Ethnobotanical study of medicinal plants with therapeutic interest in the province of Khemisset, Morocco

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Research

Abstract

Background: For centuries, the Moroccan population has been using medicinal plants to treat various diseases. However, few investigations have been conducted to document and properly preserve these traditions. This ethnobotanical study aims to compile a comprehensive inventory of medicinal plants used by the residents of Khemisset, a region noted for its significant plant biodiversity, for the treatment of various diseases.

Methods: Ethnobotanical surveys were conducted with 200 participants, evenly distributed across different divisions, over a seven-month period from January 1 to July 31, 2023. Data on the participants' traditional therapeutic practices were collected and analyzed using descriptive statistical methods and quantitative ethnobotanical indices, including the Informant Consensus Factor (ICF), Relative Frequency of Citation (RFC), Fidelity Level (NF), and Use Value (VU). Additionally, the analysis was further refined using Multiple Correspondence Analysis (MCA) and Non-metric Multidimensional Scaling (nMDS).

Results: The study highlights the enduring significance of traditional medicine among the local population, especially among the elderly and middle-aged individuals. A total of 66 species of medicinal plants were identified, with the Lamiaceae family being the most prevalent (19.70%), followed by the Asteraceae and Apiaceae families, each constituting 13.64%. MCA revealed relationships among variables such as gender, age, marital status, education, occupation, therapeutic plants, districts, and province. nMDS illustrated correlations between plant distribution and their respective divisions. Notably, leaves were the most commonly used plant part (57.2%), and the majority of preparations were made through decoction (48.4%) and administered orally (75.6%) to treat various conditions, including gastrointestinal (ICF = 0.82), urogenital (ICF = 0.73), and bronchopulmonary (ICF = 0.89) ailments.

Conclusion: This study underscores the prevalent use of aromatic and medicinal plants as traditional remedies among the Khemisset population. It aims to enhance the recognition of Moroccan traditional natural heritage while providing researchers with a valuable ethnobotanical database for the advancement of pharmacognosy.

Keywords: Ethnobotany; Khemisset; Traditional medicine; Medicinal plants; Knowledge.

Background

Despite advances in medicine and the availability of modern therapies, there remains a significant interest in traditional pharmacopeia (Abouri *et al.*, 2012). Medicinal and aromatic plants constitute a valuable medical heritage for human health, particularly in developing countries where populations rely on them for primary health care and subsistence in the absence of a modern medical system. Indigenous populations utilize various parts of plant species as phytomedicines to treat a range of infections (EL Moussaoui *et al.*, 2021; Jeddi *et al.*, 2021). In Africa, traditional medicine, in all its forms, reflects the social culture of its practitioners, mirroring their way of life and worldview. According to the World Health Organization (WHO), nearly 80% of the African population depends on traditional medicine for their primary health needs (WHO, 2002).

In Morocco, a North African country, the rich biodiversity includes 4,200 identified plant species, with nearly 400 recognized for their aromatic and medicinal properties due to the country's unique biogeographic position (Fakchich & Elachouri, 2021). This extensive diversity positions Morocco prominently among African and Mediterranean countries, which are renowned for their historical medical traditions and profound expertise in the use of medicinal plants (Radi *et al.*, 2024).

Considering this medicinal heritage knowledge, several efforts are currently being made to preserve and enhance it. Furthermore, ethnobotanical studies contribute to collect and form a very valuable source of information, that can be exploited scientifically to initiate scientific research on naturally bioactive molecules (Jeddi *et al.*2021, Benamar *et al.*2023). Currently, medicinal plants, through their extracts, have an important asset in phytotherapy and enjoy popularity due to the progressive discovery of their medicinal properties and effectiveness, especially antibacterial, anti-inflammatory, antiseptic, antiviral, antifungal, detoxifying, antitumor, and insecticidal properties, as well as their uses in other fields such as perfumery, cosmetics, aromatherapy, and agri-food (EL Moussaoui *et al.*2021, Jeddi *et al.*2021, Newman & Cragg 2012).

On the other hand, the medicinal flora of Morocco necessitates continuous monitoring and evaluation regarding both quality and quantity. In light of this, we conducted ethnobotanical research in the Khemisset province, a region that, to the best of our knowledge, had not previously been subjected to such a survey. This province is notable for its significant lithological, structural, biological, and floristic diversity, attributable to its unique relief, topography, and geographical location. The primary objectives of our study were to assess the extent of medicinal plant usage in the area, catalog the species utilized, identify the diseases treated and the methods of remedy preparation, and explore any potential correlations between the data collected and various socio-demographic factors such as age, gender, and educational level.

Materials and Methods

Presentation of the study area

The province of Khemisset, located within the Rabat-Sale-Kenitra region (Figure 1), encompasses an area of 781,000 hectares. Approximately 47.7% of this area is allocated to productive agriculture. Moreover, the province is characterized by significant forest coverage, which constitutes 40.6% of its total area (Radi *et al.* 2024). These forests play a crucial role in sustaining local biodiversity by providing habitats for a variety of plant species. Additionally, 11.7% of the land is designated as pasture and uncultivated areas. Khemisset is bordered to the north by the province of Kenifra, to the south by Khenifra and Khouribga, to the west by Rabat, Sale, and Ben Slimane, and to the east by Fes-Meknes and Ifrane. The province is administratively divided into four subdivisions (Khemisset, Tiflet, Rommani, and Oulmes) and 35 territorial communes.

The climate is Mediterranean, characterized by hot, dry summers and cold, wet winters from October to May. The area is categorized into three bioclimatic stages (Radi *et al.* 2024):
-Subhumid bioclimatic stage: Oulmes division;
-Semi-arid bioclimatic stage: Khemisset and Tiflet divisions;
-Arid bioclimatic stage: Rommani division.

Monthly precipitation is characterized by a variable rainfall pattern from year to year, reflecting the irregularity of precipitation (with annual averages between 260 and 580 mm). Snowfall can occur from mid-November in the mountainous area (Oulmes) and the temperature varies between -4°C and 48°C.

