Ethnobotanical knowledge of Medicinal plants in Fez-Meknes region: Origin of used species, plant-disease associations, used parts, and preparation forms

Souad Maache, Adel Tahraoui, Ghizlane Nouioura, Yissam Lakhdar, Karima El-Yagoubi, Ilham Elarabi and Badiaa Lyoussi

Correspondence:

Souad Maache[1], Adel Tahraoui[1,2], Ghizlane Nouioura[1], Yissam Lakhdar[2], Karima El-Yagoubi[1], Ilham Elarabi[1] and Badiaa Lyoussi

[1]Laboratory of Natural Substances, Pharmacology, Environment, Modeling, Health, and Quality of Life (SNAMOPEQ), Faculty of Sciences Dhar El Mahraz, Sidi Mohamed Ben Abdellah University, Fez, Morocco
[2]Regional Center of Education and Training Careers (CRMEF), Fez-Meknes, Morocco

*Corresponding Author: souad.maache@usmba.ac.ma

Ethnobotany Research and Applications 29:4 (2024) - http://dx.doi.org/10.32859/era.29.4.1-20
Manuscript received: 17/01/2024 - Revised manuscript received: 21/03/2024 - Published: 23/03/20x24

Research

Abstract

Background: Ethnobotanical studies conducted in the Fez-Meknes region, located in North-central Morocco, and home to UNESCO cultural sites such as Fez and Meknes, have been limited in scope. The existing studies primarily concentrate on the use of medicinal plants for treating particular ailments. The present study unveils the plentiful ethnomedicinal knowledge in the region employed to address a wide array of health concerns. The present study aims to gather and document ethnobotanical data from local populations, encompassing herbalist and non-herbalist informants in the Fez-Meknes region, with a focus on comparing their knowledge.

Methods: 478 informants participated in this study, comprising 408 local inhabitants (non-herbalists) and 70 herbalists. Semi-structured interviews were conducted at eleven sites throughout the study area to collect data. Descriptive and Multivariate statistics were used for data analysis. Comparisons have addressed both non-herbalists and herbalists among sampled sites.

*Result*s: In total, 82 species from 73 genera and 34 families were identified. Herbalists, citing 67 species to non-herbalists' 56, showed greater knowledge, with a notable 41-species overlap. The plants were mostly cultivated (40.6%) or from the wild (34.7%). Herbalists acquired knowledge from their parents and elderly individuals (52.9%), while informants from written sources. Leaves were the most used parts, while decoction and infusion were the dominant preparation modes. Administration was mostly oral to manage fifteen illness categories (i.e. digestive system, respiratory, dermatological problems).

Conclusion: The study unveils rich traditional knowledge, emphasizing the vital role of traditional medicine, especially medicinal plants, in addressing various diseases. Herbalists exhibit distinct knowledge, with partial overlap between non-herbalists and herbalists in understanding plant uses. Many plants serve versatile therapeutic purposes across different ailments, and respondents introduce novel uses for medicinal plants.

Keywords: Ethnobotanical survey, Clustering, Traditional use, Medicinal plants, Fez-Meknes region, Morocco.

Background

Many cultures have a long history of using plants as medicine to treat various ailments (Halberstein 2005; Giannenas *et al.* 2020; Sharma *et al.* 2021). For basic medical requirements, a sizable portion of the world's population, particularly in underdeveloped nations, turns on herbal treatments (Sen & Chakraborty 2017). For example, a wide range of salvia species (i.e. S. euphratica Montbret & Aucher ex Benth and S. divaricate Montbret & Aucher ex Benth) are used by Turkish populations since ancient time (Kandemir *et al.* 2017; Selvi *et al.* 2022). Due to a combination of sociocultural views, financial limitations, and restricted access to contemporary healthcare, particularly in rural areas, there is a reliance on traditional medicine (Eddouks *et al.* 2017). Equally, the medicinal plants are used for food purposes. For example, a total of 76 food plants belonging to 30 families were identified in the region of Karaisalı (Adana-Turkey) (Güneş *et al.* 2018). In traditional medicine systems, plants are widely recognized as the most readily available and cost-effective means of treating and preventing various diseases (Tahraoui *et al.* 2007). In addition, cultural and religious views strongly influence people's perceptions of medicine, favoring traditional methods. 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 underscores the importance of preserving traditional knowledge and incorporating it into modern medicine, not just in developing countries, but globally (Yuan *et al.* 2016). It is also essential to consider the traditional uses of plants and their potential benefits in the discovery and development of new medicines (Jaradat *et al.* 2017).

Given that using medicinal plants is common in underdeveloped nations, especially among traditional healers and the elderly (Haque *et al.* 2018). Morocco, a developing country with a rich culture and diverse plant life, harbors over 5,000 vascular plant species, including 900 endemics and over 600 medicinal plants (Fennane &Tattou 2008). The utilization 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 (Bouyahya *et al.* 2017; Fakchich and Elachouri 2021; Merrouni *et al.* 2021). The country boasts a long and diverse history of housing various groups of people, including indigenous Berbers, as well as those from the East (Phoenicians, Jews, and Arabo-Muslims), the South (Sub-Saharan Africans), and the North of Africa (Romans and Vandals) (Bellakhdar 1997). These diverse influences significantly contribute to the rich cultural heritage, fostering a unique national culture comprising distinct subcultures (Domínguez Martínez *et al.* 2017; Aichi *et al.* 2022). Within this cultural diversity, traditional medicine using medicinal plants stands out as a significant aspect (Chaachouay *et al.* 2022). 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 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 & Balick 2012; Aswani *et al.* 2018). Moreover, as seen worldwide, plant diversity in Morocco faces threats from overexploitation, climate change marked by prolonged heatwaves and droughts, habitat loss and fragmentation, logging, fires, fuelwood harvesting in densely populated areas, and the cultivation of invasive species like cannabis in the Rif mountains of northern Morocco (Moore *et al.* 1998; Midaoui *et al.* 2011; Specht *et al.* 2015). For example, the invasive species expand their range over local and endemic species. These factors significantly contribute to the degradation and clearance of natural vegetation (Corlett 2016). Accordingly, ethnobotanical surveys are essential for conserving and sustainably using biological resources, documenting indigenous knowledge on medicinal plant use (Polat & Satıl 2012; Mahwasane *et al.* 2013). Such studies engage policymakers and development planners in formulating effective strategies to conserve cultures, preserve ethnomedicinal knowledge, protect endangered plant species and optimize the utilization of biological resources (Cheikhyoussef *et al.* 2011).

In the past decades, Moroccan ethnobotanical research has concentrated on essential traditional plant knowledge, primarily using qualitative analysis (Benyahya *et al.* 2023; Soussi *et al.* 2023). However, the absence of standardized data collection and analysis has introduced potential inconsistencies and inaccuracies in documenting ethnomedicinal knowledge (Fakchich and Elachouri 2021). For example, studies on the Fez-Meknes region lack breadth (limited sampled sites and sampling periods), focusing on specific medicinal plants for diseases like diabetes (Jouad *et al.* 2001; Mechchate *et al.* 2020; Naceiri Mrabti *et al.* 2021), nervous system issues (Amaghnouje *et al.* 2020; Beniaich *et al.* 2022), renal diseases (Chebaibi *et al.* 2020), and digestive problems (Es-Safi *et al.* 2020), without a comprehensive representation of all provinces within the region.

The primary objective of this study is to collect and document ethnobotanical data from the local population, including both herbalist and non-herbalist informants in the Fez-Meknes region. Similarly, since the transmission of ethnobotanical knowledge is complex, occurring through vertical, horizontal, and oblique pathways, which are crucial for disseminating and

preserving cultural knowledge on plants use (Reyes-García 2010; Caballero-Serrano *et al.* 2019). This knowledge transfer may vary among enthusiasts of medicinal plants, including herbalists engaged in folk medicine and individuals from diverse social backgrounds within the general population who occasionally use plants for medicinal purposes. Consequently, the transmission of ethnobotanical knowledge is expected to differ significantly between herbalists and non-herbalist individuals, leading to substantial disparities in knowledge between these two groups. Hence, it is crucial to evaluate this assumption through a comparative examination of the knowledge held by both groups of informants.

Materials and Methods

Study area

The Fez-Meknes region (depicted in Figure 1) constitutes one of Morocco's 12 administrative divisions established in 2015. Positioned in the northern-central expanse of the country, it spans latitudes 32°58′ N to 34°91′ N and longitudes 2°8′ W to 5°9′ W. Encompassing an area of 40.07 km², the region is inhabited by 4,236,892 people, with 60.52% residing in urban locales, and is bordered by the Tangier-Tetouan-Al Hoceima region to the north, the Rabat-Sale-Kenitra region to the west, the eastern region to the southwest, and the Drâa-Tafilalet region to the south.

The Fez-Meknes region is characterized by a complex climate, with both Mediterranean and continental influences present throughout the area. Winters are marked by cold temperatures, while summers are characterized by hot weather. The high-altitude areas of the Rif, however, experience a more moderate summer climate, but have colder winters with frequent and severe frost.

Fez, a city situated in the Saïs plain between the Rif Mountains to the north and the Middle Atlas Mountains to the south, serves as the administrative center of the region. As one of Morocco's imperial cities, Fez has served as the country's capital during various historical periods and is considered to be its spiritual capital today. The city is divided into three distinct areas: the royal enclosure, the newer districts, and the old town, also known as the Medina. The Medina, a UNESCO World Heritage Site, is a unique and evocative experience with its winding streets, gates, walls, and shops grouped by specialty, all harkening back to the city's medieval past (Ez zoubi *et al.* 2022).

