Herbalists conserve significantly richer ethnomedicinal knowledge as compared to other members communities in central Morocco

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Research

Abstract

Background: Ethnobotanical research in the Fez-Meknes region (North-central Morocco), encompassing UNESCO cultural sites like Fez and Meknes, lacks breadth, focusing on the use of medicinal plants to treat specific diseases. This research unveils the plentiful ethnomedicinal knowledge in the region employed to address a wide array of health concerns. The present study aims to investigate both traditional knowledge and medicinal plants among herbalists and populations of central provinces of Morocco.

Methods: In this study, 408 non-herbalists and 70 herbalists were interviewed with semi-structured interviews at eleven sampling areas. Ethnobotanical indices and statistics were calculated to explore the gathered data. The unsupervised k-means clustering algorithm, and the Peak Density Detection algorithm were applied for data clustering from non-herbalists and herbalists.

Results: Obtained results showed that 82 species belonging to 34 families and 73 genera were recorded. Herbalists cited 67 plant species compared to 56 by non-herbalists and showed greater divergence of knowledge with a 41 species overlap. *Origanum compactum* Benth. had the highest ethnobotanical index values, and Lamiaceae was frequently used by both groups. High Informant Consensus Factor (ICF) values were observed for digestive system issues. Comparative clustering analysis revealed distinct distribution patterns among herbalists and non-herbalist informants.

Conclusions: The study reveals a wealth of traditional knowledge and highlights the importance of using medicinal plants in traditional medicine to treat a range of illnesses. While non-herbalists and herbalists share some understanding of plant uses, herbalists demonstrate unique knowledge. Many plants have adaptable therapeutic uses for a variety of illnesses, and responders offer new applications for medicinal herbs.

Keywords: Ethnobotanical survey, traditional knowledge, ethnobotanical indices, clustering, medicinal plants, central provinces of Morocco.

Background

Plants are widely acknowledged in traditional medical systems as the most accessible and economical way to cure and prevent a wide range of illnesses (Salmerón-Manzano *et al.* 2020; Soussi *et al.* 2023). Furthermore, cultural and religious beliefs strongly influence people's perceptions of medicine, favoring traditional methods (Kutal *et al.* 2021; Eshete & Molla 2021). This cultural influence allows traditional medicine to persist, with approximately 80% of the population in these countries relying on medicinal plant products for self-medication (Fakchich & Elachouri 2021). This emphasizes how crucial it is to preserve traditional knowledge and apply it to contemporary medicine everywhere, not only in developing nations. It is also crucial to consider the historical applications of plants and their possible advantages in the research and development of novel medications (Jaradat *et al.* 2016).

The use of medicinal plants in Morocco is not solely reliant on natural diversity, but also on the country's cultural heritage, shaped by its ethnic diversity, ancient history, beliefs, and sociocultural conditions (Merrouni *et al.* 2021). The country boasts a long and diverse history of housing various groups of people, including local Berbers, those from the East (Phoenicians, Arabo-Muslims and Jews), the North of Africa (Vandals and Romans), and the South (Sub-Saharan Africans) (Elachouri *et al.* 2023; Maache *et al.* 2024). These diverse influences significantly contribute to the rich cultural heritage, fostering a unique national culture comprising distinct subcultures. Within this cultural diversity, traditional medicine using medicinal plants stands out as a significant aspect. Nevertheless, the global decline in cultural knowledge, specifically regarding medicinal plants, impacts communities and individuals despite the essential role of plants in human health across nations (Brosi *et al.* 2007; Ramirez 2007; Vandebroek & Balick 2012). This decline is influenced by the cultural homogenization, modernization, changes in culture brought on by the abundance of media in the 21st century, the shift to biomedical healthcare, devaluation of traditional herbal practices, lack of cultural support, and government programs promoting medical modernization further contribute to this decline (Vandebroek and Balick 2012). Accordingly, ethnobotanical surveys are essential for conserving and sustainably using biological resources and documenting indigenous knowledge on medicinal plant use (Kumar *et al.* 2011).

Moroccan ethnobotanical research over the past few decades has mostly used qualitative analysis to focus on important traditional plant knowledge. However, the lack of regulated data collection and analysis has made it possible for the documentation of ethnomedicinal knowledge to have errors and inconsistencies (Fakchich & Elachouri 2021). Moreover, studies on the Fez-Meknes region lack breadth, focusing on specific medicinal plants for diseases like nervous system issues (Amaghnouje *et al.* 2020; Beniaich *et al.* 2022), renal diseases (Chebaibi *et al.* 2020), diabetes (Jouad *et al.* 2001; Mechchate *et al.* 2020; Naceiri Mrabti *et al.* 2021) and digestive problems (Es-Safi *et al.* 2020), without a comprehensive representation of all provinces within the region.

In this regard, the primary goal of this study is to gather and record ethnobotanical data from the local populace, including informants who are neither herbalists nor affiliated with the Fez-Meknes region. Comparably, because ethnobotanical knowledge is complex and spreads through oblique, vertical, and horizontal channels, it must be transmitted through these pathways to preserve and spread cultural knowledge about the usage of plants (Caballero-Serrano *et al.* 2019). This information sharing may differ across those who are passionate about medicinal plants, such as herbalists practicing folk medicine and people from a variety of social backgrounds in the public who occasionally utilize plants for medicinal purposes. Therefore, it is anticipated that there would be notable differences in the transmission of ethnobotanical information between herbalists and non-herbalists, resulting in major knowledge gaps between these two groups. Therefore, it is imperative to assess this assumption by means of a comparative analysis of the knowledge possessed by both sets of informants.

Materials and Methods

Study area

The Fez-Meknes region (Figure 1), one of Morocco's 12 administrative divisions, is where this study was carried out. Situated in the northern-central region of the nation, the study area extends from latitudes 32°58′ N to 34°91′ N and from longitudes 2°8′ W to 5°9′ W. This 40,007 km² region is bordered by the Rabat-Sale-Kenitra region to the west, the Tangier-Tetouan-Al Hoceima region to the north, the Oriental region to the east, and the Drâa-Tafilalet region to the south. It is home to 4,236,892 people, of whom 60.52% live in urban areas (Hafdaoui *et al.* 2023). The region around Fez and Meknes has a diverse climate, influenced by both continental and Mediterranean factors. Summertime is defined by heat, and wintertime is typified by low temperatures. However, the high-altitude areas of the Rif experience milder summers but face colder winters with frequent, severe frosts (Moinina *et al.* 2018).

The administrative hub of the area is the city of Fez, which is located in the Saïs plain between the Middle Atlas Mountains to the south and the Rif Mountains to the north. Fez, one of Morocco's imperial cities, has held the title of spiritual capital of the nation and has been its capital on several occasions throughout history. The old town, sometimes referred to as the Medina, is separated from the newer neighborhoods by the royal enclosure. The Medina, designated as a UNESCO World Heritage Site, provides a unique and immersive experience with its labyrinthine streets, historic gates, fortified walls, and specialized shops, all evoking the city's rich medieval heritage (Ez zoubi *et al.* 2022).

The ethnobotanical investigation was conducted in eleven locations across the Fez-Meknes region, including the major towns and villages of Agouray, El-Hajeb, Boulemane, Imouzzer Kandar, Fez, Ifrane, Meknes, Moulay Yacoub, Sefrou, Moulay Idriss Zerhoun, and Taounate (Figure 1).

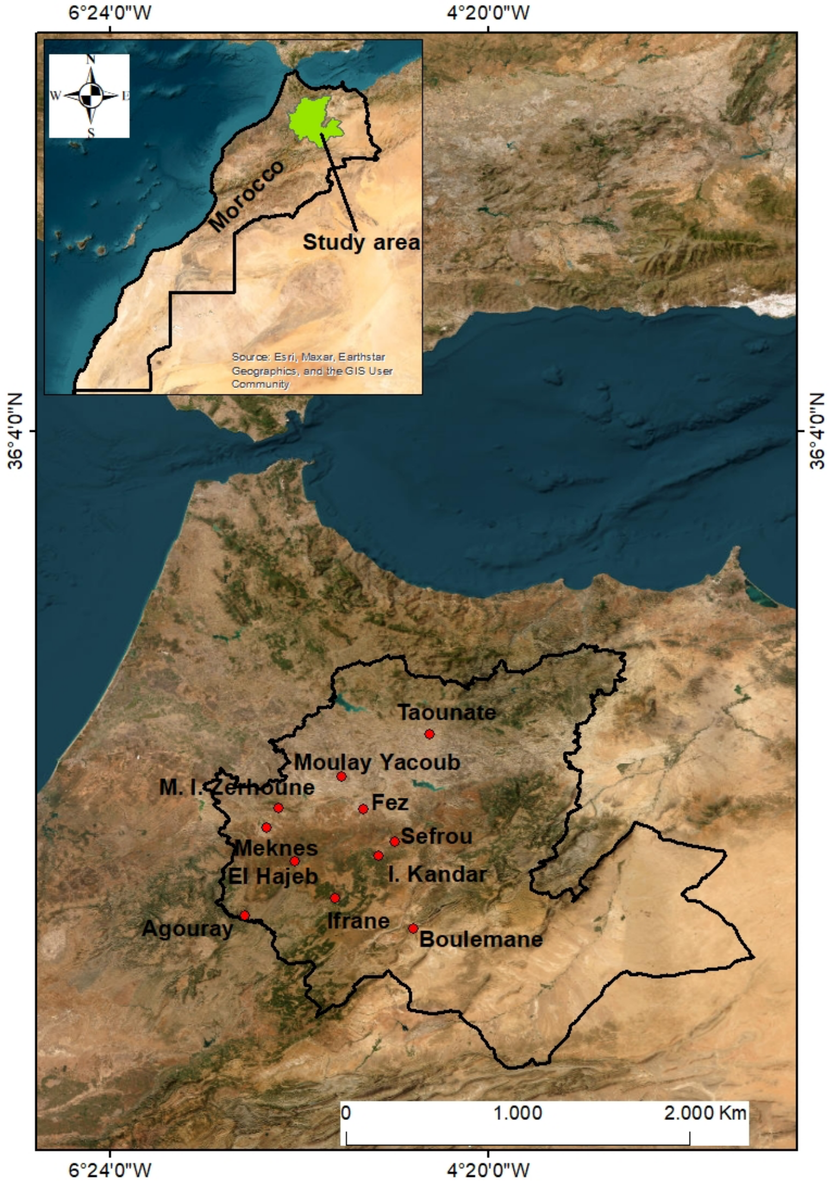

Figure 1. Geographical location of the study area

Data collection

Between April 2019 and July 2022, 408 residents and 70 herbalists participated in the ethnobotanical survey. Merely 408 of the roughly 900 contacted and invited locals contributed. The sample size of 478 was chosen considering (Cochran, 1977) methodology, which was deemed sufficient to ensure adequate representation for the study.

Key informants (herbalists) were identified through purposive sampling, while stratified random samples drawn from the general population to identify ‘knowledgeable’ participants who are not herbalists by occupation (Alexiades, 1996). To ensure a thorough representation, we chose to stratify potential respondents into distinct subgroups based on key characteristics. These include age, gender, educational level, geographic location, occupation and common spoken language/ethnicity. Informants were surveyed at markets, herbalists' shops and natural products cooperatives and outlets, in the facilities of chronic disease associations, including diabetes associations, in urban as well as in rural areas.

The participants received comprehensive information on the objectives of the survey before their participation. Participants shared that traditional knowledge was valued and safeguarded, and any use of the material outside of scholarly publications required consent and approval from the traditional proprietors (Hamdiken *et al.* 2018).

Ailment categories

We classified disorders into groups based on body systems using the World Health Organization's (WHO) ICD-10 Version classification scheme (https://icd.who.int/browse10/2010/en). This method, with minor modifications, is well recognized and compliant with standard ethnomedical practices (Staub *et al.* 2015). In the current investigation, we used the WHO's systematic categorization method in conjunction with informant-provided use data from the study area to classify disorders, yielding 15 categories. Every mention of a particular plant for a certain condition was documented as a single-use report. A single use report was recorded if a participant treated more than one disorder with a plant that fell under the same category (Musa *et al.* 2011).

Botanical collection and plant identification

The botanical identification was conducted by M. Fennane in collaboration with M. Ibn Tattou and O. Benkhnigue, who are expert botanists at the Scientific Institute in Rabat, Morocco. The plant identification followed the Moroccan identification keys, which included 'Vascular Flora of Morocco, Inventory and Chorology' (Fennane &Tattou 2005), 'Flora of North Africa' (Maire, 1952), 'Moroccan Plants Catalogue' (Jahandiez & Maire 1931), and 'Flora of Sahara' (Ozenda, 1977). Additionally, the scientific names of the plant species were reviewed by referencing the Plants of the World Online (https://powo.science.kew.org) and the Kew Botanic Garden Medicinal Plant Names services (http://www.kew.org/mpns). Voucher specimens of each plant were assigned unique codes and deposited in the herbarium.

Data analysis

Data were initially compiled using Microsoft Excel 2016. The consistency of the information was assessed using the comparative data technique of El-Gharbaoui *et al.* (2017). Medicinal usage information was considered reliable when it had been documented by a minimum of three separate informants on at least three occasions. Subsequently, a set of quantitative indices were used to calculate ethnobotanical data, including Use Report per species (UR), Relative Importance Index (RI), Cultural Importance (CI), Cultural Value Index (CV), Fidelity Level (FL), Ranking Order Priority (ROP), Informant Consensus Factor (ICF), Frequency of Citation (FC), Relative Frequency of Citation (RFC), Use Value (UV), and Pearson Correlation Coefficient (PCC). The analysis and data graphing were mainly performed using the R 4.3.1 software for Windows. Various R packages were utilized to efficiently accomplish these tasks in the following manner. Quantitative ethnobotanical indices were computed using the "ethobotanyR" package. The "corrplot" and "stats" packages were utilized, respectively, to calculate correlations and perform chi-square tests, enabling meaningful comparisons between informants from the general population and herbalists. The "circlize" package was employed for creating chord diagrams. Additionally, to cluster the data collected from both the general population informants and herbalists, we utilized the unsupervised k-means clustering algorithm, implemented with the Scikit-learn library in the Python programming language. Furthermore, we also utilized the Peak Density Detection algorithm to perform data clustering within MATLAB environment (Rodriguez and Laio 2014; Jia *et al.* 2015).

Use Report per species (UR)

To assess the cultural significance of plants, a widely employed method involves examining the total number of use-reports (UR) attributed to each species, represented by the variable "s." Mathematically, this can be expressed as follows:

$$UR_s = \sum_{u=u_1}^{u=NC} \sum_{i=i_1}^{i=N} UR_{ui}$$

Where:

N is the total number of informants, u_j (j varies from 1 to NC) represents the number of unique uses in each use category j.

URs calculates the total uses of a species (s) reported by all informants (from i_1 to i_N) within each use-category for that species. It involves counting the number of informants who mention each use-category for the species and summing all uses in each use-category (from u_1 to u_{NC}) (Tardío and Pardo-de-Santayana 2008).

Frequency of Citation (FC) and Relative frequency of citation (RFC)

The frequency of citation (FC) was calculated as follows:

$$FC = \frac{Number\ of\ times\ a\ particular\ species\ was\ mentioned}{Total\ number\ of\ times\ that\ all\ species\ were\ mentioned}$$

The RFC index, as outlined by Tardío and Pardo-De-Santayana (2008), was assessed by dividing the count of informants mentioning species use (FC) by the overall participating informant count (N) in the survey. The RFC index spans from "0," indicating no mention of plant usefulness, to "1," signifying unanimous recognition of plant utility among informants. Mathematically, RFC is calculated as FC/N.

Relative importance index (RI)

The formula employed for RI computation was as follows:

$$RIs = \frac{RFC_{s(\max)} + RNU_{s(\max)}}{2}$$

$$RFC_{s(\max)} = \frac{FCs}{\max FC}$$

$$RNU_{s(\max)} = \frac{NUs}{\max NU}$$

$$NUs = \sum_{u=u_1}^{u=NC} UR_u$$

"RFCs(max)" signifies the relative frequency of citation in relation to the maximum citation frequency. "RNUs" indicates the relative number of use-categories with respect to the maximum. This value was determined by dividing the species' usage count (NUs) by the highest value recorded in the survey (Sharafatmandrad and Khosravi Mashizi 2020).

Use value (UV)

The Use Value (UV) quantifies a species' local significance based on the frequency of utilization records provided from individuals within the study area. In ethnobotany, this parameter is commonly employed to identify the most significant species to the local community (Albuquerque *et al.* 2006). The following formula was utilized for its calculation: It is calculated by summing:

$$UV_s = \sum U_i / N$$

(∑) all usage reports (Ui) related to a specific species and dividing by the total number of informants surveyed (N). Consequently, species with the highest UV values are those that have been most frequently reported by the informants during the study (Hoffman and Gallaher 2007).