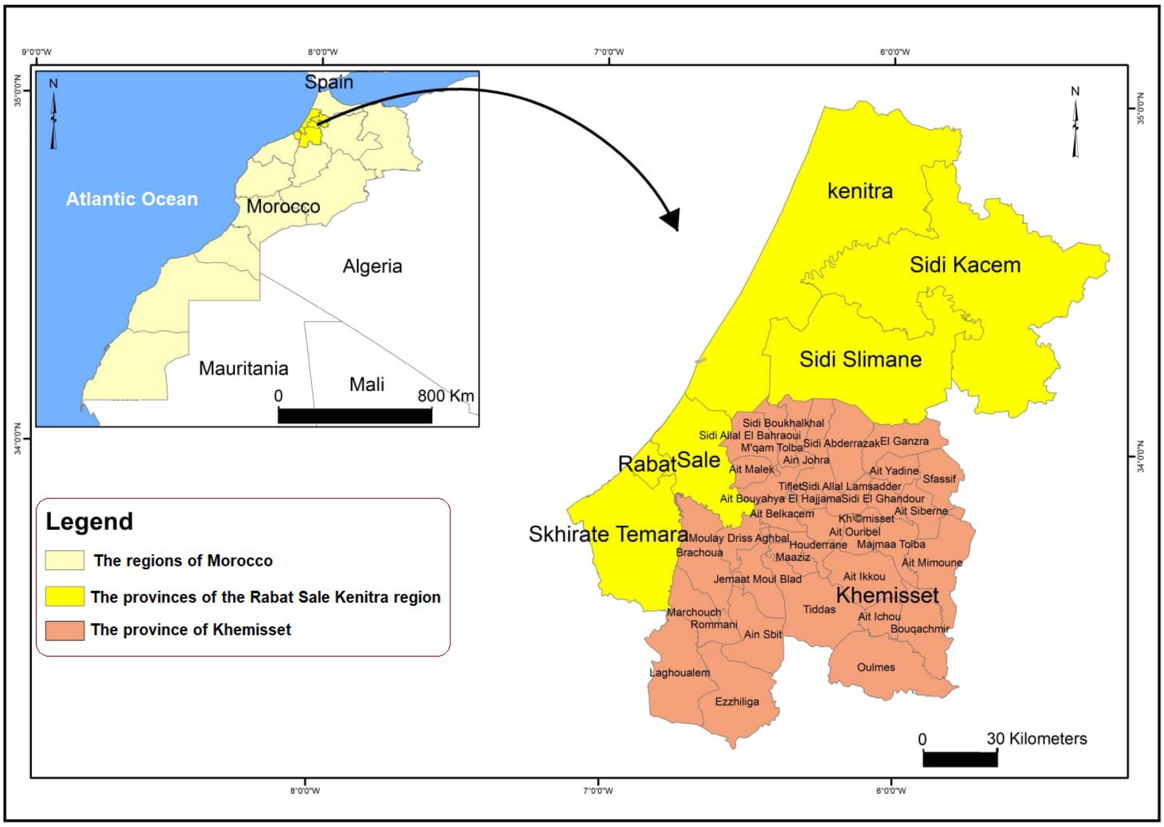

Figure 1. Geographic location of the study area in Khemisset

Data collection

The ethnobotanical survey utilized a structured questionnaire (Appendix 1), developed in collaboration with the research team from the Laboratory of Innovative Materials and Biotechnology of Natural Resources, Faculty of Sciences, Meknes. This questionnaire was administered to 200 individuals across the four divisions of Khemisset Province (Table 1). It was carried out from January to July 2023. Interviews were conducted through open-ended discussions in Arabic to facilitate free responses, either individually or in groups. Each interview lasted between thirty minutes and one hour, depending on participant availability.

The survey comprised two sections: one focusing on the respondent's personal details (surname, first name, age, sex, etc.) and the other on the plants (vernacular names, parts used, treated pathologies, etc.). The ethnomedicinal surveys were conducted utilizing the random and stratified sampling strategy (Daget & Godron, 1982), which enabled the use of a representative sample and is a useful method for getting the most comprehensive inventory feasible (Lahsissene *et al.* 2009).

Table 1. Distribution of ethnobotanical surveys by Division

Province	Division	Number of surveys
Khemisset	Khemisset	50
	Tifelt	50
	Rommani	50
	Oulmes	50
	Total	200

Plant species identification

The scientific names of the plants mentioned by the local population were obtained through direct translation of their vernacular names, at the Laboratory of Innovative Materials and Biotechnology of Natural Resources, Faculty of Sciences in Meknes. This translation carried out using specialized references such as Bellakhdar (1987, 1997), El-Hilaly *et al.* (2003), Emberger & Maire (1941), Fakchich & Elachouri (2014), Fennane (2021), Fennane *et al.* (1999, 2007), Ibn Tattou & Fennane (2008), Jahandiez & Maire (1932), Sijelmassi (1993), and Valdés (2002).

Plant samples were collected during surveys conducted with the local population, but they were only available as fragments rather than whole plants. Unfortunately, these samples did not fulfill the criteria for issuing a voucher code.

To address this issue, the global database of the European and Mediterranean Plant Protection Organization (EPPO) was used. Thus, an EPPO code was assigned to each plant species, enabling efficient and accurate identification, regardless of linguistic and regional variations.

Statistical analysis

All the data collected during this ethnobotanical survey were coded and manipulated using the R software (version 4.3.3). Sociodemographic characteristics of the participants were analyzed through simple descriptive statistics, including percentages and frequencies. Multiple Correspondence Analysis (MCA), is an extension of Correspondence Analysis (CA) that enables the examination of relationships among multiple categorical dependent variables. It can be viewed as a broader application of Principal Component Analysis (PCA) when dealing with categorical rather than quantitative data. MCA has been independently developed and is recognized under various names, including optimal scaling, dual scaling, homogeneity analysis, scalogram analysis, and quantification method. In technical terms, MCA is performed by applying Correspondence Analysis to an indicator matrix, where entries are binary (0 or 1). Adjustments are necessary for the percentages of explained variance and the interpretation of distances between points in Correspondence Analysis (Abdi & Valentin 2007). In our study, we employed Multiple Correspondence Analysis (MCA) to explore the interrelationships among the variables Sex, Age, Family Status, Education, Occupation, Therapeutic Plants Used (Local Name), and Divisions. The Non-metric multidimensional scaling (NMDS) is commonly utilized for ordination in vegetation research (Salako *et al.* 2013). When using NMDS in statistical software, the accuracy of the results can be influenced by the selection of various options. In our study (NMDS) aimed to understand the relationships between the plants and geographic locations (Divisions). We also tested whether variations in plant use are significantly related to geographic differences using a permutational multivariate analysis of variance (PERMANOVA). PERMANOVA is a computer program for testing the simultaneous response of one or more variables to one or more factors within an ANOVA experimental framework. It employs permutation techniques and can utilize various distance measures for its analysis with a significance level of 0.05, 999 permutations, and the adonis2 function from the R package "vegan" (Oksanen *et al.* 2015).

Furthermore, the data were examined using various quantitative ethnobotanical indices, such as Relative Frequency of Citation (RFC), Informant Consensus Factor (ICF), Fidelity Level (FL), and Use Value (UV), to gain a comprehensive understanding of the relationships between the studied plants and their usage by the local population.

Relative Frequency of Citation (RFC):

This index shows the relative importance of each species in the studied area. It is determined by dividing the number of informants mentioning the use of the species, corresponding to the citation frequency (FC), by the total number of people interviewed (N). It was calculated according to the following formula (Kayani *et al.*2015):

$$\mathbf{RFC} = \frac{\mathbf{FC}}{\mathbf{N}}$$

RFC values range from 0 to 1.

Informant Consensus Factor (ICF):

This value was calculated to assess the degree of homogeneity in knowledge among participants in the study area regarding the use of plants as remedies for diseases. The ICF was calculated using the following formula (Mootoosamy & Fawzi Mahomoodally 2014):

$$\mathbf{ICF} = \frac{(\mathbf{Nur} - \mathbf{Nt})}{(\mathbf{Nur} - \mathbf{1})}$$

Nur: Number of of use report for a category.
Nt: Total number of of plants used for that specific category of use by all informants.
ICF ranges from 0 to 1. A high ICF value, close to 1, indicates a strong consensus among informants regarding the use of a plant for a specific category of disease. Conversely, a low ICF value, close to 0, indicates a low consensus (Reimers *et al.*2019).

Use Value (UV):
This index, also known as "cultural importance," allows us to determine the relative importance of locally known species and the most frequently reported species in the treatment.
The use value of each species was calculated using the formula diseases:

$$\mathbf{UV} = \frac{\mathbf{\Sigma Ui}}{\mathbf{N}}$$

∑Ui: Total number of uses cited by each informant for a given species
N: Total number of of informants (Al-Fatimi 2021, Bano *et al.* 2014, Tardio & Pardo-de-Santayana 2008).

Fidelity Level (FL):
It represents the percentage of informants declaring the use of a specific plant for the same primary purpose, which can be calculated as follows (Lulekal *et al.* 2013, Mechaala *et al.* 2022):

$$\mathbf{FL} = \frac{\mathbf{Np}}{\mathbf{N}} \times \mathbf{100}$$

Np: is the number of informants stating the use of a plant species for a particular purpose
N: is the total number of usage reports for that specific purpose

Results and dDiscussion

Demographic characteristics of respondents

To collect and document the most comprehensive ethnobotanical data possible, we conducted multiple field visits throughout 2023. The demographic characteristics of each respondent are detailed in Table 2. A total of 200 local informants, were interviewed in the four divisions of the studied province. Women (57%) and men (43%) have shared medicinal knowledge. This is similar to the results of Hedidi *et al.*2020, which demonstrated that the use of medicinal plants is a practice common to both genders.

The use of medicinal plants in this area is prevalent across all age groups, with a notable predominance among individuals aged 40 to 60 years (40%), followed by those over 60 years old (31.5%). The age-related difference in usage could be attributed to older individuals possessing more ancestral knowledge and providing reliable information, while younger individuals may be influenced by modernization and skeptical of traditional medicine. These findings align with studies conducted in various regions of Morocco (Anyinam 1995, El Hafian *et al.* 2014). Moreover, married individuals are more likely to use medicinal plants compared to singles.This disparity could be due to resource-sharing arrangements in marriage, providing married individuals with more resources and a better transmission of traditional knowledge. These results are consistent with studies in Morocco (Benkhnigue *et al.* 2010, Chraibi *et al.* 2018, El Hilah *et al.* 2015).