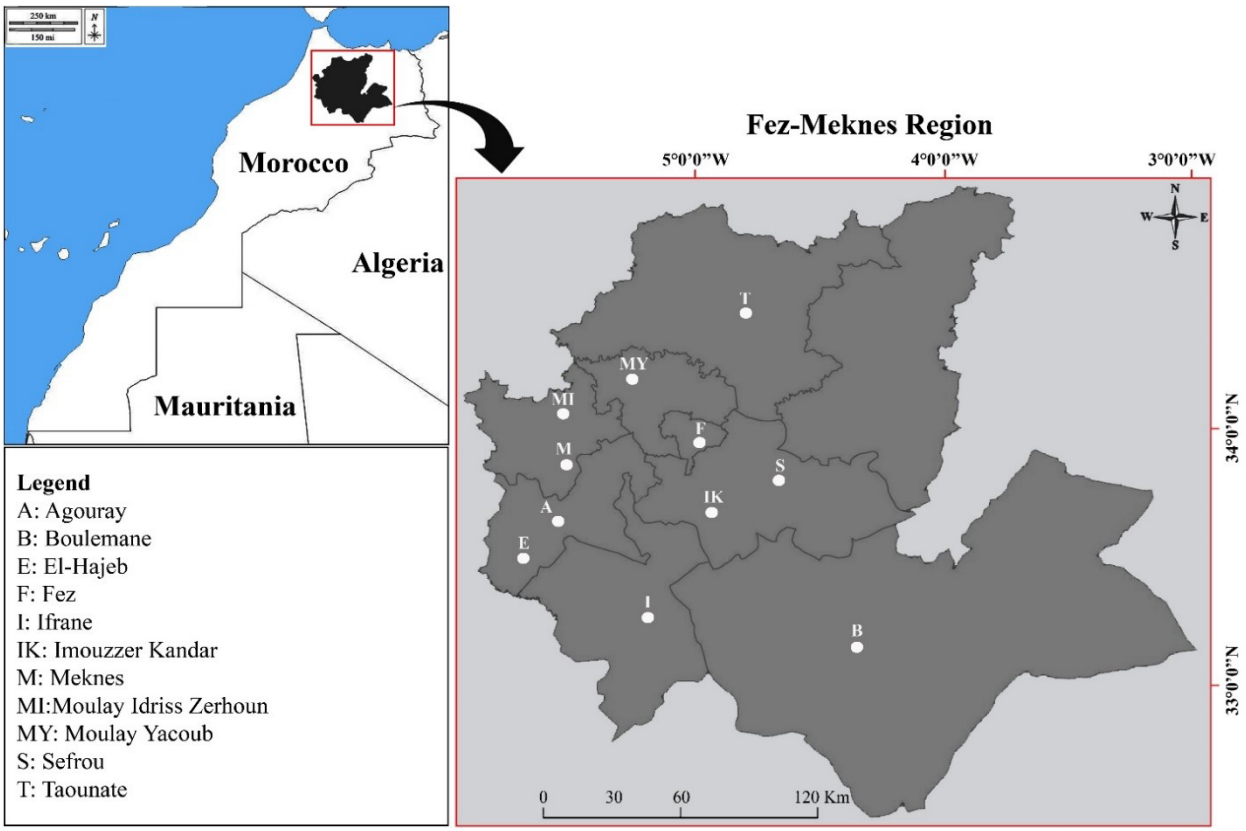

Figure 1. Geographical location of study area and sampled provinces

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

Data collection

This ethnobotanical survey spanned April 2019 to July 2022, and involved 70 herbalists and 408 local inhabitants. Out of over 900 contacted locals invited, only 408 contributed; others declined due to insufficient knowledge or chose not to participate. Data collection employed a semi-structured questionnaire, coded for analysis. An interview protocol used a two-part questionnaire. The first part gathered demographic data - sex, age, family status, education. The second part gathered plant details - vernacular names, uses, diseases, parts, toxicity. This ensured a comprehensive understanding, following Albuquerque *et al.*'s methodology (2014). The interviews were conducted in the vernacular languages spoken in the region, including Moroccan Arabic (Darija) and local Amazigh dialects. To maintain the utmost confidentiality, participation in the interview was completely voluntary and each participant was interviewed separately, as appropriate, to ensure the privacy of their responses.

Before their participation, the contributors were provided with detailed information on the goals and purpose of the survey. Clear and comprehensive explanations were given to ensure that the participants had a thorough understanding of the rationale and significance of the study and that they were able to provide fully informed consent. This approach was crucial in fostering a high level of participant engagement and cooperation throughout the study process by ensuring that the participants had a clear understanding of the survey's purpose and their role in it. The study adhered to the guidelines set forth by the Nagoya Protocol on Access to Genetic Resources and the fair and equitable sharing of benefits outlined in the Convention on Biological Diversity. The traditional knowledge shared by participants was respected and protected, and traditional owners' permission and agreement were required for any use of the information outside of scientific publication (Hamdiken *et al.* 2018).

Categories of Illness

The primary focus of ethnopharmacological study is to understand and scientifically evaluate traditional medicinal systems and the products used within them (Bieski *et al.* 2015). To gain an overview of the therapeutic diversity within these systems, field studies often categorize medicines based on their usage (Benarba *et al.* 2015).

Using the World Health Organization's classification scheme (ICD-10 Version) (https://icd.who.int/browse10/2010/en), we divided diseases into groups according to body systems (WHO). With certain adjustments, this technique is well-known and is in line with conventional ethnomedical procedures (Staub *et al.* 2015). It is noteworthy to mention that specific diagnostic labels and symptomatology were combined to successfully identify various diseases. Clear mention of certain illnesses by name, such as hypertension, diabetes mellitus, rheumatoid arthritis, and stomach ulcers, was made. However, as other informants frequently do not use medical terminology, we gathered as much information as we could about each disease word to precisely identify the ailment and its classification. In the present study, we classified diseases using both informant-provided use reports from the study area and the WHO's systematic categorization method. Each reference to a specific plant for a specific ailment was recorded as the one-use report. If a participant used a plant to treat multiple disorders within the same category, it was counted as a single-use report (Musa *et al.* 2011).

Collection and identification of medicinal plants

The validation of medicinal use required that at least three independent interviewees to mentioned it (Al-Qura'n 2009). All the listed plants were meticulously gathered, some directly from the interviewees themselves and others from the fields. The vernacular names were then transliterated into Roman syllabification from Arabic and Berber using the methods described by (Bertrand 1991) and (Bellakhdar 1997). The botanical identification was carried out by Professor M. Fennane, an experienced botanist. 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, 1934), and 'Flora of Sahara' (Ozenda 1977). Additionally, the scientific names of the plant species were reviewed by referencing the Plant List database (http://www.theplantlist.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. For each parameter, we calculated the percentages based on the number of total participants and respondents for each parameter: (%= N (recorded participants): N (Total number of participants). Statistically significant differences in category citations emerged between the two groups based on the Chi-squared test.

To analyze the relationship between used plants and treated diseases, we used Detrended Correspondence Analysis. The used plants were considered as dependent variables and treated diseases were considered as independent variables. Similarly, the correspondence between used parts, preparation modes, and medicinal plants was analyzed with Detrended Correspondence Analysis. Statistics were realized in SPSS 24 IBM. Graphs and Figures were built using GraphPad Prism 8.3.0. The ANOVA one-way test was used to compare the variation of used plants depending on the sociodemographic features of herbalists and populations. The comparison of used plants between herbalists and populations was realized by sample T-test per each sociodemographic parameter.

Results

Surveyed participants

The sociodemographic features of surveyed informants and herbalists are presented in Table 1. The study's gender distribution indicated a clear female predominance among local inhabitants, designated as non-herbalist informants (NHI), comprising 66.4% of the sample, while herbalists were predominantly male, accounting for 85.7% of the respondents. Furthermore, it was observed that a majority of both NHI and herbalists interviewed fell within the age range of 20 to 60 years old, with 74.26% and 85.71% representing the respective proportions. People over 60 years old accounted for 22.2% and 38.4%, respectively. The educational backgrounds of NHI members and herbalists differed significantly. Primarily, a substantial proportion of NHI members (about one-third) and a significant portion of herbalists (roughly half) were reported to have limited educational attainment, with either illiteracy or only primary education. In contrast, a significant majority of NHI members (63.2%) had higher education levels, including 17.4% with completed secondary education and 45.8% with tertiary education. Among herbalists, 43.5% had obtained secondary education (30.7%) or tertiary education (12.8%).

Table 1. Sociodemographic features of surveyed informants and herbalists

Parameters		Non-Herbalist Informants (N=408)	Herbalists (N=70)
Gender	Male	33.58%	85.71%
	Female	66.42%	14.29%
Age (years)	From 20-60	74.26%	85.71%
	> 60	25.74%	14.29%
Locality	Urban	61.76%	44.28%
	Suburban	24.26%	42.85%
	Rural	13.87%	12.85%
Marital status	Married	60.54%	85.71%
	Single	21.32%	14.29%
	Divorced	7.35%	0.00%
	Widowed	3.68%	0.00%
Education	No formal education	23.53%	25.71%
	Primary education	13.23%	25.71%
	Secondary education	17.40%	30.71%
	Tertiary education	45.80%	12.85%

Impact of sociodemographic on the use of Plants

The impact of sociodemographic features on the use of medicinal plants in both herbalists and the population is presented in Figure 2. Based on the obtained results, the use of plants was statistically variable depending on the sociodemographic parameters of interviewed herbalists and populations. In terms of gender, the number of used medicinal plants was superior in men of herbalists (66 plants) compared to women (49), while in population the women (55 plants) used a superior number of medicinal plants compared to men (38 plants).

In terms of age, the highest number of medicinal plants was used by participants with age of >60 (56 plants), followed by 41-50 (54 plants), 51-60 (47 plants), and 31-40 (44 plants), while the lowest use was recorded in participants aged between 20

and 38 years old (32 plants). In terms of sampled areas, urban areas recorded the highest use of medicinal plants, followed by suburban and rural areas in both herbalists and populations.

In terms of marital status, the married participants use more medicinal plants (56 plants) compared to the other statuses including divorced (33 plants), single (21 plants), and widowed (17). In herbalists, only married and single participants used medicinal plants with 65 and 57 species, respectively. Based on the education level, the use of medicinal plants varied significantly in both herbalists and populations. Herbalists with secondary education recorded the highest number of medicinal plants (66 species), followed by primary education (63 plants), and illiterates (56), while the lowest number of plants was recorded in the tertiary level (53 plants). In populations, the highest number of medicinal plants (52 species) was recorded in the tertiary level, followed by secondary (51) and illiterates (45) levels, while the lowest number of plants was recorded in the primary level (36 plants)

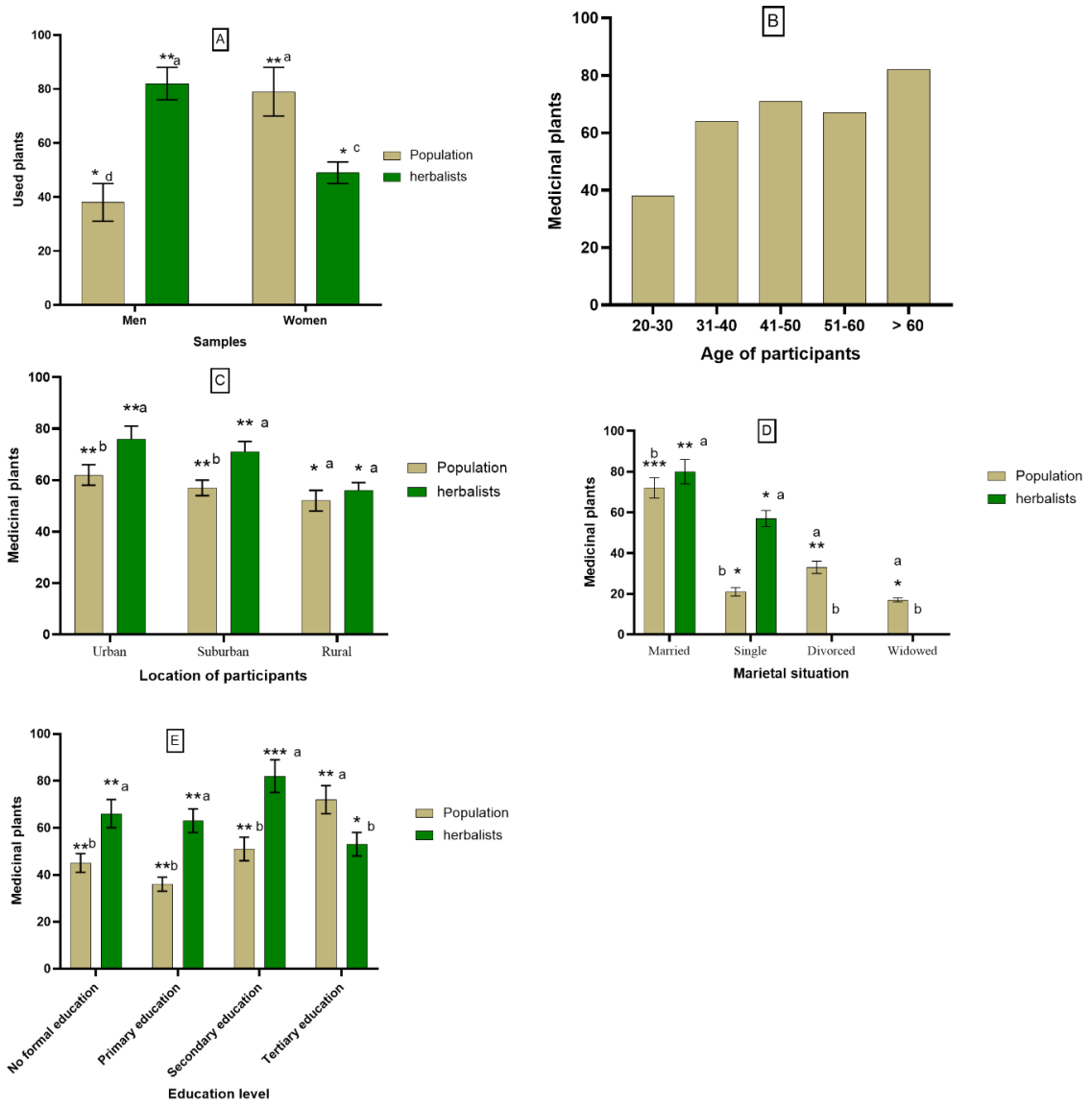

Figure 2. effect of sociodemographic features of investigated populations on the use of medicinal plants in both herbalists and population (A: gender; B: age-group; C: location; D: marital; E: education) (* denote statistically different (ANOVA one way) between parameters (****<***<**<*); a>b between herbalists and population (T-test)

