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Diversity and characteristics of the melliferous flora of Moroccan Macaronesia (Territory of Sidi Ifni)

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Abstract. The melliferous flora of Central Western Morocco, specifically within the Ait Baâmrane territory of Sidi Ifni Province, was investigated between 2016 and 2018 through surveys conducted among beekeepers. The plants foraged by bees were collected, identified, and listed. A total of 117 melliferous species were recorded, constituting 41.64% of the total flora of the study area, which encompasses 281 species. These species belong to 98 genera and 40 families. The Compositae family claims the highest representation at 17.95%, followed by Lamiatae and Leguminosae at 6.84%. Among the identified geographical zones, the continental mountainous region (Zone C) boasts the highest diversity in terms of plant habitats and species count, followed by the plateau and hills zone (Zone B), and lastly, the littoral zone (Zone A).

The region stands out for its remarkable rate of endemism, accounting for 20.51% of the 117 melliferous species. Nevertheless, several species are categorized as rare and endangered taxa, totaling 10 species. Regarding their biological types, Therophytes make up 36.75% of the foraged species, closely followed by Chamaephytes at 17.95%. Concerning flowering periods, the phenomenon occurs consistently throughout the year. Notably, spring is the dominant season, representing 42.45% of the plants, succeeded by summer at 28.98% and then winter and autumn at 15%, 10% and 13.47%, respectively. Bees strongly prefer melliferous plants adorned with yellow flowers (33.33%), followed by white flowers (30.77%). The plants mentioned in the study are sought after by bees either for their nectar and pollen (74.36%), solely for pollen (15.38%), or exclusively for nectar (8.55%).

Considering the endangered status of certain melliferous species, this study underscores the critical importance of conserving the melliferous flora. Such conservation efforts are crucial to enhance and sustain the beekeeping sector in the region.

Keywords: Ait Baâmrane, melliferous species, nectar, pollen, beekeeping, diversity, Morocco.

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Introduction

Honey is produced by bees from nectar and honeydew harvests which are modified by the action of particular enzymes. It is essentially made up of carbohydrates, water and minor elements, and notably pollen grains that make it possible to determine the plant species used by bees (Piroux, 2014). The quality of the honey collected depends on the nature of the plant species whose flowers are foraged and also the physical environment of where the plant lives (Bakenga *et al*., 2000). Because of its important floristic, faunistic and landscape diversity, Morocco is endowed with an important and unique beekeeping potential. Conferring it a great originality, the country makes it one of the most interesting regions on the biological and biogeographical level (Anon., 1997).

Honey production in Morocco plays an important socioeconomic role as a factor in the fight against poverty and as a source of supply for the local market. The Government of Morocco actively supports Moroccan beekeeping through the Green Morocco Plan (PMV). With the variety of plants found throughout the country's various regions, honey production in Morocco is crucial. The most well-known honey on a national level includes thyme honey, eucalyptus honey, euphorbia honey, rosemary honey, lavender honey, orange honey, carob honey, arbutus honey and jujube honey. In the Moroccan tradition, euphorbia and thyme honey are also regarded as medicines (Moujanni *et al*., 2017).

On the ecological level, the bee is decisive and sometimes even vital at the pollination level of plant species. Thus, the pollination of plant species by bees plays a crucial ecological role in maintaining biological diversity and the perenniality of these species. (Bertrand, 2015). In Morocco, three breeds of bees predominate two black, *Apis mellifera intermissa* known as tellienne bee and *Apis mellifera major,* and one golden yellow, *Apis mellifera sahariensis* (Moujanni *et al*., 2017). The golden yellow bee is the one that characterizes the study

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region in southern Morocco. The beekeeping sector is one of the most important sectors in terms of socioeconomic, agro-food, and ecological aspects. A lack of studies on the identification of the biogeographical origin of honey by evaluating the diversity of melliferous species has been observed in Morocco.

Melliferous plants are foraged by bees, which take in substances such as nectar, pollen, honeydew, and other products. Nectar is the basis of honey, the energy-rich (carbohydrate) food bees need to sustain the colony's life, while pollen provides the proteins, vitamins and other nutrients needed for larval development (Akunne *et al*., 2016). Flowers are the mainstay of bee life. Depending on soil type, climatic factors, and the vegetation's habitat, the flowering time may change, even for the same nectar plants (Rodionov & Shabarshov, 1986). Good information on the duration and timing of flowering is essential for good bee management (Kumar *et al*., 2013). Thorough knowledge of the type, density, and quality of bee flora in a region is a prerequisite for improving the efficiency and success of the beekeeping industry. Such information can enable beekeepers to use beekeeping at the maximum level to have a good yield of honey and other bee products. Each region has its own honey flow and dearth periods that can be short or long. This knowledge of the bee flora helps effectively manage bee colonies during these periods.

In general, honey production in the region of Ait Baâmrane is known for the production of two types of honey. Spring honey is multifloral honey, mainly Euphorbia regis-jubae Webb and Berth, and the honey of *Euphorbia officinarum* subsp. *echinus* Hooker fil. & Cosson Vindt during the summer (Terrab *et al*., 2014; Bettar *et al*., 2019).

Most studies that have been conducted nationally are directed towards the study of honey (palynological and physico-chemical characterization), while there is a deficiency in the inventories of melliferous plants. Thus, the study aim was to identify an inventory of melliferous plants in the Ait Baâmrane of the province of Sidi Ifni. This study opens new fields of scientific investigation on the subject of Moroccan apiculture.

Materials and Methods

Study area

The study was carried out in the Ait Baâmrane region in the province of Sidi Ifni. It is a tribal confederation in west-central Morocco. It is made up of six Berber and Arab tribes: Sbouya, Imestiten, Ait Abdellah, Aït Elkhoms, Aït Boubker and Aït Azza (Figure 1). The population is around 127,781, with a density of 49 ha/Km² and the area is mainly used for farming, beekeeping, sea fishing, tourism, poultry farming and raising small ruminants (Monographie Sidi Ifni, 2015).

