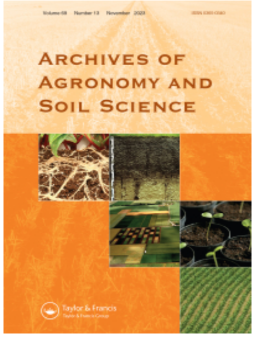

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The role of management practices on soil seed bank agrobiodiversity and agronomic sustainability in a horticultural cropping system

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ABSTRACT

Understanding how soil management practices influence the agrobiodiversity of cropping systems is crucial to promoting and maintaining agronomic sustainability in the long term. This study aimed to analyze seed bank diversity and to evaluate the effects of conventional (CONV) and alternative monoculture (ALTMO) and biannual rotation (BIROT) soil management practices in a horticultural cropping system. Soil cores were collected to identify seed bank composition and diversity indices were calculated. Additionally, soil parameters, CO_2 efflux, temperature, and moisture were monitored. The results showed that management systems did not influence the composition of soil seed banks showing a prevalence of nitrophilous species in CONV management. Furthermore, the abundance and richness in the CONV and BIROT managements were high and low respectively due to the higher nitrogen rates in the soil. In contrast, ALTMO showed low abundance and a high number of species favoring higher competitiveness with positive effects on crop productivity. A positive correlation between CO_2 soil efflux and temperature with species richness and Simpson's diversity index was observed in all management systems while the soil moisture was negatively influenced. Finally, adopting alternative management strategies can preserve and enhance agrobiodiversity, and crop yields, and may contribute to developing more eco-friendly cropping systems.

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KEYWORDS
Seed bank; horticultural crops; management systems; agrobiodiversity; agronomic sustainability

Introduction

The EU's Biodiversity Strategy for 2030 and the Farm to Fork Strategy (European Commission, 2020) are two interlinked programs promoted by the European Commission aiming to guide Member States to a sustainable future by introducing a new agricultural model whose goal is to make food systems fair, healthy, and environmentally friendly. These strategies aim to halt the loss of biodiversity, improve ecosystem services and ensure access to nutritious food for all (European Commission,

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2020). In this context agricultural cropping systems can serve a dual purpose to conserve agrobiodiversity and to guarantee global food security by ensuring high crop productivity. Soil management practices are an essential factor in maintaining ecosystem services and biodiversity that influences cropping system richness and diversity in terms of weed and seed bank species (Santín-Montanyá et al. 2016; Carpio et al. 2020). Specifically, conventional management, which combines the intensification of agricultural systems with the increased use of fertilizers and agrochemicals, has been identified as a driver for the decrease in weed diversity (Richner et al. 2015; Leuschner and Ellenberg 2017) and the depletion of the seed bank (Fracchiolla et al. 2016). On the other hand, organic farming techniques are characterized by higher crop diversity, and eco-friendly management practices with fewer inputs that promote weed diversity and soil seed bank species evenness and thus promote a general higher biodiversity in agroecosystems (Regulation (EU) no. 848/2018; Gao et al. (2022); Ancillotto et al. (2023). Crop rotation impact on species composition and abundance in weed flora and seeds in soil has been demonstrated, as well as its role in preventing the growing of aggressive weeds (Bond and Grundy 2001; Hosseini et al. 2014; de la Fuente et al. 2021). In contrast, the inclusion of cover crops has been found to suppress weed development, reducing seed survival and germination, while maintaining seed dormancy and ensuring soil fertility at the same time (Liebman and Davis 2000; Sias et al. 2021). In addition, management practices such as irrigation and tillage influence soil characteristics in terms of soil carbon dynamics, temperature and soil moisture, modifying the soil features (Gicheru et al. 2006; Abbas et al. 2020; Lembaid et al. 2021).

The soil seed bank provides insights into historical soil management practices and can serve as a good predictor of potential future management challenges (Auffret and Cousins 2011). On the other hand, the soil seed bank also represents the primary reservoirs of biodiversity that contribute to the long-term conservation, persistence and recruitment of local species and plant communities (Fisher et al. 2009; Auffret and Cousins 2011). This is achieved through the maintenance of a functional diverse species pool in response to anthropogenic disturbances (Kalamees and Zobel 2002; Dostál 2005; Clark et al. 2007; Anderson et al. 2012).

