The status and perception of medicinal plants by local population of Adrar province (Northern Mauritania)

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Research

Abstract

Background: In the province of Adrar (northern Mauritania), there is significant interest in medicinal plants and their use. However, the utilization of herbal medicines has been largely underestimated, with little or no scientific data regarding the status, perception of inhabitants of northern Mauritania, confidence in the healing properties of medicinal plants, and the conservation of traditional medicinal heritage of the local population.

Methods: The semi-structured interviews, and questionnaires were conducted between 2014 and 2016 in the 11 municipalities of Adrar province. A total of 120 participants aged from 20 to 90 years old, including 24 herbalists and 28 traditional healers. The ethnobotanical data were quantitatively analyzed using indices such as relative popularity level (RPL), rank order priority (ROP), the Medicinal Plant Knowledge index (MPKi), the Medicinal Plant Use index (MPUi), and the Informant consensus factor (ICF).

Results: In the present study, we identified 68 taxa from 27 different botanical families. The most significant family is Fabaceae, with 14 species. These plants are used to treat 50 conditions or symptoms grouped into 14 pathological groupings according to the international classification of primary care (ICPC-2). The analysis revealed that the highest value of MPU was obtained for *Vachellia tortilis* (Forssk.) Galasso &Banfi., *Adansonia digitate* L. and *Balanites aegyptiaca* (L.) Delile (MPUi= 100%). In addition, the high fidelity level (FL=100) was recorded for *Vachellia tortilis*, *Adansonia digitata* and *Balanites aegyptiaca*, these three species a very high capability (ROP=100) in improving hypertension and Diabetes. For the Informant Consensus Factor (ICF) the most prevalent groups were Cardiovascular (K) with (ICF=0.97).

Conclusions: The knowledge revealed in this study provides a particularly unique source of information on local traditional medicine and adds value to Adrar province.

Keywords: Mauritanian plants, Medicinal plants, Adrar, ethnobotany, ethnomedicine, traditional medicine.

Background

Human beings possess the ability to transmit knowledge across time and space through oral and written means (Pardo-de-Santayana and Macía 2015, Garnatje *et al*. 2017, Pardo-de-Santayana *et al*. 2013). Ethno-pharmacology combines

sociocultural and natural sciences, and understanding its historical aspects requires an examination of its development as a scientific discipline (Buenz *et al*. 2005, Leonti *et a*l. 2010; Touwaide 2010, Adams *et al*. 2011, Lardos & Heinrich, 2013, dal Cero et *al*. 2014). While written records of remedies and medical practices exist in many cultures (Heinrich, 2000, Rivera *et al*. 2006, Heinrich *et al*. 2006, Heinrich, 2010, Leonti *et a*l. 2010, 2011), ethnobiology seeks to explore and document traditional knowledge systems in a holistic manner.

The documentation of knowledge plays a vital role in the field of ethnobiology, as it serves as a foundation for further research and evaluation of indigenous pharmacopoeias (Berlin, 1992, Robineau & Soejarto, 1996, Frei *et al*. 1998, Leonti *et al*. 2001, Touwaide 2010, Leonti 2011). Despite the advancements in technology and scientific discoveries, ethno-pharmacology provides a comprehensive understanding of the ecological context, plant perception, plant use, and pharmacology within human communities (Ginzburg 1990).

According to multiple studies (Hayta *et al*. 2014, Chen *et al*. 2016, Dossou-Yovo *et al*. 2017, Monika *et al*. 2020), the utilization of plant species as traditional is of paramount importance in addressing the healthcare needs of rural communities in developing nations. In these regions, it is estimated that approximately 80% of the population relies on traditional medicines as their primary healthcare system. One of the key advantages of traditional medicines is their cost-effectiveness, safety, and affordability (WHO 2002).

Globally, about 85% of traditional medicines used in primary healthcare are derived from plant species (Farnsworth 1988, Rivera *et al.* 1995, 2014, Heinrich *et al*. 2006, Bellakhdar 2006, Leonti 2011). This highlights the immense importance of medicinal plants as a valuable indigenous heritage with global significance (Purohit & Vyas 2004). Among the reported 422,000 species of flowering plants, approximately 50,000 are utilized for medicinal purposes (Parmesan 2006). This rich diversity of medicinal plants provides a vast resource for healthcare and therapeutic applications.

Moreover, the preservation and sustainable utilization of medicinal plants are essential for maintaining cultural traditions, conserving biodiversity, and supporting local economies. By recognizing the value of traditional knowledge and promoting responsible practices, we can ensure the continued availability and accessibility of these plant resources for future generations (Tu 2016, Rigat *et al*. 2015, Garnatje *et al*. 2017, Dal Cero *et al*. 2014).

Mauritania is located at the convergence point of the Maghreb and Sub-Saharan Africa. It covers a surface area of 1,030,700 km2 and is located between latitude 15° and 27° North and longitude 05° to 17° West. It borders to the south by Senegal, to the southeast by Mali, to the northeast by Algeria, and to the north by Morocco. To the west, the coastline stretches over 700 kilometers along the Atlantic Ocean.

Ethnobotanical study documents how indigenous peoples utilize plants and manage ecosystems, which is critical for maintaining global biological integrity and might provide crucial knowledge for bioprospecting for novel food crops and medicines (Hoban *et al*. 2020, Pei *et al*. 2020, Ulian *et al*. 2020, Atanasov *et al*. 2021). The scientific community is currently paying close attention to studies on the traditional uses of plants. Several studies (Adje 1998, Awfa 1983, 1996, Hamidoun 1952, Mame N'Diak 1977, Leriche 1953, Vall 2009, Thouzery and Vall, 2011) have written about indigenous knowledge of medicinal plants throughout various areas of Mauritania, while very few study in ethnobotanical approach have been conducted in the region, there have been recent published (Yebouk *et al*. 2020).

Therefore, this study aims to document traditional medicinal plants that are used by the indigenous population of the Adrar region, the analysis of data regarding the interviewees' (socio-demographic) status, perception of the inhabitants of Northern Mauritania, confidence in the healing properties of medicinal plants, and conservation of the traditional medicinal heritage of the local population.

Material and Methods

Study area

The Wilayas (provinces) of Adrar (Figure 1), named after the Adrar Plateau, comprise a large administrative region in northern Mauritania, covering an area of 235,000 km2, which is 22.8% of Mauritania's total land area (1,030,700 km^2) (ONS 2011). Our study specifically focuses on the Wilaya of Adrar, located entirely in northern Mauritania, between 20° and 30° north latitude and 10° and 04° west longitude.

According to ANSADE (2021), the population of the Wilaya of Adrar is 60,984 inhabitants. With a population density of 0.33 inhabitants per square kilometer, Adrar is the second least populated Wilaya, following Tiris Zemmour and preceding Inchiri. The Adrar region is characterized by its significant relief, with mountain ranges that reach heights of up to 800m (the Adrar plateau) and impressive sand dunes (El Mejabat el khoubra, Erg Ouarâne), offering breathtaking views and a captivating mix of sand and stone s. Among these mountains, one can admire one of the most beautiful sites in Mauritania, the gorges of the Amogjâr pass, as well as a series of oases (ONS 2011).

Adrar is classified as having a desert climate according to the Köppen Climate Geiger's classification (Rubel & Kottek 2010). The region experiences very little precipitation throughout the year. The climate in Adrar is classified as BWh according to

the Köppen-Geiger system. The average annual temperature is 25.9 °C, and the average annual rainfall is approximately 11 mm (www.globalbioclimatics.org).

