Ethnobotanical documentation and quantitative analysis of medicinal plants used to treat rheumatic disorders in the central Algerian steppe

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Research

Abstract

Background: Rheumatic disorders are commonly managed with medicinal plants in North African semi-arid regions, where traditional knowledge remains integral to primary healthcare. Documenting these practices preserves biocultural heritage and helps identify culturally salient taxa and preparation modes relevant for future pharmacological research. This study documented medicinal plants used for rheumatic disorders in the central Algerian steppe, quantified their cultural prominence using standard ethnobotanical indices, and characterized practice regimes through composite practice indicators and multivariate profiling.

Methods: An ethnobotanical survey was conducted between 2024 and 2025 in the M'sila-Bousaâda provinces. Structured interviews with 310 informants recorded sociodemographic data and detailed information on plant use, preparation, and administration. Species were identified using regional floras. Relative frequency of citation (RFC), family importance value (FIV), and plant part value (PPV) were calculated. Four practice indicators were analyzed using latent profile analysis, with principal component analysis for visualization.

Results: Thirty species from 21 families were recorded, with Lamiaceae most represented, followed by Amaryllidaceae, Asteraceae, Myrtaceae, and Zingiberaceae. The most cited species were *Lepidium sativum* (RFC = 0.152), *Peganum harmala* (0.103), *Olea europaea* (0.103), and *Thapsia garganica* (0.087). The results revealed a preference for the use of leaves (PPV = 0.304) and aerial parts (PPV = 0.266) in the treatment of rheumatic disorders. Leaves and aerial parts predominated. Decoctions and infusions were the main preparation modes, and topical massage was the most common administration route. Three practice regimes were identified, ranging from low-intensity household care to more elaborated and socially mediated use.

Conclusions: The findings provide an updated ethnobotanical baseline related to rheumatic disorder, highlight differentiated modes of therapeutic engagement, and underscore the relevance of a practice-oriented approach in ethnobotanical research.

Keywords: Ethnobotanical survey, medicinal plants, rheumatic disorders, practice regimes, steppe, Algeria

Background

Traditional medicinal plants are increasingly recognized worldwide for their important role in the prevention and treatment of a wide range of diseases. Traditional medicine refers to a body of knowledge, beliefs, and practices used in the diagnosis, prevention, and correction of physical, mental, and social imbalances. It is primarily grounded in empirical knowledge derived from observation and experience and transmitted across generations (WHO, 1998). Herbal medicine, in particular, relies on locally available natural resources and on the cultural knowledge and skills required to exploit them effectively (Sangare *et al.* 2012). According to Mahomoodally (2013) and Ullah *et al.* (2023a), estimates by the World Health Organization indicate that a substantial proportion of populations in developing countries, up to 80%, continue to rely on traditional medicine for their primary healthcare needs.

Rheumatism is a chronic inflammatory condition affecting the joints and is commonly managed through a variety of traditional remedies. It is characterized by symptoms such as fatigue, reduced energy, mild fever, muscular and articular pain, and stiffness of the limbs. At the global scale, rheumatic diseases affect approximately 0.5 to 1% of the population (Lawrence *et al.* 1998). Although rheumatism can occur at any age, its prevalence increases markedly between 40 and 70 years, with women being more frequently affected than men (Le Loët *et al.* 2006; Alpízar-Rodríguez *et al.* 2017). While the burden of rheumatic diseases has declined in many industrialized countries, they remain a significant public health concern in Algeria and other developing countries. In Algeria, rheumatoid arthritis, considered one of the main chronic inflammatory rheumatic diseases, has an estimated prevalence of between 0.15% and 0.68% in total population, and due to its chronic nature, its disabling potential, and the significant impact it has on patients' quality of life, this disease constitutes a major public health challenge (Otmane *et al.* 2023). This is illustrated by the continued prevalence of severe complications such as rheumatic heart disease, which imposes substantial social and economic costs (Laouamri *et al.* 2008).

Despite advances in pharmacological management, including the widespread use of non-steroidal anti-inflammatory drugs (NSAIDs) and other chemotherapeutic agents, the treatment of rheumatism remains constrained by important limitations. These therapies are often associated with adverse gastrointestinal, cardiovascular, and renal effects, and they rarely induce sustained remission, thereby limiting their long-term effectiveness (Crofford, 2013). In this context, many patients increasingly turn toward alternative or complementary therapeutic approaches. Ethnopharmacological research focused on traditional medicine and medicinal plants offers promising perspectives for the identification of novel bioactive compounds and the development of alternative or adjunct therapeutic strategies (Taïbi *et al.* 2020). To this end, numerous ethnobotanical studies investigating the use of medicinal plants in traditional medicine have been conducted across various regions of the Mediterranean Basin. (Senkardes *et al.* 2022; Savvides *et al.* 2023; Chiocchio *et al.* 2024 Boutlelis *et al.* 2025; El Ghazal *et al.* 2025; Hamrouni *et al.* 2026; Lahlou *et al.* 2025).

In Algeria, herbal medicine constitutes an integral component of cultural heritage. Indigenous knowledge related to medicinal plants is widespread and has been accumulated empirically and transmitted orally across generations (Bouasla & Bouasla, 2017). This cultural wealth is supported by the country's remarkable floristic diversity, shaped by pronounced climatic, topographic, and ecological heterogeneity (Azzi *et al.* 2012). Algeria hosts an estimated 3,183 plant species, many of which possess medicinal and aromatic properties (Boussaid *et al.* 2018; Berrabah *et al.* 2019). This biodiversity represents a valuable reservoir of bioactive compounds with considerable scientific and therapeutic potential.

The present ethnobotanical survey was conducted in the provinces of M'sila and Bousaâda, located in the central Algerian steppe. This region is characterized by notable floristic diversity resulting from its climatic conditions, topography, and geographical position. The collection and use of medicinal plants for domestic healthcare remain common practices among local populations. To our knowledge, this study constitutes the first systematic effort to inventory and document medicinal plant species used specifically for the treatment of rheumatic disorders in this area. The main objective of this study is to identify and characterize the ethnobotanical relevance of medicinal plants used in traditional Algerian medicine for the treatment of rheumatism, while examining the different therapeutic practices that allow their use, in order to improve certain therapeutic recipes adapted to the region. Beyond its descriptive dimension, this work contributes to the preservation of Algeria's ethnobotanical heritage, which is increasingly threatened due to the growing use of conventional medicine. This has contributed to the gradual abandonment of these ancestral practices, thus threatening the preservation and transmission of this indigenous knowledge. It also lays the groundwork for future research aimed at the scientific valorization of traditional knowledge and the characterization of therapeutic practices.

Materials and Methods

Study area

The study was conducted in a steppe region of central Algeria, encompassing two Wilayas (administrative regions) of M'sila and Bousaâda. The area is located approximately 250 km from Algiers and lies between 34°02′ and 36°04′ N latitude and 03°50′ and 05°02′ E longitude. It is bordered by Bordj Bou-Arreridj and Sétif to the northeast, Médéa and Bouira to the northwest, Batna to the east, Djelfa to the west, and Biskra to the southeast (Figure 1). The study area extends over 18,175 km² and had an estimated population of 1,387,158 inhabitants (DPSB, 2021).

Topographically, the region comprises four major natural units: the steppe zone (55% of the territory), the Hodna plain (33%), mountainous areas (7%), and salt flats and depressions (DSA, 2014). The climate is arid, corresponding to a BSk-BWh transition under the Köppen-Geiger classification. It is characterized by cold winters, a prolonged hot and dry season, and a short cool rainy period. Mean annual precipitation is approximately 215 mm, and the average annual temperature is 19°C, with an annual evapotranspiration of approximately 1112 mm (Amroune, 2018). Vegetation is predominantly steppe, dominated by xerophytic species such as *Artemisia herba-alba* and *Stipa tenacissima* and *Lygeum spartum*, playing an essential role in soil conservation, maintaining biodiversity and combating desertification.

From a socio-economic perspective, the region relies on mixed livelihoods combining agro-pastoralism, small-scale farming, and local trade. Limited access to sustained biomedical care, particularly outside urban centers, maintains traditional medicine as a primary or complementary resource. Medicinal plant knowledge is embedded in daily practice and transmitted through local and mostly informal social networks. In a context marked by climatic exposure, occupational strain, and population aging, rheumatic disorders are prevalent, and plant-based treatments represent adaptive strategies shaped by ecological constraints and locally mediated knowledge systems.

