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Original Paper

Weed seed bank dynamics during a three year crop rotation in Mediterranean semi-arid region (Northwestern Algeria)

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A better understanding of the soil seed bank system could help agricultural systems plan more effective weed control strategies. This study aims to assess the qualitative and quantitative soil weed seed bank composition in a cereal crop grown in northern-western Algeria under conventional farming systems and semi-arid conditions. The study was evaluated each autumn for three years (2018–2019–2020). Soil samples were collected from the field zone at each depth category (0–5 cm, 5–15 cm, and 15–30 cm) and evaluated in a temperature-controlled greenhouse over six months using the seedling-emergence method. Several indexes were used to evaluate the seed bank density, diversity, and species composition. Thirty weed plants from seventeen families were recovered from the soil seed bank. Asteraceae and Poaceae were the most dominant families. The density of seed bank species varied significantly between the superficial (0–5 cm), middle depth (5–15 cm), and deeper soil depth (15–30 cm). The averages were 14,776.08 m^{-2} (19.01%), 36,977.04 m^{-2} (47.59%) and 25,943.06 m^{-2} (33.4%), respectively. According to our findings, *Chenopodium vulvaria*, *Amaranthus blitoides*, and *Convolvulus arvensis* were abundant. As a result, the weed seed bank research was critical in predicting the size and distribution of viable weed seeds in the soil. It aids in developing a sustainable weed management program in semi-arid areas by providing early warnings of weed community composition and allowing for informed decisions on long-term weed control.

Keywords: soil seed bank, seedling emergence method, species diversity, density, semi-arid area

1 Introduction

Weed control is one of agriculture's major challenges and is an expensive, complex, and controversial problem (PAN, 2018).With limited effectiveness, various weed management methods can regulate or control their dynamics. Herbicides typically play a critical role in ensuring agricultural production in conventional cropping systems due to their high efficiency and low cost (Mahé et al., 2022). However, with the growing threat of herbicide-resistant weeds (Carpenter et al., 2010). As a result, weed management requires integrated control methods based on manipulating the soil seed bank, more commonly integrated herbicide management (Schwartz-Lazaro et al., 2017).

Understanding the soil weed seed bank is required for developing more effective weed control strategies in agricultural systems (Forcella et al., 1993). Long-term weed community monitoring and seed bank dynamics are major concerns when implementing new cropping systems and are critical for assessing weed management practices' efficacy, sustainability, and applicability (Zheng et al., 2021). According to Maranon (2001), the soil seed bank is a reservoir of viable seeds present in the soil that significantly impacts the space-time distribution, dynamics, and structure of Mediterranean plant communities (Figueroa et al., 2004). Understanding the structure of weed seed banks will thus aid in predicting weed community structure and implementing appropriate control measures (He et al., 2019).

There have been few studies on seed banks in cereal crops in Mediterranean semi-arid areas, with most of the research focusing on annual legumes and grasslands.

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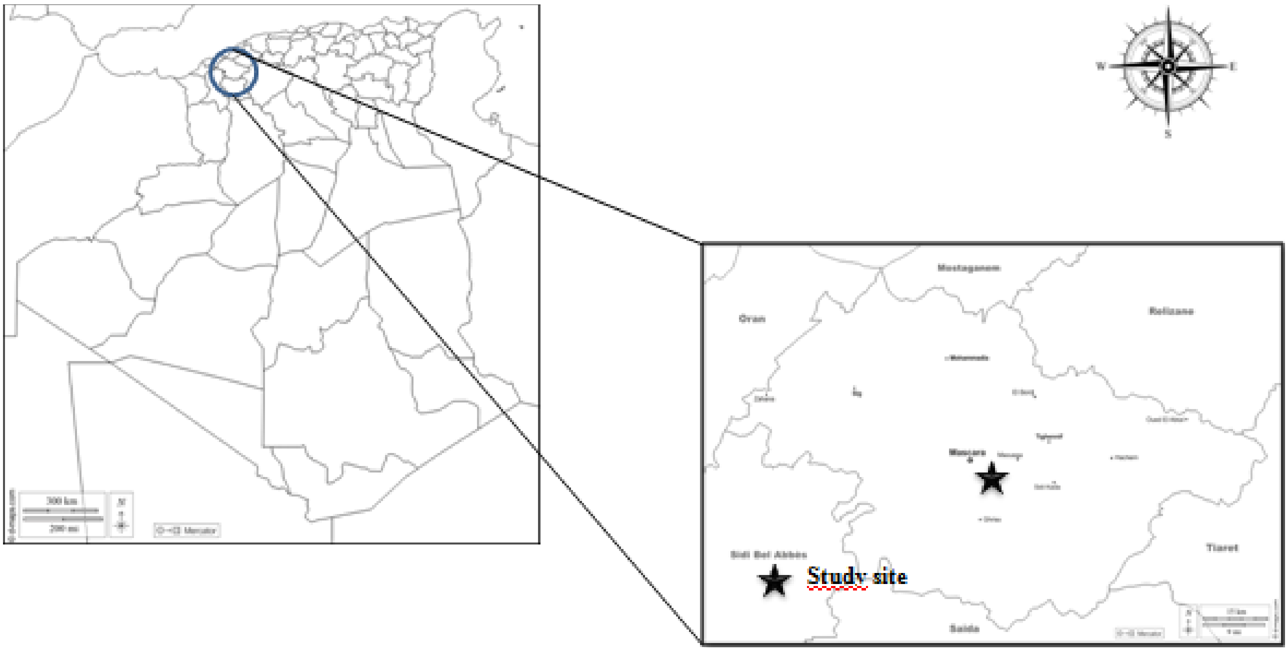


Figure 1 Study site location in Mascara (Algeria)

In this three-year study, we focused on the soil seed bank in a northwestern semi-arid region of Algeria dominated by winter cereals. This research is part of a larger project to develop integrated weed management. To this end, this work aims to determine (i) the floristic composition and structure of the germinable soil seed bank, as well as (ii) the abundance and diversity of the soil seed bank in a winter wheat field in northwestern Algeria.