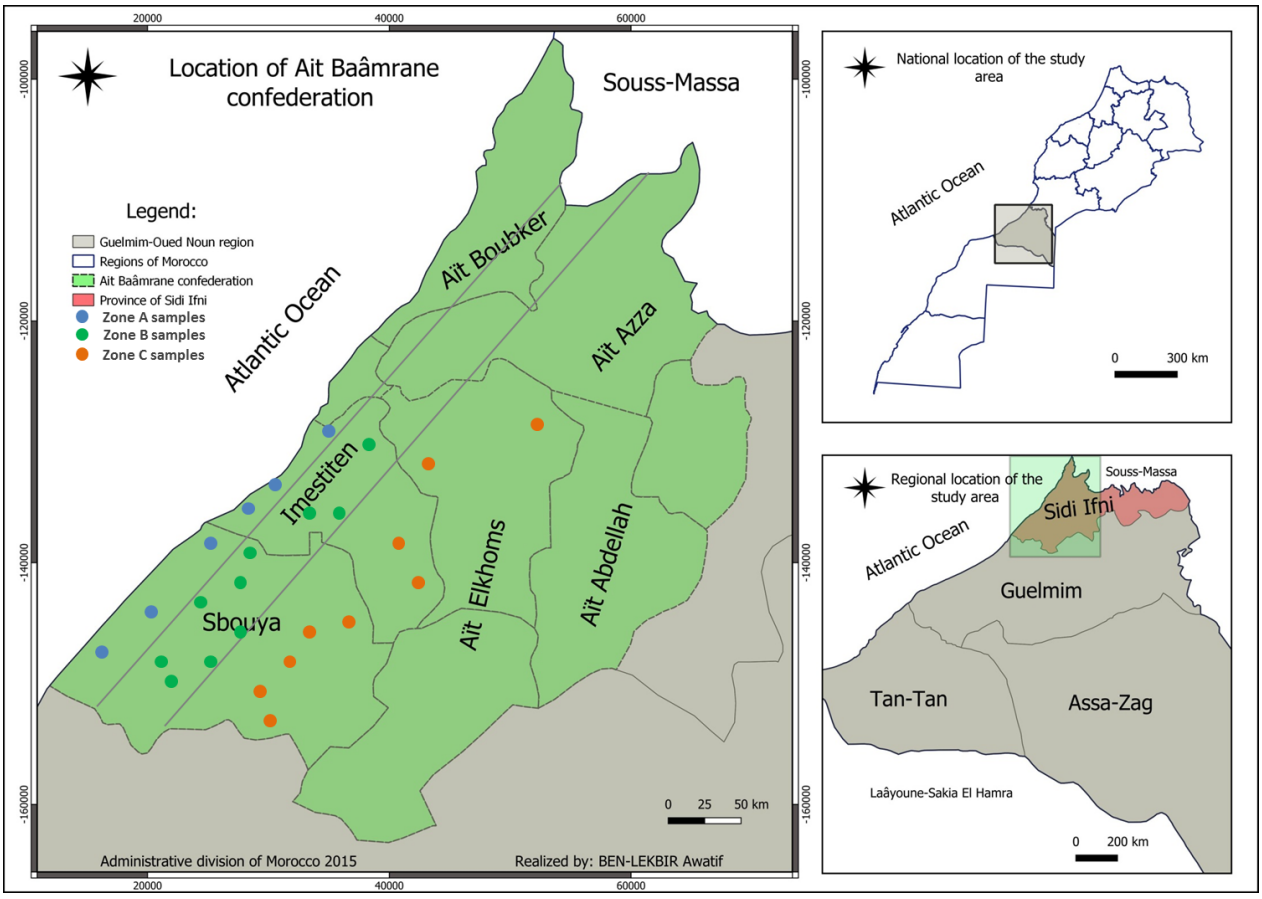

Figure 1. Location map of Ait Baâmrane's territory and sample plots of the three study areas

In the Province of Sidi Ifni, beekeeping plays an important socioeconomic role for households, providing them additional income. An average of 10,000 hives characterizes the bee population in the zone, and the average honey production in the last five years was 15,000 kg (2015-2019). The traditional beekeeping of the Ait Baâmrane of Sidi Ifni is characterized by traditional hives made of reed (S'lt), which are generally sedentary and adapted to the local floristic richness (Adam *et al*., 2016). Despite being sedentary, beekeeping in southern Morocco encompasses a wide variety of environments, including cliffs with waterfalls, cereal and argan fields, enclosed arboreal areas, monoculture areas of prickly pear trees (*Opuntia ficus-indica* (L.) Mill.), rangelands dominated by spurge or euphorbia (*Euphorbia officinarum* subsp. *echinus*), and *Argania spinosa* (L.) Skeels (Simenel, 2015) (Figure 3).

The climate in this region is Mediterranean, characterized by hot, dry summers and cool, wet winters. The coastal areas experience a more oceanic influence. The dry period persists throughout the year, with maximum temperatures occurring in summer. The average temperature is approximately 18.1°C, reaching a maximum of 22.8°C in August and a minimum of 14.4°C in January. The annual rainfall totals 203 mm, with average monthly rainfall ranging from 6 mm in July to 31 mm in December (Figure 2) (URL-1).

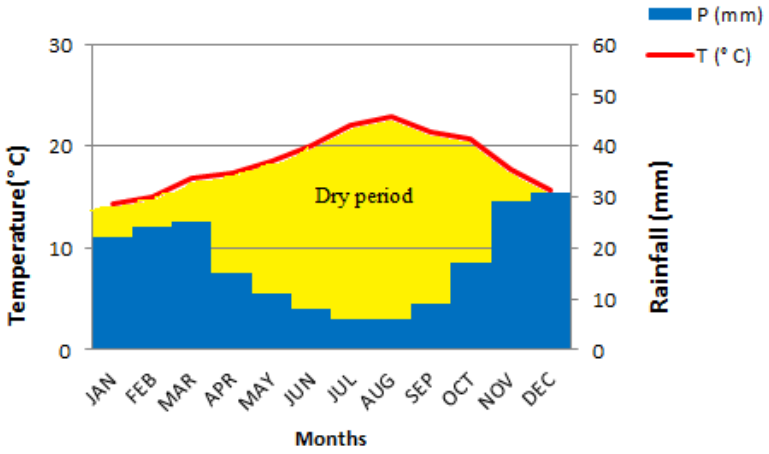

Figure 2. Ombrothermic diagram of Sidi Ifni

Additionally, the area is characterized by the quasi-permanence of oceanic winds. The special ecological conditions of this semi-arid and arid sector, with Saharan and pre-desert climates, are influenced by strong oceanic conditions that lead to significantly high air humidity levels, primarily during the summer and autumn seasons. Furthermore, temperatures remain generally moderate with minimal contrasts (M'Hirit *et al*., 1998; Yous *et al*., 2022).

With regard to plant cover, the area is characterized by a dominance of species of Mediterranean origin, along with Macaronesian species. Braun-Blanquet and Maire (1924) described this flora as 'the presence of a thermophilic flora composed of succulent elements, which, from a physiognomical perspective, bears a resemblance to the sub-Canarian stage. This led to the designation of the Moroccan Macaronesian sector.' Species such as *Euphorbia regis-jubae* Webb and Berth, *Kleinia anteuphorbium* (L.) Haw., *Asparagus pastorianus* Webb & Berthel., *Artemisia reptans* C.Sm. ex Link, and predominantly endemic species from the argan sector like *Periploca angustifolia* Labill, *Genista ifniensis* A.Caballero, and *Genista ferox* (Poir.) Dum.Cours. are present (Géhu & Biondi, 1998; Médail & Quézel, 1999). Additionally, it is noteworthy that taxa of tropical origin, many of which are relics from the Tertiary period and those of Macaronesian lineage, persist in southwestern Morocco. The argan tree (*Argania spinosa*) constitutes the climatic vegetation of the area. Being an endemic species to central-western Morocco, it stands as the sole representative of the Sapotaceae family in the northern Sahara region of North Africa (Alifriqui, 2004).

