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Insight into the soil seedbank characteristics of the arid rangelands in Libya: A case study in Marmarica Plateau, Cyrenaica (Northeastern part of Libya)

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Highlights

- **This study was conducted in Daphna, an arid rangeland area lies in the far northeastern part of Cyrenaica. This area was used as a case study to investigate the soil seedbank characteristics in the arid rangelands of Libya.**
- **Using the floatation in a salt solution method, the seeds were extracted from the soil then counted and identified.**
- **The results illustrated that the area still retained an adequate density of soil seedbank, however, the majority were for therophytes. The depressions and dykes in valleys retained higher seed density than the open flat areas..**

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ABSTRACT

The current study was conducted in Daphna area, an arid region in Cyrenaica located at the northeastern part of Libyan Sea Coast at the Libyan-Egyptian Border. The soil was sampled in 40 different sampling sites along five different sectors through scraping the soil from 0-10 cm layer (25×25 cm) in the Platea and from 0–10 cm and 10–30 cm layers in the depressions and valleys. Using the floatation in a salt solution method, the seeds were extracted from the soil, counted and identified. The majority of the extracted seed were tinny (< 5 mm) and mainly belonged to annual species. Seeds density in the plateau ranged between 0 and 25400 seed m^{-2} with an overall mean of 4110 seed m^{-2} (±949.30 SE), which is adequate density when compared to similar arid ecosystems. The low-lying lands in depressions (Sakifas) and valleys (Wadis) retained higher seed density than the higher-lying lands on the plateau, and the northern areas retained higher density than the southern areas. The higher top soil layer (0–10 cm) in both Sakifas and behind the Dykes in valleys retained higher mean density than the layer (10–30 cm). The homogeneity of seed characteristics across the plateau and the dominance of annual and short-lived species could be a sign of degradation, and the absence of many perennial species in the soil seedbank may hamper any conservation or rehabilitation effort to improve these rangelands..

1. Introduction

Dryland ecosystems occupy about 45% of the Earth's land surface, store about 20% of the global soil carbon pool and contribute up to 30–35% of terrestrial net primary production (Ochoa-Hueso *et al*., 2018). Therefore, understanding ecosystem components and dynamics of these arid areas is a key role in any conservation, rehabilitation, and sustainable management programs. Particularly, the studies of the soil seedbanks (SSBs) improve our understanding of ecosystem dynamics and the effects of disturbance on ecosystem characteristics (van Etten *et al*., 2014).

Usually, SSBs survive disturbances including climate-related disturbances, diseases, and herbivory suffered by the plants (Ma *et al*., 2012), confer resilience to the plant community in response to changing ambient conditions (Ge *et al*., 2013). Furthermore, detailed information about the SSB is crucial for interpreting the consequences of disturbance related to ecological processes and ecosystem rehabilitation (Ge *et al*., 2013). Several degraded ecosystems have been rehabilitated successfully through SSBs (Braz *et al*., 2014; Saaed *et al*., 2018), but rarely so in Africa, where studies are few and, thus, debilitate decision-making in rangeland management (Saaed *et al*., 2018).

Seeds enter the SSB via seed-rains or through physical and animal-mediated dispersion (Louda, 1989; Roberts, 1981) and leave it via germination, secondary dispersal, seeds consumption by granivores, seeds decay, and parasite attack (Fenner, 1985; Shaukat and Siddiqui, 2004; Traba *et al*., 2006). Seeds in soils play prominent ecological and evolutionary roles (Zaghloul, 2008) linking past, present, and future plant population and community structure and dynamics (Leck *et al*., 1989; Thompson and Grime, 1979). Seed banks are especially important in desert ecosystems where annual plants account for a large part of the flora and their seeds may remain viable in the soil for many years (Inouye, 1991; Kemp, 1989; Rundel and Gibson, 2005) avoiding dry seasons and extended drought periods (Kinloch and Friedel, 2005a).

Although, SSB investigation in arid rangeland areas is an essential key to understand ecosystem state and dynamic, very few SSB studies have been conducted in North Africa, especially in the arid rangelands of Libya (El-Barasi and Saaed, 2013, 2015; El-Jetlawi, 2004; El-mograby *et al*., 2018; Nafea, 2015). Rangeland ecosystems in Libya still poorly understood and little is known about how decades of mismanagement and degradation affect the SSBs in these areas. Therefore, rehabilitation and sustainable utilisation of the landscape in these areas might be hampered by the lack of SSBs information (Saaed *et al*., 2018). This is particularly important in degraded arid ecosystems such as the study area, where plants mostly propagate via seeds (Saaed *et al*., 2018).

The present study is an attempt to cover the apparent gap in the available information on the rangeland ecosystem in Libya, particularly in the northeastern part of Cyrenaica, through investigating the SSB density, composition, spatial distribution, and the main factors influencing its characteristics. The study aimed to answer these questions:

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(1) *What is the density of SSB in the study area?*
(2) *Is there any variation in seed density amongst the different landforms across the landscape?*
(3) *What is the composition of the SSB in the area?*

Understanding of SSB characteristics could explain the ecosystem state, degradation dynamics, the influence of site features, and the future ecological responses of the rangelands in the study area and similar rangelands in the region.

