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Effect of *Pteropyrum aucheri* Jaub. & Spach shrub on desert soil seed banks, application for restoring the medicinal plant *Pergularia tomentosa* L.

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ABSTRACT

Pergularia tomentosa, a medicinally valuable species in arid regions, persists at critically low densities in recently years in Iran, demanding some conservation action. Its frequent coexistence with *Pteropyrum aucheri*, a shrub known to enhance its aboveground growth, prompted our investigation into *P. aucheri*'s influence on soil seed bank (SSB) dynamics for potential restoration applications. Greenhouse germination of soil samples (beneath vs. outside shrub canopies) revealed 2,164 seedlings, with 68% (1,486) emerging from sub-canopy soils. *P. aucheri* significantly enhanced SSB density at 0-5 cm depth across functional groups: annuals (3,431 vs. 999), perennials (412 vs. 147), forbs (1,835 vs. 726), and grasses (2,048 vs. 424). Poaceae dominated the SSB composition (8 species). The complete absence of *P. tomentosa* germinants, despite its coexistence with *P. aucheri*, reveals a critical restoration constraint. This suggests that SSBs contributes minimally to *P. tomentosa* persistence and canopy-associated SSB enrichment doesn't benefit this target species. While *P. aucheri* creates favorable microsites for general SSB enrichment, its facilitation doesn't extend to *P. tomentosa* recruitment via seed banks. Restoration protocols must therefore combine shrub-retention (to maintain beneficial microhabitats) with active *P. tomentosa* reintroduction to ensure species recovery in degraded arid ecosystems. Active restoration such as direct seeding is essential.

Keywords: Facilitation effects, Medicinal plants, Passive restoration, Seed germination, Iran.

How to cite this paper

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Introduction

An evergreen perennial shrub from the Apocynaceae family, *Pergularia tomentosa* L. has a characteristic scent. Classified as a xerophyte, it grows well in arid and semiarid environments across the globe, especially in sand and gravel plains (Feulner, 2016). The plant usually reaches under one meter in height and is common in various African nations, including Egypt, Jordan, and Kenya, as well as in Asian countries like Iran, Afghanistan, and Saudi Arabia (Babaamer et al., 2013). Notably, *P.*

tomentosa is recognized for its substantial enzyme content, antifungal characteristics, and milk-clotting capabilities (Benyahia et al., 2021). The leaves, in particular, have been noted as a significant source of flavonoids and cardenolides, providing a rich supply of natural antioxidants and antitumor agents (e.g., Lahmar et al., 2022). While *P. tomentosa* offers many benefits, it is classified as endangered with very low population densities in the arid rangelands of the United Arab Emirates, Lebanon, and Iran, necessitating immediate ecological intervention (Allen et al., 2021; Hosseini Kahnuj et al., 2017). In response, restoration initiatives have been suggested in Iran. Hosseini Kahnuj et al. (2017) specifically advocated for dedicated conservation measures, proposing the planting of this species under shrub canopies or alongside waterways to support its preservation and recovery. Commonly used restoration approaches in degraded areas include passive restoration, which leverages the soil seed bank after removing grazing animals, and active restoration, such as replanting. Due to its lower expense, some ecologists argue that passive restoration should be the first strategy attempted. This method depends on a regressive ecosystem's natural succession to restore target species and plant communities without direct human involvement (e.g., Zahawi et al., 2014; Miao et al., 2016). Consequently, prior to engaging in the often-expensive active restoration process, we evaluated the soil seed bank (SSB) in the native habitat of *P. tomentosa* to determine its potential for the passive restoration of this species.Of the Earth's total land area, 36% consists of arid and semi-arid ecosystems, where shrubs function as essential foundation species. Their presence critically shapes ecosystem structure and function (Lortie et al., 2017; Jones et al., 2023). As a fundamental part of these environments, shrubs substantially alter habitat conditions by driving the spatial distribution of soil nutrients (Yang et al., 2024; Soubry et al., 2022). Research indicates that woody plants in such regions can increase mycorrhizal colonization (Armenta Calderón et al., 2019), boost soil microbial activity (Chandregowda et al., 2018), alter patterns of runoff and sediment discharge (Lu et al., 2019), and affect the soil seed bank (SSB) (e.g., Hadinezhad et al., 2021). Specifically, shrubs enrich the SSB under their canopies via two key processes: firstly, the direct trapping of seeds, especially those dispersed by wind, and secondly, by altering the local environment to boost seed production in the understory (Hadinezhad et al., 2021). Acting as ecological facilitators, they generate favorable microsites that aid in seed retention, survival, and germination. The buildup of shrub litter and foliage improves underlying soil quality, which in turn can lead to higher seed production and a greater density of buried seeds (e.g., Gomaa et al., 2023). Consequently, analyzing the SSB and its spatial and temporal dynamics in association with shrubs may provide a useful framework for the targeted conservation and restoration of other species in arid landscapes.The shrub *Pteropyrum aucheri* Jaub. & Spach is among the most significant plants found in arid and semiarid rangelands. Within Iran, this species is distributed across numerous provinces in the Irano-Turanian region, where it can grow up to 1.5 meters, making it one of the tallest shrubs in its habitat (Rechinger and Schiman-Czeika, 1968). It serves as a dominant shrub species on plains, along riversides, and in seasonal waterways (Khosravi Mashizi, 2019). Earlier research has indicated that *P. aucheri* improves soil fertility factors, including total organic matter, though its positive impact on soil is somewhat weaker relative to other shrub species (Motamedi et al., 2013; Erfanzadeh et al., 2016). This study specifically aimed to examine the influence of *P. aucheri* on the density and richness of the soil seed bank (SSB) in its environment, with a focus on assessing its facilitative role on the SSB of *P. tomentosa* for restoration objectives. Both species are indigenous and occur naturally in the region without human cultivation (Ghahreman and Attar, 1999). In the study area, they grow in close proximity, with *P. aucheri* being the dominant species and *P. tomentosa* present in scarce numbers.