According to Braun-Blanquet & Maire (1924), Macaronesia, which translates to 'the happy islands' in Greek, encompasses five archipelagos: the Azores (consisting of 10 islands), the Madeira archipelago, the smaller Salvage Islands, the Canary Islands, and the Cape Verde Islands. However, the Moroccan Macaronesian sector extends along a narrow north-south coastal strip from Safi (located 100 km north of Essaouira) to the province of Tarfaya in the northern reaches of the Moroccan Sahara (Peltier, 1982).

The work carried out within the framework of this study covered two aspects: i) a botanical study and characterization of the total flora to determine the list of species, ii) a section on traditional beekeeping and traditional, scientific, ecological, and techniques of beekeepers in the region, carried out based on a survey and field investigations. Within the framework of this study, only the information relating to the species identified as beekeeping sources by the beekeepers will be retained, and compared with the bibliographical data available on this subject.

Methods

Data collection

The fieldwork on flora and melliferous species was conducted between 2016 and 2018, involving

observations across different seasons. The study sites encompassed valleys, plateaus, mountains, plains, crop fields, fallow land, and allotment gardens with beehives. Within the study area, three distinct morphoclimatic units can be identified, delineated by a decreasing continental gradient (Table 1), which significantly influences the vegetation and its physiognomy. These units include the coastal region (Zone A), the plateaus and hills (Zone B), and the continental mountainous area (Zone C) (Figure 1).

Table 1. Geographical information of the three study areas (A-C).

Zones	Altitude (m asl)	Latitude (N)	Longitude (W)	Distance from the sea	Topography
A	0–100	29°14'32.18"N	10°16'44.21"O	0–3Km	Small plain, located along the Atlantic coast
B	100–400	29°14'16.03"N	10°12'34.69"O	3–13Km	Plateaus and hills
C	400–900	29°10'48.48"N	10° 7'7.92"O	13–17.8Km	More continental reliefs

The study was carried out on five habitats to make the results more representative (Figure 3); these habitats are distributed differently in the three study areas, of which zone C contains all the habitats, while for areas A and B, the absence of the argan tree is marked:

1. Cactus planting (CP): areas dominated by *Opuntia ficus-indica*, accompanied by other herbaceous plants (annuals and perennials) and shrubs. The species strongly present in this habitat differ from one zone to another.
2. Natural spaces with euphorbia (SE): spaces with dominance of *Euphorbia o icinarum* subsp. *echinus*, and *Euphorbia regis-jubae*, accompanied by *Kleinia anteuphorbium* and other herbaceous and bushy plants.
3. Fields close to houses (FH): generally contain cereal crops (barley and wheat) covered with scattered argan trees, cultivated plants, fruit trees (almonds, figs, etc.), and annual and perennial herbaceous plants.
4. Paths and hedges (PH): plant succession generally associating herbaceous plants, bushy shrubs, or low trees along the edge of fields and paths.
5. Argan forest (AF): ecosystem characterized by a high density of *Argania spinosa.*

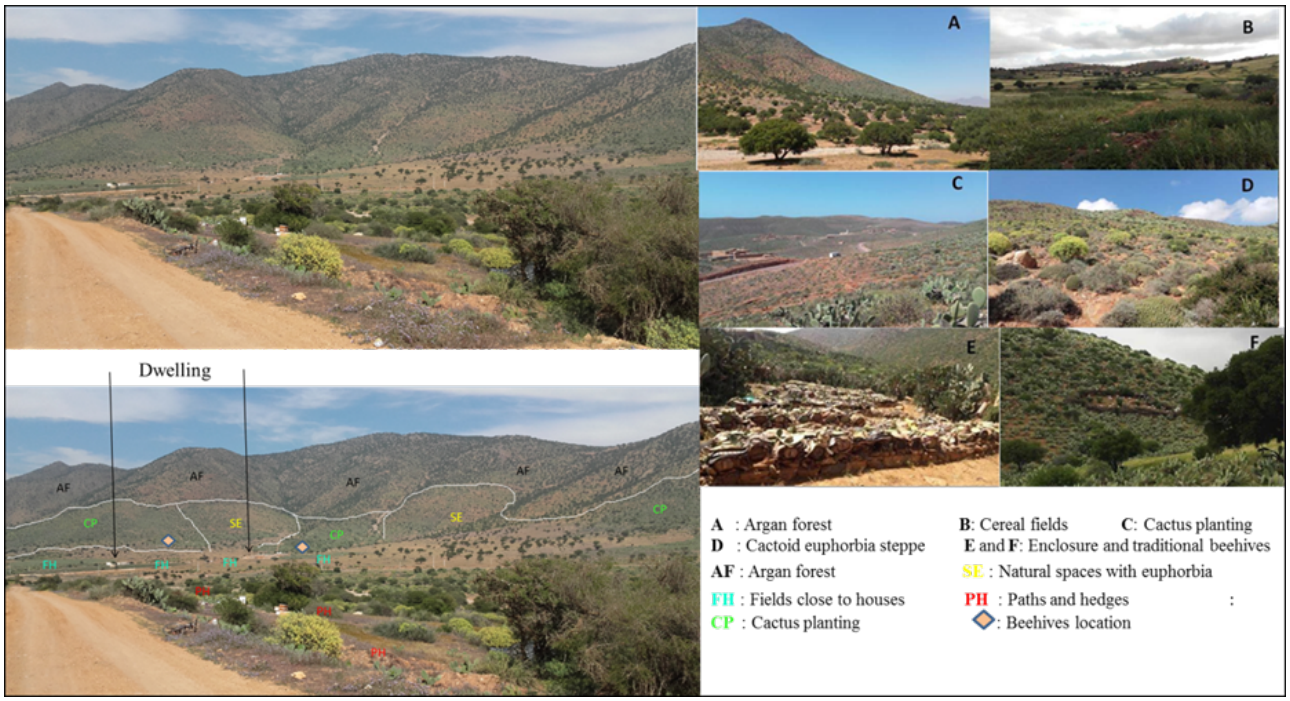

Figure 3. Landscape showing the five habitats exist in the study areas (zone C) and example of beehives location in the Ait Baâmrane.