2. Materials and methods

2.1 Study area

The study area is considered as an important rangeland area in Libya, lies in the northeastern part of Cyrenaica at the Mediterranean sea by the Libyan-Egyptian border (El-Barasi and Saaed, 2015). It is extending in an east-west rectangular shape, about of 130 km long and 25-35 km wide between longitudes 23° 54'–25° 09' east and latitudes 31° 36'–32° 06' north (Fig. 1). The study area is about 2 866 km^2 in size, comprises the western half of Marmarica Plateau (Libyan part of Marmarica Plateau). Locally the area is known as “Daphna area”.

At the far north of the study area, there is a narrow strip of plains, while the southern high plateau covers most of the area and is divided by many valleys (dry rivers), which run with water in rainy season northwardly to end at the sea. Dykes (hampering rocky dams) are present along the valleys in different places as old practices to harvest runoff water and prevent soil erosion. There are many topographical depressions “locally named Sakifas” which distributed on the plateau as narrow ribbons in an east-west direction (Annexure A). Sakifas are sites of agricultural activities; relatively, they have more soil fertility and deeper strata, which offer good root penetrability. The different landscape features in the area provide different habitat types; therefore, the area is heterogeneous in soil properties and vegetation structure. The valleys shelter many wild biotas (flora and fauna) especially endemic and rare species that disappeared from the open areas. In some places, the elevation of the plateau reaches 220 m above sea level.

In general, Marmarica Plateau is characterized by an arid climate, with fluctuated and irregular monomodal winter rainfall regime (El-Barasi and Saaed, 2015). The annual mean maximum temperature is 24°C and the mean minimum temperature is 16°C. The annual rainfall rate is of 184 mm y^{-1} at Tobruk area in the north, while at EL-Bardia area in the Far East by the Egyptian border is of 117 mm y^{-1}, and southwardly at Tobruk airport (Al-A’daam area) 25 km south the coast is of 89 mm y^{-1}. The average relative humidity is of 71%, which increases during summer and reaches its minimum value during spring. The area is distinguished with high rates of evaporation, which exceeds 2000 mm y^{-1}. Based on the UNCCD aridity index obtained from the ratio between the values of mean annual precipitation (MAP) and potential evapotranspiration (PET), the study area classified as an arid land (MAP: PET ranged between 0.05 and 0.09).

The soil in the area is typical for arid areas. It is dry soil sediment over parent calcareous rocks characterized by shallow skeletal profile, low organic matter %, high calcium carbonate%, mainly loam or sandy loam texture, and tends to be alkaline (pH ≥ 8) (El-Barasi and Saaed, 2015). As a consequence of the harsh environmental conditions, the vegetation in the area is thermo-xerophilic vegetation dominated by sparse shrubs and dwarf-shrubs constituting the permanent vegetation cover. A mass display of flowering annuals occurs after rainfall in winter and early spring, often on degraded or fallow lands (El-Barasi and Saaed, 2015).

In addition to the accumulation of anthropogenic impacts over decades (over-grazing, dry farming, gathering wood, uprooting medical and economic species, soil trampling through off-road driving), the distribution and characteristics of vegetation in the area is influenced by natural factors (position on landscape, topography, climate, and soil properties) (El-Barasi *et al.*, 2013). Generally, the vegetation in the area is very heterogeneous and lowlands and watercourses characterised by relatively denser vegetation and some tall shrubs because they received more moisture through runoff after rainfall.

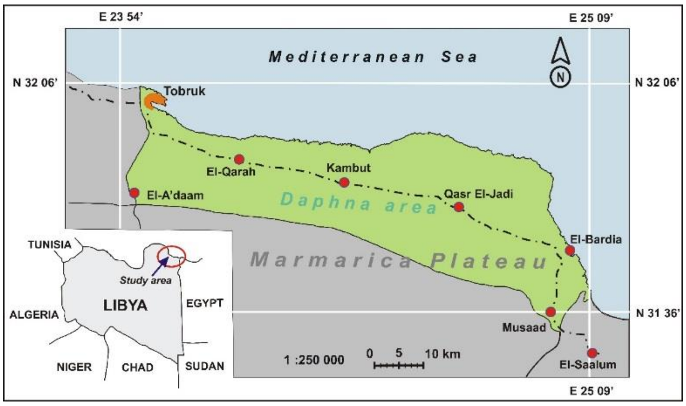

Fig. 1. The geographic location of the study area (Daphna) at the northeastern part of Cyrenaica

2.2 Soil seedbank survey

As a baseline, the SSB in this study is defined as all the seeds found in the soil or on the ground surface (Moles and Drake, 1999; Thompson and Grime, 1979). First, the area was divided into five sectors ranged between 25 and 35 km in length, each initiated from the coast and ended at the southern boundary of the study area. These sectors were at the localities, Ras-Biad (east Tobruk), El-Qarah, Kambut, Qasr EL-Gadi and Musaad respectively from the west to the east (Fig. 1). Along with each sector, the sampling sites were located systematically at five km intervals in north-southward direction. There were additional five sampling sites located at the depressions (Sakifas) and other five sampling sites collected from the sedimentary of five different Dykes.