Medicinal plants

Based on the findings of our survey conducted in the Fez-Meknes region, a total of 82 medicinal plant species belonging to 73 genera and 34 families were identified. Notably, herbalists demonstrated a broader knowledge of medicinal plants, as they mentioned 67 species spanning 31 plant families, whereas NHI members cited 56 species from 23 plant families. It is

noteworthy that a substantial overlap in the plant species reported by both groups was observed, with exactly half of the total species mentioned (41 species) being cited by both.

In the NHI group, the Lamiaceae family displayed the highest relative frequency, accounting for a substantial 43.9% and encompassing a total of 13 species. Compositae closely followed with 5 species and a relative frequency of 9.4%. The families Apiaceae and Myrtaceae ranked next, each with 13 species and relative frequencies of 8.1% and 5.6%, respectively. Amaryllidaceae occupied the fifth position, comprising 2 species and a relative frequency of 5.3%. All remaining families exhibited relative frequencies below 3% (Figure 3A). Conversely, among the herbalists, the family Lamiaceae claimed the top position with 14 species, constituting a relative frequency of 27%. Apiaceae held the second position, while Compositae shared the third position with 8 species each, representing relative frequencies of 15.9% and 10.7%, respectively. Leguminosae secured the fourth position with 5 species and a relative frequency of approximately 9.1%, while Myrtaceae occupied the fifth position with 3 species, corresponding to a relative frequency of 4.1%. The remaining families were represented with relative frequencies below 3% (Figure 3B). A Chi-squared (χ^2) test was conducted to examine the potential differences in family distribution 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 found to be less than 0.001, indicating a statistically significant association between the groups (NHI and Herbalists) and the distribution of families. Based on these findings, it can be concluded that the two groups exhibit distinct patterns in the distribution of botanical families.

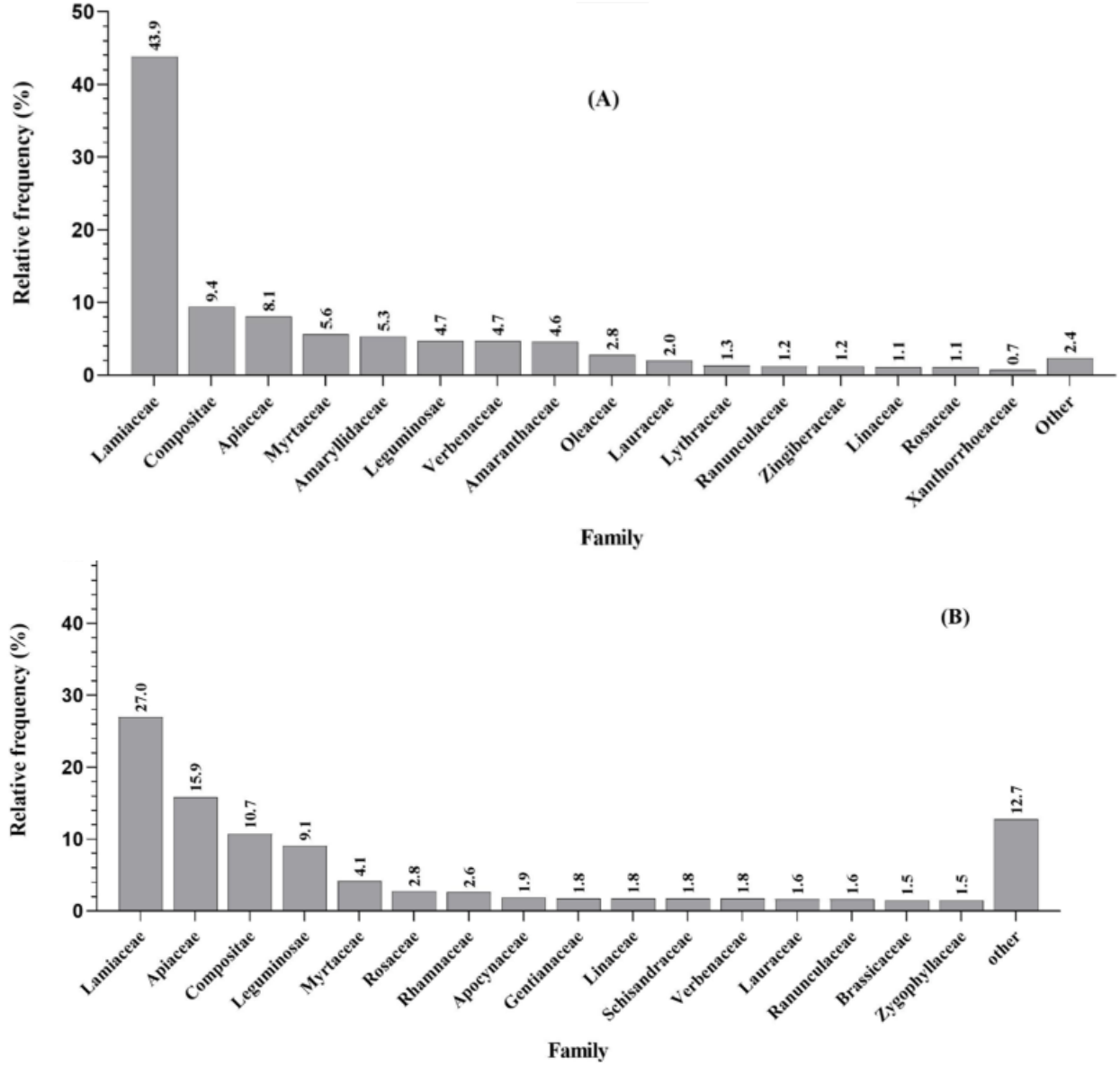

Figure 3. Relative frequency per botanical family among (A) non-herbalist informants and (B) herbalists.

Type of Illness

Fifteen illness categories were identified during the survey (Table 2). Among both NHI and herbalists, DSP (Digestive system problems) received the highest number of category citations, with comparable frequencies of 37.3% and 36.4% respectively. Similarly, ENM (Endocrine and metabolic diseases) followed closely behind, with a higher mention among herbalists (26.8%) compared to NHI (10.2%). Conversely, RPC (Respiratory problem and cold) received significantly higher category citations among NHI (19.8%) compared to herbalists (5.9%) (Figure 4). Statistically significant differences in category citations emerged between the two groups based on the Chi-squared test results ($X^2 = 28.10$, df = 15, p = 0.02). The distribution of category citations notably diverged between herbalists and the NHI, revealing an evident association between them.

Table 2. Identification of recorded diseases among interviewed herbalists and informants

Code	Category	Manifestations
CVD	Cardiovascular diseases	Hypertension, Heart nod, Arrhythmia, Heart palpitations, Hemorrhoids, Cardiac weakness, Atherosclerosis, Varicose veins
ENM	Endocrine, nutritional and metabolic diseases	Diabetes, obesity, Hyperlipidemia, Hypercholesterolemia, Thyroid disorders (hyperthyroidism, hypothyroidism and goiter), Malnutrition, Adrenal gland disorders (Cushing's disease and Addison's disease)
SMP	Skeleton-muscular system problems	Arthritis , Inflammation, Rheumatism, Joint pain, Gout, Sprain, Low back pain, Slipped disc, Sciatic nerve, Muscular tear, Sprains.
PNS	Problems of the nervous system and psychiatric disorders	Insomnia, Anxiety, Depression, Mood-enhancing, Analgesic, Narcotic, Sedative, Relaxant, headaches, Stress, Exhaustion, Amnesia (Memory enhancing), Loss of memory, Alzheimer's disease, Hallucination, Migraine, Parkinson's symptoms, Nervous breakdown, Magic practices (against "evil spirits")
USD	Urinary system diseases	Nephritis, Bladder disorders, Urolithiasis and kidney stone, Urine retention, Interstitial cystitis, Urination difficulties,
RPC	Respiratory problem and cold	Cough, Itchy throat, Cold, Bronchitis, Asthma, Pneumonia, Pertussis
DER	Dermatological problems and dermocosmotology	Burns, Pimples, Scabies, Itch, Skin cracks, Sun burn/tanning, Warts (musa), Cellulite, Acne, Eczema, Psoriasis, Cutaneous neoplasms, Ecchymoses, Cosmetic, Bruises, Vitiligo, Melisma, Skin hardness, Cutaneous ulcers, Sores, Hives, Pimples, Nail infections, Fungal infections, Erysipelas, Hair problem beauty care and capillary, Hair care, Hair growth, Hair loss, Dandruff
DSP	Digestive system problems	Intestinal problems [such as diarrhea, constipation; colic, and intestinal inflammations], Infant diarrhea, Nausea, Vomiting, Ulcer, Gases and flatulence, Gastritis, Parasitic intestinal worms, Helminthiasis, Vermifuge, Cholagogue; Irritable bowel syndrome (IBS), Biliary dyskinesia, Indigestion, Gall-bladder infection, Carminative, Laxative, Purgative, Digestive
DMD	Dental and mouth disorders	Gingivitis, Sore tooth, Gum diseases, Tooth decay, Toothache, Teeth ache, Tooth and gums care, Mouth ulcers, Mouth hygiene
BNP	Blood and nutritional problems	Anemia, Hematoma, Anorexia, Nutritional disorders, Blood purifier, Detoxing, Emetic, Antidote
EEN	Ear, eye and nose problems	Otitis, Tinnitus, Hearing problems, Conjunctivitis, Eye diseases, Eye inflammation, Rhinitis, Sinusitis, Nasal polyps
IND	Infectious Diseases	Measles, Intestinal parasites, Diarrhea, Mildew, Urinary tract infections, , Waterborne illnesses (such as typhoid, cholera and dysentery), Jaundice (hepatitis), Mumps, Sexually transmitted infections (gonorrhea, syphilis..), Covid-19, Tuberculosis, Influenza, Antiseptic
PRS	Pathologies of the reproductive system	Emmenagogue, Amenorrhea, Dysmenorrhea, Menopausal disorders, Erectile dysfunction, Frigidity, Infertility, Aphrodisiac
TIP	Traumatic injuries, poisoning and certain other consequences of external causes	Wounds, External injury, Fracture/broken bones, Food poisonings, Scorpions and snakes bites, Animal bites, Insect bites, Contusion, Poisoning,
GHU	General health and Unspecified signs or poorly defined morbid states	Fever, Jaundice, Liver problems, Pain, Asthenia and Fatigue, Headache, Body aches, Cramp and spasm, Body chills, Backache, Chest pain, Body pain, Weakness, Lack of vitality, Tonic, Invigorating, Strengthener, Stimulant, Energetic