The melliferous species and the total flora determine the specific richness of the site. According to the method adopted by Yous *et al*. (2022), 90 floristic surveys were carried out in the sampling areas. The relief was taken when the structure and physiognomy of vegetation or its habitat changed over an area equivalent to the minimum area (Guinochet, 1973), ranging from 100 to 400 m² depending on the structure of the vegetation and its environment. To streamline the process of gathering data for this particular study, a group of 67 beekeepers were interviewed through a straightforward questionnaire. This questionnaire primarily requested information on the beekeepers, including their number, gender, and age range. Additionally, it inquired about the type of hives they used and the specific activities they engaged in as beekeepers.

The information on plants was on the plants known as melliferous by the beekeeper, its vernacular name, and the flowering period. Then, the melliferous character of these plants was determined by close observation of the bees and their way of exploiting the flower. If the bees came away with pollen that was easily visible in the "pollen baskets," the plant was considered to be a pollen producer. If the bees visited the depth of the flowers at the corollas, it was considered to be a nectariferous plant. In addition, the melliferous character of these plants was confirmed by the analysis of the available databases and the following literature (Andrés, 2002; Laallam *et al*., 2011; Hamel & Boulemtafes, 2017; Gombault *et al*., 2018; Bakour *et al*., 2021).

Field data processing

The plant specimens were collected more representatively, immediately preserved in newsprint for drying, and placed under the press for identification and conservation in the regional herbarium 'Mark' of the Faculty of Sciences Semlalia, Marrakech. The specific richness was determined for the melliferous species and the total flora. Likewise, the diversity in family and genus has been evaluated for melliferous species. Local beekeepers give the common nomenclature of species.

Concerning the botanical nomenclature used, life form, flower color and flowering period were observed in the field and data was completed with the Flore pratique of Morocco (Fennane *et al*., 1999-2007-2014). In addition, the plant taxonomy was updated to follow the Angiosperm phylogeny group (APG-IV) (Chase *et al*., 2016). The endemic flora was recorded based on Morocco's Catalogue of rare, threatened, or endemic vascular plants (Fennane & IbnTattou, 1998). The status of the inventoried species was reported from the different fascicles of the Elements for a Red Book of the Vascular Flora of Morocco by Fennane (2016, 2017a, 2017b, 2017c, 2018a, 2018b, 2018c, 2018d, 2018e, 2018f).

Results

General information on the beekeepers surveyed

During the research conducted in the study area, beekeepers were observed to fall into three distinct categories. The first category consists of beekeepers who use traditional hives made of reed. The second category comprises beekeepers who use modern hives, usually the Langstroth hive. The third category consists of beekeepers who use traditional and modern hives, also known as mixed hives.

Based on interviews conducted with beekeepers in different regions, zone C is deemed the most significant, with 33 beekeepers encountered. Zone C is zone B, which had 20 beekeepers, and lastly, zone A, where beekeeping is less commonly practiced, had only 14 beekeepers. An examination of the types of hives utilized shows that all three categories are present in zone C, with the mixed hives being the most prevalent among 16 beekeepers. 14 beekeepers used traditional hives, while only three beekeepers used modern hives. Zone B had nine beekeepers with traditional hives, seven with both traditional and modern hives, and four with modern hives alone. In zone A, 11 beekeepers used traditional hives, while three used both modern and traditional hives, and no beekeepers used modern hives exclusively.

When examining the age demographics of beekeepers, it was discovered that 52% of those interviewed fell into the elderly category, ranging from 50 to 70 years old. Middle-aged beekeepers, aged 30-50, made up 34% of the interviewees, while young beekeepers in the 20-30 age range were the least common, representing only 14%. Most people in the study area engaged in agricultural, fishing, breeding, and beekeeping activities. Of those interviewed who engaged in beekeeping, 52% reported practicing agriculture and breeding, 28% engaged solely in beekeeping, and 20% participated in beekeeping alongside other activities, such as fishing (Figure 4).

Plant species foraged by bees

The study area exhibits significant floristic diversity. Based on the floristic analysis, the area boasts an estimated specific richness of 281 vascular species and subspecies, classified into 187 genera representing 48 botanical families. Among the three identified areas, Zone C exhibited the highest diversity with 47 families, followed by Zone B with 46 families, while Zone A demonstrated a slightly lower diversity with 43 families. This floristic richness is also reflected in the melliferous plant species. Detailed information regarding the melliferous species within the Ait Baâmrane territory is provided in table in the Appendix S1. The table includes information on the families to which they belong, their biological classification, species status and endemism, flower colors, flowering periods, as well as the products collected by bees during foraging.

The survey of beekeepers and observations of honeybee behavior towards flowers resulted in the identification of 117 melliferous species, which constitute 41.64% of the total flora inventory of 281 species. Based on the number of species within each family, these species can be categorized into three groups: families with a high representation, families with moderate representation, and families with low representation. In the first group, characterized by a high representation, 8 to 21 species (6% to 18%) of the total 117 melliferous species were examined. The second group includes six families with moderate representation, encompassing 4 to 6 species (3.5% to 5%). The final group, comprising 31 families, exhibited poor representation, accounting for 1 to 3 species (0.9% to 2.5%) each (Table 2).

