Ethnobotanical investigation of antidiabetic medicinal plants in Khenchela Province, Northeastern Algeria

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Ethnobotany Research and Applications 34:58 (2026) - http://dx.doi.org/10.32859/era.34.58.1-18
Manuscript received: 01/03/2026 - Revised manuscript received: 01/06/2026 - Published: 02/06/2026

Research

Abstract

Background: Diabetes mellitus represents a major global health burden, and while medicinal plants are widely used for its management in Algeria, ethnobotanical knowledge in Khenchela Province remains poorly documented; this study aimed to inventory antidiabetic plants and quantitatively document associated traditional knowledge in this region.

Methods: An ethnobotanical survey conducted in Khenchela Province (February-May 2023) among 116 purposively and snowball-sampled informants aged 30-70 years collected data on plant use and sociodemographic, analyzed via Frequency of Citation, Relative Frequency of Citation, and Family importance value indices, with Jaccard's index comparing flora to 13 regional studies.

Results: A total of 44 antidiabetic species belonging to 25 families were documented, with Asteraceae and Lamiaceae being the most represented families. Women (65.5%) and older informants (68.1% aged > 50 years) were the main holders of traditional knowledge. Among the documented species, 12 (27.3%) were also identified as edible plants commonly consumed as food or vegetables. Leaves were the most frequently used plant part (34.6%), followed by aerial parts and seeds, while infusion (53.33%) and decoction (23.33%) predominated among preparation methods. Most remedies targeted type 2 diabetes (86%) for curative purposes (93.33%). *Artemisia herba-alba* (RFC = 0.096) and *Salvia rosmarinus* (RFC = 0.078) showed the highest citation frequencies. Jaccard similarity indices ranged from 0.087 to 0.279, with the highest similarity observed with Bejaia province, Algeria (27.9%).

Conclusion: This study confirms that phytotherapy remains central to diabetes management in Khenchela, with women and the elderly holding a rich but vulnerable antidiabetic knowledge base. Moderate similarity with other Maghrebian pharmacopoeias reflects shared heritage and regional adaptations, providing a prioritized species list for future pharmacological evaluation.

Keywords: Diabetes mellitus; Ethnobotany; Traditional medicine; Algeria; Khenchela; Antidiabetic plants; *Artemisia herba-alba*; *Salvia rosmarinus*

Background

Diabetes mellitus (DM) is a complex metabolic disorder characterized by chronic hyperglycemia resulting from impaired insulin secretion, defective insulin action, or a combination of both (Arya *et al*. 2012). It ranks among the most prevalent chronic diseases worldwide, with type 2 diabetes accounting for the vast majority of cases. In 2021, an estimated 537 million adults aged 20-79 years were living with diabetes globally, and this number is projected to rise to 643 million by 2030 and 783 million by 2045, corresponding to about 1 in 8 adults if no effective action is taken. These alarming trends underscore the urgent need for effective preventive measures and innovative therapeutic strategies to mitigate the escalating public health burden of DM (Kumar *et al.* 2024).

In Algeria, the situation mirrors this global trend, with the national prevalence estimated at 12.3% and more than 4 million people currently affected (Telli *et al*. 2016; Chelghoum *et al*. 2021). The eastern highland regions, including Khenchela Province, are experiencing a particularly sharp increase in diabetes cases, placing additional strain on an already burdened healthcare system**.**

Traditional medicine, particularly the use of medicinal plants to manage chronic diseases such as diabetes mellitus, continues to be widely practiced, and its popularity has increased in recent years. Traditional medical practices vary greatly from one country or region to another and are shaped by factors such as culture, history, local biodiversity, and personal beliefs. According to the World Health Organization (WHO), nearly 80% of the population in developing countries within the African Region relies on traditional forms of medicine to meet primary healthcare needs. At the same time, the sustainable use and conservation of natural resources have become major concerns. In this context, WHO has recommended the evaluation of the safety, quality, and efficacy of traditional and plant-based medicines to support their standardization and integration into national health systems (Eddouks *et al*. 2007). Ethnobotany, which combines ethnology and botany, focuses on the relationships between humans and plants; it enables the documentation of antidiabetic remedies and the establishment of databases of medicinal plants, thereby helping to preserve ancestral knowledge that is largely transmitted through oral tradition.

The high cost of conventional diabetes treatment and the frequent inadequacy of healthcare coverage in many low- and middle-income settings drive many patients to seek traditional therapeutic alternatives. Limited geographical access to health facilities and economic barriers further contribute to insufficient diabetes care in several regions. In this context, the use of medicinal plants has become a widely adopted strategy among local populations for the management of diabetes and its complications (Fah *et al*. 2013). However, despite their growing use, the chemical composition and pharmacological mechanisms of action of many traditional preparations remain poorly characterized. There is therefore a clear need for rigorous scientific investigations—including ethnobotanical, phytochemical, and pharmacological studies—to objectively assess and validate the therapeutic claims associated with these medicinal plants (Ikhoyameh *et al*. 2024).

In Africa, medicinal plants play a fundamental role in the traditional management of chronic diseases, particularly diabetes, and numerous ethnobotanical surveys have highlighted the importance of plant-based remedies across the continent (Hammiche and Maiza 2006; Hamza *et al*. 2010; González-Tejero *et al*. 2008; Sarri *et al*. 2014). In Algeria, several investigations have documented the use of medicinal plants for antidiabetic purposes, as summarized in recent reviews of Algerian antidiabetic flora (Allali *et al*. 2008; Arya *et al*. 2012; Hamza *et al*. 2011). These studies emphasize the richness of Algeria's ethnopharmacological heritage while also revealing significant regional disparities that remain insufficiently explored. Recent ethnobotanical surveys in Bouira (Nouri *et al*. 2025) and other Algerian provinces have further enriched our understanding of antidiabetic plant use across the country. In this context, and with the aim of contributing to the preservation and valorization of traditional therapeutic knowledge, an ethnobotanical survey was conducted in Algeria, specifically in the province (Wilaya) of Khenchela, a region characterized by remarkable floristic diversity and a strong reliance on traditional medicinal practices, yet poorly documented with respect to plants used in the treatment of diabetes (Telli *et al*. 2016).

The main objective of the present study was to identify and catalogue medicinal plants traditionally used in the management of diabetes in the Wilaya of Khenchela and to document the associated therapeutic knowledge held by local populations. The findings provide a valuable scientific basis for future phytochemical and pharmacological investigations aimed at evaluating the antidiabetic potential of these plant species and supporting their rational and sustainable use in primary healthcare.

Materials and Methods

Study area

The present study was carried out in Khenchela province. Located in northeastern Algeria, the province lies at approximately 35°25′00″ N latitude and 7°08′00″ E longitude, with altitudes ranging from sea level to approximately 1,300 meters in the northern plains, while the Aurès Mountains in the northern part of the province reach elevations exceeding 2,300 meters at Djebel Chelia, the highest peak in the region. Khenchela is geographically bounded by Oum El Bouaghi and Tebessa provinces to the east, Batna and Setif provinces to the south and west, and the Aurès Mountains to the north (Fig. 1). Covering an area of approximately 9,995 km² and comprising around 40 municipalities, the province has an estimated population of 600,000, among which Chaoui (Berber) is widely spoken. The population density is relatively low, at approximately 60 inhabitants per km², with the majority (≈70%) residing in urban centers (ASWB, 2015).