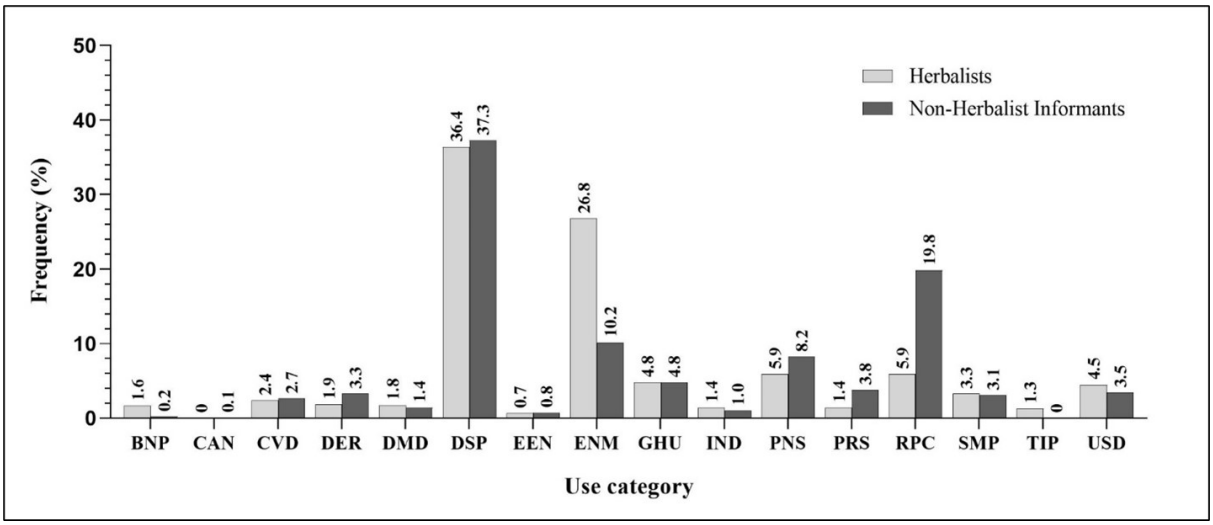

Figure 4. Frequency of illness categories and recorded disorders among herbalists and informants

Plants-diseases categories

The Figure 5 report the most 25 important plants-diseases categories associations for NHI and herbalists respectively. When analyzing the distribution of disease categories in relation to the used plant species, some significant differences have been observed between the two groups. While both groups frequently cite digestive system problems (DSP) and the use of *Origanum compactum* as a medicinal plant, notable distinctions exist between them. Figure 5 illustrates the use of the 25 most cited plant species by the NHI for treating a range of ailment categories. These categories can be organized in descending order as follows: digestive system problems (DSP), respiratory problems and cold (RPC), issues related to the nervous system (PNS), endocrine, nutritional, and metabolic diseases (ENM), general health concerns (GHU), pathologies of the reproductive system (PRS), dermatological problems (DER), urinary system diseases (USD), musculoskeletal issues (SMP), and cardiovascular diseases (CVD) (Figure 5). In contrast, the herbalist group demonstrates a distinct pattern, as they rely on the top 25 most frequently cited plant species to address various ailment categories. These categories can be arranged in descending order as follows: digestive system problems (DSP), endocrine, nutritional, and metabolic diseases (ENM), problems of the nervous system (PNS), respiratory problems and cold (RPC), urinary system diseases (USD), general health (GHU), and skeletal-muscular problems (SMP).

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* (Aci), *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* (Ccy), *Cinnamomum verum* (Cv), *Dysphania ambrosioides* (Da), *Dittrichia viscosa* (Dv), *Eucalyptus globulus* (Eg), *Marrubium vulgare* (Mv), *Nigella sativa* (Ns), *Olea europaea* (Oe), *Syzygium aromaticum* (Sar), 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* (Cer), *Ceratonia siliqua* (Cs), *Caralluma europea* (Ce), *Illicium verum* (Iv), *Myrtus communis* (Mco), *Pimpinella anisum* (Pa), *Rosa damascene* (Rd), *Senna alexandrina* (Sa), *Salvia blancoana* subsp. *mesatlantica* (Sb), 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.

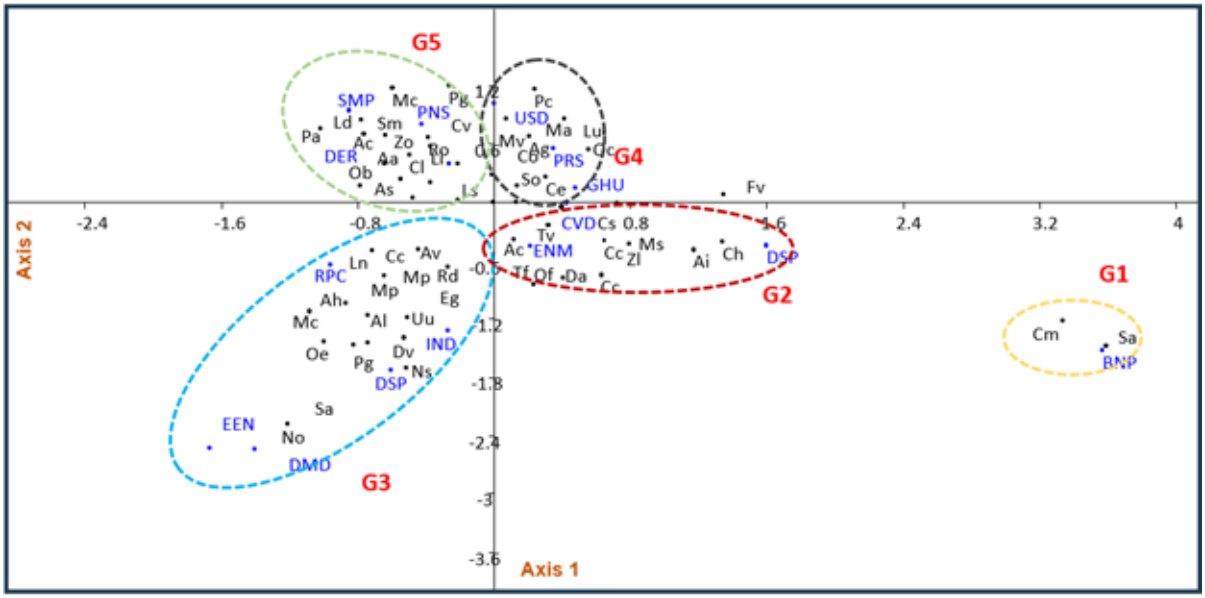

Figure 5. Plants-diseases categories associations among herbalists and informants in Fez-Meknes regions

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.

Ai: *Ajuga iva* (L.) Schreb; Ac: *Allium cepa* L.; As: *Allium sativum* L.; Av: *Aloe vera* (L.) Burm.f.; Aci: *Aloysia citriodora* (Palau) Kunth ; Avi: *Ammi visnaga* (L.) Lam.; Al: *Ammodaucus leucotrichus* Coss.; Ap: *Anacyclus pyrethrum* (L.) Lag.; Ag: *Apium graveolens* L.; Am: *Aquilaria malaccensis* Lam.; Aa: *Artemisia absinthium* L., Ah: *Artemisia herba-alba* Asso; Co: *Calamintha officinalis* Moench; Ce: *Caralluma europaea* (Guss.) N.E.Br.: Cg: *Carlina gummifera* (L.) Less; Cc: *Carum carvi* L.; Cer: *Centaurium erythraea* Rafn; Cs: *Ceratonia siliqua* L.; Ch: *Chamaerops humilis* L. ; Cca: *Cinnamomum cassia (*L.) J.Presl; Cv: *Cinnamomum verum* J.Presl; Cco: *Citrullus colocynthis* (L.) Schrad.; Cs: *Coriandrum sativum* L., Cm: *Crataegus monogyna* Jacq.; Ccy: *Cuminum cyminum* L.; Cl: *Curcuma longa* L.; Cca: *Cynara cardunculus* L.; Dv: *Dittrichia viscosa* (L.) Greuter ; Da: *Dysphania ambrosioides (*L.) Mosyakin & Clemants; Eg: *Eucalyptus globulus* Labill., Fv: *Foeniculum vulgare* Mill.; Ga: *Globularia alypum* L.; Gg: *Glycyrrhiza glabra* L.; *Hh: Herniaria hirsute* L.; Hs: *Hibiscus sabdariffa* L.; Hn: *Hyoscyamus niger* L.; Iv: *Illicium verum* Hook.f.; Ln: *Laurus nobilis* L.; Ld: *Lavandula dentata* L. ; Ls: *Lavandula stoechas* L.; Li: *Lawsonia inermis* L.; Ls: *Lepidium sativum* L.; Lu: *Linum usitatissimum* L.; La: *Lupinus albus* L.; Mv : *Marrubium vulgare* L.; Mc : *Matricaria chamomilla* L.; Ma: *Mentha aquatica* L.; Mp : *Mentha pulegium* L.; Mpu: *Mimosa pudica* L.; Mco: *Myrtus communis* L., Ns : *Nigella sativa* L.; No: *Nerium oleander* L.; Ob: *Ocimum basilicum* L.; Oe : *Olea europaea* L.; Of: *Opuntia ficus-indica* (L.) Mill.; Oc : *Origanum compactum* Benth.; Om: *Origanum majorana* L.; Pm: *Panicum miliaceum* L.; Pg: *Pennisetum glaucum* (L.) R.Br.; Pc: *Petroselinum crispum* (Mill.) Fuss ; Pa: *Pimpinella anisum* L. ; Pgr: *Punica granatum* L.; Ra: *Rhaponticum acaule* (L.) DC.; Rd: *Rosa damascena* Herrm. ; Ro : *Rosmarinus officinalis* L.; Rt: *Rubia tinctorum* L.; Rm: *Ruta montana* (L.) L.; Sb: *Salvia blancoana* subsp. *mesatlantica* (Maire) Figuerola ; So: *Salvia officinalis* L.; Sc: *Saussurea costus* (Falc.) Lipsch.; Sa: *Senna alexandrina* Mill.; *Sv: Salvia verbenaca* L. ; Sol: *Sonchus oleraceus* (L.) L.; Sar : *Syzygium aromaticum (*L.) Merr. & L.M.Perry; Ta: *Tetraclinis articulata* (Vahl) Mast.; Tv: *Thymus vulgaris* L.; Tf: *Trigonella foenum-graecum* L.; Uu: *Urtica urens* L.; Zo: *Zingiber officinale* Roscoe; Zl: *Ziziphus lotus* (L.) Lam.; Za: *Zygophyllum album* L.f

Origin of used plants

Figure 6 presents the origins of medicinal plants used in Fez-Meknes regions. Most of the included plants were sourced either 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 (Ccy)*, *Saussurea costus* (Sc), *Citrullus colocynthis* (Cco), *Cinnamomum verum* (Cv), *Senna alexandrina* (Sa), *Lawsonia inermis* (Li), and *Zingiber officinale* (Zo).