2 Material and methods

2.1 *Experimental area*

The field experiment was conducted for three consecutive years (2018–2019–2020) at the experimental farm of the Faculty of Natural Sciences and Life, University of Mascara, at Mascara (Algeria) (latitude 35° 22′ N; 00° 10′ E) (Figure 1). The elevation of the sample site was 474 m. The local climate is typically Mediterranean semi-arid, the mean annual temperature ranges between 18.3 and 19.1 °C, and rainfall ranges between 193.1 and 447.5 mm (Figure 2). Crop rotation was established on the farm on arable land of 50 ha (Table 1). The soil seed bank was assessed in a 1 ha experimental area. At the beginning of the experiment, the soil consisted of 43%, 47% silt, and 10% sand. The organic matter content was 1.9%, and the total nitrogen content was 0.09% (Table 2). The experimental field had been cultivated in a cereal-legumes-fallow crop rotation under natural rainfall conditions and surrounded by perennial vegetation (olive orchard).

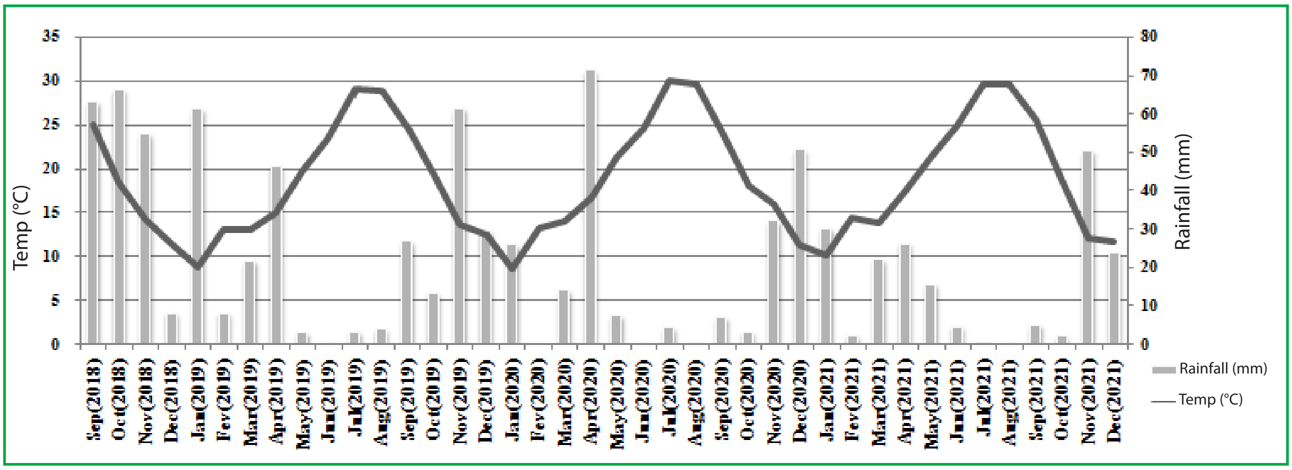


Figure 2 Meteorological data recorded during the study period

Table 1 Crop rotation in the 1 ha experimental area (2017–2020) under conventional management

Year	Crop	Principal farming operations
2017	fallow	no-till
2018	winter durum wheat	plough (August) soil tillage before sowing (November); sowing in December, followed by rolling; mineral fertilization (March); chemical weed control (April); harvesting in July
2019	leguminous: lentils	winter soil tillage before sowing (November); chemical weed control (April); harvesting in August
2020	winter durum wheat	winter soil tillage before sowing (November); sowing inDecember, followed by rolling; chemical weed control (April); harvesting in July

Table 2 Soil physico-chemical characteristics of the studied field

Parameters	Values
% clay	43
% silt	47
% sand	10
Textural class	silty clay
Total $CaCO_3$ (%)	6.7
Active $CaCO_3$ (%)	2.2
MO (%)	1.9
Total N (%)	0.09
Available N (ppm)	48
Available P_2O_5 (ppm)	50.1
Available K_2O (ppm)	318.8
Caption exchange capacity (CEC) (meq.100 g^{-1})	11.1
Ca^{++} (meq.100 g^{-1})	9
Mg^{++} (meq.100 g^{-1})	0.82
K^+ (meq.100 g^{-1})	0.677
Na^+ (meq.100 g^{-1})	0.4
Hydraulic conductivity (cm.h^{-1})	0.25

2.2 Sampling

Soil sampling was done in November for the next three years (2018–2019–2020) before cultivation operations. Each year, 50 soil cores were collected randomly from the experimental plots of 1 ha using a 5 cm diameter auger. Soil samples were collected along a W-shaped transect at three depths (0–5 cm, 5–15 cm, and 15–30 cm); each core contained 392.5 cm^3 of soil. A total of 600 cores were sampled. Each depth subsample was mixed and passed through a 4 mm sieve to remove plant fragments and stones. The soil samples were air-dried and stored at laboratory temperature until further processing.

2.3 Weed soil seed bank germination and identification

In the greenhouse, the seedling emergence method was used to estimate the number of viable seeds in the soil (Shang et al., 2013). According to Kumar et al. (2022), the seed extraction technique accurately assesses the species' composition. Soil from each depth was spread as a 3 cm deep layer over sterilised coarse sand in 50 × 50 × 5 cm germination trays. The germination trays were kept in a non-heated greenhouse under natural light conditions for six months (every year from December to June) and irrigated thrice weekly. To keep moss and algae at bay, soil samples were mixed once a week to bring non-germinated seeds to the surface. Moreover, emerging weed seedlings were counted and removed as soon as they were identified to avoid allelopathic effects on the germination of other seeds in the soil samples. Seedlings that proved difficult to identify were transplanted and grown in new pots until they could be identified.