Field investigations were conducted across multiple municipalities selected to represent the main ecological and socio-cultural zones of the province, including urban, peri-urban, and rural areas. Particular attention was given to remote and mountainous localities where traditional knowledge is often better preserved. The geographical distribution of survey sites included the municipalities of Khenchela (provincial capital), Kaïs, Chechar, Babar, and several surrounding rural communities, thereby capturing intra-regional variation in ethnobotanical knowledge.

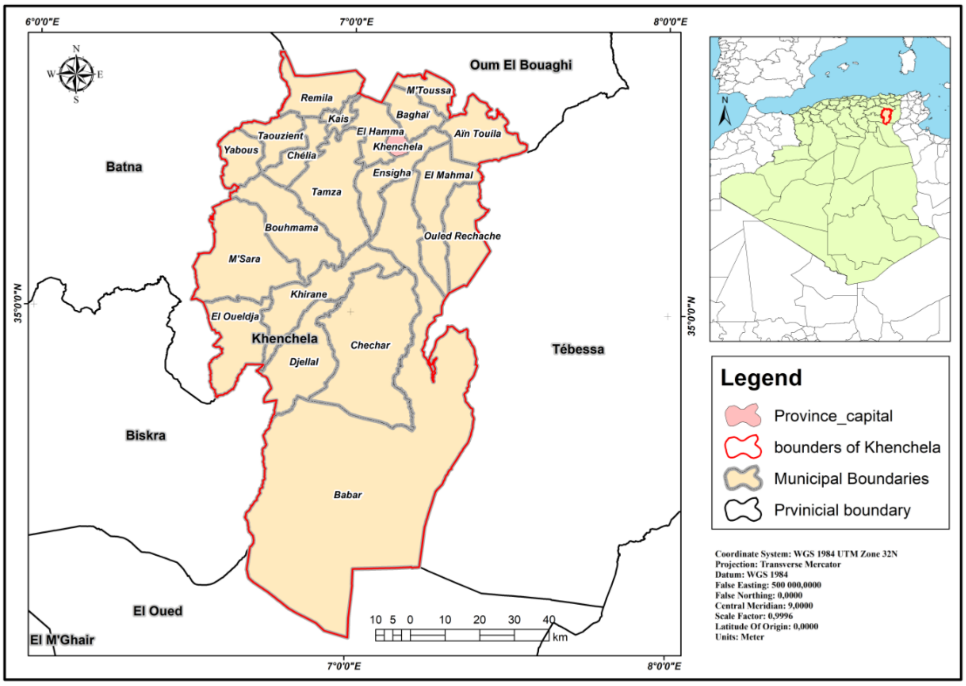

Figure 1. Map of Khenchela province, Algeria, showing the study area and the principal municipalities surveyed.

Data Collection

An ethnobotanical survey was conducted in Khenchela Province between February and May 2023 to document traditional knowledge regarding the use of medicinal plants for diabetes management. A total of 116 informants aged 30 to 70 years were recruited using purposive and snowball sampling. Initial participants, including elderly community members and medicinal plant sellers (herboristes), were identified through local health authorities and community leaders, and subsequently recommended other knowledgeable individuals. The predominance of female informants (65.5%) reflects the traditional role of women in household healthcare and herbal remedy preparation. Data were collected through face-to-face interviews using pre-tested semi-structured questionnaires covering sociodemographic characteristics, local plant names, plant parts used, methods of preparation and administration, diabetes type, and therapeutic orientation (curative or preventive). Field visits were conducted whenever possible for *in-situ* plant collection and identification. Ethical guidelines were strictly followed: research objectives were explained to all participants', verbal informed consent was obtained, and confidentiality and anonymity were assured.

Botanical identification and voucher specimens

Plant identification was carried out by the authors. Preliminary determinations were based on morphological observations following standard regional floras and taxonomic keys. To ensure taxonomic reliability, identifications were subsequently confirmed through consultations with university-affiliated botanists and, when applicable, traditional healers knowledgeable about local medicinal plants. Scientific nomenclature was validated using authoritative online databases, including the African Plant Database (https://africanplantdatabase.ch/en) and eFlore du Maghreb (https://efloramaghreb.org/). Voucher specimens from freshly collected material were prepared according to standard herbarium procedures and deposited in the herbarium of the Laboratory of Biotechnology, Water, Environment and Health (LBWEH) at Abbes Laghrour University, Khenchela, Algeria (herbarium code: H-LBWEH). Vernacular names were cross-referenced with standard ethnobotanical references for the region, notably, A Guide to Medicinal Plants in North Africa (IUCN, 2005), Medicinal Plants of North Africa (Boulos, 1983), and other classical works on Maghrebian flora.

Data Analysis

Microsoft Excel and OriginPro software were employed to perform analyses and to construct the graphical outputs required for data interpretation. The following parameters were considered when analyzing data on medicinal plants cited for the treatment of diabetes: Plant species listed, plant parts used, preparation methods, and modes of administration of herbal remedies.

Frequency of Citation

Frequency of citation (FC) reflects how regularly a species is reported within the community of traditional practitioners. It corresponds to the number of informants whose responses included each plant species in the ethnomedical survey.

Relative Frequency of Citation

The Relative Frequency of Citation (RFC) was employed to evaluate the local importance of medicinal plant species, following Tardío and Pardo-de-Santayana (2008). RFC was calculated as the ratio between the number of informants who cited a given species (FC) and the total number of informants surveyed (N), using the formula: RFC = FC / N**.**

Family Importance Value

The significance of medicinal plant families was quantified using the Family Importance Value (FIV) index. This index relates the frequency of citation for each family to the number of species (Ns) recorded in that family, thereby reflecting its overall contribution to the ethnofloristic knowledge. In this study, FIV was calculated as: $FIV = FC_{family} / Ns$, where FC_{family} is the number of informants who reported any species belonging to a given family and Ns is the number of species in that family (Phillips *et al.* 1993; Ralte *et al*. 2024).

Jaccard's Similarity Index

To assess the similarity between the medicinal flora of Khenchela and those documented in other studies, Jaccard's similarity index was employed, following the methodology recommended by Rahman *et al.* (2019). This index is particularly suited for binary presence/absence data and is widely used in comparative ethnobotanical analyses. Jaccard's index (JI) was calculated as:

$$J = c / (a + b - c)$$

where:

a = number of medicinal plant species recorded in the current study (Khenchela, n = 44)

b = number of medicinal plant species recorded in the compared study

c = number of medicinal plant species common to both studies

For comparison, 13 published ethnobotanical studies from Algeria and Morocco were selected, representing different bioclimatic zones and covering the period 2002-2025.

