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Arthropod diversity in apple orchards: the influence of hedgerows and landscape heterogeneity on community structure and ecosystem services in Medea (Algeria)

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ABSTRACT. This study investigates the role of hedgerows and landscape heterogeneity in supporting arthropod biodiversity within apple orchards in the Médéa region of Algeria. Comparing two contrasting orchard systems—one extensive with structural elements (Si El Mahdjoub) and one intensive without (Benchicao)—arthropod communities were sampled over a full annual cycle using pitfall traps, colored sticky traps, and sweep netting. A total of 251 arthropod taxa were recorded across both sites. Si El Mahdjoub exhibited significantly higher species richness (229 species vs. 184) and total abundance (4,351 vs. 3,183 individuals) compared to Benchicao. Despite similar overall species counts, Si El Mahdjoub showed greater taxonomic diversity with more even species distribution and higher effective diversity (Shannon H' and Simpson indices). The site with hedgerows supported a more functionally diverse arthropod assemblage, with higher numbers of predators (786 vs. 434) and parasites (530 vs. 482), while Benchicao was dominated by phytophagous species. Plant-arthropod richness correlation was strongly positive at Si El Mahdjoub ($r = 0.97$, $p = 0.026$) but negative at Benchicao ($r = -0.66$, $p = 0.54$). Seasonal analysis revealed that summer harbored the highest number of unique taxa (22.3%), with spring-summer overlap being most significant (32.3% shared taxa). Ordination analysis showed seasonality as the primary driver of community structure, with winter-autumn communities clustering separately from spring-summer assemblages. These findings underscore the ecological value of hedgerows and structural complexity in agricultural landscapes. Hedgerows enhance both taxonomic and functional arthropod diversity, contributing to ecosystem services such as biological pest control. The results support the resource heterogeneity hypothesis and highlight the importance of agroecological infrastructures for sustainable biodiversity management in orchard systems.

KEYWORDS: Agroecology, Conservation, Natural enemies, Phenology, Farm mosaic structure, Trophic guilds

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INTRODUCTION

Farmland biodiversity decline has altered the provisioning of ecological services in agro-ecosystems, which mediate energy and material fluxes or alter abiotic conditions (Chapin et al. 2000). Land-use composition and configuration consequently became simpler in homogeneous farmlands (Fahrig et al.

2011). Moreover, fencerows and roadsides in farmlands offer wider ranges of microenvironmental conditions for arthropod populations than in nearby crop fields (Marshall & Moonen 2002), such as sites for overwintering, feeding, or ovipositing (Landis et al. 2000; Olson & Wäckers 2007; Torretta & Poggio 2013).

The abundance and diversity of arthropods depend on the large-scale structure of agricultural landscapes, which normally consists of a mosaic of crops and non-crop habitats (Gardiner et al. 2009a, 2009b). There are a number of factors that influence both pests and natural enemies. The abundance and diversity of natural enemies of pests tend to increase with greater landscape complexity and a higher proportion of non-crop habitats (Gardiner et al. 2009a). Moreover, landscape simplification has negative effects on natural pest control (Rusch et al. 2016). However, landscape variables such as habitat complexity, quality, and patchiness, as well as the dispersal capacity of organisms (both pests and natural enemies), affect the capacity of a landscape to support biological control (Gardiner et al. 2009b). Furthermore, landscape characteristics may not affect all species equally or at the same scale (Gardiner et al. 2009a). However, fencerow removal to enlarge cropped areas annually consequently reduced arthropod species richness (Burel et al. 1998; Östman et al. 2001). Many arthropod species move between uncropped habitats and neighbouring cropped fields (spillover effects, Rand et al. 2006), which constitutes a vital ecological process for ensuring biological control and resilience in agro-ecosystems (Tscharntke et al. 2005; Boreau de Roincé 2012). Thus, uncropped habitats may function as arthropod resources for reassembling communities within fields after farming acute effects. Landscape heterogeneity modulates the predation pressure on herbivores in fencerows, thus controlling smaller populations and decreasing the outbreak probability (Bommarco 1998; Bianchi et al. 2006). Predation should be more severe in heterogeneous landscapes due to the more complex trophic structure of arthropod communities (top-down effects; Bommarco 1998). For example, generalist natural enemies can suppress pest outbreaks, or at least reduce their incidence, but effectiveness decreases as landscape homogeneity increases (Östman et al. 2001; Tscharntke et al. 2005).

Apples (*Malus domestica*) are one of the most consumed and traded temperate fruit crops in the world, followed by grapes, oranges, and bananas (Forsline et al. 2003). Apple production continually faces new challenges, such as constantly changing consumer demands due to differential preferences for taste and flavours, climate change, and biotic and abiotic stresses (Zanetti et al. 2020). An apple tree (*Malus domestica* Borkh.) is a traditional and most commonly grown fruit tree in Algeria (Abdessemed et al. 2022). Previously, the central region (Medea – Blida – Ain Defla) of Algeria represented a quarter of the total area dedicated to apple production with a total of 7.400 ha (Abdessemed et al. 2022). The provinces of Medea, which have climatic conditions most suitable for apple production, recorded the greatest yields. This region now represents the principal region of apple production in Algeria (Abdessemed et al. 2022). According to the statistics of 2024 from the agricultural directorate, the apple orchards in these regions cover a total area of 6547 ha, i.e., 33% of the total arboreal area in this province. The total production reached 539,761 quintals, with an average yield of 188.3 quintals per hectare. However, the fruit yield/ha remains low due to limited access to new technologies for pest and crop management, storage, and a lack of knowledge on the best practices required for the overall apple production. The occurrence of arthropods on apple trees has already studied in the past in only two regions. However, these studies were conducted primarily in commercial apple orchards. Guettala-Frah (2009) found 348 insect species on apple trees. Other studies were focused on the occurrence of specific groups – such as pest antagonists (Guermah et al. 2019). A common limiting factor in these studies is the methods of capture and collection of arthropods.

The main objective of our research was to assess the value of fencerows for sustaining arthropod diversity in Sidi El Mahdjoub orchard farmed mosaics. In addition, our study is also aimed at identifying the factors associated with the spatial heterogeneity at different scales that influence the structure of epigeal arthropod assemblages. Within this framework, we evaluate: (1) the taxonomic richness and relative Abundance patterns of arthropods between stations on the species richness and abundance of arthropods, (2) the Trophic guilds, and categories of occurrences of arthropods fauna importance of fencerows to retain arthropods diversity, and (3) the effects of spatial *Spatio-temporal* heterogeneity on arthropod guilds, as well as the "redundancy" (diversity) within each guild. We expect

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that fencerows not only will play a key role in sustaining arthropod diversity in farmland mosaics, but will also strongly interact with heterogeneity at wide spatial scales and hence contribute to retaining arthropod populations that provide ecosystem services to agriculture.

In the present study, we aimed to determine the species composition of the arthropod assemblage, as well as the corresponding trophic groups associated with apple orchards.

MATERIAL AND METHODS

Study area (Figs 1–2). The area of Medea (36°16'17.34"N–2°46'0.03"E), located in the semi-arid bioclimatic stage at mild winter (Driouech et al. 2020), is characterized by one winter cold (T minimal average 2.6–3.6°C) and rainy (460 mm) and a summer lime and dryness (29°C). Historically, the central regions of Algeria, namely Medea and the other two regions, accounted for 25% of the total area dedicated to apple production, with a total of 7,400 hectares under cultivation (Abdessemed et al. 2022). The first selected orchard (Benchicao ITAFV site) (locality of Medea province, latitude: 36°38'9.39", longitude: 2°57'0.82"E, altitude 1133 m, located 80 km south-west of Algiers) is in a mountainous area with a warm temperate climate. Daily maximum and minimum temperature data obtained over a period of 24 years (2000 to 2024) were collected at weather stations near selected sites belonging to the National Office of Meteorology. Average temperatures were calculated using maximum and minimum temperatures. Benchicao locality is dominated by a very large area in which fruit trees are the main cultivated crops. This orchard follows the new so-called intensive production system (Table 1, Fig. 1), with a density of trees (400 trees/ha), raised bed planting, with high production inputs (fertilizers, herbicides, and pesticides) provided at high frequency in order to reach maximum yield. Moreover, weeding was done permanently by using chemical herbicides.
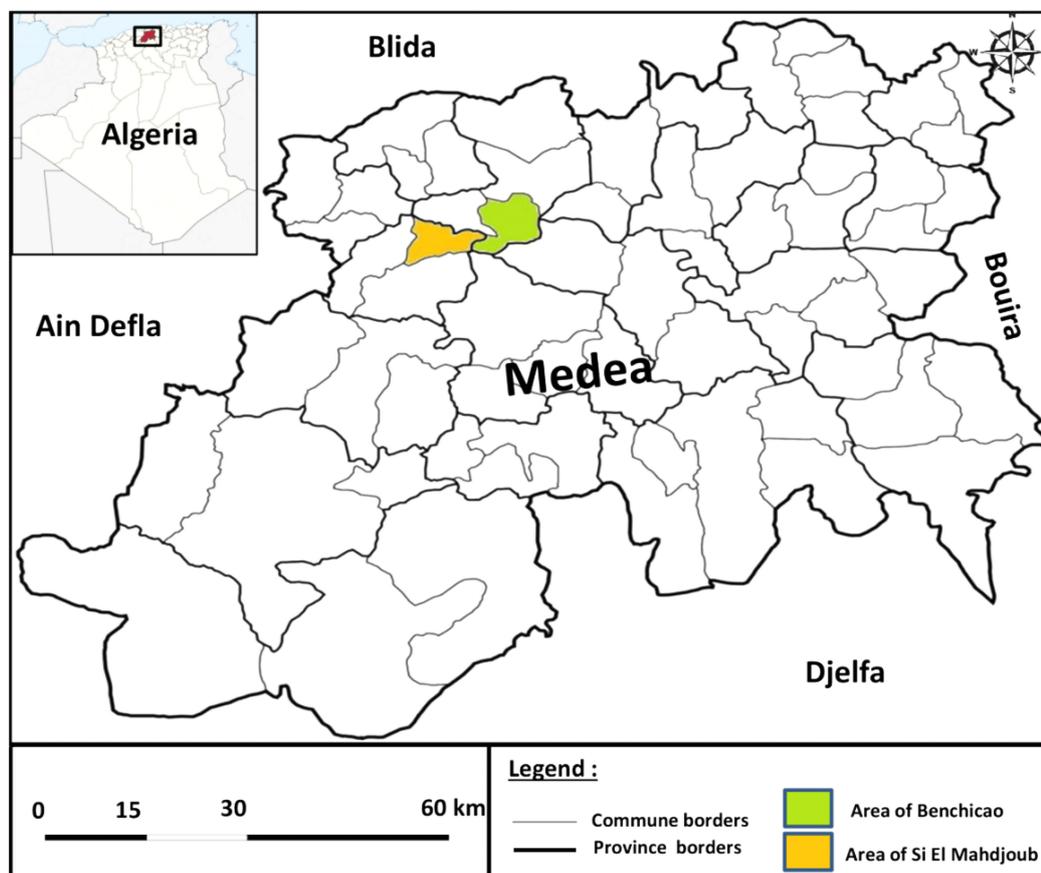

Figure 1. Geographical location of the study sites.

The second selected orchard (Sidi El Mahdjoub site) is located in the same region, 30 km south of Medea Province (locality of Medea province, latitude: 36°11'9"N, longitude: 2°50'55"E, altitude 1133 m a.s.l.), dominated by a large area of Apple and Strawberries orchards and surrounded by some vegetable crops with thick coniferous forests. This orchard adopted an extensive conventional cropping system (300 to 400 trees/ha), with a low frequency of input application and without weeding (Tables 1–2, Fig. 2). During the period from January to December to June 2023, the farmer did not apply any kind of pesticides (Table 1).

Arthropod sampling methods and identification. The study was conducted in an area in a high altitudinal range from the 2023 season (March–September 2023), namely during the Spring and Summer seasons. Arthropods were sampled during an annual cycle between January and December 2023, with two samples per month. Each station was equipped with three types of traps (Barber pitfall traps, coloured sticky traps, and sweep net moving) (Aidoo et al. 2016). Every 15 days, a regular passive trapping was carried out in both studied environments (Benchicao and Sidi El Mahdjoub) for data collection, using the Barber pitfall traps and color traps. Ten Barber pots (PT) were arranged on a homogeneous square plot with a surface area of 400 m^2 (Lamotte & Bourliere 1969). Pitfall traps are metal containers 15 cm in diameter and 18 cm in depth, placed in the ground so that the opening is flush with the ground. These pots were sunk into the ground and 2/3 filled with water and preservative liquid (detergent), preventing trapped invertebrates from escaping and being consumed by their predators (Pearce et al. 2005).

Figure 2. Comparison of landscape structures at the study sites. **A.** Orchard in Si El Mahdjoub, showing dense and spontaneous vegetation cover; **B.** Orchard in Benchicao, characterized by bare soil and absence of inter-row vegetation.

Table 1. Characteristics of the selected apple orchards.

Characters	Benchicao	Sidi El Mahdjoub
Geographical coordinates	36°38'9.39"N, 02°57'0.82"E	36°17'35.3"N, 02°72'0.65"E
Altitude, m a.s.l.	1030	900
Variety	Golden Delicious with 1/4 Starkrimson	Golden Delicious with 1/4 Starkrimson
Weeding method	Chemical/Mechanical (permanently)	Unweeded
Soil texture	Clay loam	Sandy loam
Age (years)	20	18
Surface (ha)	04	02
Planting density	400 plants/ha	400 plants/ha
Botanical richness	159 species	175 species
Chemical control	- Reduced (3 interventions per year) - Chemical weed control	- no pesticide application - Mechanical weed control

Ten pots are installed in line at regular intervals of 5 meters. The pitfall traps were left in place for 24h. For coloured sticky traps (PC yellow and white), we placed them on stones at the level of the Apple trees and changed them twice a month (Atakan & Pehlivan 2015). Method of Sweep net mowing (Roth 1963) The method of mowing the net herbaceous cover of the inter-row is carried out at a rate of 70 blows per statement; that is to say, 3 statements in total in spring and at the beginning of summer of the year 2003. Hence, one blue trap, one yellow trap, and one pitfall trap were set in the middle of the four sides of the rectangular sampling plot and along one of its diagonals (Bastide 1989). Captured insects were collected every 15 days and stored in tubes containing 70% alcohol before being processed in the laboratory. After each collection date, sampling plots of each site (Benchicao and Sidi El Mahdjoub) were changed in order to survey the whole orchard and avoid over-exhaustion of the surrounding entomofauna (Bounaceur et al. 2018). The trapped species were collected in Petri dishes and then labelled with the pot trap number and the date of trapping. Moreover, the samples were sorted, counted, and ultimately identified based on the photographic documentation of insect morphology, with specimens compared to a dichotomous key guide for insects. The images were cross-referenced with the available literature to confirm species identification. Essential taxonomic identification was performed to distinguish between species and track the diversity of the insect populations throughout the growing season. Their identification reached the taxonomic level of order, family, genus, and to the species level when possible, with a special emphasis on species of agricultural interest such as pests, disease vectors, natural enemies, and pollinators using identification guides (Perrier 1927; Balachowsky 1962; Perrier 1964; Stanek 1973; Roth 1974; Pihan 1977; Chinery 1983; Zahradnik 1984; Chouinard et al. 2000; Capinera 2008). All the insects identified are preserved in limp of collection and kept at the laboratory of entomology of the department of agronomy of Boumerdes's University.