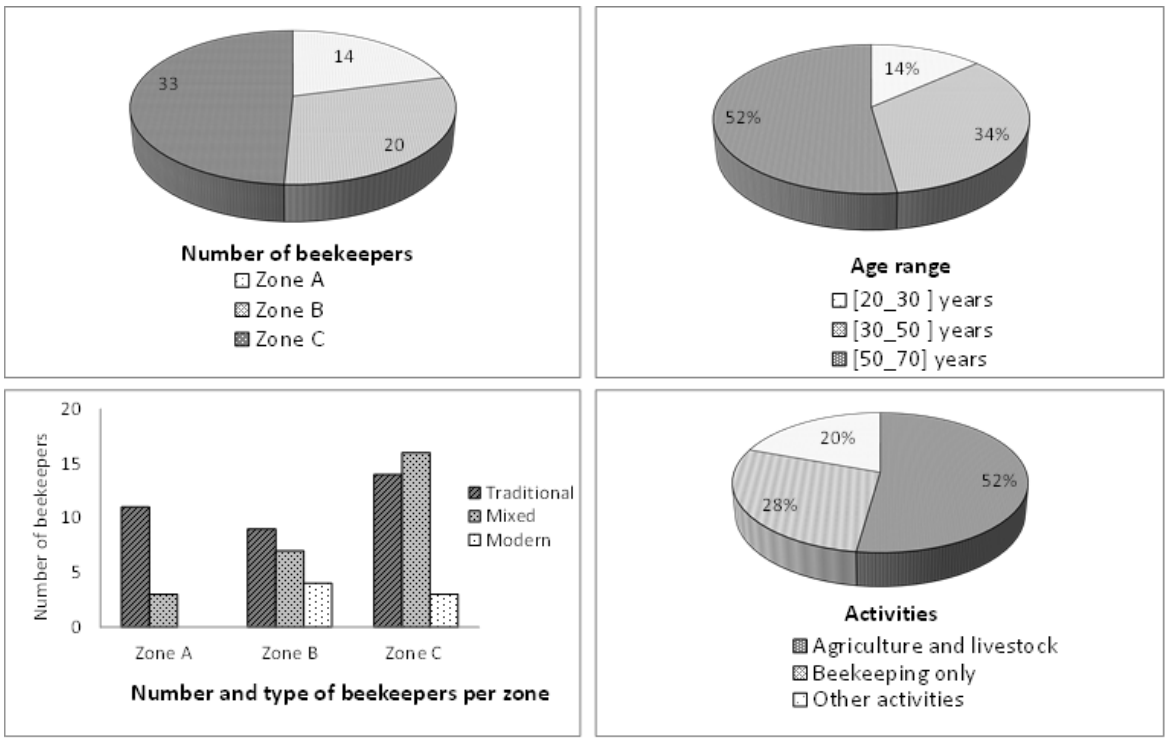

Figure 4. General information on beekeepers and their apiaries

Regarding family diversity, Compositae exhibits the highest number of species, totaling 21 species and accounting for 17.95% of the species within the study area. They are followed closely by Labiatae and Leguminosae, each with 8 species, constituting 6.84% of the total. Asparagaceae is represented by 6 species (5.13%), while Amaranthaceae and Umbelliferae feature 5 species each, contributing to 4.27% of the melliferous flora. Subsequently, Gramineae, Solanaceae, and Zygophyllaceae each contribute 4 species, equivalent to 3.42% of the melliferous flora.

Distribution of species according to the available habitats in the environment of the beehives for the three study areas

The abundance and cover of plants constructed using the Braun-Blanquet abundance-dominance coefficient scale, the scale employs the following abundance and coverage indices (Figure 5): 1: <10%, 2: 10–25%, 3: 25–50%, 4: 50–75%, and 5: 75–100%. The primary melliferous plants that characterize the three study areas are as follows:

Species highly present in zone A: *Aizoanthemopsis hispanica*, *Glebionis coronaria*, *Salsola vermiculata*, *Chenopodium ambrosioides*, *Suaeda vera*, *Asparagus albus.*

Species highly present in zone B: *Echinops spinosissimus* subsp. *spinosus*, *Asteriscus graveolens*, *Launaea arborescens*, *Fagonia cretica*, *Melilotus officinalis*, *Diplotaxis harra* subsp. *crassifolia.*

Species highly present in zone C*:* *Lavandula multifida*, *Ziziphus lotus*, *Acacia gummifera*, *Eryngium ilicifolium*, *Periploca angustifolia*, *Glebionis segetum*, *Genista tricuspidata*, *Convolvulus trabutianus*, *Argania spinosa.*

Species highly present in the three areas (A-C): *Euphorbia officinarum* subsp. *echinus*, *Euphorbia regis-jubae*, *Opuntia ficus-indica*, *Limonium sinuatum* subsp. *beaumierianum*, *Cladanthus arabicus.*

The territory comprises a diverse range of habitats. The distribution of recorded species reveals that cactus plantations exhibit the highest species richness, with 94 species. It is followed by the argan forest and natural euphorbia areas, which host 85 and 84 species, respectively. Next are the fields near the houses, housing 69 species, and finally, the alleys and hedges, with 42 species. Among the three identified geographical areas, species distribution across various habitats indicates that zone C boasts the greatest floral habitat diversity and, consequently, the highest number of species. Zone B follows, and lastly, zone A (Figure 6). Furthermore, Table 3 presents the three areas' most abundant melliferous plants within each habitat.

Conservation status and endemism rates of melliferous species

The study area is also notably rich in endemic species. The endemism rate in relation to the total number of melliferous plants stands at 20.51%, encompassing 24 species. Among these, strictly endemic plants to Morocco (E) constitute the majority, with 19 species (79.17%). This is followed by endemic plants shared between Morocco and Algeria (A), represented by two species (8.33%). Additionally, there are endemic species shared between Morocco and the Canary Islands (C), Morocco and Mauritania (M), as well as Morocco,

Table 2. Distribution of melliferous species by families

Groups	Family	Number of species
Group 1: high representation	Compositae	21
	Leguminosae	8
	Labiatae	8
	Asparagaceae	6
	Amaranthaceae	5
Group 2: moderately represented	Umbelliferae	5
	Gramineae	4
	Solanaceae	4
	Zygophyllaceae	4
Group 3: poorly represented	Aizoaceae	3
	Anacardiaceae	2
	Apocynaceae	1
	Boraginaceae	2
	Cruciferae	3
	Cactaceae	1
	Caryophyllaceae	3
	Cistaceae	2
	Convolvulaceae	3
	Crassulaceae	1
	Cupressaceae	1
	Ephedraceae	1
	Euphorbiaceae	3
	Frankeniaceae	2
	Geraniaceae	1
	Iridaceae	1
	Malvaceae	1
	Moraceae	1
	Myrtaceae	1
	Oleaceae	1
	Orobanchaceae	1
	Papaveraceae	2
	Plantaginaceae	3
	Plumbaginaceae	3
	Polygonaceae	2
	Primulaceae	1
	Rhamnaceae	1
	Rosaceae	1
	Rutaceae	1
	Sapotaceae	1
	Xanthorrhoeaceae	2

Figure 5. Heat map in which species have been grouped according to their abundance in the three study areas.

the Iberian Peninsula, and Algeria (IA), each with one species (4.17%) respectively.

For endemic species of significant beekeeping interest, we have identified the following plants that are strictly endemic to Morocco: *Kleinia anteuphorbium*, *Lycium intricatum*, *Genista ifniensis*, *Acacia gummifera*, *Echium petiolatum*, *Limonium fallax*, *Zygophyllum gaetulum*, and *Fagonia harpago*. For the endemic plants of Morocco and Algeria, there are *Argania spinosa*, and *Warionia saharae*. Hence, among the endemic species shared between Morocco and the Canary Islands, we encounter *Euphorbia regis-jubae*. Finally, the endemic species of Morocco and Mauritania such as *Euphorbia officinarum* subsp. *echinus*.

The preservation of this diverse array of melliferous plants within the zone necessitates the safeguarding of various species that are at risk of extinction. According to Fennane (2016, 2017a-c, 2018a-e) and following the IUCN criteria, the taxa categorized as common taxa (LC), indicating a low risk of extinction, comprise 74 species. There are nine species categorized as near-threatened (NT), signifying a proximity to threatened categories or a potential for future threat in the absence of specific conservation measures. Additionally, seven species fall under the non-applicable (NA) category, while four species are categorized as data deficient (DD), denoting insufficient data. Lastly, a single species is classified as endangered (EN) (e). The remaining 22 species face no risk of extinction.