Results and Discussion

Socio-demographic profile of informants

A total of 116 informants participated in the study, comprising 76 women (65.5%) and 40 men (34.5%) (Table 1). Among the female respondents, 54 (71.1%) were aged 50 years or older. Collectively, informants aged 50 years and above accounted for 68.1% of the study population, with those aged 50-60 years representing 34.5% and those aged ≥60 years representing 33.6% (Table 1). The sample included both community members knowledgeable in traditional medicine and medicinal plant traders (*herboristes*). The relatively low representation of younger informants (31.9% aged <50 years) raises concerns regarding the intergenerational continuity of this knowledge system.

The predominance of women among the informants is consistent with findings from other ethnobotanical studies in Algeria (Belmouhoub *et al*. 2022; Lakhdari *et al*. 2019) and Morocco (Mechchate *et al*. 2020; Tahraoui *et al*. 2023). This pattern reflects the traditional division of labor in Maghrebian societies, where women bear primary responsibility for household health management, including the preparation and administration of herbal remedies. As noted by Benkhnigue *et al*. (2011), the transmission of medicinal plant knowledge often occurs from mother to daughter, reinforcing women's role as knowledge custodians. The predominance of women among knowledge holders in the Wilaya of Khenchela reinforces observations from other North African regions (Eddouks *et al*. 2002; Orch *et al.* 2015). The high proportion of informants aged 50 years and above is similarly consistent with previous studies (Telli *et al*. 2016; Orch *et al*. 2015), reflecting the accumulation of experiential knowledge over time and the association of medicinal plant use with the onset of chronic diseases with advancing age. However, the transmission of this knowledge is currently at risk because it is not always guaranteed (Orch *et al*. 2015).

Table 1. Demographic profile of the informants (n=116).

Factor	Categories	Number	%
Gender	Male	40	34.48
	Female	76	65.51
Age (years)	30-40	13	11.21
	40-50	24	20.69
	50-60	40	34.48
	≥60	39	33.62

Diversity and core antidiabetic flora

We identified 44 medicinal plant species traditionally used in the Khenchela region for the management of diabetes mellitus, based on information provided by patients, herbalists, and traditional healers. Table 2 summarizes, for each species, the plant parts used, preparation methods, therapeutic status, edibility status, conservation status, and ethnobotanical indices (RFC and FIV), organized alphabetically by botanical family.

Asteraceae is the most represented family, with 6 species (13.6%), followed by Lamiaceae with 5 species (11.4%). Apiaceae and Fabaceae each include 3 species (6.8%), while Amaryllidaceae, Amaranthaceae, Myrtaceae, Rosaceae, Poaceae, and Lauraceae each have 2 species. The remaining 15 families contribute a single species (2.3%) to the antidiabetic flora (Fig. 2). The Family Importance Value (FIV) index highlights Asteraceae (FIV = 0.0069) and Lamiaceae (FIV = 0.0086) as the families with the highest scores, reflecting both their species richness and high citation frequency among informants.

The dominance of Asteraceae and Lamiaceae aligns with patterns observed across the Mediterranean basin (González-Tejero *et al*. 2008; Telli *et al*. 2016; Belmouhoub *et al.* 2022). This dominance is likely attributable to the high concentration of bioactive secondary metabolites in these families, particularly sesquiterpene lactones in Asteraceae and phenolic compounds and essential oils in Lamiaceae, which have demonstrated antidiabetic, antioxidant, and anti-inflammatory properties in numerous pharmacological studies (Heinrich *et al*. 1998; Tahraoui *et al*. 2007).

The Relative Frequency of Citation (RFC) index highlights the taxa most deeply embedded in local therapeutic practices. In our survey, *Artemisia herba-alba* (RFC = 0.096), *Salvia rosmarinus* (RFC = 0.078), *Olea europaea* (RFC = 0.052), *Camellia sinensis* (RFC = 0.052), and *Trigonella foenum-graecum* (RFC = 0.052) had the highest RFC values, indicating strong informant consensus on their therapeutic efficacy and making them priority candidates for further investigation.

The antidiabetic potential of *A. herba-alba* has been extensively documented, with studies demonstrating hypoglycemic effects mediated through increased insulin secretion, enhanced peripheral glucose utilization, and inhibition of α-glucosidase and α-amylase activities (Boudjelal *et al*. 2015; Telli *et al*. 2016; Tahraoui *et al.* 2023). These properties are largely attributed to flavonoids such as luteolin and apigenin, and phenolic acids such as chlorogenic acid (Boudjelal *et al*. 2015). Similarly, *R. officinalis* has shown promising antidiabetic effects through multiple mechanisms, including α-amylase inhibition, insulin sensitization, and antioxidant activity (Mansour *et al*. 2023; Kabubii *et al*. 2024; Alaboudi *et al*. 2025), associated with its high content of rosmarinic acid and caffeic acid (El Ouadni *et al*. 2025). The consistent high citation of *O. europaea* and *T. foenum-graecum* across studies further supports their therapeutic relevance (Mechchate *et al*. 2020; Pickering *et al*. 2022; Sarker *et al*. 2024).

Consistent with these findings, several ethnobotanical studies from other regions have reported the use of species also documented in our survey, such as *Mentha viridis* and *Thymus vulgaris* (Nouri et al. 2025), *Allium sativum* L., *Punica granatum* L., *Zingiber officinale Roscoe* (Belmouhoub *et al*. 2022), *Petroselinum crispum*, *Carum cuminum* L. (Sekkat *et al*. 2023), and *Prunus dulcis Mill*. (Skalli *et al*. 2019). This convergence in species use across different studies suggests a genuine therapeutic potential and further supports the interest of these taxa for antidiabetic research.