In Mediterranean agricultural land, few open-field horticultural crops are cultivated according to organic farming principles while more are affected by intensive use of agrochemicals and fertilizers, and the introduction of monoculture, with a subsequent reduction of agrobiodiversity (Tomaš-Simin et al. 2023). In this context, globe artichoke (*Cynara scolymus* L.) makes no exception, representing one of the most important horticultural crops cultivated mainly according to conventional practices with the use of high chemical inputs that influence weed communities (Deligios et al. 2017; Berquer et al. 2023). Therefore, studying how management practices and soil characteristics affect the composition and diversity of the soil seed bank offers valuable insights into the impact of these practices in terms of biodiversity and agronomic sustainability. Therefore, the aims of the study were i) to investigate the effects of different management practices on soil seed bank composition; ii) to analyze the agroecosystems biodiversity in terms of biodiversity index and soil characteristics, and iii) to evaluate the agronomic sustainability of horticultural cropping system.

Materials and methods

Study area and experimental design

The study was carried out at the experimental station 'Mauro Deidda' in Ottava near Sassari, in the north-west of Sardinia, Italy (40° 46′N, 8° 29′ E; 81 m a.s.l). The climate is Mediterranean, with warm and dry summers and mild winters. Rainfall events are concentrated during the period from late autumn to early spring (Lionello et al. 2006; Canu et al. 2015). Total mean annual precipitation of the area according to the historical series is 561 mm. Mean temperature values range from 24.0°C in August to 9.9°C in January.

Established in 2006, a long-term experiment (Deligios et al. 2017) on globe artichoke (*Cynara scolymus* L. cv. 'Spinoso sardo') has aimed to compare three diverse management systems with

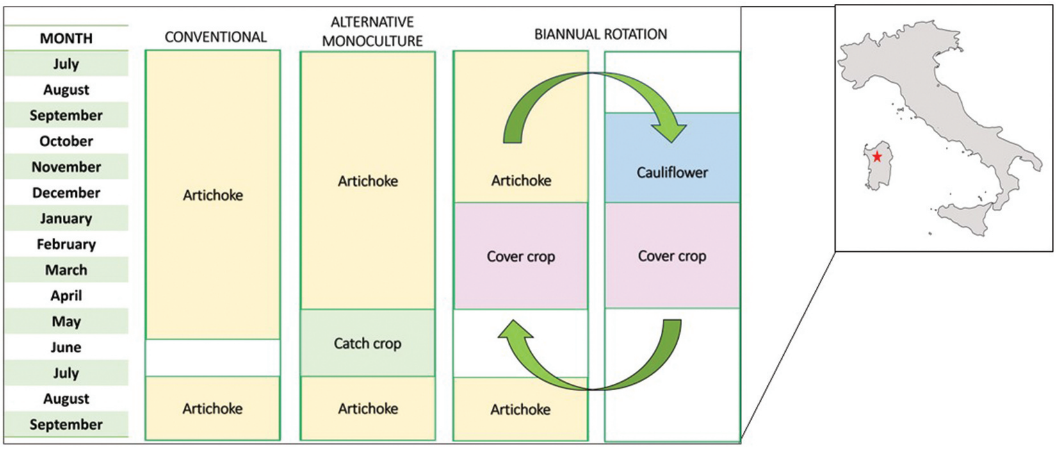

Figure 1. Timing of the three investigated cropping systems of globe artichoke at the experimental field of Ottava, Sardinia, IT.

increasing levels of tillage intensity and soil cover. The conventional system (hereafter referred to as CONV) has been permanently managed as a monoculture, with a periodical chemical fertilization, frequent weed control by mechanical means, summer irrigation, and soil incorporation of dried crop residues in June. The fertilization plan included the application of 150 kg ha^{-1} urea, 125 kg ha^{-1} of $_{P}2O_5$ as diammonium phosphate, and 150 kg ha^{-1} of K_2O as potassium sulfate. At the same time, two alternative approaches hereafter referred to as ALTMO (alternative monoculture), and BIROT (biannual rotation), have been implemented since 2006 without using mineral fertilizers, therefore entirely relying on residue management to maintain soil fertility. In the ALTMO system, globe artichoke has been cultivated in intercropping with French bean as a catch crop (*Phaseolus vulgaris* L. cv. 'Bronco'). In contrast, the BIROT system has involved a 2-year rotation of globe artichoke and cauliflower (*Brassica oleracea* var. *botrytis* L. cv. 'Nautilus') in two adjacent portions of the experimental fields, ensuring that both phases of the crop rotation were grown every year. This system included a cover crop of *Pisum sativum* L. cv. 'Navarro' in the interrow spaces of both main crops (Figure 1). All systems exhibited increasing levels of soil tillage intensity (ALTMO > CONV > BIROT) in terms of soil disturbance.