The Adrar region is home to three main ethnic groups: Maures, Sononiké, and Poular, as well as the Wolof community. The primary language spoken is Hassanya, a dialect of Arabic. The province can be divided into four departmental parts: 1. Atar regions, 2. Aoujeft, 3. Chinguitty, and 4. Ouadan (Fig. 1). The local population heavily relies on medicinal plants and traditional healers to fulfill their basic healthcare needs.

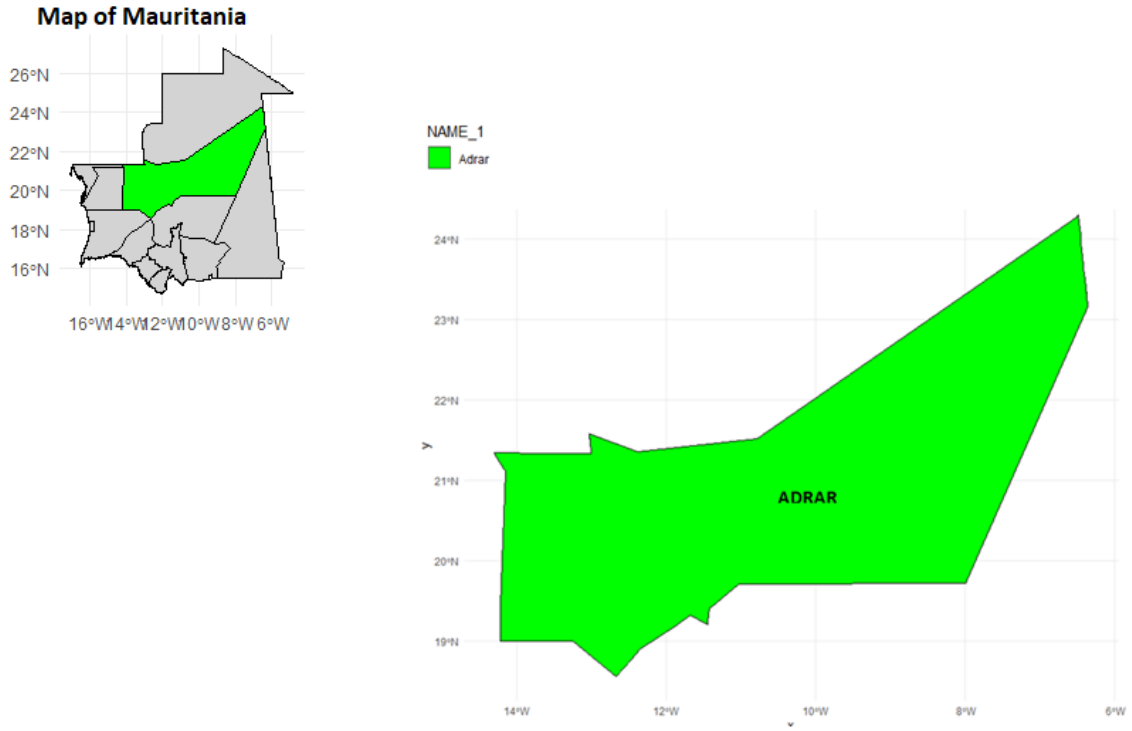


Figure 1. Map of the Adrar province, Mauritania

Ethnobotanical Approach and Surveys

The field survey conducted between 2014 and 2016 was based on the previous works of our research group (Merzouki *et al*. 1997, 2000, Yebouk *et al.* 2020, Yebouk 2021 and Redouan *et al.* 2020, 2022). The first phase of the survey involved visiting villages to identify traditional healers and individuals with extensive knowledge of the traditional use of plants. Once suitable informants were identified and selected, our ethnobotanical data collection primarily relied on open semi-structured interviews, which are participatory tools enabling the gathering of diverse information from local populations (Martin 2004). Informed consent was obtained from participants prior to questionnaire completion, and the snowball technique was employed to gather ethnobotanical data through semi-structured interviews conducted in Hassanya (the Mauritanian Arabic dialect). All researchers adhered to the ethical criteria of the International Society of Ethnobiology (2006) (http://www.ethnobiology.net).

The interviews were conducted using open-ended, indirect, and direct questions to gather information on various plant uses. The ethnobotanical fieldwork spanned a period of two years, and informants were sought in various settings: a) houses; b) streets; c) traditional medicine cabinets; d) among family, friends, and contacts; and e) through spontaneous encounters in villages, markets, fields, and mountains (Akerreta *et al*. 2010).

During the interviews, we also used a thorough and organized questionnaire that we created in partnership with the participants. This survey proved to be an invaluable instrument for compiling particular data and insights into the usage and understanding of medicinal plants. A more structured and methodical approach to the study process was made possible by the data collected, which included not just the colloquial names for plants, the sections of plants used, preparation methods, delivery systems, and the specific health issues that were being studied. The integration of interviews and standardized questionnaires enabled a comprehensive analysis of the topic. (Yebouk *et al*. 2020).

A total of 120 informants were interviewed during the fieldwork, including 24 herbalists (H) and 28 traditional healers (TH). The surveyed villages included Atar (31 informants; including 7 H and 6 TH), Tawaz (9 informants; 1 H and 1 TH), Ain ehltaya (11 informants; 2 H and 2 TH), Choum (7 informants; 2 H and 2 TH), Aoujeft (13 informants; 2 H and 2 TH), El Medah (7 informants; 1 H and 3 TH), Maeden (5 informants; 1 H and 1 TH), N'terguent (10 informants; 1 H and 3 TH), Chinguitti (9

informants; 1 H and 3 TH), Ain savra (8 informants; 2 H and 1 TH), and Ouadane (10 informants; 4 H and 4 TH). Our interviewees were natives of various localities in Adrar, predominantly from Atar, Awjeft, Chinguetti, and Ouadane.

The taxonomic identification of the plants was conducted by comparing them with identified specimens preserved in the Herbarium National Mauritanian. The voucher numbers for the included plants can be found in the results section. Each plant sample was assigned a specific code, such as "HNM00000," in accordance with the international herbarium code for Herbarium National Mauritanian (HNM).
The vernacular names of the plants were recorded in both Arabic and Roman alphabets, as provided by our informants. To categorize the illnesses treated, we utilized the worldwide disease categories outlined by the World Health Organization (WHO) in the International Classification of Primary Care (ICPC-2, 2015), as suggested by Staub *et al*. (2015).

Data analysis
In our study, various quantitative ethnobotanical data analysis techniques were employed to assess the importance of medicinal plants within the community. These techniques included the calculation of several indices.
To determine the knowledge of medicinal plants and their applications, we calculated the Medicinal Plant Knowledge index (MPKi) and the Medicinal Plant Use index (MPUi). The MPKi represents the percentage of informants who cited a particular plant, while the MPUi represents the percentage of informants who reported using a specific medicinal plant for each pathological category. These indices were calculated based on the responses obtained from the interviews and used formerly in Merzouki *et al*. (2000) and Redouan *et al*. (2022), (2023). those indices were calculated on the basis of the responses obtained through using following formulae in Eq. (1) and Eq. (2):

$$\boldsymbol{MPKi}(\%) = (\boldsymbol{Ik}/\boldsymbol{N}) \times \mathbf{100} \qquad \textbf{(1)}$$

$$\mathbf{MPUi}(\%) = \left(\frac{\mathbf{IU}}{\mathbf{N}}\right) \times \mathbf{100} \qquad (\mathbf{2})$$

Where **Ik** is the number of informants who cited the plant and **N** is the total number of interviewers.
IU is the number of interviewers who reported the use of a specific medicinal plant in each pathological category.
Where Ik is the number of informants who cited the plant; IU is the number of interviewers who reported the use of a specific medicinal plant in each pathological category, and N is the total number of interviewers.