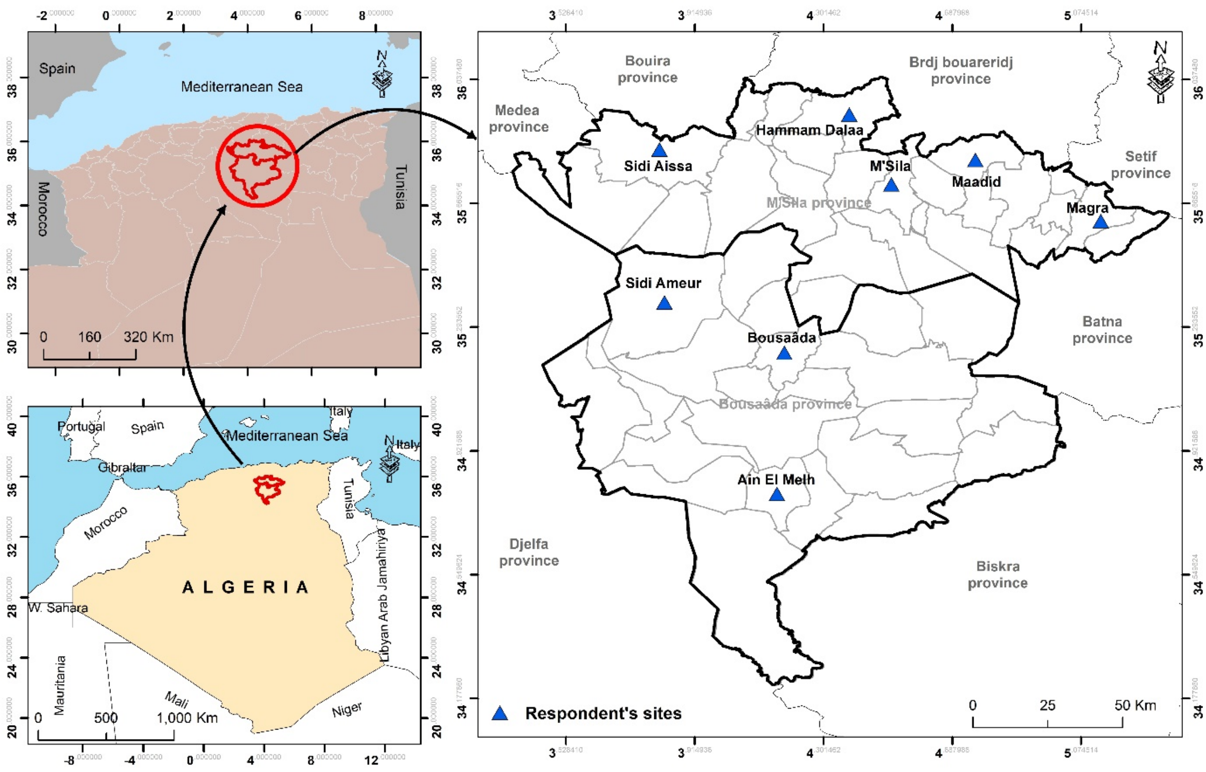

Figure 1. Geographical location of the study area

Data Collection

An ethnobotanical survey was conducted between February 2024 and September 2025 to document medicinal plants used in the treatment of rheumatic disorders among local populations in the study area. Data were collected through direct, structured interviews (in Arabic or French, depending on the linguistic and cultural preferences of the participants) carried out across eight communes, as illustrated in Figure 1.

A total of 310 local informants participated in the survey after providing informed consent. Participants were aged between 18 and 82 years, and the sample included 192 women and 118 men from diverse socio-economic backgrounds. Informants were recruited through field-based purposive sampling across the study area, with the aim of documenting medicinal plant knowledge among individuals who had used, or had direct knowledge of, traditional plant-based remedies for rheumatic disorders. Participants were approached in different local settings, including households, herbalist shops, public places, roadsides, and local community networks across the surveyed communes. This recruitment strategy was adopted because the study focused on experienced users and local knowledge holders rather than on a statistically representative sample of the general population. Before each interview, the aims and objectives of the study were clearly explained, and verbal informed consent was obtained from all participants. Interviews were conducted without time constraints, allowing respondents to express their knowledge freely and facilitating the collection of detailed and reliable ethnobotanical information.

The survey collected detailed ethnobotanical information concerning medicinal plant use. For each cited species, data included vernacular and scientific names, plant parts used, methods of preparation, modes of administration, and sources of knowledge. In parallel, sociodemographic information was recorded for each informant, including age, gender, educational level, family situation, and reasons for using traditional medicine.

Taxonomic identification and authentication of the cited plant species were carried out by the authors in the field, using locally known floristic references, including *Nouvelle flore de l'Algérie des regions désertiques méridionales* (Quézel and Santa, 1962), *Les plantes médicinales en Algérie* (Baba Aïssa, 1991), and *Plantes médicinales d'Algérie* (Beloued, 1998). Vernacular names reported by informants were cross-checked with the botanical characteristics of the cited plants and with the available regional floristic literature. Scientific nomenclature was further verified using the International Plant Names Index (IPNI, ipni.org) and The Plant List database (theplantlist.org) to ensure taxonomic consistency and accuracy.

Data Analysis

Within the defined study area, quantitative ethnobotanical indices were employed to assess the medicinal relevance, cultural importance, and use patterns of the recorded plant species. The following indices were calculated:

***Frequency of Citation* (FC) and *Relative Frequency of Citation* (RFC):** The frequency of citation (FC) represents the number of informants who mentioned the use of a given plant species and serves as an indicator of the reliability of collected information and the level of shared knowledge within the population (Kouame *et al.* 2021). The relative frequency of citation (RFC) was used to estimate the local importance of each species and was calculated by dividing FC by the total number of informants (N). The RFC was computed according to the following formula (Tardío & Pardo-de Santayana, 2008; Vitalini *et al.* 2013; Hussain *et al.* 2022; Sajid *et al.* 2023; Ullah *et al.* 2025a):

$$RFC = FC / N$$

where values range from 0 to 1, with higher values indicating greater consensus and relevance.

***Family Importance Value* (FIV):** The family importance value (FIV) was calculated to determine the relative ethnobotanical significance of plant families. This index reflects the cultural prominence of a family based on its reported use and has been widely applied in ethnobotanical studies to evaluate the biological and therapeutic relevance of higher taxonomic groups (Orch *et al.* 2020). FIV was calculated as the ratio between the number of informants citing at least one species from a given family (FC_{family}) and the total number of species recorded within that family (Ns), following Sreekeesoon and Mahomoodally (2014):

$$FIV = FC_{family} / Ns$$

***Plant Part Value* (PPV):** The plant part value (PPV) was used to assess the relative importance of different plant parts in medicinal preparations. This index provides insight into harvesting preferences and therapeutic practices. PPV was calculated by dividing the number of reported uses for a given plant part ($RU_{plant\ part}$) by the total number of reported uses for all plant parts (RU), as described by Gomez-Beloz (2002):

$$PPV = RU_{plant\ part} / RU$$

For inferential analysis, chi-square (χ^2) tests were used as the primary procedure to assess independence. For variables with an inherent ordinal structure, notably age class and education level, trend-sensitive procedures were employed: the Cochran-Armitage test for monotonic trends in binary outcomes and Cuzick's non-parametric trend test for ordered comparisons involving non-binary measures.

Exploratory practice-regime analysis

In order to complement the core ethnobotanical analyses with a synthetic perspective on patterns of medicinal plant use, an exploratory practice-regime analysis was conducted. The objective was not to model individual competencies or latent traits, but to identify recurrent configurations of practice combining preparation techniques, harvesting strategies, knowledge mediation, and species salience within the local treatment modes of rheumatic disorders.

Four theory-guided composite indices were constructed at the individual level, each capturing a distinct dimension of plant use knowledge and practice: (i) a storage-transformation index (STI) reflecting reliance on processed or stored preparations versus immediate fresh use; (ii) a harvest impact index (HII) approximating the relative ecological pressure associated with reported plant parts; (iii) a knowledge mediation index (KMI) summarizing sources and breadth of ethnomedicinal knowledge; and (iv) a weighted salience index (WSI) accounting for engagement with culturally prominent species. Index construction relied on transparent heuristic weighting grounded in ethnobotanical and conservation basic literature. Full coding schemes and weights are provided in the Appendix A1.

All indices were standardized (z-scores) prior to analysis. A latent profile analysis (LPA) was then applied to these four indices using a finite mixture framework with Gaussian distributions, estimating models with two to six profiles. As model selection was guided by information criteria, convergence diagnostics, and substantive interpretability, a three-profile solution was retained as the most parsimonious representation of the data. To enhance stability and avoid over-parameterization, residual variances were constrained to equality across profiles. Individuals were assigned to profiles based on maximum posterior probability.