Ground cover vegetation data. At each trap location, in a plot of 1 m², the vascular plant species were surveyed and identified, and the cover-abundance per plant species was recorded using the Braun-Blanquet scale, modified by Van Der Maarel (1979). The percentage of total ground cover was also recorded. This sampling was performed between the end of May and the beginning of June.

Taxonomic Richness and Composition Metrics. Species richness (S) was defined as the total number of distinct species recorded at each sampling station during each survey period, and served as a basic indicator of taxonomic diversity. Relative abundance (RA) of each species was calculated as the proportion of individuals of that species relative to the total number of individuals collected at the same station, expressed as a percentage using the formula: *RA (%) = (ni / N) × 100*, where ni is the number of individuals of species i and N is the total number of individuals captured during the sampling session. The frequency of occurrence (Occ), also referred to as the constancy index or appearance frequency, was computed following the method described by Dajoz (1985): *Occ (%) = (ri / R) × 100*, where ri is the number of sampling units in which at least one individual of species i was present, and R represents the total number of sampling units examined. To further interpret occurrence patterns, species were categorized according to the classification of Bigot & Bodot (1973) into four groups: Constant species (CN): occurring in ≥ 50% of samples, Common species (CM): present in 25–49% of samples, Accidental species (AC): present in 10–24% of samples, Very accidental species (VA): or sporadic, present in < 10% of samples. This classification allowed for a better understanding of species' ecological fidelity and the stability of their presence across habitats.

Diversity Indices. Community diversity was assessed using two widely adopted indices: the Shannon–Wiener diversity index (*H'*), the Pielou's evenness index (*E*), and the Simpson Diversity Index (*D*). The Shannon index, which integrates both richness and abundance, was calculated as: $H' = -\Sigma(Pi \times logPi)$, where *Pi* represents the proportional abundance of species *i* (*Pi = ni / N*). This index provides a robust measure of the entropy or uncertainty associated with the identity of a randomly drawn individual from the community (Magurran 2021). To evaluate the equitability of species distributions within communities, the evenness index (*E*) was calculated using the formula: $E = H' / log_2 S$, where **S** is the total number of species, and *H'* is the Shannon index. Values of E range between 0 and 1, with values close to 1 indicating an even distribution of individuals among species, and values below 0.5 suggesting community dominance by a few taxa (Barbault 1981). The Simpson diversity index (*D*) measures the probability that two individuals randomly selected from a sample belong to different species. It reflects both richness and dominance, and is calculated as: $D = 1 - \Sigma(Pi^2)$, where *Pi* is the relative abundance of

species *i*. Lower values indicate low diversity (high dominance), whereas values closer to 1 suggest greater diversity (Magurran 2021).

Statistical Analyses. To test for significant differences in diversity metrics among stations, seasons, and trophic guilds, generalized linear models (GLMs) were applied. Given the overdispersion commonly observed in ecological count data, negative binomial GLMs were used for species richness and abundance (Stoklosa et al. 2022). For continuous variables such as Shannon index, Simpson index, evenness, and maximum diversity (H_{max}), data were assumed to follow a Gaussian distribution. Pairwise comparisons and interaction effects were also assessed to explore the influence of environmental and trophic factors on community structure. In addition, a Detrended Correspondence Analysis (DCA) was performed to explore gradients in arthropod community composition across seasons and sampling sites. This ordination method allowed for the identification of ecological patterns and turnover in species assemblages, while correcting for the arch effect commonly observed in correspondence analysis.

Correlation Analysis and Taxonomic Overlap. In addition, Pearson correlation tests were performed to examine the relationships among diversity indices. A correlation matrix was produced using the R package performance (Lüdecke et al. 2021), enabling the detection of positive or negative associations between ecological variables and highlighting possible redundancy or complementarity among indices. To visualize taxonomic overlap among different sampling stations and seasons, Venn diagrams were generated, illustrating both shared and unique species across groups (Yan & Yan 2023). These diagrams provided insight into patterns of species turnover and complementarity between ecological contexts.

RESULTS

Taxonomic richness and relative abundance. Our comparative analysis of arthropod communities between Si El Mahdjoub and Benchicao revealed marked differences in species richness and community composition. Si El Mahdjoub displayed higher species richness, with 229 species recorded across 85 families, 18 orders, and 5 arthropod classes, compared to Benchicao with 184 species from 79 families (same number of classes and orders). Total abundance was similar between stations. Insects were dominant at both sites (95.81% at Si El Mahdjoub; 96.03% at Benchicao), followed by Arachnida, Chilopoda, Diplopoda, and Malacostraca. At Si El Mahdjoub, the most represented insect orders were Hemiptera (28.15%), Hymenoptera (24.51%), and Coleoptera (21.67%). At Benchicao, Coleoptera (29.03%), Hymenoptera (26.04%), and Hemiptera (14.18%) were dominant. The most abundant species at Si El Mahdjoub was *Aphis pomi* (De Geer, 1773) (6.94% of total specimens), whereas at Benchicao, *Oxythyrea subclava* (Marseul, 1878) was most abundant (8.29%) (Table 3).

Hemiptera showed higher relative abundance at Si El Mahdjoub (28.93%, 27 species). Coleoptera were more abundant at Benchicao (30.45%) but more species-rich at Si El Mahdjoub (59 species vs. 40). Hymenoptera showed comparable abundance and richness at both sites. Orthoptera were more represented at Benchicao in terms of abundance and species richness. Araneae exhibited higher species richness at Si El Mahdjoub (32 vs. 19 species) despite similar overall abundance. Several orders (Scorpiones, Isopoda, Julida, Neuroptera) were rare at both sites. Geophilomorpha and Embioptera were absent from Benchicao. Overall, Si El Mahdjoub showed higher species richness and a broader representation across several orders, whereas Benchicao was characterized by lower richness and higher dominance of a smaller set of taxa.

Rarefaction and extrapolation of arthropod species richness. Rarefaction and extrapolation analyses were conducted to evaluate the completeness of sampling and to compare species richness and diversity between the two apple orchards. Sampling coverage exceeded 97% at both stations, indicating that the majority of species present in the arthropod communities were captured during the sampling period (Fig. 3). The species accumulation curves for both stations approached asymptotes, confirming that additional sampling would likely yield few additional species. Species richness estimates based on diversity order *q = 0*, which represents the total number of species regardless of their abundance, were slightly higher at Benchicao. In contrast, diversity indices that account for species abundances (*q = 1*, exponential Shannon index, and *q = 2*, inverse Simpson index) consistently showed higher values at Si El Mahdjoub. This indicates that although Benchicao had a comparable number of species, the effective diversity, which considers both richness and abundance distribution, was greater at Si El Mahdjoub.

Table 2. Individual numbers, relative abundance, and species richness of arthropod orders captured in Si El Mahdjoub and Benchicao Stations (Medea, Algeria).

Class	AR%		Orders	Si El Mahdjoub			Benchicao		
	Si El Mahdjoub	Benchicao		N	RA (%)	SR	N	RA (%)	SR
Arachnida	3.42	3.16	Araneae	136	3.37	32	112	3.10	19
			Scorpiones	2	0.05	1	2	0.06	1
Malacostraca	0.12	0.06	Isopoda	5	0.12	1	9	0.25	1
Diplopoda	0.25	0.5	Julida	10	0.25	1	18	0.50	2
Chilopoda	0.40	0.25	Lithobiomorpha	11	0.27	1	9	0.25	1
			Geophilomorpha	5	0.12	1	0	0.00	0
Insecta	95.81	96.03	Zygentoma	9	0.22	1	8	0.22	2
			Odonata	17	0.42	2	16	0.44	2
			Plecoptera	18	0.45	2	21	0.58	2
			Orthoptera	268	6.64	16	340	9.41	24
			Dermaptera	69	1.71	5	68	1.88	4
			Mantodea	3	0.07	1	3	0.08	1
			Embioptera	0	0.00	0	2	0.06	1
			Hemiptera	1167	28.93	27	606	16.77	20
			Neuroptera	22	0.55	3	14	0.39	2
			Coleoptera	1020	25.29	59	1100	30.45	40
			Diptera	227	5.63	19	268	7.42	12
			Lepidoptera	184	4.56	13	161	4.46	10
			Hymenoptera	861	21.34	44	856	23.69	44
			Total	**4034**	**100**	**229**	**3613**	**100**	**188**

Abbreviations: RA–Relative abundance (%); N–Number of individuals; SR: Species richness.

Table 3. Number and relative abundance of arthropods sampled in Si El Mahdjoub and Benchicao stations in Medea, Northwestern Algeria.

Class	Order	Family	Taxa	Si El Mahdjoub		Ben chicao	
				N	RA%	N	RA%
Arachnida	**Araneae**	Zodariidae	*Zodarion algiricum* (Denis, 1938)	8	0.19	8	0.22
			Zodarion agricola (Denis, 1935)	8	0.19	8	0.22
			Zodarion sp.	3	0.07	3	0.08
		Gnaphosidae	*Haplodrassus dalmatensis* (Koch, 1866)	5	0.12	3	0.08
			Zelotes tenuis (Koch, 1866)	6	0.14	3	0.08
			Zelotes tristis (Koch, 1837)	8	0.19	5	0.14
			Drassylus sp.	3	0.07	5	0.14
			Cryptodrassus hungaricus (Balogh, 1935)	5	0.12	-	0.00
			Drassodes sp.	2	0.05	3	0.08
			Drassodes difficilis (Simon, 1878)	4	0.09	-	0.00
			Civizelotes medianus (Koch, 1837)	5	0.12	-	0.00
			Zelotes aeneus (Simon, 1878)	6	0.14	5	0.14
			Leptodrassus sp.	3	0.07	4	0.11
		Salticidae	*Aelurillus* sp.	5	0.12	-	0.00
			Salticus sp. 1	11	0.25	27	0.75
			Salticus sp. 2	6	0.14	-	0.00
			Chalcoscirtus nigritus (Thorell, 1875)	9	0.21	11	0.30
			Sibianor sp.	11	0.25	3	0.08
			Aelurillus luctuosus (Lucas, 1846)	5	0.12	15	0.41
			Phlegra fasciata (Hahn, 1826)	10	0.23	10	0.28
			Salticus propinquus (Lucas, 1846)	12	0.28	-	0.00
		Clubionidae	*Clubiona maculata* (Linnaeus, 1758)	9	0.21	9	0.25
			Clubiona frutetorum (Koch, 1867)	20	0.46	-	0.00
			Clubiona sp.	11	0.25	11	0.30
			Clubiona terrestris (Westring, 1851)	2	0.05	12	0.33

Class	Order	Family	Taxa	Si El Mahdjoub		Ben chicao	
				N	RA%	N	RA%
			Talavera sp.	5	0.12	-	0.00
		Lycosidae	*Trochosa albifrons* (Koch, 1872)	5	0.12	3	0.08
			Alopecosa sp.	7	0.16	2	0.06
			Lycosidae sp.	2	0.05	-	0.00
		Oecobiidae	*Oecobius maculatus* (Simon, 1870)	23	0.53	-	0.00
		Theraphosidae	*Grammostola rosea* (Walckenaer, 1837)	5	0.12	12	0.33
		Dictynidae	*Dictyna civica* (Lucas, 1849)	9	0.21	-	0.00
	Scorpiones	Buthidae	*Androctonus australis* (Linnaeus, 1758)	6	0.14	2	0.06
Malacostraca	Isopoda	Armadillidiidae	*Armadillidium vulgare* (Latreille, 1804)	5	0.12	9	0.25
Diplopoda	Julida	Julidae	*Cylindroiulus caeruleocinctus* (Wood, 1864)	10	0.23	12	0.33
			Allajulus sp.	-	0.00	8	0.22
Chilopoda	Lithobiomorpha	Lithobiidae	*Lithobius forficatus* (Linnaeus, 1758)	11	0.25	9	0.25
	Geophilomorpha	Geophilidae	*Pachymerium ferrugineum* (Koch, 1835)	17	0.39	-	0.00
Insecta	Zygentoma	Lepismatidae	*Lepisma saccharina* (Linnaeus, 1758)	9	0.21	5	0.14
			Zygentoma sp.	-	0.00	3	0.08
	Odonata	Lestidae	*Chalcolestes viridis* (Vander Linden, 1825)	6	0.14	5	0.14
		Libellulidae	*Orthetrum chrysostigma* (Burmeister, 1839)	11	0.25	11	0.30
	Plecoptera	Taeniopterygidae	*Brachyptera algirica* (Aubert, 1956)	8	0.19	10	0.28
			Brachyptera risi (Morton, 1896)	34	0.79	47	1.30
	Orthoptera	Gryllidae	*Acheta domesticus* (Linnaeus, 1758)	7	0.16	11	0.30
			Modicogryllus bordigalensis (Latreille, 1804)	22	0.51	8	0.22
			Gryllus bimaculatus (De Geer, 1773)	11	0.25	0	0.00
			Gryllus sp. 1	-	0.00	10	0.28
			Gryllus sp. 2	-	0.00	6	0.17
		Tettigoniidae	*Tettigonia viridissima* (Linnaeus, 1758)	28	0.65	7	0.19
			Tettigonia caudata (Charpentier, 1845)	10	0.23	5	0.14
			Amphiestris baetica Rambur, 1838	35	0.81	11	0.30
			Decticus albifrons (Fabricius, 1775)	-	0.00	3	0.08
		Acrididae	*Chorthippus bicolor* (Charpentier, 1825)	7	0.16	9	0.25
			Omocestus raymondi (Yersin, 1863)	32	0.74	32	0.88
			Omocestus africanus (Brunner von Wattenwyl, 1878)	18	0.42	58	1.60
			Omocestus viridulus (Linnaeus, 1758)	21	0.49	35	0.97
			Omocestus sp. 1	-	0.00	18	0.50
			Oedipoda germanica (Latreille, 1804)	12	0.28	22	0.61
			Oedipoda caerulescens (Linnaeus, 1758)	-	0.00	45	1.24
			Oedipoda sp.	-	0.00	12	0.33
			Dociostaurus maroccanus (Thunberg, 1815)	9	0.21	21	0.58
		Pyrgomorphidae	*Leptysma debilis* (Walker, 1870)	10	0.23	5	0.14
			Pyrgomorpha cognata Krauss, 1877	10	0.23	7	0.19
		Pamphagidae	*Pamphagus cristatus* (Linnaeus, 1758)	7	0.16	5	0.14
			Ocneridia volxemi (Bolívar, 1884)	3	0.07	8	0.22
			Pamphagus elephas (Linnaeus, 1758)	-	0.00	2	0.06
		Trigonidiidae	*Pteronemobius heydenii* (Fischer, 1853)	-	0.00	7	0.19
	Dermaptera	Forficulidae	*Forficula auricularia* (Linnaeus, 1758)	36	0.83	52	1.44
			Forficula sp.	8	0.19	-	0.00
			Chelidura acanthopygia (Géné, 1832)	5	0.12	6	0.17
		Carcinophoridae	*Anisolabis mauritanicus* (Lucas, 1849)	5	0.12	10	0.28
		Labidae	*Labia minor* (Linnaeus, 1758)	29	0.67	6	0.17
		Labiduridae	*Labidura riparia* (Pallas, 1773)	11	0.25	-	0.00
	Mantodea	Mantidae	*Sphodromantis lineola* (Burmeister, 1838)	3	0.07	3	0.08
	Embioptera		*Notoligotomidae* sp.	-	0.00	2	0.06
	Hemiptera	Pentatomidae	*Zicrona caerulea* (Linnaeus, 1758)	18	0.42	0	0.00
			Carpocoris mediterraneus (Tamanini, 1958)	85	1.97	29	0.80
			Carpocoris pudicus (Poda, 1761)	65	1.50	19	0.53
			Elasmotethus sp.	70	1.62	-	0.00
			Dryadocoris apicalis (Herrich-Schäffer, 1842)	27	0.62	-	0.00
			Graphosoma semipunctatum (Fabricius, 1775)	21	0.49	6	0.17
			Graphosoma lineatum (Linnaeus, 1758)	-	0.00	55	1.52
			Peribalus strictus vernalis (Wolff, 1804)	78	1.80	-	0.00
			Antestiopsis lineaticollis (Stål, 1865)	0	0.00	125	3.46
		Rhyparochromidae	*Xanthochilus saturnius* Rossi, 1790	40	0.93	10	0.28
			Aphanus rolandri (Linnaeus, 1758)	6	0.14	9	0.25
			Camptocera glaberrima (Walker, 1872)	7	0.16	-	0.00
		Pyrrhocmridae	*Pyrrhocoris apterus* (Linnaeus, 1758)	120	2.78	65	1.80
			Pyrrhocoris sp.	12	0.28	4	0.11
			Scantius aegyptius (Linnaeus, 1758)	23	0.53	-	0.00