Therefore, the objectives of this study were, first, to determine whether *P. aucheri* increases the density and species richness of the total soil seed bank beneath its canopy, and second, to evaluate its potential role in conserving *P. tomentosa* by assessing whether its facilitative effects enhance the SSB of this species. Previous reports have shown that both above and belowground parts of *P. tomentosa* beneath the canopy of *P. aucheri* were significantly larger than those outside the canopy cover (Hosseini Kahnuj et al., 2017), indicating positive facilitative effects on *P. tomentosa*.

Materials and Methods

Study area

The research was conducted in the semi-arid rangeland surrounding Kahnuj city, situated in Kerman province, Iran (57°, 42’ E and 27°, 57’ N) (Fig. 1). The average annual temperature is 25.5°C, ranging average monthly from 13°C in January to 38°C in July. The elevation is 490 meters above sea level, and mature soils are not prevalent in the area, which is predominantly occupied by lithosol and regosol. The average annual 30-years precipitation is 171.8 mm (Nezhad Afzali and Bayatani, 2018). Precipitation has an occasionally distribution in this district. The only rainfall takes place in May, December, January and February. Mean humidity in this district changed irregularly ranging between 31% in early summer and 56% in late autumn and early winter (Vatandoost et al., 2010). According to our analysis of the ten-year meteorological data from Kahnuj Meteorological Station, the average annual precipitation in 2017 was only 44.4 mm, indicating severe drought conditions. This contrasts sharply with the adjacent years (137.9 mm in 2016 and 146.56 mm in 2018) and is about the quarter of the average annual precipitation, underscoring the extremity of the 2017 drought. The flora of the province mirrors its climatic contrast. The highlands feature remnants of a dry natural forest made up of shrubs and trees like *Pistacia atlantica* and *Amygdalus scoparia*. The lowlands are sparsely covered with steppe-like vegetation. *P. aucheri* is a dominant shrub species at certain sites and a co-dominant species at other lowland locations (Dehbandi and Aftabi, 2016). The natural vegetation has suffered degradation due to human activities such as excessive grazing by goats and sheep, approximately 2 animal units per hectare. The primary livestock breeds in the area are the Raeini Cashmere goat and the Kermani sheep (Ansari-Renani et al., 2013).

Morphological characteristics of *Pergularia tomentosa*

P. tomentosa has young branches that twine around older ones. The leaves are pubescent, cordate, petiolate, and opposite, measuring 1.5–30 cm in length. The fruits are 3–6 cm long, consisting of paired spiny follicles that are inflated at the base. The flowers are pedicellate and arranged in umbelloid cymes. The seeds are ovate, truncate at the apex, and densely velvety-pubescent on both sides, with a dark brown coloration. The pappus of the seeds plays a vital role in the wind-aided dispersal of its seeds. The root system comprises woody main roots with small rootlets and lateral branches (Al-Said, 1988; Hosseini et al., 2022).

