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Original Research Paper

A Comprehensive Inventory of Wild Bees in Tlemcen (North-West of Algeria)

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Abstract

This study is among the first monographs on Algerian apoid fauna. Conducted from March 2022 to June 2022, it involves inventorying wild bees across three stations in the Tlemcen Mountains along an altitude gradient. An exhaustive list of 70 species was compiled, with the Apidae family containing 9 species. Apis mellifera was the most prevalent, comprising 33.43% of the population, followed by Bombus terrestris (20%), Xylocopa pubescens (17.14%), Xylocopa violacea (15.71%), Anthophora vestita (7.14%), Eucera notata and Eucera colaris (2.86%), and Eucera punctatissima and Eucera nigrilabris (1.43%). New apoid fauna species discovered in the Tlemcen Mountains include members of the Andrenidae family (Andrena flavipes, Andrena nigroanea), the Megachilidae family (Hoplitlis sp.), and other Vespoidea species such as Vespula vulgaris and Dasyscolia ciliata. Studies on the diversity and structure of bee populations indicated significant diversity, illustrated by the Shannon-Weaver diversity index, with the highest value of 2.65 recorded in Beni Snous. Additionally, it was observed that most species were well represented in May and June, with a notable shortage in March and April due to drought and a delayed spring. The relationships between plants and bees were examined by studying the plants visited during the flowering season. The chi-square test revealed a significant and medium correlation between bees and regions, and a significant and very strong correlation between plants and bees. The results underscore the richness of Apoids in the area and highlight the necessity of their protection, given their critical role in pollination and maintaining biodiversity in natural ecosystems and agrocenoses.

Keywords: Mountains of Tlemcen, Apoidea, inventory, natural ecosystems, plants, pollination, bees.

ملخص

تعتبر هذه الدراسة واحدة من أولى المونوغرافيات حول فونة الأبويد الجزائرية. أُجريت الدراسة من مارس 2022 إلى يونيو 2022، وشملت جرد النحل البري عبر ثلاث محطات في جبال تلمسان. تم تجميع قائمة شاملة تضم 70 نوعًا، مع احتواء عائلة النحل على 9 أنواع. كان نحل العسل (الأكثر انتشارًا، حيث شكل 33.43% من السكان، يليه النحل الطنان بنسبة 20%، والنحل الحفار بنسبة 17.14%، والنحل الحفاربنسبة 15.71%، ونحل الأنثوفورا (Anthophora vestita) بنسبة 7.14%، ونحل الأوكيرا (Eucera notata و Eucera colaris) بنسبة 2.86%، ونحل الأوكيرا (Eucera punctatissima و Eucera nigrilabris) بنسبة 1.43%. تم اكتشاف أنواع جديدة من فونة الأبويد في جبال تلمسان تشمل أفرادًا من عائلة النحل الأندريني (Andrena flavipes،Andrena nigroanea)، وعائلة النحل الميجاكليدي (Hoplitlis sp.)، وأنواع أخرى من الفيسبويديا مثل الدبور الشائع (Vespula vulgaris) والدبور الزنبار (Dasyscolia ciliata). أظهرت الدراسات على تنوع وهيكل تجمعات النحل تنوعًا كبيرًا، موضحًا بمؤشر التنوع شانون-ويفر، حيث تم تسجيل أعلى قيمة وهي 2.65 في بني سنوس. بالإضافة إلى ذلك، لوحظ أن معظم الأنواع كانت ممثلة جيدًا في مايو ويونيو، مع نقص ملحوظ في مارس وأبريل بسبب الجفاف وتأخر الربيع. تم دراسة العلاقات بين النباتات والنحل من خلال فحص النباتات التي تمت زيارتها خلال موسم الإزهار. أظهر اختبار كاي تربيع وجود علاقة ذات دلالة متوسطة بين النحل والمناطق، وعلاقة ذات دلالة قوية جدًا بين النباتات والنحل. تؤكد النتائج على غنى المنطقة بالنحل الأبويد وتسلط الضوء على ضرورة حمايتهم في المستقبل، نظرًا لدورهم الحيوي في التلقيح والحفاظ على التنوع البيولوجي في النظم البيئية الطبيعية والزراعية.

الكلمات المفتاحية: النحل البري، جبال تلمسان، النظم البيئية الطبيعية، تلقيح النباتات.