Class	Order	Family	Taxa	Si El Mahdjoub		Ben chicao	
				N	RA%	N	RA%
		Lygaeidae	*Horvathiolus superbus* (Pollich, 1781)	25	0.58	28	0.77
			Spilostethus saxatilis (Scopoli, 1763)	28	0.65	28	0.77
			Spilostethus sp.	18	0.42	-	0.00
			Nysius cymoides (Spinola, 1837)	9	0.21	0	0.00
			Graptostethus servus (Fabricius, 1787)	6	0.14	0	0.00
			Graptostethus sp.	0	0.00	22	0.61
		Coreidae	*Syromastus rhombeus* (Linnaeus, 1767)	2	0.05	-	0.00
			Centrocoris variegatus (Kolenati, 1845)	0	0.00	15	0.41
		Cicadellidae	*Platymetopius notatus* (Mulsant & Rey, 1855)	10	0.23	5	0.14
			Scaphoideus titanus (Ball, 1932)	5	0.12	9	0.25
			Scaphoideus sp.	3	0.07	0	0.00
		Reduviidae	*Reduvius personatus* (Linnaeus, 1758)	9	0.21	13	0.36
			Pygolampis bidentata (Goeze, 1778)	5	0.12	11	0.30
			Rhynocoris erythropus (Linnaeus, 1767)	8	0.19	-	0.00
		Miridae	*Lygus gemellatus* (Herrich-Schäffer, 1835)	17	0.39	-	0.00
		Aphididae	*Dysaphis plantaginea* (Passerini, 1860)	200	4.63	22	0.61
			Aphis pomi (De Geer, 1773)	300	6.94	28	0.77
		Alydidae	*Camptopus lateralis* (Germar, 1817)	-	0.00	10	0.28
	Neuroptera	Chrysopidae	*Chrysoperla carnea* (Stephens, 1836)	9	0.21	15	0.41
		Myrmeleontidae	*Creoleon aegyptiacus* (Hölzel, 1970)	8	0.19	-	0.00
			Myrmeleon inconspicuus (Rambur, 1842)	17	0.39	37	1.02
	Coleoptera	Cerambycidae	*Purpuricenus desfontainii* (Fabricius, 1792)	3	0.07	3	0.08
			Agapanthia irrorata (Fabricius, 1787)	9	0.21	3	0.08
		Dytiscidae	*Eretes* sp.	19	0.44	-	0.00
		Tenebrionidae	*Pimelia subglobosa* (Solier, 1836)	9	0.21	15	0.41
			Gonocephalum rusticum (Olivier, 1795)	7	0.16	7	0.19
			Scleron armatum (Fabricius, 1798)	4	0.09	2	0.06
			Pachychila germari (Solier, 1835)	5	0.12	-	0.00
			Scaurus sp.	10	0.23	-	0.00
			Alphitobius diaperinus (Panzer, 1797)	7	0.16	10	0.28
			Lamprocrypticus alpinus (Gyllenhal, 1827)	5	0.12	7	0.19
			Gonocephalum perplexum (Fabricius, 1792)	9	0.21	6	0.17
			Pimelia sp.	2	0.05	-	0.00
			Tentyria sp.	-	0.00	39	1.08
		Scarabaeidae	*Heliotaurus sanguinicollis* (Fabricius, 1792)	3	0.07	-	0.00
			Pimelia rotundata Brullé, 1832	5	0.12	9	0.25
			Heliotaurus sp.	8	0.19	5	0.14
			Oxythyrea funesta (Poda, 1761)	220	5.09	250	6.91
			Oxythyrea subclava (Ménétriés, 1832)	260	6.01	300	8.29
			Hoplia africana (Fairmaire, 1868)	5	0.12	-	0.00
			Protaetia sp.	25	0.58	23	0.64
			Protaetia opaca (Fabricius, 1787)	28	0.65	18	0.50
		Buprestidae	*Geotrogus deserticola* (Lucas, 1846)	55	1.27	25	0.69
			Potosia cuprea (Fabricius, 1775)	3	0.07	-	0.00
			Tropinota squalida (Scopoli, 1763)	-	0.00	185	5.11
			Anthaxia sp. 1	22	0.51	-	0.00
			Anthaxia sp. 2	3	0.07	-	0.00
			Acmaeodera cylindrica (Fabricius, 1787)	2	0.05	5	0.14
		Curculionidae	*Acmaeoderella adspersula* (Illiger, 1803)	2	0.05	1	0.03
			Acmaeodera quadrizonata (Saunders, 1871)	5	0.12	8	0.22
			Trachys minutus (Linnaeus, 1758)	5	0.12	2	0.06
			Coniocleonus sp.	5	0.12	-	0.00
			Larinus sturnus (Schaller, 1783)	9	0.21	11	0.30
			Lixus iridis (Olivier, 1807)	6	0.14	-	0.00
			Lixus algirus (Linnaeus, 1758)	10	0.23	3	0.08
		Chrysomelidae	*Asproparthenis punctiventris* (Germar, 1824)	5	0.12	3	0.08
			Elaeidobius sp.	3	0.07	-	0.00
			Larinus planus (Fabricius, 1792)	8	0.19	6	0.17
			Bruchidius sp.	5	0.12	-	0.00
		Coccinellidae	*Chrysolina bankii* (Fabricius, 1775)	11	0.25	-	0.00
			Phyllotreta sp.	10	0.23	-	0.00
			Cassida nobilis (Linnaeus, 1758)	9	0.21	-	0.00
			Rhyzobius litura (Fabricius, 1787)	7	0.16	-	0.00
			Coccinella algerica (Kovář, 1977)	22	0.51	-	0.00
			Coccinella quinquepunctata (Linnaeus, 1758)	2	0.05	5	0.14
			Coccinella septempunctata (Linnaeus, 1758)	-	0.00	37	1.02
		Carabidae	*Adalia decempunctata* (Linnaeus, 1758)	2	0.05	-	0.00

Class	Order	Family	Taxa	Si El Mahdjoub		Ben chicao	
				N	RA%	N	RA%
			Stethorus punctillum (Weise, 1891)	3	0.07	-	0.00
			Hippodamia variegata (Goeze, 1777)	5	0.12	5	0.14
			Carterus dama (Rossi, 1792)	10	0.23	-	0.00
			Calathus fuscipes (Goeze, 1777)	5	0.12	-	0.00
		Cleridae	*Zabrus spinipes* (Fabricius, 1798)	7	0.16	-	0.00
			Percus sp.	2	0.05	-	0.00
			Blemus discus (Fabricius, 1792)	-	0.00	9	0.25
			Trichodes apiarius (Linnaeus, 1758)	5	0.12	-	0.00
		Elateridae	*Trichodes leucopsideus* (Olivier, 1795)	12	0.28	10	0.28
		Tenebrionidae	*Trichodes umbellatarum* (Fabricius, 1792)	10	0.23	7	0.19
			Necrobia rufipes (De Geer, 1775)	2	0.05	2	0.06
			Agriotes lineatus (Linnaeus, 1767)	2	0.05	5	0.14
		Rhadalidae	*Aplocnemus* sp.	2	0.05	-	0.00
		Melyridae	*Clanoptilus* sp.	7	0.16	9	0.25
			Psilothrix aureola (Linnaeus, 1758)	3	0.07	3	0.08
			Clanoptilus rufus (Olivier, 1790)	-	0.00	7	0.19
		Cantharidae	*Malthodes* sp.	3	0.07	-	0.00
		Mordellidae	*Mordella aculeata* (Linnaeus, 1758)	5	0.12	-	0.00
		Silphydae	*Silpha obscura* (Linnaeus, 1758)	-	0.00	5	0.14
	Diptera	Syrphidae	*Eristalis tenax* (Linnaeus, 1758)	6	0.14	-	0.00
			Eristalis pertinax (Scopoli, 1763)	-	0.00	19	0.53
			Eupeodes corollae (Fabricius, 1794)	6	0.14	6	0.17
			Syrphus sp.	3	0.07	-	0.00
		Dolichopodidae	*Hydrophorus* sp. 1	9	0.21	4	0.11
			Hydrophorus sp. 2	11	0.25	-	0.00
		Calliphoridae	*Lucilia sericata* (Meigen, 1826)	6	0.14	6	0.17
			Lucilia sp.	5	0.12	-	0.00
		Asilidea	*Tolmerus cingulatus* (Fabricius, 1781)	7	0.16	-	0.00
			Neoitamus cyanurus (Loew, 1849)	3	0.07	-	0.00
		Muscidae	*Musca domestica* (Linnaeus, 1758)	10	0.23	21	0.58
			Hydrotaea sp.	5	0.12	-	0.00
		Canopidae	*Sicus ferrugineus* (Linnaeus, 1761)	3	0.07	5	0.14
		Tiphritidae	*Ceratitis capitata* (Wiedemann, 1824)	19	0.44	70	1.94
		Sarcophagidae	*Sarcophaga africa* (Wiedemann, 1824)	9	0.21	5	0.14
		Drosophilidae	*Drosophila kuntzei* (Duda, 1924)	2	0.05	7	0.19
		Chironomidae	*Chironomus* sp.	4	0.09	4	0.11
		Tabanidae	*Philipomyia* sp.	3	0.07	3	0.08
		Stratiomyidae	*Hermetia illucens* (Linnaeus, 1758)	3	0.07	3	0.08
		Tachinidae	*Cylindromyia auriceps* (Meigen, 1824)	5	0.12	-	0.00
	Lepidoptera	Tortricidae	*Cydia pomonella* (Linnaeus, 1758)	18	0.42	46	1.27
			Tortrix sp.	20	0.46	16	0.44
		Nymphalidae	*Melanargia lachesis* (Hübner, 1813)	20	0.46	22	0.61
			Vanessa cardui (Linnaeus, 1758)	32	0.74	42	1.16
			Maniola sp.	18	0.42	-	0.00
		Noctuidae	*Noctuidae* sp. 1	12	0.28	-	0.00
			Noctuidae sp. 2	18	0.42	10	0.28
			Noctuidae sp. 3	3	0.07	-	0.00
			Autographa gamma (Linnaeus, 1758)	9	0.21	5	0.14
		Pieridae	*Pieris brassicae* (Linnaeus, 1758)	33	0.76	20	0.55
		Papilionidae	*Papilio machaon* Linnaeus, 1758	15	0.35	12	0.33
		Lyonitidae	*Leucoptera malifoliella* (Costa, 1836)	58	1.34	20	0.55
		Tineidae	*Tineola bisselliella* (Hummel, 1823)	11	0.25	5	0.14
	Hymenoptera	Apidae	*Amegilla quadrifasciata* (de Villers, 1789)	59	1.36	15	0.41
			Anthophora bimaculata (Linnaeus, 1761)	9	0.21	13	0.36
			Anthophora sp.	2	0.05	-	0.00
			Eucera longicornis (Linnaeus, 1758)	3	0.07	3	0.08
			Eucera sp.	-	0.00	10	0.28
			Apis mellifera Linnaeus, 1758	12	0.28	9	0.25
			Bombus terrestris (Linnaeus, 1758)	31	0.72	23	0.64
			Ceratina calcarata (Say, 1823)	3	0.07	7	0.19
		Megachilidae	*Osmia cornuta* (Latreille, 1805)	10	0.23	13	0.36
			Anthidium sp.	19	0.44	14	0.39
			Hoplitis sp.	7	0.16	3	0.08
			Megachile addenda (Cockerell, 1919)	9	0.21	5	0.14
			Megachile sp.	3	0.07	-	0.00
			Megachile pilidens (Pérez, 1895)	7	0.16	9	0.25
			Chelostoma sp.	-	0.00	5	0.14

Class	Order	Family	Taxa	Si El Mahdjoub		Ben chicao	
				N	RA%	N	RA%
			Heriades sp.	-	0.00	2	0.06
			Cataglyphis cursor (Fonscolombe, 1846)	210	4.86	120	3.32
			Cataglyphis sp.	120	2.78	150	4.15
		Formicidae	*Camponotus* sp.	93	2.15	75	2.07
			Messor barbarus (Linnaeus, 1767)	94	2.17	270	7.46
			Crematogaster scutellaris (Olivier, 1792)	6	0.14	17	0.47
			Crematogaster auberti (Emery, 1869)	28	0.65	20	0.55
			Aphaenogaster sp.	28	0.65	-	0.00
		Vespidae	*Vespa affinis* (Linnaeus, 1771)	44	1.02	12	0.33
			Vespula vulgaris (Linnaeus, 1758)	105	2.43	22	0.61
			Vespula germanica (Fabricius, 1793)	15	0.35	13	0.36
			Polistes gallicus (Linnaeus, 1761)	11	0.25	13	0.36
		Pompilidae	*Anospilus orbitalis* (Jurine, 1807)	5	0.12	2	0.06
			Agenioideus apicalis (Spinola, 1808)	11	0.25	7	0.19
			Auplopus albifrons (Dalman, 1816)	-	0.00	7	0.19
		Andrenidae	*Andrena agilissima* (Scopoli, 1763)	3	0.07	5	0.14
			Andrena curvungula (Kirby, 1802)	5	0.12	5	0.14
			Andrena sp.	15	0.35	3	0.08
		Halictidae	*Halictus poeyi* (Lepeletier, 1841)	8	0.19	11	0.30
			Halictus sp.	5	0.12	8	0.22
			Lasioglossum marginatum (Schenck, 1853)	3	0.07	7	0.19
			Lasioglossum villosulum (Kirby, 1802)	5	0.12	-	0.00
			Lasioglossum sp. 1	3	0.07	2	0.06
			Lasioglossum sp. 2	11	0.25	15	0.41
		Sciaridae	*Sciara* sp.	-	0.00	2	0.06
		Chrysididae	*Chrysis nitidula* Rossi, 1790	5	0.12	5	0.14
			Chrysis sp.	3	0.07	-	0.00
			Holopyga sp.	3	0.07	5	0.14
		Braconidae	*Doryctes leucogaster* (Jurine, 1807)	5	0.12	3	0.08
		Ichneumonidae	*Brachycyrtus* sp.	6	0.14	3	0.08
			Gelis sp.	6	0.14	5	0.14
			Metopius notatus (Fabricius, 1804)	21	0.49	-	0.00
		Multilidae	*Myrmilla capitata* (Fabricius, 1793)	5	0.12	-	0.00
		Bethylidae	*Epyris* sp.	4	0.09	4	0.11

Abbreviations: RA–Relative abundance (%); N–Number of individuals.