Site selection and soil sampling

In the rangelands of Sehchah village (Kahnuj city), we identified habitats where *P. tomentosa* and *P. aucheri* co-occur. Within these habitats, three sites were selected, and at each site, five *P. aucheri* individuals were randomly chosen. The distance between two neighboring shrubs of *P. aucheri* was at least 150 meters. Ten soil cores were randomly collected beneath each shrub individual at depths of 0-5 cm and 5-10 cm using a metal soil sampler (5 cm in diameter). Similarly, ten soil cores were randomly gathered from outside the canopy of *P. aucheri* (control) within an area of approximately 0.6 square meters inside a quadrat measuring 0.8 m × 0.8 m (the average diameter of the *P. aucheri* canopy was about 90 cm, covering a soil surface area of 0.6 square meters). Due to the dominant northwestern winds in the study area (and across central Iran), we collected soil cores from the southeastern side of shrubs, opposite the prevailing wind direction, to minimize the influence of shrub litterfall on soil and vegetation in the control samples. Additionally, we ensured that sampling locations were beyond the influence zone of any neighboring shrubs, maintaining a minimum distance of 3 m from shrub canopies at each site (Casals et al., 2013; Erfanzadeh et al., 2021). For each shrub location (under or outside the canopy), soil from the ten cores was combined into a single composite sample per depth (0-5 cm and 5-10 cm). This resulted in an average of 0.98-liter soil sample in each sample for each layer, which exceeds the recommended 0.8-liter soil necessary to determine the species composition of the seed bank (Hutchings, 1986) and applied by researchers in desert ecosystems (e.g. Li et al., 2022). Following the methods of Jiang et al. (2013) and Lee et al. (2024), we collected soil samples once during early autumn (October) after the growing and seeding season. The samples were labeled and transported to the laboratory for cold stratification at 1- 4°C. Following this, they were taken to the greenhouse for a germination test (Miller and Cummins, 2003).

Greenhouse experiment

In the greenhouse, the samples were spread in a thin layer (4 mm) on 40 cm × 40 cm trays filled with sand. The sand was collected from the Caspian Sea beach, ensuring it was free of seeds and other contaminants. Each shrub individual had four trays assigned: one placed under the canopy and one outside the canopy for 'each' soil depth (a total of 60 trays for both soil depths). These trays were randomly positioned on shelves in the greenhouse, exposed to natural light, and were kept moist through tap watering. Additionally, six control trays filled with the same sand but without field soil samples were randomly placed on shelves to detect potential greenhouse and sand contamination (Hazhir et al., 2024). Seedlings were identified upon germination using the nomenclature specified by Rechinger (1964), counted, and either removed or transplanted into pots for further growth and identification if they could not be identified at that stage. After 15 weeks, with no further germination observed, the trays were allowed to dry for two weeks to crumble the samples and expose buried seeds to light. Subsequently, watering recommenced for approximately two months. Germinated seedlings were identified and incorporated into the existing greenhouse data. Finally, the residual soil was inspected for any remaining seeds by examining small random samples from the trays under a microscope and testing seeds with a needle to differentiate between firm (viable) and empty (non-viable) seeds (Erfanzadeh et al., 2010). No viable ungerminated seeds were detected during microscopic examination. Furthermore, the control trays showed zero germination during the entire greenhouse experiment.

Statistical analyses

To analyze the distribution and composition of species in the SSB, non-metric multidimensional scaling (NMDS) ordination (method = Bray-Curtis dissimilarity, k = 2) was applied. The analysis grouped the samples into four categories, each representing a specific depth within a distinct location, where soil samples were collected *under* and *outside* the shrub. Significance of differences were assessed with permutational multivariate analysis of variance (PERMANOVA) using "adonis2" function with 999 permutations and Bray-Curtis distances. In addition, we used "pairwise.adonis" function to statistically compare species composition of SSB between for categories including two sampling locations (under and outside the cushion) and two depths. The NMDS and PERMANOVA analyses were calculated in the R statistical environment (version 4.5.0; R Core Team, 2025) using the 'vegan' package (Oksanen et al., 2020).

Additionally, the total seed density, SSB density of each plant functional group (annuals, perennials, forbs, grasses, and woody species) per square meter and total species richness per soil sample were calculated (Hazhir et al., 2024).

The Shapiro-Wilk test was used to check data normality distribution. For SSB comparisons between sampling location (inside and outside the shrub) and depths, we fitted generalized linear mixed models (GLMMs) with a log-link function and Poisson distribution (Sun et al., 2023). Overdispersion was checked; if present, a negative binomial distribution would have been used. Separate models were fitted for each individual SSB characteristics, with each characteristic serving as response variables and sampling location and depth as fixed effects. All GLMM analyses were performed using the *glmmTMB* package (v1.1.2.3) in R 4.5.0. Additionally, we conducted pairwise comparisons of SSB characteristics between sampling locations in each depth via the *emmeans* package.

