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RESEARCH ARTICLE

Estimating the Taxonomic Richness and Functional Structure of Ant Communities in Olive Groves of Kabylia, Algeria

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ABSTRACT

Ants are indicators of habitat disturbance and key providers of ecological services and disservices to agricultural activities. We assessed species richness and functional structure of ant communities in olive groves of the Kabylia region, in northern Algeria. We compared three sampling methods (pitfall traps, hand capture, and bait traps) in four orchards with different elevations. We identified 53 ant species belonging to 17 genera and four subfamilies: Dorylinae, Dolichoderinae, Formicinae, and Myrmicinae. Species richness varied among orchards from 24 to 30, with species accumulation curves suggesting satisfactory coverage at all sites. Hand capture had the highest success per effort, while baits performed the worst. Overall, Kabylia's olive groves were richer in species than many Mediterranean agricultural and even some natural habitats documented in the literature, revealing relatively high ant diversity. Ants were classified into eight functional groups, with an overall composition comparable to similar studies conducted in southern Europe. Hot Climate Specialists, Generalised Myrmicinae, and Opportunists dominated, highlighting the role of thermal stress on the functional composition of the ant communities in the study sites. Many detected species may contribute to key ecological services, including soil enrichment and biological control of weeds and insects.

1 | Introduction

Agricultural expansion is one of the leading causes of habitat destruction, biodiversity loss, and ecosystem dysfunction, reducing species richness by simplifying habitat structure (Groc et al. 2017). Preserving high-quality of agricultural habitats has become a priority in biodiversity conservation programmes (Barlow et al. 2016). As a result of the negative impacts of agricultural systems, sustainable agriculture has been increasingly recognised as crucial to support biodiversity conservation (Peeters et al. 2004; Wagner et al. 2021).

Ants are among the most ecologically influential terrestrial organisms (Parker and Kronauer 2021). Due to their diversity, ubiquity, and variety of ecological habits, ants can be used as bioindicators to monitor the status of terrestrial habitats and estimate the pressures associated with environmental disturbances, including those associated with agriculture (Andersen 1995; Groc et al. 2014; Carvalho et al. 2020). They respond to environmental stress on a more precise scale than many other animals and may play a vital role in ecosystem functioning in natural and anthropogenic habitats (Delabie et al. 2009; Bihn et al. 2010; Groc et al. 2014; Dejean et al. 2015). From an agroecological point of view, effective ant management in arboricultural systems requires understanding both ants' positive and negative impacts on crops and pest species (Diame et al. 2017; Anjos et al. 2022). They make an essential contribution to agroecosystems by providing various services, such as biological control of phytophagous insects, fungi, and sometimes plants (Offenberg 2015; Offenberg and Damgaard 2019; Anjos et al. 2022; Schifani, Giannetti, and Grasso 2024), as well as by bioturbation and soil enrichment (Jones et al. 1994; Lavelle 1997). While ants also play a key role in controlling crop pests (Diame et al. 2017; Anjos et al. 2022), they may also favour some of them (Schifani, Giannetti, and Grasso 2024).

Algeria has excellent agricultural potential, which could form the basis of economic and social development (Tahraoui 2015). Olive cultivation has been an important practice of Mediterranean civilisations since ancient times. In Algeria, the olive crop plays an important economic, social, and environmental role. The national olive orchard covers an area of over 450 thousand hectares with an olive number reaching 62 million trees (Amrouni Sais et al. 2021). Its importance lies in the nutritional value of its by-products for local populations, which incorporate olive oil and olives into their daily diet, in the commercial values of these products, as well as its use in construction and heating (Smaini 2015). In Algeria, the olive tree represents one of the leading fruit species, covering more than a third (around 34.09%) of the area dedicated to tree fruit crops or around 383,443 ha (FAO 2014). It is mainly grown in the country's coastal regions, with the oldest and largest orchards in mountainous and hilly areas (Khoumeri 2009). The crop is also found in the country's western plains (Mascara, Sig, Relizane, etc.) and valleys such as the Soummam. The area under cultivation has increased considerably thanks to a national programme to develop intensive olive growing, which has been extended to steppe, pre-Saharan, and Saharan areas such as M'Sila, Biskra, and Ghardaïa (Abdessemed et al. 2018).

The ant fauna of olive groves in the Mediterranean has been mostly studied in the Iberian Peninsula and partly in Italy, with attention on its role in biological control and the effects of management (Morris et al. 1998, 2002; Redolfi et al. 1999; Ottonetti et al. 2008; Campos et al. 2013; Hevia et al. 2019; Frizzi et al. 2020; Martínez-Núñez et al. 2021).

Our study provides the first comprehensive documentation of ant communities in Kabylia's olive groves, addressing three key knowledge gaps: (1) the composition and structure of ant assemblages in North African agroecosystems, (2) the functional organisation of these communities relative to Mediterranean bioclimatic conditions, and (3) optimal sampling approaches for biodiversity assessments in olive cultivation systems. These findings establish baseline expectations for ant diversity in the region while informing both ecological theory and agricultural management practices.

2 | Materials and Methods

2.1 | Study Area

This study was conducted in some sites in the region of Tizi-Ouzou (north-east Algeria). A total of four olive orchards were selected, with altitudes ranging from 200 to 700 masl (Meters Above Sea Level) (see Figure 1). These orchards were selected across three distinct geomorphological zones. The Tamḍiqt orchard is situated within the Draa El Mizan depression, the Sidi Ali Moussa and Souk El Tenine orchards are located on the old Kabyle massif, and the Igraouène orchard lies at the foot of the Chellata foothills (Table 1). Given that each orchard represents a unique combination of elevation, soil type, and management practices (Table 1), our statistical analyses prioritise descriptive summaries (e.g., species accumulation curves, diversity indices) and exploratory comparisons (e.g., nMDS, SIMPER) to identify emergent patterns. While this approach does not support causal inferences due to unreplicated conditions, it provides a foundational understanding of ant community structure in these understudied agroecosystems. The region has a Mediterranean climate, with climatic conditions (temperature, rainfall) influenced by altitude and topography. Annual rainfall ranges from 790 mm at Tamḍiqt (the lowest altitude) to 950 mm at Igraouène (the highest altitude), while the highest average monthly temperatures are in August, ranging from 28.76°C to 26.39°C in the same orchards, respectively. A comprehensive herbarium from the four orchards was designed by one of us (LH) and identified by Dr. Laribi (University of Tizi-Ouzou), allowing for the identification of 133 plant species belonging to 43 botanical families. The most diverse family was Asteraceae, with 24 species.