Coverage-based rarefaction and extrapolation curves confirmed this pattern: at equivalent levels of sampling completeness, Si El Mahdjoub consistently supported higher effective diversity across all diversity orders. This trend was further supported by the species evenness profiles, which indicated differences in the distribution of individuals among species. At Si El Mahdjoub, individuals were more evenly distributed across species, whereas Benchicao exhibited a stronger dominance by a few highly abundant species. Overall, these analyses provide robust evidence that the arthropod community at Si El Mahdjoub is not only species-rich but also more evenly structured in terms of species abundances, while Benchicao shows higher dominance by a limited number of taxa (Fig. 3).

Correlation and diversity index between two apple orchards. Shannon's index demonstrated a highly significant positive correlation with Simpson's index ($r = 0.93$, $p < 0.001$), species richness ($r = 0.90$, $p < 0.01$), and theoretical H_{max} ($r = 0.95$, $p < 0.001$). This suggests that these parameters are complementary and coherently reflect the diversity of arthropod communities. Species richness was also positively correlated with total abundance ($r = 0.91$, $p < 0.01$) and H_{max} ($r = 0.95$, $p < 0.001$), which reflects an expected relationship: a higher number of individuals increases the likelihood of detecting a greater number of species (Fig. 4). Evenness showed positive, though not statistically significant, correlations with other indices, particularly with Simpson ($r = 0.67$) and Shannon ($r = 0.57$). This indicates that equitability may vary independently of richness or total abundance. Finally, total abundance was positively correlated with diversity indices, notably Shannon ($r = 0.78$, $p < 0.05$) and Richness ($r = 0.91$, $p < 0.01$), confirming that Si El Mahdjoub station is both more abundant and more taxonomically diverse.

Effects of station, season, and trophic guilds (GLM results). Generalized linear model (GLM) analyses were performed to evaluate the influence of station, season, and trophic guild on arthropod species richness and total abundance (Table 4). The GLM results indicated significant differences between the two stations, with Si El Mahdjoub exhibiting higher species richness and total abundance compared to Benchicao. Seasonal variation was pronounced. Both species richness and abundance peaked in spring and summer and declined in autumn and winter, reflecting the temporal dynamics of arthropod activity. Regarding trophic guilds, significant differences were also observed. Phytophagous species were the dominant group in both richness and abundance at both stations. Predators and polyphagous species were moderately represented, whereas parasitoids consistently exhibited the lowest values for both richness and abundance. Overall, the GLM analyses confirm that spatial (station), temporal (season), and ecological (trophic guild) factors significantly shape the composition and structure of arthropod communities across the two apple orchards.
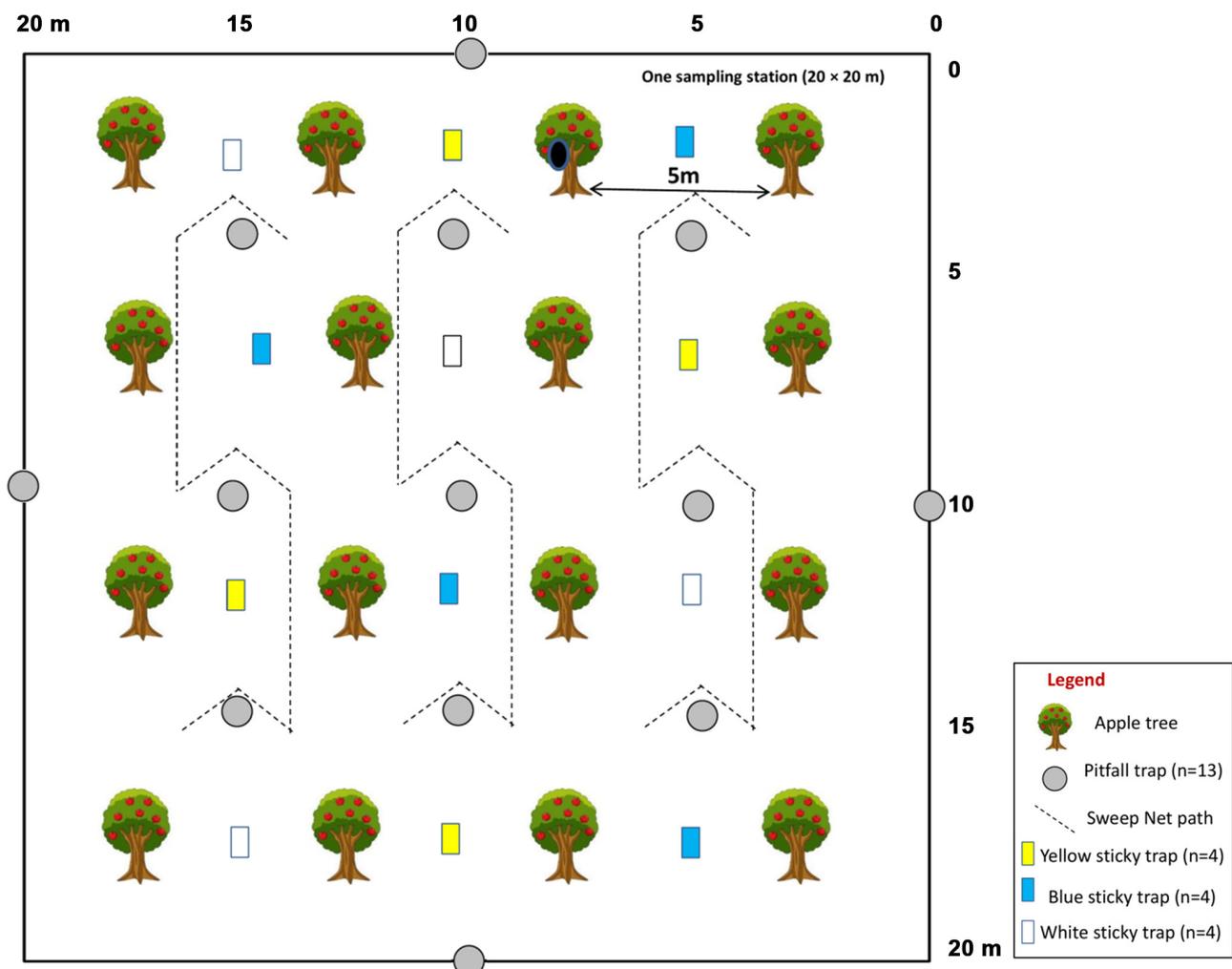
Figure 3. Non-asymptotic analysis: the rarefaction (solid line) and extrapolation (dashed line) sampling curves based on the collected data. Sample completeness estimates of orders $q = 0$, 1, and 2 (a), Observed diversity values (b) and asymptotic estimates (c), Non-asymptotic coverage-based diversity estimates of orders $q = 0$, 1, and 2 at the standardized coverage value of C_{max} (d), Evenness estimates of orders $q = 1$ and 2 at the standardized coverage value of C_{max} based on the normalized slope of a diversity profile (e) for insect populations of the studied apple orchards generated by iNEXT© online software.
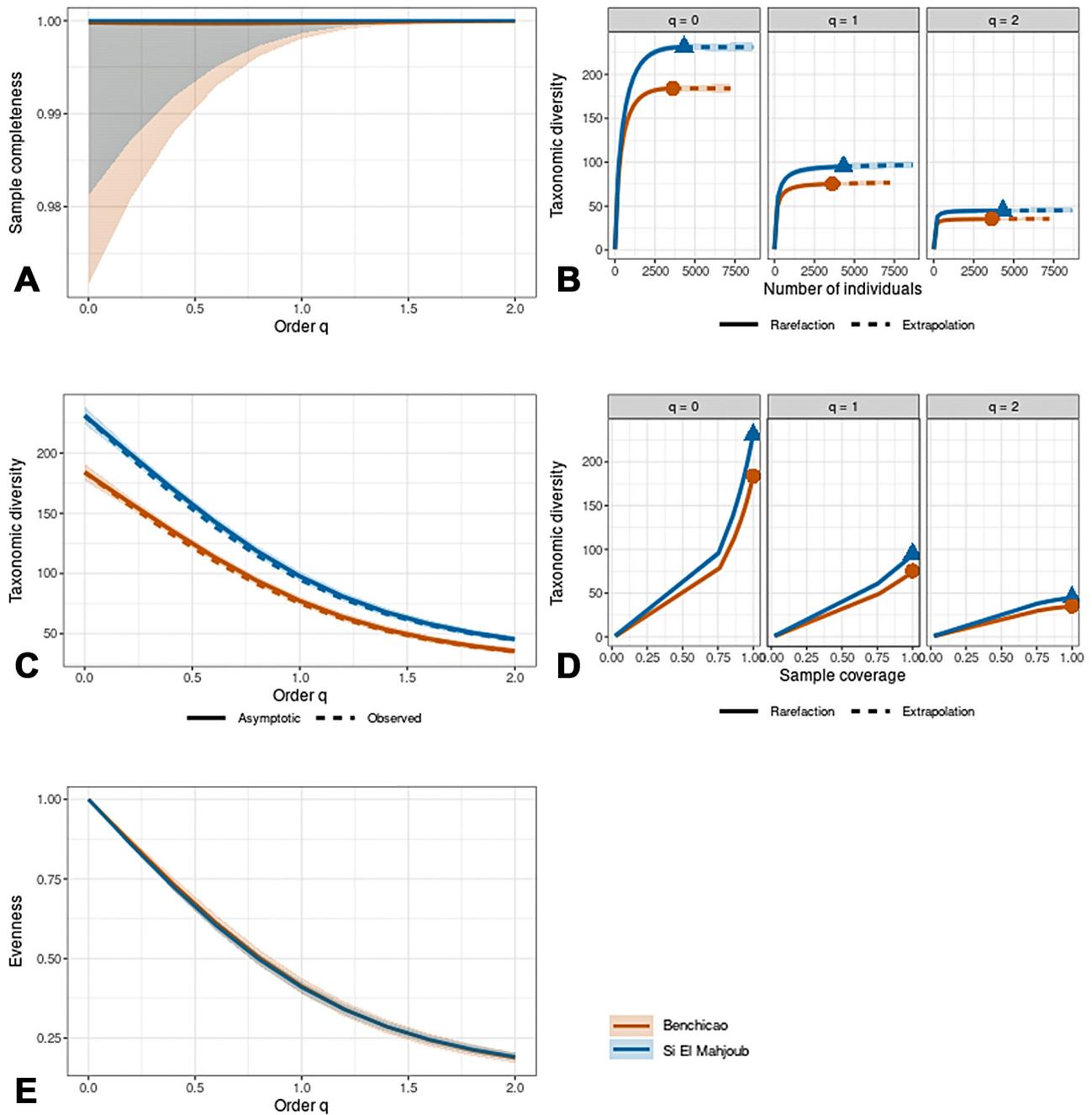
Figure 4. Pearson's correlation tests between ecological diversity indices. Pearson's correlation results are expressed as asterisks (*P-values*) and correlation coefficient values.

Correlation between plant and arthropod richness. Plant species richness varied between stations and sampling units and was used as an explanatory variable to assess its relationship with arthropod species richness. Correlation analyses were conducted separately for each station in order to account for differences in vegetation structure and spatial configuration (Fig. 5). At Si El Mahdjoub, arthropod species richness increased consistently with increasing plant species richness across sampling units. The correlation analysis revealed a strong positive relationship between plant and arthropod richness (*Pearson's R = 0.97*), which was statistically significant (*p = 0.026*). The relationship was characterized by a steep positive slope, indicating that sampling units with higher plant richness systematically supported higher numbers of arthropod species. In contrast, at Benchicao, arthropod species richness did not show a consistent response to variation in plant species richness.

Table 4. Pairwise comparison of richness and abundance using negative binomial GLM.

