A Comparative Analysis of Ethnobotanical Use of Medicinal Plants by Herbalists and Cooperatives in 3 Contrasting Provinces of Morocco

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Abstract

The use of medicinal plants in Morocco has a long history and plays an important role in health care of the Moroccan population. This study is one of the first ethnobotanical studies that compare the ethnomedicinal knowledge of two types of expert informants on medicinal and aromatic plants conducted in contrasted regions of Morocco. It documented medicinal plant uses in three provinces (Meknes, Fez and Taounate) using semi-structured interviews. Overall, 85 herbalists and 78 cooperative directors shared their knowledge of 151 plant species belonging to 64 families. This study revealed a rich diversity of medicinal plants in the three studied provinces, with a remarkable distinction in knowledge between herbalists and cooperative directors. Concerning the species used, the Asteraceae (16spp.), Lamiaceae (14spp.), Apiaceae (13spp.) and Fabaceae (10spp.) were the dominant families. *Origanum compactum* Benth was the most cited species (95%). Respiratory system diseases were the most frequent targets of the medicinal plants used (Informant agreement ratio= 0.95), whereas musculoskeletal system disorders were the lowest (0.81). This study can help identify those medicinal plants with the highest importance and utilization in these provinces. This information can hopefully be of interest to both future researchers, for pharmacological testing and conservation, and policy makers to better improve the medicinal plant research and assist those working in this sector.

Keywords: Ethnobotany, Ethnomedicine, Mediterranean Flora, Natural resources, People/Plants relationships.

Introduction

Ethnobotany is a botanical science concerning the use of plants in daily life and traditional practices (Shaltout et al., 2023). Ethnobotanical research includes not only taxonomic botanical data, but also traditional botanical knowledge in the form of a review of interpretations and associations that examines the relationships between people, plants, and the cultural preference for the use of these plants (Dharmono, 2007).

Traditional healing system has a long history and has an unmistakable and crucial role in the health system in most countries. According to the World Health Organization (WHO, 2013), about 80% of the ailing population in developing countries, including Morocco, depend on traditional healing for their primary healthcare needs; and the demand for such services is increasing (Haque et al., 2018). In addition, many medical technological innovations and drugs in modern medicine are based on guidelines of traditional medicinal knowledge of healers (Yuan et al., 2016).

There are two main kinds of traditional healers: the diviner and the herbalist (Richter, 2003). Herbalists diagnose, select, and prescribe medicines for illnesses. Their empirical knowledge plays an important role because they can diagnose illnesses and to prescribe appropriate remedies for those illnesses (Richter, 2003). However, because of the economic importance of traditional medicine, there are a recent development of cooperatives. A cooperative is an autonomous association of people who are united to meet their common economic, social, and cultural needs through a jointly owned and democratically controlled enterprise (Novkovic, 2008). Agricultural cooperatives improve smallholder production, commercialization, and, more generally, economic and social development, especially in rural areas (Tefera et al., 2016). They occupy 30%–70% of the agricultural market since the 1990s in the European Union and North America (Luo et al., 2020). The cooperatives of farmers who grow medicinal plants aim to ensure and facilitate the marketing of these plants,

and to establish linkages between farmers and pharmaceutical industries (Samant et al., 2007).

Due to its geographical position and climatic context, Morocco has a great ecological and floristic diversity, with about 4500 plant species belonging to 940 genera, and 135 families of which 951 taxa are endemic (Fennane, 2004). (El-Hilaly et al., 2003; Fougrach et al., 2007). Among these species, more than 500 plants are used for their medicinal and aromatic properties (Ennabili et al., 2000). Morocco has a long tradition of phytotherapeutics, documented since the Middle Age and the first decades of the Hegira (Elachouri et al., 2021), which has started to interest scientists, notably with the publication of the book entitled "*La Pharmacopée marocaine traditionnelle*" by Jamal Bellakhdar in 1997 (El Hassani et al., 2013).