Profiles were interpreted strictly as practice regimes, that is, recurring configurations of ethnobotanical practices, rather than as fixed social or cognitive types. To facilitate interpretation, a principal component analysis (PCA) was used as a descriptive visualization tool, allowing the geometric structure of the indices and the separation of profiles to be examined in reduced-dimension space. However, this analysis is intended as a supplementary heuristic extension of the ethnobotanical results and aims to offer an integrative view of how medicinal plants are mobilized in practice.

Results

A total of 310 local informants aged 18-82 years participated in the ethnobotanical survey conducted in the study region, provinces of M'sila and Bousaâda, as representative of the central steppe of Algeria. The results, and their discussion, are organized into three subsections: the structure of knowledge pathways and use patterns of across social categories, the ethnobotanical characteristics of the recorded medicinal flora, and an exploratory analysis of practice-related configurations.

Sociodemographic profile of local informants

Table 1 presents the sociodemographic composition of the sample (age class, gender, marital status, education) and the reported motivations for using medicinal plants to treat rheumatism. Table 2 complements by showing how sources of ethnobotanical knowledge vary across the same sociodemographic strata and motivations, thereby situating medicinal plant use within identifiable channels of information and transmission.

Age and medicinal plant use

The age distribution of users of medicinal plants for rheumatic disorders is concentrated in adulthood and older ages: the 40-60 class represents the largest share (40.3%), followed by 20-39 (29.0%) and ≥60 (24.2%), while the ≤20 group is marginal (6.5%) (Table 1). This configuration aligns with the widely observed tendency for traditional phytotherapeutic knowledge to intensify with age and accumulated practice. Comparable age-patterns are reported in Morocco (Chaachouay *et al.* 2019; Sekkout *et al.* 2024), Nigeria (Salihu *et al.* 2018; Ojetunde *et al.* 2021), and India (Christopher and Ayyanar, 2022). The low representation of younger respondents is also consistent with the idea that intergenerational transmission is under strain and increasingly uneven, a recurring concern in the ethnobotanical literature (Hseini & Kahouadji, 2007; Zemede *et al.* 2024; Anadka & Gulimane, 2024; Ourgha *et al.* 2025;). Earlier work has emphasized that oral transmission is not systematically secured, exposing local phytotherapy to gradual erosion (Anyinam, 2016; Mehdioui & Kahouadji, 2007).

Table 2 clarifies how this age gradient connects to information channels. The distribution indicates that peer-based knowledge dominates across age classes, yet reliance on herbalists and medical advice remains limited and becomes especially sparse at the oldest ages (highly significant, at 1% level). In practice, this suggests that older respondents draw heavily on socially embedded, experiential knowledge, while specialized and formal channels (herbalists, medical advice) remain secondary within this sample. In ethnobotanical terms, the age profile thus captures both (i) the social concentration of knowledge among older cohorts and (ii) the primacy of everyday peer transmission as an operating mechanism.

Table 1. Sociodemographic characteristics of local informants and gender distribution

Variables	Categories	Total	(%)	Gender		χ2 (or z)	p
				Female	Male		
Age Class	≤20	20	6.5	11	9	3.09	0.002
	20-39	90	29.0	46	44		
	40-60	125	40.3	78	47		
	≥60	75	24.2	57	18		
Family situation	Married	193	62.3	127	66	6.17	0.103
	Single	100	32.3	54	46		
	Widow	7	2.3	6	1		
	Divorced	10	3.2	5	5		
Education level	Illiterate	85	27.4	62	23	-2.75	0.005
	Intermediate	120	38.7	74	46		
	University	105	33.9	56	49		
Reasons of using traditional medicine	Effective treatment	210	67.7	122	88	4.83	0.184
	Cheaper treatment	59	19.0	42	17		
	Easy to acquire	35	11.2	23	12		
	Medication is ineffective	6	1.9	5	1		

Note: Reported statistics correspond to χ^2 values for chi-square tests and z-statistics for Cochran-Armitage trend tests for ordinal variables (age and education). Statistical significance was set at $p < 0.01$.

Gendered patterns

Women constitute the majority of medicinal plants users (61.9%) compared to men (38.1%) for rheumatic disorders treatment (Table 1), and the trend test indicates a systematic gender-age association, with women increasingly represented in older age classes (highly significant with $p = 0.002$). This pattern is consistent with Algerian ethnobotanical studies reporting stronger female involvement in household care and greater retention of ethnomedicinal knowledge (Meddour & Meddour, 2015; Bouasla & Bouasla, 2017; Belhouala & Benarba, 2021). Meddour *et al.* (2020) describe this as a largely intrafamilial, oral transmission often running from mothers to daughters, a mechanism that plausibly contributes to the observed female predominance among older cohorts.

Family situation

Married informants represent 62.3% of respondents (Table 1), a pattern also reported elsewhere in Algeria (Kadri *et al.* 2019; Brahmi *et al.* 2023; Soltani *et al.* 2025). Table 2 indicates that marital status is significantly associated with sources of knowledge (with $p = 0.002$) regarding the treatment of rheumatic disorders. Peer transmission (experience from others) remains central, yet single respondents appear relatively more represented among those citing herbalists and medical advice, suggesting more diversified or externally oriented information-seeking in the absence of the everyday caregiving routines typical of larger households. In ethnobotanical terms, marital status here plausibly captures differences in social embeddedness and care responsibilities, which shape how knowledge is accessed and validated.

Educational level

The educational profile indicates that medicinal plant use spans education levels: intermediate (38.7%) and university (33.9%) respondents together constitute the majority, while illiterate respondents still represent a substantial minority (27.4%) with significant gendered pattern distribution (with p = 0.005) (Table 1). Similar educational distributions have been reported in other Algerian surveys (Taïbi *et al.* 2021; Boutlelis *et al.* 2025; Soltani *et al.* 2025), supporting the view that rheumatic disorders treatment remains socially legitimate across schooling strata.

Table 2 adds an important nuance, namely education is linked to which knowledge channel is mobilized. The ordered-trend pattern across sources indicates a shift whereby higher education is associated with greater recourse to medical advice, while illiterate respondents are concentrated in peer-based transmission (with high significance level, at 1%). This stratification is consistent with "epistemic pluralism" in health-seeking behavior: formal education expands access to biomedical frames without displacing the practical reliance on local phytotherapeutic practices.

Reasons for using traditional medicine

Perceived efficacy is the dominant motivation for using medicinal plants to manage rheumatic disorders (67.7%), followed by lower cost (19.0%) and ease of acquiring plants (11.3%); formal medication inefficacy is rarely cited (1.9%) (Table 1). This hierarchy suggests that remedies for rheumatic disorders are valued primarily as effective and accessible therapeutic options. The broader socio-economic context supports this interpretation, high treatment costs and constrained living conditions commonly sustain reliance on medicinal plants (Orch *et al.* 2020). Table 2 shows that motivations vary significantly across knowledge sources (with high significance level, at 1%), which indicate that "why people use plants" and "how they learn about plants" are coupled. The predominance of efficacy among peer-based knowledge users is consistent with experiential validation through repeated household practice, while the smaller channels (herbalists and medical advice) appear to concentrate more selective rationales.

Table 2. Distribution of ethnobotanical knowledge sources across sociodemographic characteristics

Variables	Categories	Sources of knowledge			χ2 (or z)	p
		Experience from others	Herbalists	Medical advice		
Age Class	≤20	11	8	1	-4.47	0.000
	20-39	61	22	7		
	40-60	105	14	6		
	≥60	69	6	0		
Family situation	Married	165	24	4	20.15	0.002
	Single	66	25	9		
	Widow	6	0	1		
	Divorced	9	1	0		
Education level	Illiterate	79	6	0	2.52	0.000
	Intermediate	100	14	6		
	University	67	30	8		
Reasons of using traditional medicine	Effective treatment	168	38	4	24.24	0.000
	Cheaper treatment	43	7	9		
	Easy to acquire	31	4	0		
	medication is ineffective	4	1	1		

Note: Reported statistics correspond to χ^2 values for chi-square tests and z-statistics for Cuzick trend tests for ordinal variables (age and education). Statistical significance was set at $p < 0.01$.

Ethnobotanical characteristics of the recorded medicinal flora

Botanical families represented in the study area

The ethnobotanical survey conducted in the study region documented 30 medicinal plant species belonging to 21 botanical families, reported by local informants for the treatment of rheumatic disorders. The recorded species are presented in Table 3, which lists their botanical family, scientific and vernacular names, plant parts used, modes of preparation, routes of administration, and quantitative ethnobotanical indices, including frequency of citation (FC), relative frequency of citation (RFC), and family importance value (FIV).