	RICHNESS				
	Contrast	**Estimate**	**SE**	**Statistic**	**P value**
Station	Si E Mahdjoub- Benchicao	0.50	0.13	3.89	0.0001
Season	Autumn - Spring	-0.78	0.19	-4.13	0.0002
	Autumn - Summer	-1.14	0.19	-6.13	<0.0001
	Autumn - Winter	0.63	0.22	2.94	0.0176
	Spring - Summer	-0.36	0.16	-2.21	0.1195
	Spring - Winter	1.41	0.21	6.69	<.0001
	Summer - Winter	1.77	0.21	6.69	<.0001
Diet	Parasite – Phytophagous	-2.0716	0.222	-9.348	< 0.0001
	Parasite – Polyphagous	0.0358	0.271	0.132	1.0000
	Parasite – Predator	-1.7306	0.24	-7.218	< 0.0001
	Parasite – Saprophagous	-0.7265	0.241	-3.012	0.0312
	Phytophagous – Polyphagous	2.1074	0.225	9.374	< 0.0001
	Phytophagous – Predator	0.341	0.176	1.937	0.3795
	Phytophagous – Saprophagous	1.3451	0.189	7.128	< 0.0001
	Polyphagous – Predator	-1.7664	0.239	-7.402	< 0.0001
	Polyphagous – Saprophagous	-0.7622	0.245	-3.106	0.0233
	Predator – Saprophagous	1.0042	0.207	4.851	< 0.0001
	ABUNDANCE				
Station	**Si E Mahdjoub-Benchicao**	**0.85**	**0.27**	**3.14**	**0.0017**
Season	Autumn - Spring	-1.12	0.39	-2.84	0.0234
	Autumn - Summer	-1.51	0.38	-4.00	0.0004
	Autumn - Winter	0.47	0.37	1.26	0.5916
	Spring - Summer	-0.39	0.36	-1.07	0.7105
	Spring - Winter	1.59	0.39	4.06	0.0003
	Summer - Winter	1.98	0.39	5.05	<.0001
Diet	Parasite – Phytophagous	-2.85	0.46	-6.21	< 0.0001
	Parasite – Polyphagous	0.07	0.46	0.16	1.000
	Parasite – Predator	-1.73	0.48	-3.63	0.0038
	Parasite – Saprophagous	-1.17	0.44	-2.64	0.0881
	Phytophagous – Polyphagous	2.93	0.43	6.77	< 0.0001
	Phytophagous – Predator	1.12	0.42	2.66	0.0834
	Phytophagous – Saprophagous	1.68	0.42	4.03	0.0008
	Polyphagous – Predator	-1.81	0.44	-4.12	0.0005
	Polyphagous – Saprophagous	-1.24	0.44	-2.84	0.0511
	Predator – Saprophagous	0.56	0.43	1.31	0.780

The correlation coefficient was negative ($R = -0.66$) and not statistically significant ($p = 0.54$), reflecting substantial variability among sampling units and the absence of a clear linear relationship between the two variables. Sampling units with comparable plant richness often exhibited markedly different levels of arthropod species richness. These contrasting correlation patterns between stations are clearly illustrated in Figure 5, which shows a tight clustering of data points along the regression line at Si El Mahdjoub and a more dispersed distribution at Benchicao.
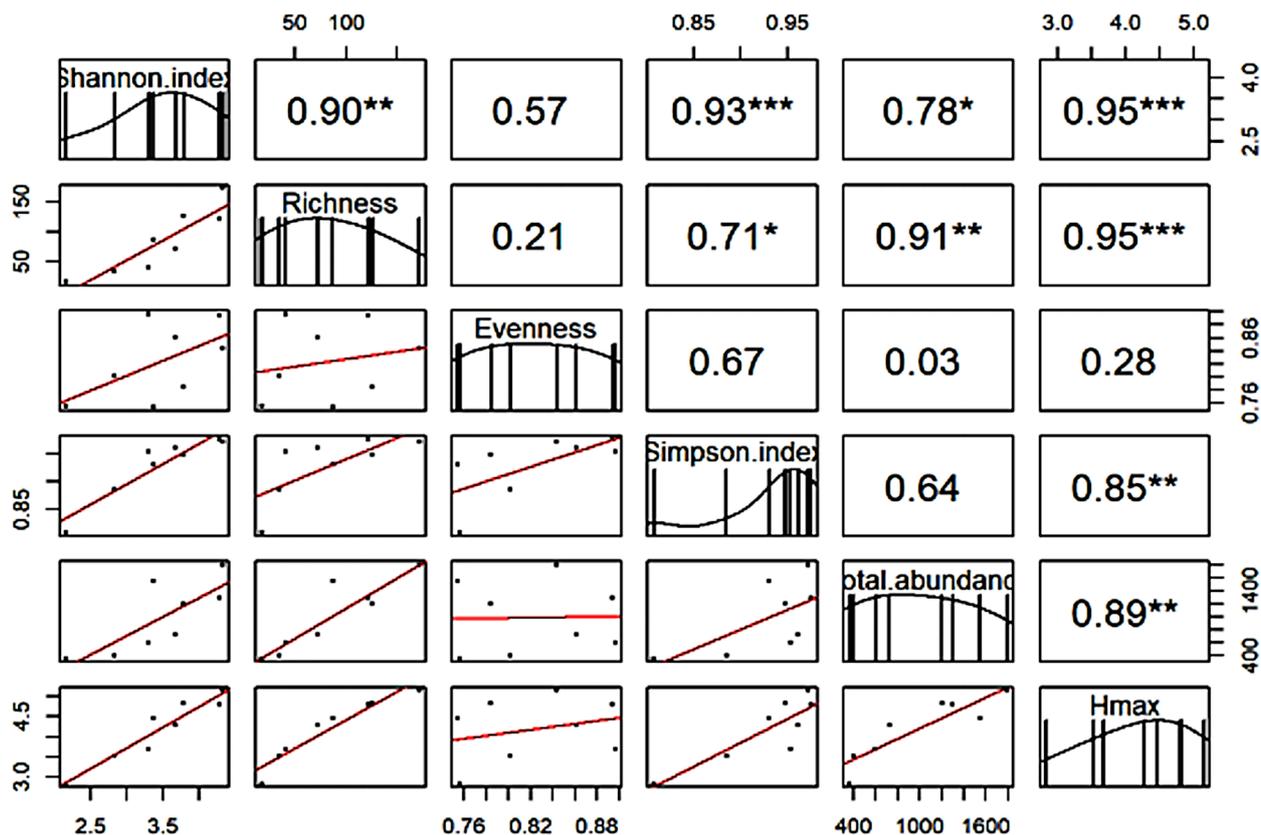
Figure 5. Correlation between plant and arthropod richness of two apple orchards.

Trophic guilds. Total arthropod abundance differed notably between the two stations. At Si El Mahdjoub, a total of 4,351 individuals were recorded, whereas Benchicao had 3,183 individuals. Despite this difference in abundance, both stations exhibited the same total species richness, with 260 species documented at each site. Analysis of the categories of occurrence revealed that common species dominated the community in both abundance and richness. At Si El Mahdjoub, common species accounted for 3,040 individuals and 177 species, whereas at Benchicao, they represented 2,218 individuals and 142 species. The constant species category was the second most represented in both abundance and richness, with 1,099 individuals and 31 species at Si El Mahdjoub compared to 781 individuals and 6 species at Benchicao. The accidental species category showed slightly higher abundance at Si El Mahdjoub (184 individuals) than at Benchicao (154 individuals), but Benchicao had higher species richness within this category (36 species vs. 23 species). Notably, the highly accidental species category was markedly more frequent at Benchicao, suggesting a greater proportion of transient taxa in this station (Fig. 6).

The trophic guild composition of arthropod communities also varied between stations. Phytophagous species were the most abundant group at both locations, with 2,218 individuals recorded at Si El Mahdjoub and 2,457 at Benchicao, representing 105 and 91 species, respectively. Predators were more abundant at Si El Mahdjoub (786 individuals) compared to Benchicao (434), while parasitoids also showed higher numbers at Si El Mahdjoub (530 individuals) than at Benchicao (482). Polyphagous taxa were slightly more numerous at Si El Mahdjoub (204 individuals) compared to Benchicao (148). In contrast, saprophagous species were more frequent at Benchicao, with 96 individuals recorded compared to 58 at Si El Mahdjoub (Fig. 7). This detailed breakdown highlights both the abundance and species richness patterns across occurrence categories and trophic guilds, providing a comprehensive overview of community structure at each station.
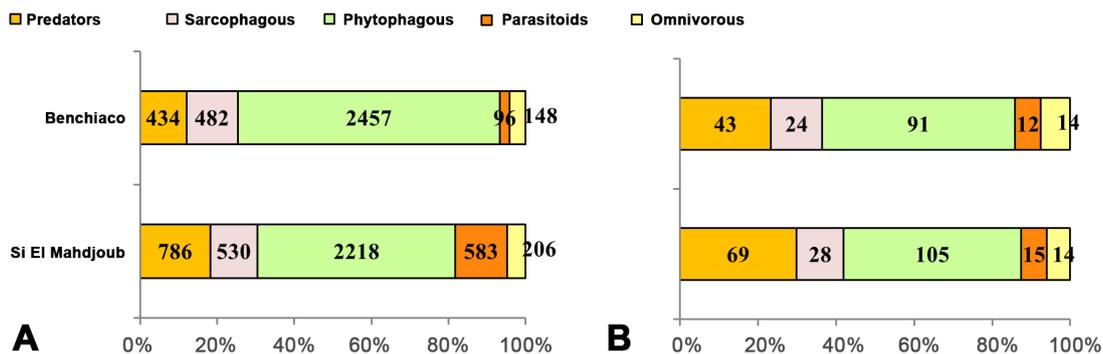
Figure 6. Categories of occurrences of arthropod fauna according to the two types of stations in Medea (Algeria). The values in the histograms represent: **A.** The absolute abundances (N); **B.** Species richness.
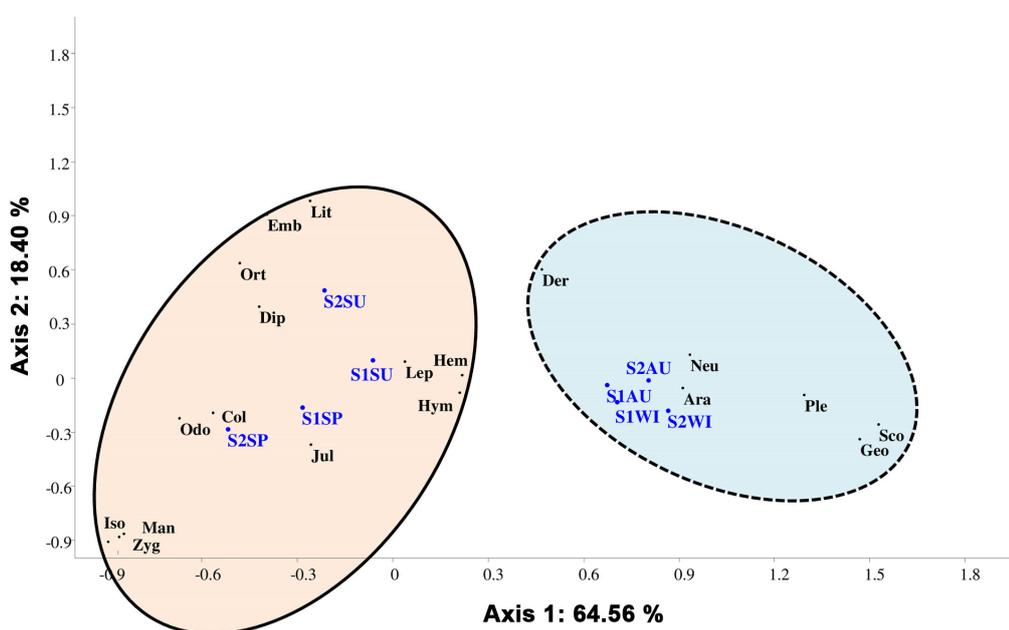
Figure 7. Trophic guilds of arthropod fauna according to the two types of stations in Medea (Algeria). The values in the histograms represent: A. the absolute abundances (N) and B. species richness. Abreviations: *S1WI*–Si El Mahdjoub winter; *S1SP*–station 1 spring, *S1SU*–Si El Mahdjoub summer, *S1AU*–Si El Mahdjoub autumn; *S2WI*–Benchicao winter; *S2SP*–Benchicao spring, *S2SU*–Benchicao summer, *S2AU*–Benchicao autumn; *Ara*–Araneae; *Sco*–Scorpiones; *Iso*–Isopoda; *Jul*–Julida; *Lit*–Lithobiomorpha; *Geo*–Geophilomorpha; *Zyg*–Zygentoma; *Odo*–Odonata; *Ple*–Plecoptera; *Ort*–Orthoptera; *Der*–Dermaptera; *Man*–Mantodea; *Emb*–Embioptera; *Hem*–Hemiptera; *Neu*–Neuroptera; *Col*–Coleoptera; *Dip*–Diptera; *Lep*–Lepidoptera; *Hym*–Hymenoptera.

Spatio-temporal for similarity analysis. A total of 251 taxa were recorded across both sites. Of these, 151 taxa were common to both Si El Mahdjoub and Benchicao. Si El Mahdjoub hosted 73 taxa that were exclusive to this site, while Benchicao recorded 27 exclusive taxa (Fig. 8A). This shows that while there is a significant overlap in species between the two orchards, each site also supports a unique set of species, with Si El Mahdjoub supporting a greater diversity of exclusive taxa. Seasonal analysis of taxonomic composition revealed that the summer season hosted the highest number of exclusive taxa, with 56 taxa recorded (22.3% of the total taxa). Spring followed with 37 exclusive taxa (14.7%). Autumn showed a limited number of exclusive taxa, with only 4 taxa (1.6%) recorded. Notably, winter exhibited no exclusive taxa, suggesting a reduction in arthropod activity during colder months. Furthermore, no taxon was found to be present across all four seasons, indicating that the arthropod community is highly dynamic and seasonal, with different species dominating at different times of the year (Fig. 8B).