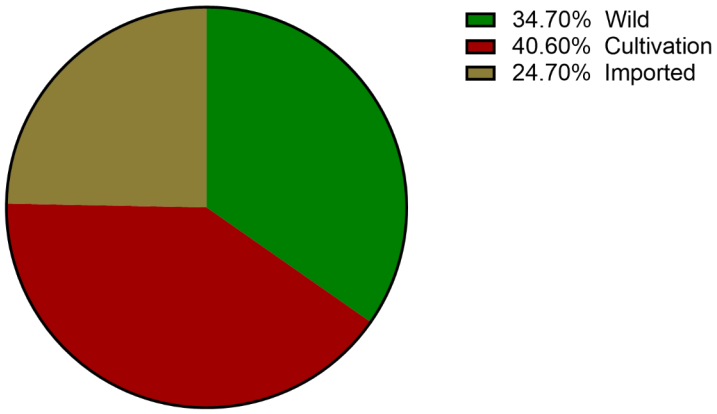

Figure 6. Origins of medicinal plants used in Fez-Meknes regions

Used parts of the plants

The used parts and usage modes of medicinal plants by both herbalists and informants in the Fez-Meknes region are presented in Figures 7 and 8. 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 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 approaches, the utilization of powdered plants and maceration is also widely acknowledged as a common means of herbal remedy formulation. In both groups, the oral route emerges as the primary method of administration for medicinal preparations. In both informant groups, the oral route stood out as the primary method of administration for medicinal preparations. However, it is worth noting that alternative routes of administration are also employed. Specifically, inhalation is utilized for respiratory illnesses, while external application is employed for dermatological problems.

Based on the Detrended Correspondences Analysis, the used parts and usage mode vary depending on the used medicinal plants. In the group G1, seeds are the most used parts of *Pennisetum glaucum* (Pg) (Figure 7). In the group G2 including 38 medicinal plants, the dominant used parts are AP (Aerial Parts), Fr (Fruit), Fl (Flower), St (Stem), Le (Leaf), and WP (Whole Plant), while in G3 dominated by 6 plants Rh (Rhizome) and Wp (Whole Plant) are the most used parts. In the group G4 including 12 plants, Se (Seed) and Ba (Bark) are the most used parts. On the other hand, in the group G1 (Figure 8) including four plants, Ra is the most dominant usage mode. In the group G2 including 4 medicinal plants, the dominant usage modes are Oi and Ju. Further, 24 medicinal plants are grouped in G3 and the dominant usage modes are Ma, Po, Pi, and Pa. Group G4 includes 19 medicinal plants and the most dominant usage modes are De and In. Moreover, Fu is the most dominant preparation mode in both *Nerium oleander* (No) and *Eucalyptus globulus* (Eg).

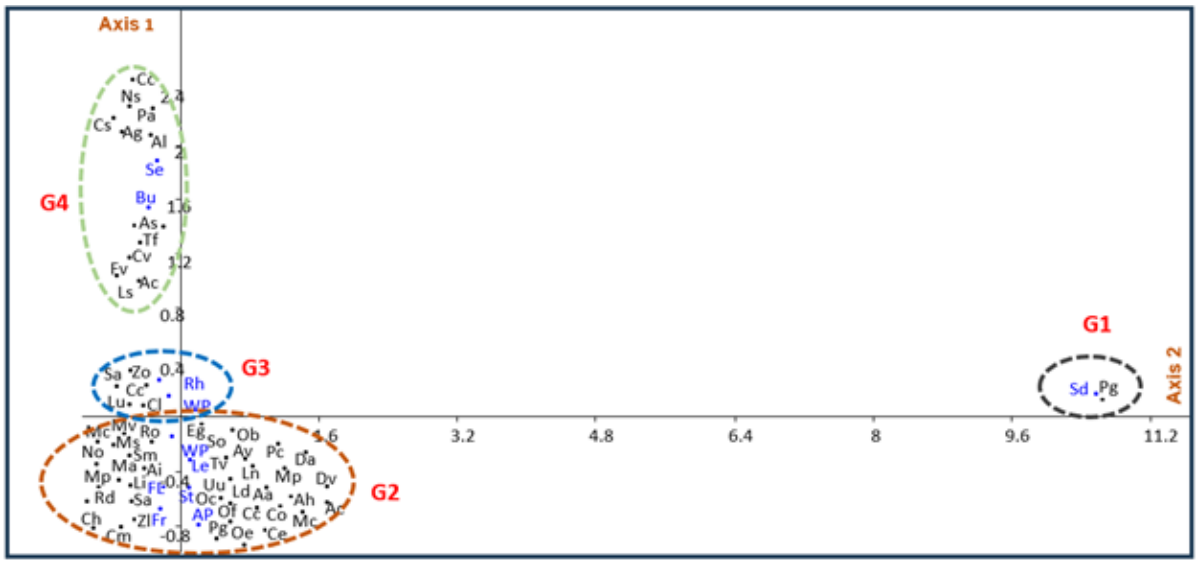

Figure 7. Used parts of medicinal plants recorded in the Fez-Meknes region

AP: Aerial Parts; Ba: Bark; Fl: Flower; Fr: Fruit; Le: Leaf; Rh: Rhizome; Rt: Root; Se: Seed; St: Stem; WP: Whole Plant.

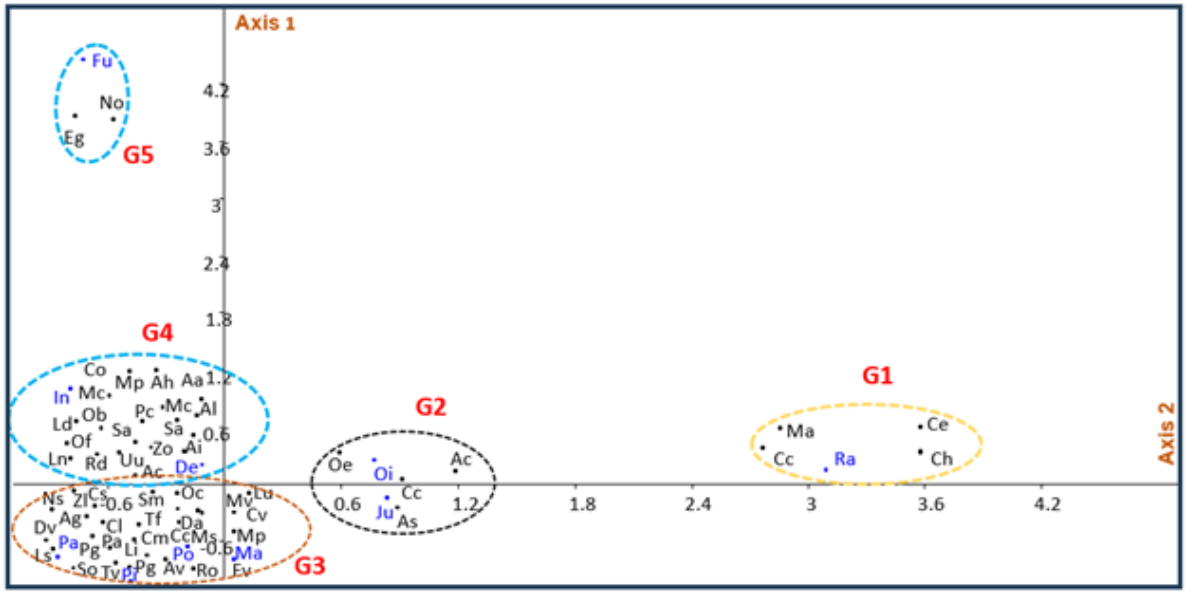

Figure 8. Usage modes of medicinal plants recorded in the Fez-Meknes region

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.

Source of Knowledge

The origins of ethnobotanical knowledge among surveyed participants are presented Table 3. Around one-fifth of the NHI participants reported acquiring their knowledge from written sources, while a mere 2.9% of herbalists mentioned reading as a means of gaining knowledge about medicinal plants. Training was identified as a source of ethnobotanical knowledge by 10% of herbalists, but none of the NHI members attributed their knowledge to formal training. In stark contrast, media (particularly the internet, radio and television) was considered a significant source of information about medicinal plants by nearly half of the NHI members. However, none of the herbalists mentioned it as a source of their ethnobotanical knowledge. The vast majority of herbalists acknowledged that their primary sources were either their parents and elderly individuals (52.9%) or the experiences of others (30%). In contrast, only a small proportion of the NHI participants recognized parents and elderly individuals as sources of information about medicinal plants. Approximately 23% of the NHI members attributed their knowledge to the experiences of others.

Table 3. Source of knowledge among surveyed informants and herbalists

Parameters		Non-Herbalist Informants (N=408)	Herbalists (N=70)
Source of knowledge	Reading	17.40%	2.86%
	Training	----	10.00%
	Media*	50.25%	----
	Parents and elderly	9.31%	52,86%
	Experience of others	23.04%	30.00%

Discussion

The present ethnobotanical study brought to light the richness of medicinal plants and their applications in addressing diverse health concerns within the Fez-Meknes region. The rich knowledge of medicinal plant practices in the Fez-Meknes region is shaped by its historical significance (Amrati *et al.* 2021; Beniaich *et al.* 2022; Finou *et al.* 2023; Benyahya *et al.* 2023). Serving as a significant crossroad, it has facilitated the exchange of ideas and traditional practices. This knowledge is enriched by historical events and the convergence of diverse civilizations-Amazigh, Arab, Jewish, and Arab-Islamic-creating a vibrant cultural tapestry (Sibony 2021). This combination creates a conducive environment in which traditional practices, including the utilization of medicinal plants, flourish. Historical and cultural elements are crucial for intergenerational knowledge transmission, facilitated by the region's cultural heritage. The convergence of historical, cultural, and geographical elements in Fez-Meknes creates a fertile environment for the cultivation and safeguarding of knowledge concerning traditional medicinal practices. This not only enriches local healthcare but also offers valuable perspectives on the interconnectedness of history, culture, and traditional healing methods.

Demographic disparities and gender dynamics in medicinal plant usage

Our findings highlight noteworthy demographic disparities between the two groups. Gender distribution favored females in the NHI group and predominantly males among herbalists. Both groups centered around ages 20 to 60, with a portion exceeding 60 years. Educational backgrounds exhibited significant differences, with a higher prevalence of higher education among NHI members compared to herbalists. These findings align with previous research conducted in Morocco, suggesting a broader trend where women demonstrate a greater inclination toward the utilization of medicinal plants compared to men. This tendency may be attributed to women's primary role as custodians of medicinal plant knowledge, stemming from their involvement in the drying, storing, and preparation of remedies for family care at the household level (Kachmar *et al.* 2021; Lemhadri *et al.* 2023). Additionally, women's strong connection to traditional knowledge further contributes to their significant role in medicinal plant practices (Eddouks *et al.* 2002). Likewise, in alignment with our study outcomes, a study by Najem *et al.(* 2021) establishes that men predominantly engage in the practice of traditional medicine and the commercial trade of medicinal plants. Additional research indicates a prevalent low level of education among herbalists in Morocco, with a considerable percentage of participants reported as either illiterate or possessing only elementary or secondary education (Chaachouay *et al.* 2022; Tahraoui *et al.* 2023).

