity of vegetation in the Tabuk region (Moawed *et al.*, 2015; Elmutairi *et al.*, 2016), medicinal uses of plants (Al-Harbi, 2017; Fakhry *et al.*, 2016), and springs (Al-Saleh, 2017) but none of these studies have focused on soil seed banks and plant litter contents. Hence, this study tries to fill a part of this research gap and to establish a piece of baseline information regarding the structure, composition, diversity, spatial variability, and site to site turnover of soil seed banks and plant litter in the area as affected by elevation, slope, water and wind erosion of the soil. This will be achieved through testing of null hypotheses that seed banks and plant litter are homogeneously distributed within and between sites, have similar diversities, seed banks belong to the above ground vegetation standing at each site and differences in altitude and slope and, hence, runoff and erosion do not affect their distribution. Results of this study are intended to make a first step and a helpful tool for future assessment, evaluation, and monitoring programs on natural vegetation of the area and the impacts of human activities.

Materials and Methods

The study area: The Tabuk region lies at the extreme Northwestern part of Saudi Arabia. The area of the Tabuk Region is 139,000 square kilometers or about 6.2% of the total area of the Kingdom. It is characterized by a unique geological formation made up of mountain series and plateaus dissected by networks of valleys that flow towards the Red Sea and the Gulf of Aqaba in the West (Alsaleh, 2017). Tabuk city falls between the Hejaz mountain and the Northern plains, at an altitude of 778 m bounded by a large mountain system to the South in addition to vast agricultural areas to the South, East, and North. All of these elements make Tabuk´s immediate natural surroundings a varied and characteristic environment. The region and the rest of the country have a semiarid to hyper-arid climate, characterized by high temperatures, deficient rainfall, and extremely high evapotranspiration. The Tabuk region is also characterized by its northerly cooling influences and by having the lowest winter temperature average in the country. Winter temperatures usually range between 6°C and 18°C, occasionally dropping below zero at night, and summer temperatures vary from 28°C to 40°C. Prevailing winds coming from the West also influence these temperatures. Mean annual rainfall is very low at 30mm (Tabuk City Profile, 2019).

The study sites: We selected two sites within Alwadi Al-Akhdar (the green valley) area which is about 90 km distant from Tabuk city to the South: the main valley, which is a tilted valley of low elevation, steep sides with a stream flowing through it, seasonally receives a great deal of runoff and characterized by patchy, mainly perennial natural vegetation, of shrubs, bushes and herbaceous species alternating with eroded bare areas, and a neighboring shallow stream of relatively higher elevation upon the plain with relatively homogeneously distributed vegetation mainly of annual species. The idea behind this selection is, primarily, to detect and quantify soil seed banks and plant litter contents in the area, their diversity, distribution, and species composition and to trace changes in these indicators between and within the two sites following geophysical variations in slope, elevation, and magnitude of runoff and soil erosion.

Soil sampling: We used the systematic sampling procedure to collect soil samples from both sites. We established a line transect of 100 m length at the bottom of both the main valley and the shallow stream parallel to the direction of flow, marking 10 sampling points along the line transect with 10m intervals. At each point, we collected soil from 30 x 30 cm and 5 cm depth at the middle, mixed them carefully with hands, removed animal feces and large gravels, and crushed large masses of soil. Then we placed soil in high-density plastic bags labeled with the site and number of points. Then we transferred the samples to the laboratory for further studies. We carried out the sampling during October 2020, about two months before winter (the rainy season).

Seed extraction and determination of plant litter dry weight: We extracted Seeds and plant litter from the soil using the seed flotation extraction method described by Gonzalez & Ghermandi (2012), where we prepared a supersaturated solution of sodium chloride by adding 350 g NaCl to 1 liter of distilled water, we took 1 kg of soil from each sample that we collected from a sampling point and split into two samples of 500 g, added each 500 g of soil to NaCl solution and agitated the mixture for 3 minutes and left it to stand for 1 hour. Then we filtered organic matter suspended on the surface gently through filter paper, spread it on filter papers, and left it to dry out for two days. We mixed the organic material obtained from both samples of 500 g soil to make the yield from 1 kg of soil, removed animal feces and other parts of non-plant origin, and recorded the dry weight of plant litter using a sensitive balance.

Seeds counts: We sorted, counted, recorded, and imaged seeds of different species associated with plant litter yield from each 1 kg of soil from both sites separately under a binocular dissecting microscope, and used a hand counter to count seeds of large numbers.