The most common plant in these areas is the common olive (*Olea europaea* Mill.), which grows alongside other important plants such as holm oak (*Quercus ilex* L.), common fig (*Ficus carica* L.), black alder (*Alnus glutinosa* L.), black ash (*Fraxinus angustifolia* Vahl), pomegranate (*Punica granatum* L.), domestic pear (*Pyrus communis* L.), and prickly pear (*Opuntia ficus-indica* (L.) Mill).

Soil textures also vary significantly. Unsaturated podzolic soils at Igraouène, Souk El Tenine, and Sidi Ali Moussa favour forest growth and robust arboriculture, while alluvial soils in Tamḍiqt are highly suitable for agriculture (MATET/CENEAP 2008).

2.2 | Sampling Methods

Sampling took place in April, May, and June 2018, using three sampling methods: pitfall traps, hand capture, and food baits, following Abdi-Hamecha et al. (2021). One pitfall trap session was conducted each month in each orchard. Each session consisted of placing five pitfall traps 15 m apart along each of two parallel transects. Pitfall traps were left for 2 days. Thus,

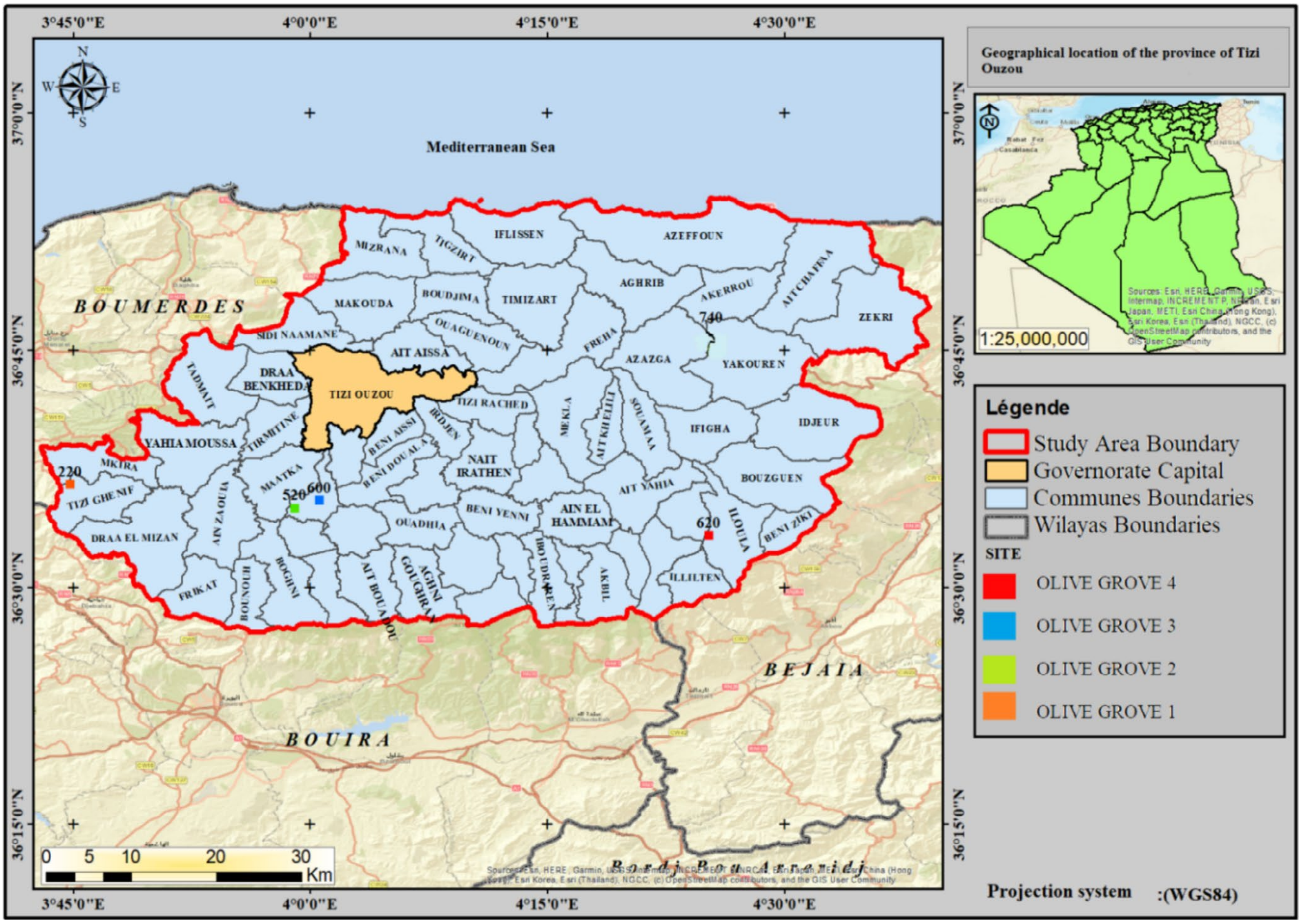

FIGURE 1 | Geographical location of the study sites.

TABLE 1 | Description of the olive groves studied.

Orchard name	Olive grove code	Geographical coordinates	Altitude (m)	Slope (%)	Orchard surface m²	Current orchard activities	Pesticides and Insecticides
Orchard Tamdiqt	1	36°36′33.7″ N; 3°44′47.1″ E	200	3 ~ 12	24833.76	Grazing Ploughing (cereal crops) Rainwater	Fertiliser 10% (NPK)
Orchard Sidi Ali Moussa	2	36°35′03.2″ N; 3°58′57.8″ E	500	12 ~ 25	15242.36	Overgrazing Rainwater	—
Orchard Souk El Tenine	3	36°35′32.9″ N; 4°00′32.8″ E	600	12 ~ 25	6739.83	Urbanisation Rainwater	—
Orchard Igraouène	4	36°33′20.5″ N 4°25′11.2″ E	700	12 ~ 25	5354.4	Rainwater	—

Note: —, Absence of pesticides and insecticides.

pitfall sampling consisted of a total of 30 pitfall traps for each orchard. The pitfall traps, made of clear plastic bottles, were filled three-quarters full of water and detergent. Around each pitfall, four baits (tuna, cookie, seeds, and honey) were placed on aluminium sheets 5 m away in the cardinal directions (Figure 2; Abdi-Hamecha et al. 2021). Thus, bait sampling consisted of a total of 120 baits for each orchard. The ants at the baits were collected after 2 h. One hour hand-capture session was conducted each month in each orchard. Collected ants were preserved in 96° ethyl alcohol and identified following Cagniant (1996a, 1996b), Cagniant (2005), Cagniant and Espadaler (1997a, 1997b), Seifert (2016, 2020a, 2020b), Barech, Khaldi, and Cagniant (2017), Barech et al. (2020), Schifani et al. (2021), and Seifert et al. (2024).