The confidence level (CI), measured as MPUi/MPKi, was also calculated to assess the level of confidence in the healing properties of medicinal plants. This index provides insight into the proportion of informants who have confidence in the efficacy of a particular plant.

The Fidelity Level (FL) was determined to identify the proportion of informants in the study area who claimed to have used specific plant species to treat a particular condition. The FL index is calculated by dividing the number of informants who used a specific plant species for a specific ailment by the total number of informants who used the species for any disease. The FL index is calculated by using the following formula in Eq. (3) (Alexiades *et al.* 1996, Friedman*et al*. 1986):

$$\boldsymbol{FL} = \boldsymbol{Np} \,/\, \boldsymbol{N} \quad (\mathbf{3})$$

Where **Np** represents the number of informants who claimed to have used a specific plant species for a specific ailment, and **N** represents the total number of informants who used the species for any disease.

The Relative Popularity Level (RPL) was used to classify plant species as popular or unpopular. Plants cited by more than half of the maximum number of informants who reported a plant for any medical use were considered popular, while the remaining plants were labeled as unpopular.
Rank Order Priority (ROP) was calculated to rank plant species based on their FL and RPL values. This index helps prioritize plant species according to their importance in the local context.

The ethnobotanical data were evaluated, and the ROP index was derived using the applicable standard procedures indicated in Friedman *et al.* (1986), Alexiades (1996) and Ali-Shtayeh *et al.* (2000). ROP is a correction factor that is used to rank plant species based on their FL and RPL values. The ROP is calculated by multiplying the RPL and FL values, as previously discussed (Friedman *et al.* 1986 and Ali-Shtayeh *et al.* 2000).

Finally, the Informant Consensus Factor (ICF) was used to determine the level of population consensus on various categories of plant usage. The informant consensus factor (ICF), as defined by Trotter and Logan (1986) was used to determine the level of population consensus on several categories of usage. The ICF values range from 0 to 1, with higher values indicating a higher level of consensus among informants. The FIC shows different levels of similarity among the obtained information and is calculated using the following formula in Eq. (4):

$$\boldsymbol{ICF} = (\boldsymbol{Nur} - \boldsymbol{Nt}) \,/ (\boldsymbol{Nur} - \mathbf{1}) \qquad (\mathbf{4})$$

Where **Nur** = number of citations for each category, **Nt** = number of species for this same category.

These quantitative ethnobotanical analyses provide valuable insights into the local knowledge and utilization of medicinal plants in the study area, allowing for a comprehensive understanding of their importance and potential therapeutic value.

Results and Discussion

Demography of informants

The demographic characteristics of the informants in our study revealed interesting patterns. A total of 120 participants were interviewed, consisting of 70 women and 50 men (Table 1), resulting in a sex ratio of 1.4 women to men. It was observed that women in the study area used plant species more frequently than men, with 58% of women surveyed reporting plant use compared to 42% among men. This finding aligns with similar studies conducted in other regions (Benkhnigue *et al*. 2011, El Hafian *et al*. 2014), highlighting the greater involvement of women in plant-based treatments and the preparation of herbal remedies for their families.

Regarding the education level of the informants, the majority were at the primary level or illiterate (Figure 2). Interestingly, as the level of education increased, the use of plants decreased. This trend may be attributed to the fact that some illiterate individuals may use medicinal plants in an irrational manner, lacking the knowledge to understand proper dosages and instructions provided by herbalists and healers. Additionally, higher education levels may lead individuals to rely more on modern healthcare systems rather than traditional remedies (Mukherjee 2002, Bodeker et al. 2005, Bandaranayake 2006).
The dominant ethnic group among the informants was Maures, followed by Wolof (Table 1). It is noteworthy that all informants in the study area were speakers of the Hassanya language, reflecting its prevalence as the primary language of communication.

In terms of occupation, the majority of informants were unemployed, comprising 40 participants. Traditional healers, herbalists, sellers, and shepherds were also represented among the informants, with 28, 24, 10, and 5 participants, respectively (Table 1). This diversity in occupations suggests that various segments of the population are involved in the use and knowledge of medicinal plants.

Regarding the income of the informants, the majority were at the Lew level (<7000 MRU/ month) (Table 1).

Overall, the demographic profile of the informants provides valuable insights into the social context and cultural practices related to the use of medicinal plants in the study area. Understanding these factors is crucial for comprehending the dynamics of plant usage and the transmission of traditional knowledge within the community.

Table 1. Demographic characteristics of the informants

Variables	Categories	Number of informants	Percentage %
Gender	Male	50	41.67
	Female	70	58.33
Age classes	Young (18-25 age)	10	08.33
	Adult (26-44 age)	25	20.83
	Middle-age (45-59 age),	30	25.00
	Old age (60 age)	26	21.66
Ethnic groups	Maures	110	91.67
	Peuls	10	08.33
Education levels	Illiterate	28	23.33
	Elementary	30	25.00
	Secondary	27	22.50
	University	20	16.67
	Others	15	12.50
Income/MRU	High>12000	20	16.66
	Middle (8000-12000)	22	18.34
	Low <8000	78	65

Medicinal plants and traditional uses

Medicinal plants and groups of diseases

In this study, a total of 68 medicinal plants belonging to 27 families were used to treat 14 different diseases (Table 2). The species list, arranged by disease categories in alphabetical order (with the ICPC-2 code). The most important families are Fabaceae with 14 species, or (20.2%), followed by Poaceae with 7 species, or 10%, Malvaceae, Capparaceae, Apocynaceae

and Cucurbitaceae (4 species each, or 6%) (Figure 6). The Fabaceae are the family most used in traditional medicine in the population living in our study area. The importance of this family is confirmed by Vall *et al*. (2015) in the entire Mauritanian territory. After the Fabaceae, we find the Poaceae are the most represented families in this survey.

Table 2. Medicinal plants with voucher, pathological groups and treated diseases & symptoms codes.