Samples were collected by scraping the soil from the uppermost 10 cm layer in an area of 25×25 cm^2, and for the Dykes and Sakifas were at two different depths (0–10 cm and 10–30 cm) to know the different SSB density in the different soil layers (soil strata). There were 30-sampling sites along the different sectors and extra five-sampling sites in the depressions and other five-sampling sites behind the Dykes, the total was 40 sampling sites. Samples were weighed and packed in sealed plastic bags, labeled, and transported to the laboratory, and then they were allowed to air dry for 72 hours before processing. Then each soil sample was pooled and thoroughly homogenized, and soil seeds were extracted by flotation in a salt solution using the modified method of Malone (1967) by Buhler and Maxwell (1993) and Price *et al.* (2010).

The floating solution was prepared by combining 20 g of sodium hexametaphosphate, 10 g of $NaHCO_3$, and 500 g of K_2CO_3. The three chemical compounds were dissolved in tap water to make one liter. The experiment was conducted using three replications per each soil sample, each weighing 100 g. Initially, each sample was immersed in one liter of the prepared solution; then the solution was thoroughly agitated using a spatula for 30 seconds and left for 60 minutes to allow the organic matter to be floated on the salt solution. The floated organic debris was separated by filtration through filter paper (15 cm in diameter). The organic materials extracted were dried, and seeds were separated from the organic materials using binocular stereomicroscope and forceps. Then seeds were counted, and the seed numbers were estimated as the average of the three replications for each sample and recalculated as a number of seeds per square meter (seed m^{-2}). Seeds were identified based on the morphological feature, although most of these seeds could not be identified to species level, we were able to identify most of them to the family level.

2.3 Data analysis

The acquired data were first verified and tabulated and then entered into a Microsoft Office Excel spreadsheet (version 2016).

Initially, the data sets were inspected using descriptive statistical analysis and then checked for normal distribution using the Shapiro-Wilk W test. Significant differences for all of the examined parameters were explored using ANOVA (one-way) followed by the Tukey HSD post hoc test. In cases where the distribution of the data was not normal, Kruskal-Wallis one-way ANOVA test and T-test were used.

3. Results and discussion

3.1 Climate

In arid areas, the climate is one of the most important factors having a direct impact on wildlife, particularly the distribution and density of plant species, in addition to its impact on the soil properties (El-Barasi and Saaed, 2015). In the Libyan context, rangelands have fragile ecosystems, as they are located within the arid and semi-arid region, about half of the rangelands is under the 100-mm isohyet (Al-bukhari *et al*., 2018). This arid climate manifested as a poor composition and dynamic of the rangeland ecosystem components above ground (i.e. vegetation) and below ground (i.e. soil and SSB). Arid climatic factors play an important role in SSB's characteristics in these zones, which are mainly composed of ephemeral and annual seeds (therophytes). These species can complete their life cycle and producing considerable quantities of seeds in just a few weeks during the rainy and wet season. The annual therophytes growth in the study area comprised about 55% of the life-form spectra (El-Barasi and Saaed, 2013).

3.2 Seed size

Most of the seeds extracted from the soil were small in size (<5 mm) (Annexure B). The prevalence of small seed size in the study area is a typical feature of SSBs in arid and overgrazed, degraded rangelands (Baskin and Baskin, 2014; Dreber and Esler, 2011; Dreber *et al*., 2011). In such ecosystems, most plants are r-strategists producing many small seeds to survive prolonged dry periods (Grombone-Guaratini and Rodrigues 2002). Seeds of small-seeded species can be either highly abundant or rare whereas large seeds are always rare (Guo *et al*., 1999).

These small (tinny) seeds are primarily from annuals and can survive in the SSB until conditions are conducive for germination (Fenner and Thompson 2005). Usually, annual and short-lived plants produced small seeds in copious quantities, as a response to aridity, and accumulate persistent seedbanks that last more than a year in the soil (Bakker *et al*., 1996). While perennials, on the other hand, produce larger but fewer seeds that normally last less than a year, i.e. they have transient SSB of K-strategists (Esler 1999; Milton and Dean 1993). Larger seeds germinate less, are less viable, eaten more, and more prone to fungal infection (Guo *et al*., 1999). Perennials depend more on their long life-span and vegetative propagation than seeds for regeneration (Amiaud and Touzard 2004).

3.3 Seed density

At the scale of the entire study area, the results revealed that the area retained an adequate density of seeds in the soil compared to other similar arid areas. Seeds density in the study area ranged between 0 and 25 400 seed m^{-2} with an overall mean of 4 110 seed m^{-2} (±949.30 SE). This seed density was less equivalent to that in northern areas of Al-Jabal Al-Akhdar which was ranged between 2 400 and 60 000 seed m^{-2} (El-Barasi and Saaed 2013), and was more or less equivalent to that in the rangeland areas south Al-Jabal Al-Akhdar which ranged between 1 200 and 20 520 seed m^{-2} (El-Barasi and Saaed 2013), and to desert areas west Al-Jabal Al-Akhdar (Ajdabya region) which ranged between 676 and 15 101 seed m^{-2} (El-mograby *et al.* 2018). However, it was more equivalent than the seed density in the Arid Mesus Area far south of Al-Jabal Al-Akhdar at the fringe of the Sahara Desert, which was ranged between 228 and 2 568 seed m^{-2} (El-Jetlawi, 2004) and to the density identified by Zaghloul (2008) in the arid Sinai in Egypt which ranged between 0 and 1 350 seed m^{-2}, and also more equivalent to the density identified by Yang and Evans (1975) who stated that the seed density in certain arid zones worldwide varies between 2450 and 8431 seed m^{-2}.