The threatened melliferous species in the area are the near-threatened (NT) taxa *Fagonia harpago*, *Argania spinosa*, *Limonium fallax*, *Rosmarinus officinalis*, *Euphorbia regis-jubae*, *Euphorbia officinarum subsp. echinus*, *Convolvulus trabutianus*, *Warionia saharae, Kleinia anteuphorbium*, and the endangered (EN (e)) taxa, *Teucrium antiatlanticum.*

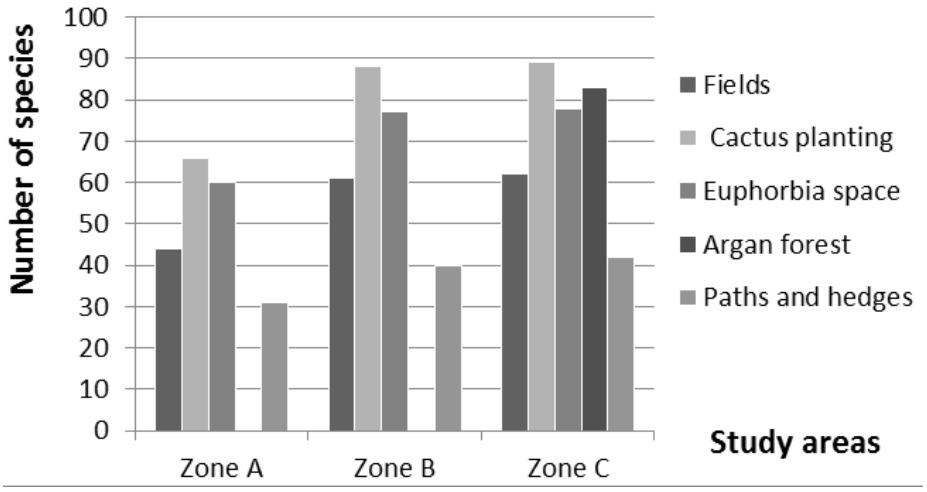

Figure 6. Distribution of species in the three study areas according to different habitats.

Biological types

The distribution of the recorded species based on their biological types reveals that Therophytes constitute 36.75% of the foraged species, while Chamaephytes and Nanophanerophytes each make up 17.95%. Hemicryptophytes and Phanerophytes account for 10.26% each, and Geophytes represent the least prevalent category at 6.84%. These figures highlight that herbaceous and shrub species hold the highest representation, while trees are comparatively less abundant within the region.

Table 3. The most abundant melliferous species according to different habitats in the three areas.

	Zone A	Zone B	Zone C
Fields close to houses (FH)	*Ficus carica*, *Olea europaea subsp. oleaster*, *Prunus dulcis*, *Coriandrum sativum*, *Foeniculum vulgare*, *Hordeum vulgare*, *Triticum sativum*, *Papaver rhoeas*, *Convolvulus althaeoides*, *Diplotaxis harra* subsp. *crassifolia*	Same as zone A	Same as zone A
Cactus planting (CP)	*Opuntia ficus-indica*, *Salsola vermiculata*, *Senecio glaucus* subsp. *coronopifolius*, *Frankenia corymbosa*, *Glebionis coronaria*, *Fagonia cretica*	*Opuntia ficus-indica*, *Asteriscus graveolens*, *Lycium intricatum*, *Paronychia argentea*, *Melilotus officinalis*, *Limonium sinuatum* subsp. *beaumierianum*, some argan trees	*Opuntia ficus-indica*, *Periploca angustifolia*, *Cladanthus arabicus*, *Senecio glaucus subsp.coronopifolius*, *Eryngium tricuspidatum*, *Limonium sinuatum* subsp. *beaumierianum*, some argan trees

	Zone A	Zone B	Zone C
Natural spaces with euphorbia (SE)	*Euphorbia officinarum* subsp. *echinus*, *Euphorbia regis-jubae*, *Kleinia anteuphorbium*, *Aizoanthemopsis hispanica*, *Chenopodium ambrosioides*, *Salsola vermiculata*, *Suaeda vera*	*Euphorbia officinarum* subsp. *echinus*, *Euphorbia regis-jubae*, *Kleinia anteuphorbium*, *Cladanthus arabicus*, *Asteriscus graveolens*, *Paronychia argentea*, *and Limonium sinuatum* subsp. *beaumierianum*	*Euphorbia officinarum* subsp. *echinus*, *and Euphorbia regis-jubae*, *Kleinia anteuphorbium*, *Convolvulus trabutianus*, *Periploca angustifolia*, *Asparagus albus*, *Lycium intricatum*, *Searsia tripartita*
Paths and hedges (PH)	*Suaeda vera*, *Salsola vermiculata*, *Cynodon dactylon*, *Limonium sinuatum* subsp. *beaumierianum*, *Scolymus hispanicus*, *Aizoanthemopsis hispanica*	*Opuntia ficus-indica*, *Launaea arborescens*, *Asphodelus tenuifolius*, *Melilotus officinalis*, *Diplotaxis harra* subsp. *crassifolia*	*Argania spinosa*, *Opuntia ficus-indica*, *Asphodelus tenuifolius*, *Echium petiolatum*, *Anagallis arvensis*, *Glebionis coronaria*, *Glebionis segetum*
Argan forest (AF)			*Argania spinosa*, *Acacia gummifera*, *Ziziphus lotus*, *Searsia pentaphylla*, *Searsia tripartita*, *Eryngium tricuspidatum*, *Convolvulus trabutianus*, *Genista tricuspidata*, *Periploca angustifolia*, *Kleinia anteuphorbium*

Flowering period

The flowering of plants occurs continuously throughout almost the entire year. However, variations exist in the number of melliferous plants based on their respective flowering periods. The majority of the identified melliferous plants exhibit blossoming during spring and summer, constituting 33 species (29.20%). This is closely followed by plants that bloom specifically in spring, accounting for 25 species (22.12%). Moreover, during the winter and spring seasons, 16 plants (14.16%) are in flower. Another 12 plants (10.62%) exhibit flowering during winter, spring, and summer. Five plants (4.42%) showcase year-round flowering, while seven species (6.19%) experience blooming during spring, summer, and autumn. The remaining 13.29% of plants exhibit flowering across various time periods. When considering the diversity of flowering plants in each season, spring records the highest number of species at 44.44%, succeeded by summer at 30.34%, winter at 15.81%, and autumn at 9.40%.