Pathological groups (ICPC2)	Conditions / symptoms codes	Species (Vouchers)
A. General and Unspecified	Measles A71	*Capparis decidua* (Forsk.) Edagew (HNM00706)
	Fever A03	*Ammodaucus leucotrichus* Coss. & Durieu
	Malaria A73	*Prosopis juliflora* (Sw.) DC.
	Intoxication A86	*Grewia bicolor*. Juss (HNM01752)
		Azadirachta indica A.Juss.
		Ziziphus mauritiana Lam. (HNM01711)
		Ziziphus lotus (L). Lam. (HNM01705)
		Salvadora persica L. (HNM01729)
		Phoenix dactylifera L. (HNM00008)
B. Sangs, Systeme hematopoietique, Lymphatique, Rate	Anaemia B81	*Vigna unguiculata* (L.) Walp. (HNM00252)
		Salvadora persica L. (HNM01729)
D. Digestive	Oral abscess D83	*Fagonia glutinosa* Del (HNM00609)
	Toothache D19	*Tamarix senegalensis* DC. (HNM00859)
	Abdominal pain epigastric D02	*Tribulus terrestris* L. (HNM00973)
	Constipation D12	*Balanites aegyptiaca* (L.) Delile (HNM00634)
	Toothache D19	*Ziziphus lotus* (L). Lam. (HNM01705)
	Diarrhoea D11	*Ziziphus mauritiana* Lam. (HNM01711)
	Viral hepatitis D72	*Zea mays* L.
	Jaundice D13	*Triticum aestivum* L.
	Toothache D19	*Sorghum bicolor* (L.) Moench. (HNM00441)
	Vomiting D10	*Panicum turgidum* Forrsk (HNM01331)
	Dyspepsia D07	*Hordeum vulgare* L.
	Mouth symptom D20	*Grewia bicolor* Juss (HNM01752)
	Heartburn D03	*Hibiscus sabdariffa* L. (HNM00351)
	Worms D96	*Adansonia digitata* L. (HNM01538)
		Mentha spicata L.
		Vachellia seyal (Delile) P.J.H. Hurter. (HNM01584)
		Vigna unguiculata (L.) Walp. (HNM00252)
		Vachellia tortilis (Forssk.) Galasso &Banfi. (HNM00620)
		Acacia ehrenbergiana Hayne (HNM01592)
		Tamarindus indica L. (HNM00116)
		Acacia senegal (L.) Willd. (HNM00320)
		Senna occidentalis (L.) Link (HNM01570)
		Senna italica Mill. (HNM01562)
		Prosopis juliflora (Sw.) DC.
		Kebirita roudairei (Bonnet). Kramina&. D. D. Sokoloff (HNM00299)
		Calotropis procera (Ait.) Ait. fil. (HNM01522)
		Adenium obesum (Forssk) Roem.&Schult (HNM00006)
		Allium sativum L.
		Allium cepa L.
		Cullen plicatum (Delile) C.H. Stirt. (HNM01983)
		Bauhinia rufescens Lam. (HNM01550)
		Arachis hypogaea L. (HNM00261)
		Euphorbia scordiifolia Jacq. (HNM01120)
		Momordica balsamina L. (HNM00194)
		Cucumis prophetarum L. (HNM00190)
		Citrullus lanatus (Thunb.) Matsumura. &Nakai (HNM00138)
		*Combretum glutinosum*Perr.ex. DC. (HNM00134)
		Guiera senegalensis J.F.Gmel. (HNM01400)

		Combretum aculeatum Vent. (HNM02328)
		Gymnosporia senegalensis (Lam.) Loes. (HNM01466)
		Capparis decidua (Forsk.) Edagew (HNM00706)
		Maerua crassifolia Forssk (HNM01452)
		Boscia senegalensis Lam. (HNM00988)
F. Eye	Eye pain F01	*Vachellia nilotica (L.) P.J.H. Hurer & Mabb. (HNM00614)*
		Vachellia flava (Forssk.) Kyal. & Boatwr. (HNM01592)
		Heliotropium bacciferum Forssk. (HNM01425)
K. Cardiovascular	Hypertension K86	*Ziziphus lotus* (L). Lam. (HNM01705)
	Haemorrhoids K96	*Ziziphus mauritiana* Lam. (HNM01711)
		Adansonia digitata L. (HNM01538)
		Vachellia tortilis (Forssk.) Galasso &Banfi. (HNM00620)
L. Musculoskeletal	Musculoskeletal disease L99	*Anastatica hierochuntica* L. (HNM01193)
	Back symptom L02	*Boscia senegalensis* Lam. (HNM00988)
	Muscle pain L18	*Allium cepa* L. *Mentha spicata* L.
		Prosopis juliflora (Sw.) DC.
N. Neurological	Headache N01	*Lawsonia inermis* L. (HNM00344) *Tamarindus indica* L. (HNM00116)
R. Respiratory	Cough R05	*Sterculia setigera* Del. (HNM01741)
	Asthma R96	*Hibiscus sabdariffa* L. (HNM00351)
	Pain respiratory system R01	*Ocimum basilicum* L. (HNM01553)
	Whooping cough R71	*Vigna unguiculata* (L.) Walp. (HNM00252)
	Bronchitis R78	*Calotropis procera* (Ait.) Ait. fil. (HNM01522)
	Breathing problem R04 Skin injury S19	*Euphorbia calyptrata* Coss. & Kralik (HNM00254)
	Foreign body in skin S15	*Cucumis prophetarum* L. (HNM00190)
	Boil S10	*Guiera senegalensis*J.F. Gmel. (HNM01400)
	Laceration S18	*Cleome arabica* L. (HNM01443)
	Rash localized S06	*Maerua crassifolia* Forssk (HNM01452)
		Kebirita roudairei (Bonnet). Kramina&. D. D. Sokoloff (HNM00299)
		Pergularia tomentosa L. (HNM01532)
		Heliotropium bacciferum Forssk. (HNM01425)
		Commiphora africana (A. Rich.) Endl (HNM00060)
		Citrullus colocynthis (L.) Schrad. (HNM02009)
		Cullen plicatum (Delile) C.H. Stirt. (HNM01983) *Ammodaucus leucotrichus* Coss. &Durieu
		Euphorbia scordiifolia Jacq. (HNM01120)
S. Skin	Acne S96	*Arachis hypogaea* L. (HNM00261)
	Skin colour change S08	*Allium cepa* L.
	Burn S14	*Allium sativum* L.
	Scabies S72	*Ammodaucus leucotrichus* Coss. & Durieu
	Skin disease S99	*Adenium obesum* (Forssk) Roem. & Schult (HNM00006)
		Senna italica Mill. (HNM01562)
		Senegalia senegal (L.) Britton (HNM00320)
		Vachellia nilotica (L.) P.J.H. Hurer & Mabb. (HNM00614)
		Lawsonia inermis L. (HNM00344)
		Cenchrus americanus (L.) Morrone (HNM00437)
		Ziziphus lotus (L). Lam. (HNM01705)
		Euphorbia balsamifera Aiton. (HNM00623)
		Balanites aegyptiaca (L.) Delile (HNM00634)
		Pergularia tomentosa L. (HNM01532)
		Heliotropium bacciferum Forssk. (HNM01425)
		Commiphora africana (A. Rich.) Endl (HNM00060)
		Citrullus colocynthis (L.) Shchard. (HNM02009)
		Euphorbia scordiifolia Jacq. (HNM01120)

T. Endocrine/Metabolic and Nutritional	Diabetes non insulindependent T90 Loss of appetite T03	*Balanites aegyptiaca* (L.) Delile (HNM00634)
		Ziziphus mauritiana Lam. (HNM01711
		Hordeum vulgare L.
		Ocimum basilicum L. (HNM01553)
		Allium sativum L.
		Arachis hypogaea L. (HNM00261) *Citrullus colocynthis* (L.) Shchard. (HNM02009)
		*Combretum glutinosum*Perr.ex. DC. (HNM00134)
		Gymnosporia senegalensis (Lam.) Loes. (HNM01466)
		Boscia senegalensis Lam. (HNM00988)
		Anastatica hierochuntica L. (HNM01193)
		Phoenix dactylifera L. (HNM00008)
		Maerua crassifolia Forssk (HNM01452)
U. Urological	Dysuria U01	*Tapinanthus globiferus (A. Rich.) van Tiegh. (HNM00626)*
	Kidney symptom U14	*Stipagrostis pungens* (Desf.) De. Winter (HNM01285)
		Ziziphus lotus (L). Lam. (HNM01705)
W. Pregnancy, Childbearing, Family Planning	Complications of puerperium W96	*Mitragyna inermis* (Willd). Kuntze. (HNM00526)
X. Female Genital	Menstrual pain X02	*Cleome arabica* L. (HNM01443)
	Breast cancer X76	*Stereospermum kunthianum* Cham. (HNM10013)
	Syphilis X70	*Commiphora africana* (A. Rich.) Endl (HNM00060)
Y. Male Genital	Impotence Y07	*Schouwia purpurea* (Forssk) Schweinf (HNM00061)
	Infertility Y10	*Cleome arabica* L. (HNM01443)