Each seedling was identified using photographs and plant specimens from Gérard de Belair's herbarium (National Superior School of Agronomy in El Harrach, Algeria).When no new seedlings appeared for two weeks, soil samples were washed with water through a 250 m mesh. The sieved plant materials were air dried before the extracted materials (seeds, plant residues, and stones) were manually separated using an MS5 stereo-microscope (Leica Microsystems, Wetzlar, Germany). After stratifying at 4 °C for a month to break seed dormancy, they were soaked for 2 hours in a 500 mg.L^{-1} gibberellic acid (GA3) (Sigma, USA) solution to accelerate germination. To encourage the germination of any remaining viable seeds from each sample, seeds were placed in Petri dishes on filter paper and watered with distilled water. The experiment was terminated when no further seedling emergences were recorded for more than eight weeks and were deemed non-viable.

2.4 Data analysis

Several indices were calculated using the following formulas to describe floristic diversity, species density, soil seed bank depth, and seasonal variation in the experimental area:

The weed seed density (*Ds*) (Olaniyan et al., 2018):

$$Ds = \frac{number\ of\ seeds}{m^2}$$

Richness index (*R*) (Margalef, 1973):

$$R = \frac{(T-1)}{\ln N}$$

Simpson's Index of Dominance (*D*) (Parish et al., 1995):

$$D = 1 - \sum pi^2$$

Shannon diversity indices (*H'*) (Zhang et al., 2017):

$$H' = -\sum pi \ln pi$$

Pielou evenness index (*J*) (Zhang et al., 2017):

$$J = \frac{H'}{H'\max}$$

Sørenson community similarity index (He et al., 2019):

$$Cs = \frac{2c}{a+b}$$

where: *pi* – the relative importance value of species *i*; *pi* = *ni*/*N*; *ni* – the total number of seeds of species *i*; *N* – the total number of seeds; *T* – the total number of species inthesample; *c* – the number of a particular species in communities A and B, and a and b are the total number of species in communities A and B

Analysis of variance (ANOVA) was used to determine the effects of the season (S) and soil depth on the density of the seed bank. The statistical data analyses were performed using Statistica 8.1 software at a significance level of 5%.

3 Results and discussion

3.1 Floristic composition and structure of seed bank

Thirty (30) weed species belonging to 17 families and 28 genera were identified (Table 3), with 27 annuals and three perennials. Therophytes were the most common biological type (80%), followed by hemicriptophytes (16.67%) and geophytes (3.33%). The Asteraceae (20%), Poaceae (16.67%), Chenopodiaceae, Apiaceae, Brassicaceae, and Polygonaceae (6.66%) families have the most species. The remaining families (Caryophyllaceae, Convolvulaceae, Fabaceae, Fumariaceae, Geraniaceae, Lamiaceae, Malvaceae, Papaveraceae, Plantaginaceae, Amaranthaceae, and Rubiaceae) each had only one species (3.33%) (Table 4). The family composition varied across the three seasons, with a similarity index ranging from 0.8 to 0.57. The highest was found between the soil seed banks of S1 and S2 (*Cs* = 0.8), S2 and S3 (*Cs* = 0.67), and S1 and S3 (*Cs* = 0.57). Broadleaf weeds dominated the seed bank composition (83.33%), followed by grasses (16.67%). The seasonal distribution of broadleaf weed seeds was erratic. The most (17 species) were discovered in the second season at 0–5 cm soil depth. The total grass weed seed was found in descending order from 5 cm to 30 cm in soil samples from all seasons, and the pressure was at 0–5 cm soil depth, with four species. However, no grass species were discovered in all depths during the third season. *Chenopodium vulvaria* was the most dominant broadleaf weed, present in all depths throughout the three seasons, while *Hordeum murinum* was the dominant grassy weed, present only in S1 and S2 (Table 5).

3.2 Density and seasonal variation in the seed bank

The results reveal that season and depth had a significant ($p < 0.05$) effect on soil seed bank density. During three consecutive years, seed density was higher in S2 (104,370.54 m^{-2}) than in S1 (86,935.86 m^{-2}), and S3 (41,782.14 m^{-2}), while it was higher in 5–15 cm than in 15–30 cm and 0–5 cm depths, with 110,931.12 m^{-2} (47.59%), 77,829.18 m^{-2} (33.4%), and 44,328.24 m^{-2} (19.01%), respectively.

The total seedling density across all seasons and soil depths was 233,088.54 (Table 6, Figure 4). *Sinapis arvensis*, *Erodium malacoides* (L.) L'Hér., *Scandix pecten veneris* and *Lolium multiflorum* seeds were recovered only from S1. *Tricicum durum* was discovered in the second season, while *Anacyclus clavatus* (Desf.) Pers. and *Malva parviflora* were discovered in the third. *Amaranthus blitoides* S. Watson, *Convolvulus arvensis*, *Lamium amplexicaule*, *Chenopodium vulvaria*, and *Fumaria parviflora* Lamcan also be noted. Furthermore, *Capsella bursa-pastoris* was discovered in the seed banks of all three seasons. Figure 3 shows information on the six species with the highest density. Throughout the study period, the density of weed seeds in the experimental fields followed a similar trend across the three layers, with seed density in the middle layer exceeding that in the deepest and upper layers.