According to the survey findings, Lamiaceae emerged as the most represented family, with six species, followed by Amaryllidaceae, Asteraceae, Myrtaceae, and Zingiberaceae, each represented by two species, while the remaining families were represented by a single species. The prominence of Lamiaceae in rheumatism treatment is consistent with its well-documented phytochemical richness. Menthol, a major constituent of *Mentha* species essential oils, has been shown to induce local antirheumatic effects (Benoit *et al.* 1976), while triterpenoid compounds and saponins, widely distributed within this family, are recognized for their anti-inflammatory and antirheumatic properties (Miliauskas *et al.* 2004; KhledKhoujaa *et al.* 2014; Kamal *et al.* 2016).

Species belonging to the Zingiberaceae, notably *Zingiber officinale* Roscoe and *Curcuma longa* L., were also frequently cited. These species are known to contain diverse bioactive compounds, including flavonoids, terpenes, quinones, anthoxanthins, catechins, and anthocyanins, which contribute to their recognized anti-rheumatoid agents (Ahmad *et al.* 2018; Sadia *et al.* 2018; Sekkout *et al.* 2024).

The family importance value (FIV) further highlights the therapeutic relevance of certain botanical families. The most prominent families according to FIV were Brassicaceae (0.152), Nitrariaceae (0.103), Oleaceae (0.103), Apiaceae (0.087), Lythraceae (0.074), Anacardiaceae (0.061), Cucurbitaceae (0.058), Lamiaceae (0.042), and Malvaceae (0.042). This indicates that these families play a central role in local phytotherapeutic practices for rheumatic disorders. The extensive use of Brassicaceae species in the management of rheumatic conditions has been widely reported in classical and contemporary ethnobotanical literature (Khare, 2008; Subramoniam *et al.* 2013; Malik *et al.* 2018; Anadka&Gulimane, 2024).

At the species level, RFC values ranged from 0.006 to 0.152, reflecting varying degrees of consensus among informants (Table 3). The highest RFC was recorded for *Lepidium sativum* L. (0.152), making it the most culturally important species for treating rheumatic conditions in the study area. Other frequently cited species included *Peganum harmala* L. (0.103), *Olea europaea* L. (0.103), *Thapsia garganica* L. (0.087), *Mentha spicata* L. (0.081), *Origanum vulgare* subsp. *glandulosum* (Desf.) Letsw. (0.081), and *Lawsonia inermis* L. (0.074). Given their high RFC values and widespread recognition by informants, these seven species were considered the main medicinal plants for managing rheumatic conditions and were therefore designated as "core plants" for subsequent analyses.

The prominence of *Lepidium sativum*, *Peganum harmala*, and *Thapsia garganica* in this survey is consistent with their frequent citation in national and international studies addressing rheumatism treatment (Rebbas *et al.* 2012; Kamal *et al.* 2016; Yabrir *et al.* 2018; Lazli *et al.* 2019; Miara *et al.* 2019; Chaachouay *et al.* 2019; Idm'hand *et al.* 2020; El Brahimi *et al.* 2022), which reinforces their ethnobotanical relevance. The most frequently cited species are of significant pharmacological interest. Indeed, *Lepidium sativum* is rich in glucosinolates, flavonoids, and phenolic compounds, while *Peganum harmala* contains β-carbolinic alkaloids such as harmine and harmaline, which are attributed with anti-inflammatory, antioxidant, and anti-arthritic properties. *Thapsia garganica*, for its part, contains bioactive lactonic sesquiterpenes, notably thapsigargine, known for its anti-inflammatory and immunomodulatory activities. These properties support the traditional use of these species in the management of rheumatic conditions (Al-Snafi, 2019; Akhtar *et al.* 2022; Mosheim, 2024).

Table 2. List of cited medicinal plants of the flora of study region identified in the ethnobotanical survey for their use in rheumatic disorders treatment.

Family /Botanical name	Local name	Plant part used	Preparation method	Administration routes	FC	RFC	FIV
Amaryllidaceae							**0.019**
Allium cepa L.	Bassla	Bulbs	Raw / Cataplasm	Oral / Massage	9	0.029	
Allium sativum L.	Thoum	Bulbs	Infusion	Massage	3	0.010	
Anacardiaceae							**0.061**
Pistacia lentiscus L.	Dharw	Aerial parts	Oil	Rinsing	19	0.061	
Apiaceae							**0.087**
Thapsia garganica L.	Derias	Aerial parts	Decoction / Cataplasm	Massage	27	0.087	
Asteraceae							**0.018**
Artemisia herba-alba Ass.	Chih	Aerial parts	Decoction	Oral	6	0.019	
Dittrichia viscosa (L.) Greuter	El Tayoune	Roots	Decoction	Massage	5	0.016	
Brassicaceae							**0.152**
Lepidium sativum L.	Hab rched	Seeds	Decoction	Oral / Rinsing	47	0.152	
Cucurbitaceae							**0.058**
Citrullus colocynthis (L.) Schrad.	Handhal	Fruits	Decoction / Cataplasm	Rinsing / Massage	18	0.058	
Cupressaceae							**0.010**
Juniperus phoenicea L.	Arar Finiqi	Aerial parts	Cataplasm	Massage	3	0.010	
Fabaceae							**0.023**
Trigonella foenum-graecum L.	El Halba	seeds	Infusion	Oral	7	0.023	
Lamiaceae							**0.042**
Marrubium vulgare L.	Meriwa	Leaves	Infusion	Rinsing	10	0.032	
*Mentha pulegium*L.	Fliou	Leaves	Decoction	Oral	3	0.010	
Mentha spicata L.	Naanea	Aerial parts	Decoction	Massage	25	0.081	
*Origanum majorana*L.	Mardkouch	Whole plant	Infusion	Oral	2	0.006	
Origanum vulgare subsp. Glandulosum (Desf.) letsw.	Zaater	Aerial parts	Infusion	Oral	25	0.081	
Salvia rosmarinus Spenn.	Iklil El Djabal	Leaves	Infusion	Oral	14	0.045	
Lauraceae							**0.010**
Laurus nobilis L.	Rand	Leaves	Infusion	Oral	3	0.010	

Lythraceae							**0.074**
Lawsonia inermis L.	Henna	Leaves	Cataplasm	Swabbing	23	0.074	
Malvaceae							**0.042**
Malva parviflora L.	Khobaiza	Leaves	Decoction	Rinsing	13	0.042	
Myrtaceae							**0.024**
Eucalyptus globulus Labill.	El kalitouss	Leaves	Infusion	Oral	6	0.019	
Syzygium aromaticum (L.) Merr. &L.M.Perry	Q'ronfel	seeds	Decoction	Massage	9	0.029	
Nitrariaceae							**0.103**
Peganum harmala L.	Harmel	Leaves	Cataplasm	Massage	32	0.103	
Oleaceae							**0.103**
Olea europaea L.	Zitoune	Fruits	Oil	Massage	32	0.103	
Ranunculaceae							**0.026**
Nigella sativa L.	Sanouj	seeds	Infusion	Massage	8	0.026	
Rhamnaceae							**0.013**
Ziziphus lotus (L.) Lam.	Sedra	Leaves	Decoction	Rinsing	4	0.013	
Scrophulariaceae							**0.010**
Verbascum sinuatum L.	Muslih al-ândar	Whole plant	Infusion	Rinsing	3	0.010	
Theaceae							**0.019**
Camellia sinensis (L.) Kuntze	Atây	Leaves	Infusion	Oral	6	0.019	
Urticaceae							**0.019**
Urtica dioica L.	Hurrigua	Leaves	Decoction	Massage	6	0.019	
Zingiberaceae							**0.044**
Curcuma longa L.	Korkoum	Bulbs	Decoction / Infusion	Massage / Oral	9	0.029	
Zingiber officinale Roscoe	Zangeabile	Bulbs	Decoction	Oral	18	0.058	

Plant part value (PPV)

The survey revealed the use of diverse plant parts in the treatment of rheumatic disorders. Figure 2 illustrates a clear predominance of leaves (0.304) and aerial parts (0.266), followed by seeds (0.180) and fruits (0.127). In contrast, bulbs (0.099), whole plants (0.020), and roots (0.013) were rarely used. This preference for leaves and aerial parts aligns with findings from other ethnobotanical studies conducted in Pakistan (Kamal *et al.* 2016; Ullah *et al.* 2023b), north-west Nigeria (Salihu *et al.* 2018), Algeria (Miara *et al.* 2019), and Morocco (Chaachouay *et al.* 2019). These plant parts are often favored due to their high concentration of bioactive compounds and their accessibility, which facilitates sustainable harvesting. The moderate use of seeds and fruits is consistent with observations by Idm'hand *et al.* (2020), who noted that their seasonal availability and specific therapeutic roles limit their broader use. The marginal use of roots and whole plants reflects a broader tendency toward non-destructive harvesting practices, as reported by Benarba *et al.* (2015), underscoring the ecological dimension of traditional phytotherapy.