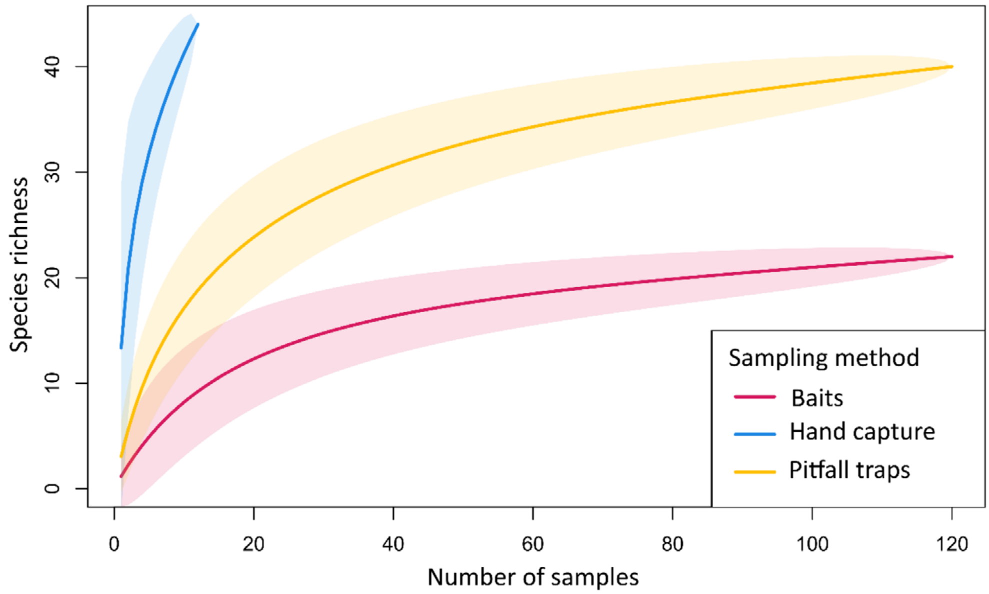

FIGURE 2 | Species accumulation curves comparing the three sampling methods employed.

2.3 | Data Analysis

Following the work of Gotelli et al. (2011) and Kasseney et al. (2019), we considered incidence data instead of the number of ants for statistical treatment, considering the social nature of ants.

Species accumulation curves were computed using the function specaccum from the R package vegan (Oksanen et al. 2022) to compare the coverage of the ant species richness at the four orchards as well as the effectiveness between the three sampling methods. *S*mean, Chao1, Jack1, and ICE were computed using the software EstimateS Version 9.1.0 (Colwell 2013). The capture efficiency of each sampling method was also assessed using a one-factor ANOVA, preceded by a data normality check with the Shapiro–Wilk test, using Statistica Version 8 (Statsoft 2012). The number of species captured for each sampling method was used for this analysis. A Tukey HSD test was then performed to compare pairwise means. However, ANOVA and Tukey HSD tests were used exclusively for descriptive comparison of variation between sites, not for hypothesis testing, given the unreplicated design.

In terms of ecological indices of composition and structure, (Majer 1983; Longino 2000) recommend using relative abundance (RA), species richness (S), Shannon's diversity index (H′), Simpson's diversity index (1-D), and Pielou's equitability index (E). We classified species according to their value of frequency of occurrence (FO) following (Bigot and Bodot 1973): Constants: FO $\geq$ 50%, Accessory: 25 $\leq$ FO $<$ 49%, Accidental: 10 $\leq$ FO $<$ 24%, and Sporadic: FO $<$ 10%.

We used ANOSIM analysis based on Bray–Curtis distances for presence/absence data to assess ant community similarity between the four olive groves. Non-metric multidimensional scaling (nMDS) was used to visualise ant community distinctions across the four sites, using the same dissimilarity measure. In addition, a SIMPER analysis was performed to determine the contribution of each species to the differences observed between olive groves. These parameters were calculated using PAST Version 3.25 software (Hammer et al. 2001).

To characterise the functional diversity at the four orchards, we classified species into functional groups based on Andersen (1995) and Hoffmann and Andersen (2023) classifications.

3 | Results

3.1 | Comparison of Sampling Methods

Species accumulation curves revealed significant differences ($F = 7.554$, $p = 0.001003$) in the effectiveness of the three sampling methods for species discovery. Although hand capture was performed with only three replicates, it proved to be the most cost-efficient method. In contrast, baits contributed less to species discovery, while pitfall traps showed intermediate performance, capturing a moderate number of species (Figure 2).

The one-way ANOVA test revealed highly significant differences between the three methods used in the Tamḍiqt and Igraouène olive groves, with marked results ($F = 10.94$, $p = 7.48\text{E-}05$ and $F = 30.25$, $p = 1.27\text{E-}10$, respectively). In contrast, the Sidi Ali Moussa ($F = 0.1861$, $p = 0.8305$) and Souk El Tenine ($F = 1.859$, $p = 0.162$) olive groves did not show statistically significant differences between the methods used. The Tukey test revealed particularly marked differences between Barber pots and manual capture ($p = 0.0009181$), as well as between Barber pots and bait traps ($p = 0.0002964$) in the Tamḍiqt olive grove. Similar results were observed in the Igraouène olive grove, where highly significant differences were found between Barber pots and bait traps, as well as between Barber pots and manual capture ($p = 0.0001074$). In fact, for the Sidi Ali Moussa olive groves (Barber pots vs. manual capture: $p = 0.8686$ and Barber pots vs. bait traps: $p = 0.8477$) and Souk El Tenine (Barber pots vs. manual capture: $p = 0.1976$ and Barber pots vs. bait traps: $p = 0.2534$),

TABLE 2 | Occurrence, number and status of ant species caught in each olive grove.