The density of SSBs is governed by many factors that include seed production, the extent of the area covered by seed-rain, the rate of seed mortality, predator's behaviour, and the density of seedling (Saaed *et al*., 2018). However, these factors vary widely in arid environments (Roberts, 1981) such as in the arid rangelands of Cyrenaica. The comparatively high density of SSB in the area most likely due to the dominance of xerophilous species which composed mainly of annual and short-lived species that produce a large number of seeds (El-Barasi and Saaed, 2013). The relatively high density of SSB in the area can provide a potential for regeneration under suitable environmental conditions such as good rainy seasons.

Amongst the different sectors in the study area, there was no distinct variation in SSBs density (p-value = 0.804), which mean that all sectors follow the same pattern in seed density (Table 1 and Fig. 2). This is in contrast to many other studies in a similar arid environment (Guo *et al*., 1998; Saaed *et al*., 2018; Zaghloul, 2008) who stated that the SSBs in arid areas characterized by high variation across the landscape. The highest mean value of SSB density was recorded in Al-Qarah sector (2760 seed m^{-2}±818.29 SE) and the lowest mean value was in Kambut sector (1 600 m^{-2}±912.14 SE). The SSBs homogeneity across the landscape in such arid ecosystems reflect the homogeneity in the above vegetation as well, which increases with rangeland degradation (Kassahun *et al.* 2009; Saaed *et al*., 2018). Stresses such as high stocking density and prolonged arid conditions act as a filter, and few species can cope with and survive these harsh conditions (El-Sheikh *et al*., 2006) resulted in a homogeneity across the landscape. This is most likely related to a breakdown of the hierarchical dominance and competitive structures of the vegetation resulting from vegetation alteration (Rutherford and Powrie 2010).

In general, the SSB densities in the northern regions of the study area were the highest, and it gradually declined in the southward direction as we approach the desert except for Musaad sector (Fig. 3), which is most likely due to the decline in vegetation cover in the southern areas. This coincides with the results of (El-Barasi and Buhwarish, 2005; Pugnaire and Lázaro, 2000) who stated that the seed density declines as we move away from the canopy of what trees surf, which however may be at the expense of seed density and diversity.

Table 1

Soil seedbank density in the different sectors according to the different soil depths.

Locality	Depth (cm)	Min. seed (m^{-2})	Max. seed (m^{-2})	Mean seed (m^{-2})	SE
Ras-Biad sector	0-10	600	3000	1800	±424.26
El-Qarah sector	0-10	600	4800	2760	±818.29
Kambut sector	0-10	0	6000	1600	± 912.14
Qasr EL-Gadi sector	0-10	0	3000	1800	±434.25
Musaad sector	0-10	600	5400	1971.42	±624.00
Depressions (Sakifas)	0-10	1800	21000	10300	±3324.15
	10-30	0	27000	8550	±6327.91
Dykes	0-10	3000	25200	12480	±4974.58
	10-30	1800	21600	10080	±352624

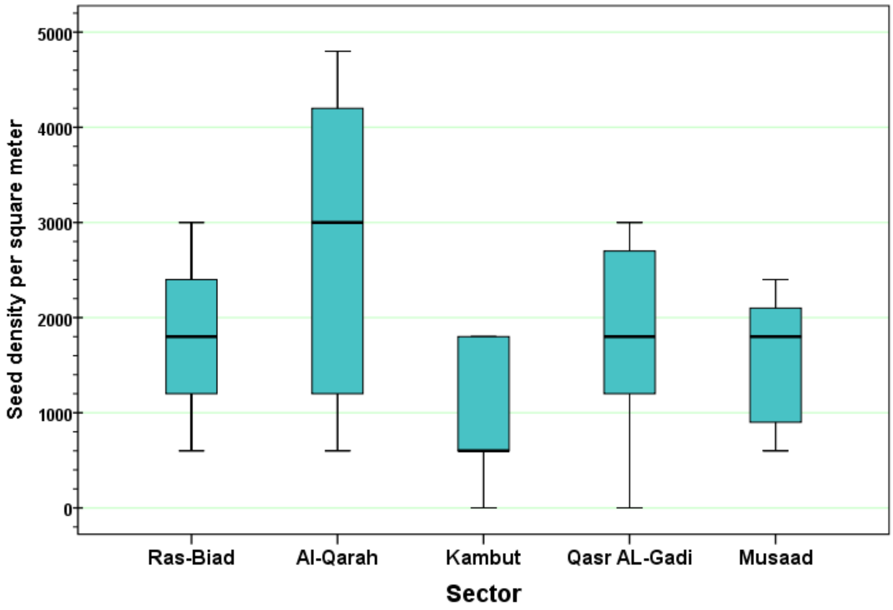

Fig. 2. Box and Whiskers plots showing the median (midline in box) and the first and third quartiles of the data for soil seedbank density at the different sectors in the study area. Bars indicate 95% confidence intervals level.