Cultural importance (CI)

The Cultural Importance Index (CI) was formulated to evaluate the extent and diversity of the usage associated with each species of cultural significance. The CI's quantifiable value is determined by aggregating the proportions of respondents who cited specific utilization categories corresponding to culturally important plants within their personal gardens (Yinebeb *et al.* 2022). Using the following formula:

$$CI = \sum_{u=1}^{NC} \sum_{i=1}^{N} \frac{UR_{ui}}{N}$$

CI is calculated by dividing the use report score (URs) by the number of informants (N) to account for the diversity of uses for a species (Tardío & Pardo-de-Santayana 2008)

Cultural value index (CV)

The Cultural Value Index (CV) was computed by summing three components through the subsequent formula:

$$CVs = \left[\frac{NUs}{NC}\right] \times \left[\frac{FCs}{N}\right] \times \left[\sum_{u=1}^{NC}\sum_{i=1}^{N}\frac{UR_{ui}}{N}\right]$$

The CVs of a species is determined by its diversity of cultural use categories (NUs/NC), relative frequency of citation (RFC), and overall cultural importance index (CI) (Yinebeb *et al.* 2022).

Family usage value (FUV)

The Family Use Value (FUV) was derived using the following formula to assess the use-values of the species, with the aim of pinpointing the most significant plant families in the study area (Hoffman & Gallaher 2007).

$$FUV = \sum UV / N$$

Here, UV denotes the use-values for species within the family, while N signifies the total count of species in each family. This approach allows for a comprehensive assessment of the importance of different plant families in the context of their traditional uses (Hoffman & Gallaher 2007).

Fidelity Level (FL%)

Fidelity Levels (FL) is a metric used to identify the primary use of a plant and assess the relative importance of use reports within specific use categories. FL is calculated using the following formula:

$$FL(\%) = Np \times 100 / N$$

where Np is the number of use reports for a specific use category and N is the total number of informants citing the species for any therapeutic purpose. FL values can range from 0 to 100, with higher values indicating that the use is more prevalent and important (Friedman *et al.* 1986).

Rank Order Priority (ROP)

The Rank Order Priority (ROP) is calculated by multiplying the degree of fidelity (FL) by the level of relative popularity (RPL). For popular plants, which have an RPL of 1, the ROP is equal to the FL. This means that the fidelity level value is also the rank order priority for popular plants (Umair *et al.* 2017). Thus, ROP = FL X RPL

Amorozo (1988) introduced a simplified RPL calculation, wherein the ratio of informants citing a specific species to those citing the most frequently mentioned species is computed (Eddouks *et al.* 2017).

Informant Consensus Factor (ICF)

The Informant Consensus Factor (ICF) is a tool of significant cultural relevance, assessing agreement among informants regarding plant species used against specific diseases. It was first introduced by Trotter and Logan in 1986 and subsequently refined by Heinrich *et al.* (2009). By categorizing ailments into different groups, the ICF value describes informants' consensus on plant usage and evaluates variability in use against reported diseases. A high ICF value near 1 signifies widespread use of well-known species, while a low ICF index close to 0 indicates random usage of species for treating reported diseases. The ICF provides a quantitative relationship between the number of use reports and the number of taxa used in each category, as shown by the following formula (Heinrich *et al.* 2009):

$$ICF = \frac{(N_{ur} - N_t)}{(N_{ur} - 1)}$$

N_{ur} refers to the overall count of use reports for each disease category, while N_t represents the number of species utilized within that particular category.

Pearson correlation coefficient

The Pearson product-moment correlation coefficient (also known as Pearson's correlation coefficient) is a measure of the strength and direction of the linear relationship between two variables. It is calculated by dividing the covariance between the two variables by the product of their standard deviations (Ibrar *et al.* 2015). The coefficient can be given by formula:

$$r = \frac{\sum_{i=1}^{n}(x_i - x)(y_i - y)}{\sqrt{\left[\sum_{i=1}^{n}(x_i - \bar{x})^2\right]\left[\sum_{i=1}^{n}(y_i - \bar{y})^2\right]}}$$

"r" stands for the Pearson correlation coefficient within the specific sample, with "x" and "y" representing the variables. "x_i" and "y_i" denote the respective values of "x" and "y" for the i^{th} individual. A "r" value of 0 signifies no link between "x" and "y," while a value above 0 suggests a positive connection. A larger absolute value indicates stronger correlation. The square of correlation (r^2) serves as a measure of the variation in the variable "y" that can be accounted for by the variability in the variable "x" (Bano *et al.* 2014). Currently, the correlation between RFC, RI, and UVs was assessed through Pearson's correlation.

Evidence acquisition

To confirm the validity of the medicinal uses reported for plants, the collected information was thoroughly evaluated. A literature search was performed using databases such as Science Direct, Google Scholar, Scopus, and PubMed, up to 2023, to investigate whether the plants used in the study area have any recorded references in scientific literature.

Results

Aromatic and medicinal plants

A total of 82 medicinal plants were recognized, representing 34 families and 73 genera. Herbalists mentioned 67 species from 31 families, while NHI members referred to 56 species from 23 families. The plant species reported by the two groups showed a significant overlap, with exactly half of the total species mentioned (41 species) being cited by both.

In the NHI group, the family Lamiaceae exhibited the highest relative frequency, accounting for 43.9% with a total of 13 species. The Asteraceae followed with 5 species and a relative frequency of 9.4%. The Apiaceae and Myrtaceae families were next, each contributing 13 species, with relative frequencies of 8.1% and 5.6%, respectively. The Amaryllidaceae ranked fifth, comprising 2 species with a relative frequency of 5.3%. All other families showed relative frequencies below 3% (Figure 2A). Among the herbalists, the Lamiaceae family also ranked first, with 14 species representing 27% of the total. The Apiaceae ranked second, while the Compositae ranked third, with eight species each, representing relative frequencies of 15.9% and 10.7%, respectively. With five species and a relative frequency of roughly 9.1%, Leguminosae took fourth place, and Myrtaceae, with three species and a relative frequency of 4.1%, took fifth place. Relative frequencies for the other families were less than 3% (Figure 2B). A Chi-square (χ^2) test was conducted to examine potential differences in the distribution of families between the two groups. The analysis yielded a χ^2 value of 70.24, with 34 degrees of freedom (*df*). The resulting *p*-value was less than 0.001, indicating a statistically significant association between the groups (INH and herbalists) and the distribution of families. Based on these results, it can be concluded that the two groups exhibit distinct patterns in the distribution of botanical families.

Illness categories

Digestive system disorders (DSP) accounted for the greatest number of category citations among both NHI and herbalists, with comparable frequencies of 37.5% and 36.4%, respectively (Figure 3). Further detailed results on other disorder categories are available in our previous publication (Maache *et al.* 2024).

Some notable distinctions between the two groups have been noted while examining the distribution of disease categories among the employed plant species (Figure 4 and 5). Although *Origanum compactum* is used as a medicinal herb and digestive system disorders (DSP) are commonly mentioned by both groups, there are some significant differences between them. The NHI's top 25 plant species are used to cure a variety of disease categories, as shown in Figure 4. The following can be used to arrange these categories in descending order: disorders of the digestive system (DSP), respiratory disorders and cold (RPC), nervous system problems (PNS), endocrine, nutritional, and metabolic diseases (ENM), general health concerns (GHU), reproductive system pathologies (PRS), dermatological disorders (DER), diseases of the urinary system (USD), musculoskeletal disorders (SMP), and cardiovascular diseases (CVD) (Figure 4). On the other hand, the herbalist group exhibits a clear pattern, utilizing the top 25 most commonly cited plant species to treat different types of ailments. Digestive system problems (DSP), endocrine, nutritional, and metabolic diseases (ENM), nervous system problems (PNS), respiratory issues and colds (RPC), urinary system diseases (USD), general health (GHU), and skeletal-muscular problems (SMP) can be grouped in descending order (Figure 5).

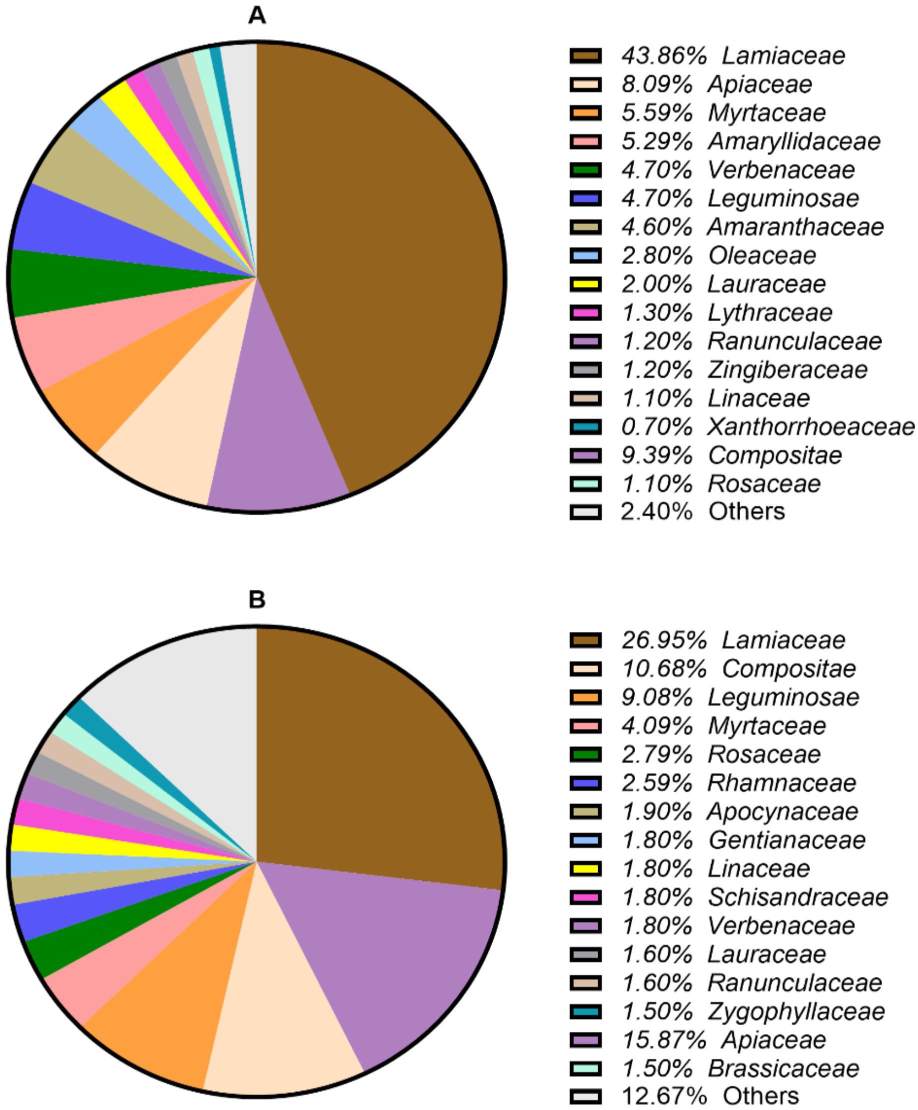

Figure 2. Proportion of each botanical family among non-herbalist informants (A) and herbalists (B)

Among the top 25 most frequently cited plant species by both the NHI and herbalists' groups, 12 species were commonly cited by both groups. These shared species encompass *Aloysia citrodora* (AC), *Artemisia herba-alba* (AH), *Foeniculum vulgare* (FV), *Lavandula dentata* (LD), *Linum usitatissimum* (LU), *Matricaria chamomilla* (MC), *Mentha pulegium* (MP), *Origanum compactum* (OC), *Rosmarinus officinalis (RO)*, *Salvia officinalis* (SO), *Thymus vulgaris* (TV), and *Trigonella foenum-graecum* (TF). In contrast, each group had its set of specific plant species. The NHI group mentioned 13 plant species, including *Artemisia absinthium* (AA), Allium cepa (AC), *Allium sativum* (AS), *Cuminum cyminum* (CC), *Cinnamomum verum* (CV), *Dysphania ambrosioides* (DA), *Dittrichia viscosa* (DV), *Eucalyptus globulus* (EG), *Marrubium vulgare* (MV), *Nigella sativa* (NS), *Olea europaea* (OE), *Syzygium aromaticum* (SA), and *Zingiber officinale* (ZO). On the other hand, the herbalists group cited 13 different plant species, namely *Ammodaucus leucotrichus* (AL), *Anacyclus pyrethrum* (AP), *Carum carvi* (CC), *Centaurium erythraea* (CA), *Ceratonia siliqua* (CS), *Caralluma europaea* (CU), *Illicium verum* (IV), *Myrtus communis* (MC), *Pimpinella anisum* (PA), *Rosa damascene (RS)*, *Senna alexandrina* (SA), *Salvia blancoana* subsp. *mesatlantica* (SS), and *Ziziphus lotus*

(ZL). It is worth noting that the cited plant species within the herbalists group exhibited a more balanced distribution across different ailment categories compared to those cited by individuals from the NHI group.

Most of the included plants were sourced through cultivation (40.6%) or gathered from the wild (34.7%). Additionally, a portion of the medicinal plant comprised species that were imported from other regions within Morocco or foreign countries (24.7%). Notable examples of such imported plants used for medicinal purposes include *Cuminum cyminum* (CC), *Saussurea costus* (SC), *Citrullus colocynthis* (CO), *Cinnamomum verum* (CV), *Senna alexandrina* (SA), *Lawsonia inermis* (LI), and *Zingiber officinale* (ZO) (Tab. 1).

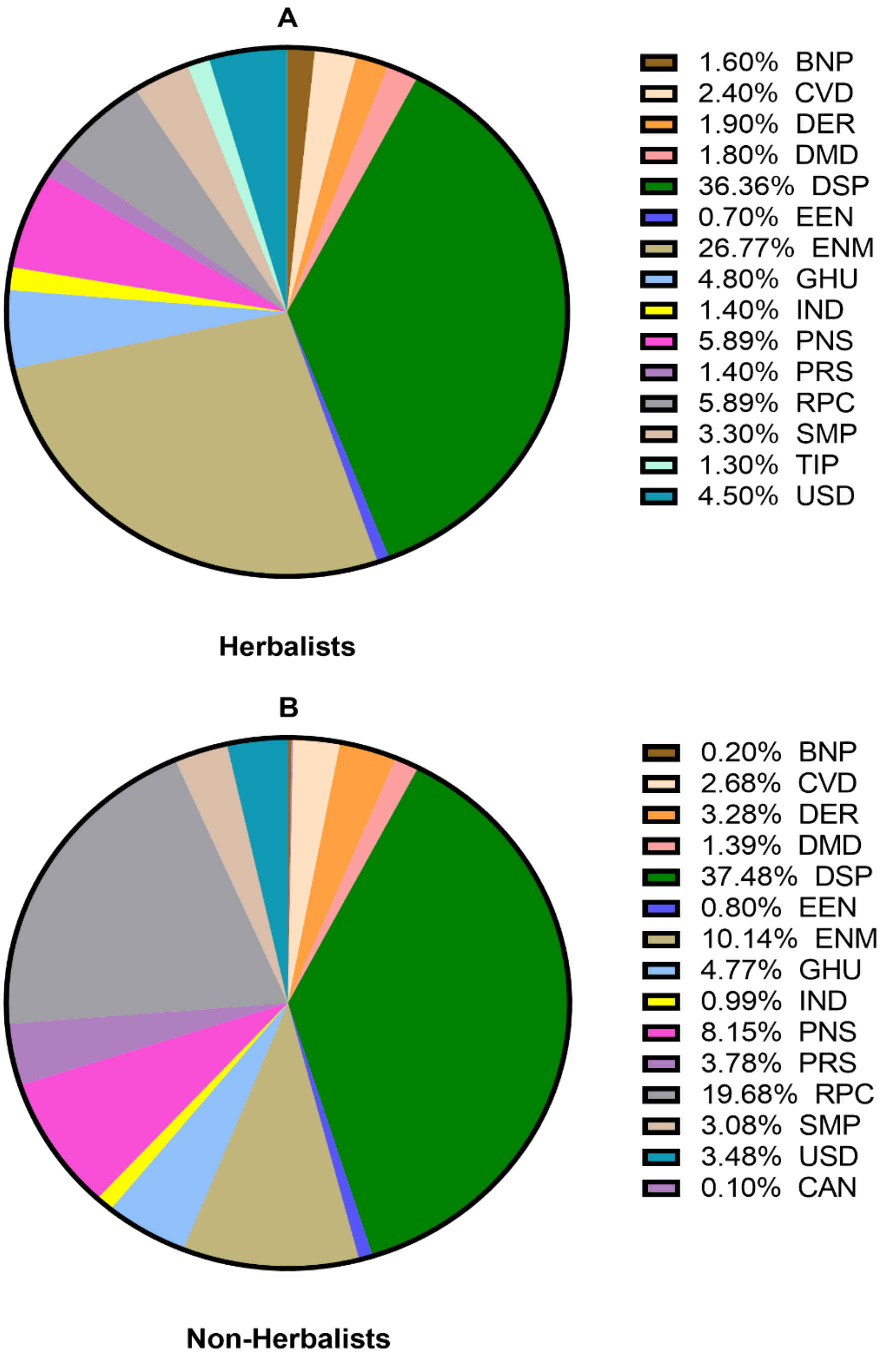

Figure 3. Frequency of illness categories and reported conditions among herbalists and informants.