In S1 (2018/2019), 22 weed species were recorded, belonging to 14 families emerged. Seed density was the highest in the middle soil layer (5–15 cm) (46,046.88

Table 3 Floristic composition, weed morphology and life form of the weed seed bank, for all the three study year

N°	Family	Scientific name	Common name	A/P	Weed morphology	Life form
1	Amaranthaceae	*Amaranthus blitoides* S. Watson	mat amaranth	A	B	T
2	Apiaceae	*Scandix pecten veneris*	shepherd's needle	A	B	T
3		*Torilis nodosa* (L.) Gaertn.	knottedhedge-parsley	A	B	T
4	Asteraceae	*Anacyclus clavatus* (Desf.) Pers.	white buttons	A	B	T
5		*Picnomon acarna* (L.) Cass	soldier thistle	A	B	T
6		*Scolymus hispanicus* L.	common golden thistle	A	B	H
7		*Silybum marianum* (L) Gaertn.	milk thistle	A	B	H
8		*Sonchus asper* (L.) Hill	prickly sow thistle	p	B	H
9		*Sonchus oleraceus* L.	common sow thistle	p	B	H
10	Brassicaceae	*Capsella bursa-pastoris* (L.) Medik	shepherd's-purse	A	B	T
11		*Sinapis arvensis* L.	wild mustard	A	B	T
12	Caryophyllaceae	*Vaccaria hispanica* (Mill.)	cowcockle	A	B	T
13	Chenopodiaceae	*Chenopodium album* L.	lambs quarters	A	B	T
14		*Chenopodium vulvaria* L.	stinking goosefoot	A	B	T
15	Convolvulaceae	*Convolvulus arvensis* L.	field bindweed	P	B	G
16	Fabaceae	*Medicago polymorpha* L.	burclover	A	B	T
17	Fumariaceae	*Fumaria parviflora* Lam	fine-leaffumitory	A	B	T
18	Geraniaceae	*Erodium malacoides* (L.) L'Hér.	mediterranean stork's bill	A	B	T
19	Lamiaceae	*Lamium amplexicaule* L.	common henbit	A	B	T
20	Malvaceae	*Malva parviflora* L.	cheeseweed	A	B	H
21	Papaveraceae	*Papaver rhoeas* L.	common poppy	A	B	T
22	Poaceae	*Avena sterilis* L.	wild oat	A	G	T
23		*Hordeum murinum* L.	wall barley	A	G	T
24		*Lolium multiflorum* Lam.	italian ryegrass	A	G	T
25		*Phalaris paradoxa* L.	awned canary-grass	A	G	T
26		*Tricicum durum* (Desf.) Husn	wheat	A	G	T
27	Polygonaceae	*Emex spinosa* (L) Campd.	spiny emex	A	B	T
28		*Polygonum aviculare* L.	common knotgrass	A	B	T
29	Rubiaceae	*Galium aparine* L	cleavers	A	B	T
30	Scrophulariaceae	*Veronica hederifolia* L.	ivyleaf speedwell	A	B	T

A – annual or biennal; P – perennial; B – broadleaf; G – grasses; T – therophyte; G – geophyte; H – hemicriptophyte

seedlings.m^{-2}) and the lowest in the superficial layer (0–5 cm) (12,610.62 seedlings.m^{-2}). The seeds of species recovered only from the first layer (0–5 cm) were *Phalaris paradoxa* and *Lolium multiflorum*, species including *Picnomon acarna* (L.) Cass, *Papaver rhoeas*, *Erodium malacoide* L'Hér. *Chenopodium album* were recovered only from the soil seed bank's second layer (5–15 cm). Seedlings including *Scandix pecten veneris*, *Silybum marianum* and *Torilis nodosa* (L.) Gaertn. were found only in the third layer (15–30 cm). *Hordeum murinum*, *Capsella bursa-pastoris*, *Chenopodium vulvaria*, *Convolvulus arvensis*, *Amaranthus blitoides* S. Watson and *Fumaria parviflora* were found in all layers.

In S2 (2019/2020), 23 weed species were recorded, belonging to 14 families emerged. Seed density was the highest in the middle soil layer (5–15 cm) (44,884.08 seedlings.m^{-2}) and the lowest in the superficial layer (0–5 cm) (23,565.3 seedlings.m^{-2}). The seeds of species recovered only from the first layer (0–5 cm) were *Papaver rhoeas*, *Silybum marianum* and *Medicago polymorpha*. *Vaccaria hispanica* (Mill.) was recovered only from the second layer (5–15 cm). *Tricicum durum* was found only in the third layer (15–30 cm). Species

Table 4 Number of species in different families over the three seasons

Family	S1	S2	S3
Poaceae	4	4	0
Asteraceae	3	5	3
Amaranthaceae	1	1	1
Chenopodiaceae	2	2	1
Apiaceae	2	0	0
Brassicaceae	2	1	1
Polygonaceae	1	2	1
Caryophyllaceae	1	1	0
Convolvulaceae	1	1	1
Fabaceae	1	1	0
Fumariaceae	1	1	1
Geraniaceae	1	0	0
Lamiaceae	1	1	1
Malvaceae	0	0	1
Papaveraceae	1	1	0
Plantaginaceae	0	1	1
Rubiaceae	0	1	1
Total number of species	22	23	13

Table 5 Number of species under the weed morphology

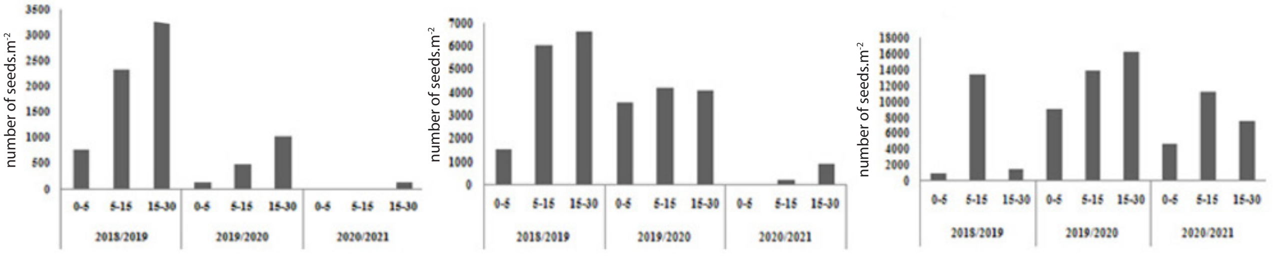
Season	Depth (cm)	Broad leaf	Grass
S1	0–5	8 (66.67%)	4(33.33%)
	5–15	15(88.24%)	2(11.76%)
	15–30	11(91.67%)	1(8.33%)
S2	0–5	17(85%)	3(15%)
	5–15	14(82.35%)	3(17.65%)
	15–30	11(91.67%)	1(8.33%)
S3	0–5	5(100%)	0
	5–15	8(100%)	0
	15–30	10(100%)	0

including *Amaranthus blitoides* S. Watson, *Chenopodium album*, *Chenopodium vulvaria*, *Convolvulus arvensis*, *Lamium amplexicaule*, *Veronica hederifolia* L., *Polygonum aviculare* and *Capsella bursa-pastoris* were found in all layers.