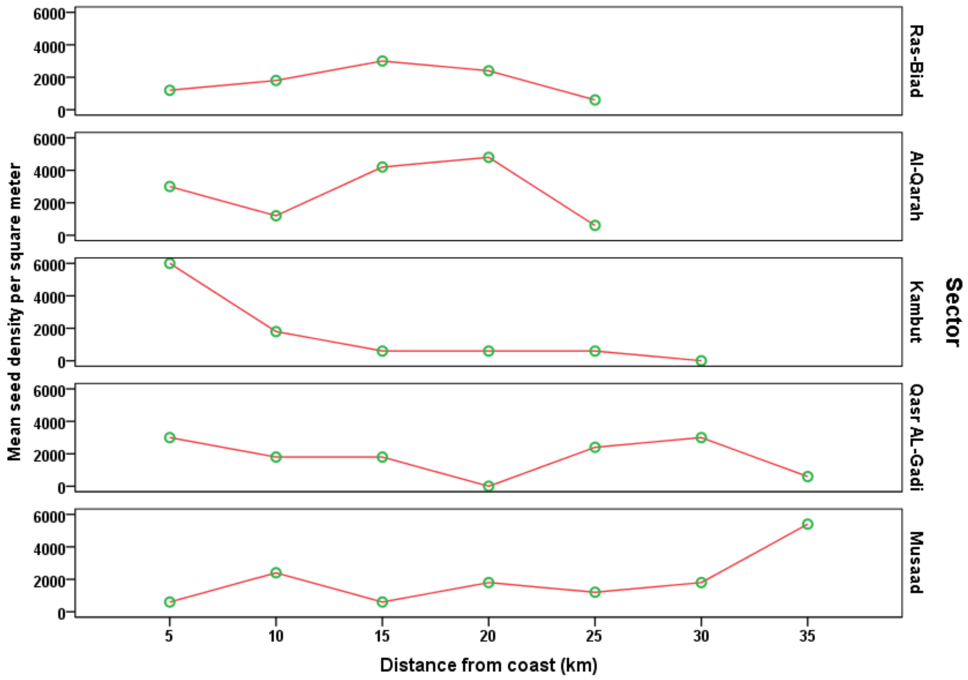

Fig. 3. Lines representing soil seedbank density in the different sectors based on the distance in kilometers from the seacoast southwardly.

The Sakifas and Dykes showed significant differences in seed density when compared to the open areas, the *p*-value were 0.003 and 0.000 respectively. The SSB density in Sakifas ranged between 0 and 27000 seed m^{-2} and behind Dykes ranged between 1800 and 25200 m^{-2} (Table 1). The higher seed density in Sakifas might be ascribed to the clustered seed-rain of some plants species as *Peganum harmala* which dominated these depressions. These such species produce a big quantity of seeds, which is also reported previously by Nelson and Chew (1977). The high seed density in the Sakifas and behind Dykes could be also attributed to the accumulation of soil particles and organic matter including seeds in these low-lying areas from the surrounding higher catchment areas via wind and runoff water. The results illustrated that the seed density in the soil behind Dykes increased with time (Fig. 4). This illuminates the importance and influence of these Dykes overtime on the enrichment of SSB as well as in preserving soil from erosion.

The disparity in landform of the study area plays a major role in the spatial variation of soil, vegetation, and SSB across the landscape. Due to the hydrological system that consists of many depressions and drainage courses, the runoff water after rains is redistributed across the area and the low lands receive a higher quantity of water. Overall, the study area, the Sakifas and valleys retained higher SSB density than the higher-lying areas on the plateau. The highest SSB density was behind Dykes, and the lowest density was in the open land on the plateau (Fig. 5). This is may be attributed to the poorer vegetation cover on the plateau in addition to the impact of soil erosion when compared to the depressions and valleys, which is compatible with the finding of (Peco *et al.*, 1998). Obviously, shrubby areas, depressions, and litter-covered patches retain seeds more effectively than smooth bare areas (Kinloch and Friedel, 2005a). This phenomenon in these zones is considered as an effective factor in increasing vegetation cover and species diversity and enriching SSB density.

When compare the SSB density between the different layers of soil strata, the mean values in the upper layer (0–10 cm) of the Sakifas and Dykes were higher than the lower layer (10–30 cm) (Fig. 6). The higher density of SSB in the upper layer than the lower layer in these low lands (Sakifas and Dykes) may be attributed to the accumulation of soil particles and new seeds with time, as most of the seeds are present in the 0-10 cm soil layer (Bernhardt *et al*., 2008; Edwards and Crawley, 1999).