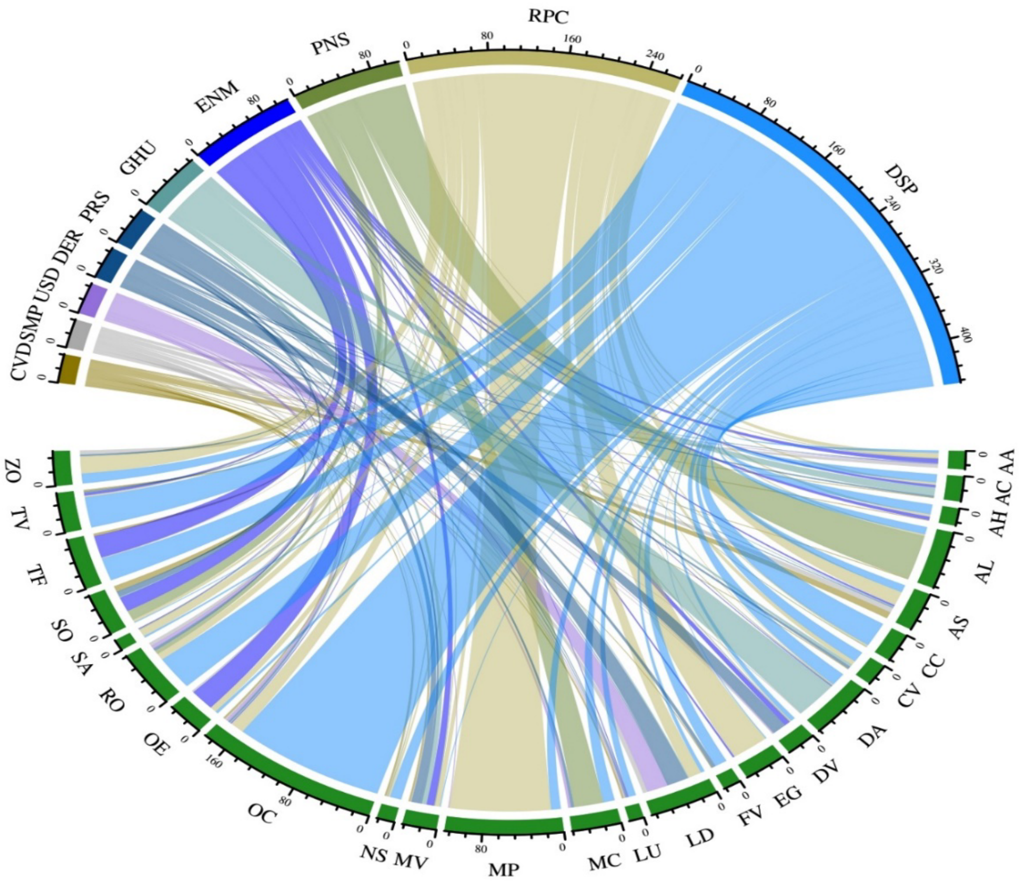

Figure 4. Chord diagram depicting 1190 usage reports across 25 medicinal species and seven categories, as reported by informants from the non-herbalist informants in the Fez-Meknes Region, Morocco: emphasizing prevalent use categories in the upper half and spotlighting the most cited medicinal plants in the lower half.

AA: *Artemisia absinthium* L., AC: *Allium cepa* L., AH: *Artemisia herba-alba* Asso, AL: *Aloysia citrodora* Paláu, AS: *Allium sativum* L., CC: *Cuminum cyminum* L., CV: *Cinnamomum verum* J.Presl, DA: *Dysphania ambrosioides* (L.) Mosyakin & Clemants, DV: *Dittrichia viscosa* (L.) Greuter, EG: *Eucalyptus globulus* Labill., FV: *Foeniculum vulgare* Mill., LD: *Lavandula dentata* L., LU : *Linum usitatissimum* L., MC : *Matricaria chamomilla* L., MP : *Mentha pulegium* L., MV : *Marrubium vulgare* L., NS : *Nigella sativa* L., OC : *Origanum compactum* Benth., OE : *Olea europaea* L., RO : *Rosmarinus officinalis* L., SA : *Syzygium aromaticum* (L.) Merr. & L.M.Perry, SO: *Salvia officinalis* L., TF: *Trigonella foenum-graecum* L., TV: *Thymus vulgaris* L, ZO: *Zingiber officinale* Roscoe

CVD: Cardiovascular diseases, SMP: Skeleton-muscular system problems, USD: Urinary system diseases, DER: Dermatological problems and dermocosmotology, PRS: Pathologies of the reproductive system, GHU: General health and Unspecified signs, ENM: Endocrine, nutritional and metabolic diseases, PNS: Problems of the nervous system and psychiatric disorders, RPC: Respiratory problem and cold, DSP: Digestive system problems.

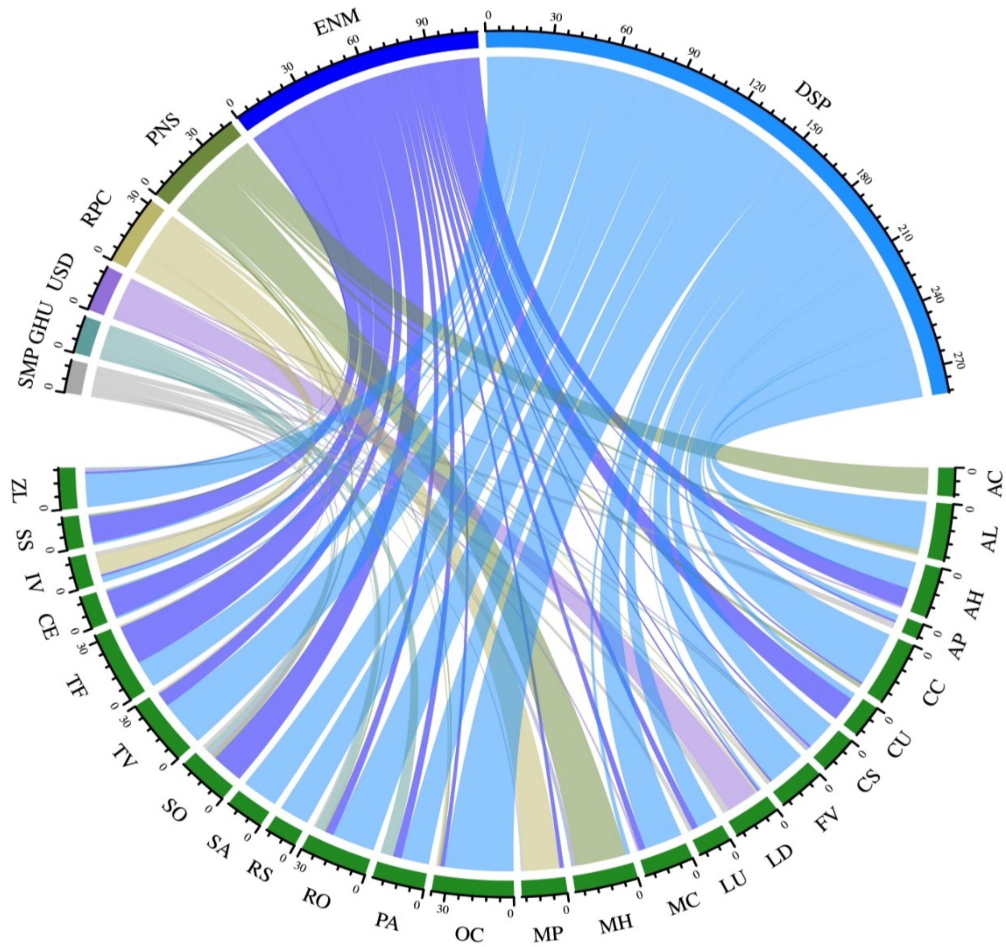

Figure 5. Chord diagram of 527 Usage Reports across 25 medicinal species and seven categories as perceived by herbalists in the Fez-Meknes Region, Morocco: Mapping use categories in the upper half and highlighting the most cited medicinal plants in the lower half.

AC: *Aloysia citrodora* Paláu, AH: *Artemisia herba-alba* Asso, AL: *Ammodaucus leucotrichus* Coss., AP: *Anacyclus pyrethrum* (L.) Lag., CC: *Carum carvi* L., CE: *Centaurium erythraea* Rafn, CS: *Ceratonia siliqua* L., CU: *Caralluma europaea* (Guss) N.E.Br., FV: *Foeniculum vulgare* Mill., IV: *Illicium verum* Hook.f., LD: *Lavandula dentata* L., LU: *Linum usitatissimum* L., MC: *Myrtus communis* L., MH: *Matricaria chamomilla* L., MP: *Mentha pulegium* L., OC: *Origanum compactum* Benth., PA: *Pimpinella anisum* L., RO: *Rosmarinus officinalis* L., RS: *Rosa damascene* Mill., SA: *Senna alexandrina* Mill., SO: *Salvia officinalis* L., SS: *Salvia blancoana* subsp. *mesatlantica* (Maire) Figuerola, TF: *Trigonella foenum-graecum* L., TV: *Thymus vulgaris* L., ZL: *Ziziphus lotus* (L.) Lam.

SMP: Skeleton-muscular system problems, GHU: General health and Unspecified signs, USD: Urinary system diseases, RPC: Respiratory problem and cold, PNS: Problems of the nervous system and psychiatric disorders, ENM: Endocrine, nutritional and metabolic diseases, DSP: Digestive system problems.

Among the two groups of informants, leaves emerged as the most frequently mentioned plant parts, with both groups recognizing their significance. Following leaves, the use of the whole plant was predominantly highlighted by NHI participants. Decoction and infusion emerge as the primary techniques in the preparation of herbal remedies, surpassing alternative methods in popularity. In addition to these two fundamental techniques, the use of powdered plants and maceration are also widely recognized as common methods for formulating phytotherapeutic remedies. In both groups, the oral route is the main method for administering medicinal preparations. However, it is important to note that alternative routes of administration are also utilized. More specifically, inhalation is employed for treating respiratory conditions, while external application is used for dermatological issues (Tab. 1).

Table 1. Medicinal plants utilized in the treatment of various ailments in the central Fez-Meknes region, Morocco.

Families and Plant species [Voucher specimen]	Local name	Ecological distribution	Cited by	Part used	Methods of use and (Route of administration)	Uses Categories	Recorded literature uses in Morocco
Amaranthaceae							
Dysphania ambrosioides (L.) Mosyakin & Clemants [FM-31]	mḫīnza	Sp, Cu	NHI	Le, WP	De, In, Ju, Ma, Po (Or)	DSP, **GHU**	Idm'hand, Msanda, et Cherifi 2020 (●); Kharchoufa *et al.* 2018) (■); Teixidor-Toneu *et al.* 2016 (■)
			H	Le	In, De, Ju (Or)	**DSP**	
Allium cepa L. [FM-04]	bṣel, beṣla	Cu	NHI	Bu, WP	Ju, De (Or), Ra (Or), Ra (EA)	CVD, **DSP**, ENM, GHU, RPC, DER	Bellakhdar *et al.* 1991 (■) ; Mechchate *et al.* 2020 (■) ; Salhi *et al.* 2019; Tahraoui *et al.* 2007 (■)
Allium sativum L. [FM-51]	tūma, tiskert	Cu	NHI	WP, Bu, Se	De, Ra, Ma, Po (Or)	CVD, DSP, IND, **RPC**, SMP	Barkaoui *et al.* 2017 (●); Bellakhdar *et al.* 1991 (■); Eddouks *et al.* 2017 (♦); El-Hilaly, Hmammouchi, et Lyoussi 2003 (♦); Tahraoui *et al.* 2007 (■) ; Tahraoui *et al.* 2023 (♦)
Apiaceae							
Ammi visnaga (L.) Lam. [FM-57]	bū šniḫa, tabešnîḫt	Sp	H	Fr, Se	De, Ma (Or) Po (EA)	DMD, DSP, **ENM**, DER	Amrati *et al.* 2021 (●); Beniaich *et al.* 2022) (●); Eddouks *et al.* 2002 (■); El-Hilaly *et al.* 2003 (■); Hachlafi *et al.* 2020 (■); Mechchate *et al.* 2020 (■); Tahraoui *et al.*2023 (♦)
Ammodaucus leucotrichus Coss. [FM-19]	kemmūn ṣūfi	Cu, Im	NHI	Se	De, In (Or)	**DSP**	Chebaibi *et al.* 2020 (●); Es-Safi *et al.* 2020 (■); Idm'hand, Msanda, et Cherifi (●); Merzouki, Ed-derfoufi, et Molero Mesa 2000 (■)
			H	Se	De, In, Ma (Or)	**DSP**	
Apium graveolens L. [FM-21]	krāfes	Cu	NHI	Se	Po (Or)	**ENM**, SMP, USD	Amrati *et al.* 2021 (●); El-Hilaly *et al.* 2003 (■); Hachlafi *et al.* 2020 (■); Lemhadri *et al.* 2023 (♦); Mechchate *et al.* 2020 (■); Youbi *et al.* 2016 (♦)
			H	WP, Se	Po, Ju (Or)	ENM, **GHU**	

Carum carvi L. [FM-17]	karwiyâ	Cu, Im	NHI	Fr, Se, Le, Fl	De, In, Ma, Po (Or)	**DSP**, ENM,	Barkaoui *et al.* 2017 (●); Eddouks *et al.* 2017 (■); Eddouks *et al.* 2002 (●); Jamila et Mostafa 2014 (■); Mechchate *et al.* 2020 (■); Mrabti *et al.* 2019 (■); Tahraoui *et al.* 2007 (●)
			H	Se	De, In, Po (Or)	**DSP**, PNS	
Coriandrum sativum L. [FM-36]	qezbūr	Cu	NHI	Se	De, Po (Or)	**DSP**, ENM, SMP, PRS	Abouri *et al.* 2012 (♦); El-Hilaly *et al.* 2003 (♦); Es-Safi *et al.* 2020 (■); Kachmar *et al.* 2021 (●); Kharchoufa *et al.* 2018 (♦); Tahraoui *et al.* 2007 (■); Zougagh *et al.* 2019 (●)
			H	Se	Po (Or)	**ENM**, GHU, SMP	
Cuminum cyminum L. [FM-18]	kemmūn	Im	NHI	Se	De, In, Po, Ra, Oi (Or)	**DSP**, RPC,	Abouri *et al.* 2012 (♦); Amrati *et al.* 2021 (●); Bellakhdar *et al.* 1991 (■); Beniaich *et al.* 2022 (●); Kachmar *et al.* 2021 (■); Merzouki *et al.* 2000 (■); Ouhaddou *et al.* 2015 (♦)
Foeniculum vulgare Mill. [FM-35]	n-nāfaɛ, âmsâ, tamsawt	Cu, Im	NHI	WP, Se	De, In, Ma, Po (Or)	**DSP**, PRS	Amrati *et al.* 2021 (●); Bellakhdar *et al.* 1991 (■); Eddouks *et al.* 2002 (●); El-Hilaly *et al.* 2003 (♦); Es-Safi *et al.* 2020 (■); Jamila and Mostafa 2014 (♦); Kachmar *et al.* 2021 (♦); Kharchoufa *et al.* 2018 (♦); Mechchate *et al.* 2020 (●); Mrabti *et al.* 2019 (●); Ouarghidi *et al.* 2013 (♦); Tahraoui *et al.* 2007 (●); Teixidor-Toneu *et al.* 2016 (♦)
			H	Se	De, In, Po (Or)	**DSP**	
Petroselinum crispum (Mill.) Fuss [FM-34]	mɛadnūs, imẓi	Cu	NHI	WP, Le	De, In (Or)	PRS, **USD**	Amrati *et al.* 2021 (●); Kachmar *et al.* 2021 (♦); Lemhadri *et al.* 2023 (♦); Mechchate *et al.* 2020 (■); Ouhaddou *et al.* 2015 (■); Tahraoui *et al.* 2007 (●); Ziyyat *et al.* 1997 (●)
			H	Se, Le	Po, De (Or)	DSP, GHU, ENM, **USD**	
Pimpinella anisum L. [FM-11]	ḥabbat ḥlāwa	Cu	NHI	Se	In (Or), Po (EA)	**DSP**, PRS DER	