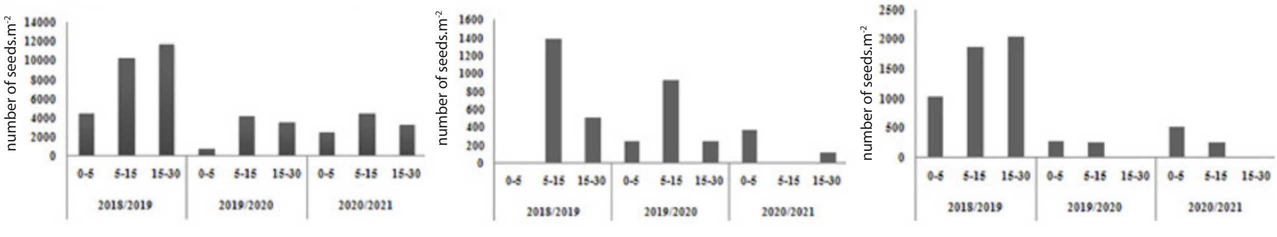
In S3 (2020/2021), 13 weed species belonging to 11 families were recorded. Seed density was the highest in the middle soil layer (5–15 cm) (20,000.16 seedlings.m^{-2}) and the lowest in the superficial layer (0–5 cm) (8,152.32 seedlings.m^{-2}). The seed of species recovered only from the first layer (0–5 cm) was *Anacyclus clavatus* (Desf.) Pers. *Galium aparine* L was recovered only from the second layer (5–15 cm). *Capsella bursa-pastoris* was found only in the third layer (15–30 cm). Species, including *Chenopodium vulvaria* and *Amaranthus blitoides* S. Watson, were found in all layers.

3.3 *Weed diversity indices*

The richness index, Shannon Wienner index, Evenness index, and Simpson index were used to calculate species diversity at different depths (0–5 cm, 5–15 cm, and 15–30 cm) over three seasons. The findings indicate that weed seed banks' Richness Index (Table 7) varied by season. The soil seed bank's species richness index was highest in S2 at 0–5 cm (3.64) and lowest in S3 at



Capsella bursa-pastoris (L.) Medik. *Convolvulus arvensis* L. *Chenopodium vulvaria* L.



Amaranthus blitoides S. Watson *Lamium amplexicaule* L. *Fumaria parviflora* Lam

Figure 3 Change in seed density of dominant weeds in all seasons

Table 6 Weed seed density (m^{-2}) in soil seed banks according to study season and soil depth

Species	2018/2019			2019/2020			2020/2021		
	0–5	5–15	15–30	0–5	5–15	15–30	0–5	5–15	15–30
Amaranthus blitoides S. Watson.	4,458.3	10,232.64	11,718.96	764.28	4,186.08	3,566.64	2,547.6	4,418.64	3,311.88
Anacyclus clavatus (Desf.) Pers.	0	0	0	0	0	0	127.38	0	0
Avenasterilis L.	509.52	930.24	0	254.76	465.12	0	0	0	0
Capsella bursa-pastoris (L.) Medik	764.28	2,325.6	3,311.88	127.38	465.12	1,019.04	0	0	127.38
Chenopodium album L.	0	930.24	0	1,019.04	1,395.36	1,273.8	0	0	0
Chenopodium vulvaria L.	764.28	13,488.48	1,273.8	8916.6	1,3953.6	16,304.64	4,585.68	11,162.88	7,515.42
Convolvulus arvensis L.	1,528.56	6,046.56	6,623.76	3,566.64	4,186.08	4,076.16	0	232.56	891.66
Emex spinosa (L) Campd.	764.28	465.12	0	127.38	465.12	0	0	0	0
Erodium malacoides (L.) L'Hér.	0	1,395.36	0	0	0	0	0	0	0
Fumaria parviflora Lam	1,019.04	1,860.48	2,038.08	254.76	232.56	0	509.52	232.56	0
Galium aparine L.	0	0	0	254.76	0	382.14	0	232.56	0
Hordeum murinum L.	1,019.04	465.12	254.76	254.76	465.12	0	0	0	0
Lamium amplexicaule L.	0	1,395.36	509.52	254.76	930.24	254.76	382.14	0	127.38
Lolium multiflorum Lam.	254.76	0	0	0	0	0	0	0	0
Malva parviflora L.	0	0	0	0	0	0	0	232.56	636.9
medicago polymorpha L.	254.76	465.12	0	254.76	0	0	0	0	0
Papaver rhoeas L.	0	930.24	0	254.76	0	0	0	0	0
Phalaris paradoxa L.	764.28	0	0	509.52	930.24	0	0	0	0
Picnomon acarna (L.) Cass	0	465.12	0	127.38	232.56	0	0	0	0
Polygonum aviculare L.	0	0	0	1,528.56	6,976.8	4,330.92	0	1,395.36	382.14
Scandix pecten veneris L.	0	0	254.76	0	0	0	0	0	0
Scolymus hispanicus L.	509.52	465.12	0	509.52	0	127.38	0	0	0
Silybum marianum (L) Gaertn.	0	0	764.28	509.52	0	0	0	0	0
Sinapis arvensis L.	0	1,395.36	509.52	0	0	0	0	0	0
Sonchus asper (L.) Hill	0	0	0	764.28	232.56	0	0	0	127.38
Sonchus oleraceus L.	0	0	0	0	232.56	127.38	0	0	254.76
Torilis nodosa (L.) Gaertn.	0	0	254.76	0	0	0	0	0	0
Tricicum durum (Desf.) Husn	0	0	0	0	0	127.38	0	0	0
Vaccaria hispanica (Mill.)	0	2,790.72	764.28	0	232.56	0	0	0	0
Veronica hederifolia L.	0	0	0	3,311.88	9,302.4	4,330.92	0	2,093.04	254.76
Total number of seedlings (m^{-2})	12,610.62	46,046.88	28,278.36	23,565.3	44,884.08	35,921.16	8,152.32	20,000.16	13,629.66
Total number of species	12	17	12	20	17	12	5	8	10