Subfamilies	Sites / Species	Orchard 1 Pi	Orchard 1 Ni	Orchard 2 Pi	Orchard 2 Ni	Orchard 3 Pi	Orchard 3 Ni	Orchard 4 Pi	Orchard 4 Ni	Functional groups
Dorylinae	*Dorylus fulvus* (Westwood, 1839)	(0)	0	(1)	1	(0)	0	(0)	0	TCS
Dolichoderinae	*Bothriomyrmex atlantis* (Forel, 1894)	(0)	0	(1)	16	(0)	0	(0)	0	C
	Tapinoma magnum (Mayr, 1861)	(4)	16	(11)	155	(30)	276	(5)	33	DD
	Tapinoma cf. *erraticum*	(0)	0	(1)	4	(3)	5	(0)	0	O
	Tapinoma simrothi (Krausse, 1911)	(5)	17	(17)	96	(16)	212	(0)	0	DD
Formicinae	*Camponotus alii* (Forel, 1890)	(0)	0	(0)	0	(0)	0	(11)	32	SC
	Camponotus barbaricus xanthomelas (Emery, 1905)	(0)	0	(7)	7	(1)	1	(0)	0	SC
	Camponotus cruentatus (Latreille, 1802)	(0)	0	(0)	0	(0)	0	(9)	28	SC
	Camponotus dichrous (André, 1882)	(0)	0	(0)	0	(4)	7	(0)	0	SC
	Camponotus lateralis purius (Santschi, 1929)	(0)	0	(0)	0	(1)	1	(0)	0	SC
	Camponotus micans (Nylander, 1856)	(0)	0	(0)	0	(0)	0	(5)	11	SC
	Camponotus ruber (Emery, 1925)	(2)	2	(1)	1	(8)	36	(0)	0	SC
	Camponotus spissinodis (Forel, 1909)	(0)	0	(0)	0	(2)	2	(1)	1	SC
	Camponotus thoracicus (Fabricius, 1804)	(3)	4	(7)	63	(9)	31	(0)	0	SC
	Cataglyphis viatica (Fabricius, 1787)	(12)	41	(8)	49	(22)	108	(12)	70	HCS
	Lasius barbarus (Santschi, 1931)	(0)	0	(1)	1	(0)	0	(0)	0	CCS
	Lasius sp.	(0)	0	(1)	2	(2)	8	(0)	0	CCS
	Lepisiota frauenfeldi atlantis (Santschi, 1917)	(1)	1	(0)	0	(0)	0	(0)	0	O
	Plagiolepis atlantis (Santschi, 1920)	(3)	70	(10)	103	(4)	18	(3)	3	O
	Plagiolepis barbara (Santschi, 1911)	(1)	1	(31)	49	(4)	42	(1)	1	O
Myrmicinae	*Aphaenogaster depilis* (Santschi, 1911)	(12)	71	(12)	51	(10)	26	(10)	27	O
	Aphaenogaster mauritanica (Dalla Torre, 1893)	(0)	0	(0)	0	(0)	0	(7)	20	O
	Aphaenogaster sardoa ujhelyii (Szabó, 1910)	(1)	1	(8)	94	(1)	1	(1)	1	O
	Aphaenogaster strioloides (Forel, 1890)	(0)	0	(0)	0	(0)	0	(1)	1	O
	Aphaenogaster testaceopilosa s.str. (Lucas, 1849)	(6)	15	(17)	183	(30)	195	(6)	54	O
	Aphaenogaster testaceopilosa cabylica (Stitz, 1917)	(0)	0	(2)	3	(5)	8	(0)	0	O
	Aphaenogaster canescens (Emery, 1895)	(0)	0	(0)	0	(0)	0	(1)	1	O
	Crematogaster auberti levithorax (Forel, 1902)	(3)	38	(9)	52	(0)	0	(2)	2	GM
	Crematogaster laestrygon normandi (Santschi, 1921)	(15)	181	(0)	0	(0)	0	(2)	6	GM

(Continues)

Subfamilies	Sites / Species	Orchard 1 Pi	Orchard 1 Ni	Orchard 2 Pi	Orchard 2 Ni	Orchard 3 Pi	Orchard 3 Ni	Orchard 4 Pi	Orchard 4 Ni	Functional groups
	Crematogaster scutellaris algirica (Lucas, 1849)	(6)	35	(7)	149	(11)	129	(4)	19	GM
	Crematogaster sordidula (Nylander, 1849)	(0)	0	(0)	0	(1)	1	(1)	1	GM
	Crematogaster scutellaris tenuispina (Forel, 1902)	(1)	1	(0)	0	(2)	5	(0)	0	GM
	Messor barbarus (Linnaeus, 1767)	(16)	110	(4)	91	(13)	106	(4)	5	HCS
	Messor capitatus (Latreille, 1798)	(2)	5	(3)	10	(3)	4	(8)	33	HCS
	Messor grandinidus (Emery, 1912)	(0)	0	(0)	0	(0)	0	(1)	1	HCS
	Messor lobicornis (Forel, 1894)	(0)	0	(2)	4	(0)	0	(0)	0	HCS
	Messor picturatus (Santschi, 1927)	(3)	12	(3)	31	(1)	3	(0)	0	HCS
	Messor medioruber (Santschi, 1910)	(0)	0	(0)	0	(0)	0	(7)	14	HCS
	Messor semoni (Forel, 1906)	(0)	0	(0)	0	(0)	0	(4)	17	HCS
	Messor striativentris (Emery, 1908)	(1)	1	(1)	2	(0)	0	(0)	0	HCS
	Messor striatulus (Emery, 1891)	(1)	1	(0)	0	(0)	0	(0)	0	HCS
	Monomorium andrei (Saunders, 1890)	(2)	2	(0)	0	(0)	0	(0)	0	HCS
	Monomorium monomorium (Bolton, 1987)	(0)	0	(0)	0	(0)	0	(2)	2	O
	Monomorium salomonis (Linnaeus, 1758)	(5)	25	(6)	209	(14)	122	(1)	3	HCS
	Pheidole pallidula (Nylander, 1849)	(2)	5	(6)	13	(2)	15	(6)	39	GM
	Solenopsis longiceps (Forel, 1907)	(0)	0	(0)	0	(0)	0	(1)	1	C
	Strongylognathus afer (Emery, 1884)	(0)	0	(1)	3	(0)	0	(0)	0	C
	Temnothorax algiricus (Forel, 1894)	(0)	0	(1)	1	(2)	3	(0)	0	CCS
	Temnothorax annibalis (Santschi, 1909)	(1)	1	(0)	0	(0)	0	(0)	0	CCS
	Temnothorax recedens (Nylander, 1856)	(0)	0	(0)	0	(2)	3	(0)	0	CCS
	Temnothorax spinosus (Forel, 1909)	(0)	0	(0)	0	(1)	1	(0)	0	CCS
	Tetramorium atlante (Cagniant, 1970)	(0)	0	(5)	38	(15)	111	(3)	6	O
	Tetramorium biskrense (Forel, 1904)	(0)	0	(3)	29	(11)	142	(5)	18	O
	Total: (S = *Richness*) & Individuals	(24)	656	(30)	1510	(30)	1622	(29)	450	

Abbreviations: C, cryptic species; CCS, cold climate specialists; DD, dominant dolichoderinae; GM, generalised myrmicinae; HCS, hot climate specialists; Ni, abundance values for species *I* in all methods; O, opportunists; Pi, number of occurrences of species *i* in all methods combined, in brackets; SC, subordinate camponotini; TCS, tropical climate specialists.

no significant difference was observed between the methods used to capture the ants.