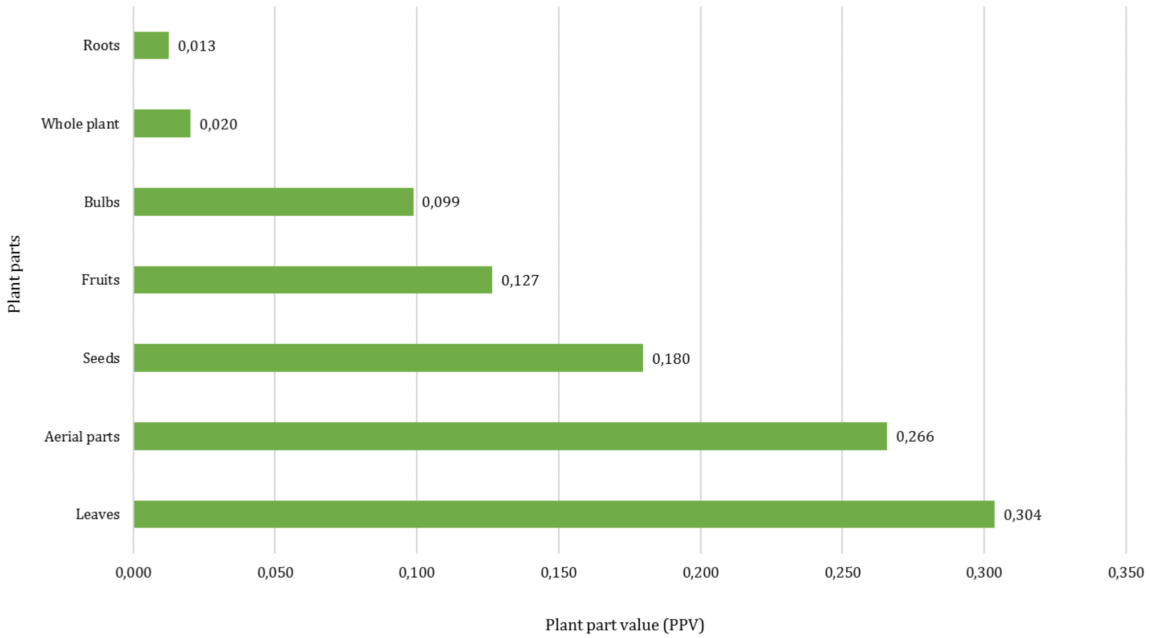

Figure 2. Plant part used in rheumatic disorders treatment

Modes of preparation and routes of administration

Various preparation techniques are employed by local populations to facilitate the extraction and administration of active compounds. As shown in Figure 3, decoction is the most commonly used preparation method (42.53%), followed by infusion (23.04%), cataplasm (20.76%), and oil-based preparations (12.91%), while raw consumption remains marginal. The predominance of decoction has been widely reported in Algerian ethnobotanical studies (Benarba *et al.* 2015; Yabrir *et al.* 2018; Radjai *et al.* 2025) and is also consistent with findings from Nigeria, Morocco, Pakistan and India (Salihu *et al.* 2018; Chaachouay *et al.* 2019; Ullah *et al.* 2025b; Limboo *et al.* 2026). The use of infusion by some respondents is likely justified by the need to preserve biomolecules from evaporation, thereby maintaining the compounds responsible for the plant's anti-rheumatoid effects (Sekkout *et al.* 2024).

Regarding administration routes of rheumatic disorders treatments (Figure 4), topical massage was the most frequently reported method (42.28%), followed by oral administration (31.39%), rinsing (20.51%), and swabbing (5.82%). Topical application of herbal remedies has been extensively documented in the management of chronic joint pain and inflammatory conditions (Namsa *et al.* 2009; Christopher & Ayyanar, 2022; Anadka & Gulimane, 2024). Both topical and oral routes enable rapid physiological action and sustained therapeutic effects, supporting their widespread adoption in traditional rheumatism management (Rehman *et al.* 2015; Chermat & Gharzouli, 2015).

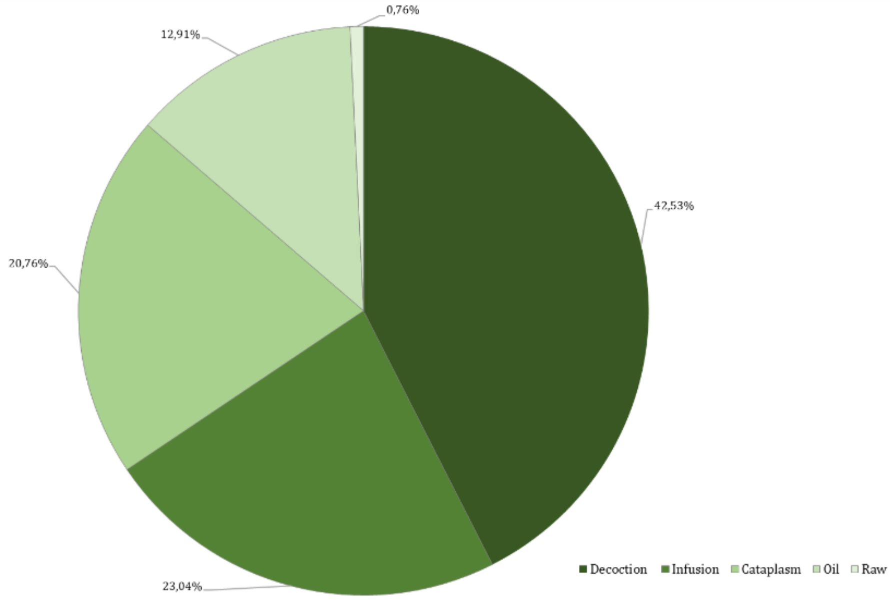

Figure 3. Frequency of different methods of preparation of the recorded species

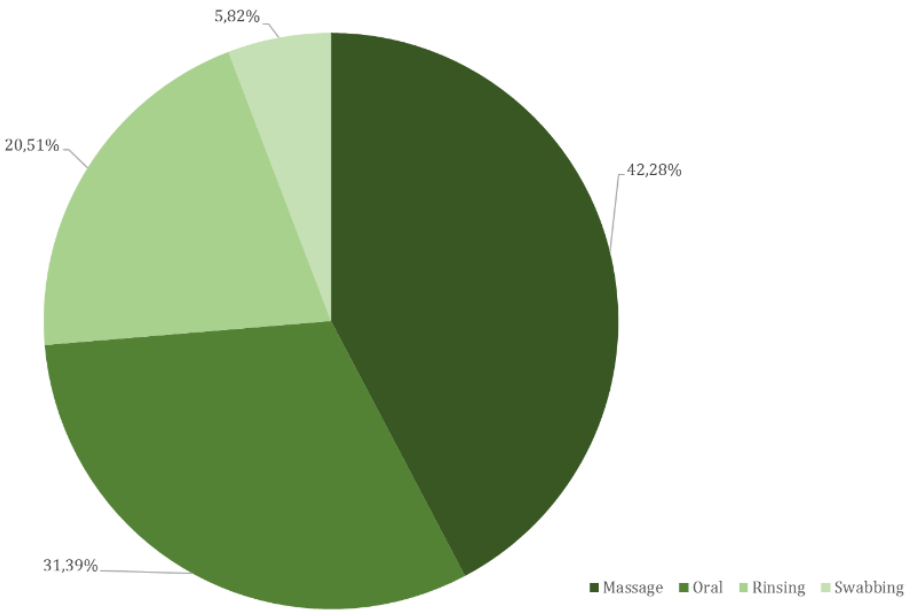

Figure 4. Frequency of different administration routes of the recorded species

Distribution of the most commonly used state of the plant

The state in which medicinal plants are used constitutes an important technical dimension of traditional phytotherapy for rheumatic disorders, as it directly influences the concentration and stability of bioactive compounds. In the study area, the majority of remedies were prepared from fresh plant material (52.9%), followed by dried plant parts (42.26%), while only a small fraction of preparations relied on processed or treated plant material (4.84%) (Figure 5). This distribution is comparable to findings reported in Morocco by Chaachouay *et al.* (2019), and in India by Limboo *et al.* (2026), where fresh plant use similarly dominated ethnobotanical practices.