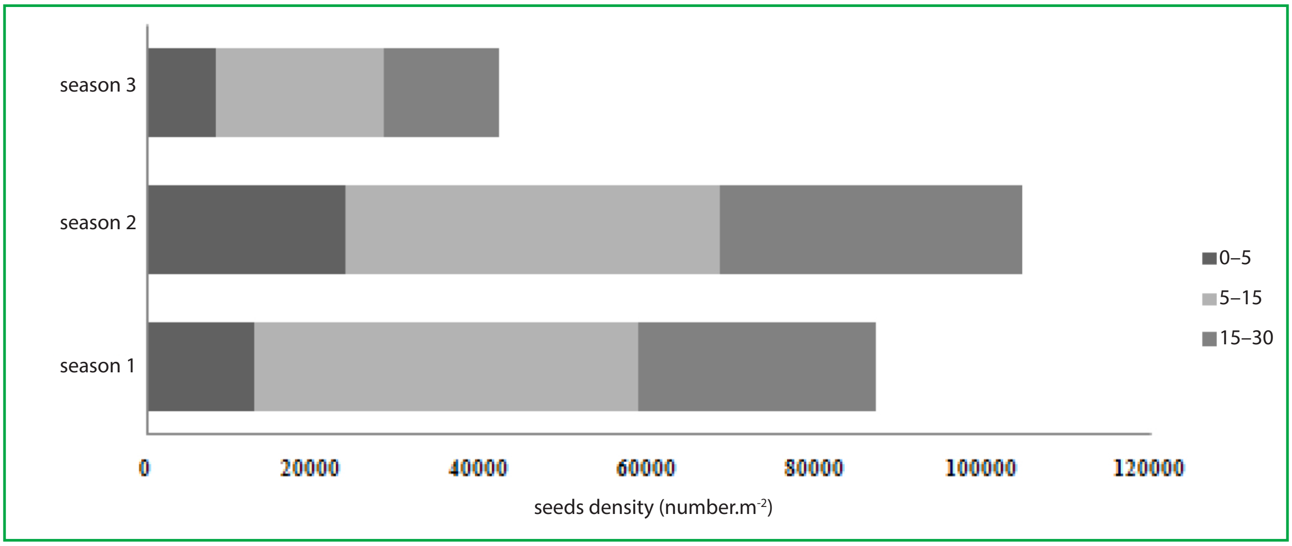


Figure 4 Total density in the weed seed bank

10–15 cm (0.96). Shannon's diversity index for the soil seed bank community showed a high value of weed biodiversity in S1 and S2, the highest values were found at 0–5 cm and 5–15 cm soil depth (*H'* = 2.13 and *H'* = 2.2 in S1 and *H'* = 2.14 and *H'* = 2.02 in S2, respectively), while the lowest values were recorded in S3 with *H'* = 1.07, *H'* = 1.29 and *H'* = 1.37 at 0–5 cm, 5–15 cm and 15–30 cm oil depth, respectively. Also, in S1 and S2, Simpson's dominance index decreased in the order middle layers > superficial layers > deeper layers, and in S3, it decreased in the order deeper layers > middle layers > superficial layers. With depth layers, the Evenness index decreased over the experiment period. The first 0–5 cm soil depth had the highest value, 0.86, followed by 0.71 in S2 and 0.66 in S3.

3.4 Similarity in species composition over the three seasons

The results show that the species composition similarity between soil seed banks was generally low over the three-year study period (ranging from (*Cs*: 0.40–0.51). The highest similarity was found between S2 and S3 (*Cs* = 0.51), followed by S1 and S2 (*Cs* = 0.44) and S1 and S3 (*Cs* = 0.40). The results showed that the species composition in S2 and S3 was more similar (Table 8).

Table 8 Weed species similarity index

	S1	S2	S3
S1	1	0.44	0.40
S2		1	0.51
S3			1

Understanding the soil seed bank is critical for predicting the distribution of weed communities and identifying potential problems in agroecosystem weed management (Restuccia et al., 2020). We identified 30 species, with therophytes dominating (80%). Thus, it refers to therophytes' short life cycles, which allow them to withstand environmental stresses and a significant level of anthropogenic disturbance caused by agricultural

Table 7 Indices of diversity and evenness

Season	Depth	Richness index	Shannon diversity index	Evenness index	Simpson index
S1	0–5	2.39	2.13	0.86	0.83
	5–15	3.03	2.2	0.78	0.84
	15–30	2.04	1.75	0.71	0.75
S2	0–5	3.64	2.14	0.71	0.8
	5–15	3.04	2.02	0.71	0.82
	15–30	1.95	1.71	0.69	0.74
S3	0–5	0.96	1.07	0.66	0.58
	5–15	1.57	1.29	0.62	0.62
	15–30	1.93	1.37	0.6	0.63

techniques (Mesquita et al., 2015). *Chenopodium vulvaria*, *Amaranthus blitoides* S. Watson, and *Convolvulus arvensis* were this experiment's most common germinating species.