Results

Soil seed bank composition and similarity

In total, 2164 seeds were germinated in the greenhouse. Of these, 1486 seeds were discovered under the *P. aucheri* canopy, with 1156 seeds at 0-5 cm and 330 seeds at 5-10 cm soil depths. Additionally, 678 seeds were observed outside the shrub canopy, comprising 341 seeds at 0-5 cm and 337 seeds at 5-10 cm depths. Overall, a total of 37 species from 18 families were detected in the SSB. The largest number of species belonged to the Poaceae and Asteraceae families, with 8 and 6 species, respectively. 29 species were commonly found beneath and outside the shrub canopy, while 3 species were exclusively found under the canopy and 5 species exclusively outside the canopy. A total of 32 species from 17 families were identified in soil samples collected beneath the shrub canopy, while 34 species from 16 families were germinated in soil samples collected outside the shrub canopy (see Appendix 1). Annual species, including *Bromus rechingeri* H. Scholz, *Asteriscus pygmaeus* (DC.) Coss. & Durieu, *Stipa capensis* Thunb., and *Setaria glauca* (L.) Beauv., dominated the SSB composition. The results on the NMDS1 and NMDS2 axes and PERMANOVA test indicated that there were significant differences in scores among the four categories ($F = 20.25$, $p = 0.000$) (Fig. 2). Furthermore, pairwise comparisons among the four categories revealed significant differences in SSB composition between areas under and outside the shrub canopy at the 0-5 cm depth (Table 1).

Soil seed bank density and richness

The results of GLMMs indicated that the main effect of sampling location on total richness and density and, annual and forb densities was significant, with the highest richness and densities observed beneath the canopy. A main effect of depth on total richness, total density and SSB densities of functional groups was observed, with the highest richness and densities found at the surface depth. The interaction effect of sampling location and depth on total richness, total density and density of all functional groups (excluding woody species) was found to be significant (Table 2). The pairwise comparison results revealed that at depth of 0-5 cm, the highest total richness, total density, as well as the density of annuals, forbs, and grasses, were present underneath the shrub canopy (See Fig. 3). There was no significant difference at the density of the SSB of perennials and woody species between underneath and outside the shrub canopy (Fig. 3). Furthermore, at depth of 5-10 cm, only the density of perennials differed significantly between underneath and outside the shrub canopy, with the highest density observed underneath the shrub canopy. The total richness, total density and SSB density of other functional groups did not show significant differences at this depth between underneath and outside the shrub canopy (Fig. 3). Our target species, *Pergularia tomentosa*, was not observed in either greenhouse germination trials, nor was it detected during microscopic analysis of soil samples.

Discussion

Our results partially supported the initial hypothesis: while *Pteropyrum aucheri* exhibited positive facilitative effects on SSBs by increasing total seed richness, density, and functional group densities, these effects were species-specific. Notably, no significant enhancement was observed for our target species, *Pergularia tomentosa* (consistent with species-specific SSB dynamics reported by Suleiman et al., 2023). The findings suggest that shrubs like *P. aucheri* can act as critical seed reservoirs, supporting passive recovery of herbaceous species in degraded arid sites (Auffret et al., 2024). SSBs are essential for ecosystem resilience and reflect regeneration potential, particularly in harsh desert environments where active restoration is often costly due to extreme temperatures and low precipitation (Suleiman et al., 2023). While SSBs enable passive restoration at the community level (Auffret et al., 2024), their efficacy varies across species. For taxa like *P. tomentosa*, showing limited SSB persistence, active restoration may be necessary to ensure (re)colonization post-disturbance.