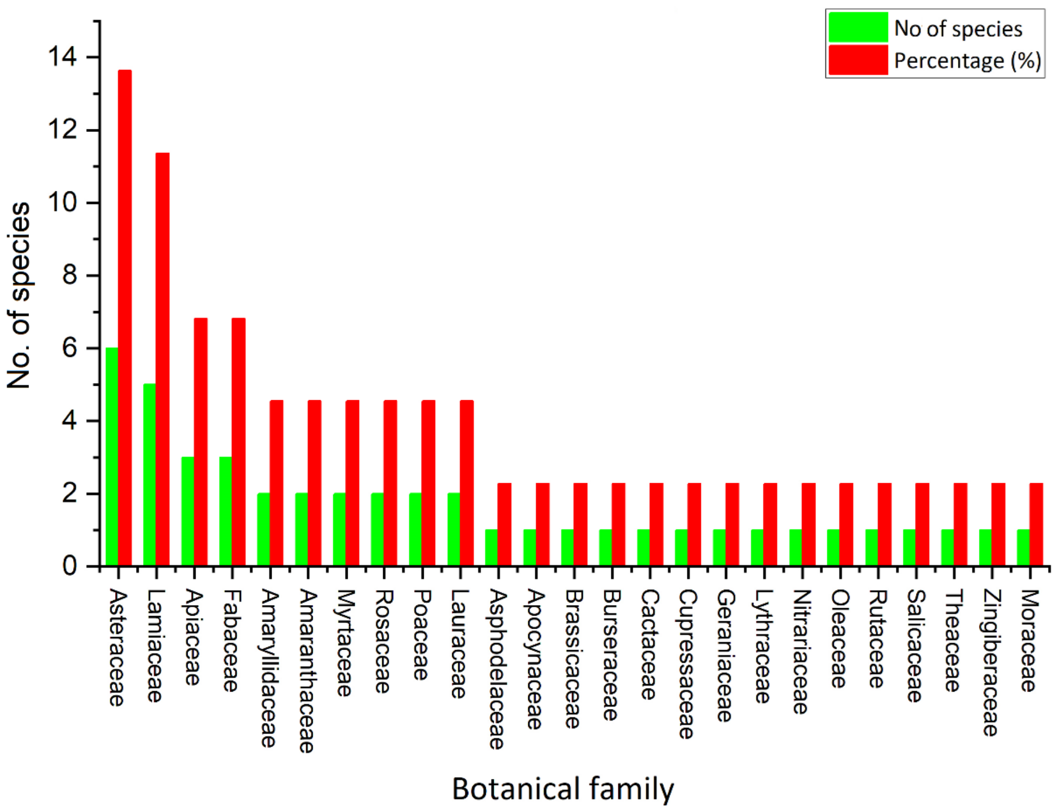

Figure 2. Distribution of medicinal species according to botanical Family.

Table 2. Medicinal plants traditionally used to treat diabetes mellitus in Khenchela province, Algeria.

Family	Species	Local name	Edible	IUCN	Specimen	Used part	Used method	Status	Diabetes type	Sex	No. of citations	RFC	FIV
Amaranthaceae	*Atriplex halimus*	Gtaf/El Katf	No	NE	H-LBWEH-23-022	Leaves	Infusion	Curative	Type 2	03 W, 01 M	4	0.035	0.0087
	Spinacia oleracea L.	Salg	Yes	NE	H-LBWEH-23-025	Leaves	Infusion	Curative	Type 2	02 W	2	0.0175	
Amaryllidaceae	*Allium cepa* L.	Bsal	Yes	NE	H-LBWEH-23-001	Bulb	Decoction, Fresh	Curative	Type 1 and 2	2W	2	0.0175	0.0087
	Allium sativum L.	Thoum	Yes	NE	H-LBWEH-23-002	Bulb	Infusion, Topical app. to the feet	Curative	Type 2	02 W	2	0.0175	
Apiaceae	*Apium graveolens* L.	Kraffes	Yes	NE	H-LBWEH-23-020	Aerial part, Seeds	Decoction, Fresh	Curative	Type 2	03 W	3	0.026	0.0087
	Cuminum cyminum L.	Kamoun	No	NE	/	Fruits	Decoction	Curative	Type 2	01 W	1	0.0087	
	Petroselinum crispum	Maadnous	Yes	NE	H-LBWEH-23-011	Aerial part	Powder, Infusion	Curative	Type 2	02 W	2	0.0175	
Asphodelaceae	*Aloe ferox* Mill.	El mor w Sbor	No	LC	/	Seeds	Infusion, Topical app. to the feet	Curative	Type 2	01W	1	0.0087	0.0087
Asteraceae	*Anthemis nobilis*	Babounje	No	LC	H-LBWEH-23-003	Flowers	Infusion	Curative	Type 2	02 M	2	0.0175	0.0069
	Artemisia absinthium L.	Chedjret Maryem	No	NE	H-LBWEH-23-004	Aerial part	Infusion	Curative	Type 2	02 W	2	0.0175	
	Artemisia herba-alba Asso	Chih	No	NE	H-LBWEH-23-023	Aerial part	Infusion, Decoction	Curative	Type 2	06 W, 05 M	11	0.096	
	Cynara cardunculus L.	Khorchef	Yes	NE	H-LBWEH-23-005	Aerial part	Infusion	Curative	Type 2	01 W	1	0.0087	
	Helianthus annuus L.	Nouaret echams	No	NE	/	Roots	Infusion, Maceration	Curative	Type 2	01 W	1	0.0087	
	Taraxacum officinale F.H. Wigg.	Tarkhashqoun/ Hendba	Yes	NE	H-LBWEH-23-024	Leaves, Roots	powder	Curative	Type 2	01 W	1	0.0087	
Apocynaceae	*Nerium oleander* L.	Defla	No	NE	H-LBWEH-23-028	Leaves	Infusion	Curative	Type 2	01 M	1	0.0087	0.0087
Brassicaceae	*Lepidium sativum* L.	Hab Er chad	Yes	NE	/	Seeds	Decoction	Curative	Type 2	01 W, 01 M	2	0.0175	0.0087
Burseraceae	*Boswellia sacra* Flueck.	Al-lubbān/ Loubane	No	NE	/	Exudates	Infusion, Maceration	Curative	Type 2	02 W	2	0.0175	0.0087

Cactaceae	*Opuntia ficus-indica* L	Hindi	Yes	NE	H-LBWEH-23-010	Flowers	Decoction	Curative	Type 2	01 W	1	0.0087	0.0087
Cupressaceae	*Juniperus phoenicea* L.	Aràar	No	NE	H-LBWEH-23-007	Leaves	Infusion	Curative, Preventive	Type 2	03 W, 02 M	5	0.043	0.0086
Fabaceae	*Cassia angustifolia Vahl (≃ Senna alexandrina)*	Sana makki	No	NE	/	Leaves, Aerial part	Infusion	Curative	Type 2	01 W	1	0.0087	0.0087
	Ceratonia siliqua L.	El Kharoub	Yes	NE	H-LBWEH-23-032	Fruits	Infusion	Curative	Type 2	01 M	1	0.0087	
	Trigonella foenum-graecum L.	Halba	Yes	NE	/	Seeds	Infusion	Curative, Preventive	Type 2	04 W, 02 M	6	0.052	
Geraniaceae	*Geranium robertianum* L.	Ibrat er-raâi	No	NE	H-LBWEH-23-006	Leaves, Flowers	Infusion	Curative	Type 2	02 W	2	0.0175	0.0087
Lamiaceae	*Mentha viridis* L.	Naanaa	Yes	NE	H-LBWEH-23-008	Aerial part	Infusion	Curative	Type 2	02 W, 01 M	3	0.026	0.0086
	Origanum majorana L.	Bardakoch	Yes	NE	H-LBWEH-23-030	Leaves	Infusion	Curative	Type 2	02 W, 01 M	3	0.026	
	Salvia officinalis	Mermiya	Yes	NE	H-LBWEH-23-031	Leaves, Flowers	Infusion	Curative	Type 2	01 W, 01 M	2	0.0175	
	Salvia rosmarinus Spenn. (= *Rosmarinus officinalis*)	Iklil el Jabal	Yes	NE	H-LBWEH-23-017	Aerial part	Infusion, Decoction	Curative	Type 1 and 2	05 W, 04 M	9	0.078	
	Thymus vulgaris L.	Zaatar	Yes	NE	H-LBWEH-23-019	Aerial part	Infusion	Curative	Type 1 and 2	03 W	3	0.026	
Lauraceae	*Cinnamomum verum* L.	L'Qarfa / Karfa	No	NE	/	Leaves, Flowers	Infusion	Curative	Type 2	02 W, 01 M	3	0.026	0.0028
	Laurus nobilis L.	*Rand*	Yes	NE	H-LBWEH-23-029	Leaves	Infusion	*Curative*	*Type 2*	*01 W*	*1*	0.0087	
Lythraceae	*Punica granatum* L.	Roumane	Yes	NE	H-LBWEH-23-027	Fruits (pericarp)	Infusion, Maceration	Curative	Type 2	02 M	2	0.0175	0.0087