The predominance of fresh material can be attributed to local perceptions regarding therapeutic potency, as fresh tissues are often considered to contain higher concentrations of active compounds. Variations in the utilization state of plants are closely linked to physiological factors, including metabolic activity and secondary metabolite availability at the time of harvesting. However, reliance on fresh plant material also raises ecological concerns. Fresh plants are harvested and used immediately, which limits opportunities for storage and conservation and may accelerate local depletion of frequently cited species. As noted by Adnan and Hölscher (2012), intensive harvesting of fresh plant material exposes medicinal species to increased pressure compared to the use of dried forms, which allow for preservation and more regulated exploitation.

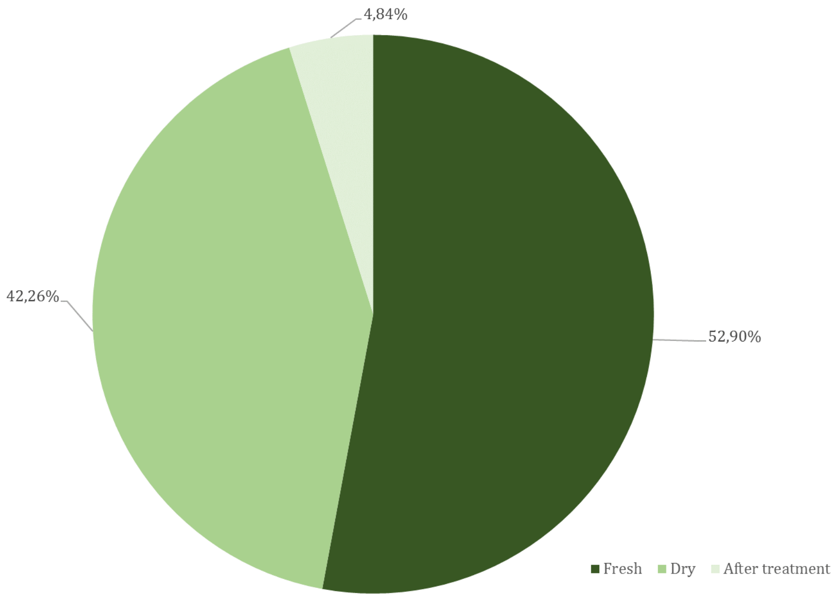

Figure 5. Distribution of the most used plant state

Repertoire size and core plant use

Table 4 evaluates whether patterns of medicinal plant use for rheumatic disorders in the study area, measured through repertoire size (number of cited species per informant) and reliance on core plants count (the seven species mentioned earlier), vary across sociodemographic characteristics and stated reasons. Generally, the results show no statistically significant associations between age class, family situation, or education level and either reason of plant use (almost all $p > 0.10$). Neither the number of species mobilized nor the propensity to rely on culturally salient plants appears to differ systematically across these social categories. This absence of association indicates that both the breadth of individual phytotherapeutic repertoire and the shared core of widely used species are evenly distributed within the study population.

Table 4. Distribution of plants use across sociodemographic characteristics

Variables	Repertoire Size		Core Plants	
	χ2 (or z)	p	χ2 (or z)	p
Age class	-1.61	0.107	-1.00	0.314
Family situation	3.00	0.222	0.55	0.756
Education level	1.55	0.119	0.85	0.390
Reasons of using traditional medicine	5.90	0.433	14.64	0.023

Note: Reported statistics correspond to χ^2 values for chi-square tests and z-statistics for Cuzick trend tests for ordinal variables (age and education). Statistical significance was set at $p < 0.01$.

In contrast, reasons for using traditional medicine display a differentiated effect. While motivations are not associated with repertoire size ($p = 0.433$), they are significantly related to reliance on core plants ($p = 0.023$). This result indicates that reasons of using traditional medicine shapes which plants are selected rather than how many are used. Informants driven by perceived efficacy tend to converge on a limited set of widely recognized species, whereas other motivations, such as affordability, accessibility, or recourse following biomedical failure, are associated with more heterogeneous selections that extend beyond the plant core. The findings suggest that variation in medicinal plant use is structured primarily by therapeutic motivation rather than by sociodemographic position. The local phytotherapy of rheumatic disorders thus appears socially shared in scope, with differentiation emerging at the level of practice orientation and selection criteria, rather than through unequal distribution of knowledge across social groups.

Utilized plant species: Spontaneous, cultivated, and introduced varieties

The medicinal species recorded in the survey were classified by their nature into spontaneous, cultivated, and introduced categories, reflecting the ecological and agronomic diversity of the M'sila-Bousaâda region (Table 4). Spontaneous species constituted the largest proportion (53.34%), followed by cultivated species (36.66%), while introduced species accounted for a relatively small share (10%). This distribution indicates a clear preference for locally available flora, with spontaneous and cultivated plants being far more commonly used in the treatment of rheumatism than introduced taxa.

Table 4. Spontaneous, cultivated and introduced species used species for rheumatic disorders treatment in study region

Species	Spontaneous	Cultivated	Introduced
Allium cepa L.		x	
Allium sativum L.		x	
Pistacia lentiscus L.	x		
Thapsia garganica L.	x		
Artemisia herba-alba Ass.	x		
Dittrichia viscosa(L.) Greuter	x		
Lepidium sativum L.		x	
Citrullus colocynthis(L.) Schrad.	x		
Juniperus phoenicea L.	x		
Trigonella foenum-graecum L.		x	
Marrubium vulgare L.	x		
Mentha pulegium L.	x		
Mentha spicata L.		x	
*Origanum majorana*L.		x	
Origanum vulgare subsp.*glandulosum*(Desf.) Ietsw.	x		
Salvia rosmarinus Spenn.	x		
Laurus nobilis L.	x		
Lawsonia inermis L.		x	
Malva parviflora L.	x		
Eucalyptus globulus Labill.		x	
Syzygium aromaticum (L.) Merr. &L.M.Perry			x
Peganum harmala L.	x		
Olea europaea L.		x	
Nigella sativa L.		x	
Ziziphus lotus (L.) Lam.	x		
Verbascum sinuatum L.	x		
Camellia sinensis (L.) Kuntze			x
Urtica dioica L.	x		
Curcuma longa L.			x
Zingiber officinale Roscoe		x	

This pattern reflects both the depth of local ethnobotanical knowledge and the richness of the regional plant landscape, which together support sustained reliance on native and traditionally managed species. The limited use of introduced plants suggests that therapeutic practices remain strongly embedded in local ecological contexts. However, the high dependence on spontaneous species also underscores the need for conservation-oriented management. To ensure the sustainability of plant medicinal resources, it is essential to promote appropriate conservation strategies, sustainable and regulated harvesting practices, and awareness programs for local communities, thus contributing to the preservation of these species and their sustainable use in traditional medicine systems (Kala, 2005; Bouasla & Bouasla, 2017; Ullah *et al.* 2024).

Origin of information on medicinal plants

Knowledge regarding the use of medicinal plants for rheumatism was acquired predominantly through experience of others (i.e. peer experience and interpersonal transmission), reported by 79.53% of respondents (Figure 6). This finding highlights the central role of oral transmission and shared experiential learning in maintaining phytotherapeutic practices within the study area. Smaller proportions of informants reported relying on herbalists (16.13%) or medical professionals (4.52%) as sources of information.

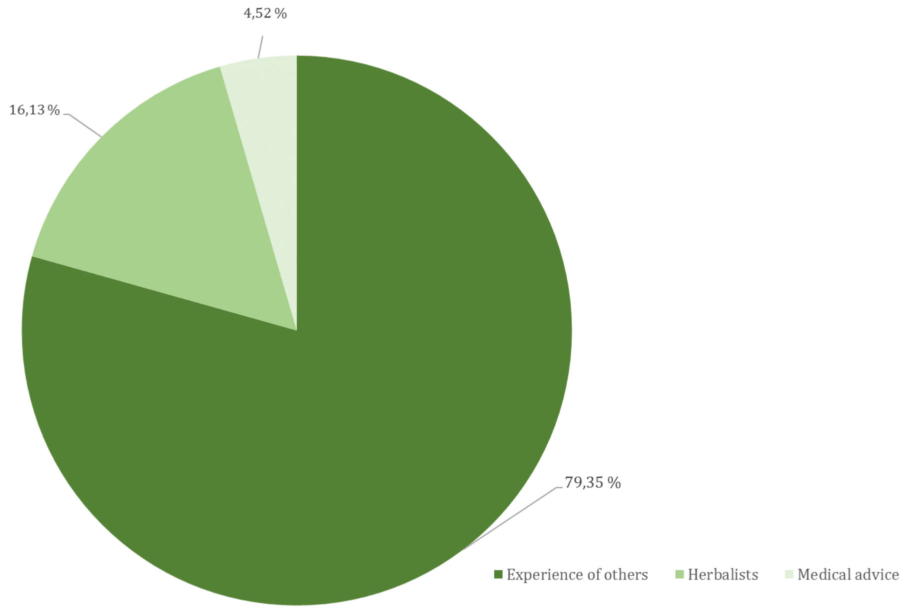

Figure 6. Origin of information on medicinal plants

These results closely mirror those reported by Chaachouay *et al.* (2019) in Morocco, where more than 80% of users similarly acquired ethnobotanical knowledge through community experience. The predominance of informal transmission pathways underscores the social embeddedness of traditional medicine and reinforces the importance of community networks in sustaining therapeutic knowledge. At the same time, the limited contribution of formal medical sources suggests that ethnobotanical practices in the region continue to function largely outside institutional healthcare frameworks, relying instead on collective memory and long-established local expertise.