According to Rahali et al. (2011), the dominant species in soil seed banks in the wheat crop grown under conventional, minimum, and no-till systems in the semi-arid zone of Setifare *Chenopodium vulvaria* L., *Avena sterilis*, *Polygonum aviculare* L., and *Veronica hederifolia* L. According to Hosseini et al. (2014), in continuous wheat, annual species dominated in most rotations, and the population of broad leaves was higher than grass plants when the ratio of grasses/broad leaves was 1/2 under irrigated or dry land cropping. According to Andreasen et al. (2018), these species can produce many seeds and are thus well-adapted to changes in sowing season or crop rotation. They are distinguished by their year-round germination and longer flowering periods, which are thought to increase the possibility of herbicide resistance.

The densities of seedlings in our seed bank were higher than those in the Sétif provenance in northeastern Algeria (Rahali et al., 2011). Butkeviciene et al. (2021) estimate that there are between 20.2 and 71.4 thousand weed seeds in 1 m^2 of sampled soil at depths ranging from 0 to 20 cm. According to Mirsky et al. (2010), cover crops and ploughing can significantly reduce the seed banks of weedy fields in a single field season. Hosseini et al. (2014) reported that the most important densities of soil seed banks were found in the lower soil layer (15–25 cm) in continuous cropping of irrigated wheat and continuous cropping of dry land wheat due to the continuous use of mouldboard ploughs. Weed seed germination capacity is indirectly influenced by the depth at which they are placed in the soil, which can result in temperature, oxygen, and light differences (Feledyn-Szewczyk et al., 2020). Piskier and Sekutowski (2013) discovered that weed seeds were evenly dispersed throughout all 0–20 cm soil layers during conventional tillage (plough). The field with the mouldboard plough had the lowest topsoil density. As a result, although this tool was only used every three years, 52% of seeds were discovered at a depth of 15–30 cm (Colbach et al., 2014; Hosseini et al., 2014).

Smith and Gross (2006) observed that the composition and abundance of weed seed banks in winter wheat rotations changed rapidly. Herbicides may affect species richness, but they usually have a greater effect on relative abundance than on species composition (Derksen et al., 1995). Vasileiadis et al. (2007) discovered that herbicide-treated crops had lower total seed densities of annual broad-leaved species. The effectiveness of broad-leaved herbicide during the trial could explain the decrease in seed bank size of *Papaver rhoeas* and *Polygonum aviculare* (Izquierdo et al., 2009). In this study, the diversity of the soil seed bank varied according to season, with S3 having the lowest weed diversity. According to Izquierdo et al. (2009), weed diversity indices calculated for the entire field revealed a decrease in diversity and evenness in the second year and a slight increase in the third year.

4 Conclusions

This study discussed the diversity, floristic composition, and vegetation structure in a wheat field soil seed bank in northwestern Algeria. A total of 30 plant species from families were reported. Broadleaf weeds have the highest seed density and species composition. All seasons yielded seeds of *Amaranthus blitoides* S. Watson, *Convolvulus arvensis*, *Lamium amplexicaule*, *Chenopodium vulvaria*, *Fumaria parviflora* Lam., and *Capsella bursa-pastoris*. The soil seed bank in seasons 2 and 3 was the most similar in species composition ($Cs = 0.51$), while the soil seed bank in seasons 1 and 3 was the least similar ($Cs = 0.40$). The soil seed bank contained 44,328.24 to 110,931.12 m^{-2} seedlings per square meter. S1 had the smallest weed seeds, while S2 had the largest. This finding is useful for understanding soil seed bank dynamics variation in a semi-arid environment. The qualitative and quantitative knowledge of the soil seed bank, as well as the spatial distribution of weed seeds, can be used to predict weed dynamics and develop sustainable weed management protocols.

Reference

Andreasen, C., Jensen, H. A., & Jensen, S. M. (2018). Decreasing diversity in the soil seed bank after 50 years in Danish arable fields. *Agriculture, Ecosystems & Environment*, 259, 61–71. https://doi.org/10.1016/j.agee.2018.02.034

Butkevičiene, L.M., Skinuliene, L., Auželienė, I., Bogužas, V., Pupalienė, R., & Steponavičienė, V. (2021). The influence of long–term different crop rotations and monoculture on weed prevalence and weed seed content in the soil. *Agronomy*, 11, 1367. https://doi.org/10.3390/agronomy11071367

Carpenter, J. E., & Gianessi, L. P. (2010). Economic impacts of glyphosate-resistant weeds. *Glyphosate Resistance in Crops and Weeds: History, Development, and Management* (pp. 297–312).

Colbach, N., Busset, H., Roger-Estrade, J., & Caneill, J. (2014). Predictive modelling of weed seed movement in response to superficial tillage tools. *Soil and tillage research*, 138, 1–8. https://doi.org/10.1016/j.still.2013.12.002

Derksen, D. A., Thomas, A. G., Lafond, G. P., Loeppky, H. A., & Swanton, C. J. (1995). Impact of post emergence herbicides on weed community diversity within conservation-tillage systems. *Weed Research,* 35(4), 311–320. https://doi.org/10.1111/j.1365-3180.1995.tb01794.x

Feledyn-Szewczyk, B., Smagacz, J., Kwiatkowski, C. A., Harasim, E., & Woźniak, A. (2020). Weed flora and soil seed bank composition as affected by tillage system in three-year crop rotation. *Agriculture*, 10(5), 186. https://doi.org/10.3390/agriculture10050186

Figueroa, J. A., Teillier, S., & Jaksic, F. M. (2004). Composition, size and dynamics of the seed bank in a mediterranean shrubland of Chile. *Austral Ecology*, 29(5), 574–584. https://doi.org/10.1111/j.1442-9993.2004.01392.x

Forcella, F., Eradat-Oskoui, K., & Wagner, S. W. (1993). Application of weed seedbank ecology to low input crop management. *Ecological Applications*, 3(1), 74–83. https://doi.org/10.2307/1941793

He, Y. H., GAO, P. L., & Qiang, S. (2019). An investigation of weed seed banks reveals similar potential weed community diversity among three different farmland types in Anhui Province, China. *Journal of Integrative Agriculture*, 18(4), 927–937. https://doi.org/10.1016/S2095-3119(18)62073-8