3.2 | Ant Taxonomic Richness

A total of 4238 individuals from four subfamilies, comprising 17 ant genera and 53 ant species (Table 2), were collected and identified. Myrmicinae (9 genera) was the most diverse subfamily, followed by Formicinae (5 genera). Dolichoderinae included two genera and four species, while Dorylinae had only one genus and one species. *Camponotus* and *Messor* (9 species) and *Aphaenogaster* (7 species) were the most represented genera. We recorded 24 taxa for Tamḍiqt, 30 for Sidi Ali Moussa and Souk El Tenine, and 29 for Igraouène (Table 2).

A predominance of the Myrmicinae subfamily was observed in the surveys conducted in each orchard, with relative abundance rates of 77% at Tamḍiqt, 64% at Sidi Ali Moussa, 54% at Souk El Tenine, and 60% at Igraouène (Figure 3). The Formicinae subfamily ranked second in Tamḍiqt (RA = 18.14%), Sidi Ali Moussa (RA = 18.21%), and Igraouène (RA = 32.44%). In contrast, Dolichoderinae (RA = 30.39%) dominated mainly over Formicinae (RA = 15.66%) in Souk El Tenine.

Several species emerged as the most abundant across all surveys conducted in each orchard, providing a clear picture of the dominant species and their relative abundance. *Tapinoma magnum* Mayr, 1861 (11.33%) was followed by *Aphaenogaster testaceopilosa* (Lucas, 1849) (10.55%) and *Monomorium salomonis* (Linnaeus, 1758) (8.47%). The most abundant species across all the olive groves is also the most frequent, notably *Aphaenogaster testaceopilosa* (Lucas, 1849) (FO = 30.41%), *Cataglyphis viatica* (Fabricius, 1787) (FO = 27.84%), and *Tapinoma magnum* Mayr, 1861 (FO = 25.77%), which are considered accessory species.

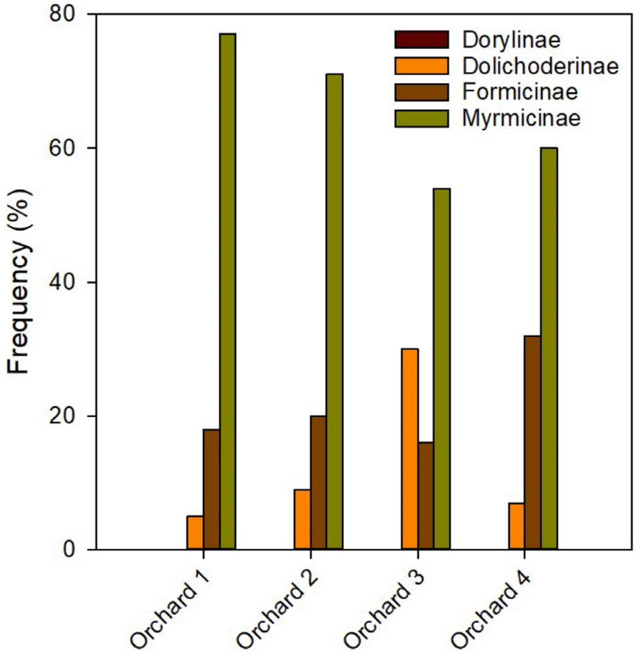

FIGURE 3 | Relative abundance (%) of different Formicidae subfamilies recorded at the different study sites.

3.3 | Species Richness and Diversity Indexes

Species accumulation curves testified good coverage at all orchards, with the four curves reasonably approaching asymptote (Figure 4). The total number of species predicted by the ICE estimator ranged from 28.76 (Tamḍiqt) to 36.48 (Sidi Ali Moussa) (Table 3).

The Chao 1 estimator recorded the highest value of all sites (50.15) in Sidi Ali Moussa, indicating a high presence of uncommon species and significant hidden diversity. The other olive groves show Chao 1 values ranging from 28.16 (Tamḍiqt) to 37.93 (Igraouène), indicating many undetected species. Jack 1 estimates are also consistent with this trend, ranging from 30.83 (Tamḍiqt) to 38.84 (Sidi Ali Moussa) (Table 3; Figure 5).

The highest values for species represented by a single individual were recorded in Igraouène and Sidi Ali Moussa, with nine singletons each, indicating the presence of several rare species at these sites. Tamḍiqt and Souk El Tenine had a slightly lower number of species represented by a single individual, 7 and 6, respectively. Species represented by two individuals ranged from 2 in Sidi Ali Moussa to 6 in Souk El Tenine, suggesting a slightly greater presence of uncommon species in the latter (Figure 5).

Diversity indices were consistently high across orchards (Simpson: 0.88–0.92; Shannon: 2.77–3.08 bits), with both measures peaking at the highest-elevation site (Igraouène). Finally, Pielou's equitability also showed high values, oscillating between 0.86 and 0.91 (Table 3).