Moraceae	*Ficus carica* L.	Karmouss	Yes	NE	H-LBWEH-23-016	Fruits, Leaves	Decoction, Powder, Fresh	Curative	Type 2 and 1	02 W	2	0.0175	0.0087
Myrtaceae	*Eucalyptus globulus* L.	Calitouss	No	NE	/	Leaves	Infusion, Decoction	Curative	Type 2	02 W	2	0.0175	0.0086
	Myrtus communis L.	Erihan	No	NE	H-LBWEH-23-009	Leaves, Aerial part	Infusion	Curative	Type 2	02 W, 03 M	5	0.043	
Nitrariaceae	*Peganum harmala* L.	Harmel	No	NE	H-LBWEH-23-026	Seeds	Maceration	Curative	Type 2	02 W, 01 M	3	0.026	0.0086
Oleaceae	*Olea europaea* L.	Zitoun	Yes	NE	H-LBWEH-23-021	Leaves	Infusion, Decoction	Curative	Type 2	03 W, 03 M	6	0.052	0.0086
Poaceae	*Hordeum vulgare* L.	Chaair	Yes	NE	/	Seeds	Decoction	Curative	Type 1	01 W	1	0.0087	0.0087
	Stipa tenacissima L.	Halfa	No	NE	H-LBWEH-23-018	Aerial part	Decoction	Curative	Type 2	01 M	1	0.0087	0.0087
Rosaceae	*Prunus cerasus* L.	Hab el mlouk hamed	Yes	NE	H-LBWEH-23-013	Fruits	Fresh	Curative	Type 2 and 1	01 M	1	0.0087	0.0078
	Prunus dulcis (Mill.)	Loz mor	Yes	NE	H-LBWEH-23-014	Seeds	Infusion, Decoction	Curative	Type 2	01 M	1	0.0087	
Rutaceae	*Ruta montana* L.	El fidjel	No	NE	H-LBWEH-23-015	Leaves	Infusion	Curative	Type 2	01 W	1	0.0087	0.0078
Salicaceae	*Populus nigra* L.	Safsaf	No	NE	H-LBWEH-23-012	Leaves	Infusion	Curative	Type 2	01 W	1	0.0087	0.0078
Theaceae	*Camellia sinensis* L. Kuntze	Atay	No	NE	/	Leaves	Infusion, Decoction	Curative	Type 2 and 1	04 W, 02 M	6	0.052	0.0086
Zingiberaceae	*Zingiber officinale* Roscoe	Zanjabil	Yes	NE	/	Rhizomes	Maceration	Preventive	Type 2	01 W, 03 M	4	0.035	0.0087

Legend: W = women; M = men; NE = Not Evaluated; LC = Least Concern; RFC = Relative Frequency of Citation. RFC values in bold indicate the highest citation frequencies (≥0.050).

Plant parts and preparation methods

Different parts of the plant are used to prepare traditional antidiabetic remedies, but in unequal proportions. According to the results of this study, leaves are the most frequently used, accounting for 34.6% of all cited preparations, followed by aerial parts (21.2%) and seeds (13.5%). Fruits and flowers are used less often, each accounting for 9.6% of preparations, while roots and bulbs contribute 3.9% each; rhizomes and exudates are the least used, with 1.9% each (Fig. 3A). The predominance of one organ over another in therapy reflects differences in the concentration of bioactive compounds within each part (Bouzabata 2013; Peltzer and Pengpid 2019). Our findings agree with published data, as leaves are not only easy to collect but also the main site of photochemical reactions, rich in active metabolites and serving as a reservoir of bioactive compounds (Bouzabata 2018). From a biological perspective, leaves play a central role in photosynthesis and often serve as sites for the accumulation of secondary metabolites responsible for therapeutic properties (Chaachouay et al. 2019). Similar observations were reported by Diatta *et al*. (2013), Dougnon *et al*. (2016), and Nigatu *et al.* (2018), who also found leaves to be the most commonly used plant part in traditional medicine. This finding is consistent with studies in Ouargla (Telli *et al*. 2016) and Bejaia (Belmouhoub *et al*. 2022).

Regarding preparation methods, infusion is the most commonly used (53.3%), followed by decoction (23.3%), while maceration, fresh preparations, powders, and topical applications are reported less frequently (8.3%, 6.7%, 5.0%, and 3.3%, respectively) (Fig. 3B). Decoction and infusion are also the most widely documented methods in the scientific literature (Aburjai *et al*. 2007; Al-Qura'n 2009). Their popularity is attributed to their ability to enhance the extraction of bioactive compounds and, in the case of decoction, to help reduce or neutralize potential toxic effects associated with some traditional formulations (Salhi *et al*. 2010). These water-based extraction techniques are simple, cost-effective, and appropriate for extracting polar bioactive compounds, such as flavonoids, phenolic acids, and tannins, that are believed to contribute to antidiabetic activity (Al-Ishaq *et al*. 2019). Furthermore, their simplicity of preparation, widespread cultural acceptance, and efficiency in extracting a broad spectrum of bioactive compounds explain their predominance (Belhaj *et al*. 2020; Benaradj and Boucherit 2022; Aouissat *et al*. 2026).