Ordination analysis was performed to explore the seasonal structuring of arthropod communities. The first axis of the ordination accounted for 64.56% of the total inertia, while the second axis accounted for 18.40%. This ordination highlighted strong seasonal structuring, with winter and autumn samples clustering closely together, while spring and summer samples were more dispersed. This suggests that the community structure during the colder months (winter and autumn) was more similar, whereas spring and summer exhibited greater variability in species composition. Importantly, no clear spatial separation between the two stations (Si El Mahdjoub and Benchicao) was observed in the ordination, indicating that seasonality, rather than site-specific factors, is the primary driver of arthropod community structure across the studied period (Fig. 9).
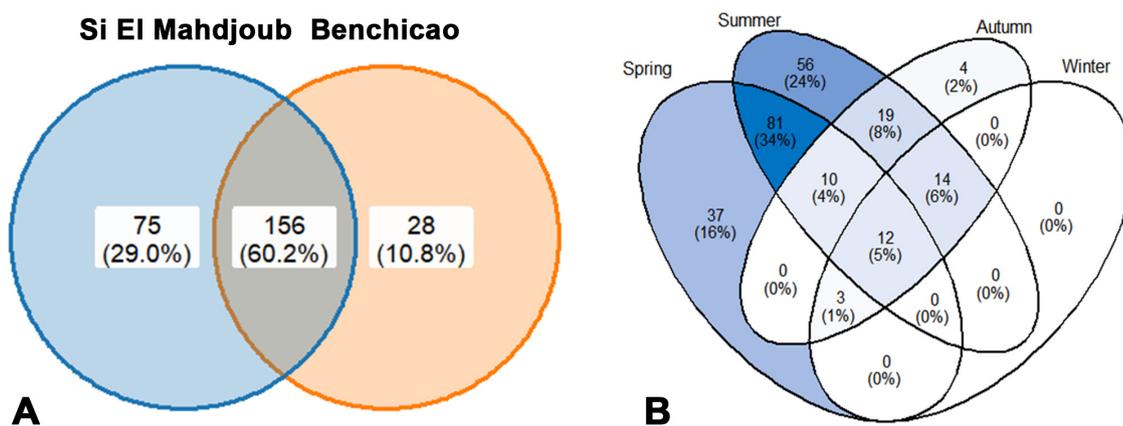
Figure 8. Venn diagram displaying arthropod taxa richness according to **A.** Stations (Station 1: Si El Mahfjoub, Station 2: Benchicao); **B.** Seasons.
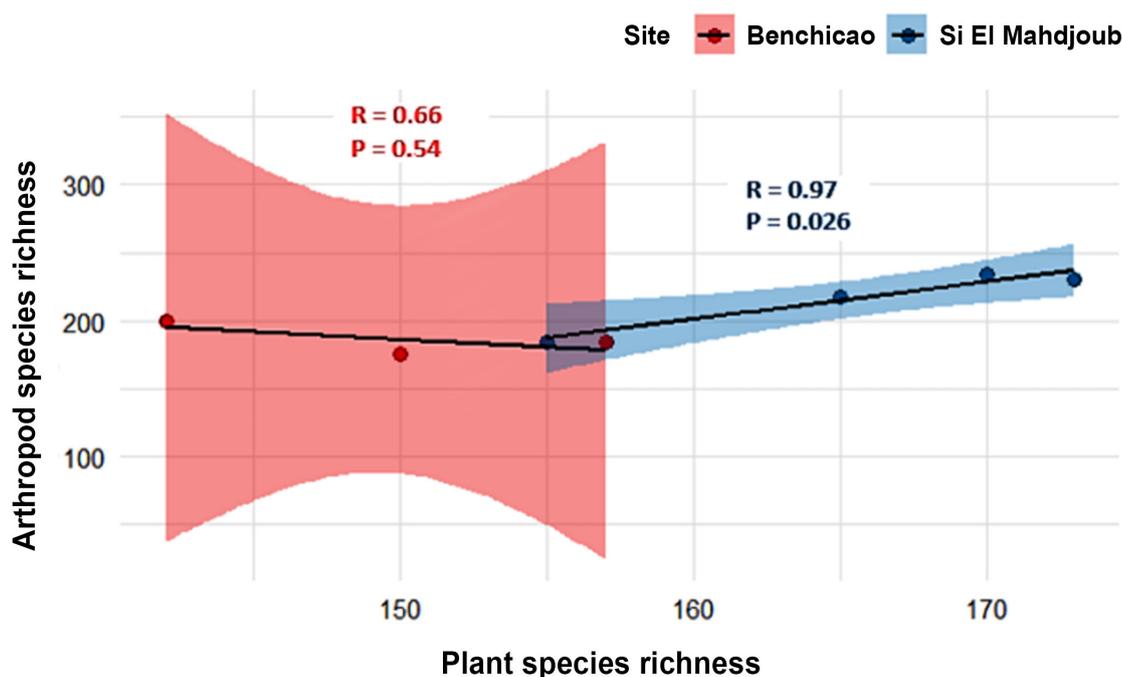
Figure 9. Detrended Correspondence Analysis (DCA) of arthropod community composition across seasons and study sites.

DISCUSSION

The observed differences in arthropod richness and community composition between Si El Mahdjoub and Benchicao are consistent with the broader ecological expectation that habitat complexity and landscape heterogeneity promote biodiversity by increasing resource availability, microhabitat diversity, and refuge opportunities (Tscharntke et al. 2005; Boreau de Roincé 2012). Such landscape-driven patterns can shape both herbivore communities and the assemblages of natural enemies associated with them, especially in structurally diverse orchard environments (Landis et al. 2000). Variation among key taxa may also reflect differences in habitat simplification and disturbance intensity between orchards, as agricultural intensification is frequently linked to reduced diversity and increased dominance by fewer taxa (Bengtsson et al. 2005). In addition, vegetation structure can influence the abundance and distribution of several groups, including Orthoptera, often associated with herbaceous-dominated habitats (Marini et al. 2009), and Araneae, whose diversity commonly increases with vegetation structural complexity by providing more hunting and refuge sites (Pekar & Kocourek 2004). Together, these patterns support the idea that landscape features such as hedgerows and field margins can enhance biodiversity in agroecosystems by supplying additional resources, shelters, and connectivity, with implications for ecological functioning and pest regulation (Altieri 1999).

Rarefaction and extrapolation analyses provided a robust basis for comparing arthropod diversity between orchards while accounting for sampling effort. Using the iNEXT approach (Hsieh & Chao 2016), the high sampling coverage (>97%) at both sites suggests that the main diversity patterns are unlikely to be artifacts of incomplete sampling. Although Benchicao exhibited slightly higher richness when considering incidence-based diversity ($q = 0$), abundance-weighted diversity metrics ($q = 1$ and $q = 2$) consistently indicated higher effective diversity at Si El Mahdjoub. This divergence between $q = 0$ and $q \geq 1$ suggests that differences between orchards are driven less by the presence of rare species than by changes in dominance structure and the distribution of individuals among species. The higher effective diversity and more even abundance distribution at Si El Mahdjoub are consistent with reduced dominance by a small number of taxa and a potentially greater functional balance. In contrast, the stronger dominance pattern at Benchicao may indicate community simplification under environmental or anthropogenic constraints. Such shifts—reduced evenness and increased dominanceare commonly associated with disturbance and may affect ecological resilience and the long-term provisioning of ecosystem services (Tscharntke et al. 2005). These interpretations should be understood as associative rather than strictly causal, but the combined diversity profiles nevertheless indicate that the two orchards differ not only in richness but also in community organization.

At the regional scale, the dominance of Insecta observed in our orchards is consistent with previous studies in Algerian apple systems. Frah et al. (2009) reported Insecta as the prevailing class (≈95.9%) in *Malus domestica* orchards in the Khenchela region. Other surveys also show substantial variability in richness and taxonomic composition across apple orchards: Guettala-Frah (2009) recorded 348 species distributed among 97 families and 13 orders in the Aurés region, whereas Guermah et al. (2019) reported 125 species across 64 families, 10 orders, and 3 classes in the Sidi Naâmane area (Tizi-Ouzou), with Insecta remaining dominant (88.5%) followed by Arachnida (7.07%). Comparable insect-dominated assemblages, coupled with strong variability in richness and evenness, have been reported in other Algerian agroecosystems, supporting the broader relevance of our findings. Bounaceur et al. (2018) reported Coleoptera and Hymenoptera as the lowest represented taxa at Mitidja Vineyard (North Algeria) (4.25% and 3.38% respectively). Ali-Arous et al. (2024) reported 1114 insects in two citrus orchards in the Chlef region, with higher family richness in extensive systems than in intensive systems, suggesting that management intensity can influence community structure. Additional studies similarly highlight differences across crops and regions: Ben Mokhtar et al. (2025) recorded 106 species belonging to 54 families across three classes in a table grapes cultivars in Boumerdes vineyard (Northern Algeria); Frah et al. (2015) estimated 134 species across six classes in an olive grove near Sefiane; and Aouimeur et al. (2017) identified 244 species across four classes in the palm groves of Oued Souf, with Insecta accounting for 92.7% of the total. Collectively, these studies indicate that Insecta generally dominate arthropod assemblages in Algerian cultivated landscapes, while the magnitude and structure of diversity vary according to local context.

Order-level dominance patterns in our dataset, notably the prominence of Coleoptera and Hymenoptera, align with previous work. Chafaa (2013) reported Coleoptera and Hymenoptera as the most represented taxa in an olive grove in Batna (47.1% and 18.9%, respectively), and Ounis et al. (2014) similarly found Coleoptera to dominate soil fauna in an apricot orchard (46.67%). The predominance of Coleoptera has also been observed beyond orchard systems: Mecheri et al. (2014) identified Coleoptera (Carabidae) as the most abundant family in a pine forest in the Djelfa semi-arid region, although with lower overall richness than observed here, underscoring the influence of habitat type and environmental context. Regarding specific taxa, the prevalence of *Oxythyrea funesta* and *Oxythyrea sybelaya* in our dataset is consistent with the importance of beetles in these agroecosystems. In apple orchards of the Aurés region, Frah et al. (2009) reported *Coccinella septempunctata* (Linné 1758) as the most abundant species, whereas Guermah et al. (2019) found *Coccinella algerica* and *Oxytheria funesta* to dominate beetle assemblages in Tizi Ouzou, indicating that dominant species can shift across regions and orchard conditions. The low representation (<10%) of several orders may reflect ecological rarity and functional specialization, yet such groups may still contribute to ecosystem functioning; the ecological significance of beetles as prey for secondary consumers and as bioindicators of environmental health has also been emphasized (Sánchez-Fernández et al. 2006).

Correlation patterns among diversity indices indicated strong internal consistency in how arthropod diversity was captured across metrics. Shannon's index was highly and positively correlated with Simpson's index ($r = 0.93$, $p < 0.001$), richness ($r = 0.90$, $p < 0.01$), and theoretical maximum diversity H_{max} ($r = 0.95$, $p < 0.001$), suggesting that these parameters provide complementary views of community diversity. Richness was also positively correlated with total abundance ($r = 0.91$, $p < 0.01$) and H_{max} ($r = 0.95$, $p < 0.001$), which is consistent with the expectation that increased numbers of individuals increase the probability of detecting additional species. In contrast, evenness showed only moderate, non-significant correlations with other indices, indicating that equitability can vary somewhat independently from richness and abundance. Overall, the positive relationships between total abundance and diversity metrics support the interpretation that Si El Mahdjoub combines higher abundance with higher taxonomic diversity.

GLM comparisons further indicated significant differences in richness and abundance across stations, seasons, and trophic groups, reinforcing that the two orchards differ not only in diversity level but also in the structuring factors shaping these communities. The consistently higher richness and abundance at Si El Mahdjoub may be linked to landscape configuration, as hedgerows and vegetated borders can enhance habitat heterogeneity and provide microclimatic refuges that support higher biodiversity (Marshall & Moonen 2002; Jonsson et al. 2008). Seasonality exerted a strong influence on both richness and abundance, with communities peaking in spring and summer, consistent with the dependence of arthropod activity on temperature, phenology, and food availability in temperate and Mediterranean contexts (Wyss 1995). This strong temporal signal also implies that biodiversity assessments based on restricted sampling windows may misrepresent annual diversity patterns.

Feeding guild patterns provide additional insight into ecosystem functioning. Phytophagous species dominated in richness and abundance, which is expected in orchard ecosystems where plant resources are seasonally abundant. The trophic composition similarly showed dominance of phytophages, predators, and polyphages, with low representation of saprophages, parasitoids, and coprophages. This structure is consistent with patterns reported from Algerian fruit systems: in apricot orchards, foliage-feeders were dominant, followed by predators and polyphages, with only a small representation of saprophages, parasitoids, and coprophages (Chafaa et al. 2019). Beyond orchards, xylophages, frugivorous insects, and saproxylics can attack various plants (Villiers 1979; Ricklefs & Miller 2005), whereas many phytophagous insects are relatively selective for particular host plants. Low-frequency guilds nonetheless play important roles. Coprophages contribute to soil formation and organic matter incorporation (Bachelier 1978) and promote nutrient recycling (Dajoz 1985), while saprophages contribute to decomposition and humus formation through interactions with microorganisms and fungi (Villiers 1979).

The interpretation of diversity values can be further contextualized by published benchmarks. Diversity is generally considered higher as diversity index values increase (Blondel 1979). In the Tizi Ouzou region, Guermah et al. (2019) reported $H = 4.31$ bits with $H_{max} = 6.64$ bits. Using pitfall trapping

across three steppe sites in Djelfa, diversity ranged from 1.9 to 4.0 bits depending on site (Guerzou et al. 2014). In an olive orchard in Sefiane (Batna), diversity and H_{max} values varied with sampling method (Frah et al. 2015). Evenness values likewise vary across systems and methods: moderate evenness has been reported in Tizi Ouzou (Guermah et al. 2019), lower ranges in apricot orchard soil fauna (Ounis et al. 2014), and higher values in olive orchards depending on method (Frah et al. 2015). These comparisons highlight that both habitat context and sampling method influence diversity estimates and should be considered when interpreting orchard biodiversity.

The observed abundance and diversity patterns may also be influenced by management practices, including phytosanitary treatments. Arthropod proliferation and diversity are often favored where phytosanitary treatments are absent, potentially allowing the persistence of diverse auxiliary fauna composed of predators and parasitoids that may contribute to maintaining pest populations at economically acceptable levels. In this context, identifying arthropod taxa and clarifying their trophic relationships provides a scientific basis for designing integrated pest management strategies as alternatives to intensive pesticide use, while supporting biodiversity conservation and environmental protection. Contrasting relationships between plant and arthropod richness in the two orchards further suggest that the effects of plant diversity depend strongly on habitat structure. In Si El Mahdjoub, plant richness was strongly and positively correlated with arthropod richness (*Pearson's R = 0.97, p = 0.026*), consistent with the resource heterogeneity hypothesis whereby plant diversity enhances structural complexity and resource availability, promoting higher faunal diversity (Altieri 1999). In Benchicao, the relationship was moderately negative and non-significant (*R = −0.66, p = 0.54*), suggesting that in simplified habitats, plant richness alone may be insufficient to sustain a diverse arthropod community. This relationship should nevertheless be interpreted cautiously, as correlation strength can be sensitive to sampling design and the number of sampling units. More generally, these orchard-specific patterns reinforce that structural elements such as hedges and field margins mediate the translation of plant diversity into arthropod diversity (Tscharntke et al. 2005; Chaplin-Kramer et al. 2011).

From a management perspective, enhancing field margins at the landscape scale can increase natural enemy diversity and contribute to reduced pest incidence through additional resources and refuges (Landis et al. 2000; Torretta & Poggio 2013). However, field-margin vegetation can also attract or concentrate certain pests, implying that increases in uncropped habitats can have contrasting outcomes depending on the balance between herbivores and natural enemies. Cultural practices can further modulate these responses. Weed presence within crops has been related to improved pest suppression in diversified agroecosystems because natural enemies may increase and regulate herbivores more effectively (Risch 1987). Weeds can also enhance the longevity and fecundity of natural enemies by providing nectar, pollen, and shelter (Drapela et al. 2008; Rusch et al. 2013). Nevertheless, plant-derived resources may also benefit herbivores (Lavandero et al. 2006), and increased plant diversity does not necessarily translate into improved pest suppression in all contexts (Fiedler et al. 2008; Isaacs et al. 2009), emphasizing the need for balanced habitat-management strategies.

Evidence from human-dominated landscapes supports these interpretations at broader scales. Less-intensive land use generally favors biodiversity (Tylianakis et al. 2006), and comparisons between organic and conventional farms frequently show higher richness of weeds and beneficial arthropods under organic management (Pluess et al. 2010; Holzschuh et al. 2008; Letourneau et al. 2012). At the landscape scale, the presence of natural habitats can enhance the richness and abundance of beneficial arthropods in crops (Letourneau et al. 2012; Gardiner et al. 2009b), and similar patterns have been documented across crops and regions (Chaplin-Kramer et al. 2011). Methodological critiques nevertheless stress that many studies focus primarily on plot-scale diversity, which may underestimate cross-scale processes and landscape effects (Tylianakis et al. 2006; Clough et al. 2007). Consequently, biodiversity assessments should integrate multiple spatial scales to clarify the links between landscape structure, crop management, and arthropod communities.