Introduction

Apoids (wild bees and honeybees) are crucial for maintaining ecological balance and enhancing agricultural productivity through their pollination services. They contribute significantly to the health of ecosystems and the success of crops, which underscores their importance beyond mere biodiversity. Despite their global significance, apoids have been extensively studied primarily at faunistic and behavioral levels, but North Africa remains relatively unexplored. In Algeria, the research on this fauna is notably insufficient and fragmentary. Until recently, this fauna remained poorly known. The study of the Algerian bee population can largely be summarized by the following studies: Lucas (1849), Fries (1895-1901), Saunders (1901, 1908), Alfken (1914), and Scheuchl in the regions of Algiers and Médéa, and in the northwest of Algeria, which was limited to the region of Tlemcen, along with the work of Benoist (1961) on species collected from the genus Halictus in the region of Ouargla (Algerian Sahara). The existing data are incomplete and not precise, as new species have been observed later. The most recent studies conducted throughout the country include Louadi (1998a, 1998b, 1999) in Constantine, Tazerouti (2002) in northeastern Algeria and around Algiers, and Benachour et al. (2007), Louadi et al. (2007a, 2007b, 2008) in northeastern Algeria, and Aouar-Sadli (2008) in the region of Tizi-Ouzou. These works, although somewhat incomplete, have contributed significantly to understanding the Algerian insect fauna, with the work of Louadi et al. (2008) summarizing fauna inventories in Eastern Algeria.

The main recent data contributing to a better knowledge of this group of insects in Algeria include studies by Benachour and Louadi (2013), Benarfa et al. (2013), Aguib et al. (2014), Bakiri et al. (2016), Maghni (2017), and Chichoune (2018), focusing mainly on the northeastern regions of Algeria. Some other regions of the country have also been subjects of taxonomic studies of bees, such as the works of Bendifallah et al. (2010, 2012, 2013) in the region of Mitidja, and those of Bendifallah (2015) in the northwestern regions of Algeria. Preliminary inventories have also been conducted in some Saharan localities by Djouama (2016) and Cherair (2016) in the Djelfa region.

This work attempts to fill gaps and provide an original contribution to the apoid fauna of the Tlemcen region. It is challenging to address the major problem of the lack of knowledge concerning the systematics and biology of the species of interest. Before any analysis, it is essential to synthesize the bibliographic data related to this subject. In Algeria, apart from the authors of the last century (Saunders, 1901, 1908; Alfken, 1914; Schulthess, 1924; Roth, 1923), the fundamental aspects to address include establishing an inventory of the species of apoids in the Tlemcen region, the spatio-temporal biogeography of the beekeeping fauna, and its diversity in various locations, particularly in mountainous areas, according to altitude and slope. High mountain regions can provide endemic or new species to science and Algeria. Additionally, this study will examine flower selection, foraging behavior, and pollination efficiency in natural habitats.

Materials and Methods

The study area encompasses the southwestern part of the Wilaya of Tlemcen (Figure 01), focusing on three mountainous stations within the communes of Beni Snous and Ain Ghraba. The research spanned four months, from March to June 2022. Given the vastness of the area, several criteria were considered, including floristic richness, and each station was examined during the plants' flowering season. Bee collections were conducted in safe environments for the researchers and their equipment, primarily along roadsides, which often host spontaneous plants due to their ability to accumulate rainwater. Beni Snous Station is positioned at the western exit of Beni Snous near the village of Beni Achir, with coordinates 01°33'41" W, 34°38'35" N, and an altitude of 835 meters (Figure 02a). Ain Ghraba Station, situated a few kilometers from the northern exit of Ain Ghraba along the road, is located at 01°23'21" W, 34°42'50" N, with an altitude of 829 meters (Figure 02b). Ahfir Station, located in the municipality of Ain Ghraba at coordinates 01°25'58.5" W, 34°46'31.6" N, and an altitude of 854 meters, features a Mediterranean semi-arid to cool climate (Figure 02c). The terrain is mountainous with fragmented reliefs revealing several plains, the largest extending in the central plain. The soils are mostly shallow to medium deep, derived from sedimentary rocks, including calcareous sandstone and sandy limestone. The diverse vegetation, including holm oak and Zea oak woods, supports a variety of wildlife.

Sampling, preparation and spreading of specimens

For the collection of bee specimens during the sampling period, we utilized a butterfly net and plastic tubes. Specimens were captured randomly using the butterfly net, which consists of a metal circle with a very light fabric (tulle) bag attached to it, mounted on a handmade sleeve. The collector uses the net to pursue and capture flying insects, which are then carefully transferred into a glass jar without causing damage, following the method described by Farval (2003). This approach has proven effective for capturing wild bees of varying sizes, often while they are in flight. According to Dubuc (2012), stinging insects such as wasps, bees, and bumblebees are typically caught in a butterfly net and placed in a container to be killed with ethyl acetate. However, Aguib (2014) advises that using poison to kill bees is riskier and not recommended compared to freezing. Despite this, preservation in ethanol-filled tubes was preferred. This approach has proven effective for capturing wild bees of varying sizes, often while they are in flight.