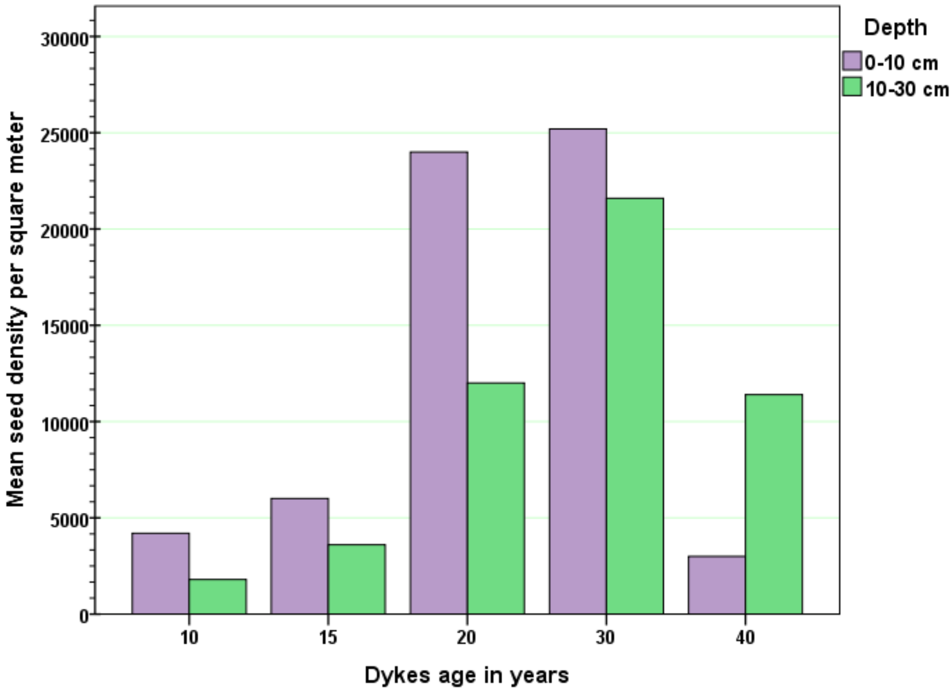

Fig. 4. Bars representing mean soil seedbank density in the soil behind Dykes of different ages (years) showing the importance of these Dykes in retaining and increasing soil seedbank with time.

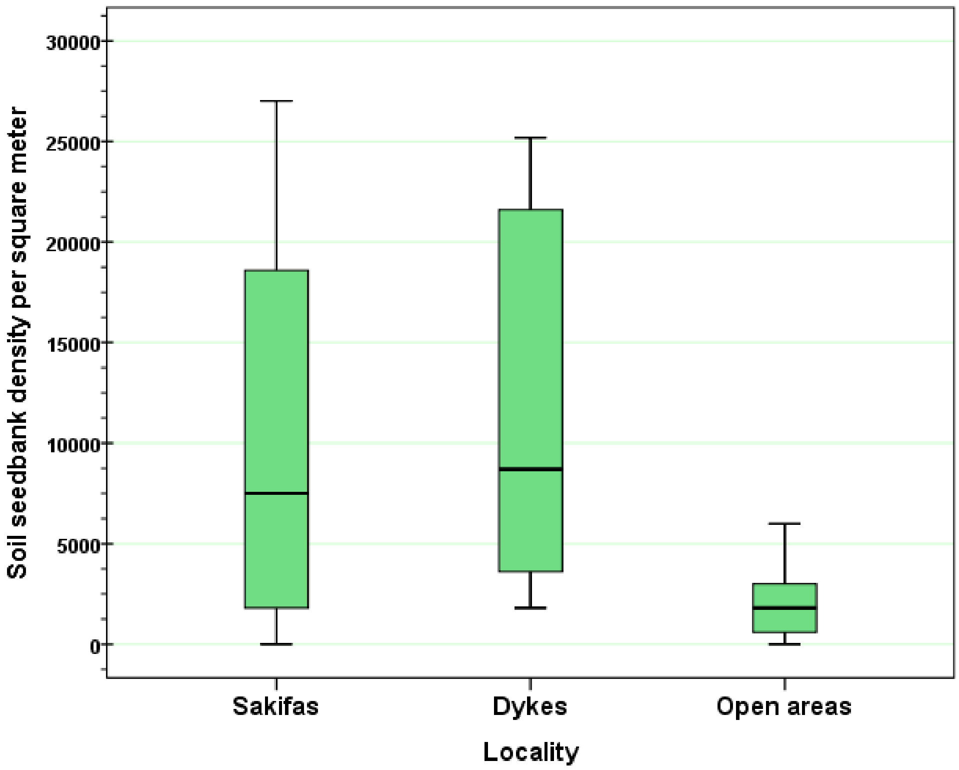

Fig. 5. Box and Whiskers plots showing the median (midline in box) and the first and third quartiles of the data for soil seedbank density in different localities in the study area. Bars indicate 95% confidence intervals level.