Comparisons of abundance, richness, and occurrence categories (common, constant, accidental, and highly accidental species) between the two orchards further emphasize the role of habitat structure in shaping community organization. Si El Mahdjoub exhibited higher total abundance than Benchicao, while both sites shared the same overall species richness. Common species dominated both stations,

whereas constant species were more abundant and species-rich at Si El Mahdjoub, indicating a more persistent community. In contrast, highly accidental species were more numerous at Benchicao, which is commonly associated with disturbed or simplified habitats (Bengtsson et al. 2005).

The trophic structure of arthropod communities was dominated by phytophagous taxa, but the relative balance among trophic groups differed between sites. Si El Mahdjoub supported higher abundances of predators and parasitoids than Benchicao, while Benchicao showed stronger dominance by phytophagous taxa. Such differences are consistent with the idea that structurally diversified environments can enhance natural enemy communities and contribute to pest regulation (Fiedler et al. 2008). Comparable trophic distributions have been reported in Algerian apple systems, with pests typically dominating, followed by predators and parasitoids, and low representation of saprophages and coprophages (Guettala-Frah 2009). Differences in habitat context can also be important when comparing orchard rows to adjacent fencerows or complex margins, as natural enemy dominance may be stronger in non-crop habitats than in managed orchard interiors; maintaining trophic balance may therefore depend on whether management and habitat structure provide resources and microhabitats required across seasons (Landis et al. 2000).

The higher diversity observed here compared with apple production orchards in the Aurés region and compared with a Spanish cornfield system suggests that local conditions at Si El Mahdjoub may be particularly favorable for arthropod biodiversity (Frah et al. 2009; Ponce et al. 2011). Climatic differences between the two environments may also contribute to community contrasts. More broadly, habitats that provide alternative prey, pollen, nectar, shelter, and overwintering sites are essential for sustaining natural enemies in agricultural landscapes (Landis et al. 2000). Structural components such as fencerows, trees, and spontaneous vegetation can therefore function as key habitat features supporting beneficial arthropods and facilitating movement, and more complex orchard alleys may act as migration bio-corridors. The importance of tree habitats and structural elements for pest management has been supported in other systems (Dix et al. 1995; Grout & Stephen 1995; Corbett & Rosenheim 1996). Seasonal turnover and ordination patterns indicate that seasonality is a dominant driver of arthropod community structure in the study area. Community separation along the first two Detrended Correspondence Analysis axes, together with the clustering of colder-season assemblages versus warmer-season assemblages, supports a strong temporal signal in composition. The absence of strong spatial separation between stations in ordination space suggests that temporal variation outweighs spatial differences at the scale considered. This dominance of seasonal dynamics is consistent with studies emphasizing the role of phenology and seasonal community turnover in arthropod assemblages (Jonsson et al. 2008).

Overall, these results underscore the importance of local environmental characteristics in structuring arthropod communities in apple orchards. The greater richness and diversity observed at Si El Mahdjoub suggest an environment more favorable to biodiversity, likely driven by higher landscape complexity and the presence of agroecological infrastructures such as hedges and field margins. The strong positive relationship between plant and arthropod richness at this site further supports the resource heterogeneity hypothesis, reinforcing the central role of structural elements in enhancing biodiversity within orchard systems. These findings also highlight the need for more detailed characterization of landscape features in future research. Quantifying the density, spatial arrangement, and floristic composition of hedgerows and field margins at both study sites would provide a stronger basis for disentangling the mechanisms through which habitat structure influences arthropod communities. Complementary studies focusing on specific trophic interactions would also improve understanding of how landscape complexity affects pest regulation and other ecosystem services.

In addition, integrating such empirical data into ecological modeling frameworks would enable predictions of how alternative management strategies may influence biodiversity and ecosystem functioning in perennial crop systems. From an applied perspective, incorporating structural landscape elements into orchard design therefore emerges as a promising pathway for reconciling agricultural productivity with biodiversity conservation, particularly in Mediterranean agroecosystems where intensification pressures continue to increase.

REFERENCES

Abdessemed, S., Fellak, A., Abdessemed, A. & Khan, A. (2022) Status, challenges and opportunities for apple production in the Eastern Algeria. *Horticultural Science (Prague)*, 49 (3), 147–153. https://doi.org/10.17221/103/2021-HORTSCI

Aidoo, O.F., Kyerematen, R., Akotsen-Mensah, C. & Afreh-Afreh-Nuamah, K. (2016) Abundance and diversity of insects associated with citrus orchards in two different agroecological zones of Ghana. *American Journal of Experimental Agriculture*, 13 (2), 1–18. https://doi.org/10.9734/AJEA/2016/26238

Ali-Arous, S., Labdaoui, Z., Benelhadj-Djelloul, M. & Djelouah, K. (2024) Influence of different citrus cropping systems on insect diversity in the Northern West of Algeria. *Arab Journal of Plant Protection*, 42 (4), 406–418. https://doi.org/10.22268/AJPP-001263

Altieri, M.A. (1999) The ecological role of biodiversity in agroecosystems. *Agriculture, Ecosystems & Environment*, 74 (1–3), 19–31. https://doi.org/10.1016/S0167-8809(99)00028-6

Aouimeur, S., Guezoul, O., Ababsa, L. & Sekour, M. (2017) Aperçu sur la faune arthropodologique du Souf (Sahara septentrional-est, Algérie). *Revue des Bioressources*, 7 (1), 1–15. https://doi.org/10.12816/0045879

Atakan, E. & Pehlivan, S. (2015) Attractiveness of various colored sticky traps to some pollinating insects in apple. *Turkish Journal of Zoology*, 39 (3), 474–481. https://doi.org/10.3906/zoo-1403-62

Bachelier, G. (1978) *La Faune des Sols: Son Ecologie et Son Action.* Office de la Recherche Scientifique et Technique Outre-Mer (O.R.S.T.O.M). Paris. France. 391 p.

Balachowsky, A. (1962) *Entomologie Appliquée à l'Agriculture. Tome I: Coléoptères*. Masson et Cie. Publisher location, Paris. pp. 146–229.

Barbault, R. (1981) *Écologie des Populations et des Peuplements: Des Théories aux Faits*. Collection Maîtrises de biologie, Paris & New York. 674 pp + 124 pl.

Bastide, A. (1989) *Méthodologie d'Echantillonnage sur Terrain*. Masson, Paris. 280 pp.

Bengtsson, J., Ahnström, P. & Weibull, A.C. (2005) The effects of organic agriculture on biodiversity and abundance: a meta-analysis. *Journal of Applied Ecology*, 42 (2), 261–269. https://doi.org/10.1111/j.1365-2664.2005.01005.x

Ben Mokhtar, R., Bissaad, F.Z., Marniche, F. & Bounaceur, F. (2025) Comparatif monitoring arthropod: auxiliary-pest complex in vineyard table grapes cultivars in Boumerdes vineyards, northern Algeria. *Journal of Agriculture and Applied Biology*, 6 (2), 155–166. https://doi.org/10.11594/jaab.06.02.02

Bianchi, F.J.J.A., Booij, C.J.H. & Tscharntke, T. (2006) Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural pest control. *Proceedings of the Royal Society B: Biological Sciences*, 273 (1589), 1715–1727. https://doi.org/10.1098/rspb.2006.3530

Bigot, L. & Bodot, P. (1973) Contribution à l'étude biocénotique de la garrigue à *Quercus coccifera* – II. Composition biotique du peuplement des invertébrés. *Vie et Milieu*, 23 (2), 229–249.

Blondel, J. (1979) *Biogéographie et Ecologie*. Masson, Paris. 179 pp.

Bommarco, R. (1998) Reproduction and energy reserves of a predatory carabid beetle relative to agroecosystem complexity. *Ecological Applications*, 8 (3), 846–853. https://doi.org/10.1890/1051-0761(1998)008[0846:RAEROA]2.0.CO;2

Boreau de Roincé, C. (2012) *Biodiversité et Aménagements Fonctionnels en Verger de Pommiers: Implication des Prédateurs Généralistes Vertébrés et Invertébrés Dans le Contrôle des Ravageurs*. Doctoral dissertation, AgroParisTech. 192 pp.

Bounaceur, F., Bissaad, F.Z. & Doumandji-Mitiche, B. (2018) Étude de la biocénose viticole du nord algérien. *Lebanese Science Journal*, 19 (2), 150–176. https://doi.org/10.22453/LSJ-019.2.150176

Burel, F., Baudry, J., Butet, A., Clergeau, P., Delettre, Y., Le Coeur, D., Dubs, F., Morvan, N., Paillat, G., Petit, S., Thenail, C., Brunel, E. & Lefeuvre, J.-C. (1998) Comparative biodiversity along a gradient of agricultural landscapes. *Acta Oecologica*, 19 (1), 49–60. https://doi.org/10.1016/S1146-609X(98)80007-6

Capinera, J.L. (2008) *Encyclopedia of Entomology.* Second Edition. 4 vols., Dordrecht, The Netherlands: Springer Science + Business Media. 4346 pp.

Chafaa, S., Belkhadria, S. & Mimeche, F. (2019) Entomofauna investigations in the apricot orchards, *Prunus armeniaca* L. (Rosales: Rosaceae), in Ouled Si Slimane, Batna, North East Algeria. *Biodiversity Journal*, 10 (2), 95–100. https://doi.org/10.31396/Biodiv.Jour.2019.10.2.95.100

Chapin, F.S., Zavaleta, E.S., Eviner, V.T., Naylor, R.L., Vitousek, P.M., Reynolds, H.L., Hooper, D.U., Lavorel, S., Sala, O.E., Hobbie, S.E., Mack, M.C. & Díaz, S. (2000) Consequences of changing biodiversity. *Nature*, 405 (6783), 234–242. https://doi.org/10.1038/35012241

Chaplin-Kramer, R., O'Rourke, M.E., Blitzer, E.J. & Kremen, C. (2011) Chaplin-Kramer, R., O'Rourke, M.E., Blitzer, E. J. & Kremen, C. (2011) A meta-analysis of crop pest and natural enemy response to landscape complexity. *Ecology letters*, 14 (9), 922–932. https://doi.org/10.1111/j.1461-0248.2011.01642.x

Chinery, M. (1983) *Les Insectes d'Europe*. Bordas, Paris. 380 pp.

Chouinard, G., Firlej, A., Vanoosthuyse, F. & Vincent, C. (2000) *Guide d'Identification des Ravageurs du Pommier et de Leurs Ennemis Naturels*. Conseil des productions végétales du Québec inc., Canada, 69 pp.

Clough, Y., Kruess, A. & Tscharntke, T. (2007) Local and landscape factors in differently managed arable fields affect the insect herbivore community of a non-crop plant species. *Journal of Applied Ecology,* 44 (1), 22–28. https://doi.org/10.1111/j.1365-2664.2006.01239.x

Corbett, A. & Rosenheim, J.A. (1996) Impact of a natural enemy overwintering refuge and its interaction with the surrounding landscape. *Ecological Entomology,* 21 (2), 155–164. https://doi.org/10.1111/j.1365-2311.1996.tb01182.x

Dajoz, R. (1985) *Précis d'Ecologie*. Eighth Edition. Dunod, Paris. 505 pp.

Dix, M.E., Johnson, R.J., Harrell, M.O., Case, R.M., Wright, R.J., Hodges, L., Brandle, J.R., Schoeneberger, M.M., Sunderman, N.J., Fitzmaurice, R.L., Young, L.J. & Hubbard, K.G. (1995) Influence of trees on abundance of natural enemies of insect pests: A review. *Agroforestry Systems,* 29 (3), 303–311. https://doi.org/10.1007/BF00704876

Drapela, T., Moser, D.G., Zaller, J. & Frank, T. (2008) Spider assemblages in winter oilseed rape affected by landscape and site factors. *Ecography,* 31 (2), 254–262. https://doi.org/10.1111/j.0906-7590.2008.5250.x

Driouech, F., ElRhaz, K., Moufouma-Okia, W., Arjdal, K. & Balhane, S. (2020) Assessing future changes of climate extreme events in the CORDEX-MENA region using regional climate model ALADIN-climate. *Earth Systems and Environment*, 4 (3), 477–492.

Fahrig, L., Baudry, J., Brotons, L., Burel, F.G., Crist, T.O., Fuller, R. J., Sirami, C., Siriwardena, G.M. & Martin, J.-L. (2011) Functional landscape heterogeneity and animal biodiversity in agricultural landscapes. *Ecology Letters,* 14 (2), 101–112. https://doi.org/10.1111/j.1461-0248.2010.01559.x

Fiedler, A.K., Landis, D.A. & Wratten, S.D. (2008) Habitat management for natural enemies: A meta-analysis of its effect on pest control. *Agriculture, Ecosystems & Environment,* 127 (1–2), 12–21.

Forsline, P.L., Aldwinckle, H.S., Dickson, E.E., Luby, J.J. & Hokanson, S. (2003) Collection, maintenance, characterization and utilization of wild apples of Central Asia. In: Janick, J. (ed.) *Horticultural Reviews: Wild Apple and Fruit Trees of Central Asia.* Vol. 29. John Wiley & Sons, New York, pp. 1–62. https://doi.org/10.1002/9780470650868.ch1

Frah, N., Khelil, M.A. & Medjdoub-Bensaad, F. (2009) Circulating entomofauna in orchards of apple trees in the region of the Aures (Eastern Algeria). *African Journal of Agricultural Research,* 4 (3), 178–186.

Frah, N., Baala, H. & Loucif, A. (2015) Étude d'arthropodofaune dans un verger d'olivier à Séfiane (wilaya de Batna Est Algérien). *Lebanese Science Journal,* 16 (2), 37–45.

Gardiner, M.M., Fiedler, A.K., Costamagna, A.C. & Landis, D.A. (2009a) Integrating conservation biological control into IPM systems. In Radcliffe, E.B., Hutchison, W.D. & Cancelado, R. (eds) *Integrated pest management: Concepts, tactics, strategies and case studies.* Cambridge University Press, UK, pp. 151–162. https://doi.org/10.1017/CBO9780511626463.013

Gardiner, M.M., Landis, D.A., Gratton, C., DiFonzo, C.D., O'Neal, M., Chacon, J.M., Wayo, M.T., Schmidt, N.P., Mueller, E. & Heimpel, G.E. (2009b) Landscape diversity enhances biological control of an introduced crop pest in the north-central USA. *Ecological Applications,* 19 (1), 143–154. https://doi.org/10.1890/07-1265.1

Grout, T.G. & Stephen, P.R. (1995) New windbreak tree contributes to integrated pest management of citrus. *Citrus Journal,* 5 (4), 26–27.