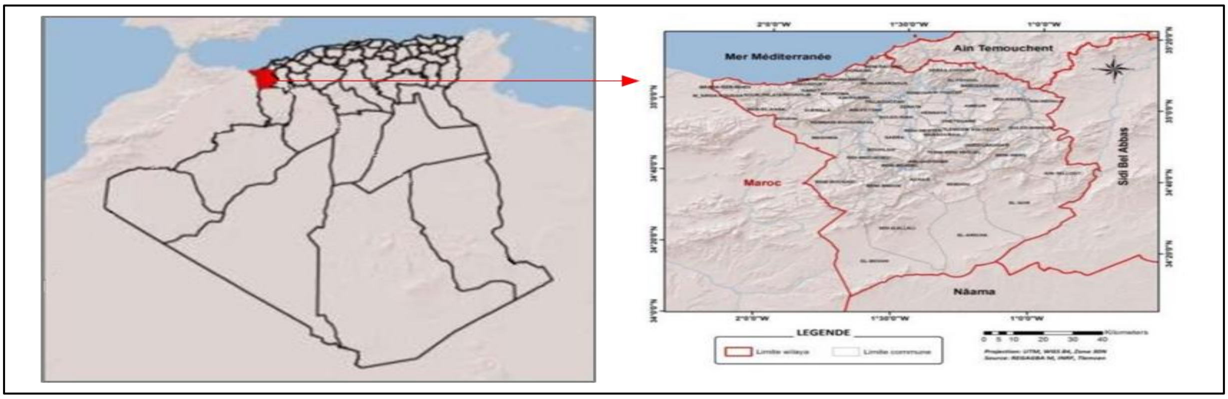

Figure 01. Presentation of the Tlemcen study area –Algeria (Regagba et al., 2023)

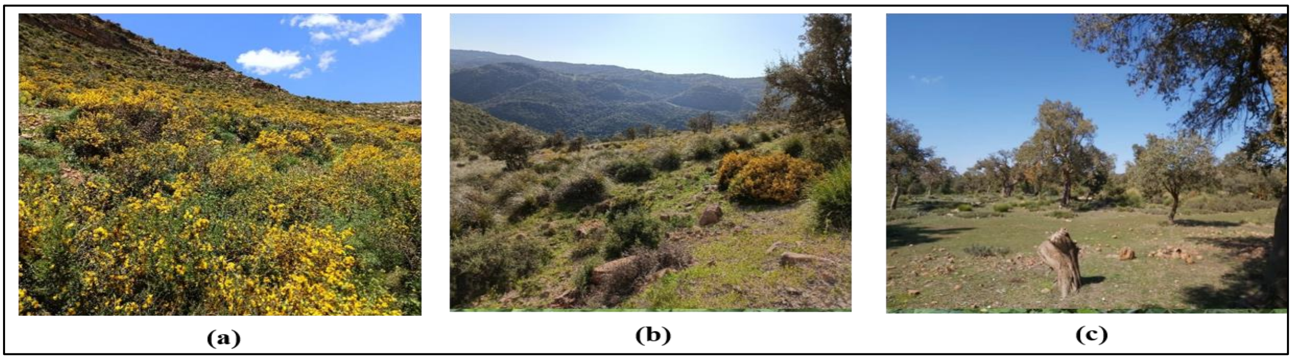

Figure 02. Beni Snous Station (a), Ain Ghraba Station (b), Ahfir Station(c) (Original photos)

The insects are prepared meticulously to facilitate accurate identification (Figure 03). Once dead, insects assume unnatural positions that must be adjusted through proper preparation. Pinning the insect correctly is crucial and varies by order; for Hymenoptera, the pin should be placed on the right side of the thorax. The thorax of the Andrena is pierced with an entomological pin ranging from size 000 to 4, depending on the insect's size. The bee is then fixed on a polystyrene plate, and its appendages are highlighted using a fine forceps or pin. The mouthparts, antennae, wings, and legs are carefully detached from the body to facilitate examination (Perron, 1994). The insect is left to dry for several hours or up to two or three days. Each mounted and dried specimen will have two labels. The first label includes information about the bee: the location where it was collected, its geographical coordinates, altitude, date of collection, the plant foraged by the bee, and the collector's name. The second label contains the scientific name of the Andrena, the name of the first author who described it, the date of its description, and sometimes the sex of the specimen. Additionally, the name of the person who identified the taxa and the date of identification are also included. This meticulous labeling ensures precise documentation and facilitates further research and verification. In the other hand, the census and determination of the flora were conducted during the flowering period of plants throughout the entire study period at the three stations. The purpose of this census is to establish the list of plants characterizing each station during the study period. This identification was carried out following the methods described by Léon Provancher, as detailed in Jean-Marie Perron's work Insectes et autres organismes décrits par Léon Provancher. Provancher's extensive entomological research, which includes 1,216 species descriptions published between 1869 and 1892, provides a comprehensive basis for identifying and cataloging species (Perron, 1994). Some of the plants visited by the apoids are the following (Figure 04).