Quantitative ethnobotany

Use of medicinal plants by the population of the Adrar region

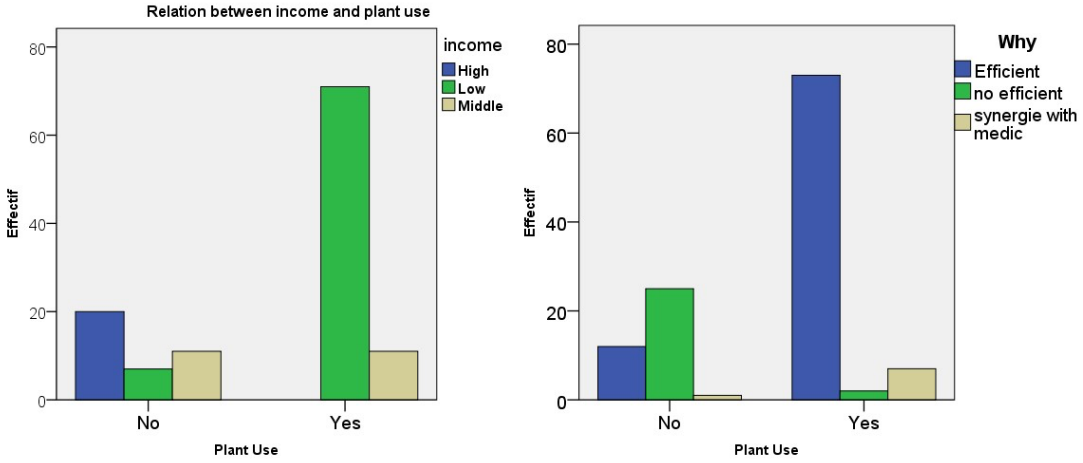
In Figure 2, two main groups were identified in terms of the use of medicinal plants. The first group represented individuals who extensively used medicinal plants in their daily lives. The second group consisted of people who were not accustomed to consuming medicinal plants for various reasons

Based on the result in figure 2a, it is evident that the use of plants for medicinal purposes in the Adrar province is closely linked to economic factors. Individuals with low income are the ones who predominantly utilize these plants and search for them for therapeutic reasons.

Our survey revealed a noteworthy correlation between income levels and healthcare preferences. Individuals with lower incomes demonstrated a tendency to favor the use of plant-based remedies over modern pharmaceuticals (Figure 2a). This inclination can be attributed to several factors, including affordability and accessibility. Due to financial constraints, those with limited income often opt for plant-based alternatives, which are often more economically viable. Additionally, the cultural significance and historical ties to traditional practices play a role in shaping these preferences. Conversely, our findings also indicated that individuals with higher incomes exhibited a reduced reliance on plant-based remedies, possibly due to greater access to and awareness of modern medical treatments. These insights underscore the intricate interplay between socioeconomic factors and healthcare choices, highlighting the need for a nuanced approach to healthcare that considers individual circumstances and beliefs (Mackenbach *et al*. 1989; Anderson *et al*. 2016).

The motivation behind the use of medicinal plants was analyzed in Figure 2b. Two main groups were observed: the first group consisted of individuals who did not use herbal remedies as they perceived them to be ineffective, instead relying on conventional medicine. The second group included individuals who used herbal remedies due to their perceived effectiveness, affordability, and alignment with their culture and traditions.

These results findings indicate a concerning trend of decreasing faith in traditional medicine and the potential loss of traditional knowledge among the population in the Adrar region. The results align with previous research by Redouan *et al*. (2020) that reported similar patterns. It highlights the need for efforts to preserve and promote traditional ethnobotanical knowledge in the region to ensure its conservation for future generations.



(a) **(b)**

Figure 2. Use of Medicinals plants (a) relation between income and plant use (b) the motivations behind the use of medicinal plants by the population of the Adrar region.

In this study, herbalists and traditional healers often demonstrate a preference for utilizing plant-based remedies rooted in their extensive experiential knowledge (Figure 3). Their reliance on plants is a result of their accumulated wisdom and practical understanding of the therapeutic properties inherent in various botanical species. Due to their years of hands-on experience, these practitioners have honed their skills in identifying, preparing, and administering plants for healing purposes.

The use of plants by herbalists and traditional healers is deeply influenced by their familiarity with the plants' effects, interactions, and applications. Their expertise allows them to discern which plants are best suited to address specific ailments based on observed outcomes and historical practices. This experiential wisdom empowers them to tailor treatments to individual patients and their unique health conditions, contributing to the holistic approach characteristic of traditional healing systems (Fakchich *et al*. 2022, Belhouala & Benarba 2021)

Furthermore, the preference for plant-based remedies among herbalists and traditional healers underscores the reverence for nature's healing potential ingrained in many traditional medicinal practices. The reliance on plants as a primary source of therapeutic interventions exemplifies the intrinsic connection between these practitioners and the natural world (Adje 1998). This relationship is often rooted in cultural heritage and passed down through generations, reinforcing the role of plants as integral components of traditional healing traditions (Karunamoorthii *et al*. 2013).

The study analyzed the level of knowledge and use of medicinal plant species in the study area. Two indexes were calculated for each plant: the knowledge index (MPKi) and the use index (MPUi). The higher the values of MPKi and MPUi, and the closer the confidence level index (Cl = MPUi / MPKi) to 1, the more widespread the knowledge and use of a specific medicinal plant.

The three plant species with the highest use and knowledge indexes (100% and Cl=1) were *Vachellia tortilis*, *Adansonia digitata*, and *Balanites aegyptiaca*. Additionally, two plant species, *Anastatica hierochuntica* and *Ocimum basilicum*, had a confidence level of 1 with both MPUi and MPKi at 5%.

Six plant species recorded a knowledge index of 100*%: Ziziphus lotus, Triticum aestivum, Stipagrostis pungens, Sorghum bicolor, Maerua crassifolia,* and *Commiphora africana*.

Overall, the average use and knowledge indexes of all species investigated in the study provide insights into the traditional pharmacopeia and ethnobotanical information of the studied population. The average confidence level is also applicable, indicating the overall confidence in the knowledge and use of medicinal plants in the community.