			H	Se	De, Ma, Po (Or)	**DSP**, ENM, GHU, PRS	Amrati *et al.* 2021 (●); Bellakhdar *et al.* 1991 (♦); Eddouks *et al.* 2002 (●); El-Hilaly *et al.* 2003 (♦); Hachlafi *et al.* 2020 (♦); Jamila and Mostafa 2014 (♦); Kachmar *et al.* 2021 (♦); Mrabti *et al.* 2019 (■); Skalli, Hassikou, et Arahou 2019 (■); Tahraoui *et al.* 2023 (●)
Apocynaceae							
Caralluma europaea (Guss) N.E.Br. [FM-05]	daġhmūs	Sp	NHI	WP, St	Ra (Or)	ENM, **PRS**	Benkhnigue *et al.* 2014 (■)
			H	AP	Ju (Or)	DSP, **ENM**	
Nerium oleander L. [FM-06]	defla, alili	Sp	NHI	Le	Fu (Inh), De (Or)	DMD, DSP, EEN, **RPC**	Barkaoui *et al.* 2017 (■); Bnouham *et al.* 2002 (♦); Eddouks *et al.* 2002 (♦); El-Hilaly *et al.* 2003 (■); Jouad *et al.* 2001 (■); Laadim *et al.* 2017 (■); Lemhadri *et al.* 2023 (♦); Merzouki *et al.* 2000 (●); Mrabti *et al.* 2019 (■); Salhi *et al.* 2019 (●); Tahraoui *et al.* 2023 (♦); Tahraoui *et al.* 2007 (■); Teixidor-Toneu *et al.* 2016 (■); Ziyyat *et al.* 1997 (■)
Arecaceae							
Chamaerops humilis L. [FM-07]	dūm	Sp	NHI	Fr	Ra (Or)	BNP, DSP, **ENM**, PRS	Benkhnigue *et al.* 2014 (■); Bnouham *et al.* 2002 (♦); El-Hilaly *et al.* 2003 (♦); Hachi, Atmane, et Zidane 2016 (■); Lemhadri *et al.* 2023 (■); Ouarghidi *et al.* 2013 (■)
			H	Fr, Bu	Po, Ra (Or)	**ENM**, PRS, USD	
Brassicaceae							
Lepidium sativum L. [FM-10]	ḥabb r-ršād, l-ḥarf	Cu, Im	NHI	WP, Se	De, Po (Or)	DSP, ENM, PRS, RPC, **SMP**	Abouri *et al.* 2012 (♦); Amrati *et al.* 2021 (●); Beniaich *et al.* 2022 (●);

			H	Se	In, Ra (Or)	**ENM**, SMP, RPC, DSP, BNP, GHU	Eddouks *et al.* 2017 (●); Jamila and Mostafa 2014 (♦); Mechchate *et al.* 2020 (■); Skalli *et al.* 2019 (■); Tahraoui *et al.* 2007 (■); Teixidor-Toneu *et al.* 2016 (♦); Youbi *et al.* 2016 (♦)
Cactaceae							
Opuntia ficus-indica (L.) Mill. [FM-13]	hendiya, zaεbul	Cu	NHI	Fr, Fl, St	De, In (Or)	**ENM**	Amrati *et al.* 2021 (●); Barkaoui *et al.* 2017 (■); El-Hilaly *et al.* 2003 (■); Hachlafi *et al.* 2020 (■); Lemhadri *et al.* 2023 (♦); Mechchate *et al.* 2020 (■); Merzouki *et al.* 2000(■); Tahraoui *et al.* 2023 (♦)
			H	St, Fl	De, In (Or)	DSP, **ENM**, USD	
Caryophyllaceae							
Herniaria hirsuta L. [FM-67]	herrāst l-ḥjar, ḥrīša	Sp	H	Le, AP	De, In, Ma (Or)	**USD**	Amrati *et al.* 2021 (●); Jouad *et al.* 2001 (♦); Tahraoui *et al.* 2023 (♦)
Compositae							
Anacyclus pyrethrum (L.) Lag. [FM-58]	tāġendest, εāqer qerḥā	Sp	H	Ro	De, Po (Or)	DSP, **DMD**, SMP	Jamila and Mostafa 2014 (♦); Merzouki *et al.* 2000 (■); El Midaoui *et al.* 2011 (♦); Ouarghidi *et al.* 2013 (♦)
Artemisia absinthium L. [FM-46]	šība	Cu	NHI	Le, AP	De, In (Or)	DSP, ENM, **RPC**, SMP,	Bnouham *et al.* 2002 (♦); Eddouks *et al.* 2002 (♦); El-Hilaly *et al.* 2003 (♦); Hachlafi *et al.* 2020 (■); Es-Safi *et al.* 2020 (■); Kharchoufa *et al.* 2018 (♦); Lemhadri *et al.* 2023 (♦); Tahraoui *et al.* 2007 (♦); Ziyyat *et al.* 1997 (■); Zougagh *et al.* 2019 (●)
Artemisia herba-alba Asso [FM-48]	šīḥ, îzrî	Sp	NHI	WP, AP, Le, Fl	De, In (Or)	**DSP**, ENM, IND, RPC	Amrati *et al.* 2021 (●); Jamila and Mostafa 2014 (♦); Lemhadri *et al.* 2023 (♦); Merzouki *et al.* 2000 (♦); Tahraoui *et al.* 2007 (♦)
			H	AP	De, In, Po (Or)	**DSP**, ENM, IND	
Carlina gummifera (L.) Less. [FM-60]	addād, ahfyūn	Sp	H	Rt	Fu (Inh), Pl (EA)	IND, **TIP**	Ouarghidi *et al.* 2013 (●); Ouhaddou *et al.* 2015 (●)

Cynara cardunculus L. [FM-50]	ṭimṭa, ḥekk, ḫeršūf	Cu	NHI	Fr, Le	De, Ra (Or)	**ENM**, GHU	Amrati *et al.* 2021 (●); Jamila and Mostafa 2014 (♦); Lemhadri *et al.* 2023 (●); Merzouki *et al.* 2000 (●); Ouarghidi *et al.* 2013 (●); Tahraoui *et al.* 2007 (■)
Dittrichia viscosa (L.) Greuter [FM-27]	magramān , amerril	Sp	NHI	WP, Le	De, In (Or), Po (EA)	DSP, ENM, **DER**	Bellakhdar *et al.* 1991 (■); El Mansouri, Ennabili, et Bousta 2011 (■); Ennabili, Gharnit, et Hamdouni 2000 (♦); Es-Safi *et al.* 2020 (■); Hachi *et al.* 2016 (■); Jamila and Mostafa 2014 (♦); Kachmar *et al.* 2021 (♦); Mouhajir *et al.*, 2001 (●); Ouhaddou *et al.* 2015 (●); Tahraoui *et al.* 2007 (●); Teixidor-Toneu *et al.* 2016 (♦); Ziyyat *et al.* 1997 (■)
			H	Le, Ro	De, In (Or), Po (EA)	ENM, TIP, **DER**	
Matricaria chamomilla L. [FM-03]	bābnūj, bābūnej	Sp	NHI	WP, Fl, Le	De, In (Or)	**PNS**	Abouri *et al.* 2012 (♦); Beniaich *et al.* 2022 (■); Eddouks *et al.* 2017 (■); Eddouks *et al.* 2002 (●); Jamila and Mostafa 2014 (●); Kachmar *et al.* 2021 (♦); Lemhadri *et al.* 2023 (●); Merzouki *et al.* 2000 (♦); (Mouhajir *et al.* 2001) (●); Mrabti *et al.* 2019 (●)
			H	Fl	In (Or)	**PNS**	
Rhaponticum acaule (L.) DC. [FM-75]	tāfrā	Sp	H	Le, Ro	De (Or)	DSP, **ENM**	Ouarghidi *et al.* 2013 (■)
Saussurea costus (Falc.) Lipsch. [FM-79]	l-qūst, l-qūst l-hindi	Im	H	Rh	Po, In (Or)	**CVD,** DSP, ENM**,** SMP, USD	Hachlafi *et al.* 2020 (●)
Sonchus oleraceus L. [FM-80]	kettān l-ḥnāš, l-ġerrīma	Sp	H	Le	De (Or)	**ENM**	Mouhajir *et al.* 2001 (●)
Cucurbitaceae							
Citrullus colocynthis (L.) Schrad. [FM-64]	leḥdej, ḥdej, âferzîz	Im	H	Fr, Sd	In, Ma (Or), Pl (EA)	**ENM**	Barkaoui *et al.* 2017 (■); (Chaachouay *et al.* 2019) (■); Eddouks *et al.* 2017 (■); Jamila and Mostafa 2014 (♦); Jouad *et al.* 2001 (■); Lemhadri *et al.* 2023 (●); Ouarghidi *et al.* 2013 (●);

							Skalli *et al.* 2019 (■); Tahraoui *et al.* 2023 (♦); Ziyyat *et al.* 1997 (■)
Cupressaceae							
Tetraclinis articulata (Vahl) Mast. [FM-81]	ɛarɛār, el-ɛarɛār, âzuka	Sp, Cu	H	Fr, Le	De (Or)	DSP, **ENM**, GHU, PRS	Bellakhdar *et al.* 1991 (■); Eddouks *et al.* 2002 (♦); El-Hilaly *et al.* 2003 (●); Jamila and Mostafa 2014 (♦); Kachmar *et al.* 2021 (♦); Lemhadri *et al.* 2023 (♦); Merzouki *et al.* 2000 (♦); Mrabti *et al.* 2019 (■); Tahraoui *et al.* 2023 (♦)
Gentianaceae							
Centaurium erythraea Rafn [FM-61]	guṣṣat l-ḥayya	Sp	H	Fl, Le	De, In, Po (Or)	**ENM**	El-Hilaly *et al.* 2003 (●); Hachlafi *et al.* 2020 (■); Jamila and Mostafa 2014 (♦); Jouad *et al.* 2001 (■); Kachmar *et al.* 2021 (♦); Merzouki *et al.* 2000 (♦); Tahraoui *et al.* 2023 (♦)
Lamiaceae							
Ajuga iva (L.) Schreb. [FM-45]	šendgūra, tûf ṭolba	Sp	NHI	WP, Le	In (Or)	DSP, **ENM**	Abouri *et al.* 2012 (♦); Barkaoui *et al.* 2017 (■); El-Hilaly *et al.* 2003 (●); Hachlafi *et al.* 2020 (■); Es-Safi *et al.* 2020 (■); Jamila and Mostafa 2014 (♦); Lemhadri *et al.* 2023 (♦); Mrabti *et al.* 2021 (■); Tahraoui *et al.* 2023 (♦); Teixidor-Toneu *et al.* 2016 (●); Youbi *et al.* 2016 (●)
			H	AP, Fl, Le	De, In, Po (Or)	DSP, **ENM**,	
Calamintha officinalis Moench [FM-29]	mantā, l-mantā	Sp, Cu	NHI	Le	In (Or)	DSP, **PNS**, RPC, SMP, USD	Beniaich *et al.* 2022 (■); El-Hilaly *et al.* 2003 (♦); Mechchate *et al.* 2020 (■); Mrabti *et al.* 2019 (■)
			H	Le, AP	De, In (Or)	DMD, ENM, **PNS**, RPC	
Lavandula dentata L. [FM-15]	ḫūzama	Cu, Im	NHI	WP, Le, Fl	De, In (Or)	DSP, PRS, RPC, SMP, **USD**	Barkaoui *et al.* 2017 (●); Beniaich *et al.* 2022 (●); Eddouks *et al.* 2017 (●); Hachlafi *et al.* 2020 (♦); Jamila and

			H	Fl, Le	De, In (Or)	SMP, **USD**	Mostafa 2014 (■); Mechchate *et al.* 2020 (●); Mrabti *et al.* 2019 (●); Tahraoui *et al.* 2023 (♦); Teixidor-Toneu *et al.* 2016 (♦)
Lavandula stoechas L. [FM-71]	ḥelḥāl	Sp	H	AP, Le	De, In (Or)	DSP, SMP, **USD**	Abouri *et al.* 2012 (■); Barkaoui *et al.* 2017 (●); El-Gharbaoui *et al.* 2017 (♦); El-Hilaly *et al.* 2003 (■); Es-Safi *et al.* 2020 (♦); Jamila and Mostafa 2014 (♦); Kachmar *et al.* 2021 (■); Lemhadri *et al.* 2023 (♦); Mechchate *et al.* 2020 (●); Tahraoui *et al.* 2023 (♦)
Marrubium vulgare L. [FM-30]	merriūt, merrîwa, ifezzi	Sp	NHI	WP, Le	De, In, Ju, (Or) Po (EA)	CVD, **ENM**, GHU, RPC, PRS, DER, EEN	Barkaoui *et al.* 2017 (■); Chaachouay *et al.* 2019 (■); El-Hilaly *et al.* 2003 (■); Es-Safi *et al.* 2020 (■); Idm'hand, Msanda, et Cherifi 2020 (■); Jamila and Mostafa 2014 (♦); Kachmar *et al.* 2021 (♦); Mechchate *et al.* 2020 (■); Mouhajir *et al.* 2001 (■); Mrabti *et al.* 2019 (■); Salhi *et al.* 2019 (♦); Tahraoui *et al.* 2007 (■); Teixidor-Toneu *et al.* 2016 (♦)
			H	Le	In, Ma, Po (Or)	DSP, **ENM**	
Mentha pulegium L. [FM-09]	fliyyo, fliyou	Sp	NHI	WP, Fl, Le	De, In, De (Or) Fe (Inh)	DSP, **RPC**	Eddouks *et al.* 2017 (♦); El-Hilaly *et al.* 2003 (♦); Jamila and Mostafa 2014 (■); Kharchoufa *et al.* 2018 (♦); El Midaoui *et al.* 2011 (■); Tahraoui *et al.* 2023 (♦); Tahraoui *et al.* 2007 (♦); Teixidor-Toneu *et al.* 2016 (♦); Ziyyat *et al.* 1997 (■)
			H	Le, AP	De, In (Or)	ENM, **RPC**, SMP	
Mentha suaveolens Ehrh. [FM-33]	mšīštru, l-marsitā, timerşad	Sp	NHI	Le	De, In, Po, Ju,	CVD, **DSP**, ENM, PRS, RPC	Abouri *et al.* 2012 (♦); Jamila and Mostafa 2014 (♦); Lemhadri *et al.* 2023 (■); Skalli *et al.* 2019 (■); Teixidor-Toneu *et al.* 2016 (♦); Zougagh *et al.* 2019 (●)
			H	Le	Pl (EA), De, Po (Or)	DER, **IND**	

Mentha aquatica L. [FM-28]	mantā l-mā, mantā lmrūj	Sp	NHI	Le	Ra, In (Or)	GHU, PRS, **PNS**, SMP	Not found
Ocimum basilicum L. [FM-12]	ḥbaq, laḥbaq	Cu	NHI	WP, Le	De, In (Or)	DSP, **PNS**, RPC	El-Gharbaoui *et al.* 2017 (♦); El-Hilaly *et al.* 2003 (●); Hachlafi *et al.* 2020 (●); Es-Safi *et al.* 2020 (■); Hachi *et al.* 2016 (●); Idm'hand, Msanda, et Cherifi 2020 (●); Jouad *et al.* 2001 (●); Lemhadri *et al.* 2023 (♦); Merzouki *et al.* 2000 (●); Tahraoui *et al.* 2023 (♦)
Origanum compactum Benth. [FM-53]	zaɛtar, za'tar, ṣa'tar	Sp, Cu	NHI	WP, AP, Le	De, In, Ma, Po (Or)	CVD, **DSP**, PRS, RPC, SMP, USD	Bnouham *et al.* 2002 (♦); Eddouks *et al.* 2002 (■); El-Hilaly *et al.* 2003 (■); Hachlafi *et al.* 2020 (■); Idm'hand, Msanda, et Cherifi 2020 (■); Jamila and Mostafa 2014 (■); Mechchate *et al.* 2020 (■); Tahraoui *et al.* 2023 (♦); Ziyyat *et al.* 1997 (■)
			H	Le, AP	De, In, Po (Or)	**DSP**, ENM, PNS, TIP, USD	
Origanum majorana L. [FM-73]	Merdedūš	Cu	H	Le, AP, Fl	De, In (Or)	ENM, PNS, RPC, **DSP**, GHU	Amrati *et al.* 2021 (●); El-Hilaly *et al.* 2003 (■); Hachlafi *et al.* 2020 (♦); Jamila and Mostafa 2014 (♦); Kachmar *et al.* 2021 (■); Merzouki *et al.* 2000 (■); Tahraoui *et al.* 2007 (●)
Rosmarinus officinalis L. [FM-02]	azīr	Cu, Sp	NHI	WP, Le	De, In (Or), Po (EA)	**DSP**, PNS, RPC, SMP, USD, DER	Kharchoufa *et al.* 2018 (■); Mechchate *et al.* 2020 (■); Merzouki *et al.* 2000 (■); Mouhajir *et al.* 2001 (■); Ouhaddou *et al.* 2015 (■); Salhi *et al.* 2019 (); Skalli *et al.* 2019 (♦); Tahraoui *et al.* 2023 (■); Tahraoui *et al.* 2007 (■); Ziyyat *et al.* 1997 (■)
			H	Le, AP	De, In, Po (Or)	CVD, **DSP**, ENM, PNS, SMP	
Salvia blancoana subsp. *mesatlantica* (Maire) Figuerola [FM-40]	sālmiya, es-sâlmiya, tamejjūt	Cu	NHI	WP, Le	De, In, Po (Or)	**ENM**, PNS, RPC	Not found
			H	Fl, Le	In (Or)	DSP, **ENM**, PNS	