The majority of informants are illiterate or at the primary level. The low level of education is not a constraint on the knowledge of plants and their uses or the transmission of ethnobotanical information from one generation to the next by oral means. These results are consistent with other research (Chaachouay *et al.* 2020, El Hachlafi *et al.* 2020).

The survey additionally indicates that housewives, herbalists, shopkeeper, healers, and farmers have a significant role in the utilization of medicinal plants within the province. This highlights the diverse interactions between humans and plants and underscores the importance of preserving traditional knowledge.

Table 2. Demographic characteristics of respondents

	Categories	Number	Percentage (%)
Gender	Female	114	57
	Male	86	43
Age	<20	9	4,5
	20-40	48	24
	40-60	80	40
	>60	63	31,5
Marital Status	Married	166	83
	Single	34	17
Level of education	Illiterate	116	58
	Primary	56	28
	Secondary	21	10,5
	Higher education	7	3,5
Vocation (profession)	Herbalist	46	23
	Healer	30	15
	Farmers	27	13,5
	Shopkeeper	34	17
	Housewife	51	25,5
	Others	12	6

The multiple correspondence analysis (MCA)

Multiple correspondence analysis (MCA) is a multidimensional exploratory method that creates a synthetic representation of categories derived from various qualitative criteria a survey. In our analysis, we utilized MCA to explore the interrelationships among the variables Gender, Age, Family Status, Education, Vocation, Plants used in Therapeutics (Local Name), Divisions and Province, without imposing any specific hypotheses regarding their associations. The MCA was applied to the dataset comprising these variables, resulting in a scatter plot of individuals positioned along two factorial axes (Figure 2). The first two axes collectively captured 13.33% of the dataset's total inertia, indicating a notable representation of the data's variability within this plane. Although this percentage may seem relatively low, it surpasses the reference value of 6.87%, suggesting a significant explanatory power of this plane (the reference inertia was determined as the 0.95-quantile of inertias obtained from 667 random datasets with similar dimensions, generated based on a uniform distribution).

To identify associations between variables, we computed the chi-square distance between various categories of variables and respondents. These associations were then visualized in Euclidean space, where variables positioned closely to each other at the periphery of the plot indicated positive associations, orthogonal variables indicated independence, and variables positioned 180 degrees apart signified negative associations. The proximity of variables to the plot's periphery represented the strength of their association. This visualization facilitated a clearer understanding of the relationships between different variables within our dataset.

The correlation ratios squared across the two dimensions (Figure 2) highlight the variables with the most substantial contributions to the first dimension, listed in descending order as Plants used in therapeutics, Education level, Division, and Family status. Gender exhibits a minimal contribution, whereas Vocation and Age demonstrate a moderate contribution to the second dimension. To achieve a deeper comprehension of these associations, a comprehensive depiction of the categories is imperative (Figure 3).

This detailed portrayal enables the classification of all modalities into two distinct groups in dimension 1 and two groups in dimension 2.

Dimension 1:

-Group 1 (characterized by a positive coordinate on the axis) shares:

A high frequency of modalities such as Division: Tifelt, Education: Higher Education, Family Status: Single, Plants used in therapeutics (Local Name) : Bechnikha, Karwiya, El kosbour, Krafes, Naanaâ, Kalitûs, Zebouj, Zaytoune, Balaâmane, El heriga, Louiza, Besla, Kharoub, Halba, Fliou (from most common to rarest).

A low frequency of modalities such as Family Status: Married, Education: Illiterate, Division: Oulmes.

-Group 2 (characterized by negative coordinates on the axis) shares:
A high frequency of modalities such as Education: Illiterate, Division: Oulmes, Family Status: Married.
A low frequency of modalities such as Gender: Homme, Family Status: Single, Education: Secondary, Division:Tifelt.

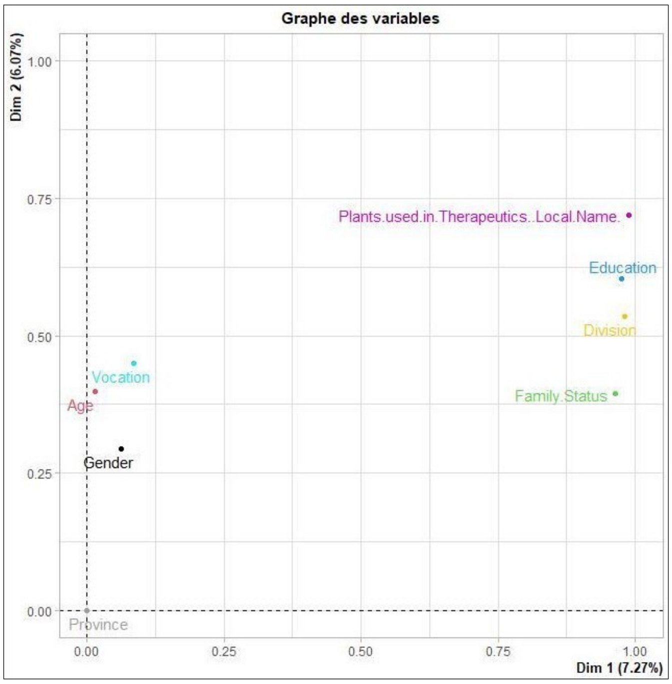

Figure 2. Map of categorical variables

Dimension 2:
The first group shares characteristics such as a high frequency of modalities like Division: Khemisset, Plants used in therapeutics (Local Name): Bechnikha, Karwiya, El kosbour, Chiba, Hellala, Jemra, Dâd, Tafs, Khorchef, L, Kharoub, Halba, Fliou, Naanaâ, Lahbaq, Marriout, Salmia, Defla, Mkhinza, Zebouj, Zaytoune, Balaâmane, El heriga, Louiza, Besla, Touma, Bûhamou, Bakkola, Harmel (from most common to rarest), Family Status: Single, Education: Secondary, Gender: Homme, Age:20-40, and Education:Higher Education.

The second group shares characteristics such as a low frequency of modalities like Education: Illiterate, Division: Oulmes, Family Status: Married, Vocation: Housewife, Gender: Femme, Age=>60, and Plants used in therapeutics (Local Name): El babounj, Khzama, Kohila, Halhale, Zaatar, Merdedoûch, Zaaitra, Rayhane, Khartal, Zwan, Drou, Btem (from most common to rarest).

Our in-depth examination using Multiple Correspondence Analysis (MCA) reveals distinct profiles within the data by highlighting associations among various variables such as gender, age, family status, education level, vocation, plants used in therapeutics, divisions, and provinces. The first dimension primarily differentiates individuals with higher education, who are single and from Tifelt, and who use a diverse range of therapeutic plants, from those with lower education, who are married and from Oulmes, with a different set of plant uses.

The second dimension distinguishes mainly between younger individuals (20-40 years old), with secondary or higher education, who are single and from Khemisset, versus older individuals (>60 years old), often illiterate, married, and from Oulmes, who use a distinct set of plants. These results highlight varied profiles based on education, family status, and geographic location, providing an in-depth understanding of the relationships among these variables within the dataset.