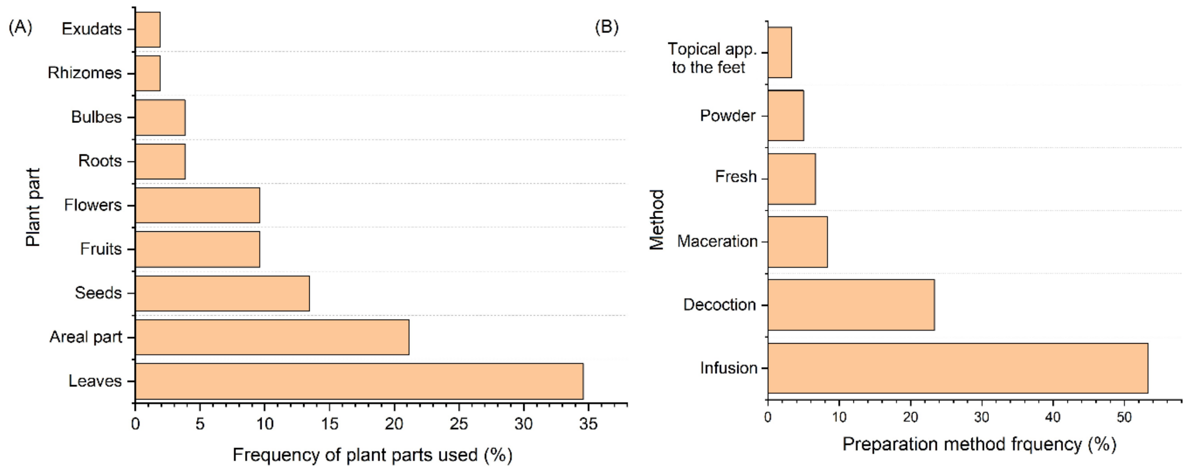

Figure 3. (A) Frequency of plant parts used for the preparation of antidiabetic remedies. (B) Preparation methods followed of antidiabetic remedies among diabetic patients.

Diabetes types and therapeutic orientation

Algeria harbors a rich diversity of medicinal plants that are traditionally used in diabetes management, as reported in several ethnobotanical studies (Benarba *et al*. 2015; Boudjelal *et al*. 2012 and 2013; Bradai *et al.* 2015; Hamza *et al*. 2009). This diversity is closely linked to the country's broad geographical extent and pronounced climatic gradients, ranging from Mediterranean ecosystems in the north, across the Atlas Mountains, to the hyper-arid Saharan zones in the south.

In the present survey, most of the documented medicinal plants are used for the management of type 2 diabetes (T2D), which accounts for 86% of all reported uses, whereas only 14% target type 1 diabetes (T1D) (Fig. 4A). The Alluvial (Sankey-type) diagram further illustrates that the majority of preparations—particularly infusions and decoctions—are directed towards T2D and mainly involve leaves and aerial parts of plants (Fig. 4B). This predominance of T2D indications likely reflects both the higher prevalence of T2D in the general population and the fact that T1D is an insulin-dependent form of the disease, for which effective control primarily relies on exogenous insulin rather than on herbal therapies (Skalli *et al*.

2019). This pattern is consistent with other Algerian (Belmouhoub et al. 2022; Chelghoum *et al*. 2021) and Moroccan (Mechchate *et al*. 2020; Tahraoui *et al*. 2023) studies.

Most of the high-RFC species, such as *Salvia rosmarinus*, *Artemisia herba-alba* and *Olea europaea*, are predominantly used in the form of leaf or aerial-part infusions for the management of type 2 diabetes, which is consistent with the overall pattern observed in the alluvial diagram (Fig. 4B). Medicinal plants are rich sources of secondary metabolites that act as bioactive compounds. The antidiabetic properties of these plants have been attributed to the presence of phenolic compounds, flavonoids, terpenoids, coumarins, alkaloids, saponins, and other bioactive constituents known to exert glucose-lowering effects (Liyanagamage *et al*. 2020).

Regarding therapeutic orientation, a pronounced dominance of the curative mode is evident, representing 93.3% of citations, while the preventive approach is only marginally represented (6.7%) (Fig. 4C). In this study, "curative use" is operationally defined as the use of medicinal plants to treat or manage already diagnosed diabetes, whereas "preventive use" refers to the use of plants to delay disease onset or control early metabolic disturbances in individuals not yet diagnosed. This substantial imbalance indicates that local populations primarily turn to medicinal plants after the onset of diabetes symptoms rather than as a preventive measure, highlighting an opportunity for health education programs to emphasize the potential role of certain plants in diabetes prevention. This tendency may also be attributed to the immediate and more easily quantifiable outcomes associated with curative measures.

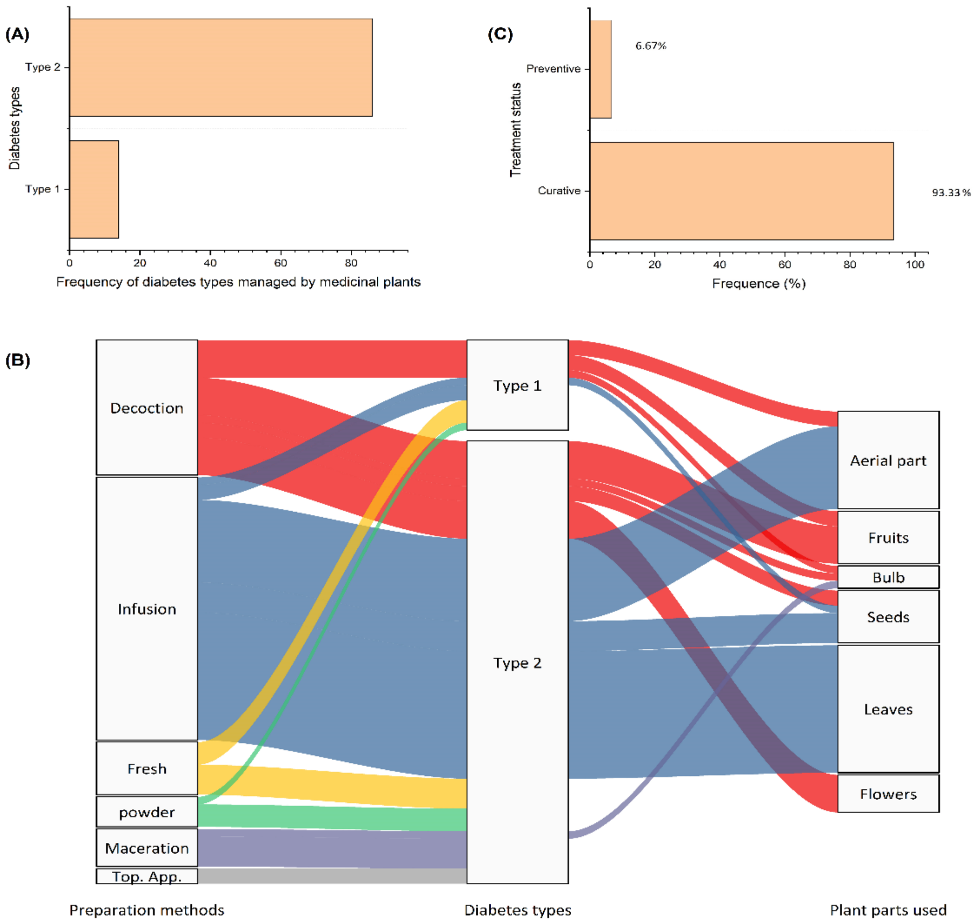

Figure 4. Diabetes types and therapeutic orientation. (A) Use of medicinal plants according to diabetes types; (B) Flow diagram (Sankey plot) illustrating the relationships between preparation methods, diabetes types, and plant parts used. The width of each flow corresponds to the frequency of use reports.; (C) Frequency of the therapeutic orientation (curative versus preventive) of reported remedies