Practice regimes and profiles of medicinal plant use

Drawing on the practice indicators derived from the survey conducted in the central Algerian steppe (M'sila–Bousaâda), we implemented an exploratory multivariate classification to identify recurrent practice regimes underlying medicinal plant use for rheumatic-related disorders (see Appendix A1). The aim was to move beyond species-by-species reporting and to characterize how remedies are assembled in practice through combinations of (i) processing and storage aspects, (ii) harvesting handling, (iii) knowledge pathways, and (iv) engagement with the locally salient anti-rheumatic species. Four standardized indices were used as the analytical basis, as described in method subsection 2.3 and Appendix A1. These indices were entered into a latent profile analysis (LPA) to identify coherent configurations of practice, with PCA used as a descriptive check on multivariate structure and visualization.

The LPA supported a three-profile solution, with assigned class sizes of Profile 1 (n = 159, 51.3%), Profile 2 (n = 130, 41.9%), and Profile 3 (n = 21, 6.8%). Figure 7 (A–D) presents the distribution of the four standardized indices across these profiles using boxplots, and the contrasts are systematic across the main dimensions that organize practice regimes. For STI (Panel A), profiles display a clear monotonic ordering: Profile 1 is concentrated below the sample mean (−0.76 ± 0.67), consistent with relatively immediate and minimal transformation-related practices, i.e. greater reliance on fresh plant states and simple preparation modes. Profile 2 is shifted upward (0.69 ± 0.50), indicating greater use of stored plant states and more elaborated preparation modes; and Profile 3 shows the highest STI values (1.52 ± 0.35) with comparatively tight dispersion, suggesting a consistently high level of transformation and preparation intensity (in terms of plant states and preparation modes) among this small subgroup.

Panel C (KMI) provides the strongest differentiation in the data. Profiles separate sharply along this axis, with Profile 1 centered well below zero (−0.48 ± 0.59), Profile 2 shifted modestly above the mean (0.29 ± 0.95), and Profile 3 markedly elevated (1.80 ± 1.07). Substantively, this pattern indicates that practice regimes differ most clearly in the degree to which anti-rheumatic treatment relies on three mediated knowledge pathways (Experience from others / herbalists / medical advice) and on a broader active repertoire at the individual level. The WSI (Panel D) similarly reveals strong separation: Profile 1 remains below the sample mean (−0.42 ± 0.61), Profile 2 is slightly above it (0.14 ± 0.89), and Profile 3 is highly elevated (2.26 ± 0.74), indicating concentrated reliance on culturally salient anti-rheumatic species within this regime. In contrast, HII (Panel B) does not align with the monotonic ordering observed for the other indices: Profile 2 shows a modest positive mean (0.14 ± 0.96), whereas Profile 1 (−0.09 ± 1.05) and Profile 3 (−0.18 ± 0.77) fall slightly below zero. The overlap and dispersion observed in Figure 7 therefore suggest that harvesting impact (in terms of plant parts used and extraction pressure) varies substantially across individuals and is not the primary dimension along which regimes are separated, even though it remains informative for within-regime heterogeneity.

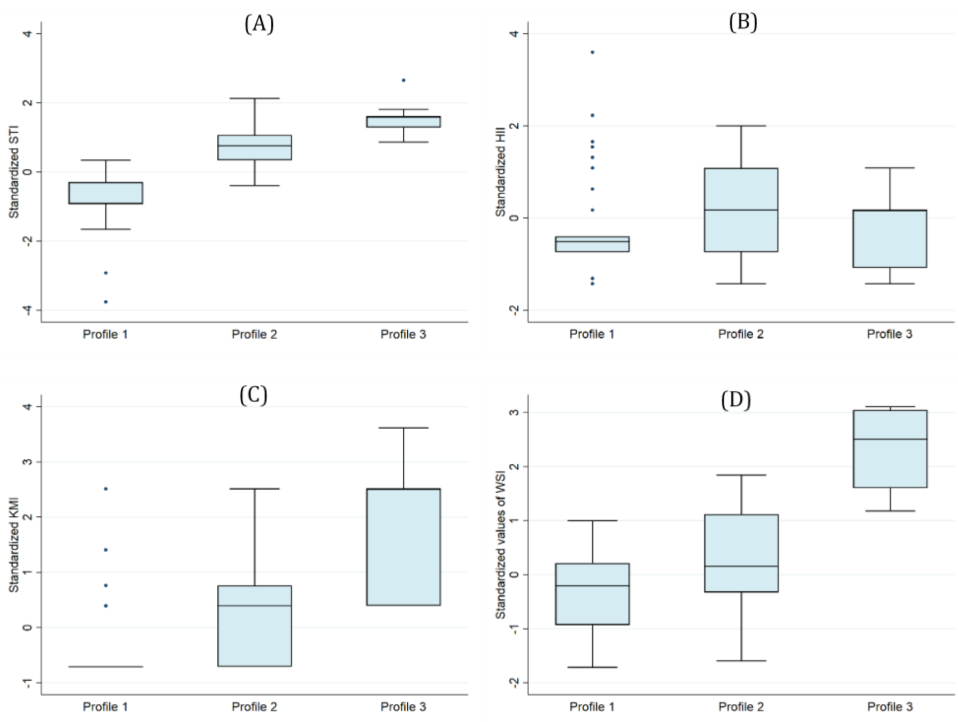

Figure 7. Distribution of standardized practice indices by profile

Figure 8 projects the 310 informants onto the first two principal components computed from the four standardized practice indicators, with points colored by assigned profile membership. This projection provides an informative multivariate geometry consistent with the regime structure observed in the boxplots. The first two principal components explained 70.07 % of the total variance, with PC1 accounting for 44.88 % and PC2 for 25.19 %. The first component is expected to be dominated by three indices that show the clearest between-profile separation, namely: STI, KMI, and particularly WSI, thereby ordering individuals along a gradient of practice elaboration and engagement with salient remedies (in terms of plant states and preparation modes, as well as the breadth of culturally prominent species used), while the second component captures residual dispersion associated more closely with harvesting handling choices (HII). In the plot, Profile 1 clusters primarily at negative PC1 values, Profile 2 occupies an intermediate band with partial overlap, and Profile 3 is displaced toward strongly positive PC1 scores, forming a compact group consistent with its markedly elevated STI, KMI, and WSI values.

The distribution of profiles within the sample indicates that medicinal plant use for rheumatic disorders is structured primarily as a graded spectrum of practice intensity rather than as socially segmented bodies of knowledge. The majority of informants are situated in Profile 1 and 2, configurations characterized by low to moderate levels of preparation and storage (fresh versus stored plant states and simpler preparation modes), limited knowledge mediation, and reliance on a broadly shared set of species. These profiles correspond to forms of routine, household-based ethnomedicine, where therapeutic practices are embedded in everyday experience and circulated through peer transmission (Malik *et al.* 2018; Amsalu *et al.* 2025). Their partial overlap in the multivariate space reflects continuity rather than rupture and suggest that most local health management for rheumatic discomfort operates within a common cultural framework, with variation arising from situational adjustments rather than from distinct knowledge systems. From an ethnobotanical perspective, this supports the interpretation of the local phytotherapeutic practices as a collectively held repertoire, accessible across social categories and mobilized flexibly in response to ordinary therapeutic needs (Febriyanti *et al.* 2024; Awoke *et al.* 2025).