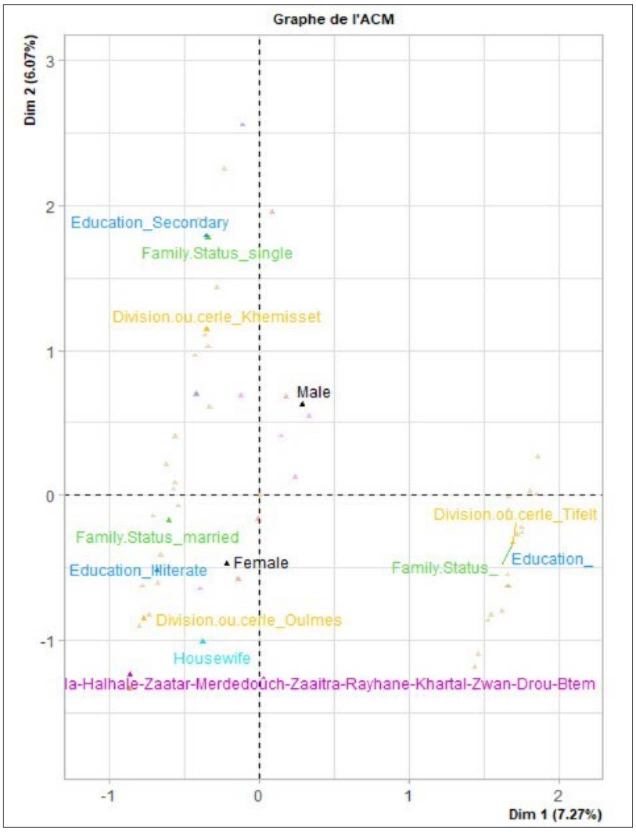

Figure 3. Visualization of Multiple Correspondence Analysis (MCA)

Floristic analysis

Diversity of medicinal plants

The floristic analysis of the ethnobotanical survey identified 66 species of medicinal and/or aromatic plants (table 3) used in traditional medicine by the local community. Among the 27 botanical families cited by respondents (Figure 4), the most representative are Lamiaceae, Asteraceae, Apiaceae. Other studies have also showed the preponderance of ethnomedicinal use of plant species belonging to these families (Daoudi *et al.* 2016 , El Finou *et al.* 2023, El Yaagoubi *et al.* 2023).

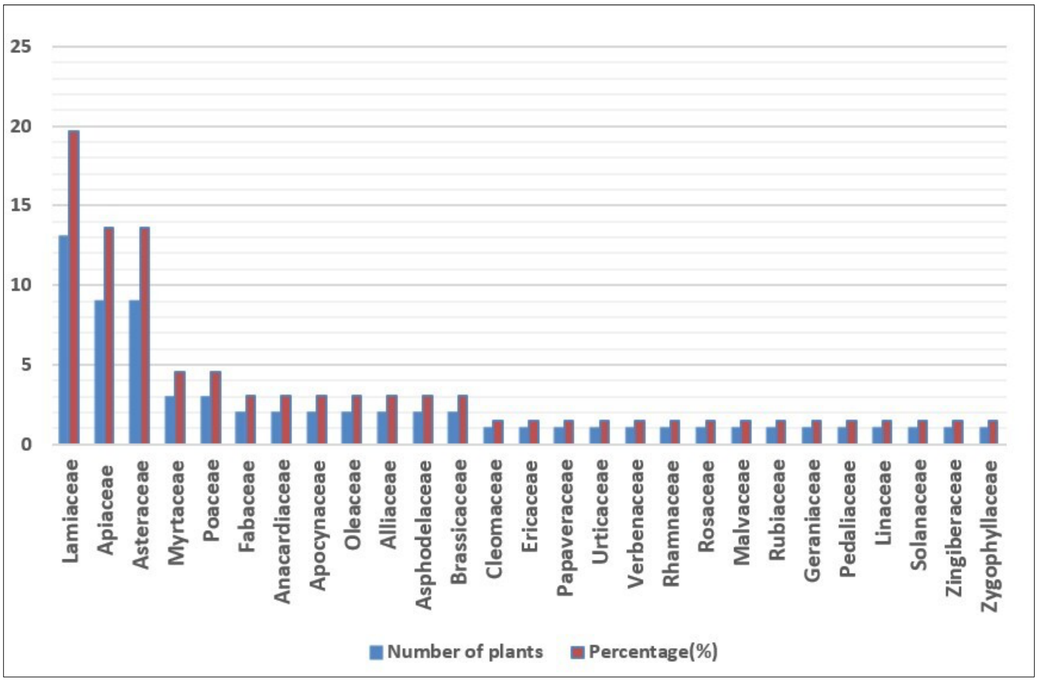

Figure 4. Families of recorded plant species

Dissimilarity Analysis of Samples across Plants used in Therapeutics in Different Divisions Using NMDS.
The analysis reveals a substantial correlation between the observed distances and those calculated by the ordination, with a coefficient of determination R2 equal to 0.993. This robust correlation underscores the reliability of the adjustment performed by the nMDS method. Additionally, the low stress value, at only 0.084 and well below the threshold of 0.3, further confirms the high-quality adjustment achieved by NMDS. These analyses collectively emphasize the robustness and effectiveness of the method employed in this study.

The NMDS analysis, depicted in Figure 5, conspicuously showcases the similarities among plants utilized for therapeutic purposes across the Oulmes, Tifelt, Khemisset, and Rommani divisions. It unveils that particular plants exhibit closer associations with specific divisions, notably Tifelt and Khemisset. Additionally, there is an intersection of plants in these two divisions, suggesting shared characteristics with both divisions and indicating a similarity in their distribution.

In light of the visually suggestive results from the nMDS graph, the need for rigorous statistical validation of our hypothesis is clear. Our PERMANOVA analysis reveals a significant relationship between plant dispersal and Divisions (R^2=0. 407; p = 0.001).

The results reveal a significant relationship between the dispersion of plants and the divisions in which they are found. This relationship suggests that the distribution patterns of different plant species are not random but are influenced by specific characteristics of the divisions ($P < 0.05$), including bioclimatic and environmental aspects. This trend is particularly observable in the Tifelt and Khemisset Divisions, which share the same semi-arid bioclimatic stage (Figure 5).

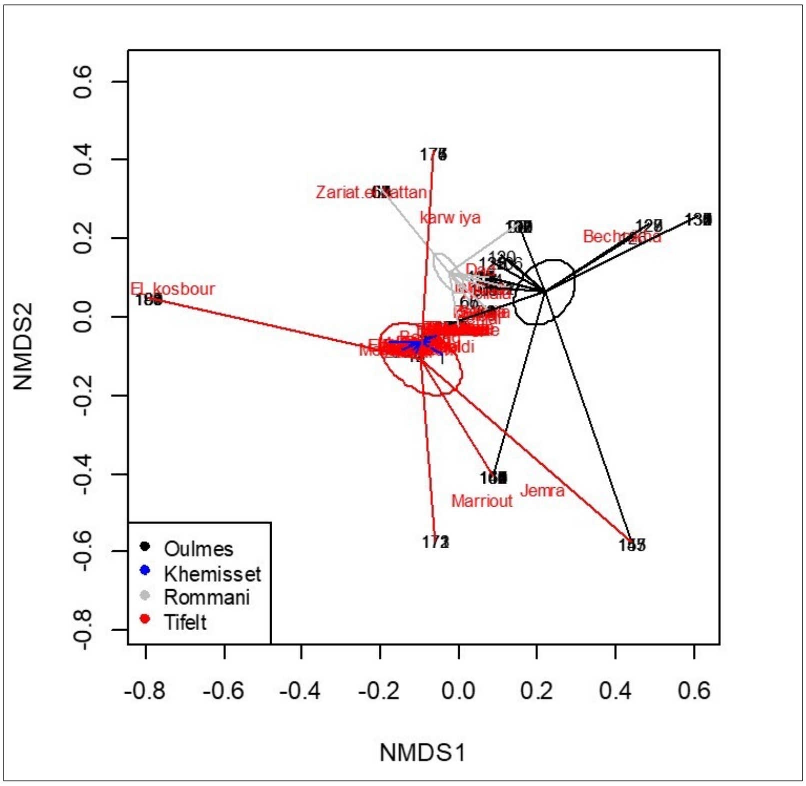

Figure 5. Non-metric multidimensional scaling (NMDS) plot based on Bray-Curtis

Parts of medicinal plants used for treatment
In this study areas, leaves were found to be the predominant plant parts utilized by local residents, accounting for 57.2%, followed by the whole plant at 12%, and then the use of fruits at 8 % (Figure 6). This preference can be explained by the ease of collecting leaves, which require minimal effort for treating various ailments, compared to other plant parts such as flowers, roots, fruits, and seeds (Giday *et al.* 2009, Sargin 2015). These findings are consistent with previous research by Chaachouay *et al.* 2020 and Hachi *et al.* 2015, indicating that leaves were the most commonly used plant parts due to their practical application. Additionally, leaves are involved in photosynthesis and often serve as sites for storing secondary metabolites (total polyphenols) that contribute to the plant's medicinal properties (Bigendako-Polygenis & Lejoly 1990).