Statistical analysis
Two statistical analyses were employed in this study: Centesimal Frequency (C.F.) and the Shannon-Weaver Index (H'). The Centesimal Frequency measures the relative abundance of inventoried species by calculating the ratio of the number of individuals of a species (ni) to the total number of individuals (N), multiplied by 100 (Dajoz, 1985).

$$F.C = (ni/N) \times 100$$

Figure 03. Preparation and spreading of specimens (Original photos)

For the analysis of the relative abundance of Apidae species across different stations, we employed the Chi-square test of independence using the R software. This test was applied to determine whether there is a statistically significant association between the two categorical variables: species and region. In addition, we calculated Cramer's V coefficient to measure the strength of this association.

The Shannon-Weaver Index (H'), used as the second measure, was computed according to its specific formulation:

$$H' = - \sum pi \, Log \, pi$$

pi = the proportional abundance or percent abundance of a species present (pi = ni/N).

ni = the number of individuals counted for a species present.

N = the total number of individuals counted; all species combined.

S = the total or cardinal number of the species list.

These indices were instrumental in assessing the biodiversity and relative abundance of species across the study area.

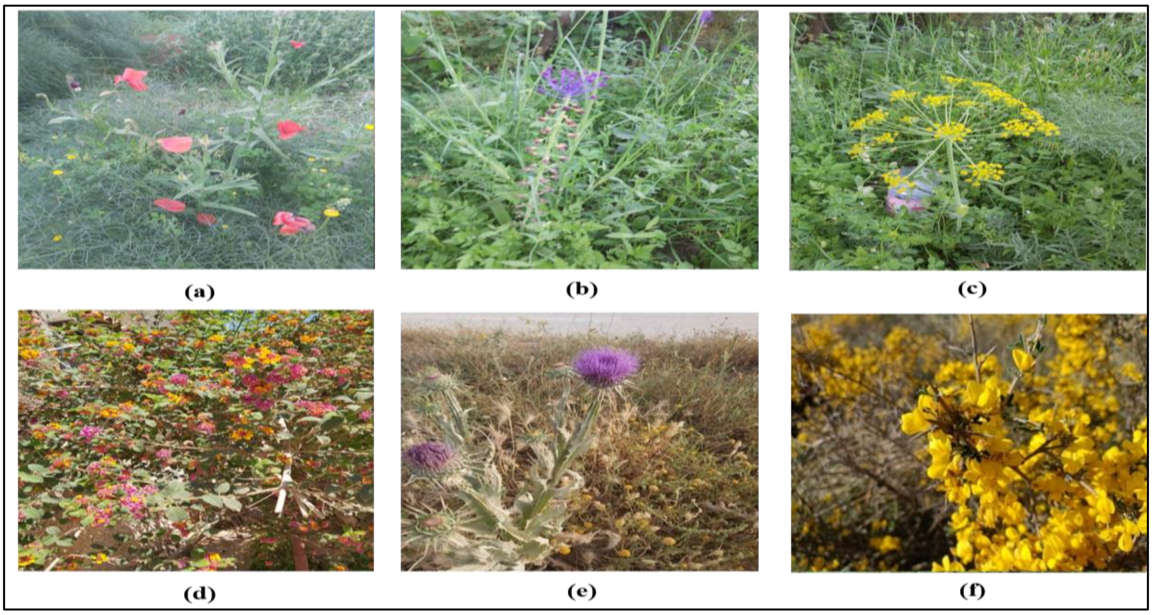

Figure 04. *Papaver rhoeas* " Poppy " of the papaveraceae family (a), *Muscari comosum* " Muscari à toupet " of the family Liliaceae (b), *Foeniculum vulgare* " Common fennel " of the Apiaceae family (c), *Lantana camara* of the Verbenaceae family (d), *Onopordum macracan* of the family Asteraceae (e), *Calicotome villosa* of the family Fabaceae (f) (Original photos)

Results

Composition of the Apidae fauna in the study area

Collected after a period of investigation from March 2022 to June 2022, a total of 92 bee specimens were gathered, of which 70 were identified across 9 species, predominantly from the family Apidae, encompassing 5 differents genera. Table 1 details the number of specimens collected for each species, along with the specific region of collection. Other families were excluded due to their insignificant numbers compared to Apidae. The species ***Apis mellifera*** dominated the collection with 22 specimens, followed by ***Bombus terrestris*** with 14 individuals. ***Xylocopa pubescens*** and ***Xylocopa violacea*** were represented by 12 and 11 specimens, respectively. Additionally, four differents species of the genus ***Eucera*** were identified, though their total count was relatively low at 6 specimens. The species ***Anthophora vestita*** was represented by 5 specimens.