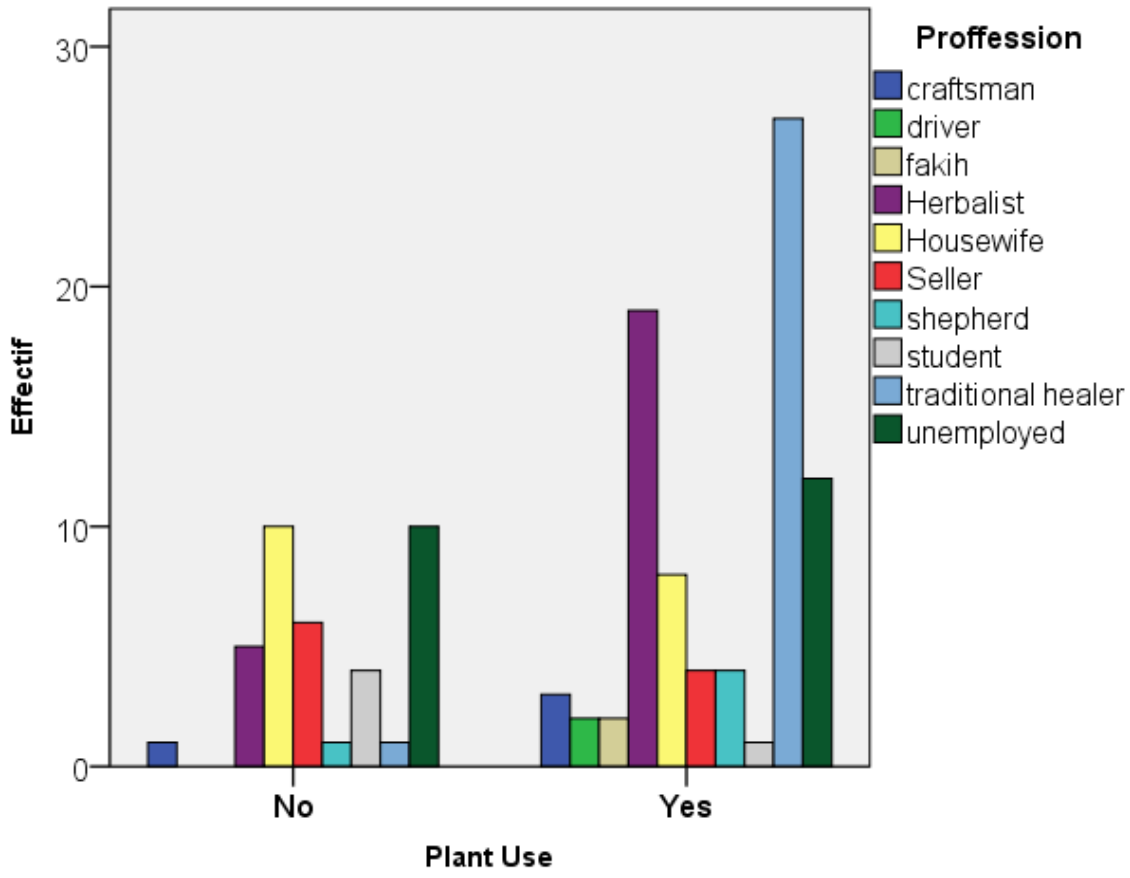


Figure 3. Distribution of respondent's using (Yes) or not (No) medicinal plants according to their profession.

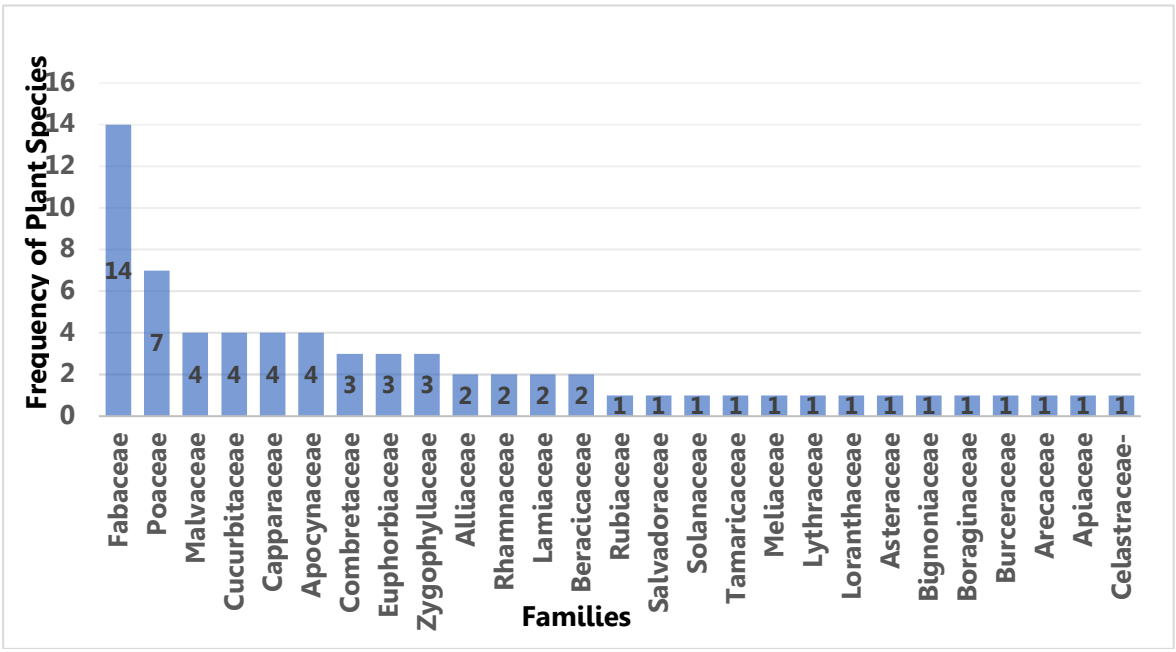


Figure 4. Frequently reported plant families for treating diseases and symptoms in the Adrar province.

Figure 5 likely represents a visual representation of the use and knowledge indexes (MPUi and MPKi) for various plant species. It could show the distribution and percentages of these indexes for the different plants studied in the research.

The study identified *Vachellia tortilis, Adansonia digitata* and *Balanites aegyptiaca* as the species with the highest use indexes (MPUi = 100%). The widespread use of these plants can be attributed to their accessibility, effectiveness in treating diseases, and the experiences gained by traditional healers.

The research suggests that the utilization of a specific medicinal plant by a population can be influenced by various characteristics of the plant. Availability plays a significant role, as plants that are accessible throughout the year tend to be more widely used compared to those with limited availability. This hypothesis is supported by previous studies by researchers such as De Medeiros *et al*. (2020)

Overall, Figure 5 likely provides a visual representation of the utilization and knowledge patterns of medicinal plant species, offering insights into the importance of accessibility and availability in the use of these plants by the indigenous population.