Salvia officinalis L. [FM-41]	sālmiya, es-sâlmiya, tamejjūt	Cu, Im	NHI	WP, Le	De, In, Ma, Po (Or)	CVD, **ENM**, PNS, PRS, RPC	Barkaoui *et al.* 2017 (■); Chaachouay *et al.* 2019 (■); Eddouks *et al.* 2017 (♦); El-Gharbaoui *et al.* 2017 (♦); Idm'hand, Msanda, et Cherifi 2020 (■); Jamila and Mostafa 2014 (♦); (Kabbaj *et al.* 2012) (●); Kachmar *et al.* 2021 (■); Lemhadri *et al.* 2023 (♦); Mechchate *et al.* 2020 (■); Mrabti *et al.*, 2019 (■); Skalli *et al.* 2019 (■); Tahraoui *et al.* 2023 (♦)
			H	Le	In (Or)	BNP, CVD, **ENM**, GHU, PNS, PRS	
Salvia verbenaca L.	ḫiyyāṭa	Sp	H	Le	De, In (Or), Po (EA)	**ENM**, SMP, DER	Lemhadri *et al.* 2023 (♦); Salhi *et al.* 2019 (♦)
Thymus vulgaris L. [FM-55]	zɛitra, tazukennit	Sp, Cu	NHI	WP, AP, Le	De, In (Or), Po (EA)	CVD, **DSP**, ENM, RPC DER,	El-Gharbaoui *et al.* 2017 (♦); Hachlafi *et al.* 2020 (■); Es-Safi *et al.* 2020 (■); Hachi *et al.* 2016 (■); Kachmar *et al.* 2021 (■); Tahraoui *et al.* 2023 (♦); Tahraoui *et al.* 2007 (■); Youbi *et al.* 2016 (♦); Zougagh *et al.* 2019 (●)
			H	Le, AP	De, In, Po (Or)	**DSP**, ENM	
Lauraceae							
Cinnamomum cassia (L.) J.Presl	qārfā,, l-qārfā, l-ġlīdā	Im	H	Ba	De, Po (Or)	**DSP**, RPC, SMP	Chebaibi *et al.* 2020 (●)
Cinnamomum verum J.Presl [FM-22]	lakrafā, qarfa al-ḥârra	Im	NHI	WP, Se	De, In, Ma, Po (Or)	**DSP**, GHU, PRS, RPC	Hachlafi *et al.* 2020 (♦); Kachmar *et al.* 2021 (♦); Mechchate *et al.* 2020 (●); Ouhaddou *et al.*, 2015 (■); Skalli *et al.* 2019 (●)
Laurus nobilis L. [FM-56]	ɛṣat sīdna mūsa, rend	Cu	NHI	Le	De (Or)	**RPC**	Abouri *et al.* 2012 (♦); Jamila and Mostafa 2014 (●); Kachmar *et al.* 2021 (■); Merzouki *et al.* 2000 (♦); Mouhajir *et al.* 2001 (●); Ziyyat *et al.* 1997 (♦)
			H	Le	De, In (Or)	**DSP**, ENM	
Leguminosae							
Ceratonia siliqua L. [FM-62]	l-ḫerrūb, sliġwa	Cu	H	Fr, Se	Po, Ra (Or)	**DSP**	El-Hilaly *et al.* 2003 (■); Hachlafi *et al.* 2020 (●); Es-Safi *et al.* 2020 (■); Jamila

							and Mostafa 2014 (♦); Lemhadri *et al.* 2023 (♦); Merzouki *et al.* 2000 (■); Mrabti *et al.* 2019 (●); Skalli *et al.* 2019 (●); Tahraoui *et al.* 2023 (♦)
Glycyrrhiza glabra L. [FM-66]	ɛarq s-sūs	Sp	H	Rt	De, In, Po (Or)	ENM, USD, **RPC**, PRS	Amrati *et al.* 2021 (●); Hachlafi *et al.* 2020 (♦); Es-Safi *et al.* 2020 (●); Jamila and Mostafa 2014 (♦); Lemhadri *et al.* 2023 (♦); Merzouki *et al.* 2000 (■); Ouarghidi *et al.* 2013 (♦); Skalli *et al.* 2019 (■)
Lupinus albus L. [FM-72]	termis	Cu, Im	H	Sd	Po, In (Or)	BNP, **ENM**, GHU	Bellakhdar *et al.* 1991 (■); Idm'hand, Msanda, et Cherifi 2020 (■); Jamila and Mostafa 2014 (♦); Mechchate *et al.* 2020 (■); Merzouki *et al.* 2000 (■); Mrabti *et al.* 2019 (■); Tahraoui *et al.* 2023 (♦)
Mimosa pudica L. [FM-32]	mimosā, l- mimosā	Cu	NHI	Le	In (Or)	**DSP**, RPC	Not found
Senna alexandrina Mill. [FM-42]	sānā, sānā makki	Im	NHI	Le	De, In (Or)	BNP, **DSP**	El Mansouri *et al.* 2011 (■); Es-Safi *et al.* 2020 (■); Ouhaddou *et al.* 2015 (■)
			H	Le	De, In, Po (Or)	**DSP**	
Trigonella foenum-graecum L. [FM-24]	l-ḥelba, afiḍās, tifiḍas	Cu, Im	NHI	Se, WP	De, In, Ma, Po (Or)	CVD, **DSP**, ENM	Barkaoui *et al.* 2017 (■); Eddouks *et al.* 2017 (♦); El-Hilaly *et al.* 2003 (♦); Es-Safi *et al.* 2020 (■); Idm'hand, Msanda, et Cherifi 2020 (■); Jamila and Mostafa 2014 (■); Jouad *et al.*2001 (■); Kachmar *et al.* 2021 (♦); Laadim *et al.* 2017 (■); Mechchate *et al.* 2020 (■); Merzouki *et al.* 2000 (●); Mrabti *et al.* 2019 (■); Tahraoui *et al.* 2023 (♦); Tahraoui *et al.* 2007 (■); Teixidor-Toneu *et al.* 2016 (♦); Ziyyat *et al.* 1997 (■)
			H	Se	Ma, Po (Or)	CVD, **ENM**, RPC, DSP	
Linaceae							

Linum usitatissimum L. [FM-20]	kettān, zerrîɛt l-kettân	Cu, Im	NHI	Fr, Se, Le	De, Ma (Or) Po (EA)	CVD, **DSP**, ENM, PRS, SMP, USD, DER	Chaachouay *et al.* 2019 (■); Eddouks *et al.* 2002 (■); Hachlafi *et al.* 2020 (■); Es-Safi *et al.* 2020 (■); Jouad *et al.* 2001 (■); Lemhadri *et al.* 2023 (♦); Mechchate *et al.* 2020 (■); Merzouki *et al.* 2000 (■); Mouhajir *et al.* 2001 (●); Salhi *et al.* 2019 (■); Skalli *et al.* 2019 (■); Tahraoui *et al.* 2023 (♦)
			H	Se	In, Ma, Po (Or)	**DSP**, ENM, SMP	
Lythraceae							
Lawsonia inermis L. [FM-14]	ḥenna, l-ḥenna	Im	NHI	Le	In, Po, Pa (EA)	**DER**	Bellakhdar *et al.* 1991 (♦); Eddouks *et al.* 2017 (■); Eddouks *et al.* 2002 (●); Jamila and Mostafa 2014 (♦); Kachmar *et al.* 2021 (♦); Lemhadri *et al.* 2023 (♦); Mouhajir *et al.*, 2001 (■); Salhi *et al.* 2019 (♦); Tahraoui *et al.* 2023 (♦); Teixidor-Toneu *et al.* 2016 (■)
Punica granatum L. [FM-39]	rommān,, tarommānt	Cu	NHI	Fr, Le	De, Pa (Or)	**DSP**, DMD, ENM	Eddouks *et al.* 2002 (■); El-Hilaly *et al.* 2003 (■); Hachlafi *et al.* 2020 (■); Es-Safi *et al.* 2020 (■); Idm'hand, Msanda, et Cherifi 2020 (■); Jamila and Mostafa 2014 (♦); Lemhadri *et al.* 2023 (♦); Mechchate *et al.* 2020 (■); Merzouki *et al.* 2000 (♦); Salhi *et al.* 2019 (●); Tahraoui *et al.* 2007 (■); Tahraoui *et al.* 2023 (♦); Teixidor-Toneu *et al.* 2016 (■)
			H	Ba, Fr	Po, De (Or)	**DSP**, ENM	
Malvaceae							
Hibiscus sabdariffa L. [FM-68]	kārkādil	Im	H	Fl	Ju, In (Or)	**CVD**, PNS, SMP	Hachlafi *et al.*, 2020 (■); Idm'hand, Msanda, et Cherifi 2020 (●)
Myrtaceae							
Eucalyptus globulus Labill. [FM-16]	kalitûs, kalibtûs	Cu, Sp	NHI	WP, Le	De, In (Or), Fu (Inh)	ENM, **RPC**	Eddouks *et al.* 2002 (■); Hachlafi *et al.* 2020 (■); Jouad *et al.* 2001 (♦);

			H	Le	Fu (Inh), De (Or)	**RPC**, USD	Kachmar *et al.* 2021 (■); Lemhadri *et al.* 2023 (♦); Mechchate *et al.* 2020 (■); Merzouki *et al.* 2000 (●); Mrabti *et al.* 2019 (■); Tahraoui *et al.* 2023 (♦); Ziyyat *et al.* 1997 (♦)
Myrtus communis L. [FM-38]	Rīḥān	Sp	NHI	WP, Le	De, In (Or), Po (EA)	**DSP,** RPC, DER	Eddouks *et al.* 2017 (■); El-Hilaly *et al.* 2003 (♦); Hachlafi *et al.* 2020 (♦); Idm'hand, Msanda, et Cherifi 2020 (■); Jamila and Mostafa 2014 (■); Jouad *et al.* 2001 (■); Kachmar *et al.* 2021 (■); Mechchate *et al.* 2020 (■); Merzouki *et al.* 2000 (■); Mrabti *et al.* 2019 (■); Tahraoui *et al.* 2023 (♦); Ziyyat *et al.* 1997 (■)
			H	Le	De, In, Po (Or)	**DSP**, ENM	
Syzygium aromaticum (L.) Merr. & L.M.Perry [FM-37]	qrānfūl	Im	NHI	WP, Se, Le	De, In (Or)	**DMD**, DSP, RPC	Chebaibi *et al.* 2020 (●); Idm'hand, Msanda, et Cherifi 2020 (●); Lemhadri *et al.* 2023 (■); Skalli *et al.* 2019 (●); Ziyyat *et al.* 1997 (●); Zougagh *et al.* 2019 (■)
			H	Fl	De, Po (Or)	**DMD**	
Oleaceae							
Olea europaea L. [FM-54]	zitūn, z-zūtin	Cu	NHI	AP, Le, Fr	De, In, Oi (Or)	DMD, **ENM**, RPC	Barkaoui *et al.* 2017 (■); Eddouks *et al.* 2017 (■); Es-Safi *et al.* 2020 (●); Jamila and Mostafa 2014 (■); Jouad *et al.* 2001 (♦); Lemhadri *et al.* 2023 (♦); Mrabti *et al.* 2019 (■); Skalli *et al.* 2019 (■); Tahraoui *et al.* 2007 (♦); Tahraoui *et al.* 2023 (♦); Teixidor-Toneu *et al.* 2016 (♦); Ziyyat *et al.* 1997 (♦); Zougagh *et al.* 2019 (■)
			H	Le, Fr	De, In (Or)	**ENM**	
Plantaginaceae							
Globularia alypum L. [FM-65]	taselġa, aselġa, 'ayn lerneb	Sp	H	Le, AP	De (Or)	**ENM**	Abouri *et al.* 2012 (♦); Eddouks *et al.* 2002 (■); Jamila and Mostafa 2014 (♦); Merzouki *et al.* 2000 (♦);

							Tahraoui *et al.* 2023 (♦); Ziyyat *et al.* 1997 (■)
Poaceae							
Panicum miliaceum L. [FM-74]	illān	Im, Cu	H	Se	Po, Ra (Or)	BNP, **SMP**	Bnouham *et al.* 2002 (■); Lemhadri *et al.* 2023 (●)
Pennisetum glaucum (L.) R.Br. [FM-08]	ed-dhrā, dūrā	Cu	NHI	Sd	Po (Or)	**SMP**	Not found
Ranunculaceae							
Nigella sativa L. [FM-43]	šanūj, l-ḥabba sawda	Cu, Im	NHI	Se	De, In, Po (Or)	CVD, **DSP**, RPC	Abouri *et al.* 2012 (♦); Eddouks *et al.* 2002 (■); Hachlafi *et al.* 2020 (♦); Es-Safi *et al.* 2020 (■); Idm'hand, Msanda, et Cherifi 2020 (■); Jamila and Mostafa 2014 (♦); Kachmar *et al.* 2021 (●); Mechchate *et al.* 2020 (■); Mouhajir *et al.* 2001 (♦); Mrabti *et al.* 2019 (■); Skalli *et al.* 2019 (■); Tahraoui *et al.* 2023 (♦); Teixidor-Toneu *et al.* 2016 (♦)
			H	Se	De, Po, Ra (Or)	CVD, **DSP**, ENM, RPC	
Rhamnaceae							
Ziziphus lotus (L.) Lam. [FM-44]	sedra, tazuggwart, nnbeg	Sp	NHI	Fr, Le	De, In, Po (Or)	**DSP**, RPC	El-Hilaly *et al.* 2003 (♦); Hachlafi *et al.* 2020 (■); Idm'hand, Msanda, et Cherifi 2020 (■); Kachmar *et al.* 2021 (♦); Mrabti *et al.* 2019 (■); Ouarghidi *et al.* 2013 (■); Tahraoui *et al.* 2023 (♦)
			H	Fr, Le	In (Or) Po (EA),	**DSP**, ENM, GHU, IND, USD, DER	
Rosaceae							
Crataegus monogyna Jacq. [FM-01]	admām	Sp	NHI	Fr	Po (Or)	BNP, **CVD**	Merzouki *et al.* 2000 (●)
			H	Fr, Le	In (Or), Po (EA)	**CVD**, DER	
Rosa damascene Mill. [FM-52]	ward beldi, tiḫfert	Cu	NHI	Fl	De, In	**DSP**	Eddouks *et al.* 2017 (■)
			H	Fl	De (Or),	**DSP**,	

					In (EA)	EEN	
Rubiaceae							
Rubia tinctorum L. [FM-76]	fūwa, tiğmit	Im	H	Ro	De, Po (Or)	**BNP**, CVD	Eddouks *et al.* 2002 (■); Jouad *et al.* 2001 (●); Lemhadri *et al.* 2023 (●); Ouarghidi *et al.* 2013 (♦); Youbi *et al.* 2016 (●)
Rutaceae							
Ruta montana (L.) L. [FM-77]	fjīla, awermi	Sp	H	AP	De, In (Or)	**ENM**	Bellakhdar *et al.* 1991 (●); Eddouks *et al.* 2002 (●); Jouad *et al.* 2001 (♦); Lemhadri *et al.* 2023 (●); Merzouki *et al.* 2000 (●); Ouarghidi *et al.* 2013 (●); Tahraoui *et al.* 2007 (■); Ziyyat *et al.* 1997 (■)
Schisandraceae							
Illicium verum Hook.f. [FM-70]	l-badiāne, badīāna	Cu	H	Fr	De, In, Po (Or)	DSP, **RPC**, SMP	Hachlafi *et al.* 2020 (♦); Lemhadri *et al.* 2023 (■); Youbi *et al.* 2016 (♦)
Solanaceae							
Hyoscyamus niger L. [FM-69]	benj āswad, sokrāne	Sp	H	Sd	Po (EA) Fu (Inh)	**DER**, TIP DSP, IND	Sargın *et al.* 2013(●); Bulut and Tuzlacı 2015(●)
Thymelaeaceae							
Aquilaria malaccensis Lam. [FM-59]	āğhriss	Cu, Im	H	Ba	Ma, In (Or)	**ENM**	(El Boullani *et al.* 2022) (■)
Urticaceae							
Urtica urens L. [FM-25]	l-ḥurrayga, timezrit	Sp	NHI	WP, AP, Le	De, In (Or)	**DSP**	Bnouham *et al.* 2002 (♦); Ouhaddou *et al.* 2015 (●); Zougagh *et al.* 2019 (●)
Verbenaceae							
Aloysia citrodora Paláu [FM-26]	lwīza	Cu	NHI	WP, Le	De, In (Or)	DSP, **PNS**, RPC	Abouri *et al.* 2012 (■); El Mansouri *et al.* 2011 (■); Ouhaddou *et al.* 2015 (♦)
			H	AP, Le	De, In (Or)	**PNS**, PRS	
Xanthorrhoeaceae							
Aloe vera (L.) Burm.f. [FM-47]	siber, sābrā	Cu	NHI	WP, Le, St	Po (EA), De (Or)	**DER**, DSP, ENM, RPC	Amrati *et al.* 2021 (●); Tahraoui *et al.* 2007 (■)
Zingiberaceae							

Curcuma longa L. [FM-23]	l-ḫarqūm, ḫarqūm	Im	NHI	WP	Ma, Po (Or)	**DSP,** PNS	Amrati *et al.* 2021 (●); Bellakhdar *et al.* 1991 (♦); Kachmar *et al.* 2021 (♦); Lemhadri *et al.* 2023 (●); Merzouki *et al.* 2000 (♦); Skalli *et al.* 2019 (●)
Zingiber officinale Roscoe [FM-49]	skinjbir	Im	NHI	Rh, WP	De, In (Or)	DSP, **RPC**, PRS, SMP	Amrati *et al.* 2021 (●); Barkaoui *et al.* 2017 (●); Bellakhdar *et al.* 1991 (♦); Idm'hand, Msanda, et Cherifi 2020 (●); Mechchate *et al.* 2020 (●); Merzouki *et al.* 2000 (■); Skalli *et al.* 2019 (●)
			H	Rh	De, In, Po (Or)	GHU, PRS, **RPC**	
Zygophyllaceae							
Zygophyllum album L.f. [FM-82]	εaggāya, l-εaggāya, tirṭa	Im	H	Rt, Le	Po, De (Or)	DSP, **ENM**, SMP, USD	Bnouham *et al.* 2002 (■)

Sp: Spontaneous; **Cu**: Cultivated; **Im**: Imported; **H**: Herbalists; **NHI**: Non-Herbalist Informants; **AP**: Aerial Parts; **Ba**: Bark; **Fl**: Flower; **Fr**: Fruit; **Le**: Leaf; **Rh**: Rhizome; **Rt**: Root; **Se**: Seed; **St**: Stem; **WP**: Whole Plant.; **De**: Decoction; **Fu**: Fumigation/Steam; **In**: Infusion; **Ju**: Juice; **Ma**: Maceration; **Oi**: Oil; **Pa**: Paste; **Pl**: Poultice; **Po**: Powder/Crushed; **Ra**: Raw; **EA**: External application; **Inh**: Inhalation; **Or**: Oral route.; **BNP**: Blood and nutritional problems; **CVD**: Cardiovascular diseases; **DER**: Dermatological problems and dermocosmotology; **DMD**: Dental and mouth disorders; **DSP**: Digestive system problems; **EEN**: Ear, eye and nose problems; **ENM**: Endocrine, nutritional and metabolic diseases; **GHU**: General health and Unspecified signs or poorly defined morbid states; **IND**: Infectious Diseases; **PNS**: Problems of the nervous system and psychiatric disorders; **PRS**: Pathologies of the reproductive system; **RPC**: Respiratory problem and cold; **SMP**: Skeleton-muscular system problems; **TIP**: Traumatic injuries, poisoning and certain other consequences of external causes; **USD**: Urinary system diseases.; **N**.B: In bold, the primary use for the respective plant species is highlighted; Plant species with: ■= similar use(s); ♦= partially overlapping use (s); ● = different use (s).