Ethnomedicinal plant species and traditional knowledge

The current study documented the traditional use of 82 ethnomedicinal plant species originating from 34 families, acknowledged for their therapeutic properties in treating a spectrum of diseases. Spanning across eleven carefully chosen sites within the Fez-Meknes region, the study was designed to capture the traditional knowledge embedded in the local population (NHI) and herbalists concerning the utilization of medicinal plants. Within the NHI group, the families Lamiaceae, Apiaceae, and Compositae stand out, each boasting 13 species, with Compositae closely following with five species. In the herbalists group, Lamiaceae takes the lead with 14 species, surpassing Apiaceae and Compositae, each hosting eight species, while Leguminosae ranks fourth with five species. Overall, the findings align with existing literature data, indicating a prevalent overuse of species from these families in both groups, consistent with reports on widespread utilization in Morocco (El-Ghazouani *et al.* 2021; Tahraoui *et al.* 2023) and the broader Mediterranean region (Bellakhdar *et al.* 1991; Miara *et al.* 2018).

Origins and usage patterns of medicinal plants

In this study, we investigated the origin of medicinal plants used in Fez-Meknes region, which is one of the neglected aspects in the previous ethnobotanical surveys in the area. The majority of recorded plants were collected from the growing farmlands, followed by wild species, while the imported species were less abundant. The origin of medicinal plants is one of the important features to understand the trend of local populations toward medicinal herbs. In this study, despite the abundance of wild medicinal florae in Morocco (Fennane and Rejdali Moh 2016; Msanda *et al.* 2021), the recorded species were dominated by cropped plants. This trend is due to the strategy of Morocco toward the cultivation of wild medicinal plants instead of using wild and rare species (Merrouni *et al.* 2021; Ibourki *et al.* 2022). This strategy aimed to protect the wild florae of Morocco threatened by environmental factors and overexploitation (Ouarghidi *et al.* 2017; Bourgou *et al.* 2021). Currently, Merrouni *et al.* (2021) conducted a deep Ethnobotanical survey of medicinal plants used by populations of Nadour, Figuig, Berkane, and other areas of North-eastern Morocco. These authors investigated the origin of used plants and recorded that the most used species were collected from the wild, which agrees with our results. The low percentage of imported species in our survey could be governed by the richness of medicinal plants in Morocco, including endemic species such as *Argania spinosa* and *Salvia lavandulifolia* subsp. *mesatlantica* (Nafis *et al.* 2021; Maache *et al.* 2023). Equally, in terms of medicinal herbs, Morocco is one of the important exporting countries in North Africa and the Mediterranean Basin (Zrira 2017; Elachouri 2018). Morocco exports more than 70 medicinal plants and their derivatives (Zrira 2017) with revenues generated from MAP export of about US$ 55.9 million (Bouiamrine *et al.* 2017).

Methods and preparation techniques of medicinal plants

This study also investigated the used parts and preparation modes among recorded medicinal plants in Fez-Meknes. Among the two groups of informants, leaves emerged as the most frequently mentioned plant parts, with both groups recognizing their significance, followed by the whole plant. Decoction and infusion emerge as the primary techniques in the preparation of herbal remedies, surpassing alternative methods in popularity. The utilization of powdered plants and maceration is also widely acknowledged as a common means of herbal remedy formulation. In both groups, the oral route emerges as the primary method of administration for medicinal preparations. However, these parameters vary from one plant to another as demonstrated by the multivariate analysis.

Various studies have addressed the preparation mods used parts, and administration approaches in medicinal plants from various areas of Morocco (Bouyahya *et al.* 2017; Amaghnouje *et al.* 2020; Fakchich and Elachouri 2021). Currently, El Yaagoubi *et al.* (2023) conducted a large study on medicinal plants used in traditional medicine in the same areas. In result, recorded medicinal plants were used with three modes Decoction, brewing, and cataplasm. Equally, the most used part was fruit, which is different from our result. Since both studies were realized in the same sites, the variation could be attributed to the knowledge of users and source of information about the used parts and preparation mode. In another study, (Amaghnouje *et al.* 2020) recorded infusion (58%) followed by decoction (22%) as the most dominant preparations in medicinal plants used to manage depression and anxiety in Fez-Meknes Region. In other regions of Morocco, Chetoui *et al. (*2021) mentioned decoctions (40.20 %) and infusions (34.42 %) as the dominant modes of Herbal medicine used to manage type 2 diabetes patients in the Beni Mellal-Khenifra region. These results confirm the variability of preparation modes, used parts, and administration approaches depending on the sampled population and used plants, which agrees with our results.

The source of knowledge related to medicinal plants is one of the investigated features in this study. The surveyed participants acquired their knowledge from written sources, while a mere 2.9% of herbalists mentioned reading as a means of gaining knowledge about medicinal plants. Training was identified as a source of ethnobotanical knowledge by 10% of herbalists, but none of the participants attributed their knowledge to formal training. In stark contrast, media (particularly the internet, radio and television) was considered a significant source of information about medicinal plants by nearly half of the informants. The vast majority of herbalists acknowledged that their primary sources were either their parents and elderly individuals (52.9%) or the experiences of others (30%). In contrast, only a small proportion of the NHI participants recognized parents and elderly individuals as sources of information about medicinal plants. Approximately 23% of the NHI members attributed their knowledge to the experiences of others.

Sources of ethnobotanical knowledge

The source of knowledge and practice in traditional medicine is very crucial in the transmission of medical practices from one generation to another (Adekannbi 2018; Lima Mota *et al.* 2023). Therefore, its investigation is suggested to clarify the trends and predictions of the future of traditional medicine and the use of therapeutic plants. For example, El-Ghazouani *et al.* (2021) conducted a field survey among herbalists and house women in the Agadir area to investigate the source of knowledge. In results, sixty-six percent of herbalists learned about herbal remedies from family members, primarily parents and grandparents. Fifteen percent of herbalists derived their knowledge from firsthand experience. On the other hand, about 25% of housewives claimed to have learned from others, while roughly 75% of them reported that their expertise came from personal experience. In another study, Beniaich *et al. (*2022) conducted an ethnobotanical survey about medicinal plants used in the traditional treatment of asthenia, insomnia, and oral and gum infections in the region Fez-Meknes (Morocco). In results, 70% of herbalists learned their knowledge from the experiences of other herbalists, 15% from publications on alternative medicine, 5% from personal experience, and 10% during training cycles.

Divergences from prior studies: cited medicinal plant species in Fez-Meknes region.

Based on a review of twenty published articles spanning the period from 2001 to 2023, with a primary focus on the Fez-Meknes region or smaller plots within it, we systematically categorized the cited plants into three distinct groups:

- Previously Documented Species (56 plants): This group comprises plant species that have been previously documented in studies conducted within the region or its surrounding areas. While their usage has been noted, some variations exist. For instance, *Artemisia herba-alba*, commonly mentioned in prior research, was traditionally recommended for digestive system problems, endocrine disorders, and nutritional/metabolic diseases. However, a recent study by Amrati *et al.* (2021) suggested its potential use in treating cancer within the region.
- Another set of plants comprises eight species with limited mentions in prior studies, including *Aloysia citriodora*, *Caralluma europaea*, *Globularia alypum*, *Hibiscus sabdariffa*, *Rosa damascena*, *Salvia verbenaca*, *Senna alexandrina*, and *Urtica urens*. To the best of our knowledge, these plants have received unique citations, and their applications for various purposes remain relatively unexplored and diverge from the findings of the current study. For instance, *Caralluma europaea*, identified in our study, is used for treating reproductive system pathologies, endocrine disorders, nutritional and metabolic diseases, as well as digestive issues. Interestingly, Mechchate *et al.* (2020) also mention this plant, citing its potential for treating flu, fatigue, cardiovascular problems, cancer, and regulating the menstrual cycle. Similarly, while a study by Lyoussi *et al.* (2023) previously highlighted the potential of *Globularia alypum* in alleviating hypertension, our study exclusively recommends it for addressing endocrine disorders and nutritional and metabolic diseases.

- The last group encompasses thirteen plants, representing approximately 16% of the total mentioned. Notably, these plants have not been previously documented in studies conducted within the Fez-Meknes region or any of its constituent areas. The plant species in this group include *Aquilaria malaccensis*, *Carlina gummifera*, *Dysphania ambrosioides*, *Hyoscyamus niger*, *Mentha aquatica*, *Mimosa pudica*, *Panicum miliaceum*, *Pennisetum glaucum*, *Rhaponticum acaule*, *Salvia blancoana* subsp. *mesatlantica*, *Saussurea costus*, *Sonchus oleraceus*, and *Zygophyllum album.* This represents a novel contribution, enhancing our knowledge of the local flora and underscoring the importance of further exploration into their properties, uses, and potential benefits. In essence, this realization emphasizes the richness and diversity of plant knowledge within the study area, highlighting the need for continued investigation into lesser-known species.

These results contribute significantly to the existing ethnobotanical literature in Morocco, emphasizing the richness and diversity of plant knowledge in the region. In essence, this study makes a substantial contribution to our understanding of the local flora, highlighting the importance of continued exploration into lesser-known species.

Conclusion

In this study, we inventoried the medicinal plants used by both herbalists and non-herbalist informants in the region of Fez-Meknes (Central Morocco). In details, we searched the variation of used species depending on sociodemographic, illness, origin, and source of knowledge features. Then, we documented the used parts and preparation modes of recorded medicinal plants. The obtained results demonstrated a wide range of therapeutic species, which were variable depending on the characteristics of studied populations and treated illnesses. The highest number of species was mentioned in the herbalists with 82 plants, while populations used only 23 species. The used plants were impacted by the age, gender, age, location, marital, and education statuses of both herbalists and populations. Most of the included plants were sourced either through cultivation or gathered from the wild. Equally, we recorded a dependance between used plants and 25 treated diseases. Among both non-herbalists and herbalists, digestive system problems received the highest record, followed by Endocrine and metabolic diseases, and Respiratory problem and cold. Among the two groups of informants, leaves and whole plant emerged as the most frequently mentioned plant parts, while decoction and infusion emerged as the primary techniques in the preparation of herbal remedies. The utilization of powdered plants and maceration is also widely acknowledged as a common means of herbal remedy formulation. Respondents have introduced novel applications for medicinal plants, indicating potential avenues for future phytochemical and pharmacological research. This ethnobotanical study may contribute to formulating policy on research of natural drugs and the biodiversity conservation in the Fez-Meknes region.

Declarations

Ethics approval and consent to participate: Before conducting interviews, prior informed consent was obtained from all participants. No further ethics approval was required.

Consent for publication: Not applicable

Data Availability Statement: The data used to support the findings of this study are included within the article

Competing interests: Not applicable

Funding: Not applicable

Author contributions: S.M. conducted the field surveys and played a key role in drafting the initial manuscript, A.T. conceptualized the study, contributed to statistical analysis, and drafted the initial manuscript, G.N. and K.E.L. contributed to the field survey and data curation, Y.L. contributed to data curation and statistical analysis, I.E and B.L. provided supervision for data arrangement, presentation, and analysis.

Literature cited

Achour S, Chebaibi M, Essabouni H, Bourhia M, Ouahmane L, Mohammad Salamatullah A., AM Aboul-Soud, M, Giesy, JP. 2022. Ethnobotanical study of medicinal plants used as therapeutic agents to manage diseases of humans. Evidence-Based Complementary and Alternative Medicine.