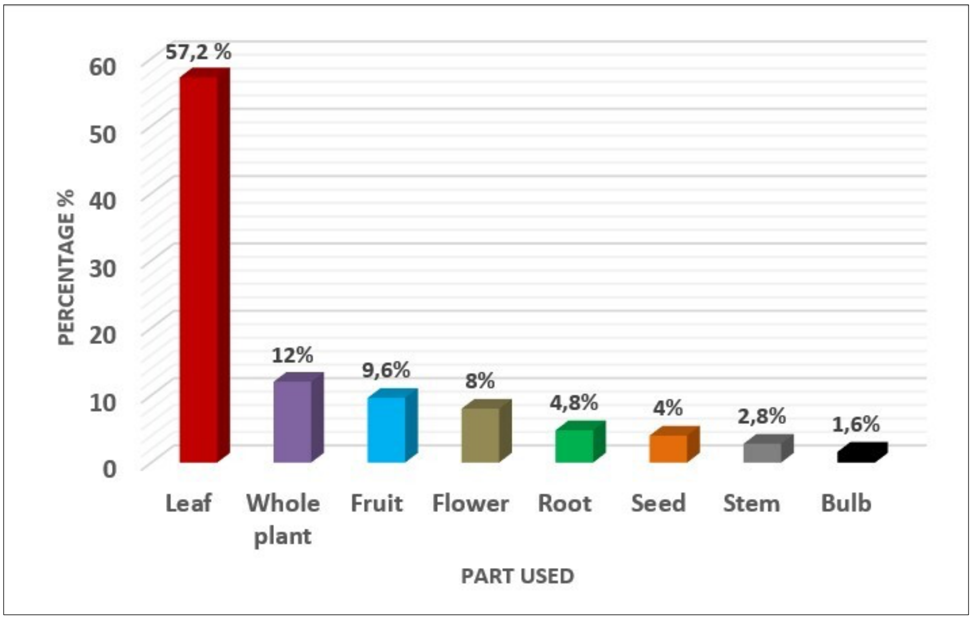

Figure 6. Parts of medicinal plants used in the territory of Khemisset

Preparation method and administration mode

The surveyed population employs various preparation methods to extract derivatives from medicinal plants. Decoction is the predominant method, employed by 48.4% of respondents (Figure 7). The frequent use of decoction can be attributed to its effectiveness in extracting the most active ingredients and mitigating or eliminating the toxic effects of certain recipes (Benlamdini *et al.* 2014, Hachi *et al.* 2015). These findings are consistent with national reports indicating that decoction is the most common method for preparing therapeutic recipes (Benkhnigue *et al.* 2010, EL Hassani *et al.* 2013, Slimani *et al.* 2016, Salhi *et al.*2010).

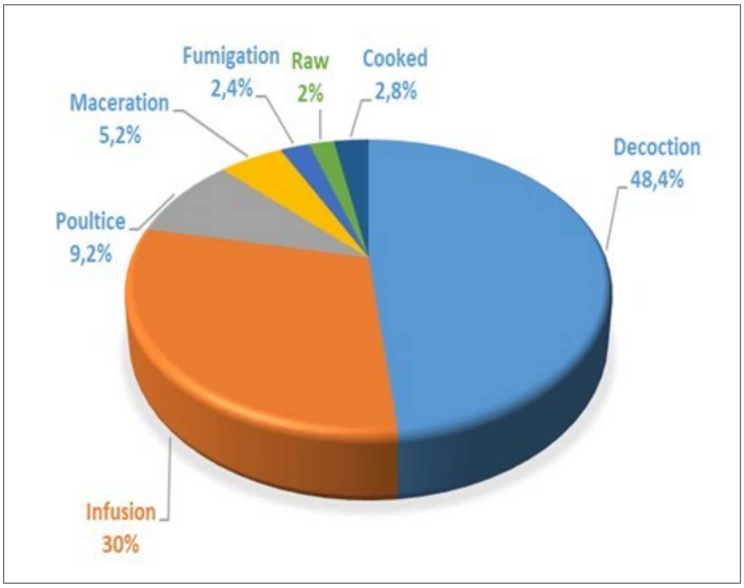

Figure 7. Frequency of methods preparation of plants

Plant preparations are primarily administered internally, through oral ingestion or inhalation, in 77.2 % of cases, while external application is observed in 22.8% of cases (Figure 8). The predominance of oral administration, which is related to the high incidence of internal diseases in the study area (Polat and Satıl 2012), has also been observed in studies conducted in Morocco (El Hachlafi *et al.* 2020) and Algeria (Benarba *et al.* 2014 , Chermat & Gharzouli 2015).

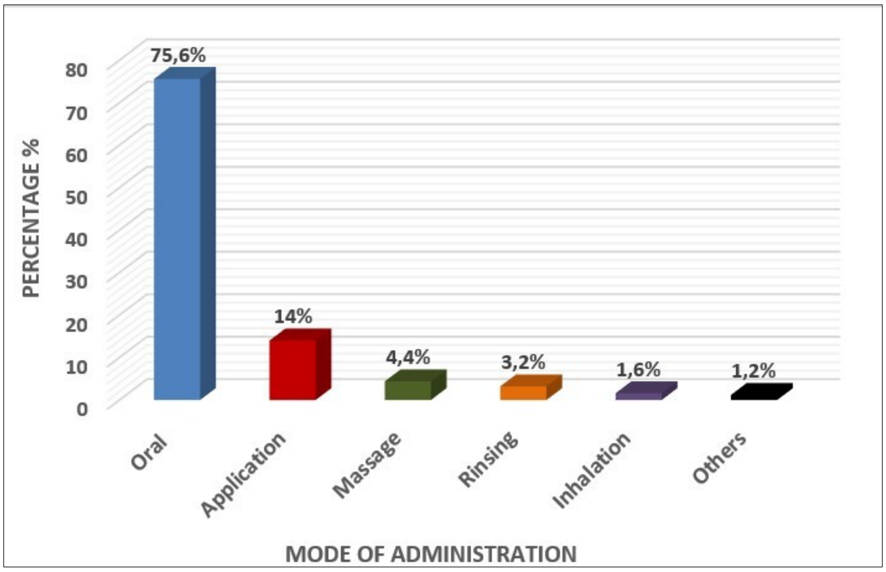

Figure 8. Frequency of plant administration modes

Dose and duration of use

In the Khemisset province divisions, most individuals interviewed used medicinal plants without adhering to precise doses, often not considering high doses to be toxic or fatal. The ethnobotanical study reveals that medicinal plants are used in various doses: 36.5% by spoonful, 32.2% by glass, 31% by pinch, 11% by ointment, and 7.5% by handful (Figure 9 A). As for the duration of treatment, 48% of participants apply these plants for a single day, 23% for one week, 8% for one month, and 21% continue usage until the ailment is resolved (Figure 9B). However, administering medicinal plants in imprecise and irrational doses poses potential health risks, as there is often a correlation between dosage and toxicity (Bellakhdar 1997; Sreekeesoon & Mahomoodally 2014).