Sources of Ethnobotanical Knowledge

In terms of knowledge sources regarding medicinal plants, a considerable portion of NHI members (50.25%) turn to the media for information. Conversely, most herbalists primarily obtain their knowledge from their parents or elderly individuals (52.86%) or through the experiences of others (30%). It's important to highlight that only a limited number of herbalists indicated having received formal training (Figure 6).

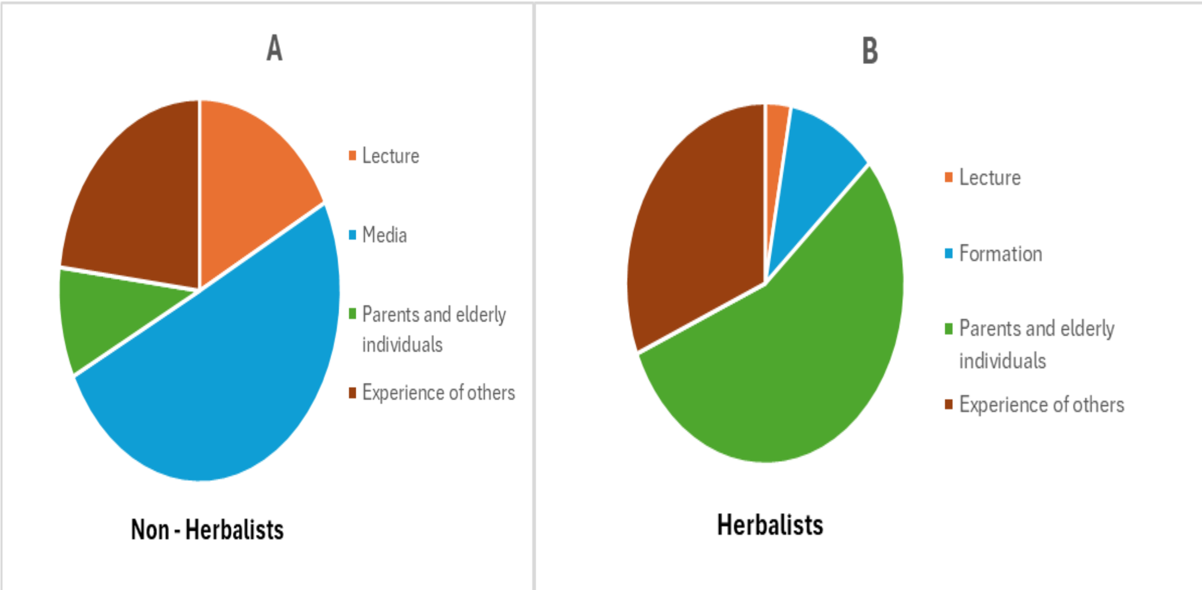

Figure 6. Frequency of sources of ethnobotanical knowledge among herbalist and informant participants

Quantitative analyses

The species *Origanum compactum* came out as having the greatest Use Report (UR) per species value, according to data collected from both the NHI and herbalists (Tables 2 and 3). Notably, the observed values peaked at 187 for informants from the NHI and 38 for herbalists.

Cultural Importance (CI), Use Value (UV), and Relative Frequency of Citation (RFC) ratings within NHI show a range from 0.01 to 0.55. Interestingly, *Origanum compactum* holds the top spot with the highest index value of 0.55, followed by *Mentha pulegium* in second place with a value of 0.35. With respective values of 0.20, *Lavandula dentata* and *Aloysia citriodora* share third place. *Origanum compactum*, with a value of 0.19, was the species with the highest CV index, followed by *Lavandula dentata*, *Mentha pulegium*, and *Rosmarinus officinalis*, all of which had a value of 0.02. The values of the Relative Importance (RI) index range from 0.05, which corresponds to *Urtica urens*, to a significant 0.96, which denotes the importance of *Origanum compactum*. Once more using information gathered from NHI, the Fidelity Level (FL) index highlights several plants, including *Ajuga iva*, *Ammodaucus leucotrichus*, *Crataegus monogyna*, and *Laurus nobilis*, that have a perfect reliability score of 100%. The range of the Relative of Plant Species (ROP) index is 0.5% to 85%. With a ROP value of 85%, *Origanum compactum* stands out at the front. *Mentha pulegium*, *Dysphania ambrosioides*, and *Aloysia citriodora* come next, with ROP values of 56.7%, 28.9%, and 24.4%, respectively.

The Cultural Importance (CI), Use Value (UV), and Relative Frequency of Citation (RFC) indexes show a broad range of values for the herbalist group, ranging from 0.03 to 0.54. With an RFC value of 0.50, *Origanum compactum* holds the highest rank. *Rosmarinus officinalis* (0.43) and *Carum carvi* (0.39) come in second and third, respectively. Regarding the CI and UV indices, the following 10 plant species have the greatest values: *Pimpinella anisum*, *Artemisia herba-alba*, *Origanum compactum* (0.54), *Trigonella foenum-graecum* (0.49), *Rosmarinus officinalis* (0.46), *Thymus vulgaris* (0.43), *Carum carvi*, *Matricaria chamomilla* (0.41), *Ammodaucus leucotrichus* (0.39), and *Salvia officinalis* (0.37).

Conversely, *Salvia verbenaca* (0.06), *Sonchus oleraceus* (0.04), and *Hibiscus sabdariffa* (0.06) were the species with the lowest UV and CI. Further, *Origanum compactum* (9.05 × 10-2), *Rosmarinus officinalis* (7.84×10^{-2}), and *Salvia officinalis* (5.94×10^{-2}) had the greatest CV indexes ranging from 0.01×10^{-2} to 9.05×10^{-2}. Moreover, *Origanum compactum* (RI = 0.84), *Rosmarinus officinalis* (RI = 0.80), and *Salvia officinalis* (RI = 0.80) had the highest RI indexes. On the other hand, *Aquilaria malaccensis*, *Senna alexandrina*, *Olea europaea*, *Globularia alypum*, *Eucalyptus globulus*, *Citrullus colocynthis*, and *Herniaria* *hirsuta* were the plant species with the highest FL (100) values. Furthermore, *Thymus vulgaris* (ROP=64.3%), *Origanum compactum* (ROP=91.4%), *Carum carvi* (ROP=73.5%), *Ammodaucus leucotrichus* (ROP=68.1%), *Matricaria chamomilla* (ROP=67.8%), *Trigonella foenum-graecum* (ROP=62.9%), and *Rosmarinus officinalis* (ROP=56.1%) showed different values of ROP (Table 3).

Table 2. Quantitative ethnobotanical indices for plant species cited by informants from the Non-Herbalist Informants.

Species	Main use	URs	RFC	CI	CV (*10^{-2})	RI	UV	FL(%)	ROP (%)
Ajuga iva (L.) Schreb.	**ENM**	11	0.03	0.03	0.01	0.12	0.03	100.00	5.88
Allium cepa L.	**DSP**	29	0.09	0.09	0.30	0.35	0.09	34.48	5.35
Allium sativum L.	**RPC**	49	0.13	0.15	1.03	0.48	0.15	37.78	9.90
Aloe vera (L.) Burm.f.	**DER**	10	0.03	0.03	0.02	0.21	0.03	40.00	2.14
Aloysia citriodora Palau	**PNS**	66	0.20	0.20	1.01	0.36	0.20	81.82	28.88
Ammodaucus leucotrichus Coss.	**DSP**	8	0.02	0.02	0.00	0.07	0.02	100.00	4.28
Apium graveolens L.	**ENM**	4	0.01	0.01	0.00	0.15	0.01	50.00	1.07
Artemisia absinthium L.	**RPC**	21	0.06	0.06	0.18	0.37	0.06	28.57	3.21
Artemisia herba-alba Asso	**DSP**	30	0.09	0.09	0.30	0.35	0.09	41.38	6.64
Calamintha officinalis Moench	**PNS**	7	0.02	0.02	0.01	0.24	0.02	33.33	1.25
Caralluma europea Zohary	**PRS**	3	0.01	0.01	0.00	0.10	0.01	66.67	1.07
Carum carvi L.	**DSP**	12	0.04	0.04	0.02	0.12	0.04	91.67	5.88
Chamaerops humilis L.	**ENM**	4	0.01	0.01	0.00	0.19	0.01	25.00	0.53
Cinnamomum verum J.Presl	**DSP**	25	0.07	0.07	0.18	0.29	0.07	52.00	6.95
Coriandrum sativum L.	**DSP**	12	0.04	0.04	0.03	0.21	0.04	50.00	3.21
Crataegus monogyna Jacq.	**CVD**	4	0.01	0.01	0.00	0.10	0.01	100	2.14
Cuminum cyminum L.	**DSP**	33	0.09	0.10	0.18	0.22	0.10	93.75	16.54
Curcuma longa L.	**DSP**	4	0.01	0.01	0.00	0.10	0.01	50.00	1.07
Cynara cardunculus L.	**ENM**	4	0.01	0.01	0.00	0.10	0.01	75.00	1.60
Dittrichia viscosa (L.) Greuter	**DER**	30	0.08	0.09	0.34	0.39	0.09	53.57	8.59
Dysphania ambrosioides (L.) Mosyakin & Clemants	**GHU**	65	0.19	0.19	1.45	0.44	0.19	70.31	24.44
Eucalyptus globulus Labill.	**RPC**	42	0.12	0.12	0.30	0.25	0.12	95.12	21.36
Foeniculum vulgare Mill.	**DSP**	18	0.05	0.05	0.06	0.18	0.05	72.22	6.95
Laurus nobilis L.	**RPC**	3	0.01	0.01	0.00	0.05	0.01	100.00	1.60
Lavandula dentate L.	**USD**	69	0.18	0.20	1.71	0.48	0.20	36.07	13.31
Lawsonia inermis L.	**DER**	4	0.01	0.01	0.00	0.06	0.01	100.00	2.14
Lepidium sativum L.	**SMP**	7	0.02	0.02	0.01	0.25	0.02	42.86	1.60
Linum usitatissimum L.	**DSP**	15	0.04	0.04	0.09	0.36	0.04	53.33	4.28
Marrubium vulgare L.	**ENM**	43	0.11	0.13	1.04	0.60	0.13	21.05	4.84
Matricaria chamomilla L.	**PNS**	49	0.15	0.15	0.56	0.31	0.15	63.27	16.58
Mentha aquatica L.	**PNS**	6	0.02	0.02	0.01	0.20	0.02	90.60	2.91
Mentha pulegium L.	**RPC**	117	0.35	0.35	2.38	0.45	0.35	90.60	57.08
Mentha suaveolens Ehrh.	**DSP**	17	0.04	0.05	0.12	0.40	0.05	50.00	4.55
Mimosa pudica L.	**DSP**	4	0.01	0.01	0.00	0.10	0.01	50.00	1.07
Myrtus communis L.	**DSP**	8	0.02	0.02	0.01	0.16	0.02	75.00	3.21
Nerium oleander L.	**RPC**	4	0.01	0.01	0.00	0.19	0.01	25.00	0.53
Nigella sativa L.	**DSP**	18	0.05	0.05	0.09	0.27	0.05	70.59	6.79
Ocimum basilicum L.	**PNS**	10	0.03	0.03	0.02	0.16	0.03	40.00	2.14
Olea europaea L.	**ENM**	41	0.12	0.12	0.56	0.38	0.12	66.67	14.62
Opuntia ficus-indica (L.) Mill.	**ENM**	5	0.02	0.02	0.00	0.06	0.02	100.00	2.67
Origanum compactum Benth.	**DSP**	187	0.55	0.55	20.31	0.96	0.55	85.03	85.03
Pennisetum glaucum (L.) R.Br.	**SMP**	4	0.01	0.01	0.00	0.06	0.01	100.00	2.14
Petroselinum crispum (Mill.) Fuss	**USD**	17	0.04	0.05	0.05	0.22	0.05	92.31	8.39

Pimpinella anisum L.	**DSP**	14	0.04	0.04	0.03	0.17	0.04	85.71	6.42
Punica granatum L.	**DSP**	16	0.04	0.05	0.04	0.17	0.05	71.43	6.11
Rosa damascene Mill.	**DSP**	12	0.04	0.04	0.01	0.08	0.04	100.00	6.42
Rosmarinus officinalis L.	**DSP**	65	0.19	0.19	1.72	0.49	0.19	63.08	21.93
Salvia blancoana subsp. *mesatlantica* Maire	**ENM**	6	0.02	0.02	0.01	0.15	0.02	66.67	2.14
Salvia officinalis L.	**ENM**	49	0.14	0.15	1.07	0.49	0.15	38.30	10.04
Senna alexandrina Mill.	**DSP**	7	0.02	0.02	0.01	0.11	0.02	85.71	3.21
Syzygium aromaticum (L.) Merr. & L.M.Perry	**DMD**	29	0.09	0.09	0.25	0.31	0.09	55.17	8.56
Thymus vulgaris L.	**DSP**	46	0.13	0.14	0.60	0.35	0.14	82.22	20.23
Trigonella foenum-graecum L.	**DSP**	59	0.16	0.17	0.75	0.33	0.17	50.91	16.06
Urtica urens L.	**DSP**	3	0.01	0.01	0.00	0.05	0.01	100.00	1.60
Zingiber officinale Roscoe	**RPC**	40	0.12	0.12	0.36	0.29	0.12	53.85	11.52
Ziziphus lotus (L.) Lam.	**DSP**	3	0.01	0.01	0.00	0.10	0.01	66.67	1.07

Table 3. Quantitative ethnobotanical indices for plant species cited by herbalists.