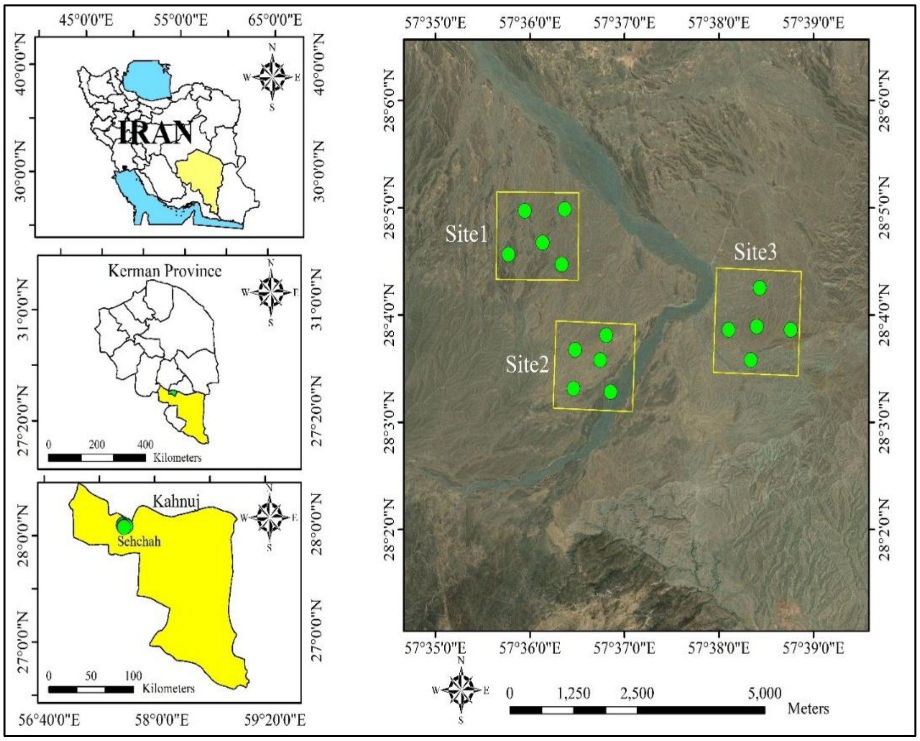

Figure 1. Geographical location of the study area in Kahnuj county, Kerman Province, Iran

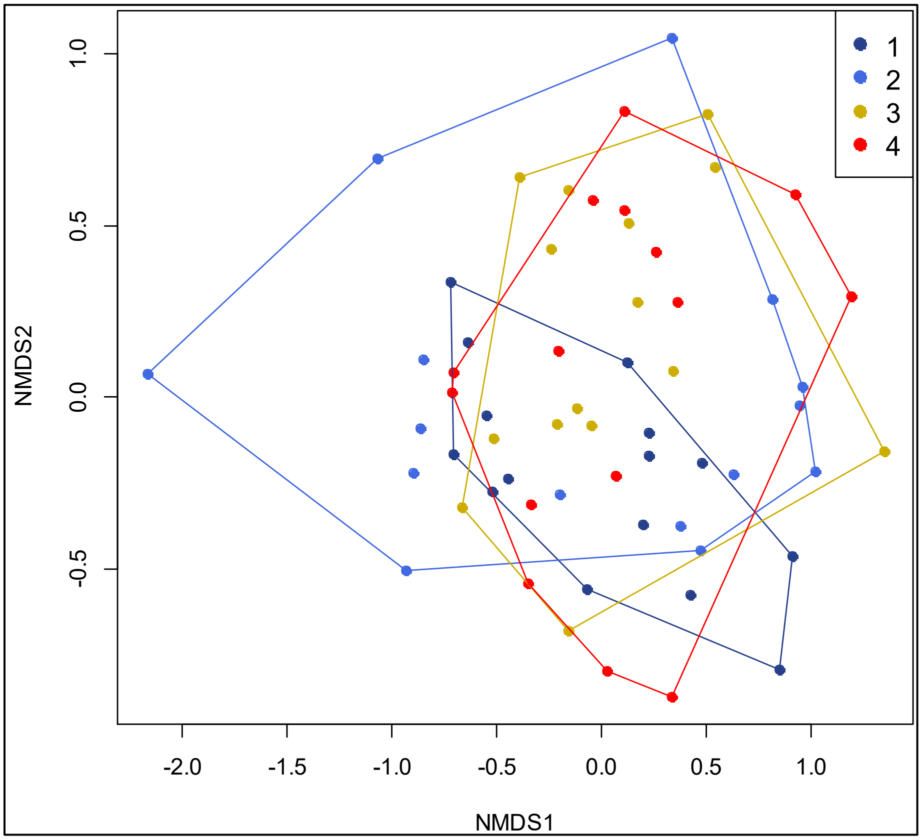

Figure 2. Non-metric multidimensional scaling (NMDS) of the soil seed bank (SSB) composition (Stress = 0.018). 1: Soil samples under *Pteropyrum aucheri* canopy at 0-5 cm depth, 2: Soil samples under *P. aucheri* canopy at 5-10 cm depth, 3: Soil samples outside *P. aucheri* canopy at 0-5 cm depth, 4: Soil samples outside *P. aucheri* canopy at 5-10 cm depth.