Edible species and conservation status

Among the 44 documented species, 12 (27.3%) were also identified as edible plants commonly consumed as food or vegetables in the region (Table 2). These include *Spinacia oleracea* (spinach), *Apium graveolens* (celery), *Cynara cardunculus* (artichoke), *Ficus carica* (fig), *Opuntia ficus-indica* (prickly pear), *Petroselinum crispum* (parsley), *Allium cepa* (onion), *Allium sativum* (garlic), *Mentha viridis* (spearmint), *Origanum majorana* (marjoram), *Trigonella foenum-graecum* (fenugreek), and *Prunus dulcis* (almond). The overlap between food and medicine highlights the dual value of these species in local culture and suggests that their regular dietary consumption may contribute to the prevention or management of metabolic disorders, including diabetes. Species such as *A. sativum*, *A. cepa*, *T. foenum-graecum*, and *O. europaea* are regularly consumed as part of the traditional diet and may contribute to diabetes management through their cumulative dietary intake. This finding aligns with the growing recognition of functional foods in chronic disease management. The dual use of these plants as both food and medicine also implies a favorable safety profile, as their long history of dietary consumption provides empirical evidence of low toxicity at culinary doses.

Based on the IUCN Red List assessment, none of the documented species were classified as threatened (Vulnerable, Endangered, or Critically Endangered) (Table 2). The majority of species were categorized as "Not Evaluated" (NE; 42 species, 95.5%), while two species (*Aloe ferox* and *Anthemis nobilis*) were classified as "Least Concern" (LC; 4.5%). This indicates that current harvesting practices for diabetes management are not directly threatening the conservation status of these species. However, the high proportion of "Not Evaluated" species underscores the need for systematic conservation assessments of medicinal plants in the region. Continued monitoring of harvesting practices is recommended, particularly for species with high citation frequencies such as *A. herba-alba* and *S. rosmarinus*.

Toxicity considerations

The use of medicinal plants in diabetes management is not without risks and may lead to adverse effects. These effects are generally associated with the administered dose, misidentification of plant species, as well as inappropriate preparation and administration practices (Nasri and Shirzad 2013; Hamza *et al*. 2019). Adverse effects, including severe and potentially fatal outcomes, have been reported among vulnerable populations such as pregnant women, children, and patients with pre-existing health conditions. Furthermore, toxic effects may also arise from allergic reactions, the presence of impurities, or interactions with conventional medications (Maurya *et al*. 2019; Liyanagamage *et al.* 2020).

Several plant species documented in the present survey are recognized for their toxic potential (Table 3). *Nerium oleander* L., cited by one male informant, is a highly cardiotoxic plant containing cardiac glycosides such as oleandrin, which can induce severe arrhythmias, atrioventricular block, and potentially fatal cardiac arrest even at low doses (Langford and Boor 1996; Osterloh *et al*. 1982). Its inclusion in the local pharmacopoeia is particularly concerning and warrants immediate attention in terms of public health education.

*Artemisia absinthium*_L., reported by two female informants, contains thujone, a neurotoxic compound associated with seizures, tremors, and hallucinations at high doses (Höld *et al*. 2000; Efferth *et al*. 2011). *Peganum harmala* L., cited by three informants, contains β-carboline alkaloids that exhibit psychoactive properties and act as monoamine oxidase (MAO) inhibitors, potentially causing tremors, hallucinations, and adverse interactions with other medications (El Bahri and Chemli 1988; Moloudizargari *et al*. 2013). Aloe ferox Mill. May cause gastrointestinal disturbances and electrolyte imbalances with chronic use of its leaf latex (Boudreau and Béland 2006). *Ruta montana* L. is known for its hepatotoxic and phototoxic effects, as well as its abortifacient properties, making it particularly dangerous for pregnant women (Abdel-Mogib *et al*. 2002).

The presence of these potentially toxic species in the local antidiabetic pharmacopoeia highlights a critical knowledge gap regarding safe preparation methods, appropriate dosages, and contraindications. Traditional healers may possess empirical knowledge to mitigate toxicity, but such information was not systematically captured in the present survey. Furthermore, potential herb-drug interactions remain entirely unexplored, which is particularly concerning given that many diabetic patients may combine herbal remedies with conventional antidiabetic medications, potentially leading to hypoglycemic episodes or other adverse effects (Nasri and Shirzad 2013; Hamza *et al*. 2019).

These observations underscore the necessity of rigorous phytochemical and toxicological evaluation of traditionally used antidiabetic plants to establish safe dosage ranges and identify potential contraindications prior to their recommendation as complementary therapies.

Comparative analysis with other maghrebian pharmacopoeias

The comparative analysis using Jaccard's similarity index revealed varying degrees of similarity between the medicinal flora of Khenchela and those documented in 13 other studies from Algeria and Morocco (Table 4). Jaccard indices ranged from J

= 0.087 (8.7% similarity) with the High Atlas region of Morocco (Belhaj *et al.* 2021) to JI = 0.279 (27.9% similarity) with Bejaia, Algeria (Belmouhoub *et al*. 2022).

The highest similarity was observed with studies from semi-arid Mediterranean regions of Algeria, including Bejaia (JI = 0.279), M'Sila (JI = 0.258), Safi-Essaouira (JI = 0.208), and Sidi Bel Abbès (JI = 0.203). These values, while moderate, indicate a shared core of antidiabetic plants across these regions, which can be attributed to comparable bioclimatic conditions and similar vegetation types. Moderate similarity was also found with Ouargla (JI = 0.194) and Rabat (JI = 0.194), reflecting the widespread use of xerophytic species such as *Artemisia herba-alba*, which are well-adapted to semi-arid and Saharan environments. The lowest similarity was observed with the High Atlas (JI = 0.087), consistent with the distinct high-altitude montane ecology of this region, which harbors many endemic species not found in Khenchela.

Overall, the relatively low Jaccard values (all ≤ 0.28) indicate that while a limited set of species is widely shared across the Maghreb, each region possesses a distinct antidiabetic flora shaped by local ecological conditions and cultural practices.

The species most commonly shared across studies were *Artemisia herba-alba, Olea europaea, Trigonella foenum-graecum, Salvia rosmarinus, and Allium sativum*, indicating a shared ethnomedicinal heritage across the Maghreb. These species form a "core" antidiabetic pharmacopoeia that transcends regional boundaries. At the same time, the moderate Jaccard values (most below 0.5) indicate that each region also possesses a significant proportion of locally specific species, reflecting adaptations to local ecological conditions and cultural practices.

Table 3. Toxicological evaluation of selected antidiabetic medicinal plants documented in Khenchela Province.