Species	**Main use**	**URs**	**RFC**	**CI**	**CV (*10^{-2})**	**RI**	**UV**	**FL (%)**	**ROP (%)**
Ajuga iva (L.) Schreb.	**ENM**	7	0.10	0.10	0.13	0.23	0.10	85.71	15.79
Aloysia citrodora Palau	**PNS**	14	0.20	0.20	0.53	0.33	0.20	92.86	34.21
Ammi visnaga (L.) Lam.	**ENM**	11	0.16	0.16	0.82	0.47	0.16	27.27	7.89
Ammodaucus leucotrichus Coss.	**DSP**	27	0.34	0.39	3.53	0.59	0.39	95.83	68.09
Anacyclus pyrethrum (L.) Lag.	**DMD**	18	0.20	0.26	2.06	0.58	0.26	50.00	23.68
Apium graveolens L.	**GHU**	12	0.13	0.17	0.74	0.44	0.17	77.78	24.56
Aquilaria malaccensis Lam.	**ENM**	9	0.13	0.13	0.11	0.19	0.13	100.00	23.68
Artemisia herba-alba Asso	**DSP**	26	0.31	0.37	3.88	0.63	0.37	59.09	40.43
Calamintha officinalis Moench	**PNS**	10	0.11	0.14	0.65	0.49	0.14	50.00	13.16
Caralluma europea Zohary	**ENM**	15	0.21	0.21	0.61	0.34	0.21	80.00	31.58
Carlina gummifera (L.) Less.	**TIP**	4	0.03	0.06	0.02	0.15	0.06	100.00	10.53
Carum carvi L.	**DSP**	29	0.39	0.41	3.20	0.57	0.41	96.30	73.49
Centaurium erythraea Rafn	**ENM**	15	0.20	0.21	0.86	0.39	0.21	92.86	36.66
Ceratonia siliqua L.	**DSP**	18	0.21	0.26	1.83	0.53	0.26	93.33	44.21
Chamaerops humilis L.	**ENM**	4	0.06	0.06	0.06	0.25	0.06	50.00	5.26
Cinnamomum cassia (L.) J.Presl	**DSP**	7	0.10	0.10	0.27	0.35	0.10	28.57	5.26
Citrullus colocynthis (L.) Schrad.	**ENM**	7	0.10	0.10	0.07	0.16	0.10	100.00	18.42
Coriandrum sativum L.	**ENM**	13	0.14	0.19	0.53	0.33	0.19	60.00	20.53
Crataegus monogyna Jacq.	**CVD**	8	0.10	0.11	0.15	0.23	0.11	100.00	21.05
Dittrichia viscosa (L.) Greuter	**DER**	13	0.09	0.19	0.32	0.27	0.19	66.67	22.81
Dysphania ambrosioides (L.) Mosyakin & Clemants	**DSP**	5	0.06	0.07	0.08	0.25	0.07	75.00	9.87
Eucalyptus globulus Labill.	**RPC**	5	0.06	0.07	0.05	0.18	0.07	100.00	13.16
Foeniculum vulgare Mill.	**DSP**	21	0.29	0.30	2.29	0.54	0.30	90.00	49.74
Globularia alypum L.	**ENM**	9	0.13	0.13	0.11	0.19	0.13	100.00	23.68
Glycyrrhiza glabra L.	**RPC**	9	0.10	0.13	0.34	0.35	0.13	57.14	13.53
Herniaria hirsuta L.	**USD**	5	0.07	0.07	0.03	0.13	0.07	100.00	13.16
Hibiscus sabdariffa L.	**CVD**	4	0.06	0.06	0.06	0.25	0.06	50.00	5.26
Hyoscyamus niger L.	**DER**	8	0.06	0.11	0.17	0.31	0.11	75.00	15.79
Illicium verum Hook.f.	**RPC**	16	0.20	0.23	1.53	0.51	0.23	64.29	27.07
Laurus nobilis L.	**DSP**	6	0.09	0.09	0.10	0.21	0.09	66.67	10.53

Lavandula dentata L.	**USD**	22	0.30	0.31	3.77	0.68	0.31	71.43	41.35
Lavandula stoechas L.	**USD**	7	0.09	0.10	0.23	0.34	0.10	50.00	9.21
Lepidium sativum L.	**ENM**	19	0.17	0.27	1.85	0.55	0.27	41.67	20.84
Linum usitatissimum L.	**DSP**	15	0.20	0.21	0.86	0.39	0.21	71.43	28.20
Lupinus albus L.	**ENM**	7	0.09	0.10	0.17	0.27	0.10	83.33	15.35
Marrubium vulgare L.	**ENM**	16	0.19	0.23	1.14	0.44	0.23	92.31	38.87
Matricaria chamomilla L.	**PNS**	29	0.39	0.41	5.33	0.70	0.41	88.89	67.84
Mentha pulegium L.	**RPC**	20	0.26	0.29	1.47	0.45	0.29	94.44	49.71
Mentha suaveolens Ehrh.	**IND**	7	0.06	0.10	0.15	0.31	0.10	75.00	13.82
Myrtus communis L.	**DSP**	25	0.34	0.36	4.08	0.66	0.36	79.17	52.09
Nigella sativa L.	**DSP**	17	0.19	0.24	1.51	0.50	0.24	61.54	27.53
Olea europaea L.	**ENM**	8	0.11	0.11	0.09	0.18	0.11	100.00	21.05
Opuntia ficus-indica (L.) Mill.	**ENM**	10	0.14	0.14	0.41	0.33	0.14	70.00	18.42
Origanum compactum Benth.	**DSP**	38	0.50	0.54	9.05	0.81	0.54	91.43	91.43
Origanum majorana L.	**DSP**	9	0.11	0.13	0.49	0.43	0.13	50.00	11.84
Panicum miliaceum L.	**SMP**	5	0.06	0.07	0.05	0.18	0.07	75.00	9.87
Petroselinum crispum (Mill.) Fuss	**USD**	6	0.07	0.09	0.16	0.32	0.09	60.00	9.47
Pimpinella anisum L.	**DSP**	26	0.30	0.37	3.71	0.61	0.37	61.90	42.35
Punica granatum L.	**DSP**	11	0.16	0.16	0.33	0.28	0.16	63.64	18.42
Rhaponticum acaule (L.) DC.	**ENM**	6	0.09	0.09	0.10	0.21	0.09	83.33	13.16
Rosa damascene Mill.	**DSP**	19	0.21	0.27	0.77	0.34	0.27	93.33	46.67
Rosmarinus officinalis L.	**DSP**	32	0.43	0.46	7.84	0.80	0.46	66.67	56.14
Rubia tinctorum L.	**BNP**	8	0.11	0.11	0.17	0.24	0.11	87.50	18.42
Ruta montana (L.) L.	**ENM**	7	0.10	0.10	0.13	0.23	0.10	85.71	15.79
Salvia officinalis L.	**ENM**	26	0.30	0.37	5.94	0.80	0.37	71.43	48.87
Salvia blancoana subsp. *mesatlantica* Maire	**ENM**	15	0.20	0.21	0.86	0.39	0.21	92.86	36.66
Salvia verbenaca L.	**ENM**	4	0.04	0.06	0.05	0.23	0.06	66.67	7.02
Saussurea costus (Falc.) Lipsch.	**CVD**	8	0.09	0.11	0.33	0.40	0.11	50.00	10.53
Senna alexandrina Mill.	**DSP**	17	0.24	0.24	0.39	0.31	0.24	100.00	44.74
Sonchus oleraceus L.	**ENM**	3	0.04	0.04	0.01	0.11	0.04	100.00	7.89
Syzygium aromaticum (L.) Merr. & L.M.Perry	**DMD**	5	0.07	0.07	0.03	0.13	0.07	100.00	13.16
Tetraclinis articulate (Vahl) Mast.	**ENM**	5	0.04	0.07	0.08	0.29	0.07	66.67	8.77
Thymus vulgaris L.	**DSP**	30	0.39	0.43	3.31	0.57	0.43	81.48	64.33
Trigonella foenum-graecum L.	**ENM**	34	0.39	0.49	5.00	0.64	0.49	70.37	62.96
Zingiber officinale Roscoe	**RPC**	9	0.07	0.13	0.31	0.38	0.13	60.00	14.21
Ziziphus lotus (L.) Lam.	**DSP**	22	0.30	0.31	3.77	0.68	0.31	76.19	44.11
Zygophyllum album L.f.	**ENM**	13	0.17	0.19	0.64	0.36	0.19	75.00	25.66

Among NHI, the Informant Consensus Factor (ICF) values were high for diseases of the digestive system (FIC = 0.92), respiratory system (FIC = 0.89), and nervous system (ICF = 0.88) (Table 4). In the herbalists, Informant Consensus Factor (ICF) values achieved the highest ICF value (ICF = 0.88), followed by Endocrine, nutritional, and metabolic diseases (ENM) as well as eye, Ear, and nose problems (EEN), ranking second (ICF = 0.80). Problems related to the nervous system ranked third (ICF = 0.77).

Table 4. Informant consensus factor (ICF) analysis of plant species reported by the non-herbalist informants or herbalists for treating various ailments.

Category of Diseases	N_{ur}		N_t		ICF	
	NHI	H	NHI	H	NHI	H
BNP	3	15	3	7	0.00	0.57
CVD	39	22	15	10	0.63	0.57
DER	48	17	16	9	0.68	0.50
DMD	21	16	5	5	0.80	0.73
DSP	547	333	46	42	0.92	0.88
EEN	11	6	4	2	0.70	0.80
ENM	149	245	28	50	0.82	0.80
GHU	70	44	11	18	0.86	0.60
IND	15	13	3	8	0.86	0.42
PNS	121	54	16	13	0.88	0.77
PRS	56	13	17	10	0.71	0.25
RPC	291	54	33	17	0.89	0.70
SMP	45	30	19	18	0.59	0.41
TIP	0	12	0	5	0.00	0.64
USD	51	41	12	18	0.78	0.58

ICF: Informant Consensus Factor; **Nt:** number of species utilized within a category; **Nur:** count of use reports

H: Herbalists; **NHI**: Non-Herbalist Informants

BNP: Blood and nutritional problems; **CVD**: Cardiovascular diseases; **DER**: Dermatological problems and dermocosmotology; **DMD**: Dental and mouth disorders; **DSP**: Digestive system problems; **EEN**: Ear, eye and nose problems; **ENM**: Endocrine, nutritional and metabolic diseases; **GHU**: General health and Unspecified signs or poorly defined morbid states; **IND**: Infectious Diseases; **PNS**: Problems of the nervous system and psychiatric disorders; **PRS**: Pathologies of the reproductive system; **RPC**: Respiratory problem and cold; **SMP**: Skeleton-muscular system problems; **TIP**: Traumatic injuries, poisoning and certain other consequences of external causes; **USD**: Urinary system diseases.

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n both the NHI and herbalists, a significant correlation was recorded between the relative frequency of citation (RFC) and the use value (UV) ($R^2 = 0.98$ and 0.96, respectively, $p < 0.01$) (Figure 7A and 7B), while correlation was lower between RFC and RI ($R^2 = 0.71$ and 0.74 within the NHI and herbalist groups, respectively, $p < 0.01$) (Figure 7C and 7D). A correlation was recorded between RI and RFC ($R^2 = 0.73$ and 0.80 within the NHI and herbalist groups, respectively, $p = 0.01$) (Figure 7E and 7F).

Data clustering

The representation of the clustering results is showcased in Figures 8, 9, and 10. The analysis of the Herbalists' Data revealed that the optimal choices based on the aforementioned indices were k=4 and k=2 (Figures 8A and 8B, respectively). In NHI-derived data, the most optimal values for the K-means algorithm were k=3 and k=2 (Figures 9A and 9B, respectively). The clustering analysis reveals that both algorithms, K-means and peak density detection, confirm that species were split into two groups for herbalists' data. Twelve species (*Ammodaucus leucotrichus*, *Carum carvi*, *Ceratonia siliqua*, *Foeniculum vulgare*, *Myrtus communis*, *Origanum compactum*, *Pimpinella anisum*, *Rosa damascene*, *Rosmarinus officinalis*, *Senna alexandrina*, *Thymus vulgaris* and *Ziziphus lotus*) were affected to the first cluster (C1), while the 52 other species were assigned to the second cluster (C2). The results of the algorithms are different for the three species (*Artemisia herba-alba*, *Linum usitatissimum* and *Trigonella foenum-graecum*); the K-means algorithm has assigned them to the first cluster C1 while the peak detection algorithm has attributed them to the second cluster C2. In NHI-derived data, the overarching trend unveiled a cohesive amalgamation, placing all plant species within a unified cluster, demonstrating a shared pattern. However, *Origanum compactum* stood out distinctly, indicating outlier characteristics that set it apart from the homogeneity observed within the rest of the plant species.

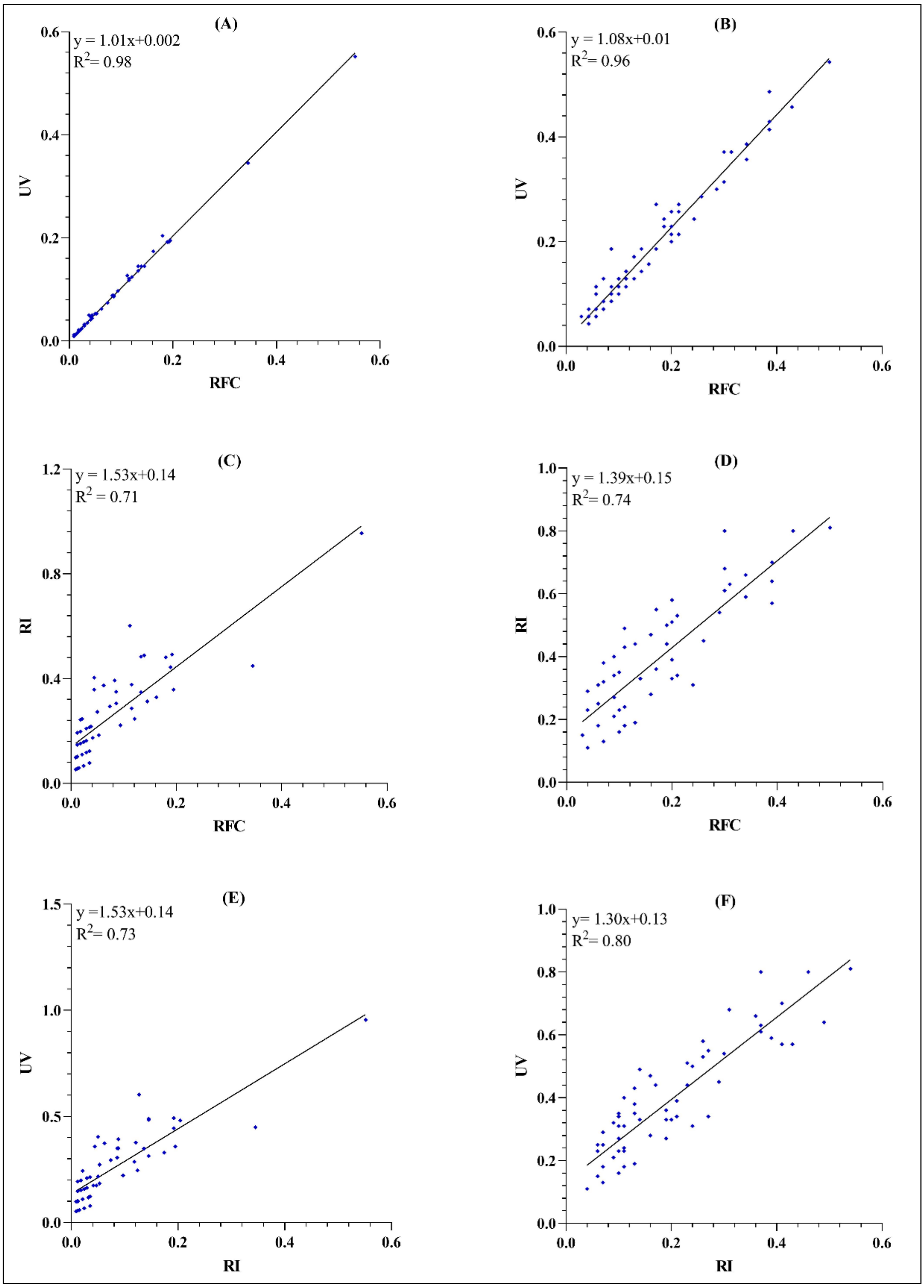

Figure 7. Correlations between the different quantitative indices among Non-Herbalist Informants (NHI) and Herbalists (H). Correlation analysis using simple linear regression at the 95% confidence level between Use Value (UV) and Relative Frequency of Citation (RFC) (A (NHI) and B (H)), Relative Importance (RI) and Relative Frequency of Citation (RFC) (C (NHI) and D (H)), Use Value (UV) and Relative Importance (RI) (E (NHI) and F (H)).

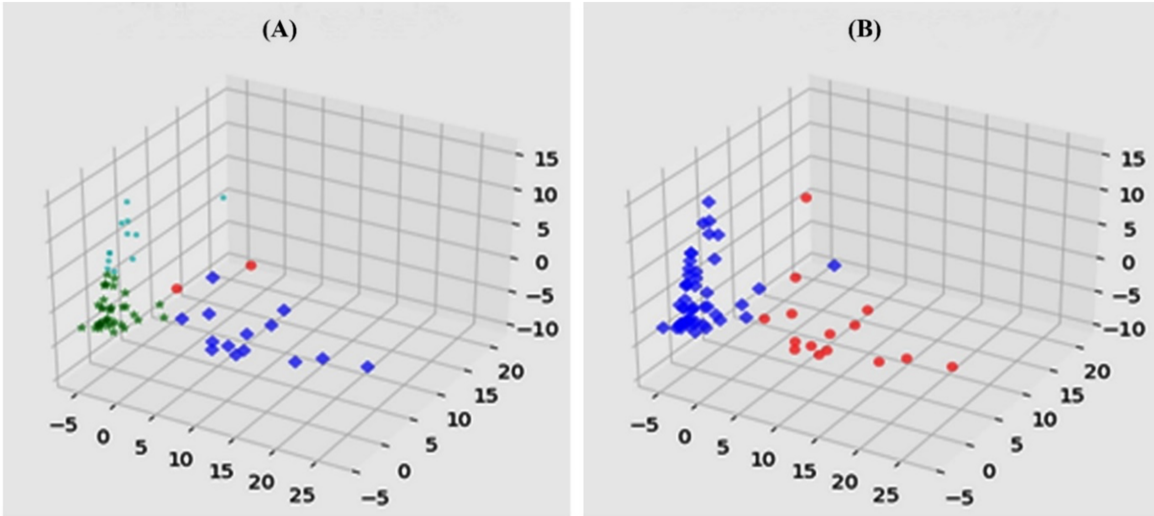

Figure 8. 3D scatter plot of herbalist-derived data using K-means algorithm: (A) K=4 with PCA (6 components), and (B) K=2 with PCA (6 components).