Table 01. The species listed with their different families and regions

Locations Species	Ahfir	Ain Ghoraba	Beni Snous	Total
	Apidae	(9 Taxons)		
Anthophora vestita	2	3	0	5
Apis mellifera	6	12	4	22
Bombus terrestris	11	1	2	14
Eucera colaris	0	0	2	2
Eucera notata	0	0	2	2
Eucera nigrilabris	0	0	1	1
Eucera punctatissima	0	0	1	1
Xylocopa violacea	3	0	8	11
Xylocopa pubescens	5	2	5	12
	Andrenidae	(2 Taxons)		
Andrena flavipes	0	1	0	1
Andrena nigroanea	0	1	0	1
	Megachilidae	(1 Taxon)		
Hoptilis sp	0	0	1	1
	Vespidae	(1 Taxon)		
Vespula vulgaris	0	0	14	14
	Scoliidae	(1 Taxon)		
Dasyscolia ciliata	0	0	5	5
Total	27	20	45	92

Spatial distribution of species surveyed and Relative abundance (R.A.)

Further analysis revealed that during the study period, 70 specimens were collected from three stations. Table 2 mentions their number for each species in the surveyed stations. According to this table, the Ahfir station had the highest number of specimens collected (27 individuals), followed by Beni Snous (25 individuals) and Ain Ghraba (18 individuals). Bombus terrestris was the most abundant species in Ahfir with 11 individuals. In Beni Snous, Xylocopa violacea and Xylocopa pubescens were the most present with 8 and 5 individuals, respectively. In the locality of Ain Ghraba, 12 specimens of Apis mellifera and 3 specimens of Anthophora vestita were counted.

Relative abundance of Apidae species surveyed, expressed as the percentage of individuals of a particular species relative to the total number of individuals. This calculation was performed for each species found across the different study stations. The results in Table 2 highlight the variation in species abundance between stations. *Bombus terrestris* was the most abundant species at the Ahfir station, comprising 40.70% of the total individuals. At Ain Ghraba, *Apis mellifera* was the most prevalent, representing 66.70% of the population. In Beni Snous, *Xylocopa violacea* accounted for 32% of the fauna (Figure 05, 06).

Furthermore, the chi-square test results (p = 0.001) indicate a statistically significant influence of the region on the distribution of species. This suggests that the distribution of Apidae species is not random but is influenced by specific regional characteristics. The significant chi-square test result means that there is a strong association between the type of species and the region where they were found, implying that certain environmental or ecological factors unique to each region may favor the presence of specific species

Table 02. Relative abundance of Apidae species in different stations with P value and Cramer's V

		Region						Total	
		Ahfir		Ain Ghraba		Beni Snous			
		Head-count	% in region	Head-count	% in region	Head-count	% in region	Head-count	% in region
Species	*Bombus terrestris*	11	40,70%	1	5,60%	2	8,00%	14	20,00%
	Anthophora vestita	2	7,40%	3	16,70%	0	0,00%	5	7,10%
	Xylocopa pubescens	5	18,50%	2	11,10%	5	20,00%	12	17,10%
	Apis mellifera	6	22,20%	12	66,70%	4	16,00%	22	31,40%
	Eucera colaris	0	0,00%	0	0,00%	2	8,00%	2	2,90%
	Eucera punctatissima	0	0,00%	0	0,00%	1	4,00%	1	1,40%
	Eucera notata	0	0,00%	0	0,00%	2	8,00%	2	2,90%
	Eucera nigrilabris	0	0,00%	0	0,00%	1	4,00%	1	1,40%
	Xylocopa violacea	3	11,10%	0	0,00%	8	32,00%	11	15,70%
P-Value[1]	***								
Cramer's V	0,548								

*1 : *** Highly significant*

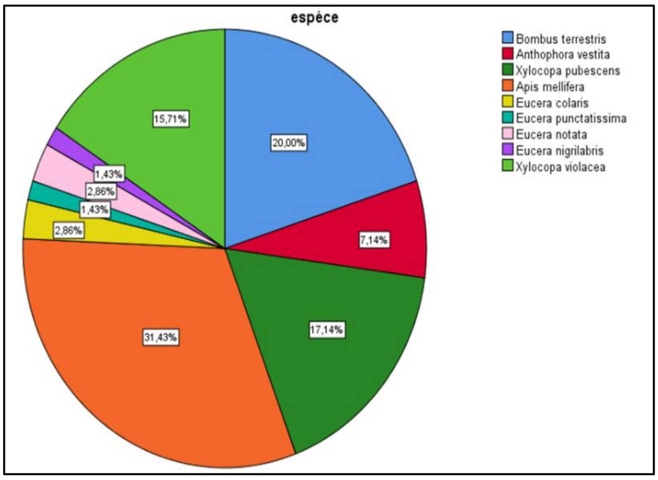

Figure 5. Relative abundance of apidae species compared to the total number of individuals