Seed bank sampling

The soil seed bank was sampled for each management system along two growing seasons: 2010–2011 and 2011–2012, following a 4-year transition period to organic management using the methodology proposed by Franca et al. (2018). A total of 96 soil cores (16 cores × 3 managements × 2 growing seasons) were extracted and delivered to laboratory for further processing. An initial analysis allowed us to distinguish between the transient seed bank (TS) and the persistent seed bank (PS), using the weed seedling emergence methodologies of Walck et al. (2005) and Perez et al. (1998), respectively. For both analyses, soil cores were placed in a growth chamber under controlled and undisturbed conditions, with regular watering over a period of two months. Data on seed germination belonging to TS were collected weekly.

Subsequently, for PS determination samples were subjected to three treatments of dormancy breakdown: (i) hot stratification, (ii) cold stratification, and (iii) gibberellic acid (GA) treatment. Seeds that did not germinate were treated with triphenyl tetrazolium chloride (TTC) and tested based on the activity of dehydrogenases enzymes (de Barros França-Neto and Krzyzanowski 2019).

Seedlings that emerged were counted and plant species were identified according to the nomenclature of the Italian Checklist as reported on the Portal to the Flora of Italy (2023), as well as according to Bartolucci et al. and Galasso et al. (Bartolucci et al. 2018; Galasso et al. 2018), to assess their native vs. alien status in the flora of Italy.

Species diversity and similarity in the soil seed bank

To estimate species diversity, Shannon Weiner's index (H'), the Evenness index (E), Simpson's dominance index (D), the Margalef index (d), species richness (S), and relative seed abundance were calculated.

Shannon Weiner's diversity index H' (Shannon 1949) takes into account both the number of species (richness) and the relative abundance of each species. The Evenness index was calculated to indicate the degree of homogeneity in the abundance of different species expressed as the relationship between Shannon Weiner's diversity index H' and the number of species (S). Simpson's dominance index was selected as an indicator to quantify the biological diversity of the soil seed bank in all treatments.

To assess the similarity in terms of seed banks between different management systems, a measure of beta diversity (β) was calculated using the qualitative Sørensen's index (Magurran 1988).

Soil characteristics and environmental variables

Soil chemical characteristics, annual soil CO_2 efflux (SR), volumetric water content (VWC) and temperature data were collected over the 2 years of the seed bank study to assess their correlation with the composition and diversity of the seed bank.

Each year of the experiment, soil samples were collected and analyzed to determine the main soil parameters, including soil organic matter (SOM), total nitrogen content, and the C:N ratio. The dynamics of heterotrophic SR were monitored weekly following the methodology of Alberti et al. (Alberti et al. 2010) using a portable non-dispersive infrared gas analyzer (IRGA) EGM-4 (PP-Systems, Hitchin, UK) connected to an SRC-1 chamber. Simultaneously, soil temperature and soil water content (VWC) were measured using a probe, and a FieldScout TDR 300 (Spectrum Technologies Inc.), respectively.

Monitoring of artichoke head harvests

Globe artichoke yields were monitored starting from the achievement of the commercial head stage in late autumn (51–59 BBCH phenological phase; (Archontoulis et al. 2010)). For each management system and year, four sampling areas were established, each consisting of ten artichoke plants. The number and weight of the 1^{st}, 2^{nd}, and 3^{rd} order heads were recorded at seven-day intervals, excluding atrophic heads. The average yield (kg ha^{-1} heads) was estimated by multiplying the crop density (9524 plants ha^{-1}) by the sum of the mean head weights (1^{st}, 2^{nd}, and 3^{rd} order) in each management system.

Data analysis

Differences in α and β diversity among the management systems and artichoke yields were analyzed using analysis of variance (R ver. 4.2.1 on R Studio software). Pairwise comparisons of means were conducted using Tukey's multiple comparison tests at a significance level of $p \leq 0.05$.

Pearson's correlation coefficients between all the diversity indices studied and the soil variables (soil analysis, SR, temperature, and VWC) were calculated.

Non-metric multidimensional scaling (NMDS), a non-parametric ordination technique, was used to assess the relationship between species composition (in the soil seed bank) and the type of management. This was done using two dimensions (k = 2) and the Bray Curtis similarity index as the distance measure. The analysis was conducted using the *metaMDS* function in the Vegan package in

R version 4.2.1. This allowed us to explore patterns of weed species similarities among management systems. The resulting NMDS axis values were arranged in such a way that management systems with similar species composition were positioned close to each other in the ordination space.