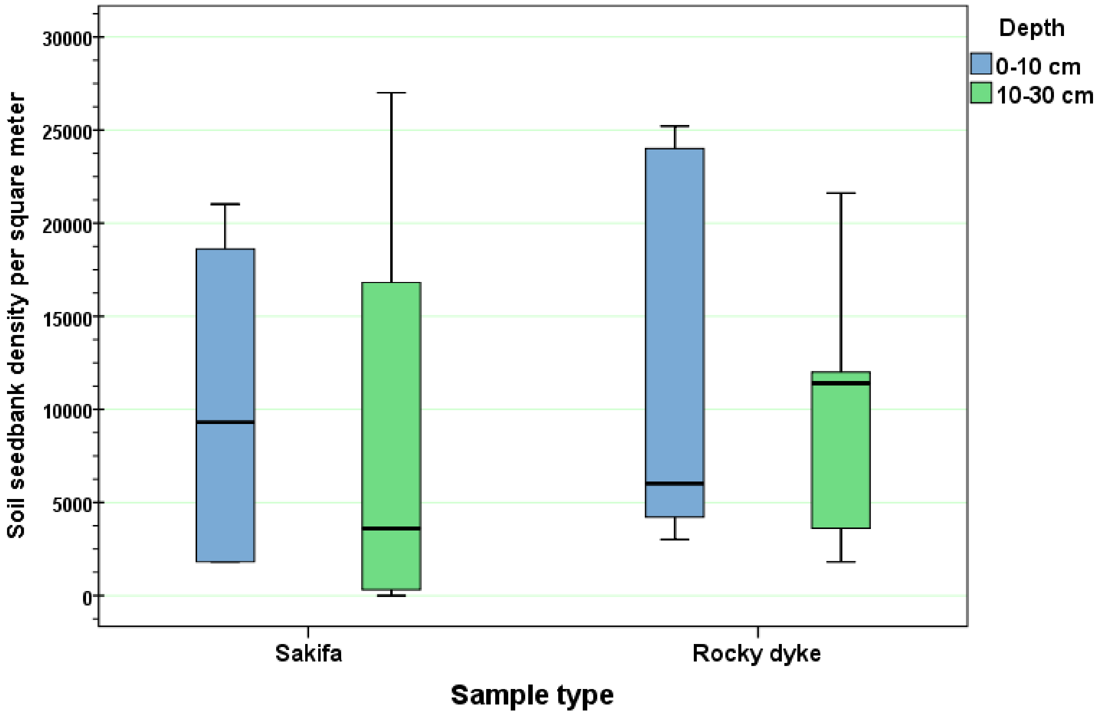

Fig 6. Box and Whiskers plots showing the median (midline in box) and the first and third quartiles of the data for soil seedbank density in different soil depths (0–10 and 10–30 cm) at Sakifas and behind Dykes. Bars indicate 95% confidence intervals level.

3.4 Seed composition

The SSB in any area is an important part of the vegetation (Major and Pyott, 1966). Therefore, the composition of SSB reflects the ground layer vegetation composition, both as a seedling in the field and as mature vegetation (Nafea, 2015). On the other hand, the SSB reveals clues to past vegetation (Leck and Simpson, 1987). New seeds are continuously added by seed-rain; representing a record of the past and present state of vegetation in the area and nearby vicinity (Batanouny *et al*., 1991). The present and future floristic composition and other main characteristics of vegetation are controlled by the ability of seeds present in the soil to germinate and establish as seedlings (Batanouny *et al*., 1991).

In arid rangelands, the SSB is of vital importance as the short-lived and ephemeral plants that dominate the ground layer vegetation in extreme and variable climates exist for the majority of the time as stored seeds only (Inouye, 1991). Some perennial plants also rely on SSBs to enable populations to re-establish after long periods of drought (Kinloch and Friedel, 2005b). This is more so in arid zones as the study area.

Flowering plants in the area constituted of 71 families, 395 species mostly shrubs, dwarf shrubs, and annual herbs (Saaed, 2008) constituted 31% of eastern Libyan species and 23% of Libyan flora. In the SSB, most seeds belonged to Brassicaceae (43.3 %), Chenopodiaceae (10 %), Fabaceae (10 %), and the remainder (36.7 %) (Table 2 and Fig. 7). This is similar to many other arid areas in Libya (El-Mograby *et al*., 2018) and worldwide (Esler 1999, De Villiers *et al*., 2003). These families possess drought-resistance and/or drought-avoidance features in response to the ambient dry conditions of the area. They are also common in areas currently suffering long periods of disturbance, i.e. overgrazing (Hoffmann *et al*. 2015). The scarcity of grasses and legumes seeds in the SSB of the area is unlike similar environments elsewhere (Figueroa *et al*., 2004; Peco *et al*., 1998). This phenomenon can be attributed to a low proportion of grasses and legumes in the above-ground vegetation due to the long history of overgrazing, as they are often very palatable and preferred by livestock (Samuels *et al*., 2016). Although, the seed coat characteristics of legumes are hard and of good quality and enable the seeds to persist for a longer time in the soil, their scarce is mainly due to early grazing before reaching the flowering stage.

It may also be attributed to the effect of predators and/or secondary seed dispersal by wind or runoff after the rain. Seed harvesting insects and rodents are very selective and can affect the composition of SSBs in such arid environments as well (DeFalco *et al*., 2009).

In line with other studies in arid region (Dean and Milton, 1991; Saaed *et al*., 2018; Van Rooyen and Grobbelaar, 1982), annual species were well represented in the SSB, similar to the above-ground vegetation. The annuals are active only during the rainy season, their appearance and abundance change from one year to another depending on the amount and frequency of rain. Annuals are comprised mostly of winter-growing species and are abundant after good rains. Their abundance indicates the desert nature of the climate (Raunkiær 1934; Rossa and Willert 1999). Which, supposed to be more resistant to long summer drought as they pass summer in the form of seeds (Van der Merwe and Van Rooyen, 2011).The perennials, on the other hand, form more or less the permanent framework of the vegetation and do not suffer such drastic temporal changes in presence or abundance.

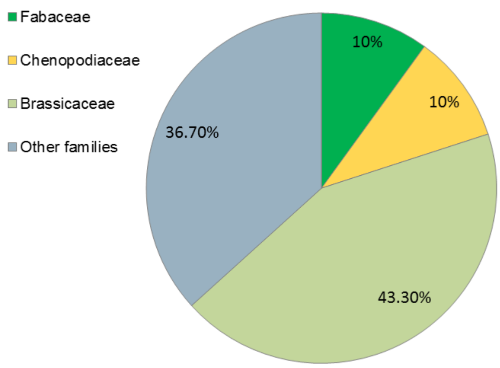

Fig. 7. Percentage of seed families based on the number of species in the entire study area.

Table 2

Species of isolated soil seeds.