In addition to the chi-square test, Cramer's V coefficient was calculated to measure the strength of the association between species and regions. With a Cramer's V value of 0.548 (54.8%), which is less than 70%, we can infer that the relationship between these two parameters is of moderate strength. This indicates that while there is a notable correlation between species and regions, it is not overwhelmingly strong. This moderate association suggests that other factors might also be influencing species distribution and that regional characteristics play a significant, but not exclusive, role in determining the presence of specific Apidae species. The combination of these statistical analyses underscores the importance of regional factors in shaping the distribution and abundance of Apidae species.

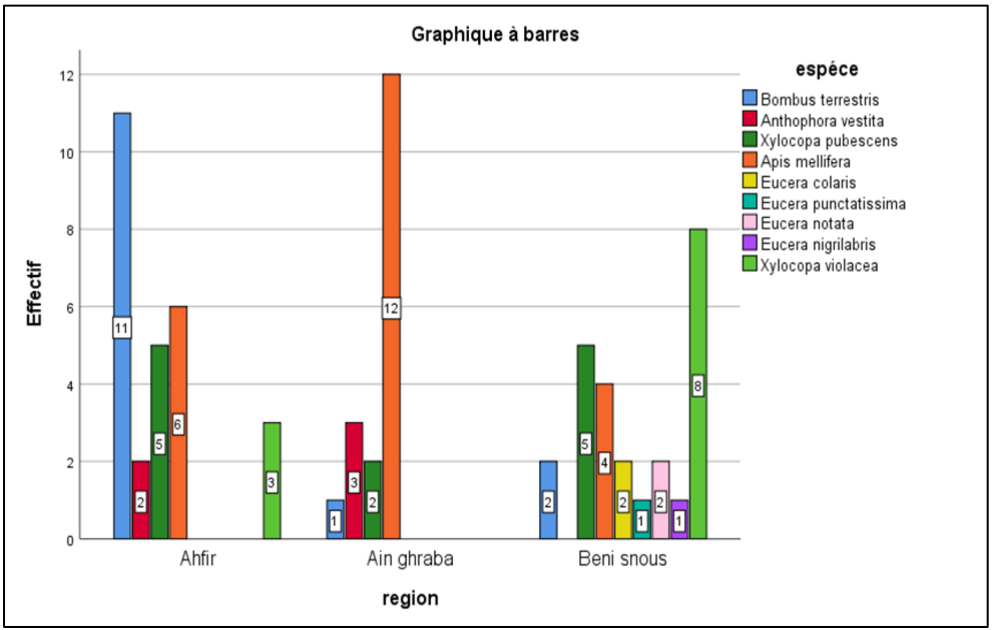

Figure 6. Histogram of number of species according to the region

Table 0 3. Relative abundance of apidae species in relation to plants visited

		The specific plant										Total	
		Papaver rhoeas		*Thapsia garganica*		*Lantana camara*		*Muscari comosum*		*Onopordum macracanthum*			
		Head-count	% in the specific plant	Head-count	% in the specific plant	Head-count	% in the specific plant	Head-count	% in the specific plant	Head-count	% in the specific plant	Head-count	% in the specific plant
Species	*Bombus terrestris*	14	70,00%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	14	20,00%
	Anthophora vestita	0	0,00%	5	100,00%	0	0,00%	0	0,00%	0	0,00%	5	7,10%
	Xylocopa pubescens	0	0,00%	0	0,00%	12	100,00%	0	0,00%	0	0,00%	12	17,10%
	Apis mellifera	0	0,00%	0	0,00%	0	0,00%	0	0,00%	22	100,00%	22	31,40%
	Eucera colaris	2	10,00%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	2	2,90%
	Eucera punctatissima	1	5,00%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	1	1,40%
	Eucera notata	2	10,00%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	2	2,90%
	Eucera nigrilabris	1	5,00%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	1	1,40%
	Xylocopa violacea	0	0,00%	0	0,00%	0	0,00%	11	100,00%	0	0,00%	11	15,70%
P-Value[1]	***												
Cramer's V	1												

*1 : *** Highly significant*

Based on the results presented in Table 03, which details the relative abundance of apidae species in relation to their visited plants, it is clear that *Onopordum macracanthum* and *Papaver rhoeas* were the most frequently visited, with 22 and 14 individuals captured, respectively (Figure 07). *Lantana camara* followed closely with 12 specimens recorded. This pattern strongly indicates a preference among apidae species for these specific botanical species. Moreover, the Chi-square test revealed a significant influence (p = 0.001) between apidae species and the plants they visited. This statistical significance suggests that the association observed is not random but rather reflects a meaningful ecological relationship. Additionally, the coefficient of Cramer's V was calculated to be 1.000, indicating a perfect association between apidae species and their preferred plants. This perfect association underscores the strong dependency of apidae species on specific plant species within their foraging range. The presence or absence of these plants directly influences the presence and abundance of apidae species in the study area, highlighting the specialized and tightly coupled nature of bee-plant interactions in ecological communities.