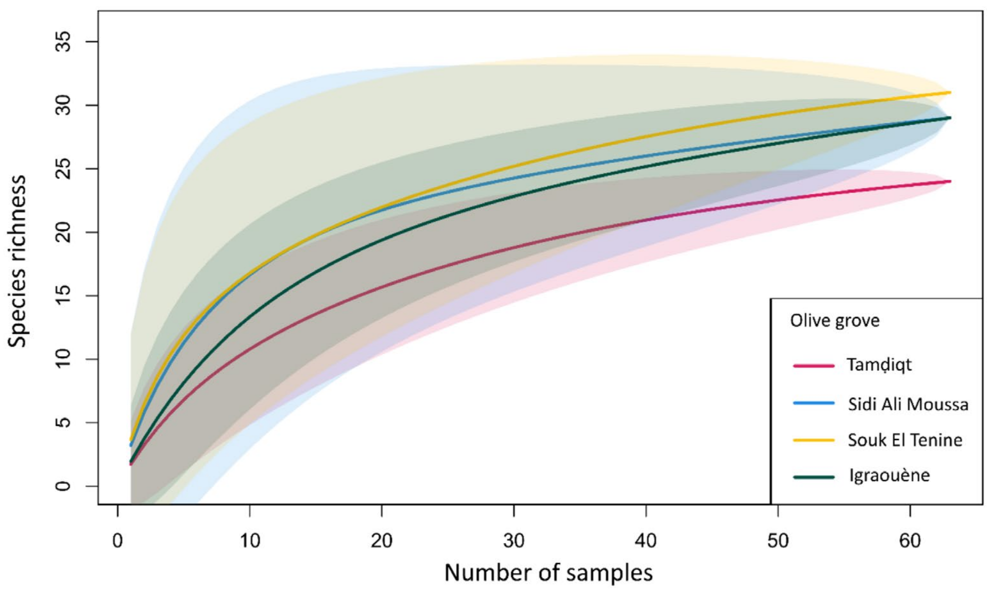

FIGURE 4 | Species accumulation curves comparing the four investigated sites based on all sampling methods combined.

TABLE 3 | Comparison of ant species diversity and diversity indices in four olive groves (Tamḍiqt, Sidi Ali Moussa, Souk El Tenine and Igraouène) with different sampling methods.

Sites	Orchard (1) Tamḍiqt				Orchard (2) Sidi Ali Moussa				Orchard (3) Souk El Tenine				Orchad (4) Igraouène			
Sampling methods	BP	MH	BT	Total (S)	BP	MH	BT	Total (S)	BP	MH	BT	Total (S)	BP	MH	BT	Total (S)
Number of species	22	12	3	24	15	29	16	30	18	27	14	30	27	13	4	29
Diversity indexes	H′(bits)	Hmax	(E)	Sim. (1-D)	H′(bits)	Hmax	(E)	Sim. (1-D)	H′(bits)	Hmax	(E)	Sim. (1-D)	H′(bits)	Hmax	(E)	Sim. (1-D)
	2.77	3.18	0.87	0.88	2.99	3.40	0.88	0.92	2.93	3.40	0.86	0.9	3.08	3.37	0.91	0.92
Richness estimators	ICE	Chao1	Jack1	Sobs.	ICE	Chao1	Jack1	Sobs.	ICE	Chao1	Jack1	Sobs.	ICE	Chao1	Jack1	Sobs.
	28.76	28.16	30.83	24	36,48	50,15	38,84	30	35,44	32,99	35,9	30	35.84	37.93	37.76	29

Abbreviations: (E), equitability; (S), specific richness; BP, barber pots; BT, bait traps; H′, Shannon index; H_{max}, the highest possible diversity; MH, manual harvest; Sim. (1-D), Simpson (1-D); Sobs., observed richness.

Analysis by ANOSIM indicated that ant populations in the olive groves are not entirely distinct but show a moderate level of differentiation ($R = 0.358$, $p\text{-}value = 0.0016$), suggesting some level of overlap between groups. According to the SIMPER analysis, the average difference between the olive groves was 77%. All the ant species that contributed to this disparity are listed in Appendix S1. Three groups were graphically presented through a 2D projection of the ant communities from the study sites obtained from an nMDS ordination. Visual analysis of this projection reveals a marked proximity between the communities of sites 2 and 3, which appear closely grouped. In contrast, the communities from sites 1 and 4 are separated from those of sites 2 and 3, positioned further apart in the ordination space (Figure 6).

3.4 | Functional Diversity

Species were assigned to eight functional groups: C—Cryptic Species (*Bothriomyrmex atlantis* Forel, 1894, *Solenopsis longiceps* Forel, 1907, *Strongylognathus afer* Emery, 1884), CCS—Cold Climate Specialists (*Lasius barbarus* (Santschi, 1931), *Temnothorax* spp.), DD—Dominant Dolichoderinae (*Tapinoma magnum* Mayr, 1861, *T. simrothi* Krausse, 1911), GM—Generalised Myrmicinae (*Crematogaster* spp., *Pheidole pallidula* (Nylander, 1849)), HCS—Hot Climate Specialists (*Cataglyphis viatica* (Fabricius, 1787), *Messor* spp., *Monomorium Andrei* Saunders, 1890, *M. salomonis* (Linnaeus, 1758)), O—Opportunists (*Aphaenogaster* spp., *Lepisiota frauenfeldi atlantis* (Santschi, 1917), *Monomorium monomorium* Bolton, 1987, *Plagiolepis* spp., *Tapinoma* cf. *erraticum*, *Tetramorium* spp.), SC—Subordinate Camponotini (*Camponotus* spp.), TCS—Tropical Climate Specialists (*Dorylus fulvus* (Westwood, 1839)).

Cryptic Species occurred only in Sidi Ali Moussa and Igraouène, accounting for 3%–7% of their faunas. Cold Climate Specialists were absent from Igraouène (4%–13% in the other groves), and Tropical Climate Specialists represented 3% in Sidi Ali Moussa (one species). All other functional groups occurred in all groves (Figure 7). Dominant Dolichoderinae expectedly represented a relatively small abundance (RA = 6% ± 2%, as mean ± SD), while generalised Myrmicinae and Subordinate Camponotini had similar abundances, accounting for 15% ± 5% and 13% ± 5%, respectively. The most abundant groups were Hot Climate Specialists (24% ± 7%) and Opportunists (30% ± 5%).

4 | Discussion

With an average fauna of 28 taxa, the olive groves of Tizi-Ouzou (Kabylia region) proved to be richer in species compared to other olive groves and agricultural settings in the Mediterranean in which similar assessments were carried out (e.g., Redolfi et al. 1999; Campos et al. 2013; Hevia et al. 2019; Giannetti et al. 2021; Henine-Maouche et al. 2022). Furthermore, with over 50 taxa recorded from just four sites, they surpassed the number of species recorded in many natural and semi-natural areas around southern Europe (Castracani et al. 2010; Schifani, Grasso, et al. 2024). An assessment on the