Statistical analysis: We employed Paleontological Statistics (PAST) version 4.03 to produce summary statistics, the probability distribution (Anderson-Darling test), and the test for equal means (number of seeds) between different sampling points and between different species for each site. We obtained diversity indices of seeds of different species, carried out a test for equal means (plant litter dry weight g/kg soil) between the two sites and used the software to produce a normal probability plot of plant litter at both sites. We calculated the percentage composition of each seed species at both sites using the following equation:

$$\frac{\text{Total no. of species seeds}}{\text{Total no. of seeds of all species}} \times 100$$

Result and Discussion

Distribution of seed banks between sampling points: Anderson-Darling normality test and the coefficient of variation in (Table 1) showed that the distribution of seeds from different species at most of the sampling points is not normal (p Monte Carlo < 0.05). Meaning that most values have deviated from their means and different species contributed to the seed bank by varying numbers of seeds at different sampling points. This result agrees with what was stated early by Harper *et al*., (1965); Archibold, (1981); Thompson, (1986), that buried seeds are distributed heterogeneously even in a small area. Shiferaw *et al*., (2018) reported a similar finding that seed populations in the soil are heterogeneous and abnormally distributed. Test for equal means of the number of seeds between different sampling points of both sites showed no significant differences ($p \leq 0.05$). The total number of seeds from all species at each sampling point showed extreme values at some points of both sites while relatively close values at the rest of the points. This is most probably because seed banks were concentrated at the points along the canyon and the shallow stream where there are short dense bushes of perennial species that form windbreaks, protect the soil from water erosion and cause the seeds to accumulate at covered points while the bare areas contained relatively lower numbers of seeds. In this regard, Timothy *et al*., (2013) stated that soil erosion can create islands of low seeds in bare sites and higher seed abundance in covered areas and they also drew attention to the potential impact and biodiversity significance of erosion on seed banks. Moreover, Koc *et al*., (2013) reported that the differences in the spatial distribution of plant species in the seed banks were mainly due to geo-morphological heterogeneity. Major & Pyott (1966); Leck *et al*., (1989); Halpern *et al*., (1999) related the high variability of seed bank density to the patchy distribution of parent plants and the patterns of seed dispersal.

Distribution of seed banks between species: Table 2 summarizes statistics of the number of seeds of each species and the normality test of their distribution between different sampling points. All species in the main valley and six species out of eight in the shallow stream exhibited abnormal distribution. At the main valley, *Senecio* sp. (Fig. 9) was the dominant species and showed abnormal distribution with the highest coefficient of variation, while at the shallow stream, *Brassica* sp. (Fig. 5) was the dominant and normally distributed. This finding disagrees with the argument of Zhang *et al*., (2012) that although the dominant species have a normal distribution, the less abundant ones usually have an abnormal distribution. *Senecio* sp. is characterized by the high productivity of small flat seeds of lightweights with tufts of trichomes that help dispersion by wind. *Brassica* sp. also produces copious numbers of minute light spherical seeds in small pods. This may explain their supremacy in the number of seeds in the soil seed bank over other species and confirms that seed dispersal, germination/dormancy, and size properties of species have great impacts on the spatial distribution of soil seed bank (Thompson *et al*., 1998; Abe *et al*., 2008; Pazos & Bertiller, 2008; Stromberg *et al*., 2008). Decocq *et al*., (2004) also attributed the dominance of species in soil seed banks to similar biotic and dispersal reasons. *Ambrosia artemisiifolia* (Fig. 2) showed the lowest total number of seeds in the main valley, while *Citrullus lanatus* (Fig. 6) showed the lowest coefficient of variation i.e. its seeds were best evenly distributed between points. Test for equal means resulted in a non-significant difference in the number of seeds between species in the main valley ($p \leq 0.05$). At the shallow stream, Seeds of *Brassica* sp. with *Spermacoce alata* (Fig. 10) were much better distributed between sampling points (had a low coefficient of variation values) compared to other species. *Asphodelus fistulosus* (Fig. 4) seeds were the lowest in number (only 3) and *Senecio* sp. seeds had the lowest evenness of distribution between points. We also found that the difference between species in the number of seeds at the shallow stream was significant ($p \leq 0.05$).