Results

Soil seed bank composition and a and ß diversity

Table 1 shows the plant species composition of the seed bank quantified during the experimental period. In the two years, a total of 1433 seedlings emerged, comprising 35 species from 17 families. The dominant families included *Asteraceae*, *Fabaceae*, and *Poaceae*. Four species were identified as alien to the flora of Italy, and they were mainly concentrated in the CONV management (e.i. *Oxalis pes-caprae* and *Amaranthus blitoides*) while 3 native species (*Poa annua*, *Sonchus oleraceus*, and *Stellaria media*) were common to all management systems. Out of the total seedlings identified, 68.6% were annual species (therophytes), while 31.4% were pluriannual species (scapose hemicryptophytes and biannual hemicryptophytes).

Table 1. Seed bank composition in the three investigated globe artichoke cropping systems.

Plant species	Family APG IV	Life-form	CONV	ALTMO	BIROT
Amaranthus blitoides S.Watson	*Amaranthaceae*	T	X	X	X
Ammi majus L.	*Apiaceae*	T		X	
Daucus carota L.		H	X	X	
Anthemis arvensis L.	*Asteraceae*	T	X		X
Glebionis coronaria (L.) Cass. ex Spach		T	X	X	X
Glebionis segetum (L.) Fourr.		T	X		X
Picris hieracioides L.		H	X	X	X
Silybum marianum (L.) Gaertn.		H			X
Sonchus asper (L.) Hill		T/H			X
Sonchus oleraceus L.		T/H	X	X	X
Dittrichia viscosa (L.) Greuter		H	X	X	X
Capsella bursa-pastoris (L.) Medik. subsp. *bursa-pastoris*	*Brassicaceae*	H*			X
Raphanus raphanistrum L.		T		X	
Cerastium glomeratum Thuill.	*Campanulaceae*	T	X	X	X
Campanula erinus L.		T	X	X	X
Stellaria media (L.) Vill.		T/H	X	X	X
Beta vulgaris L. subsp. *maritima* (L.) Arcang.	*Chenopodiaceae*	H	X	X	
Medicago arabica (L.) Huds.	*Fabaceae*	T	X	X	X
Medicago polymorpha L.		T	X	X	X
Trifolium campestre Schreb.		T	X		X
Heliotropium europaeum L.	*Heliotropiaceae*	T	X		X
Lamium purpureum L.	*Lamiaceae*	T			X
Oxalis pes-caprae L.	*Oxalidaceae*	G	X		
Fumaria officinalis L.	*Papaveraceae*	T			X
Papaver hybridum L.		T	X		X
Veronica persica Poir.	*Plantaginaceae*	T	X	X	X
Avena fatua L.	*Poaceae*	T	X		X
Dactylis glomerata L.		H	X	X	
Lolium rigidum Gaudin		T	X		
Poa annua L.		T	X	X	X
Setaria italica (L.) P.Beauv.		T		X	
Polygonum aviculare L. subsp. *aviculare*	*Polygonaceae*	T	X	X	X
Rumex crispus L.		H	X		
Portulaca oleracea L.	*Portulacaceae*	T	X	X	X
Lysimachia arvensis (L.) U.Manns & Anderb.	*Primulaceae*	T	X	X	X

Family and species are reported in alphabetical order. Abbreviations: G: geophytes, H: scapose hemicryptophytes (* = biannual), T: therophytes, T/H therophytes or biannual hemicryptophytes, CONV: conventional cropping system, ALTMO: alternative monoculture, BIROT: biannual rotation. X = species present in the cropping system.

Table 2. One-way ANOVA F-test statistics for the effect of management on species richness, abundance, and diversity indices.

Management	df	Species richness		Relative abundance		Shannon's index		Evenness index		Margalef index		Simpson index	
CONV		21 a		622 a		0.11		0.25		3.36 a		3.79 a	
ALTMO		13 b		251 c		0.35		0.65		2.71 b		0.81 c	
BIROT		20 a		599 b		0.35		0.43		3.58 a		2.81 b	
		F	*Sig.*	*F*	*Sig.*	*F*	*Sig.*	*F*	*Sig.*	*F*	*Sig.*	*F*	*Sig.*
Management	2	10.22	< .001	15.01	< .001	2.40	< .05	2.52	< .05	3.38	< .05	7.20	< .05

Within the same column, means followed by different letters are significantly different at $p < .05$ according to one-way ANOVA.
Abbreviation: CONV: conventional, ALTMO: alternative monoculture, BIROT: biannual rotation.

Table 3. Effect of management on Sørensen's similarity index.

Management	df	CONV	ALTMO	BIROT
CONV		1	0.35 b	0.39 b
ALTMO			1	0.51 a
BIROT				1
		F	*Sig.*	
Management	2	3.86	< .05	

Within the same column, means followed by different letters are significantly different at $p < .05$ according to one-way ANOVA.
Abbreviation: CONV: conventional, ALTMO: alternative monoculture, BIROT: biannual rotation.