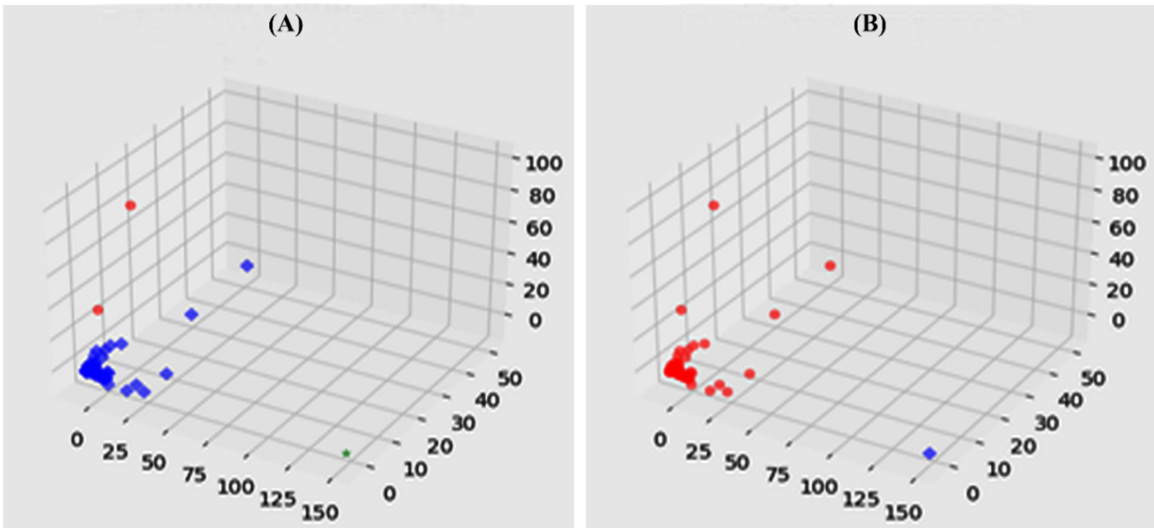

Figure 9. 3D scatter plot of non-herbalist informants -derived data using K-means Algorithm: (A) K=3 with PCA (6 components), and (B) K=2 with PCA (6 components)

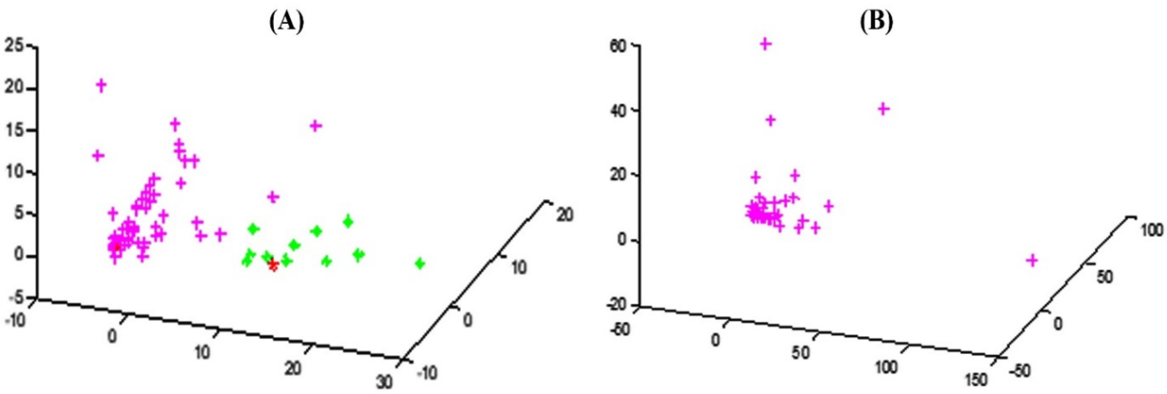

Figure 10. 3D Clustering Visualization with Peak Density Detection algorithm: Comparison of Clustering results for herbalists and non-herbalist informants' data (A) herbalists-derived data, (B) non-herbalist informants -derived data.

Discussion

Our findings indicate that across the provinces that were studied, 82 species of medicinal plants belonging to 34 families have been recognized for their potential to treat a wide range of illnesses. The purpose of the study was to document the traditional knowledge about the use of medicinal plants that the local community (NHI) and herbalists had ingrained. The Lamiaceae, Apiaceae, and Compositae families are the most numerous in the NHI group, each with thirteen species; Compositae is next with five. Lamiaceae leads the herbalists category with 14 species, more than Apiaceae and Compositae combined, which have eight species each. Leguminosae comes in fourth place with five species. Overall, the results are in line with data from the literature that shows a common overuse of these families' species in both herbalists and informants of Morocco (El-Gharbaoui *et al.* 2017; Tahraoui *et al.* 2023) and other Mediterranean regions (Bellakhdar *et al.* 1991; Miara *et al.* 2018). For example, Maache *et al.* (2024) recorded the use of over 82 medicinal plants by participants from the Fez-Meknes region in central Morocco.

The examination of medicinal plant knowledge revealed both substantial similarities and noteworthy distinctions between the NHI and herbalists. Although there were variations in the number of cited medicinal species (56 by the NHI group and 67 by herbalists), a significant overlap was observed, with precisely half of the total plant species (41 out of 82) being mentioned by both groups. However, it also underscores discernible differences in the understanding of medicinal plants between NHI and herbalists. Remarkably, the plant species *Origanum compactum* stood out as the most frequently cited plant, with higher RFC as well as UV values, in both the NHI and herbalist groups, underscoring its substantial prominence among both communities. Regarding group size and the associated number of cited plant species, it is apparent that herbalists referenced a notably greater number of plants in comparison to individuals from the NHI group. Furthermore, we have frequently observed distinctions between the NHI group and herbalists concerning their agreement on which plants to use, the methods of utilization, and the specific purposes for employing them. *Lepidium sativum*, a plant cited by informants from both groups: the NHI group mentioned using a decoction or powder derived from the entire plant to address issues related to the skeletal-muscular system (SMP), while herbalists recommended utilizing the seeds either as an infusion or in their raw form to alleviate endocrine, nutritional, and metabolic diseases (ENM). Therefore, despite the high regard for herbalists in both Arabic and Amazigh cultures due to their knowledge of medicinal plants (Teixidor-Toneu *et al.* 2016; El-Ghazouani *et al.* 2021), their ethnobotanical knowledge may not necessarily align with that of NHI participants. This agrees with earlier studies from the southwest region of Morocco that have compared the utilization of medicinal plants among herbalists and housewives (El-Ghazouani *et al.* 2021). The reasons behind this difference are suggested to be that herbalists may have easier access to rare plants, often obtained from different regions or imported, while local populations don't have. For example, *Saussurea costus*, *Cinnamomum cassia*, *Citrullus colocynthis*, *Hibiscus sabdariffa*, *Rubia tinctorum*, *Panicum miliaceum*, and *Zygophyllum album* were exclusively cited by herbalists, with no mentions from the NHI group. Conversely, NHI exhibits a stronger inclination toward citing food plants and spices for medicinal purposes in comparison to herbalists, such as *Allium sativum* and *Allium cepa*, which are commonly found in people's homes or readily available in local markets (Alqethami *et al.* 2017).

Citation counts by illness category study show significant differences between the two groups, which differs slightly from findings published by El-Ghazouani *et al.* (2021) in the southwest region of Morocco. The most common complaints among NHI and herbalists were related to digestive tract issues. Evidence-based therapy techniques support the effectiveness of herbal medications in the management of gastrointestinal illnesses (Rokaya *et al.* 2014; Czigle *et al.* 2022). Respiratory problems (RPC) hold the second position in terms of citation among NHI members, while among herbalists, endocrine and metabolic disorders (ENM), mainly diabetes mellitus, are ranked second in terms of occurrence.

These findings are supported by current literature. For example, the use of medicinal plants such as ginger, eucalyptus, and garlic for respiratory health has surged, reflecting global interest in complementary approaches amid the COVID-19 pandemic (Villena-Tejada *et al.* 2021; Pranskuniene *et al.* 2022). Furthermore, the traditional usage of medicinal plants for treating diabetes has been documented in Morocco; many species are efficient in decreasing blood sugar, indicating their critical role in the management of diabetes (Naceiri Mrabti *et al.* 2021; Bouyahya *et al.* 2021; Arraji *et al.* 2024).

This study employs ethnobotanical indices to quantify plant species' significance in traditional knowledge systems, providing insights into their cultural, practical, and economic value. *Origanum compactum* ranks highest in key indices like Use Report (UR), Use Value (UV), Cultural Importance (CI), and Relative Importance (RI). Among non-herbalists, it has the highest UR (187) and CI/UV values (0.55), followed by *Mentha pulegium* and *Lavandula dentata*. Herbalists supported the importance of *Origanum compactum*, *Rosmarinus officinalis*, and *Trigonella foenum-graecum*. These findings align with regional studies, showing *Origanum compactum* as frequently cited and widely used in traditional medicine, underscoring its vital role in local communities (Kachmar *et al.* 2021; Benamar *et al.* 2023; Jeddi *et al.* 2024). Comparable trends have been shown for *Mentha pulegium*, *Lavandula dentata*, *Rosmarinus officinalis*, and *Trigonella foenum-graecum*, which rank among the most frequently cited taxa not solely in Fez-Meknes region but also across other areas of Morocco (Mechchate *et al.* 2020; Chebaibi *et al.* 2020; Kachmar *et al.* 2021; Naceiri Mrabti *et al.* 2021). The correlation among key indices (UV, RFC, and RI) indicates strong consensus on the importance of frequently cited plants. This positive relationship suggests that higher usage by informants enhances a plant's perceived availability, integration into local practices, and status. Availability thus plays a crucial role in making certain species preferred in traditional healthcare (Vijayakumar *et al.* 2015).

Fidelity levels of 100% for plant species such as *Ajuga iva* and *Senna alexandrina* signify their sustained application in medicinal practices. When FL values are high, they denote the plant is predominantly used for a single therapeutic category; low FL values, on the other hand, reveal its use across multiple categories of diseases (Majeed *et al.* 2020; Lemhadri *et al.* 2023). High Informant Consensus Factor (ICF) values (≥ 0.88) pertaining to digestive, respiratory, and nervous disorders denote a robust concordance regarding the therapeutic use of these plants for such use categories. Conversely, lower ICF values concerning reproductive and musculoskeletal problems imply a broader spectrum of remedies or a lesser level of consensus among respondents (Chander *et al.* 2014).

In the Rank Order Priority (ROP) index, among the 67 species cited by herbalists, eight achieved an ROP above 50%, with an average close to 28%. In contrast, within the NHI group, only two out of the 56 cited species reached an ROP above 50%, resulting in an average ROP of less than 10%. Such a divergence underscores the distinct consensus within the herbalist community in the utilization of plants, showcasing a heightened level of agreement compared to informants from the general population. This finding contradicts the observations documented in the study by El-Ghazouani *et al.* (2021), which explicitly asserted that housewives exhibit a stronger consensus in determining which plants to use for addressing specific ailments compared to herbalists.

Most cited plants by both NHI and herbalists are commonly employed throughout the country. The study highlights novel applications for specific plants reported by either group. Among the surveyed species, eight were cited uniquely or for unrelated purposes. For instance, *Mentha aquatica*, *Mimosa pudica*, and *Pennisetum glaucum*, cited by the NHI group for the nervous system (PNS), digestive system problems (DSP), and skeletal-muscular system problems (SMP), respectively, present new applications. In contrast, herbalists identified *Carlina gummifera*, *Saussurea costus*, *Sonchus oleraceus*, and *Cinnamomum cassia* for treating traumatic injuries (TIP), cardiovascular diseases (CVD), endocrine, nutritional, and metabolic diseases (ENM), and digestive system problems (DSP).

The clustering analysis shows clear differences in how herbalists and non-herbalists use plants for medicinal uses. Herbalists concentrate on two main groups: one with 12 essential medicinal species central to traditional practices, and another with 52 additional plants of broader but lesser importance. However, the clustering algorithms showed differences. K-means grouped *Artemisia herba-alba*, *Linum usitatissimum*, and *Trigonella foenum-graecum* with key medicinal plants, while peak density placed them in a broader group. This could be explained by the fact that K-means makes tight clusters by minimizing variance, while peak density unveils trends that span wider, providing richer understanding of data distribution (Nigro *et al.* 2022).Within the data sourced from NHI group, the clustering analysis reveals a generalized pattern, aggregating the majority of species collectively, with *Origanum compactum* positioned as an outlier, indicating its distinctive cultural relevance. Such findings underscore the manner in which the specialized knowledge of herbalists differentiates them from the more generalized practices of non-herbalists. This underscores the critical importance of safeguarding plant diversity and traditional knowledge.

Research indicates that ethnobotanical knowledge and skills are culturally transmitted within societies through various mechanisms, including oral traditions, social networks, and intergenerational learning. Significantly, the exchange of information among users within social and familial networks stands out as a key factor contributing to this transmission phenomenon (Lozada *et al.* 2006; El-Ghazouani *et al.* 2021). However, it is crucial to recognize that instances of horizontal transmission are often sporadic, and informants may face challenges in recalling detailed information (Lozada *et al.* 2006). Furthermore, given that over 50% of NHI respondents acknowledge media usage (TV, radio, internet), exploring the evolving dynamic among social networks, the internet, and medicinal plant utilization in the general population is a pertinent research avenue. Insights from studies on the internet and social media's impact on medical information access, healthcare practices, and patient education are valuable (Delgado-López and Corrales-García 2018; Bhuiyan *et al.* 2020). Online social networks' interactive nature can influence health-related information dissemination (Ibarra-Yruegas *et al.* 2015).

Herbalists acquire ethnobotanical knowledge through a combination of intergenerational transmission, experiential learning, scientific research, and the study of historical and traditional practices, highlighting the diverse and rich sources of knowledge acquisition in the field of herbalism (Mahwasane *et al.* 2013; Popović *et al.* 2016). The knowledge transmission among herbalists often occurs through direct mentorship from elder herbalists within their communities or families, allowing for the preservation and dissemination of traditional uses of medicinal plants native to their region (Hopkins *et al.* 2015; Popović *et al.* 2016; Tahraoui *et al.* 2023). Popović *et al.* (2016) emphasize the growing scientific interest in ethnobotany and herbal medicine, highlighting how herbalists gain knowledge from diverse sources, including scientific research and integrative medicine publications. Despite this, herbalists often seek knowledge from books and position themselves near specialized markets, enabling the horizontal transfer of information from more educated individuals to those with lower educational backgrounds (El-Ghazouani *et al.* 2021). Herbalists develop an in-depth knowledge of indigenous plant use by participating in apprenticeships and immersing themselves in nature. The expertise retained by herbalists includes insights into plant parts and the traditional methods employed in plant preparation to address diverse health conditions (Wanjohi *et al.* 2020; Figueirêdo Júnior *et al.* 2022). For instance, in the central Middle Atlas region of Morocco, practitioners of traditional medicine rely predominantly on their accumulated experience rather than scientific evidence when recommending specific plants for the treatment of respiratory diseases (Najem *et al.* 2021). This Traditional Ecological Knowledge serves as a vital component of herbalism, empowering herbalists to effectively diagnose health issues and formulate plant-based remedies that honor cultural wisdom and respect the healing potential inherent in nature's offerings (Abo *et al.* 2008; Caballero-Serrano *et al.* 2019).

Conclusion

This study finds rich biodiversity and substantial traditional knowledge in the study area, highlighting the important role of traditional medicine, specifically medicinal plants, in treating a variety of diseases. It inventories medicinal plants used by herbalists and non-herbalist informants in the central provinces of Morocco. It is the first explicit work that sheds light on medicinal plant knowledge of non-herbalist respondents alongside that of herbalists in the same region. Herbalists are known for their unique knowledge, which is reflected in the variety of plant species and preparation techniques they employ. While non-herbalists and herbalists address similar health issues, analysis shows that their understanding of plant uses only partially overlaps. The reasons for these differences in plant usage between the two groups could be attributed to different pathways of knowledge transmission as well as factors such as media influence and a decline in interest in traditional medicine among younger generations. Furthermore, the majority of plants are adaptable, having multiple therapeutic uses for a range of illness categories. The respondents have presented new uses for medicinal plants, suggesting possible directions for phytochemical and pharmacological studies in the future. This ethnobotanical study could help shape biodiversity conservation policies in the Fez-Meknes region by highlighting the importance of preserving traditional medical knowledge that has been passed down through the centuries. However, more research is needed to explore the knowledge of traditional medicine in rural, urban, and peri-urban areas of Morocco.

Declarations

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