Within the study area, the provision of nectar and pollen is nearly continuous throughout the year. However, this supply varies across the three identified areas based on the specific melliferous species that define each zone. The main sources of nectar and pollen supply, categorized by the months of the year, for areas A, B, and C, are sequentially detailed in Tables S1-S3.

The supply of nectar and pollen occurs almost year-round for all three areas. It reaches its peak during spring and summer and declines during fall and winter. Based on the three aforementioned tables, the following families - Compositae, Cactaceae, Euphorbiaceae, and Plumbaginaceae - serve as sources of nectar and pollen across all three areas. Additionally, Caryophyllaceae, Convolvulaceae, Leguminosae, and Solanaceae are common to areas B and C. The Amaranthaceae family, on the other hand, is a distinguishing feature of zone A.

During the summer, the most abundant melliferous species in all three areas is *Euphorbia officinarum* subsp. *echinus*, often accompanied by other species. This particular species holds significance for beekeepers, not only locally, but also on a national scale. Its importance lies in enabling the production of high-quality honey during a period of scarcity in melliferous plants for the bees.

Color of the flowers

In terms of the flower colors observed among the recorded species, a notable diversity is evident. The most prevalent color is yellow, with 39 species (33.33%) exhibiting this hue. White flowers follow closely with 36 species (30.77%), while pink flowers account for 13 species (11.11%), and blue flowers are represented by 10 species (8.55%). Additionally, green flowers are found in 7 species (5.98%), mallow-colored flowers in 5 species (4.27%), and red, brown, and beige flowers are each found in 2 species (1.71%). Lastly, only one species (0.85%) is characterized by crimson flowers.

Types of products taken from plants during foraging

Based on the count of plant species serving as sources of both pollen and nectar, 87 species, or 74.36%, provide bees with both nectar and pollen. Eighteen species (15.38%) are polliniferous, supplying bees solely with pollen, while 10 species (8.55%) are nectariferous, supplying bees exclusively with nectar. One species is visited for fruit juice (0.85%), and another species is foraged simultaneously for pollen and honeydew (0.85%).

Spring emerges as the most prolific period for melliferous plants (Figure 7). Among them, the species that serve as both nectariferous and polliniferous (NP) sources are most abundant, trailed by polliniferous species (P), and finally, nectariferous species (N). Summer ensues with a significant number of both nectariferous and polliniferous species, followed by an equivalent count of nectariferous and polliniferous

species. For fall and spring, the species count remains nearly identical; the distinguishing factor lies in the number of polliniferous species, with four in fall and just two in winter. Species that blossom during autumn and winter provide a crucial supply of nectar and pollen, while those present in spring and summer facilitate the preparation of bee colonies for prolific nectar production (honeydew).

Discussion

In the study area, traditional beekeeping is the most practiced, characterized by reed hives that are generally sedentary and adapted to the local melliferous flora. The beekeepers in the area are generally older people (between 40 and 70 years old) who are sedentary and practice agriculture and livestock farming to a large extent. This is due to the varied requirements of modern beekeeping on different levels; it requires a lot of skills compared to traditional beekeeping, from the point of view of equipment, moving the hives which is done only at night and requires a significant physical effort (transhumance), and means of transport.

These results differ from those found in other regions of Morocco where modern beekeeping is more important, for example in the study of Khabbach *et al*. (2013) in the pre-Rif of the province of Taza (northern Morocco), where the respondents (90.9% men) have an average age of 46 ± 12.6 years (58.9 ± 22.1 years for women and 44.7 ± 10.4 years for men), and the local beekeepers are young compared to other Moroccan regions. Then, those of Bakour *et al*. (2021) whose age range of the beekeepers interviewed is as follows: 50% of the beekeepers are between 40 and 60 years old, 39.39% between 20 and 40 years old, and 10.61% older than 60 years old.

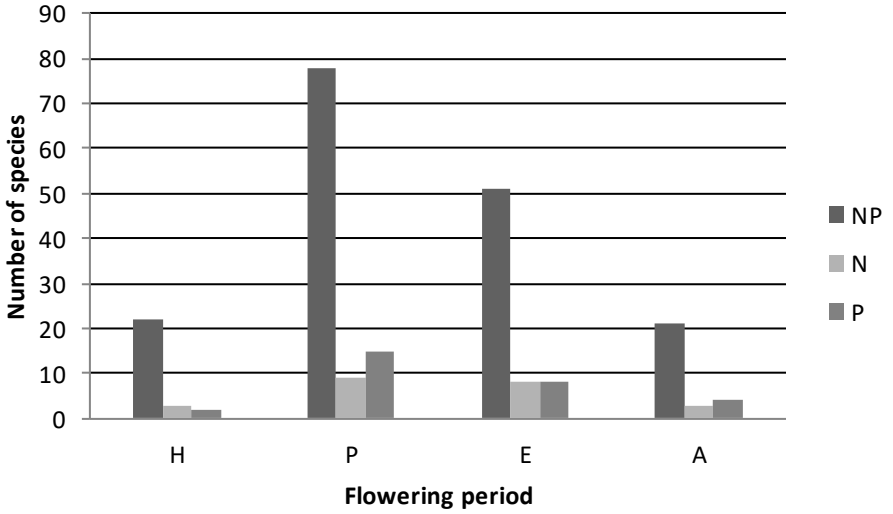

Figure 7. Distribution of food harvested by bees during periods of the year. Abbreviations are: H, winter, P, spring, E, summer and A, autumn.

Regarding the diversity of melliferous species, 117 species were identified. In terms of comparison of these results with those found in other studies at the national level, the number of honey plants identified in this study (117 species) is higher than the 28 species found by Khabbach *et al*. (2013) in the Province of Taza, the 21 species obtained by Libiad *et al*. (2011) in the region of Taounate. Thus, they are more diverse than the 60 species identified by Terrab *et al*. in the central Rif region of Morocco, the 78 species at Mokrisset in northern Morocco by Ennabili *et al*. (2000), and finally, the 102 species recorded in central-northern Morocco by Bakour *et al*. (2021).

According to the results obtained, all the species cited as honey plants by the beekeepers are indicated as species of apicultural interest in the databases and the literature analyzed. It confirms that the beekeepers know the melliferous plants around them perfectly well.