Regarding the type of seed bank, we found that in CONV and ALTMO management systems, most species belonged to the transient type (66.6%), while the opposite trend was observed in BIROT, where most species belonged to the permanent seed bank (52.4%).

When analyzing individual effects of management on the richness of species in the seed bank and relative abundance, statistical differences were observed ($p < .001$) (Table 2). Specifically, the highest values for both variables were observed in CONV and BIROT, indicating that the density of emerged seedlings declined in relation to the level of soil disturbance, following the sequence CONV (77.5 seedlings m^{-2}) > BIROT (69.0 seedlings m^{-2}) > ALTMO (31.7 seedlings m^{-2}).

Regarding the Margalef index, statistical differences were observed only in the ALTMO organic management system, with values calculated at 2.71 ($p < .01$). Similarly, Shannon and Evenness index indices had the highest value in both organic management systems with significant differences between the management systems for the Shannon index (Table 2). The Simpson diversity index showed significant differences among management systems. Specifically, the highest diversity values were calculated for the CONV management followed by the BIROT and ALTMO systems.

Sørensen's indices were calculated to compare the similarity in terms of common species in the seed bank composition among different management systems (Table 3). Among the management systems, the seed bank species composition showed an increase in quantitative indices when comparing the two alternative management systems. Our findings indicate a higher number of common and shared species in alternative systems (51%) compared to the CONV system.

Effects of soil characteristics on diversity soil seed bank

The individual effects of soil variables on diversity indices of soil seed bank data were estimated using Pearson's correlation coefficients (r) and are reported in Figure 2. The result of the analysis showed a positive linear correlation between Margalef and Simpson's indices and soil temperature and annual CO_2 efflux of the soil. Furthermore, we found a high correlation between soil temperature with the Margalef index (0.72) and a high correlation between soil CO_2 emissions and the Simpson index (0.76).

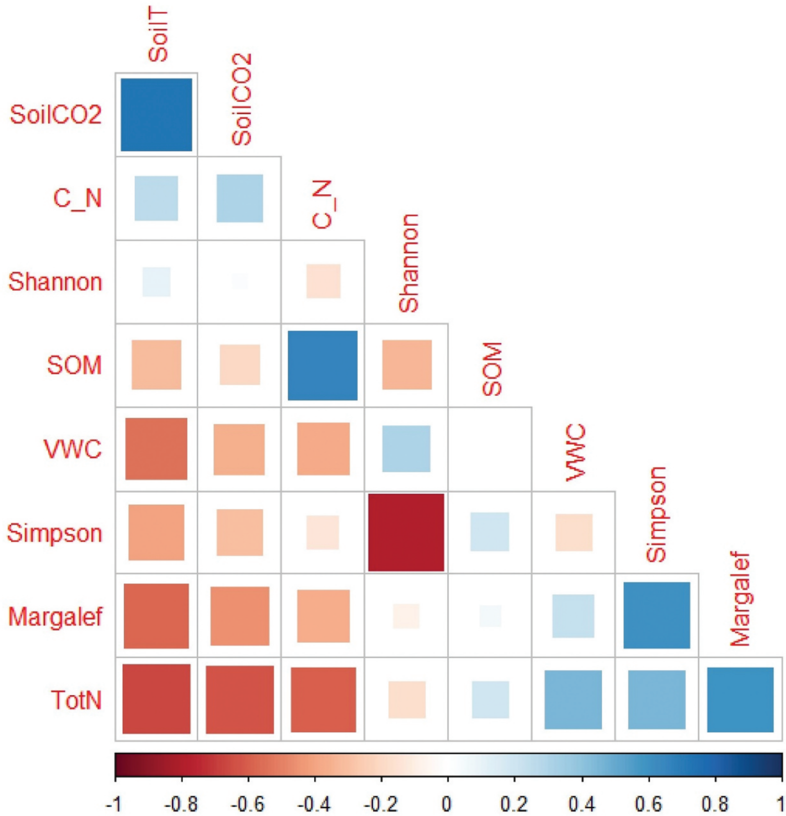

Figure 2. Pearson's significant correlations among the soil parameters and diversity indices. Colored cells are those with $p < .01$, with color intensity directly proportional to the correlation coefficients. According to the scale, blue and red colors correspond to positive and negative correlations, respectively. The variables analyzed were: SoilT (soil temperature), SoilCO2 (soil CO2 efflux), C_N (carbon to nitrogen ratio), Shannon (Shannon index), SOM (soil organic matter), VWC (volumetric water content), Simpson (Simpson index), Margalef (Margalef index) and TotN (soil total nitrogen content).