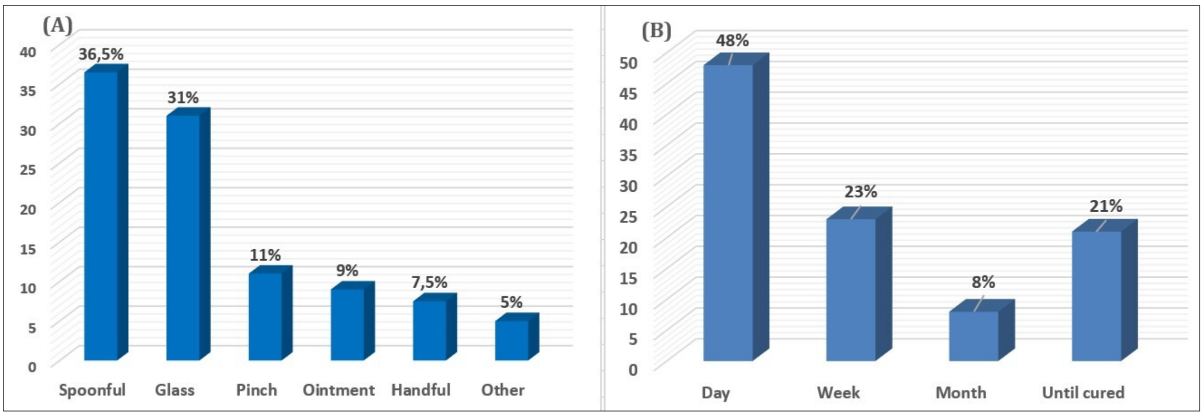

Figure 9. Dose and duration of use

Quantitative ethnobotanical analysis

Treated ailments and Informant Consensus Factor (ICF)

This ethnobotanical survey reveals that the majority of medicinal plant species documented in the Khemisset province are utilized for the treatment or alleviation of various diseases, which are classified into eight categories: gastrointestinal disorders, urogenital disorders, bronchopulmonary disorders, rheumatism, diabetes, nervous system disorders, oral and dental disorders, and skin disorders. Among these, Bronchopulmonary disorders (ICF=0.89), gastrointestinal disorders (ICF=0.82), urogenital disorders (0.73), and skin disorders (0.67) exhibited the highest ICF values.

High ICF values indicate a reliable consensus among informants regarding the medicinal use of plant species for treating these diseases (Lin *et al.* 2002). These results are consistent with findings by Chaouchye *et al.* (2020) in the Rif region of Morocco and Chisamile *et al.* (2023) in northern Mali.

Relative Frequency of Citation (RFC)

The RFC was employed to evaluate the most frequently used species in the study area, with values ranging from 0.002 to 0.92 (Table 3). The species with the highest RFC values included *Lavandula x intermedia* Abrial (0.92), *Thymus vulgaris* L. *(0.88), Origanum compactum* Benth. (0.85), *Pistacia lentiscus* L. (0.83), *Lavandula stoechas* L. (0.82), *Mentha pulegium* L *(0.81), Eucalyptus camaldulensis* Dehnh (0.80), *and Matricaria chamomilla* L. (0.80). Conversely, *Ferula communis* L. had the lowest RFC value (0.02), followed by *Visnaga daucoides* Gaertn. (0.04), and *Eryngium triquetrum* Vahl (0.06).

The elevated RFC values can be explained by the fact that these plants are the most well-known and have been used for a long time by most informants, which represents a source of reliability. Species with higher RFC values should be prioritized for phytochemical and pharmaceutical analysis to identify their active compounds for potential drug development (Kayani *et al.* 2015, Mukherjee *et al.* 2012, Vitalini *et al.* 2013).

Fidelity Level (FL)

Fidelity Level (FL) is an essential metric for assessing the efficacy of specific plant species against various ailments (Ahmad *et al.* 2018).

Data analysis revealed FL values ranging from 26.74% to 100% (Table 3). Nineteen species, namely *Cuminum cyminum* L*, Foeniculum vulgare* Mill , *Artemisia absinthium* L, *Atractylis gummifera L, Pulicaria odora* (L.) Rchb, *Cynara cardunculus* L*, Scolymus hispanicus* L*, Eucalyptus camaldulensis* Dehnh*, Hordeum murinum* L*, Pistacia lentiscus* L*, Arbutus unedo* L*, Allium cepa* L *, Asphodelus microcarpus* Parl, *Lepidium sativum* L*, Brassica nigra* (L.) W.D.J.Koch, *Rosa centifolia* L, *Malva sylvestris* L*, Rubia peregrine* L*,* Alpinia *officinarum* Hance present a FL = 100% for treating six diseases.
Additionally, 32 other medicinal plant species demonstrated significant fidelity levels, ranging from 53.3% to 91.83%. *Trigonella foenum-graecum* L (91.83%), *Matricaria chamomilla* L (87.5%), *Origanum compactum* Benth (86.21%), and *Lavandula stoechas* L (84.91%) were the plant species with the highest fidelity levels. On the other hand, 15 species had fidelity level below 50%, with *Peganum harmala L.* showing the lowest FL (26.74%) for bronchopulmonary disorders.

Generally, an FL of 100% for a specific plant indicates that all reports of its use referred to the same treatment method (Srithi *et al.* 2009). Plant species with the highest FL values indicate a good healing potential against a specific mentioned disease, while a lower fidelity level implies that a particular use of a plant is not preferred (Asnake *et al.* 2016). Our results align with those of El Hachlafi *et al.* 2020 and others studies conducted in the Rabat region of Morocco.

Use Value (UV)

The Use Value (UV) indicates the relative importance of the use of medicinal plant species in a specific area. A higher UV signifies a greater significance of a plant within the community (Hassan *et al.* 2019). In this study, UV values ranged from 0.03 to 0.64 (Table 3). The most frequently mentioned species were *Thymus vulgaris* L (0.64), *Mentha pulegium* L *(0.63), Matricaria chamomilla* L *(0.62), Lavandula stoechas* L *(0.61), Lavandula x intermedia* Abrial and *Pistacia lentiscus L (0.60), Rosmarinus officinalis L (0.59), Origanum compactum* Benth *(0.58),* and *Carum carvi* L *(0.56).* Conversely, the lowest UV were observed for *Brassica nigra* (L.) K.Koch (0.03), followed by *Malva sylvestris L* and *Alpinia officinarum* Hance (0.04).
These low values are likely due to these species being less integral to the traditional medicine practices of the local population. The results underscore the significant role of the mentioned species in the cultural and heritage knowledge of the Khemisset area's population. These species thus represent valuable resources that should be conserved and promoted. Similar findings have been reported in other regions of Morocco, including Taza Province (Northern Morocco) by Ghabbour *et al.* 2023 and Driouch Province (Northeast) by Ajjoun *et al.* 2021, as well as in Algeria by Hedidi *et al.* 2024.

Correlation analysis between RFC and UV

The Pearson correlation coefficient (r) between UV and RFC is 0.8397, indicating a significant correlation between the proportion of plant species usage and the frequency of specific uses mentioned by informants. The coefficient of determination (r^2) quantifies the proportion of variance in plant citations that can be attributed to their usage within the local population. A high r^2 value reflects a strong model fit for explaining the relationship between these ethnobotanical indices. In this study, the coefficient is approximately 0.7052, meaning that 70.52% of the variability in UV can be explained by RFC (Ahmad *et al.* 2014, Chen *et al.* 2008). Consequently, RFC and UV demonstrate a linear relationship across all species (Barkatullah *et al.* 2015).

Table 3. List of medicinal and aromatic plants active against various diseases in the province of Khemisset