Many ethnobotanical studies are conducted with the local communities (Shaltout et al., 2023), others with expert informants (Corroto & Macía, 2021), while some studies combine responses from experts and general informants (Thomas et al., 2009; Cámar a-Leret et al., 2014; Júnior et al., 2016; Ahmed et al., 2023). Expert informants are participants recognized by the rest of the community members for their traditional knowledge, such as traditional healers, herbalists, and cooperative directors operating in the medicinal and aromatic plant (MAP) sector. They allow to obtain a large part of the traditional knowledge while spending less time in the field (Cartaxo et al., 2010; B elayneh et al., 2012; Demie et al., 2018; Corroto & Macía, 2021). So, it is an effective and rapid method to document traditional knowledge. Such recollection of traditional knowledge is of importance, since this knowledge is easily lost because of the oral transmission between generations, the disinterest of young people in traditional culture, the lack of documentary databases on traditional medicinal practices and also the degradation of plant resources due to urbanization, climate change and other human actions (Benbrahim et al., 2004; Voeks & Leony, 2004; Almeida et al., 2012; Bellia & Pieroni, 2015; Elachouri et al., 2021).

Abbouyi et al. (2014) have interviewed traditional healers to produce an inventory of MAP and their medicinal uses by the population of El Jadida city. Because they are collected by the traditional healers, the used MAPs are supposed to reflect the local plant biodiversity. Therefore, in different regions, it is expected to observe different MAPs. Furthermore, since the creation of the first cooperative in 2004 in Bellouta (APDESPN, 2012), we have noted a remarkable increase in MAP cooperatives: 10 in 2005, 69 in 2010 (Bouchafra, 2011) and 175 in 2022 (CoopMaroc). The objectives of their creation were to improve the quality of life of the rural population, commercialize and preserve natural resources. Fadil et al. (2015) have conducted surveys in cooperatives of the Meknes-Tafilalet region with the purpose of valorising the flora and the ethnopharmacological heritage of this region. More recently, Naceiri Mrabti et al. (2021) performed an ethnobiological survey of antidiabetic plants used in the Taza region. In contrast to healers, cooperatives use MAPs that are less reflecting the local biodiversity. It is therefore essential to study the uses of medicinal plants by different types of informants, in order to reflect their economic and cultural importance (Ahmed et al., 2023).

The use of plants can be learnt through different indicators (Hoffman et al. 2017). For instance, Relative Frequency of Citation (RCF) represents the proportions of informants who mentioned the use of a species (Tardío & Pardo-de-Santayana, 2008). The use-value index (UV) is also a common index representing the relative importance of a given species (Hoffman & Gallaher 2007). Other indices based on informants' reports, such as UV and IAR (see methods), can also be used. All these indices are important since they allow quantitative comparisons among different populations.

The present study aimed to present (1) a difference between the knowledge of two types of informants; the herbalists who have existed for a long time and who are traditional sellers of MAPs and traditional recipes, and the directors of the cooperatives who are modern sellers of MAPs and natural preparations made from

these plants, (2) the diversity of MAPs used in three provinces of Morocco, (3) a variability of medicinal plant knowledge between the provinces, and (4) the differences between the three provinces and between the two types of informants, with respect to the plants used, the parts used, the methods of preparation, and the therapeutic indications.

Methodology

1. Study area and socio-demographic data

The present study was conducted in an area composed of three provinces (Meknes, Fez and Taounate) of Morocco (Fig.1), representing three different biogeographical units. The Meknes province has a strategic geographical position and a strong agricultural potential, as it includes three types of habitats: mountains (Pre-Rif and Western Middle Atlas), the central plateau of Meknes-Sais, and the plains (Ain Jemaa and Mejjat). The Fez province is characterized by a long urban history, dating back to the year 789, as well as a strategic geographical position due to the valleys of the Mikkes, Sebou and Lebene (Despois & Raynal, 1967). The third study zone, Taounate, is a predominantly rural province (only 12% is urbanized) and is characterized by its mountainous landscape, especially in the northern part which covers about 40% of the total area of the province, and where elevations reach 1800 m. It is crossed by six large rivers constituting the main tributaries of the Oued Ouergha. In the southern part with undulating relief, the altitudes vary from 1000m at the Jbel Zeddour to 150 m along the Oued Inaouen (Zoukh, 2014). More than 7.27% of the total area of Taounate province is covered by forests (compared to 1.10% in Meknes and 0.09% in Fez), dominated by the green oak forest and formation of Quercus suber, and characterised by a temperate Mediterranean climate (DCEFLCD, 2015).

Taounate is a predominantly rural province, with a high illiteracy rate and a low employment rate compared to the two other provinces, namely Meknes and Fez (Table 1).