Distribution of species between the two sites and percentage species composition: We detected a total of nine species at both sites belonging to seven families (Table 3). The shallow stream soil had a higher number of species (8) while the main valley soil contained 5 species. All species represented in the soil seed banks of both sites are herbaceous. This result is harmonious with that of Senbeta & Teketay, (2002) who found that only a few woody plants were represented by a few seeds in the seed bank, suggesting that woodiest plants typically use the seed rain, or coppicing from stumps, as alternative regeneration routes. Guo *et al*., (1999) and Marone *et al*., (1998) indicated the scarce presence of perennials in the seed bank of desert ecosystems in comparison with the short-lived species. Bertiller, (1998) justified this by predation in the soil of large seeds of long-lived species more than small seeds of short-lived plants. *Senecio* sp. (96.78%) dominated the percentage composition by the number of seeds in the soil seed bank of the main valley, while *A. artemisiifolia* showed the lowest contribution to the seed bank of this site (0.25%). *Brassica* sp. showed the highest percentage composition in the shallow stream and *A. fistulosus* made the lowest percentage composition. We found that four species were common between the two sites and *Euphorbia serpens* (Fig. 7) appeared in the main valley only while *S. alata*, *Brassica* sp*., Aethusa cynapium* (Fig. 3), and *A. fistulosus* were only in the shallow stream. We also noticed that most of the standing above ground perennial and annual species was not represented in the seed banks of both sites. Khan, (1993); Aziz & Khan, (1996) also found a poor relationship between existing vegetation and underground seed reserves in desert communities. (Baskin & Baskin, (1998); Crowley & Garnett, (1999); Marone *et al*., (2000) attributed this poor relationship to seed predation, while Baker, (1989); Esmailzadeh *et al*., (2011) attributed it to lack of dormancy mechanisms. Gomaa (2012) also reported a lower similarity index between the seed bank and the above-ground vegetation in desert Wadi compared to other sites. Decocq *et al*., (2004) reviewed two hypotheses that may explain that parent plants of seed banks do not belong to the above ground community: "temporal segregation hypothesis" that buried seeds originated from parent plants growing in the stand in the past and maintained as a result of extended longevity; the "spatial segregation hypothesis" that buried seeds originated apart from the stand.

Seed banks diversities: Table 4 shows different diversity indices of the two sites in seed banks. Dominance_D in the main valley (0.9372) was higher than that of the shallow stream (0.3121) meaning that the seed bank of the main valley was dominated by a fewer number of species. Simpson_1-D, evenness, and equitability which contrast the dominance_D were in favor of the shallow stream (seed bank was evenly made by different species). The shallow stream was more diverse in species and had a higher Shannon_H diversity index (1.453) than the main valley (0.1728). The global diversity index (Whittaker) which shows the species turn over and shift in species composition from one site to another was 0.38462, given that a global diversity index value of 1 means a complete change in species between sites.

Table 1. Summary statistics and distribution of seeds between sampling points.

	Statistics	Sampling points									
		1	2	3	4	5	6	7	8	9	10
Main valley	Taxa	5	5	5	5	5	5	5	5	5	5
	Total	2003	36	23	17	19	1207	18	24	25	203
	Mean	400.6	7.2	4.6	3.4	3.8	241.4	3.6	4.8	5	40.6
	Std. error	399.850	5.1029	2.7857	2.9257	3.800	2396515	2.2271	4.5541	3.3615	39.8517
	Anderson-Darling A	1.202	0.7243	0.499	0.9409	1.205	1.196	0.5077	1.112	0.6854	1.179
	P(Monte Carlo)	0.0001	0.0171	0.119	0.0028	0.0001	0.0001	0.1025	0.0001	0.0209	0.0002
	C.V	223.188	158.479	135.4123	192.4168	223.6068	221.9872	138.332	212.152	150.333	219.485
	Test for equal means: $p = 0.5677^{NS}$										
Shallow stream	Taxa	8	8	8	8	8	8	8	8	8	8
	Total	16	16	104	77	50	95	27	215	16	118
	Mean	2	2	13	9.625	6.25	11.875	3.375	26.875	2	14.75
	Std. error	1.253566	1.72171	9.029713	5.541846	3.368711	10.8996	2.36746	12.4059	0.73192	8.76631
	Anderson-Darling A	1.206	2.019	1.548	1.09	1.261	2.157	1.587	0.7043	0.4579	1.138
	P(Monte Carlo)	0.0014	0.0001	0.0002	0.003	0.0007	0.0001	0.0002	0.0407	0.2022	0.0016
	C.V	177.281	243.486	196.4607	162.8541	152.4505	259.6104	198.406	130.565	103.509	168.100
	Test for equal means: $p = 0.2567^{NS}$										

NS = Non-significant difference ($p \leq 0.05$)

Table 2. Distribution of seed banks between species at the two sites.