Families and Scientific name (EPPO Code)	Vernacular name Arabe	Treated ailments	RFC	FL	UV	Corresponding references
Alliaceae						
***Allium cepa* L. (ALLCE)**	**Besla**	GI	0.22	100.00	0.09	(Bellakhdar *et al.*1991, Benkhnigue *et al.* 2010, Bouayyadi *et al.* 2015
***Allium sativum* L. (ALLSA)**	**Touma**	GI-**BP**	0.65	72.46	0.28	(Bellakhdar *et al.* 1991, Benkhnigue *et al.* 2010, Bouayyadi *et al.* 2015
Anacardiaceae						
***Pistacia lentiscus L.* (PIALE)**	**Drou**	**GI-**UG	0.83	100.00	0.60	(Hedidi al.2024)
***Pistacia atlantica* Desf. (PIAAT)**	**Btem**	GI-RH-**UG**	0.79	44.95	0.42	(Bellakhdar *et al.* 1991, El-Hilaly *et al.* 2003, Fakchich & Elachouri 2014, Jeddi *et al.*2021)
Apiaceae						
***Visnaga daucoides Gaertn*. (AMIVI)**	**Bechnikha**	S-**BO**	0.04	53.30	0.19	Bellakhdar 1997, El-Hilaly *et al.* 2003, Salhi *et al.* 2010)
***Cuminum cyminum* L. (CVUCY)**	**Camoun**	**GI**	0.22	100	0.12	(Bellakhdar *et al.* 1991, Benkhnigue *et al.* 2010, Bouayyadi *et al.* 2015)
***Carum carvi* L. (CRYCA)**	**Karwiya**	**BP**-SN	0.68	60.97	0.56	(Bellakhdar 1997, Benkhnigue *et al.* 2010, El Hilaly *et al.* 2003)
***Foeniculum vulgare* Mill. (FOEVU)**	**Nafaa**	**GI**	0.24	100.00	0.36	(Bellakhdar 1997, Benkhnigue *et al.* 2010, El Hilaly *et al.* 2003)
***Coriandrum sativum* L. (CORSA)**	**El kosbour**	**GI**-UG-SN	0.38	48.08	0.12	(Bellakhdar *et al.* 1991,El Hilaly *et al.* 2003,Fakchich & Elachouri 2014)
***Apium graveolens L.* (APUGV)**	**Krafes**	GI-UG-**SN**	0.14	63.38	0.08	(El-Hilaly *et al.* 2003, Bellakhdar 1997, Bouayyadi *et al.* 2015)
***Eryngium triquetrum* Vahl. (ERXTQ)**	**mrîzla**	SN-**S**	0.06	71.19	0.12	Lahsissène *et al.*2009
***Ferula communis L.* (FERCO)**	**Awli**	**UG**-GI	0.02	68.85	0.14	Al-yahya *et al.*1998
***Pimpinella anisum L.* (PIMAN)**	**Habbat halâwa**	GI-**UG**-SN	0.21	45.65	0.09	(Bellakhdar 1997, El-Hilaly *et al.* 2003)
Apocynaceae						
***Nerium oleander L.* (NEROL)**	**Defla**	**S**-RH	0.14	65.58	0.05	(Bellakhdar *et al.*1991, El-Hilaly *et al.* 2003)
***Caralluma europaea* (Guss.) N. E. Br. (CBQEU)**	**Daghmous**	RH-**BP**-UG	0.14	43.48	0.09	Benlamdini *et al.* 2014, Bouayyadi *et al.* 2015,Hachi *et al.* 2015)
Asphodelaceae						
***Asphodelus microcarpus* Parl. (ASHRA)**	**Berwag**	RH	0.41	100.00	0.08	(Bellakhdar *et al.*1991)
***Urginea maritima (L.) Baker* (URGMA)**	**Laansal**	**RH**-S	0.32	60.98	0.05	(El Alami *et al.*2016) (El-Hilaly *et al.* 2003)
Asteraceae						
***Artemisia absinthium L.* (ARTAB)**	**Chiba**	**BP**	0.24	100.00	0.10	(Benlamdini *et al.* 2014, El Hachlafi *et al.* 2020, El-Hilaly *et al.* 2003)

***Artemisia herba-alba* Asso. (ARTHA)**	**Chih**	**UG**-SN-BO	0.32	76.92	0.11	(Bellakhdar 1997, Benkhnigue *et al.* 2010, Benlamdini *et al.* 2014, Bouayyadi *et al.* 2015;)
***Ormenis mixta (L.) Dumort.* (Unavailable)**	**Hellala**	**SN**-GI-S	0.67	63.29	0.41	(Bouayyadi *et al.* 2015, Salhi *et al.* 2010)
***Calendula arvensis* L. (CLDAR)**	**Jemra**	***S***-*RH*	0.48	61.72	0.05	(Miara *et al.*2021)
***Atractylis gummifera* L. (ATKGU)**	**Dâd**	*GI*	0.41	100.00	0.18	(Bouabid *et al.*2020)
***Pulicaria odora* (L.) Rchb. (PULOD)**	**Tafs**	*SN*	0.07	100.00	0.09	(Bellakhdar 1997)
***Cynara cardunculus* L. (CYUCA)**	**Khorchef**	*GI*	0.18	100.00	0.07	(Benkhnigue *et al.* 2010, Bouayyadi *et al.* 2015)
***Scolymus hispanicus* L. (SCYHI)**	**Jarnij**	*GI*	0.21	100.00	0.06	(Lahsissène 2010)
***Matricaria chamomilla* L. (MATCH)**	**El babounj**	**SN-**GI-S-BP	0.80	87.50	0.62	(Bouayyadi *et al.* 2015, Salhi *et al.* 2010)
Brassicaceae						
***Lepidium sativum L.* (LEPSA)**	**Hab rchad**	BP	0.23	100.00	0.09	(Bellakhdar 1997, Benkhnigue *et al.* 2010, Bouayyadi *et al.* 2015)
***Brassica nigra* (L.) *W.D.J.Koch* (BRSNI)**	**Bûhamou**	GI	0.34	100.00	0.03	(Bellakhdar *1997*)
Cleomaceae						
***Cleome violacea L.* (CLEVL)**	**Mkhinza**	*S-**BP-**UG*	0.53	71.42	0.26	(Rhattas *et al.*2016)
Ericaceae						
***Arbutus unedo* L. (ARDUN)**	**Sasno**	***GI***	0.26	100.00	0.09	(El Alami & Chait 2017, El-Hilaly *et al.* 2003)
Fabaceae						
***Ceratonia siliqua L.* (CEQSI)**	**L-Kharoub**	**G**I-D-S	0.59	48.91	0.38	(Bellakhdar *et al.* 1991, Benkhnigue *et al.* 2010,El Hassani *et al.* 2013,El-Hilaly *et al.* 2003)
***Trigonella foenum-graecum* L. (TRKFG)**	**Halba**	**GI**-D	0.28	91.83	0.14	(Bellakhdar *et al.* 1991, Bouayyadi *et al.* 2015, Fakchich & Elachouri 2014)
Geraniaceae						
***Geranium maculatum* (GERMA)**	**Aatercha**	UG-RH-**S**-BP-GI	0.26	29.76	0.08	(Rhattas *et al.*2016)
Lamiaceae						
***Lavandula x intermedia* Abrial (LAVIN)**	**Khzama**	**UG**-BP	0.92	71.18	0.60	(Hedidi *et al.*2024)
***Lavandula multifida* L. (LAVMU)**	**Kohila**	**UG**-BP-GI	0.36	68.85	0.05	(Bellakhdar *et al.* 1991)
Lavandula stoechas* L. *(LAVST)	**Halhale**	UG-**BP**	0.82	84.91	0.61	(Bellakhdar *et al.* 1991)
***Mentha pulegium* L. (MENPU)**	**Fliou**	BP-**D**-SN	0.81	40.32	0.63	(Bellakhdar *et al.* 1991, Benkhnigue *et al.* 2010, Benlamdini *et al.* 2014, El-Hilaly *et al.* 2003)