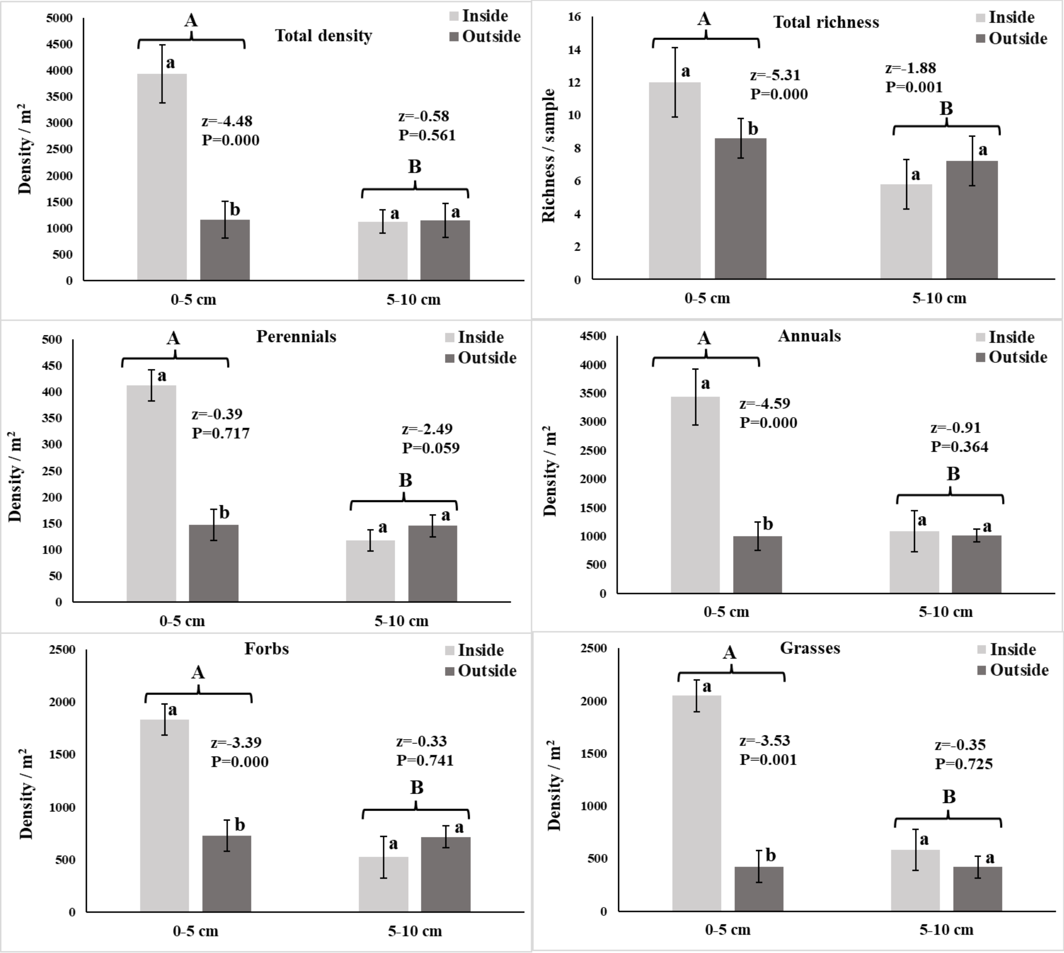

Figure 3. Total density, species richness, and functional group densities of the soil seed bank beneath and outside *Pteropyrum aucheri* canopy. Lowercase letters denote significant differences between microsites (beneath vs. outside canopy) within each soil depth separately, and uppercase letters indicate significant differences between soil depths (main effect of depth).

Table 1. Pairwise comparisons of soil seed bank composition conducted among four categories (beneath vs. outside *Pteropyrum aucheri* canopy at two soil depths) using PERMANOVA with the 'pairwise.adonis' function in the vegan package. InUp: Soil samples under *P. aucheri* canopy at 0-5 cm depth, InLow: Soil samples under *P. aucheri* canopy at 5-10 cm depth, OutUp: Soil samples outside *P. aucheri* canopy at 0-5 cm depth, OutLow: Soil samples outside *P. aucheri* canopy at 5-10 cm depth.

Pairs	df	Sum of Square	F. Model	R2	p value
InUp vs. InLow	1	0.51	1.49	0.05	0.161
InUp vs. OutUp	1	0.77	2.56	0.08	0.004
InUp vs. OutLow	1	0.71	2.25	0.07	0.010
InLow vs. OutUp	1	0.5	1.41	0.05	0.154
InLow vs. OutLow	1	0.32	0.85	0.03	0.606
OutUp vs. OutLow	1	0.04	0.11	0.01	0.997

Table 2. The effects of sampling location (beneath and outside the *Pteropyrum aucheri* canopy) and soil depth (0-5 cm and 5-10 cm) and their interactions on total richness, total density, and soil seed bank density of functional groups.

		Chi-square	p value
Total density	Sampling location	29.59	0.000
	Soil depth	29.47	0.000
	Location × depth	27.09	0.000
Total richness	Sampling location	6.77	0.021
	Soil depth	152.10	0.000
	Location × depth	25.21	0.000
Annual density	Sampling location	40.15	0.001
	Soil depth	27.50	0.002
	Location × depth	25.87	0.000
Perennial density	Sampling location	2.49	0.124
	Soil depth	22.07	0.000
	Location × depth	6.69	0.046
Forb density	Sampling location	5.81	0.033
	Soil depth	8.08	0.000
	Location × depth	6.19	0.043
Grass density	Sampling location	0.39	0.537
	Soil depth	11.85	0.000
	Location × depth	10.56	0.000
Shrub density	Sampling location	0.69	0.418
	Soil depth	11.16	0.000
	Location × depth	0.69	0.418