Site	Statistics	*E. serpens*	*C. lanatus.*	*A. artemisiifolia*	*G. aparine*	*Senecio* sp.	-	-	-
Main valley	Sample points	10	10	10	10	10	-	-	-
	Total no. of seeds	10	79	9	17	3460	-	-	-
	Mean	1	7.9	0.9	1.7	346	-	-	-
	Std. error	0.4944132	3.377869	0.4068852	0.7608475	218.1683	-	-	-
	Anderson-Darling A	1.238	1.086	1.042	1.141	2.003	-	-	-
	P(Monte Carlo)	0.0022	0.004	0.0045	0.0024	0.0001	-	-	-
	C.V	156.3472	135.2122	142.9649	141.5301	199.3956	-	-	-
	Test for equal means: $p = 0.05775^{NS}$								
	Statistics	***S. alata***	***Brassica* sp.**	***A. artemisiifolia***	***A. cynapium***	***G. aparine***	***C. lanatus***	***Senecio* sp.**	***A. fistulosus***
Shallow stream	Sample points	10	10	10	10	10	10	10	10
	Total no. of seeds	63	363	115	11	4	75	100	3
	Mean	6.3	36.3	11.5	1.1	0.4	7.5	10	0.3
	Std. error	0.15275	9.129926	4.009018	0.2211083	0.4068852	4.465298	10.94537	1.868154
	Anderson-Darling A	2.033	2.904	1.674	1.683	0.6976	0.9108	0.5906	0.3663
	P(Monte Carlo)	0.3784	0.0948	0.0122	0.0483	0.0002	0.0002	0.0001	0.0001
	C.V	93.772	95.3507	122.7871	116.9713	174.8015	169.035	288.7136	161.0153
	Test for equal means: $p = 0.0002808$*								

* = Significant difference ($p \leq 0.05$)

Variation in soil-plant litter contents: Table 5 shows the dry weight of plant litter (g/kg of soil) from all sample points at both sites. The main valley had a higher mean dry weight of soil-plant litter, but the variance in dry weight of plant litter indicated that the main valley was of more heterogeneity in the distribution of plant litter in the soil. (Fig. 1) further demonstrates the horizontal distribution of plant litter in the soil of both sites, it is clear that the normal distribution line fits much better to the sample values of the shallow stream, while that of the main valley was far from normality in their distribution. This may be attributed to the same factors that affected the distribution and concentration of the seed bank along the main valley (frequency of occurrence of bushes that make physical barriers of wind and runoff and bare areas). The difference between means of plant litter dry weight between the two sites was also not significant ($p \leq 0.05$).

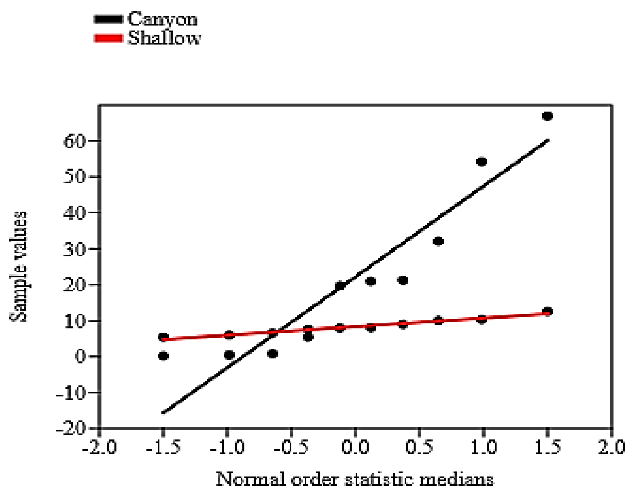

Fig. 1. plant litter normal probability plot for the canyon and the shallow stream.

Conclusion

We detected a total of nine seed species belonging to seven families in the two sites. The distribution of the seed banks within the two sites, between sampling points, and between species was abnormal and showed great heterogeneity. Morphological characteristics, seed productivity, and dispersal strategies affected the distribution, dominance, and species composition of seed banks. Differences in the mean number of seeds between the sampling point and between species of the main valley were not significant. The difference in the mean number of seeds between species on the shallow site was significant. The difference in mean plant litter in the soil between the two sites was also not significant. Soil seed banks of both sites were made of herbaceous species and the parent plant species of seed banks do not belong to the above ground vegetation. The shallow stream site had a higher seed diversity index with better evenness of distribution between species, and the canyon site had a higher total number of seeds with higher dominance (less evenness). Furthermore, we found a considerable turnover in species between the two sites. Mean plant litter (g/kg soil) in the canyon soil was higher than that of the shallow stream soil, but the normal distribution line fitted the plant litter values of the shallow stream much better than that of the canyon. Elevation, slope, and erosion influenced the size, diversity, and distribution of soil seed banks and plant and plant litter in the area. Normality test seems to be better than test for equal means to trace spatial variability in soil seed banks and plant litter contents. Based on these findings we can reject the null hypotheses stated for this study.