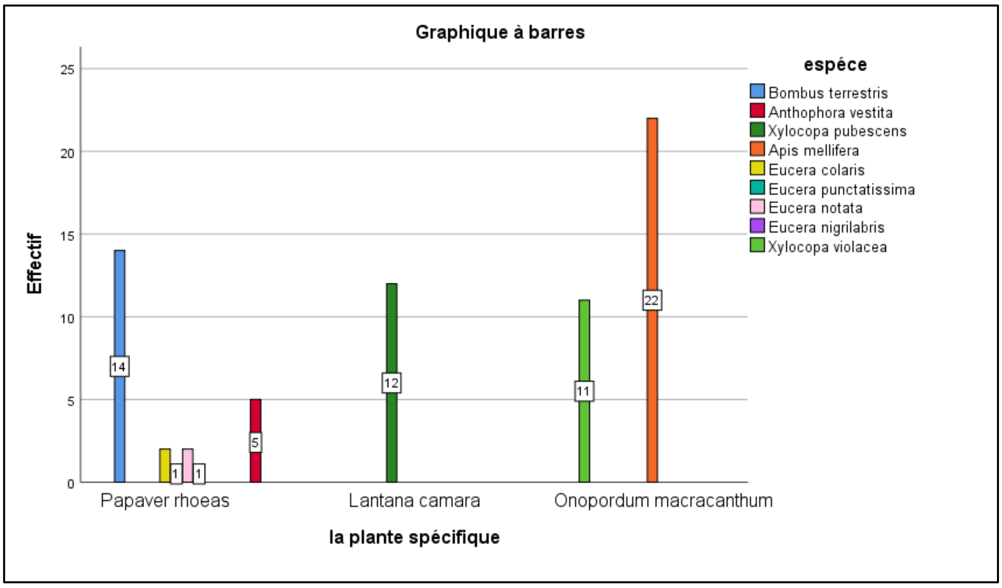

Figure 7. Distribution of the main Apidae species recorded on the main botanical species

Shannon-Weaver Diversity Index analysis

The Shannon-Weaver diversity index values reflect the varying ecological conditions and resource availability at each station, capturing both the abundance and evenness of species present. Specifically, the high Shannon-Weaver diversity index at Beni Snous, equal to H' = 2.65, indicates a highly diverse apidae community. A value of H' > 2.5 generally suggests a well-balanced ecosystem where multiple species are present in significant numbers, based on ecological principles (Magurran, 2004). In contrast, Ahfir exhibits moderate diversity, with an H' value of 2.09 falling between 1.5 and 2.5. This suggests a reasonably diverse apidae population, but not as balanced or diverse as Beni Snous. Furthermore, a Shannon-Weaver index value below 1.5 is typically indicative of low diversity. Thus, the low diversity index at Ain Ghoraba, with H' = 1.40, indicates a less diverse apidae community (Magurran, 2004). This low diversity could be attributed to several factors, such as limited floral resources, environmental stressors, or habitat degradation, which reduce the number of species that can successfully inhabit and reproduce in the area. Additionally, the dominance of *Apis mellifera* in Ain Ghoraba, as noted in other findings, could lead to competitive exclusion of other species, further lowering diversity.

Discussion

The findings of this study could provide valuable insights into the composition, spatial distribution, and ecological interactions of Apidae species in the study area from March to June 2022. A total of 92 bee specimens were collected, with 70 identified across 9 species, predominantly from the family Apidae, encompassing 5 differents genera. Also, the dominance of *Apis mellifera* (22 specimens) should be noted in alignement with global trends, as this species often emerges as the most frequently encountered due to its adaptability and widespread use in apiculture (Ilaria and Giovanni, 2023).