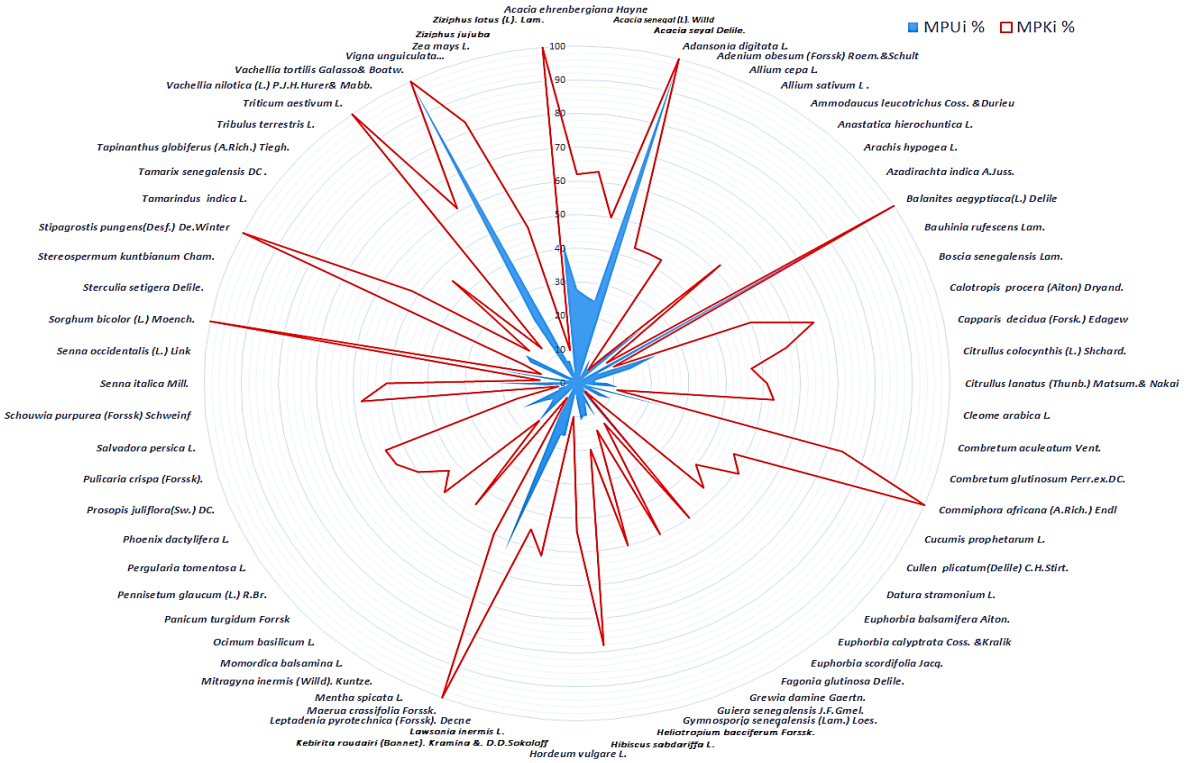


Figure 5. Species inventoried in our study area with Knowledge index (MPKi) and the use index (MPUi)

Relative Popularity Level (RPL)

The relative popularity level (RPL) was determined for the plant species mentioned by the informants. Out of the 68 species cited, 12 were classified as popular with an RPL value of 1.0. These popular plant species *include Maerua crassifolia, Vachellia tortilis, Adansonia digitata, Balanites aegyptiaca, Ziziphus lotus, Capparis decidua, Combretum glutinosum, Arachis hypogaea, Acacia Senegal, Senna italica, Boscia senegalensis,* and *Phoenix dactylifera*. The plants that received low ROP values likely experienced this due to either the influence of modernization among the recent generations or the presence of a generation gap caused by lifestyle changes in contemporary times (Al-Robai *et al*. 2020). These factors could have contributed to a diminished recognition and utilization of certain medicinal plants among the population.

The high popularity of these plants can be attributed to their perceived efficacy and the awareness among indigenous people regarding their use as herbal medicine. This study provides valuable baseline information on the traditional knowledge of plant usage for specific conditions in the local population. Similar findings have been reported in previous studies conducted among Bedouins in the Negev district and in the Palestinian territory (Friedman *et al*. 1986 and Ali-Shtayeh *et al*. 2000) .

These findings align with earlier studies conducted on the utilization of medicinal plants among the Bedouin community in the Negev district (Friedman *et al.* 1986), as well as a survey on medicinal plants conducted in the Palestinian area (Ali-Shtayeh *et al.* 2000). Among the popular plant species, *Vachellia tortilis, Adansonia digitata, Balanites aegyptiaca, Senna italica,* and *Phoenix dactylifera*have been identified as being used for treating hypertension, non-insulin dependent diabetes, and constipation in the study region. *Capparis decidua* and *Acacia senegal* are used for relieving fever and skin injuries, respectively.

Overall, the RPL analysis provides insights into the popularity and usage patterns of different plant species for specific conditions within the Mauritanian population.

Table 2 displays the FL (Fidelity Level), RPL (Relative Popularities Level), and ROP (Relative Overall Priority) values for 35 out of 68 plants that were reported to be used by three or more participants for the treatment of specific categories of ailments. The calculated FL, RPL, and ROP values for these selected plants varied within the range of 39-100%, 0.24-1, and 14-100, respectively.
The result showed that the following three plants, *Vachellia tortilis, Adansonia digitata and Balanites aegyptiaca,* achieved a very high-Fidelity level (FL=100). Additionally, these three species demonstrated a very high capability (ROP=100) in improving hypertension and diabetes.

These results suggest that these three plants hold significant importance in the traditional medicinal practices of the Mauritanian population, particularly in the management of hypertension and diabetes. The high-Fidelity Level implies that these plants are consistently and exclusively used for the treatment of the mentioned conditions. Furthermore, their high ROP values
highlight their overall priority and potential efficacy in addressing these health issues.

Table 3. Highly utilized species of the study are along with FL, RPL and ROP

Species (Vouchers)	**Major ailment**	**N**	**NA**	**NP**	**FL**	**RPL**	**ROP**
Maerua crassifolia Forssk. (HNM01452)	Diabetes non insulin dependent T90	100	6	59	0.59	1.00	0.59
Vachellia tortilis (Forssk.) Galasso &Banfi. (HNM00620)	Hypertension K86	100	3	100	1.00	1.00	1.00
Adansonia digitata L. (HNM01538)	Hypertension K86	100	3	100	1.00	1.00	1.00
Balanites aegyptiaca (L.) Delile (HNM00634)	Diabetes non insulin dependent T90	100	3	100	1.00	1.00	1.00
Ziziphus lotus (L). Lam.(HNM01705)	Diabetes non insulin dependent T90	98	7	63	0.64	1.00	0.64
Capparis decidua (Forsk.) Edagew (HNM00706)	Fever A03	93	2	90	0.96	1.00	0.96
Combretum glutinosum Perr. ex. DC. (HNM00134)	Abdominal pain epigastric D02	83	4	65	0.78	1.00	0.78
Arachis hypogaea L. (HNM00261)	Rash localized S06	71	4	60	0.84	1.00	0.84
Acacia senegal (L.) Willd. (HNM00320)	Skin injury S19	55	3	45	0.88	1.00	0.88
Senna italica Mill. (HNM01562)	Constipation D12	52	3	52	1.00	1.00	1.00
Boscia senegalensis Lam. (HNM00988)	Heartburn D03	51	3	40	0.78	1.00	0.78
Phoenix dactylifera L. (HNM00008)	Constipation D12	51	5	51	1.00	1.00	1.00
Vachellia nilotica (L.) P.J.H. Hurer & Mabb. (HNM00614)	Hemorrhoids K96	45	3	20	0.44	0.9	0.40
Vachellia seyal (Delile) P.J.H. Hurter. (HNM01584)	Menstrual pain X02	45	3	10	0.22	0.9	0.20
Euphorbia scordiifolia Jacq. (HNM01120)	Skin injury S19	42	2	10	0.23	0.84	0.23
Cleome arabica L. (HNM01443)	Menstrual pain X02	39	4	15	0.39	0.78	0.30
Lawsonia inermis L. (HNM00344)	Burn S14	35	3	14	0.41	0.7	0.28
Tamarindus indica L. (HNM00116)	Vomiting D10	30	2	12	0.40	0.6	0.24
Heliotropium bacciferum Forssk.. (HNM01425)	Eye pain F01	27	2	15	0.55	0.54	0.30
Cucumis prophetarum L. (HNM00190)	Cough R05	27	4	13	0.48	0.54	0.26
Calotropis procera (Ait.) Ait. fil	Whoopingcough R71	25	3	13	0.48	0.50	0.24
Leptadenia pyrotechnica (Forssk). Decne (HNM01919)	Boil S10	25	4	12	0.40	0.50	0.24
Allium cepa L.	Back symptom L02	24	4	11	0.45	0.48	0.22