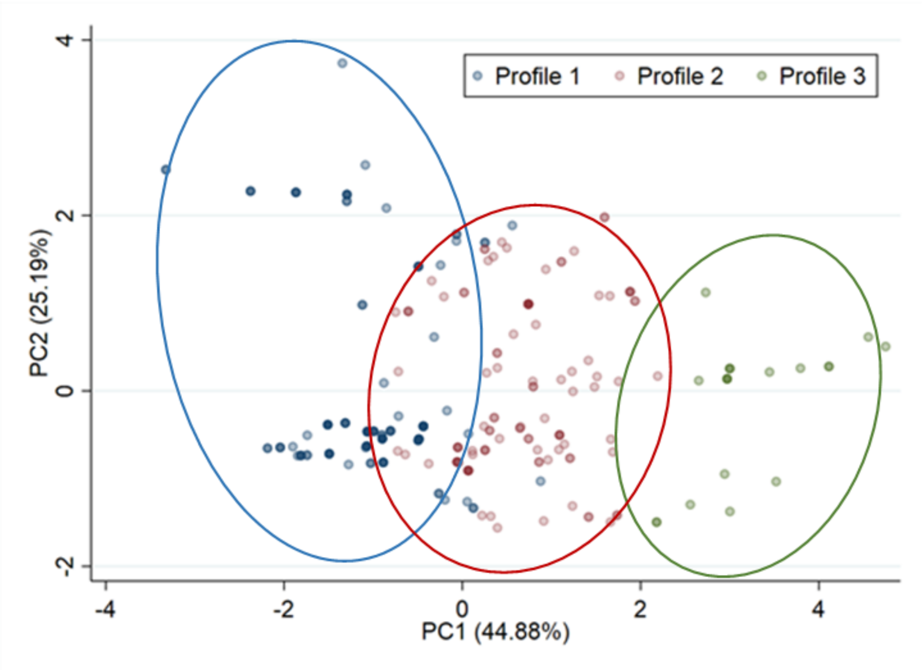

Figure 8. Practice regimes based on composite indices in principal component space

By contrast, Profile 3 represents a small but structurally distinct configuration, marked by substantially higher levels of preparation intensity (greater reliance on processed plant states and more elaborate preparation modes). This profile appears to correspond to situations of therapeutic escalation, in which routine household practices are deemed insufficient and recourse is made to more elaborated techniques and socially recognized expertise (Bruschi *et al.* 2011; Gitima *et al.* 2025; Latif & Nawaz, 2025). Its limited prevalence underscores that such intensified practices are not the norm but are mobilized selectively, likely in response to persistent or severe conditions. This differentiation is analytically relevant because it reveals how traditional medicine operates as a layered system of care, capable of shifting between low-intensity domestic management and more specialized interventions without fragmenting into separate knowledge domains (Chebii *et al.* 2020; Yao *et al.* 2023; Zhao *et al.* 2025). The interest lies in demonstrating that variation in plant use reflects modes of engagement and situational demand, rather than unequal access to knowledge or erosion of tradition, thereby providing a deeper understanding of how medicinal plant systems function in practice in given zone.

While this study provides valuable information on the traditional use of medicinal plants for rheumatic conditions in the M'Sila-Bousaâda region, some limitations must be considered. The sample size, although substantial, may not fully reflect the diversity of local ethnobotanical knowledge. Furthermore, the reliance on informants' recollections may have introduced recall bias, and seasonal variations in plant availability may have influenced the frequency with which certain species were mentioned.

Conclusion

This ethnobotanical study documents a rich and coherent body of traditional knowledge related to the management of rheumatic disorders in M'sila and Bousaâda, the semi-arid region of central Algeria. A total of 30 medicinal plant species belonging to 21 botanical families were recorded, which confirm the importance of local plant resources in everyday therapeutic practice. The dominance of Lamiaceae, followed by Amaryllidaceae, Asteraceae, Myrtaceae, and Zingiberaceae, is consistent with patterns reported in other Mediterranean and semi-arid contexts and reflects both phytochemical richness and cultural familiarity. At the species level, the high frequency of citation of *Lepidium sativum, Peganum harmala, Olea europaea, Thapsia garganica, Mentha spicata, Origanum vulgare* subsp. *glandulosum*, and *Lawsonia inermis* underscores their central role in traditional pharmacopoeia, thus highlighting their ethnomedicinal relevance in the treatment of rheumatic conditions.

Patterns of use further reveal a pragmatic and ecologically embedded therapeutic system. The marked preference for leaves and aerial parts, combined with the predominance of decoctions, infusions, and topical massage, reflects both perceived therapeutic efficacy and accessibility of plant materials. Reliance on spontaneous and cultivated species, rather than introduced taxa, highlights the close articulation between local ecological conditions and medicinal practices. At the same time, this dependence raises concerns regarding harvesting pressure on frequently used species, particularly in the absence of formal conservation or management strategies. Conservation strategies, including the sustainable harvesting and cultivation of the most valuable medicinal species, should be encouraged to prevent the erosion of plant resources and traditional knowledge. From an ethnobotanical perspective, these findings emphasize the need to integrate traditional knowledge preservation with sustainability considerations in semi-arid environments.

Beyond its descriptive contribution, the study offers a complementary, exploratory insight into how medicinal plants are mobilized in practice, through standardized indicators capturing transformation and preparation intensity, knowledge mediation, harvesting handling, and reliance on salient species. The analysis of practice-related indicators suggests that ethnomedicinal use is organized as a continuum of engagement, structured into three profiles ranging from low-intensity, household-based care (fresh plant states and simpler preparation modes) to a smaller set of more elaborated and mediated practices mobilized in specific therapeutic situations (processed plant states and more complex preparation modes). Importantly, this variation does not reflect unequal access to plant knowledge but rather differences in therapeutic orientation and situational demand. While this regime-based perspective remains heuristic, it provides a useful framework for visualizing and interpreting heterogeneity in plant use without fragmenting the ethnobotanical corpus into rigid user types.

The medicinal species identified in this study constitute an important component of the ethnomedicinal heritage of the M'sila-Bousaâda region and, as such, require the implementation of appropriate conservation measures to ensure their preservation and sustainable use. The protection of natural habitats, the promotion of responsible harvesting practices, and the transmission of traditional knowledge to future generations appear essential. Furthermore, additional phytochemical, pharmacological, and toxicological investigations are necessary to validate the therapeutic efficacy and safety of the species most frequently cited in the management of rheumatic conditions. Finally, the results obtained could provide a useful scientific basis for developing health policies that promote the recognition and reasoned integration of traditional medicine within primary healthcare systems.

Declarations

Ethics approval and consent to participate: Before beginning the ethnobotanical study, we obtained verbal consent from all participants.

Availability of data and materials: Data are available on request.

Competing interests: Authors have nothing to declare.

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Author contributions: N.M. collected the data, analysis anddiscussion, and wrote the initial draft. R.B. participated in the theoretical background and monitoring data collection, A.M.B. helped in statistical analysis, and supervise the final version of the text. All authors read and approved the final manuscript.

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Appendix

Index construction method used for practice-regime analysis

This appendix provides the technical details required to reproduce the construction of the four theory-based indices used in the latent profile analysis, namely: the Storage-Transformation Index (STI), Harvest Impact Index (HII), Knowledge Mediation Index (KMI), and Weighted Salience Index (WSI). All indices were computed at the individual informant level. Variables were coded as binary (1 = reported, 0 = not reported) unless otherwise specified. Weights were assigned as transparent analytical basis to structure observed practice configurations as demonstrated in the following table.

Index	Dimension	Variable	Coding	Weight	Rationale
STI	State of plant	Fresh	0/1	−0.8	Immediate, non-stored use
		Treatment	0/1	+0.8	Additional processing
		Dry	0/1	+1.5	Stored or delayed use
	Preparation mode	Infusion	0/1	+0.5	Extractive preparation
		Decoction	0/1	+1.2	Thermal processing
		Cataplasm	0/1	+0.8	Topical preparation
		Oil	0/1	+1.8	Lipid-based extraction
		Raw	0/1	−1.5	Intentional unprocessed use
HII	Plant part used	Roots	0/1	+0.8	Destructive harvesting
		Bulbs	0/1	+1.8	Highly destructive harvesting
		Whole plant	0/1	+1.2	High ecological impact
		Seeds	0/1	+0.8	Removal of reproductive parts
		Fruits	0/1	−0.5	Low-impact harvesting
		Leaves	0/1	−0.8	Renewable harvesting
		Aerial parts	0/1	−0.6	Low ecological pressure
KMI	Source of knowledge	Herbalists	0/1	+1.5	Specialized mediation
		Peers	0/1	−0.8	Social transmission
		Medical advice	0/1	+0.8	Institutional input
	Practice breadth	Repertoire size	Integer	+1.5	Number of species used
WSI	Species use	All species	0/1	Species-specific frequency	Engagement with commonly reported species

Note: For the WSI, each species weight corresponds to its relative frequency of citation in the sample. The index is calculated as the sum of weighted species used by each informant. All indices were standardized (z-scores) prior to multivariate analysis.