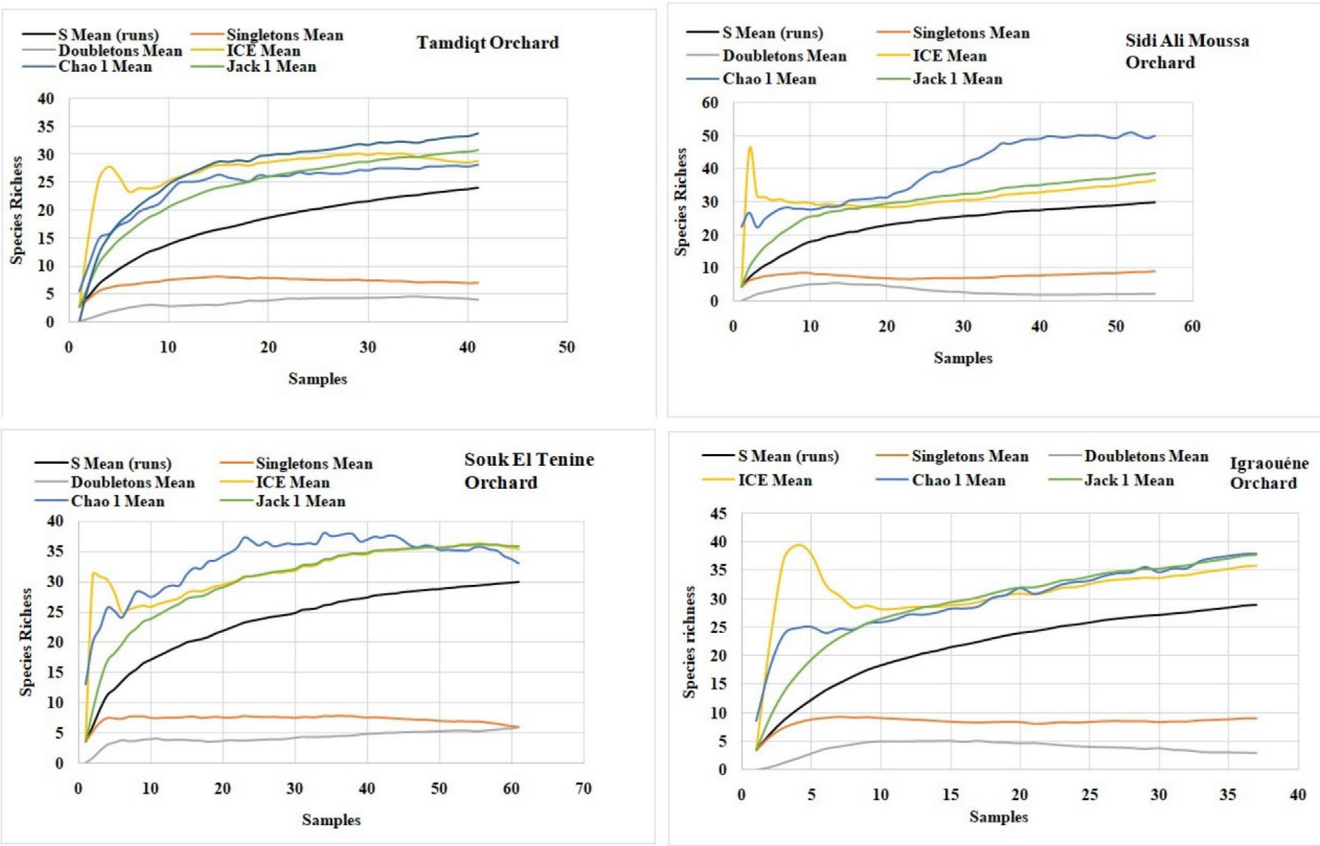

FIGURE 5 | Species accumulation curves and wealth estimators using all sampling methods combined for the different olive groves.

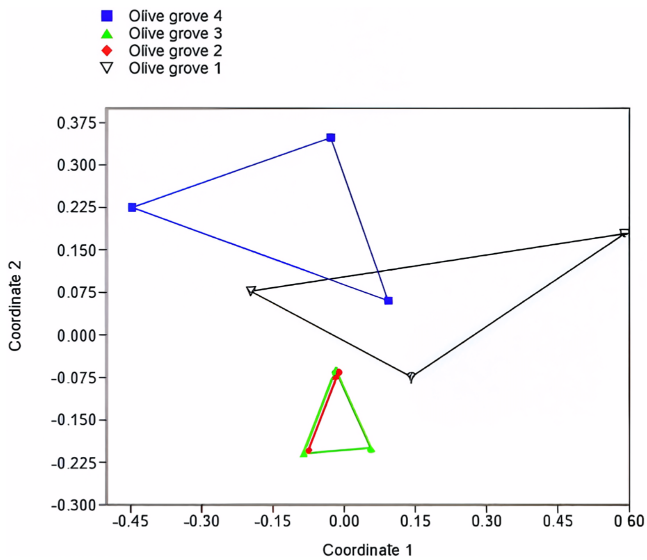

FIGURE 6 | nMDS test carried out for olive groves in Kabylia (all methods—occurrence data).

Yakouren oak forest, about 22 km away from the Igraouène orchard we investigated, found a similar number of species (28) but a different composition: the genus *Monomorium*, usually related to xerothermophilous and open habitats, was missing, *Tapinoma magnum* was the only dolichoderine and was relatively rare, while *Pheidole*, *Camponotus*, and *Crematogaster* ants were the most frequently encountered (Abdi-Hamecha et al. 2021). It is important to highlight that north-western Africa stands out as a particularly rich area within the Mediterranean region, which, in turn, is a global hotspot for rare ant species (Kass et al. 2022). However, more investigations across Mediterranean olive orchards will be needed to compare ant faunas and richness patterns in the region.

The high species richness observed in the areas we studied may also be attributed to more biodiversity-friendly management practices, including the absence of pesticides and insecticides, as well as the use of rainwater for irrigation rather than conventional water sources. This less intensive agricultural management approach warrants further investigation, as also do the effects of different management practices and environmental conditions. For instance, grazing (which is more intensive in Sidi Ali Moussa) may allow for more sunlight to reach the soil by reducing the herbaceous cover and favour more thermophilic species like *Cataglyphis viatica*, while nearby urbanisation (as in Souk El Tenine) could also favour disturbance-tolerant taxa. These observed patterns at Igraouène (more natural surroundings) and Tamḍiqt (yearly ploughing) highlight how unique management-environment combinations may shape communities. To disentangle the effects of these factors—and to explore potential synergistic interactions among them (Vicente et al. 2024)—further investigations involving multiple sites and replicates per set of characteristics will be needed. Certain aspects of the relative abundance of subfamilies, such as the numerical dominance of Myrmicinae, were comparable to those found in other studies on the Algerian myrmecofauna (Djioua and Sadoudi-Ali Ahmed 2015; Labbaci et al. 2015; Chemala et al. 2017; Barech, Khaldi, and Espadaler 2017; Abdi-Hamecha