Gymnosporia senegalensis (Lam.) Loes. (HNM01466)	Jaundice D13	24	3	10	0.41	0.48	0.20
Cullen plicatum (Delile) C.H. Stirt. (HNM01983)	Bronchitis R78	24	4	12	0.50	0.48	0.24
Mentha spicata L.	Toothache D19	22	4	10	0.45	0.44	0.20
Citrullus colocynthis (L.) Shchard. (HNM02009)	Diabetes non insulin dependent T90	21	2	21	1.00	0.42	0.42
Acacia ehrenbergiana Hayne (HNM01592)	Dyspepsia D07	21	4	12	0.57	0.42	0.24
Pergularia tomentosa L. (HNM01532)	Skin injury S19	20	4	10	0.50	0.4	0.20
Commiphora africana (A.Rich.) Endl. (HNM00060)	Breast cancer X76	18	6	18	1.00	0.36	0.36
Vigna unguiculata (L.) Walp. (HNM00252)	Anaemia B81	18	3	9	0.50	0.36	0.18
Ocimum basilicum L. (HNM01553)	Asthma R96	18	2	7	0.39	0.36	0.14
Ammodaucus leucotrichus Coss	Asthma R96	14	5	14	1.00	0.28	0.28
Guiera senegalensis J.F.Gmel. (HNM01400)	Diarrhoea D11	13	3	10	0.76	0.26	0.20
Anastatica hierochuntica L. (HNM01193)	Musculoskeletal disease L99	12	3	7	0.58	0.24	0.14
Cleome arabica L. (HNM01443)	Menstrual pain X02	39	4	15	0.39	0.78	0.30
Lawsonia inermis L. (HNM00344)	Burn S14	35	3	14	0.41	0.7	0.28

N: Number of total informants, NA: Number of ailments, Np: Number of informants who reported use of species, FL: Fidelity level, RPL: Relative popularity level, ROP: Rank order priority.

Informant Consensus Factor (ICF)

The Informant Consensus Factor (ICF) was calculated for different pathological groups in the study area. Table 4 displays the 14 identified groups and their corresponding ICF values. The most prevalent groups were Cardiovascular (K) with an ICF value of 0.97, followed by Digestive (D), Eye (F), and Male Genital (Y), each with an ICF value of 0.96. This indicates a high level of agreement among informants regarding the use of medicinal plants for these specific health concerns. We have observed alignment with our research findings from a study carried out in in Laayoune Boujdour Sakia El Hamra Region, Morocco (Taha *et al*. 2022).

Following closely were the Neurological (N) and Musculoskeletal (L) groups, both with an ICF value of 0.90. The General and Unspecified (A) group and the Endocrine/Metabolic and Nutritional (T) group had an ICF value of 0.94. These findings highlight the significant reliance on traditional medicinal herbs among the indigenous population in the studied region.

Moreover, high ICF values can guide researchers in identifying promising plant species for further exploration of bioactive compounds.

Table 4. Informant Consensus Factor (ICF) for the different pathological groups treated

Pathological Group (ICPC2)	**Health conditions/symptoms**	**N Taxa**	**nUR**	**Sum UR**	**Sum Taxa**	**IFC**
General and unspecified (A)	Fever	3	94	116	8	0,93
	Intoxication	1	2			
	Malaria	3	16			
	Measles	1	4			
Blood, Blood Forming Organs and Immune Mechanism (B)	Anemia	3	20	20	3	0,89
Digestive (D)	Abdominal pain epigastric	18	612	1284	49	0,96
	Constipation	4	133			
	Diarrhea	5	235			
	Dyspepsia	2	6			
	Heartburn	3	33			
	Jaundice	3	66			
	Mouth symptom	2	8			
	Oral abscess	1	3			

	Teeth ache	3	90			
	Viral hepatitis	3	33			
	Vomiting	2	32			
	Worms	3	33			
Eye (F)	Eye pain	2	34	34	2	0,96
Cardiovascular (K)	Hemorrhoids	1	15	161	5	0,97
	Hypertension	4	146			
Musculoskeletal (L)	Back symptom	2	29	41	6	0,87
	Muscle pain	2	4			
	Musculoskeletal disease	2	8			
Neurological (N)	Headache	2	21	21	2	0,95
Respiratory (R)	Asthma	4	24	91	18	0,81
	Breathing problem	2	11			
	Bronchitis	3	12			
	Cough	5	26			
	Pain respiratory system	1	15			
	Whooping cough	1	3			
Skin (S)	Acne	1	3	286	18	0,94
	Boil	2	12			
	Burn	2	23			
	Foreign body in skin	1	4			
	Laceration	1	5			
	Rash localized	3	13			
	Scabies	1	4			
	Skin colour change	2	44			
	Skin disease	1	57			
	Skin injury	8	121			
Endocrine/ Metabolic and Nutritiona (T)	Non-insulin dependent diabetes	13	227	230	14	0,94
	Loss of appetite	1	3			
Urologique (U)	Dysuria	2	21	32	3	0,93
	Kidney symptom	1	11			
W	Complications of puerperium	1	3	3	1	1
Female Genital (X)	Breast cancer	1	2	22	3	0,90
	Menstrual pain	2	17			
	Syphilis in women	1	3			
Male Genital (Y)	Impotence	1	20	31	2	0,96
	Infertility	1	11			

Conclusion

In conclusion, the study conducted in the Adrar province revealed the extensive use of medicinal plants by the local population. A total of 68 species belonging to 27 families were documented, with the Fabaceae family being the most utilized for treating various diseases.

The findings emphasize the strong connection between medicinal plants and the daily lives of the Adrar people. Despite the availability of modern healthcare facilities, traditional medicine remains deeply rooted in the community, indicating the continued relevance and value of traditional plant-based remedies.

Indigenous people tend to use medicinal plants that align with income-related factors. This could imply that the choice of medicinal plants is influenced by economic considerations, such as accessibility, affordability, or availability. In other words, the selection of medicinal plants for use might be influenced by the economic resources available to the indigenous communities. The results also raise concerns about the conservation of ethnobotanical knowledge in the region. The Adrar province faces challenges such as low vegetation cover, recurring droughts, landscape degradation, grazing, and wood fuel gathering. Therefore, the documented 68 medicinal plant species hold significant importance in the context of arid and semi-arid areas.

The high Relative Popularity Level (RPL) of certain plant species indicates their popularity among the local population for treating specific illnesses. These popular species warrant further investigation to explore their bioactive compounds and potential biological activities, which could lead to the development of new and effective medications.

Overall, this study provides valuable insights into the traditional medicinal practices and plant knowledge of the Adrar province. It establishes a foundation for collaboration between traditional health practitioners and the scientific community, aiming to bridge the gap between traditional medicine and modern healthcare approaches.

Declarations

List of abbreviations: ANSADE: Agence Nationale de la Statistique et de l'Analyse Démographique et Economique, RPL: Relative popularity level, ROP: rank order priority, FL: Fidelity level UR: Use report, MPKi: Medicinal Plant Knowledge index, MPUi: Medicinal Plant Use index, CI: confidence level index, ICF: Informants Consensus Factor.
Ethics statement: Prior to the survey, we obtained oral informed consent from each participant**.**
Consent for publication: Not applicable.
Availability of data and materials: All the data are presented in figures, tables and appendix in the manuscript and are available with the corresponding author.
Competing interests: The authors declare that they have no competing interests.
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Authors' contributions: **Cheikh Yebouk**: Conducting field surveys of the work, Drafting the work, Analysis and interpretation of data for the work, Corresponding author and submission. **Fatima Zahrae Redouan and Hala Elhachimi**: Participated in the drafting of work, Analysis and interpretation of data for the work. **Abderrahmane Merzouki**: Drafting and conception and design of the work, Revising and critically of the content, Final approval of the version to be published.

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