The richness of melliferous plants in the three areas studied depends on biotic and abiotic environmental factors. Among the factors that affect the distribution of these species are the continentality index, the soil substrate and the climatic conditions. In addition, zone A is characterized by a subtropical Mediterranean climate, a sandy-clay substrate with a high salinity level, and a very high atmospheric humidity. For zone B, the substrate is essentially granitic, giving skeletal and sandy soils, and the atmospheric humidity is still quite high, with a strong maritime influence. Finally, in zone C, where the substrate comprises primary sandstone and shale, the climate is much more continental, Mediterranean-type, with a more attenuated maritime influence. It makes Zone C the most diverse in terms of plant habitats and therefore in terms of the number of species, of which the most relevant to bees are *Eryngium ilicifolium*; *Eryngium tricuspidatum*; *Cladanthus arabicus*; *Kleinia anteuphorbium*; *Paronychia argentea*; *Convolvulus trabutianus*; *Euphorbia officinarum* subsp. *echinus*; *Euphorbia regis-jubae*; *Limonium sinuatum* subsp. *beaumierianum*; *Ziziphus lotus*; *Lycium intricatum*; and *Asphodelus tenuifolius*. Secondly, Zone B, where the most relevant species are *Asteriscus graveolens*; *Cladanthus arabicus;* *Diplotaxis harra* subsp. *crassifolia*; *Paronychia argentea*, *Euphorbia officinarum* subsp. *echinus*; *Euphorbia*

regis-jubae; *Melilotus officinalis*; *Limonium sinuatum* subsp. *beaumierianum*; *Lycium intricatum* and *Fagonia cretica*. Finally, zone A, where the most relevant species are *Aizoanthemopsis hispanica*, *Salsola vermiculata*, *Suaeda vera*, *Asparagus albus*, *Glebionis coronaria*, *Euphorbia officinarum* subsp. *echinus*, *Euphorbia regis-jubae*, *Limonium fallax*, and *Limonium sinuatum* subsp. *beaumierianum*.

The results showed that the studied area has an important value from the point of view of melliferous plant richness and beekeeping production. The knowledge of the melliferous plants of a region by the beekeepers is interesting. It allows them to manage their hives by choosing the most abundant plants and those with a long flowering period. Thus, it facilitates the choice of the location of the hives and the protection of the melliferous species sensitive to the pressures related to the activities (grazing, plowing of the ground) and the species in danger of extinction.

According to the results obtained, the floral calendar is in favor of the bees. It shows an availability of nutrients almost throughout the year. These results are in line with the study of Khabbach *et al*. (2013), in which they observed a significant supply of nutrients for bees during different periods of the year, and those of Mekious *et al*. (2016), they found that the supply of nectar and pollen occurs throughout the year, with a peak during February, March and April, the latter corresponding to the great honey-flow period. The Ait Baâmrane region has an important traditional beekeeping activity. It is characterized by traditional hives, mostly sedentary reed hives. This availability of nectar and pollen throughout the year allows a continuous foraging activity, which does not require beekeepers to feed the bees as is done for modern hives, for example, in Europe and other parts of Morocco during the winter.

Comparing our study with others studying the characterization of honey pollen in the same or neighboring regions, we coincide with those obtained by Terrab *et al*. (2014), using a pollen analysis done on honey samples from the region. They found that Euphorbia honey from the Ifni Massif region (southwestern Morocco) is from two species *Euphorbia officinarum* subsp. *echinus* and *E. regis-jubae*. Thus, the most frequent families found are Compositae and Euphorbiaceae (present in 100% of the samples), Cruciferae (90%), Umbelliferae and Caryophyllaceae (80%), Resedaceae (73%), Leguminosae (70%), Boraginaceae (63%) and Plumbaginaceae (53%). Then, for *Euphorbia officinarum* subsp. *echinus* honey, the most characteristic accompanying species are *Eryngium ilyciolium*, present in more than 90% of the samples, followed by *Bellis sp*., *Capsella* f. and *Reseda sp*. (85%). However, for the *E. regis-jubae* honeys, the most characteristic accompanying species are *Crepis* f., present in 100% of the samples, followed by *Anthemis* f., *Bellis sp*., *Capsella* f., *Coronilla viminalis*, *Lotus* f. and *Limonium* f. pollen type (95%), and by *Kleinia anteuphorbium* and *Paronychia argentea* (90%).

While differing from those obtained by Boutoub *et al*. (2021), that found that the pollen of melliferous species most relevant in a sample of honey collected in the region of Guelmim-Oued Noun and closer to Ait Baâmrane are, *E. officinarum* (55.67%), *Quercus rotundifolia* (10.31%), *Genista hirsuta* (6.88%), *Thymus lotocephalus* (4.95%), *Cistus albidus* (4.08%), *Ilex aquifolium* (2.97%), *Malus sylvestris* (2.9%), *Malus domestica* (2.83%), *Eucalyptus cinerea* (2.32%), *Cistus crepis* (2.1%), *Campanula primulifolia* (1.64%), *Lavandula viridis* (1.46%). Also, they differ from those found in a sample collected in a nearby region (Souss-Massa region, more exactly Tiznit) whose most frequent pollens are *E. officinarum* (44.22%), *Pinus pinaster* (14.16%), *Caesalpinia pulcherrima* (6.33%), *Malus domestica* (6.22%), *Quercus suber* (4.99%), *Eucalyptus globulus* (4.73%), *Caesalpinia spinosa* (4.35%), *Cistus crepis* (3.62%), *Artemisia vulgaris* (3.15%), *Salvia officinalis* (2.5%), *Asparagus albus* (2.05%), *Populus nigra* (1.90%), *Lavandula viridis* (1.81%).

Conclusions

This study makes it possible to identify a diversity of melliferous species in the Ait Baâmrane of Sidi Ifni. A total of 117 melliferous species were recorded, representing 41.64% of the 281 species of the total flora. Herbaceous plants and shrubs are the most represented. Thus, most melliferous species recorded are both nectariferous and polliniferous, which favors the practice of beekeeping in the area. In addition, a palynological study of the quality of the honey produced by the bees of Ait Baâmrane is also necessary to evaluate the contribution of local plants in the production. In this study, the characteristics of the honey-bearing plants of the territory of Ait Baâmrane were demonstrated on the biological and floristic levels and according to the biogeographical distribution of the beekeeping habitats.

The area is made up of a diversity of habitats for the distribution of species, namely, fields near houses, cactus plantations, natural areas with euphorbia, argan forests and paths and hedges. Hence, the link between the diversity of the habitats of the beekeeping rangelands is a strategic choice in the traditional beekeeping of the Ait Baâmrane. As beekeepers must set up their beehives, bees benefit from all of their habitats, which make it possible to offer bees a diversified diet according to needs and seasons.

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Authorship Contribution

AB: Conceptualization Data curation; Formal analysis, Methodology, Preparation,Writing-Original draft Writing-Review and Editing; FY: Methodology; AO: Conceptualization, Supervision; MA: Conceptualization, Supervision, Funding Acquisition.

Conflict of Interest

None.

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Supplementary Material

Table S1. Flowering period (1-12) of the main melliferous plants in zone A.

Table S2. Flowering period (1-12) of the main melliferous plants in zone B.

Table S3. Flowering period (1-12) of the main melliferous plants in zone C.

Appendix S1. Melliferous species in Sidi Ifni (Ait Baâmrane region).