***Mentha suaveolens* Ehrh. (MENSU)**	**Marsita**	SN-**BP**	0.28	71.42	0.14	(Benkhnigue *et al.* 2010, El-Hilaly *et al.* 2003, Salhi *et al.* 2010)
***Mentha viridis* L. (MENSP)**	**Naanaâ**	SN-**BP**	0.32	68.49	0.21	(Bellakhdar *et al.* 1991, Benkhnigue *et al.* 2010, Bouayyadi *et al.* 2015 , El-Hilaly *et al.* 2003)
***Ocimum basilicum* L. (OCIBA)**	**Lahbaq**	S-UG-**GI**	0.28	42.38	0.06	(Bouayyadi *et al.* 2015, Salhi *et al.* 2010)
***Origanum compactum* Benth. (ORICO)**	**Zaatar**	*GI*-***BP***-*OD*	0.85	86.21	0.58	(Bellakhdar *et al.* 1991, Benlamdini *et al.* 2014, El Hilaly *et al.* 2003, Fakchich & Elachouri 2014)
***Origanum majorana* L. (MAJHO)**	**Merdedoûch**	***GI***-*OD-SN*	0.25	41.23	0.07	(Bellakhdar *et al.* 1991,El Hachlafi *et al.* 2020,El Hilaly *et al.* 2003, Salhi *et al.* 2010)
***Rosmarinus officinalis* L. (RMSOF)**	**Azir**	***BP***-*S-OD*	0.76	74.10	0.59	(Bellakhdar *et al.*1991, El-Hilaly *et al.* 2003, Salhi *et al.* 2010)
***Marrubium vulgare* L. (MAQVU)**	**Marriout.**	***UG-BP***	0.23	62.93	0.05	(Bellakhdar *et al.* 1991, Benkhnigue *et al.* 2010, El Hilaly *et al.* 2003, Fakchich & Elachouri 2014, Salhi *et al.* 2010)
***Salvia officinalis* L. (SALOF)**	**Salmia**	UG-**GI**-BP	0.72	68.30	0.46	(Bellakhdar *et al.* 1991, Bouayyadi *et al.* 2015, El-Hilaly *et al.* 2003)
***Thymus vulgaris* L. (THYVU)**	**Zaaitra**	**GI**-BP-OD-SN	0.88	78.87	0.64	(Bellakhdar 1997, Fakchich & Elachouri 2014)
Linaceae						
***Linum usitatissimum L.* (LIUUT)**	**Zariat el kattan**	**UG**-SN-S	0.11	47.16	0.07	(Bellakhdar 1997)
Malvaceae						
***Malva sylvestris L.* (MALSI)**	**Bakkola**	GI	0.26	100.00	0.04	(Bellakhdar *et al.* 1991, Benkhnigue *et al.* 2010, Bouayyadi *et al.* 2015)
Myrtaceae						
***Eucalyptus camaldulensis* Dehnh. (EUCCM)**	**Kalitûs**	*BP*	0.80	100.00	0.26	(Bellakhdar 1997, El-Hilaly *et al.* 2003)
***Eugenia caryophyllata* Thunb. (SYZAR)**	**Qronfel**	**OD**-BP-D	0.37	65.22	0.36	(Bellakhdar 1997, Benlamdini *et al.* 2014, Bouayyadi *et al.* 2015, Salhi *et al.* 2010)
***Myrtus communis L.* (MYVCO)**	**Rayhane**	*OD-UG-**GI***	0.76	45.80	0.51	(Bellakhdar *et al.* 1991, Bouayyadi *et al.* 2015, El-Hilaly *et al.* 2003)
Oleaceae						
***Olea europea* L. subsp. Oleaster (OLVES)**	**Zebouj**	***D***-*GU-BD-BP*	0.34	38.46	0.08	(Bellakhdar *et al.* 1991, El-Hilaly *et al.* 2003, Fakchich & Elachouri 2014)
***Olea europea L.* (OLVEU)**	**Zaytoune**	***D***-*OD-BP*	0.42	33.61	0.13	(Bellakhdar *et al.*1991, El-Hilaly *et al.* 2003, Fakchich & Elachouri 2014)
Papaveraceae						
***Papaver rhoeas* L. (PAPRH)**	**Balaâmane**	***S***-*RH*	0.40	62.50	0.09	(Bellakhdar *et al.* 1991,El Hassani *et al.* 2013,El-Hilaly *et al.* 2003)

Pedaliaceae						
***Sesamum indicum* L. (SEGIN)**	**Ajeljlane**	**UG**-SN-GI	0.36	48.08	0.06	(Chaachouay *et al.*2020)
Poaceae						
***Pennisetum typhoides* Burn. (PESGL)**	**Illân**	OD-**GI**	0.09	65.94	0.06	(Bouayyadi *et al.* 2015)
Hordeum murinum L. (HORMU)	**Khartal**	**GI**	0.19	100.00	0.08	Bellakhdar 1997
***Lolium rigidum* Gaudin. (LOLRI)**	**Zwan**	**D**-GI	0.34	54.94	0.14	(Bellakhdar 1997)
Rhamnaceae						
Zyziphus lotus (L.)* Lam *(ZIPNU)	**Sedra**	**D**-GI	0.78	58.82	0.44	(Bouayyadi *et al.* 2015, Benlamdini *et al.* 2014, El Hachlafi *et al.* 2020, El-Hilaly *et al.* 2003)
Rosaceae						
***Rosa centifolia L* (ROSCE)**	**Ward beldi**	S	0.16	100.00	0.09	(Bellakhdar *et al.* 1991, El-Hilaly *et al.* 2003, Fakchich & Elachouri 2014)
Rubiaceae						
***Rubia peregrina L.* (RBIPE)**	**Foua**	BP	0.30	100.00	0.12	(Bammi et Douira 2002)
Solanaceae						
***Mandragora autumnalis* Bertol. (MNDAU)**	**Bid al ghul**	**RH**-S	0.34	64.93	0.09	(Bouayyadi *et al.* 2015)
Urticaceae						
***Urtica urens* L. (URTUR)**	**El heriga**	*S*-***RH***	0.76	61.72	0.12	(Benkhnigue *et al.* 2010, Bouayyadi *et al.* 2015, El-Hilaly *et al.* 2003,Fakchich & Elachouri 2014)
Verbenaceae						
***Verbena officinalis L.* (VEBOF)**	**Louiza**	***SN***-*GI*	0.42	73.53	0.24	(Bellakhdar *et al.* 1991, Bouayyadi *et al.* 2015)
Zingiberaceae						
***Alpinia officinarum* Hance. (AIIOF)**	**Kho-denjal**	GI	0.10	100.00	0.04	(Basri *et al.*2017)
Zygophyllaceae						
***Peganum harmala L.* (PEGHA)**	**Harmel**	**BP**-RH-BD-S	0.26	26.74	0.09	(Bellakhdar *et al.* 1991, Benkhnigue *et al.* 2010, Hseini & Kahouadji 2007, Salhi *et al.* 2010)

Conclusion

This ethnobotanical study highlights the profound expertise in traditional phytotherapy among the local population, who depend on traditional medicine for treating various diseases. These practices underscore the rich and diverse floristic heritage of the Khémisset province. The survey documented 66 species of medicinal plants from 27 botanical families, with Asteraceae, Fabaceae, and Apiaceae being the most represented. Additionally, leaves are the most commonly used part of the plant, and most treatments are prepared by decoction and administered orally to treat a large number of diseases, including gastrointestinal, urogenital, and bronchopulmonary disorders.

However, despite the persistence of traditional medicine in the region, it is concerning to note that knowledge and practices are not always transmitted to future generations.

In conclusion, this study not only reveals the traditional medicinal knowledge of the Khémisset population but also provides a valuable ethnobotanical database for researchers to use in future phytochemical and pharmacological investigations.

Declarations

Ethics approval and Consent to participate: Before beginning the ethnobotanical study, we obtained verbal consent from all participants. The data were collected with respect to confidentiality, anonymity and consent of the respondents who were informed about the aim of this study before the interviews.

Consent for publication: Not applicable.

Availability of data and materials: The data featured in this manuscript can be obtained from the corresponding author.

Competing interests: It is stated by the authors that they do not possess any conflicting interests.

Author contributions: Conceptualization: MR; Methodology: MR, AA, TB, AAE and RA; Experimentation. Formal analysis and investigation: MR, FZA, SB, NH and HKh; Writing - original draft preparation: MR; Writing - review and editing: AEI and TZ; Supervision: MR.

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Appendix 1. Questionnaire sheets: Ethnobotanical study of medicinal plant.

Informant:

-Name: ………

-Age: ………..

-Gender: ……..

-Commune: ………

-Division: …….

-Level of study: Illiterate □ Koranic school □ Primary □ Secondary □ University □

Material vegetal:

- When you feel sick, you address: Experiences of others □ Herbalist □ Pharmacy □ Books □ Others □
- Vernacular name: ……………………………………………………Scientific name: ……………………………….
- Local □ or Introduced from other regions □

- Used part: Stem □ Flower □ Fruit □ Seed □ Bark □ Rhizome □ Bulb □ Leaf □ Whole plant □ Root □

-**Use form:** ……….

- **Method of preparation**: Infusion □ Decoction □ Maceration □ Cataplasm □ Fumigation □ Raw □ Cooked □ Others: ………………………..

- Administration mode: Oral □ Inhalation □ Massage □ Rinse □ Others □:

- **Dose used:** - Do you use the plants with precise doses? Yes □ No □

- Dosage:

+ Number of catches: ………………………..

+ Length of Use: One day □ One week □ One month □ Until healing □

-Types of diseases:

Gastro-intestinal disorders □ Uro-genital disorders □ Broncho-pulmonary disorders □ Rheumatism □ Diabetes □ Nervous system disorders □ Skin disorders □ Oral and dental disorders □

- Results:

Healing □ Improvement □ Ineffective □ - Side Effects □ If yes, then - Just undesirable □