Spatial distribution analysis could reveal distinct differences in species abundance across the three stations: Ahfir exhibited the highest number of specimens (27 individuals), followed by Beni Snous (25 individuals) and Ain Ghraba (18 individuals). The prevalence of Bombus terrestris in Ahfir (40.70% of total individuals) and the dominance of Xylocopa violacea and Xylocopa pubescens in Beni Snous are consistent with species-specific preferences observed in similar environments by Bendifallah et al. (2013). Bombus terrestris in Ahfir constructs its nests underground, often in pre-existing holes, which protect colonies from environmental threats (Fernández, 2020). This nesting strategy, coupled with its generalist foraging behavior, enables the species to thrive in the region, where floral diversity directly influences its reproductive success. The species typically produces two generations annually, with larval survival depending on the availability of nectar and pollen. The presence of Xylocopa violacea and Xylocopa pubescens in Beni Snous, which share similar dietary and nesting preferences, may lead to resource competition (Dafni et al, 2010), potentially influencing the reproductive dynamics of these species and affecting local plant community structures. This underscores the complex ecological interactions within these environments. Wild Apoidea exhibit an intense flight period in spring in Northwest Algeria, coinciding with the peak flowering period of winter and spring plants. This pattern is corroborated by similar findings in Tunisia (Sonet & Jacob-Remacle, 1987) and studies in Belgium and France, which note peak abundance of Megachilidae, Andrenidae, and Apidae in April. In contrast, the species inventoried in the Northeast of Algeria by Bendana (2017) included oligolectic or polylectic species with diverse floral choices, indicating varied foraging behaviors and plant preferences.

Data from the Biosystematics and Ecology Laboratory at the University Frères Mentouri of Constantine, covering studies from 1994 to 2014, reported 24 Apidae species, with solitary bees like *Eucera notata* and *Eucera numida* showing the highest abundances. Louadi and Doumandji (1998a, 1998b) also highlighted significant Apidae diversity in the Constantine region and other parts of Northeast Algeria, attributing this richness to the availability of diverse flowers and potential nesting sites.

The significant relation ($p < 0.05$) between Apidae species and specific regions, confirmed by chi-square test results, underscores the influence of regional characteristics such as floral diversity and habitat structure on species distribution (Gordon et al, 2022). Cramer's V coefficient of 0.548 (54.8%) further indicates a moderate association strength between species and regions, reflecting the complex interplay of biotic and abiotic factors shaping bee communities (McMenamin et al, 2016).

The preference of Apidae species for specific plants, as evidenced by the strong association between species and visited plants ($p = 0,001$; Cramer's V = 1.000), highlights the critical role of floral resources in supporting bee abundance and diversity (Ammann *et al*, 2024). Diversity indices, particularly the Shannon-Weaver index, further reveal ecological conditions and resource availability across stations, with Beni Snous exhibiting the highest diversity (H' = 2.65) and Ain Ghraba showing lower diversity (H' = 1.40), indicative of varying habitat quality and potential stressors affecting bee communities (Cabirol, *et al.* 2023; Magurran, 2004).

Comparison with previous studies, such as Ouahab and Bendifallah (2021), which identified 155 differents bee species seven years earlier in the same zone, highlights the impact of climate change on seasonal shifts, potentially caused by global warming, affecting floral phenology. These changes have led to delayed flowering seasons, resulting in premature emergence of some species that are disoriented and lack sufficient resources, potentially leading to mortality. The disparity in species richness between our study and Ouahab and Bendifallah's can be attributed to the protected status of their study areas, which likely supported higher species counts. This underscores the importance of habitat protection and suggests the need for expanded conservation efforts in vulnerable regions like the mountainous areas of Tlemcen (Schmidt et al, 2021 ; Klaus et al, 2024).

In conclusion, while our study provides critical insights into Apidae composition and distribution in the study area, there are notable contrasts with previous research and challenges encountered during fieldwork. Despite setbacks such as specimen escapes and trap sabotage, our findings emphasize the crucial role of regional factors and plant associations in shaping bee communities. Furthermore, the observed decline in apidae species highlights the pressing need for collective efforts such as habitat conservation and management strategies to support diverse bee populations essential for ecosystem health and pollination services. Urgent action is imperative to raise awareness and safeguard this invaluable natural resource. This study provides a foundational basis for future research and conservation initiatives aimed at preserving bee populations and their critical ecological roles.

Recommendation

To build on the insights gained from this study and address existing knowledge gaps, several recommendations for future research aim to deepen the understanding of bee diversity, ecology, and genetics, and support effective conservation strategies, including:

- Extend research to underexplored regions of Algeria and North Africa.
- Provide insights into morphological variations and adaptations to different ecological niches through classic morphometric and geo-morphometric techniques to study the physical characteristics and shapes of bee species.
- Explore genetic diversity and evolutionary relationships among bee species using bioinformatics tools and genetic sequencing techniques.

- Employ genomic data to identify genetic markers associated with resilience to climate change and disease.
- Conduct phylogenetic analyses to elucidate the evolutionary relationships among bee species and enhance the understanding of the historical and evolutionary processes that have shaped the current diversity of Apidae.

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