Appendix. Photos of seed species detected in the seed banks of the study sites.

Fig. 2. *Ambrosia artemisiifolia* seed.

Fig. 3. *Aethusa cynapium* seed.

Fig. 4. *Asphodelus fistulosus* seed.

Fig. 5. *Brassica* sp. seed.

Fig. 6. *Citrullus lanatus* seeds.

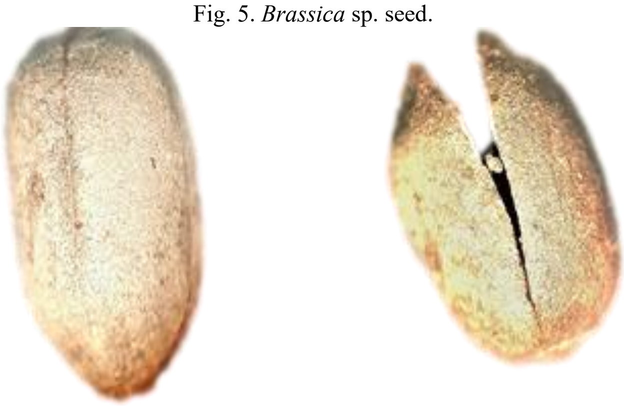

Fig. 7. *Euphorbia serpens* seeds.

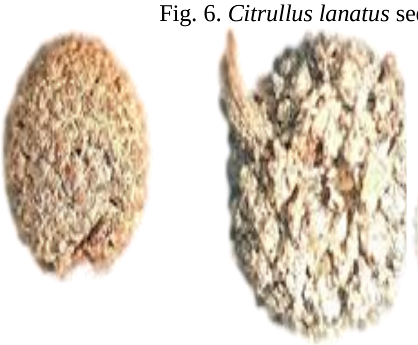

Fig. 8. *Galium aparine* seeds.

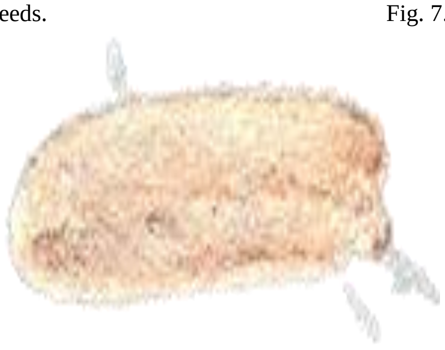

Fig. 9. *Senecio* sp. seed.

Fig. 10. *Spermacoce alata* seeds.

Table 3. Percentage composition and distribution of species between the two sites.

Species	Family	Percentage composition	
		Main	Shallow
Senecio sp. L.	Asteraceae	96.78	13.81
Galium aparine L.	Rubiaceae	0.48	0.55
Ambrosia artemisiifolia L.	Asteraceae	0.25	15.88
Citrullus lanatus (Thunb.) Matsum. & Nakai	Cucurbitaceae	2.21	10.36
Euphorbia serpens Kunth	Euphorbiaceae	0.28	0
Spermacoce alata Aubl.	Rubiaceae	0	7.32
Brassica sp. L.	Brassicaceae	0	50.14
Aethusa cynapium L.	Apiaceae	0	1.51
Asphodelus fistulosus L.	Asphodelaceae	0	0.41

Table 4. Diversity indices in seed banks of the canyon and the shallow stream and test for equal means number of seeds/sampling point.

Diversity index	Main valley	Shallow stream
Taxa_S	5	8
Individuals	3575	724
Dominance_D	0.9372	0.3121
Simpson_1-D	0.06278	0.6879
Shannon_H	0.1728	1.453
Evenness_e^H/S	0.2377	0.5346
Equitability_J	0.1074	0.6988
Global beta diversity (Whittaker)	0.38462	
N	10	10
Mean	358.3	73.4
Variance	4.70	4004.5
Test for equal means	t : 1.3085^{NS}	

Table 5. Plant litter dry weight (g/kg soil) at the canyon and the shallow stream with variance and test for equal means.

Sampling point	Plant litter dry weight (g)/kg soil	
	Main	Shallow
1	0.44	7.6
2	21	6.62
3	5.44	10.05
4	67.00	10.33
5	19.76	8.06
6	0.19	5.42
7	0.83	6.01
8	32.11	9.00
9	21.33	12.58
10	54.24	7.98
N	10	10
Mean	22.234	8.365
Variance	537.27	4.7734
Dif. Between means	13.869	
Test for equal means	t = 1.8838^{NS}	

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