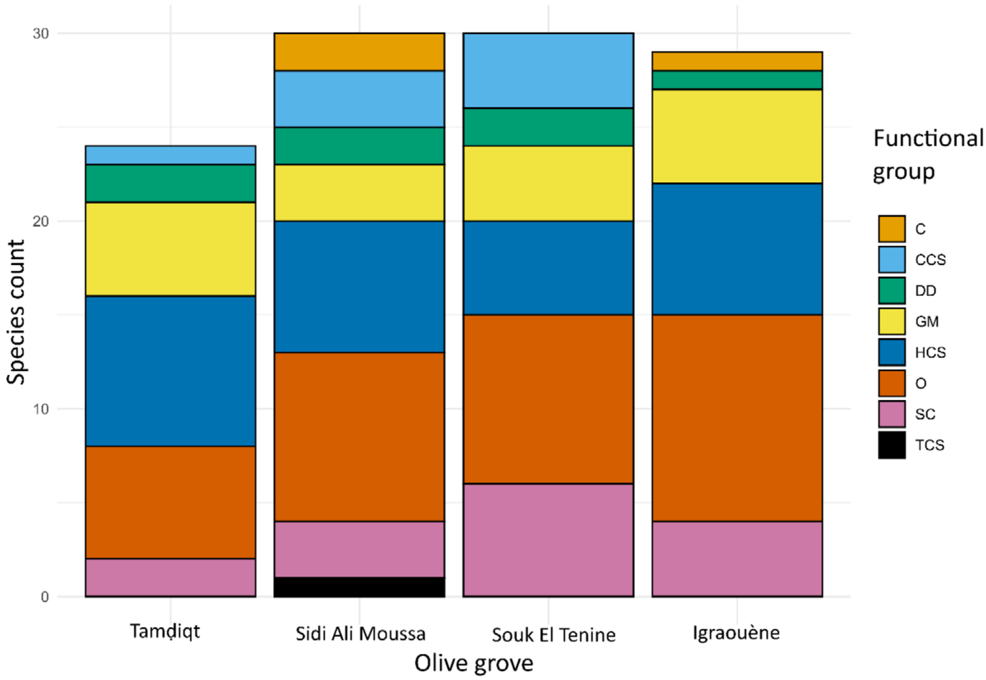

FIGURE 7 | Functional group composition of the ant fauna at the investigated sites.

et al. 2021); Henine-Maouche et al. 2022). In terms of functional diversity, the groups we identified were generally similar to those recorded elsewhere in temperate Palearctic regions (Andersen 1997; Hoffmann and Andersen 2023), with the notable exception of the army ant *Dorylus fulvus*, a rare member of this predominantly tropical genus found in the Palearctic (Guénard et al. 2017). More specifically, the functional composition of the community was overall similar to that of the Mediterranean region of southern Europe, in which thermal stress is a dominant factor, with a high representation of Generalised Myrmicinae, Hot Climate Specialists, and Opportunists (Hoffmann and Andersen 2023). Generalised Myrmicinae represent a relatively ubiquitous group capable of using quick recruitment and mass mobilisation to monopolise food sources, while Opportunists are ruderal species that tend to become more abundant in contexts in which stress (e.g., thermal) or disturbance (e.g., management) limit ant productivity (Andersen 1995). Hot Climate Specialists tend to avoid competition with other ants due to their specialisations, and in our study were represented by the seed-harvesting genus *Messor* and the extremely heat-tolerant *Cataglyphis* (Andersen 1995). Multiplying the efforts for functional assessments of ants in the regions will advance the ability to make comparative studies and more refined interpretations.

Ant species recorded in this study have various habits, including species from open habitats (*Messor* spp.), arboreal-nesting (*Crematogaster scutellaris* (Lucas, 1849), *Temnothorax algiricus* (Forel, 1894)) and ground-dwelling (*Aphaenogaster* spp., *Cataglyphis viatica* (Fabricius, 1787), *Pheidole pallidula* (Fabricius, 1787), *Tetramorium* spp.), predators or scavengers, as well as endogean species (*Bothriomyrmex xatlantis*; Forel, 1894). While most species are free-living, two are social parasites of ants (*B. xatlantis*; Forel, 1894, *Strongylognathus afer*; Emery, 1884). Some of these ants have already been associated with specific ecological services or disservices in agroecosystems: *Messor* spp. are known for enriching the soil and can control weeds (Baraibar et al. 2011; De Almeida et al. 2020). Species in the *Tapinoma nigerrimum* complex can control olive moth *Prays oleae* and fruit flies, including the *Bractocera oleae* olive fly (Morris et al. 2002; Campolo et al. 2015; Martínez-Núñez et al. 2021), alongside other predatory ants such as *Crematogaster scutellaris* and *Temnothorax* ants from the *algiricus* complex (Giannetti et al. 2022). At the same time, some of these species may also favour outbreaks of honeydew-producing pests in olive orchards (Frizzi et al. 2020) and in vine and citrus (Mansour et al. 2012).

The Mediterranean is a key region for the diversity of both ants and agricultural systems. Moreover, the role of ants in providing ecosystem services and disservices for agriculture has long been studied, preferably in tropical agroecosystems (Offenberg 2015; Anjos et al. 2022).

Although North Africa is home to a remarkable diversity of ant species, the taxonomy of ants in the region still requires substantial revision (Kass et al. 2022). In this context, our study examines the diversity of ants in traditional olive groves within the agroecosystems of Kabylia.

5 | Conclusions

We documented an ant fauna of 53 species across just four orchards, revealing a significant richness of the olive orchard of Algeria's Kabylia region in the context of natural and agricultural Mediterranean landscapes. Hand capture, while being much more influenced by the expertise of the collectors compared to the other methods, proved to be by far the most cost-effective sampling strategy, providing a fundamental contribution to our assessment. On the other hand, baits made a very modest contribution, attracting only a few species, and pitfall traps showed an intermediate performance. Our data provide an important baseline for studies on ant biodiversity in olive orchards. Despite the cultural, ecological, and economic relevance of olives in the Mediterranean, still little is known about their impact on insect fauna. Future research efforts should not only aim at comparing ant communities of olive orchards across different regions or with those of nearby natural habitats, but also at disentangling the complex interplay of management and environmental conditions that influence them, promoting biodiversity-friendly approaches.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Appendix S1:** Mean dissimilarity and percentage of contribution of each species sampled using SIMPER similarity analysis.