For the same indices, we observed a weak relationship with soil parameters such as soil organic matter (SOM g kg^{-1}) and C:N ratio, while a strong negative correlation was observed between the indices and VWC (−0.92). Surprisingly, the Shannon index showed no correlation with soil temperature and a negative correlation (−1.00) with the mean annual emission rate of soil. However, the same index was highly negatively correlated with the soil parameters analyzed.

Relationship between management type and soil seed bank

Seed bank composition was influenced by the management systems. The similarity matrix, graphically represented as a two-dimensional graph (NMDS, k = 2, non-metric fit: $r^2 = 1.0$; Figure 3), shows that in axis 1 the variance is explained by 44.6% of the original distance matrix, while axis 2 accounted for 38.5%. In the ordination of the soil seed bank, the Cartesian axes separated two distinct regions. The positive region (I and IV quadrants) was where the CONV group was located, and the negative region (II and III quadrants) was where the organic managements (BIROT and ALMO) were situated. The NMDS ordination graph clearly distinguished species that were exclusively associated with CONV management, such as *O. pes-caprae* and *R. crispus*, from those associated with organic managements, such as *A. majus* and *R. raphanistrum* for ALTMO and *C. bursa-pastoris* and *F. officinalis* for BIROT,

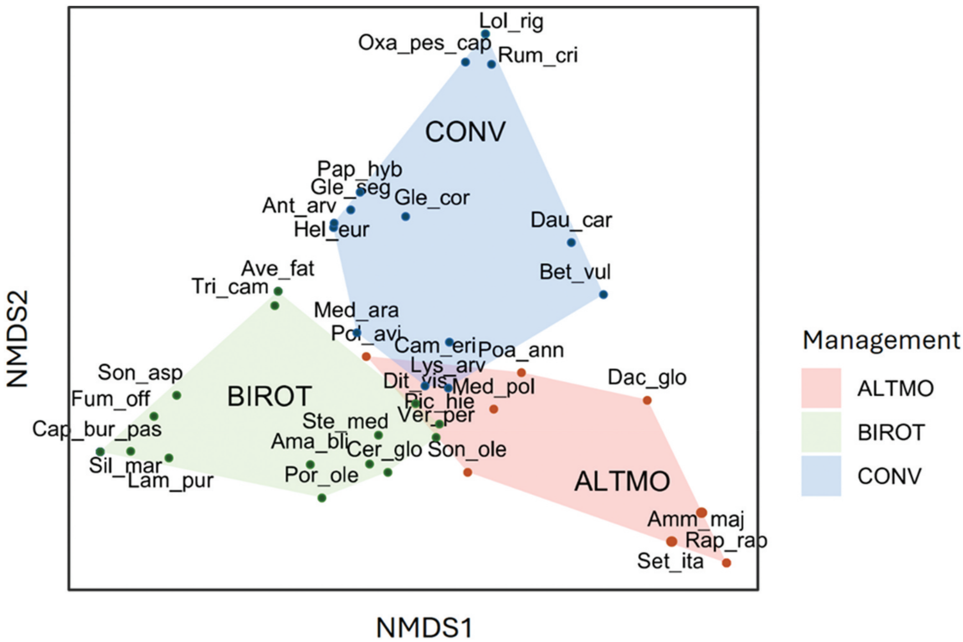

Figure 3. Results of Non-metric multidimensional scaling (NMDS) ordination of the seed bank composition among managements at the Ottava site. ALTMO: alternative monoculture, BIROT: biannual rotation and CONV: conventional cropping system.

respectively. However, there were several species common to all the different management types. The homogeneity of the seed bank composition, evaluated in terms of mean Euclidean distance between managements in the NMDS ordination, decreased when comparing CONV to the organic managements. Specifically, there was a significant distance along axis 2 between CONV to BIROT, measuring 1.1 NMDS distance units, as well as between CONV to ALMTO, measuring 1.4 NMDS distance units.

Productivity of globe artichoke plants

The results of the one-way ANOVA (Table 4) revealed significant differences at $p < .001$ associated with management for each growing season. We observed the lowest values for the CONV management in both years, with a total dry biomass head weight of 556 kg ha^{-1} for the 2010–11 growing season and 1153 kg ha^{-1} for the 2011–12 growing season, respectively. In the case of organic

Table 4. Results of the one-way ANOVA F-test statistics (kg ha^{-1}) for each management system and year.