Adekannbi JO. 2018. Relationship between orthodox and traditional medical practitioners in the transmission of traditional medical knowledge in Nigeria. Health Information & Libraries Journal 35:130-140. doi: 10.1111/hir.12209

Aichi A, Ezaidi S, Abioui M, Ezaidi A. 2022. Cultural Heritage in Imghranes Massif (Drâa-Tafilalet Region, Morocco): An Optimist's Contribution and opportunity for the local people and Sustainable Tourism. International Journal of Innovation and Applied Studies 37:387-391

Al-Qura'n S. 2009. Ethnopharmacological survey of wild medicinal plants in Showbak, Jordan. Journal of Ethnopharmacology 123:45-50. doi: 10.1016/j.jep.2009.02.031

Amaghnouje A, Slighoua M, Es-safi I, El Jaoudi R, Elyoubi A, Bousta D, Grafov A. 2020. Ethnobotanical Survey of Medicinal Plants Used in the Traditional Treatment of Depression and Anxiety in Fez-Meknes Region. Phytothérapie 18:220-229. doi: 10.3166/phyto-2020-0225

Amrati FE-Z, Bourhia M, Slighoua M, Salamatullah AM, Alzahrani A, Ullah R, Bari A, Bousta D. 2021. Traditional medicinal knowledge of plants used for cancer treatment by communities of mountainous areas of Fez-Meknes-Morocco. Saudi Pharmaceutical Journal 29:1185-1204. doi: 10.1016/j.jsps.2021.09.005

Aswani S, Lemahieu A, Sauer WHH. 2018. Global trends of local ecological knowledge and future implications. PLOS ONE 13:e0195440. doi: 10.1371/journal.pone.0195440

Bellakhdar J. 1997. The traditional Moroccan pharmacopoeia: ancient Arabic medicine and popular knowledge. Journal of Medicinal Plants Research 8(2): 504-512.

Bellakhdar J, Claisse R, Fleurentin J, Younos C. 1991. Repertory of standard herbal drugs in the Moroccan pharmacopoea. Journal of Ethnopharmacology 35:123-143. doi: 10.1016/0378-8741(91)90064-K

Benarba B, Belabid L, Righi K, amine Bekkar A, Elouissi M, Khaldi A, Hamimed A. 2015. Ethnobotanical study of medicinal plants used by traditional healers in Mascara (North West of Algeria). Journal of Ethnopharmacology 175:626-637. doi: 10.1016/j.jep.2015.09.030

Beniaich G, Salim R, Ech-chihbi E, El-Hajjaji F, Rais Z, Abdellaoui A, Taleb M. 2022. Ethnobotanical survey about medicinal plants used in traditional treatment of insomnia, asthenia, and oral and gum infections in the region Fez-Meknes, Morocco. Environ Sci Pollut Res 29:133-145. doi: 10.1007/s11356-021-14439-8

Benyahya H, Mohti H, El Rhaffari L, Abdelhamid Z. 2023. Qualitative and Quantitative Ethnobotanical Analysis of the Knowledge of Indigenous Populations on Medicinal Plants in the Meknes Region of Morocco. Universal Journal of Plant Science 10:1-25. doi: 10.13189/ujps.2023.100101

Bertrand P-Y. 1991. Les noms des plantes au Maroc. Doc. Sc. et Techniques, Inst. Agronomique et Vétérinaire Hassan II, Rabat). 166 p

Bieski IGC, Leonti M, Arnason JT, Ferrier J, Rapinski M, Violante IM, Balogun SO, Pereira JF, Figueiredo RD. 2015. Ethnobotanical study of medicinal plants by population of Valley of Juruena Region, Legal Amazon, Mato Grosso, Brazil. Journal of Ethnopharmacology 173:383-423. doi: 10.1016/j.jep.2015.07.025

Bouiamrine EH, Bachiri L, Ibijbijen J, Nassiri L. 2017. Fresh medicinal plants in middle atlas of Morocco: Trade and threats to the sustainable harvesting. Journal of Medicinal Plants Studies 5:123-128

Bourgou S, Ben Haj Jilani I, Karous O, Megdiche-Ksouri W, Ghrabi-Gammar Z, Libiad M, Khabbach A, El Haissoufi M, Lamchouri F, Greveniotis V, Avramakis M. 2021. Medicinal-Cosmetic Potential of the Local Endemic Plants of Crete (Greece), Northern Morocco and Tunisia: Priorities for Conservation and Sustainable Exploitation of Neglected and Underutilized Phytogenetic Resources. Biology 10:1344. doi: 10.3390/biology10121344

Bouyahya A, Abrini J, Bakri Y, Dakka N. 2017. Phytochemical screening and evaluation of antioxidant and antibacterial activities of Origanum compactum extracts. Phytothérapie 15:379-383. doi: 10.1007/s10298-017-1101-8

Brosi BJ, Balick MJ, Wolkow R, Lee R, Kostka M, Raynor W, Gallen R, Raynor A, Raynor P, Lee Ling D. 2007. Cultural Erosion and Biodiversity: Canoe-Making Knowledge in Pohnpei, Micronesia. Conservation Biology 21:875-879. doi: 10.1111/j.1523-1739.2007.00654.x

Caballero-Serrano V, McLaren B, Carrasco JC, Alday JG, Fiallos L, Amigo J, Onaindia M. 2019. Traditional ecological knowledge and medicinal plant diversity in Ecuadorian Amazon home gardens. Global Ecology and Conservation 17:e00524. doi: 10.1016/j.gecco.2019.e00524

Chaachouay N, Douira A, Zidane L. 2022. Herbal Medicine Used in the Treatment of Human Diseases in the Rif, Northern Morocco. Arab Journal of Science and Engineering 47:131-153. doi: 10.1007/s13369-021-05501-1

Chebaibi M, Bousta D, Iken I, Hoummani H, Ech-Choayeby A, Najdi A, Houssaini TS, Achour S. 2020. Ethnopharmacological Survey of Medicinal Plants Used in Traditional Treatment of Kidney Diseases in Fez-Meknes Region, Morocco. Phytothérapie 18:99-114. doi: 10.3166/phyto-2019-0189

Cheikhyoussef A, Shapi M, Matengu K, Mu Ashekele H. 2011. Ethnobotanical study of indigenous knowledge on medicinal plant use by traditional healers in Oshikoto region, Namibia. Journal of Ethnobiology Ethnomedicine 7:10. doi: 10.1186/1746-4269-7-10

Chetoui A, Kaoutar K, Boutahar K, El Kardoudi A, BenChaoucha-Chekir R, Chigr F, Najimi M. 2021. Herbal medicine use among Moroccan type 2 diabetes patients in the Beni Mellal-Khenifra region. Journal of Herbal Medicine 29:100480. doi: 10.1016/j.hermed.2021.100480

Corlett RT. 2016. Plant diversity in a changing world: Status, trends, and conservation needs. Plant Diversity 38:10-16. doi: 10.1016/j.pld.2016.01.001

Domínguez Martínez O, Colmenares Fernández M, García Hermida A. 2017. Cultural heritage and development: the M'hamid Oasis in Southern Morocco. Journal of Cultural Heritage Management and Sustainable Development 7:2-13. doi: 10.1108/JCHMSD-05-2016-0030

Eddouks M, Ajebli M, Hebi M. 2017. Ethnopharmacological survey of medicinal plants used in Daraa-Tafilalet region (Province of Errachidia), Morocco. Journal of Ethnopharmacology 198:516-530. doi: 10.1016/j.jep.2016.12.017

Eddouks M, Maghrani M, Lemhadri A, Ouahidi ML, Jouad H. 2002. Ethnopharmacological survey of medicinal plants used for the treatment of diabetes mellitus, hypertension and cardiac diseases in the south-east region of Morocco (Tafilalet). Journal of Ethnopharmacology 82:97-103. doi: 10.1016/S0378-8741(02)00164-2

Elachouri M. 2018. Chapter 5 - Ethnobotany/Ethnopharmacology, and Bioprospecting: Issues on Knowledge and Uses of Medicinal Plants by Moroccan People. In: Mandal SC, Mandal V, Konishi T (eds. Natural Products and Drug Discovery. Elsevier, pp 105-118

El-Gharbaoui A, Benítez G, González-Tejero MR, Molero-Mesa J, Merzouki A. 2017. Comparison of Lamiaceae medicinal uses in eastern Morocco and eastern Andalusia and in Ibn al-Baytar's Compendium of Simple Medicaments (13th century CE). Journal of Ethnopharmacology 202:208-224. doi: 10.1016/j.jep.2017.03.014

El-Ghazouani F, El-Ouahmani N, Teixidor-Toneu I, Yacoubi B, Zekhnini A. 2021. A survey of medicinal plants used in traditional medicine by women and herbalists from the city of Agadir, southwest of Morocco. European Journal of Integrative Medicine 42:101284. doi: 10.1016/j.eujim.2021.101284

El Yaagoubi W, Ghadraoui LE, Soussi M, Ezrari S, Belmalha S. 2023. Large-scale ethnomedicinal inventory and therapeutic applications of medicinal and aromatic plants used extensively in folk medicine by the local population in the middle atlas and the plain of Saiss, Morocco. Ethnobotany Research and Applications 25:1-29

Es-Safi I, Mechchate H, Amaghnouje A, Jawhari FZ, Bari A, Cerruti P, Avella M, Grafov A, Bousta D. 2020. Medicinal plants used to treat acute digestive system problems in the region of Fez-Meknes in Morocco: An ethnopharmacological survey. Ethnobotany Research and Applications 20:1-14

Ez zoubi Y, Lairini S, El Amrani S, El-Akhal F, Farah A, Bouslamti R, El Ouali Lalami A. 2022. Ethnobotanical survey of herbs used in the preservation of food products in Fez, Morocco. Journal of Ethnic Foods 9:29. doi: 10.1186/s42779-022-00144-5

Fakchich J, Elachouri M. 2021. An overview on ethnobotanico-pharmacological studies carried out in Morocco, from 1991 to 2015: Systematic review (part 1). Journal of Ethnopharmacology 267:113200. doi: 10.1016/j.jep.2020.113200

Fennane M, Rejdali Moh. 2016. Aromatic and medicinal plants of Morocco: Richness, diversity and threats. Bulletin de l'Institut Scientifique, Rabat 27-42

Fennane M, Tattou MI. 2008. Statistiques et commentaires sur l'inventaire actuel de la flore vasculaire du Maroc. Flora 1986:

Fennane M, Tattou MI. 2005. Flore vasculaire du Maroc: Inventaire et chorologie. Vol 1, Pteridophyta, Gymnospermae, Angiospermae (pp)

Finou HE, Salhi N, Halmoune A, Rhaffari LE. 2023. Ethnobotanical Survey of Aromatic and Medicinal Plants Used in Traditional Medicine and Agri-Food in The Fez-Meknes Region. Biology, Medicine, & Natural Product Chemistry 12:133-141. doi: 10.14421/biomedich.2023.121.133-141

Giannenas I, Sidiropoulou E, Bonos E, Christaki E, Florou-Paneri P. 2020. Chapter 1 - The history of herbs, medicinal and aromatic plants, and their extracts: Past, current situation and future perspectives. In: Florou-Paneri P, Christaki E, Giannenas I (eds. Feed Additives. Academic Press, pp 1-18

Güneş S, Savran A, Paksoy MY, Çakılcıoğlu U. 2018. Survey of wild food plants for human consumption in Karaisalı. Adana-Turkey). Indian Journal of Traditional Knowledge 17(2).