Hosseini, P., Karimi, H., Babaei, S., Mashhadi, H. R., & Oveisi, M. (2014). Weed seed bank as affected by crop rotation and disturbance. *Crop Protection*, 64, 1–6. https://doi.org/10.1016/j.cropro.2014.05.022

Izquierdo, J., Blanco-Moreno, J. M., Chamorro, L., Gonzalez-Andujar, J. L., & Sans, F. X. (2009). Spatial distribution of weed diversity within a cereal field. *Agronomy for sustainable development*, 29, 491–496. https://doi.org/10.1051/agro/2009009

Kumar, R., Kumawat, N., Mishra, J. S., Ghosh, D., Ghosh, S., Choudhary, A. K., & Kumar, U. (2022). Weed dynamics and crops productivity as influenced by diverse cropping systems in eastern India. *Indian Journal of Weed Science*, 54(1), 18–24. http://dx.doi.org/10.5958/0974-8164.2022.00003.X

Mahé, I., Chauvel, B., Colbach, N., Cordeau, S., Gfeller, A., Reiss, A., & Moreau, D. (2022). Deciphering field-based evidences for crop allelopathy in weed regulation. A review. *Agronomy for Sustainable Development*, 42(3), 1–20. https://doi.org/10.1007/s13593-021-00749-1

Marañón, T. (2001) Ecología del banco de semillas y dinámica de comunidades mediterráneas. In Zamora, R., Pugnaire, F.I. (eds), *Ecosistemas mediterráneos*. Análisis funcional. CSIC, AEET (pp. 153–182).

Margalef, R. (1973). Information theory in ecology. http://hdl.handle.net/10261/284346

Mirsky, S. B., Gallandt, E. R., Mortensen, D. A., Curran, W. S., & Shumway, D. L. (2010). Reducing the germinable weed seedbank with soil disturbance and cover crops. *Weed Research*, 50(4), 341–352. https://doi.org/10.1111/j.1365-3180.2010.00792.x

Olaniyan, J., Isimikalu, T., Affinnih, K., Ahamefule, H., Ajiboye, G., & Ajala, O. (2018). Soil Properties and Land-Use Influence on Weed Occurrence in the Southern Guinea Savanna of Nigeria. *Albanian Journal of Agricultural Sciences*, 17(1), 13–22.

PAN – Pesticide Action Network Europe. Alternative Methods in Weed Managment to Glyphosate; Intergrated Weed Management. Pesticide Action Network Europe: Brussels, Belgium, 2017. Available online: https://www.pan-europe.info/sites/paneurope.info/files/Report_Alternatives%20to%20Glyphosate_July_2018.pdf

Parish, T., Lakhani, K. H., & Sparks, T. H. (1995). Modelling the relationship between bird population variables and hedgerow, and other field margin attributes. II. Abundance of individual species and of groups of similar species. *Journal of Applied Ecology*, 362–371. https://doi.org/10.2307/2405102

Piskier, T., & Sekutowski, T. R. (2013). Effect of simplified tillage on the number and distribution of weed seeds in soil. *J. Res. Appl. Agric. Eng*, 58, 109–117.

Rahali, A., Makhlouf, M., & Benkherbache, N. (2011) Influence de l'itinéraire technique su r le stock semencier de mauvaises herbes de la zone semi-aride de Sétif. In Bouzerzour, H., Irekti, H., Vadon, B. (eds.), *4. Rencontres Méditerranéennes du Semis Direct*. Zaragoza: CIHEAM/ATU-PAM/INRAA/ITGC/FERT (pp. 153–162). (Options Méditerranéennes: Série A. Séminaires Méditerranéens; n. 96) http://om.ciheam.org/article.php?IDPDF=801430

Restuccia, A., Scavo, A., Lombardo, S., Pandino, G., Fontanazza, S., Anastasi, U., Cristina, A., & Mauromicale, G. (2020). Long-term effect of cover crops on species abundance and diversity of weed flora. *Plants*, 9(11), 1506. https://doi.org/10.3390/plants9111506

Shang, Z.H., Deng, B., Ding, L.M., Ren, G.H., Xin, G.S., Liu, Z.Y., Wang, Y.L., & Long, R.J. (2013). The effects of three years of fencing enclosure on soil seed banks and the relationship with above-ground vegetation of degraded alpine grasslands of the Tibetan plateau. *Plant Soil,* 364 (1–2), 229–244. https://doi.org/10.1007/s11104-012-1362-9

Smith, R. G., & Gross, K. L. (2006). Rapid change in the germinable fraction of the weed seed bank in crop rotations. *Weed science*, 54(6), 1094–1100. https://doi.org/10.1614/WS-06-090R.1

Vasileiadis, V. P., Froud Williams, R. J., & Eleftherohorinos, I. G. (2007). Vertical distribution, size and composition of the weed seedbank under various tillage and herbicide treatments in a sequence of industrial crops. *Weed Research*, 47(3), 222–230. https://doi.org/10.1111/j.1365-3180.2007.00564.x

Zhang, M., Chen, F., Wu, Y., Ma, Y., Guan, S., & Huang, Y. (2017). Characteristics of the soil seed bank of planted and natural restored draw-down zones in the Three Gorges Reservoir Region. *Ecological Engineering*, 103, 127–133. https://doi.org/10.1016/j.ecoleng.2017.03.011

Zhang, Z., Li, R., Zhao, C. et al. (2021). Reduction in weed infestation through integrated depletion of the weed seed bank in a rice-wheat cropping system. *Agron. Sustain. Dev*., 41, 10. https://doi.org/10.1007/s13593-020-00660-1

Zhao, N., He, M. X., Li, H. Y., & Meng, W. Q. (2016). The influence of substrates rates on the germination characteristic of a soil seed bank. In *IOP Conference Series: Earth and Environmental Science* (p. 012018). IOP Publishing. DOI10.1088/1755-1315/41/1/012018