Families	Species	Family (%)
Zygophyllaceae	*Peganum harmala*	3.33
Fabaceae	*Onobrychis crista-galli* *Medicago orbicularis* *Medicago truncatula*	10
Leonticaceae	*Leontice leontopetalum*	3.33
Thymelaeaceae	*Thymelaea hirsuta*	3.33
Primulaceae	*Anagallis arvensis*	3.33
Santalaceae	*Thesium humile*	3.33
Resedaceae	*Reseda lutea*	3.33
Papaveraceae	*Papaver rhoeas*	3.33
Brassicaceae	*Diplotaxis harra* *Diplotaxis muralis* *Enarthrocarpus pterocarpus* *Rapistrum rugosum* *Didesmus bipinnatus* *Erucaria microcarpa* *Cakile aegyptiaca* *Carrichtera annua* *Moricandia arvensis* *Biscutella didyma* *Lobularia libyca* *Matthiola tricuspidata* *Sisymbrium irio*	43.33
Polygonaceae	*Emex spinosus*	3.33
Hypecoaceae	*Hypecoum geslini*	3.33
Asteraceae	*Carthamus lanatus*	3.33
Poaceae	*Avena fatua*	3.33
Chenopodiaceae	*Haloxylon scoparia* *Atriplex halimus* *Suaeda vera*	10
14	**30**	**100**

4. Conclusion

Although the study area has suffered long mismanagement and land degradation, it is still retained adequate seed density in the soil. However, the majority of the seeds belonged to annual species. In the open plateau areas, there was no distinct variation in SSB density, which might be a sign of degraded rangelands. The seed density showed a general decline trend from north to southward direction as we approach the desert at the south. Due to the topographical features and big drainage system, which redistribute runoff water after rainfall, the depressions and valleys significantly retained higher seed density when compared to the higher-lying lands on the plateau. This can be noticed as a higher vegetation cover in these low-lying lands. Besides the important role of the Dykes (small hampering dams) in harvesting runoff water and conserve soil, this study demonstrated their importance in increasing SSB density and diversity, which improves with time (Dyke age). Although the study showed adequate seed density in the soil, the dominance of annual and short-lived species in the SSB and the absence of many perennial species may hamper the rehabilitation effort that depends only on the SSB in the area, which may necessitate active interventions for any successful management effort. A conservation program and reseeding of the area with indigenous perennial shrubby species in rainy seasons and in selected areas specially designed for rehabilitation is urgently needed.

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Annexure A: Photos of the different landforms and vegetation framework in the study area.

Topographical depression
(Hafalaze Sakifa) south Kambut village).

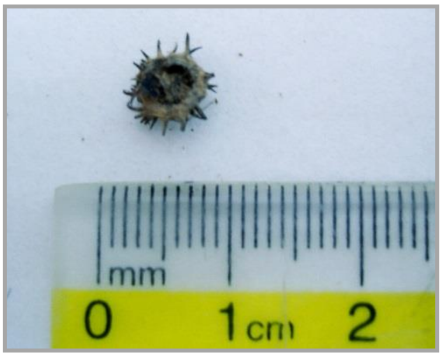
The southern parts of the study area retained the least soil seedbank density due to the low vegetation cover and sever erosion effect.

The natural vegetation on Marmarica Plateau which is the main source of soil seedbank. The species which appear in the photo are: *Thymelaea hirsuta, Atriplex halimus and Haloxylon scoparium.*

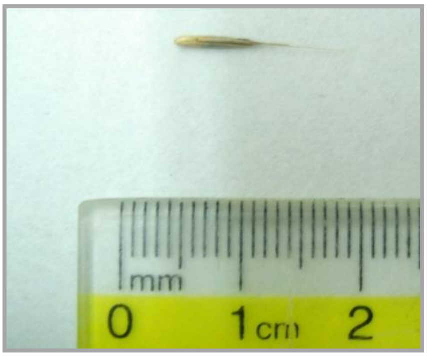
The Dykes, which have been built in the flat area, play a significant role in increasing soil seedbank and conserving the soil.

Annexure B: Samples from the isolated soil seedbank in the study area showing size, shape, and the identification of some of the seeds.

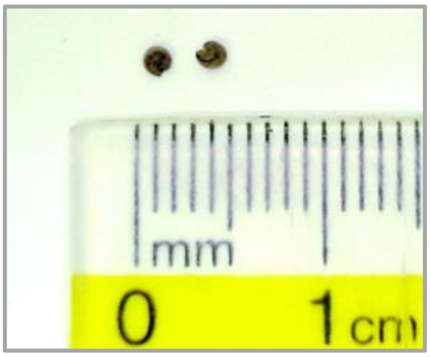
Vicia monantha



Medicago orbicularis



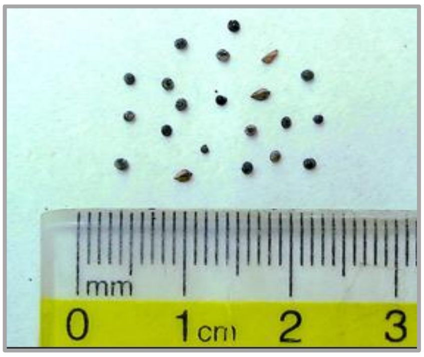
Avena fatua



Malva reflexa

Vicia abgustifoia

Peganum harmala



Different seeds for various plant species

Leontice leontopetalum