Halberstein RA. 2005. Medicinal Plants: Historical and Cross-Cultural Usage Patterns. Annals of Epidemiology 15:686-699. doi: 10.1016/j.annepidem.2005.02.004

Hamdiken M, Bouhalit S, Kechrid Z. 2018. Effect of Ruta chalepensis on Zinc, Lipid Profile and Antioxidant Levels in the Blood and Tissue of Streptozotocin-Induced Diabetes in Rats Fed Zinc-Deficient Diets. Canadian Journal of Diabetes 42:356-364. doi: 10.1016/j.jcjd.2017.08.239

Haque MdI, Chowdhury ABMA, Shahjahan Md, Harun MdGD. 2018. Traditional healing practices in rural Bangladesh: a qualitative investigation. BMC Complementary and Alternative Medicine 18:62. doi: 10.1186/s12906-018-2129-5

Ibourki M, Ait Bouzid H, Bijla L, Sakar EH, Asdadi A, Laknifli A, El Hammadi A, Gharby S. 2022. Mineral Profiling of Twenty Wild and Cultivated Aromatic and Medicinal Plants Growing in Morocco. Biological Trace Element Research 200:4880-4889. doi: 10.1007/s12011-021-03062-w

Jahandiez E, Maire R. 1931. Catalogue Des Plantes Du Maroc:(Spermatophytes et Ptéridophytes). Tome Premier. Ptéridophytes, Gymnospermes et Monocotylédones. Minerva

Jahandiez E, Maire R. 1934. Catalogue des plantes du Maroc (Spermatophytes et Ptéridophytes). Imprimerie Minerva

Jaradat NA, Zaid AN, Hussen F, Ali İ. 2017. The Effects of Preservation Methods of Grapevine Leaves on Total Phenols, Total Flavonoids and Antioxidant Activity. Marmara Pharm J 21:291-297. doi: 10.12991/marupj.300361

Jouad H, Haloui M, Rhiouani H, El Hilaly J, Eddouks M. 2001. Ethnobotanical survey of medicinal plants used for the treatment of diabetes, cardiac and renal diseases in the North centre region of Morocco (Fez-Boulemane). Journal of Ethnopharmacology 77:175-182. doi: 10.1016/S0378-8741(01)00289-6

Kachmar MR, Naceiri Mrabti H, Bellahmar M, Ouahbi A, Haloui Z, El Badaoui K, Bouyahya A, Chakir S. 2021. Traditional Knowledge of Medicinal Plants Used in the Northeastern Part of Morocco. Evidence-Based Complementary and Alternative Medicine 2021:e6002949. doi: 10.1155/2021/6002949

Kandemir A, Türkmen Z, Selvi S, Çakılcıoğlu L, Polat S. 2017. The anatomical and micromorphological properties of three endemic and medicinal Salvia species (Lamiaceae) in Erzincan (Turkey). Plant Biosystems 151(1):63-73. doi: 10.1080/11263504.2015.1076083

Lemhadri A, Achtak H, Lamraouhi A, Louidani N, Benali T, Dahbi A, Bouyahya A, Khouchlaa A, Shariati MA, Hano C, Lorenzo JM. 2023. Diversity of Medicinal Plants Used by the Local Communities of the Coastal Plateau of Safi Province (Morocco). FBS 15:1. doi: 10.31083/j.fbs1501001

Lima Mota MR, Lauer-Leite ID, Novais JS de. 2023. Intergenerational transmission of traditional ecological knowledge about medicinal plants in a riverine community of the Brazilian Amazon. Polibotánica 311-329. doi: 10.18387/polibotanica.56.16

Lyoussi B, Bakour M, Cherkaoui-Tangi K, El-Hilaly J, Hano C. 2023. Ethnobotanical Survey and Pharmacological Screening of Medicinal Plants Used as Antihypertensive in Sefrou Province (Middle-North of Morocco): Benefits and Challenges. Frontiers in Bioscience-Scholar 15(1):4.

Maache S, Zbadi L, Ghouizi AE, Soulo N, Saghrouchni H, Siddique F, Sitotaw B, Salamatullah AM, Nafidi HA, Bourhia M, Lyoussi B, Elarabi I. 2023. Antioxidant and antimicrobial effects of essential oils from two salvia species with in vitro and in silico analysis targeting 1AJ6 and 1R4U proteins. Scientific Reports 13:14038. doi: 10.1038/s41598-023-41178-2

Mahwasane ST, Middleton L, Boaduo N. 2013. An ethnobotanical survey of indigenous knowledge on medicinal plants used by the traditional healers of the Lwamondo area, Limpopo province, South Africa. South African Journal of Botany 88:69-75. doi: 10.1016/j.sajb.2013.05.004

Maire R. 1952. Flore de l'Afrique du Nord (Maroc, Algérie, Tunisie, Tripolitaine, Cyrénaïque et Sahara)

Mechchate H, Es-safi I, Jawhari FZ, Grafov A, Bousta D. 2020. Ethnobotanical Survey About the Management of Diabetes With Medicinal Plants Used by Diabetic Patients in Region of Fez-Meknes, Morocco. Ethnobotany Research and Applications 19:12

Merrouni IA, Kharchoufa L, Bencheikh N, Elachouri M. 2021. Ethnobotanical profile of medicinal plants used by people of North-eastern Morocco: Cross-cultural and Historical approach (Part I). Ethnobotany Research and Applications 21:1-45

Miara MD, Bendif H, Ait Hammou M, Teixidor-Toneu I. 2018. Ethnobotanical survey of medicinal plants used by nomadic peoples in the Algerian steppe. Journal of Ethnopharmacology 219:248-256. doi: 10.1016/j.jep.2018.03.011

Midaoui ME, Maataoui A, Benbella M, Houssa AA, Labazi N. 2011. Ethnobotanical Study of Some Aromatic and Medicinal Plants in the Middle Atlas Mountains of Morocco. Natural Product Communications 6:1934578X1100601011. doi: 10.1177/1934578X1100601011

Moore HM, Fox HR, Harrouni MC, Alami AE. 1998. Environmental challenges in the Rif mountains, northern Morocco. Environmental Conservation 25:354-365. doi: 10.1017/S0376892998000435

Msanda F, Mayad EH, Furze JN. 2021. Floristic biodiversity, biogeographical significance, and importance of Morocco's Arganeraie Biosphere Reserve. Environ Sci Pollut Res 28:64156-64165. doi: 10.1007/s11356-020-11936-0

Musa S, Abdelrasool F, Elsheikh E, Ahmed LA, Mahmoud AL, Yagi SM. 2011. Ethnobotanical study of medicinal plants in the Blue Nile State, South-Eastern Sudan. Journal of Medicinal Plants Research 5:4287-4297

Naceiri Mrabti H, Bouyahya A, Naceiri Mrabti N, Jaradat N, Doudach L, Faouzi ME. 2021. Ethnobotanical Survey of Medicinal Plants Used by Traditional Healers to Treat Diabetes in the Taza Region of Morocco. Evidence-Based Complementary and Alternative Medicine 2021:e5515634. doi: 10.1155/2021/5515634

Nafis A, Hassani L, Marraiki N, Al-Rashed S, Elgorban AM, Syed A, Iriti M. 2021. Antimicrobial and synergistic effect of Moroccan native Argania spinosa essential oil for modulating of antibiotics resistance. Natural Product Research 35:6078-6082. doi: 10.1080/14786419.2020.1821018

Najem M, Ibijbijen J, Nassiri L. 2021. Ethnobotanical treatment of respiratory diseases in the central Middle Atlas. Morocco): Qualitative and quantitative approach. European Journal of Integrative Medicine 46:101358. doi: 10.1016/j.eujim.2021.101358

Ouarghidi A, Powell B, Martin GJ, Abbad A. 2017. Traditional Sustainable Harvesting Knowledge and Distribution of a Vulnerable Wild Medicinal Root (*A. pyrethrum* var. *pyrethrum*) in Ait M'hamed Valley, Morocco. Econ Bot 71:83-95. doi: 10.1007/s12231-017-9374-2

Ozenda P. 1977. Flora of the Sahara. Flora of the Sahara

Polat R, Satıl F. 2012. An ethnobotanical survey of medicinal plants in Edremit Gulf (Balıkesir - Turkey). Journal of Ethnopharmacology 139:626-641. doi: 10.1016/j.jep.2011.12.004

Ramirez CR. 2007. Ethnobotany and the loss of traditional knowledge in the 21st century. Ethnobotany Research and Applications 5:245-247

Reyes-García V. 2010. The relevance of traditional knowledge systems for ethnopharmacological research: theoretical and methodological contributions. Journal of Ethnobiology and Ethnomedicine 6:32. doi: 10.1186/1746-4269-6-32

Selvi S, Polat R, Çakilcioğlu U, Celep F, Dirmenci T, Ertuğ ZF. 2022. An ethnobotanical review on medicinal plants of the Lamiaceae family in Turkey. Turkish Journal of Botany 46:283-332. doi: 10.55730/1300-008X.2712

Sen S, Chakraborty R. 2017. Revival, modernization and integration of Indian traditional herbal medicine in clinical practice: Importance, challenges and future. Journal of Traditional and Complementary Medicine 7:234-244. doi: 10.1016/j.jtcme.2016.05.006

Sharma A, Khanna S, Kaur G, Singh I. 2021. Medicinal plants and their components for wound healing applications. Future Journal of Pharmaceutical Science 7:53. doi: 10.1186/s43094-021-00202-w

Sibony J. 2021. phonetical and phonological adaptations of Hebrew loanwords in Moroccan judeo-arabic: the case of FEZ. Romano-Arabica 103

Soussi M, Yaagoubi WE, Squalli W, Benjelloun M, El Ghadraoui L. 2023. Comparative ethnobotanical survey of Pimpinella anisum, Coriandrum sativum, Carum carvi in three zones of Morocco: Therapeutic uses, sources of knowledge, and efficacy against diseases and food purposes. Ethnobotany Research and Applications 26:1-.18

Specht MJ, Pinto SRR, Albuquerque UP, Tabarelli M, Melo FP. 2015. Burning biodiversity: Fuelwood harvesting causes forest degradation in human-dominated tropical landscapes. Global Ecology and Conservation 3:200-209. doi: 10.1016/j.gecco.2014.12.002

Staub PO, Geck MS, Weckerle CS, Casu L, Leonti M. 2015. Classifying diseases and remedies in ethnomedicine and ethnopharmacology. Journal of Ethnopharmacology 174:514-519

Tahraoui A, El-hilaly J, Ennabili A, Maache S, Laamech J, Lyoussi B. 2023. Ethnobotanical Study of Medicinal Plants used by Traditional Health Practitioners to Manage Diabetes Mellitus in Safi and Essaouira Provinces (Central-Western Morocco). Tropical Journal of Natural Product Research 7. p2178

Tahraoui A, El-Hilaly J, Israili ZH, Lyoussi B. 2007. Ethnopharmacological survey of plants used in the traditional treatment of hypertension and diabetes in south-eastern Morocco (Errachidia province). Journal of Ethnopharmacology 110:105-117. doi: 10.1016/j.jep.2006.09.011

Vandebroek I, Balick MJ. 2012. Globalization and Loss of Plant Knowledge: Challenging the Paradigm. PLOS ONE 7:e37643. doi: 10.1371/journal.pone.0037643

Yuan H, Ma Q, Ye L, Piao G. 2016. The Traditional Medicine and Modern Medicine from Natural Products. Molecules 21:559. doi: 10.3390/molecules21050559

Zrira S. 2017. Some Important Aromatic and Medicinal Plants of Morocco. In: Neffati M, Najjaa H, Máthé Á (eds) Medicinal and Aromatic Plants of the World - Africa Volume 3. Springer Netherlands, Dordrecht, pp 91-125