Guermah, D., Medjdoub-Bensaad, F. & Aouar-Sadli, M. (2019) Evaluation of arthropods diversity on apple crop ('Red Delicious') in Sidi Naâmane area (Tizi-Ouzou), Algeria. *Acta agriculturae Slovenica,* 113 (1), 137–146. https://doi.org/10.14720/aas.2019.113.1.12

Guerzou, A., Derdouk, W., Guerzou, M. & Doumandji, S. (2014) Arthropod diversity in steppe region of Djelfa area (Algeria). *International Journal of Zoology and Research,* 4, 41–50.

Guettala-Frah, N. (2009) *Entomofaune, Impact Economique et Bio-écologie des Principaux ravageurs du Pommier Dans la Région des Aurès.* Unpublished Ph.D. Dissertation. University of Batna, Algeria. 178 pp.

Holzschuh, A., Steffan-Dewenter, I. & Tscharntke, T. (2008) Agricultural landscapes with organic crops support higher pollinator diversity. *Oikos,* 117 (3), 354–361. https://doi.org/10.1111/j.2007.0030-1299.16303.x

Hsieh, T.C. & Chao, A. (2016) iNEXT: An R package for rarefaction and extrapolation of species diversity. *Methods in Ecology and Evolution,* 7 (12), 1451–1456. https://doi.org/10.1111/2041-210X.12613

Isaacs, R., Tuell, J., Fiedler, A., Gardiner, M. & Landis, D. (2009) Maximizing arthropod-mediated ecosystem services in agricultural landscapes: The role of native plants. *Frontiers in Ecology and the Environment*, 7 (4), 196–203. https://doi.org/10.1890/080035

Jonsson, M., Wratten, S.D., Landis, D.A. & Gurr, G.M. (2008) Recent advances in conservation biological control of arthropods by arthropods. *Biological Control,* 45 (2), 172–175. *Biological Control*, 45 (3), 294–303. https://doi.org/10.1016/j.biocontrol.2008.01.006

Lamotte, M. & Bourlière, F. (1969) *Problèmes d'Ecologie: L'Echantillonnage des Peuplements Animaux des Milieux Terrestres.* Masson et Cie, Paris. 303 pp.

Landis, D.A., Wratten, S.D. & Gurr, G.M. (2000) Habitat management to conserve natural enemies of arthropod pests in agriculture. *Annual Review of Entomology,* 45 (1), 175–201. https://doi.org/10.1146/annurev.ento.45.1.175

Lavandero, B., Wratten, S.D., Didham, R.K. & Gurr, G. (2006) Increasing floral diversity for selective enhancement of biological control agents: A double-edged sword? *Basic and Applied Ecology*, 7 (3), 236–243. https://doi.org/10.1016/j.baae.2005.09.004

Letourneau, D.K., Bothwell, S.G. & Stireman, J.O. (2012) Perennial habitat fragments, parasitoid diversity and parasitism in ephemeral crops. *Journal of Applied Ecology,* 49 (6), 1405–1416. https://doi.org/10.1111/1365-2664.12001

Lüdecke, D., Ben-Shachar, M.S., Patil, I., Waggoner, P. & Makowski, D. (2021) Performance: An R package for assessment, comparison and testing of statistical models. *Journal of Open Source Software,* 6 (60), 3139. https://doi.org/10.21105/joss.03139

Magurran, A.E. (2021) Measuring biological diversity. *Current Biology,* 31 (19), R1174–R1177. https://doi.org/10.1016/j.cub.2021.07.049

Marini, L., Fontana, P., Battisti, A. & Gaston, K.J. (2009) Response of orthopteran diversity to abandonment of semi-natural meadows. *Agriculture, Ecosystems & Environment*, 132 (3–4), 232–236. https://doi.org/10.1016/j.agee.2009.04.003

Marshall, E.J.P. & Moonen, A.C. (2002) Field margins in northern Europe: Their functions and interactions with agriculture. *Agriculture, Ecosystems & Environment,* 89 (1–2), 5–21. https://doi.org/10.1016/S0167-8809(01)00315-2

Mecheri, H., Ghanem, R., Adjami, Y., Masna, F., & Ouakid, M.L. (2014) Les Coléoptères des pinèdes des zones semi-arides en Algérie. Beetles pine forests in semi-arid areas in Algeria. *Al-Wahat Journal of Research and Studies*, 7 (2), 82–90.

Olson, D. M. & Wäckers, F. L. (2007) Management of field margins to maximize multiple ecological services. *Journal of Applied Ecology,* 44 (1), 13–21. https://doi.org/10.1111/j.1365-2664.2006.01241.x

Östman, Ö., Ekbom, B. & Bengtsson, J. (2001) Landscape heterogeneity and farming practice influence biological control. *Basic and Applied Ecology,* 2 (4), 365–371. https://doi.org/10.1078/1439-1791-00072

Ounis, F., Frah, N. & Medjdoub-Bensaad, F. (2014) Diversité de la faune du sol dans une parcelle d'abricotier à Takout (Batna, Est de l'Algérie). *International Journal of Agriculture Innovation and Research*, 2 (4), 542–544.

Pearce, J.L., Schuurman, D., Barber, K.N., Larrivée, M., Venier, L.A., McKee, J. & McKenney, D. (2005) Pitfall trap designs to maximize invertebrate captures and minimize captures of nontarget vertebrates. *The Canadian Entomologist,* 137 (2), 233–250. https://doi.org/10.4039/N04-029

Pekár, S. & Kocourek, F. (2004) Spiders (Araneae) in the biological and integrated pest management of apple in the Czech Republic. *Journal of Applied Entomology*, 128 (8), 561–566. https://doi.org/10.1111/j.1439-0418.2004.00884.x

Perrier, R. (1927) *La faune de la France. Tome VII. Hyménoptères.* Librairie Delagrave, Paris. 211 pp.

Perrier, R. (1964) *La faune de la France. Tome VI. Les Coléoptères (1re partie)*. Librairie Delagrave, Paris. 192 pp.

Pihan, J.C. (1977) *Je reconnais les Insectes*. Collection Agir & Connaître: André Leson, Paris. 127 + 156 pp.

Pluess, T., Opatovsky, I., Gavish-Regev, E., Lubin, Y. & Schmidt-Entling, M. H. (2010) Non-crop habitats in the landscape enhance spider diversity in wheat fields of a desert agroecosystem. *Agriculture, Ecosystems & Environment,* 137 (1–2), 68–74. https://doi.org/10.1016/j.agee.2009.12.020

Ponce, C., Bravo, C., García de León, D., Magaña, M. & Alonso, J.C. (2011) Effects of organic farming on plant and arthropod communities: A case study in Mediterranean dryland cereal. *Agriculture, Ecosystems & Environment,* 141 (1–2), 193–201. https://doi.org/10.1016/j.agee.2011.02.030

Rand, T.A., Tylianakis, J.M. & Tscharntke, T. (2006) Spillover edge effects: The dispersal of agriculturally subsidized insect natural enemies into adjacent natural habitats. *Ecology Letters,* 9 (6), 603–614. https://doi.org/10.1111/j.1461-0248.2006.00911.x

Ricklefs, R.E. & Miller, G.L. (2005) *Écologie*. De Boeck & Larcier, Bruxelles / Paris. 822 pp.

Risch, S.J. (1987) Agricultural ecology and insect outbreaks. In: Barbosa, P. & Schultz, J.C. (eds) *Insect Outbreaks*. Academic Press, San Diego, CA, USA, pp. 217–238. https://doi.org/10.1111/2041-210X.12613

Roth, M. (1963) Comparaisons de méthodes de capture en écologie entomologique. *Revue de Pathologie Végétale et d'Entomologie Agricole de France,* 42 (3), 177–197.

Roth, M. (1974) *Initiation à la morphologie, la systématique et la biologie des insectes*. O.R.S.T.O.M., Collection Initiations – Documentation Techniques, Paris. 213 pp.

Rusch, A., Bommarco, R., Jonsson, M., Smith, H.G., Ekbom, B. & Landis, D. (2013) Flow and stability of natural pest control services depend on complexity and crop rotation at the landscape scale. *Journal of Applied Ecology,* 50 (2), 345–354. https://doi.org/10.1111/1365-2664.12055

Rusch, A., Chaplin-Kramer, R., Gardiner, M.M., Hawro, V., Holland, J., Landis, D., Thies, C., Tscharntke, T., Weisser, W., Winqvist, C., Woltz, M. & Bommarco, R. (2016) Agricultural landscape simplification reduces natural pest control: A quantitative synthesis. *Agriculture, Ecosystems and Environment,* 221, 198–204. https://doi.org/10.1016/j.agee.2016.01.039

Sánchez-Fernández, D., Abellán, P., Mellado, A., Velasco, J. & Millán, A. (2006) Are water beetles good indicators of biodiversity in Mediterranean aquatic ecosystems? The case of the Segura River Basin (SE Spain). *Biodiversity and Conservation*, 15 (14), 4507–4520. https://doi.org/10.1007/s10531-005-5101-x

Staněk, V.J. (1973) *Encyclopédie Illustrée des Insectes*. Gründ, Paris. 5487 pp.

Stoklosa, J., Blakey, R.V. & Hui, F.K. (2022) An overview of modern applications of negative binomial modelling in ecology and biodiversity. *Diversity,* 14 (5), 320. https://doi.org/10.3390/d14050320

Torretta, J.P. & Poggio, S.L. (2013) Species diversity of entomophilous plants and flower-visiting insects is sustained in the field margins of sunflower crops. *Journal of Natural History,* 47 (3–4), 139–165. https://doi.org/10.1080/00222933.2012.742162

Tscharntke, T., Klein, A.M., Kruess, A., Steffan-Dewenter, I. & Thies, C. (2005) Landscape perspectives on agricultural intensification and biodiversity–ecosystem service management. *Ecology Letters*, 8 (8), 857–874. https://doi.org/10.1111/j.1461-0248.2005.00782.x

Tylianakis, J.M., Klein, A.M., Kruess, A., Steffan-Dewenter, I. & Thies, C. (2005) Landscape perspectives on agricultural intensification and biodiversity–ecosystem service management. *Ecology Letters*, 8 (8), 857–874. https://doi.org/10.1111/j.1461-0248.2005.00782.x

Van Der Maarel, E. (1979) Transformation of cover-abundance values in phytosociology and its effects on community similarity. *Plant Ecology,* 39 (2), 97–114. https://doi.org/10.1007/BF00052021

Villiers, A. (1979) *Initiation à l'Entomologie: Anatomie, Biologie et Classification*. Société Nouvelle des Éditions Boubée & Cie, Paris. 334 p. + 20 pl.

Wyss, E. (1995) The effects of weed strips on aphids and aphidophagous predators in an apple orchard. *Entomologia Experimentalis et Applicata*, 75 (1), 43-49. https://doi.org/10.1111/j.1570-7458.1995.tb01908.x

Yan, L. & Yan, M.L. (2023) *ggvenn: Draw Venn diagram by "ggplot2"* (Version 0.1.10) [R package]. CRAN. https://CRAN.R-project.org/package=ggvenn/ [Accessed June 20, 2025]

Zahradnik, J. (1984) *Guide des Insectes*. Hatier, Paris. 352 pp.

Zanetti, M., Samoggia, A. & Youn, J. (2020) Fruit sector strategic management: An exploration of agro-food chain actors' perception of market sustainability of apple innovation. *Sustainability,* 12 (16), 6542. https://doi.org/10.3390/su12166542

تنوع بندپایان در باغ‌های سیب: تأثیر حصارهای گیاهی و ناهمگونی چشم‌انداز بر ساختار جامعه و سودمندی اکوسیستم در مدیهٔ (الجزایر)

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چکیـده: این تحقیق، به بررسی نقش حصارهای گیاهی و ناهمگونی چشم‌انداز در حمایت از تنوع بندپایان در باغ‌های سیب در منطقه مدیهٔ الجزایر می‌پردازد. در دو سیستم باغی با مدیریت متضاد، یکی وسیع با عناصر ساختاری (سی ال محاجوب) و دیگری فشرده بدون عناصر ساختاری (بنچیکو)، جوامع بندپایان در طول یک چرخه سالانه کامل با استفاده از تله‌های گودالی، تله‌های چسبنده رنگی و تورهای جمع‌آوری نمونه‌برداری شدند. در مجموع ۲۵۱ گونه بندپای مختلف در هر دو محل ثبت شد. سی ال محاجوب دارای غنای گونه‌ای به‌طور معناداری بالاتر (۲۲۹ گونه در مقابل ۱۸۴) و فراوانی کل (۴۳۵۱ در مقابل ۳۱۸۳ فرد) نسبت به بنچیکو بود. با وجود تعداد مشابه گونه‌ها، سی ال محاجوب تنوع تاکسونومی بیشتر، با توزیع گونه‌ها به‌طور یکنواخت‌تر و تنوع مؤثر بالاتر (شاخص‌های شانون ′H و سیمپسون) را نشان داد. محل دارای حصارهای گیاهی یک مجموعه بندپایان دارای عملکردی متنوع‌تر با تعداد بیشتری از شکارچیان (۷۸۶ در مقابل ۴۳۴) و انگل‌واره‌ها (۵۳۰ در مقابل ۴۸۲)، را حمایت می‌کند، در حالی در بنچیکو گونه‌های گیاه‌خوار غالب بودند. همبستگی غنای گیاه–بندپا در سی ال محاجوب به‌طور قوی مثبت (r = 0.97, p = 0.026) اما در بنچیکو منفی بود (r = -0.66, p = 0.54). تحلیل فصلی نشان داد که بیشترین تعداد گونه‌های منحصر به فرد در تابستان یافت شدند (۲۲٫۳٪) و همپوشانی بهار–تابستان (۳۲٫۳٪ گونه‌های مشترک) که بیشترین اهمیت را داشت. تحلیل ترتیبی نشان داد که فصول به‌عنوان عامل تعیین کنندهٔ ساختار جامعه عمل کرده و با جوامع زمستان–پائیز به‌طور جداگانه از مجموعه‌های بهار–تابستان خوشه‌بندی می‌شوند. این یافته‌ها بر ارزش اکولوژیکی حصارهای گیاهی و پیچیدگی ساختاری در چشم‌اندازهای کشاورزی را تأکید دارند. حصارهای گیاهی تنوع تاکسونومی و عملکردی بندپایان را افزایش داده و به سودمندی اکوسیستم خصوصاً کنترل بیولوژیک آفات کمک می‌کنند. نتایج نشان‌دهندهٔ تایید فرضیه ناهمگونی بوده و نشان‌دهندهٔ اهمیت زیرساخت‌های کشاورزی–اکولوژیکی را برای مدیریت پایدار تنوع زیستی در سیستم‌های باغی هستند.

واژگـان کلیدی: کشاورزی بوم‌شناختی، حفاظت، دشمنان طبیعی، فنولوژی، ساختار موزاییکی مزرعه، روابط تغذیه‌ای