Management	df	2010-2011		2011-2012	
CONV		566.1 c		1153.2 c	
ALTMO		936.3 b		2049.8 a	
BIROT		984.5 a		1961.7 b	
		F	*Sig.*	*F*	*Sig.*
Management	2	4.25	<.001	4.25	<.001

Within the same column, means followed by different letters that are significant.
Abbreviation: CONV: conventional, ALTMO: alternative monoculture, BIROT: biannual rotation.

management, the total globe artichoke head yield was significantly higher in the first growing season for the BIROT management, while in the 2011–12 growing season, the opposite trend was observed. Specifically, the globe artichoke yield was 2050 kg ha^{-1} for ALTMO compared to the BIROT management, which had a yield of 1962 kg ha^{-1}.

Discussion

In this work, we draw up how conventional and organic practices influence seed bank composition and diversity, focusing on the effects of three management systems. A total of 35 species (predominantly therophytes) with low emerged seedling density was observed in CONV and BIROT management, probably due to the increased soil disturbance degree. Our results suggest an increase of agrobiodiversity within the organic managements, with positive influence also on artichoke productivity. The irrigation practice had influenced soil CO_2 dynamics and temperature, positively affecting soil seed bank richness and diversity, thus representing an important factor of variation of biodiversity in the agroecosystem.

Effects of management practices on the soil seed bank

The composition of the soil seed bank in agroecosystems is closely related to the type of cropping system (i.e. monoculture vs. rotation), agronomic management (i.e. conventional vs. organic, use of cover crops (Melander et al. 2020; Cechin et al. 2022)), tillage practices, and climate conditions (Barberi et al. 1998; Carter and Ivany 2006, Rotchés-Ribalta et al. 2020; Plue et al. 2021; Ahmadzadeh et al. 2022) and other biotic and abiotic factors. Furthermore, the composition of seed banks often mirrors the above-ground flora of agricultural management systems with both immediate and long-term impacts on weed species abundance and diversity (Schwartz-Lazaro and Copes 2019, Rotchés-Ribalta et al. 2020; Pavlović D et al. 2023). As can be expected, our study also shows that the species characterizing the soil seed bank are mostly the same as those that are most abundant in the weed flora observed in artichoke fields in the Mediterranean region (Al Mohandes Dridi et al. 2012; Fracchiolla et al. 2022).

In addition, Restuccia et al. (2019) underline *Medicago polymorpha*, *Sonchus asper* and *Sonchus oleraceus* as dangerous weeds of agricultural systems. Other harmful species found in our field experiment such as *Amaranthus blitoides*, *Glebionis coronaria*, *Rumex crispus* and *Oxalis pes-caprae* are also considered weeds. *O. pes-caprae*, native to South Africa, is one of the most common invasive alien species in Mediterranean islands, in disturbed and ruderal habitats, but also widely distributed in agroecosystems (Petsikos et al. 2007) which have brought forth losses of plant native diversity (approximately 10%), specifically of annual species (Vilà et al. 2006). The presence of *O. pes-caprae* in CONV system is probably favored by disturbance, soil movements and by the higher soil nutrient levels, which can be more efficiently exploited by invasive species (Sala et al. 2007). In addition, the higher water availability under irrigation conditions increases susceptibility to being colonized (Juárez-Escario et al. 2017; Mojzes et al. 2020).

Scientific studies investigating the interactions between seed bank density, composition, and fertilization regimes have shown contrasting results. For instance, Lal et al. (2016) demonstrated the positive effects of organic regimes on seed bank density while mineral fertilization has been linked to decreased weed species density and species richness. However, a study by Jiang et al. (2014) suggested that a balanced nutrient regime in the soil can reduce seed bank density while maintaining biodiversity and agroecosystem stability. Our study highlights that high nitrogen (N) availability promotes higher relative species abundance, mainly nitrophilic, in the system managed with mineral fertilizer (Moreau et al. 2014). On the other hand, ALTMO management resulted in a reduction in species richness and relative seed bank abundance to favor biodiversity. These findings suggest that achieving a proper balance of soil nutrients through a combination of intercropping and crop residue management can regulate seed bank density, thus promoting community diversity.

Since the tillage also affects the type of seed bank, our findings indicate an increase in the number of seeds belonging to the permanent seed bank in the BIROT management. This specialization reduces the available space for weed community regeneration, maintaining a diverse seed population characterized by numerous species, each present at a low density (Maia et al. 2004). This specialization plays a critical role in controlling weed populations and preserving biodiversity within the community.