Medicinal Plant	Part Used	Risk Level	Type of Toxicity	Possible Toxic Effects	References
Nerium oleander L.	Leaves, flowers, latex	Very high	Cardiotoxic	Cardiotoxicity (cardiac glycosides), arrhythmias, atrioventricular block, cardiac arrest	Langford & Boor, 1996; Osterloh *et al*., 1982
Artemisia absinthium L.	Aerial parts (leaves, stems)	High	Neurotoxic	Neurotoxicity due to thujone, seizures, tremors, hallucinations	Höld *et al*., 2000; Efferth *et al*., 2011
Aloe ferox Mill.	Leaf latex (sap)	Moderate to high	Gastrointestinal, nephrotoxic	Chronic diarrhea, electrolyte imbalance (hypokalemia), renal impairment	Boudreau & Béland, 2006
Cassia angustifolia Vahl	Leaves, pods	High	Gastrointestinal, metabolic	Laxative dependence, hypokalemia, intestinal mucosa damage	Lemli *et al*., 1980
Eucalyptus globulus Labill.	Essential oil (leaves)	High (essential oil)	Neurotoxic	CNS depression or excitation, seizures due to eucalyptol (1,8-cineole)	Tisserand & Young, 2014
Peganum harmala L.	Seeds, roots	Very high	Neurotoxic, psychoactive	Hallucinogenic effects, MAO inhibition, tremors	El Bahri & Chemli, 1988; Moloudizargari *et al*., 2013
Ruta montana L.	Leaves, aerial parts	High	Hepatotoxic, reproductive, phototoxic	Hepatotoxicity, abortifacient effects, photosensitization, dermatitis	Abdel-Mogib *et al*., 2002

Study limitations

Several limitations should be considered when interpreting the findings of this study. First, the survey was conducted between February and May, which may have influenced the availability and identification of certain seasonal plant species, potentially underestimating the full diversity of antidiabetic flora in the region. Second, the sample size (n = 116), while appropriate for a preliminary ethnobotanical inventory, represents a modest proportion of the provincial population, and the findings may not fully capture the diversity of local practices across all 40 municipalities. Third, the study relied on informant self-reporting of diabetes type, which may introduce diagnostic uncertainty given limited access to clinical confirmation in some rural areas. Fourth, detailed information on remedy dosages, treatment duration, frequency of administration, and clinical outcomes was not systematically collected, limiting the clinical applicability of the findings. Fifth, the predominance of female informants (65.5%), while reflective of gendered healthcare roles, may introduce a gender bias in the documented knowledge. Finally, the study did not include systematic documentation of potential toxicity mitigation strategies employed by traditional healers, which represents an important avenue for future research.

Despite these limitations, this study provides essential foundational data for prioritizing species for further investigation. Future research should focus on: (i) phytochemical characterization and isolation of bioactive compounds from high-RFC species; (ii) *in vitro* and *in vivo* pharmacological evaluation of antidiabetic activity; (iii) comprehensive toxicity assessment and establishment of safety profiles; (iv) investigation of potential herb-drug interactions with conventional antidiabetic medications; (v) ethnobotanical surveys in additional municipalities to capture the full regional diversity; and (vi) development of strategies for the preservation and intergenerational transmission of traditional knowledge.

Table 4. Comparative analysis of antidiabetic medicinal plants (44 species) recorded in Khenchela Province with previously published studies from Algeria and Morocco.

Reported areas (Country)	Total taxa in paper	Common Taxa	% of Taxa with same uses	% of Taxa with different uses	JI	Citation
Bejaia (Algeria)	43	19	37.2	7.0	0.279	Belmouhoub *et al*. (2022)
M'Sila (Algeria)	39	17	38.5	5.1	0.258	Boudjelal *et al*. (2013)
Bouira (Algeria)	43	14	38.7	6.5	0.192	Nouri *et al*. (2025)
Sidi Bel Abbès (Algeria)	33	13	33.3	6.1	0.203	Lakhdari *et al*. (2019)
Azilal (Morocco)	26	11	34.6	7.7	0.186	Mahzoune *et al*. (2026)
Fès-Meknès (Morocco)	50	15	26.0	4.0	0.190	Mechchate *et al.* (2020)
Ouargla (Algeria)	67	18	22.4	4.5	0.194	Telli *et al*. (2016)
Rabat (Morocco)	30	12	33.3	6.7	0.194	Skalli *et al*. (2019)
Errachidia (Morocco)	47	14	25.5	4.3	0.182	Tahraoui *et al*. (2007)
Tafilalet (Morocco)	36	12	27.8	5.6	0.176	Eddouks *et al.* (2002)
Souk Ahras (Algeria)	39	11	23.1	5.1	0.153	Bouzabata & Mahomoodally (2020)
Safi and Essaouira (Morocco)	84	22	21.4	4.8	0.208	Tahraoui *et al*. (2023)
High Atlas (Morocco)	144	15	8.3	2.1	0.087	Belhaj *et al*. (2021)

Note: JI = Jaccard Index calculated as c/(a+b−c) where a = total taxa in Khenchela (44), b = total taxa in compared study, c = taxa common in both areas. Taxa with same uses refers to species sharing identical therapeutic indications for diabetes management.

Conclusion

This ethnobotanical survey conducted in Khenchela Province documents a rich and still widely used repertoire of 44 medicinal plant species employed in diabetes management, with women (65.5%) and older informants (68.1% aged ≥50 years) acting as the primary custodians of this knowledge. The predominance of leaf-based infusions and the high RFC values recorded for *Artemisia herba-alba* (RFC = 0.096) and *Salvia rosmarinus* (RFC = 0.078) point to a culturally coherent core of antidiabetic remedies deserving priority in future phytochemical and pharmacological investigations. The overlap between food and medicine for 27.3% of documented species underscores their dual value in local culture and suggests potential applications in nutritional interventions. The Jaccard similarity analysis revealed moderate similarity with other Maghrebian pharmacopoeias (JI = 0.087-0.279), reflecting both shared ethnomedicinal heritage and unique regional adaptations.

This study provides essential foundational data for prioritizing species for further investigation. Future research should focus on phytochemical characterization, pharmacological evaluation of antidiabetic activity, comprehensive toxicity assessment of high-RFC species, and strategies for preserving and transmitting traditional knowledge. Taken together, these findings highlight both the therapeutic potential and the vulnerability of local traditional knowledge, underscoring the need for developing safe, evidence-based phytomedicines that can complement conventional diabetes care.

Declarations

Ethics approval and consent to participate: Ethics approval and consent to participate: The study protocol adhered to internationally accepted ethical guidelines for ethnobotanical research involving human participants. Prior to each interview, the research objectives were clearly explained to participants, and verbal informed consent was obtained. Participants were assured of the confidentiality and anonymity of their responses.

Consent for publication: Not applicable

Availability of data and materials: Not applicable

Competing interests: Not applicable

Funding: Not applicable

Author contributions: N.M. contributed to conceptualization, investigation, formal analysis, data curation, and writing of the original draft. S.B. contributed to validation and manuscript review and editing. S.S. contributed to investigation, validation, and data curation. S.G. and N.L. contributed to conceptualization, investigation, and writing. L.A. and A.B.

contributed to methodology, validation, and manuscript review and editing. A.F., K.A., H.M., and S.H. contributed to methodology development, validation of the findings, and manuscript review and editing.

Acknowledgements

We would like to thank all participating informants for their time, cooperation, and valuable contributions to this research.

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