In this study, the total density of SSB plants is relatively high, aligning with research in Asian deserts (Hadinezhad et al., 2021; Li et al., 2022) and American deserts (e.g. Luis et al., 1998).However, the overall SSB density differs from the observations in other desert regions (e.g. Zhang and Li, 2018), potentially due to the presence of higher cover of woody plants in those areas. Given that the NMDS and PERMANOVA results show distinct groupings for samples from outside and beneath the shrub canopy in the upper soil layer, our findings indicate that *P. aucheri* alters SSB composition while also increasing SSB density under the canopy. Previous studies, such as Tessema et al. (2017), Foronda et al. (2020), and Hadinezhad et al. (2021), have documented how shrubs can augment the number of buried seeds in the soil through direct seed trapping or indirect mechanisms involving other animal or plant species, resulting strong changes in SSB composition. Our research reveals a greater richness and abundance of seeds within shrub canopies compared to open areas in arid ecosystems. Therefore, conservation efforts could prioritize woody species, such as *P. aucheri*, which can bolster population and community regeneration by fostering abundant SSBs for some species within desert communities.

We found that annual plant species accounted for the largest proportion of species in the study area. This finding is consistent with studies on SSBs in the desert ecosystem in China (Zhang and Li, 2018), the Hexi Corridor desert in China (Lu et al., 2019), the grassland desert Sevilleta National Wildlife Refuge in the USA (Loydi and Collins, 2021), and the Ulan Buh desert in Inner Mongolia (Li et al., 2022). Annuals are well-known for their ability to produce persistent SSBs.

In deserts, they exhibit strong tolerance to water deficiency and have a larger niche breadth compared to perennials (Jia et al., 2017). Most annual plants complete their entire life cycle during a short period of rainy times and produce a large number of tiny seeds. Additionally, heavy grazing may contribute to the prevalence of annuals in the SSBs in our area. Li et al. (2024) demonstrated that heavy grazing significantly increased annual plants in the top 5 cm of soil. In addition to producing large quantities of seeds that are dispersed shortly after maturation, annuals employ an "escape" strategy by falling into cracks and depressions in the soil to avoid seed consumption (Li et al., 2008). Consequently, annuals play a crucial role in mitigating species extinction and vegetation degeneration in severe desert environments through their abundant SSBs (Li et al., 2008).

Analysis of the soil seed bank in the study area revealed that the Poaceae family was predominant. This outcome is consistent with earlier investigations in the African savanna (Savadogo et al., 2017) and semi-arid grasslands of China (Li et al., 2024). In the African savanna context, genera like *Aristida* and *Eragrostis* were common in SSBs, whereas *Leymus chinensis*, *Stipa grandis*, and *Cleistogenes squarrosa* were identified as the most abundant Poaceae species in the Chinese study (Li et al., 2024). Further supporting this pattern, De Andrade and Miranda (2014) noted that Poaceae species (64%) often dominate post-disturbance in savanna environments, and Li et al. (2014) recorded *Eragrostis pilosa* as a frequent SSB component. Grasses are known for forming highly persistent seed banks, a trait linked to their production of numerous small seeds (Erfanzadeh, 2020). In contrast, the abundance of shrub seeds in the SSB was remarkably low, with greenhouse trials yielding only eight germinants from three species—a pattern frequently observed in desert seed bank research. Woody plants typically form transient seed banks; their seeds are often attractive to predators, struggle to incorporate into the soil due to their larger size, and are produced in limited quantities (Erfanzadeh, 2020).

Surprisingly, no of *P. tomentosa* seeds germinated in the greenhouse, despite their efficient wind-mediated dispersal via pappus, which facilitates trapping by shrub canopies. Furthermore, meteorological data revealed significant variations in seed production conditions for this species. Notably, no germinants emerged, whether in soil collected from open areas or beneath *P. aucheri*, suggesting that seed bank germination alone is insufficient for restoring all plant species in SSBs. While this species likely forms a transient seed bank similar to other woody plants, its absence in the SSB may reflect methodological limitations in seed detection due to sampling constraints. Practical limitations often result in only sampling a small percentage of the total area of a study site, leading to an underestimation of species richness and density within the seed bank for a particular species (Bossuyt and Honnay, 2008). Consequently, there is a need for more comprehensive future studies to validate methodologies and increase the number of soil samples collected in the desert.

Conclusion

Of particular significance in desert ecosystems, this research underscores the vital role of preserving facilitator shrub species, which substantially increase both the density and richness of the soil seed bank to the advantage of herbaceous plant communities. The results highlight the crucial function these shrubs serve in restoring overgrazed landscapes by enriching the SSB. *P. tomentosa*, however, represents a significant exception to this pattern. Despite the general enhancement of the SSB beneath shrubs, this medicinal species does not sustain a viable seed bank, even with facilitation. Its absence from both the SSB and the standing vegetation is concerning and suggests a risk of extinction, as natural regeneration seems improbable. Therefore, although the conservation of shrubs is fundamental for broader ecosystem recovery, the persistence of *P. tomentosa* likely depends on targeted, active measures such as direct seeding or transplantation.