Diversity and similarity in soil seed bank

The higher species richness observed in BIROT management confirms the positive effects of crop rotation practices on α agrobiodiversity, as observed by other authors such as Ulber et al. (2009), Chamorro et al. (2016) and Rotchés-Ribalta et al. (2020). Monoculture practice influenced diversity by leading to the specialization of many species with a high number of seedlings such as in the case of the alien weed *O. pes-caprae*, but with less diverse seed communities compared to organic managements. The Sørensen similarity index, calculated as a beta-diversity index, exhibited increasing values with the degree of complexity of agricultural management. Specifically, this index revealed higher similarity in species abundance between the two organic management systems. This implies that, although the application of organic practices positively contributed to greater species richness and abundance, it did not result in significant changes in the composition of floristic species compared to conventional management. However, the high similarity in the composition of the seed bank between organic managements provides a high level of conservation of herbaceous diversity (Aude et al. 2004; Fried et al. 2009).

The Sørensen similarity findings were further supported by the NMDS analysis, which revealed a lower Euclidian distance between the two organic managements. This signifies greater homogeneity in seed bank composition and lower relative species abundance. However, a clear separation between species did not occur, demonstrating that management is not the sole factor influencing the seed bank composition and diversity in horticultural fields. Studies conducted by Chick et al. (2018) in the Mediterranean region suggest that climatic and edaphic factors also interact with seed bank composition, influencing diversity. Therefore, further analysis of these factors would be crucial for a better understanding of dynamics in horticultural cropping systems.

Soil parameter implications on diversity soil seed bank

Some studies have explored the effect of soil temperature on seed germination and changes in seed dormancy status (Benech-Arnold and Sanchez 2004; Ooi et al. 2009; Hoyle et al. 2013). Others have highlighted the influence of soil moisture on density and species richness (Lundholm and Stark 2007; An et al. 2020). Nevertheless, the relationship between these parameters and soil seed bank diversity remains relatively unexplored. Our data suggests a strong correlation between soil temperature, CO_2 efflux seed bank richness and Simpsons' dominance index. Additionally, we observed a negative correlation between volumetric water content and Shannon and Simpson's indices, as well as seed bank species richness. Studies conducted by Ma et al. (2020) also reported a positive correlation between seed bank richness and soil temperature. Similarly, He et al. (2021) found that increasing soil moisture led to reductions in the richness of the transient seed bank. Understanding the relationship between seed bank richness, dominance, diversity indices, and soil characteristics holds particular significance in managing horticultural systems under irrigation regimes. In such systems, water distribution can alter soil edaphic characteristics, resulting in reduced soil temperatures (Karandish and Shahnazari 2016; Alli and Omofunmi 2021). Therefore, our study suggests that irrigation practices play a crucial role in influencing the long-term diversity and richness of the seed bank in agricultural soils.

Relationship between globe artichoke yield and agrobiodiversity

In agricultural systems, the preservation of biodiversity plays a pivotal role in upholding essential ecosystem services crucial for food production, nutrient recycling, and pollination, and other ecologically significant processes (Altieri 1999; Moonen and Bàrberi 2008). Our study highlights the relationship between management systems and artichoke yields, showing that the adoption of environmentally sustainable management practices can enhance crop productivity. This increased productivity may be attributed to the long-term improvement in soil fertility, driven by increased soil organic matter content, as observed by Deligios et al. (2017); Deligios et al. (2021) in the horticultural cropping system of globe artichoke cv. 'Spinoso sardo'. Additionally, it's worth considering that the positive effects may also be associated with ecosystem services resulting from the enhancement and maintenance of the agrobiodiversity in organically managed systems.

Conclusions

Overall, our study provided valuable insights into the effects of management systems on soil seed bank dynamics in a Mediterranean cropping system. Our results indicated that management practices significantly affected the abundance of seed bank species, though the impact on species composition is limited. Management practices also influenced diversity preservation (estimated as α and β diversity). High nitrogen inputs and intensive soil disturbance were associated with greater species richness and abundance, but lower diversity. This suggests that increased human activity (fertilizer application and tillage) negatively impacts the seed bank's composition and structure, highlighting the need for stricter control of specialized and invasive weed species.

Conversely, the adoption of organic practices was associated with more diversity of species, although the seed bank community showed greater homogeneity and uniformity in species composition. In contrast, conventional practices favored a specialization by nitrophilic species within the seed bank, resulting in reduced biodiversity. The study also highlights the impact of irrigation practices on soil seed bank diversity. Specifically, water distribution influences soil temperature and moisture, promoting structural heterogeneity and contributing to long-term seed turnover conservation. In conclusion, adopting alternative management based on an organic approach enhances agrobiodiversity in horticultural cropping systems without compromising crop yields.

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Data availability statement

Data will be made available on request.

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