Appendix 1. Soil seed bank density (seeds/m^2) for each plant species beneath and outside *Pteropyrum aucheri* canopy at two soil depths in Kerman Province, Iran. A: annual, B: biennial, P: perennial; Cr: cryptophyte, He: hemicryptophyte, Ph: phanerophyte, Th: therophyte.

					Under the canopy		Outside the canopy	
Plant Species	Plant Family	Growth form	Growth span	Growth form	0-5 cm	5-10 cm	0-5 cm	5-10 cm
Anagallis arvensis	Primulaceae	Forb	A	Th	7	7	10	7
Anthemis austro-iranica Rech.f., Aellen&Esfand.	Asteraceae	Forb	A	Th	0	0	3	0
Asphodelus tenuifolius Cav.	Xanthorrhoeaceae	Forb	A	Th	662	340	302	336
Asteriscus pygmaeus (DC.) Coss. & Durieu	Asteraceae	Forb	A	Th	132	34	92	78
Biscutella didyma L.	Brassicaceae	Forb	A	Th	10	0	3	0
Bromus rechingeri H. Scholz	Poaceae	Grass	A	Th	808	170	187	170
Bromus tectorum L.	Poaceae	Grass	A	Th	65	20	3	3
Calotropis procera (Aiton) W.T.Aiton	Asclepiadaceae	Shrub	P	Ph	7	0	7	0
Digitaria nodosa Parl.	Poaceae	Grass	P	He	3	0	0	0
Erodium cicutarium (L.) L'Hér.	Geraniaceae	Forb	A	Th	78	24	10	14
Festulolium miliaceum L.	Poaceae	Grass	A	Th	0	0	10	10
Filago desertorum Pomel	Asteraceae	Forb	A	Th	3	0	0	3
Forsskaolea tenacissima L.	Urticaceae	Forb	P	He	17	3	51	61
Galium uperceratum L.	Rubiaceae	Forb	A	Th	3	3	10	10
Helichrysum sp.	Asteraceae	Forb	P	He	3	0	3	0
Herniaria hirsuta subsp. cinerea (DC.) Arcang.	Caryophyllaceae	Forb	A	Th	163	44	61	61
Hyparrhenia hirta (L.) Stapf	Poaceae	Grass	P	He	14	10	10	7
Lappula sinaica (A.DC.) Asch. & Schweinf.	Boraginaceae	Forb	A	Th	7	3	0	3
Leptaleum filifolium (Willd.) DC.	Brassicaceae	Forb	A	Th	7	14	3	7
Lepyrodiclis sp.	Caryophyllaceae	Forb	A	Th	0	3	14	20
Lycium edgeworthii Sch.-Tem.	Solanaceae	Shrub	P	Ph	0	0	3	0

Malva sylvestris L.	Malvaceae	Forb	P	Cr	3	0	0	0
Medicago sativa L.	Leguminosae	Forb	P	Cr	14	20	0	0
Misopates orontium (L.) Raf.	Scrophulariaceae	Forb	A	Th	68	71	34	34
Notoceras bicorne (Aiton)	Brassicaceae	Forb	A	Th	20	3	3	3
Paronychia arabica (L.) DC.	Caryophyllaceae	Forb	A	Th	190	65	34	31
Pimpinella barbata (DC.) Boiss.	Apiaceae	Forb	A	Th	14	3	10	7
Plantag opsyllium L.	Plantaginaceae	Forb	A	Th	82	24	17	20
Plantago trichophylla L.	Plantaginaceae	Forb	A	Th	51	14	31	31
Reichardia tingitana (L.) Roth	Asteraceae	Forb	A	Th	0	0	3	0
Setaria glauca (L.) Beauv.	Poaceae	Grass	A	Th	459	109	61	65
Sisymbrium irio L.	Brassicaceae	Forb	A	Th	88	31	7	3
Spergularia diandra (Guss.) Heldr.	Caryophyllaceae	Forb	A(B)	Th	31	3	3	0
Stipa capensis Thunb.	Poaceae	Grass	A	Th	482	102	85	95
Stipa parviflora Desf.	Poaceae	Grass	P	Cr	431	0	71	65
Urospermum picroides (L.) Scop. ex F.W.Schmidt	Asteraceae	Forb	P	He	0	0	7	0
Ziziphus nummularia (Burm.f.) Wight & Arn.	Rhamnaceae	Shrub	P	Ph	3	0	7	0

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