2. Data collection

We complied with the Code of Ethics of the International Society of Ethnobiology (ISE, 2008). A short conversational prelude, in which the background of the research and the purpose of the study were explained prior to conducting the interviews. A verbal consent was obtained from the participants, who were assured confidentiality and anonymity.

Ethnobotanical data were collected using a semi-structured interview method with local experts, considered key informants by Martin (2010), during two sessions (February-March 2020 and July 2020–February 2021). We looked for herbalists in popular neighbourhoods, traditional souks, and various markets. Local populations also helped to find some herbalists. The lists of cooperatives in each province were provided by the provincial departments of water and forests, the National Agency for Medicinal and Aromatic Plants, and the website www.coopmaroc.com.

During each interview, information collected were vernacular name of MAPs, illnesses treated, plant parts used, and preparation methods for each species cited, as well as the interviewed information (gender, marital status, academic level, age, and years of experience). Preliminary identifications of medicinal species using vernacular names were made by informants in the field. Species were first identified based on their common names, using the repertory of standard herbal drugs in the Moroccan pharmacopoeia (Bellakhdar et al., 1991). Some doubtful species were taken to the laboratory for taxonomic confirmation based on *the Practical flora of Morocco* (Fennane et al., 1999a) and *Vascular flora of Morocco* (Fennane et al., 1999b, 2007, 2014). The scientific names of the plant samples were finally checked with the Plant List website (https://wfoplantlist.org/). Voucher specimens collected during the

fieldwork were deposited in Biotechnology and Bio-Resources Valorisation Laboratory, Moulay Ismail University, Meknes, Morocco.

The medicinal uses of the plants were grouped into 12 categories regarding their use: "infections" (INF), "digestive system disorders" (DIG), "skin/subcutaneous cellular tissue disorders" (SKI), "respiratory system disorders" (RES), "endocrine system disorders" (END), "genitourinary system disorders" (GEN), "musculoskeletal system disorders" (MUS), "circulatory system disorders" (CIR), "sensory system disorders" (SEN); "metabolic System disorders" (MET), "nervous system disorders" (NER) and "pregnancy/ birth disorders" (PRE).

3. Data Analysis

3.1. Demographic data

Descriptive statistics were used to summarize the raw data collected from the questionnaires.

3.2. Distribution of medicinal plants

The difference in species used in the study provinces and the difference in information given by the two types of informants (herbalists and cooperative directors) were analysed and investigated with a principal coordinate analysis (PCoA; function dudi.pco, package ade4 (Dray& Dufour, 2007) based on Sorensen indices (vegan R package, (Oksanen et al., 2015). Finally, permutation tests were performed using the adonis function (vegan package v 2.6-4).

3.3. Comparison of the collected species

3.3.1. Diversity of medicinal plants

The species diversity of each province was evaluated by calculating different indices:

- Family Use Value (FUV) is the sum of the informant use values for a species and divide by the total number of informants; $\mathbf{FUV= \Sigma\ UV_s/(n_s)}$ with n_s = total number of species within a given botanical family (Hoffman & Gallaher, 2007).

- The use-value index (UV) is a quantitative measure of the relative importance of a given species and is calculated as follows: $\mathbf{UVs=U_{is}/n_{is}}$ with U_{is} is the number of uses of the species n_{is} is the total number of informants (Hoffman & Gallaher, 2007).

- Relative frequency of citation (RFC) was simply calculated by dividing the number of informants who mentioned the use of a species by the total number of informants in the survey. The RFC was used to compare the results of informants from the three study areas (Tardío & Pardo-de-Santayana, 2008).

- The Informant Agreement Ratio (IAR) is an index to test the homogeneity of knowledge about the use of species for the treatment of different use categories and is calculated as follows: **IAR= Nur - Nt/(Nur - 1)** where Nur is the number of citations in each category and Nt is the number of used species. IAR ranges between 0 and 1. IAR values close to 0 indicate that uses are totally different, whereas values close to 1 indicate a high degree of consensus of informants regarding uses of species (Hoffman & Gallaher, 2007).

3.3.2. Used plant parts, preparation methods, and therapeutic indications

The plant parts used, their preparation methods and the diseases in each province were analysed by R software (R Core Team, 2021). The common plants in the three provinces were grouped together and their therapeutic uses, preparation methods, and plant parts used in each province were compared.

Results and discussion

1. Demographic characteristics of the informants

A total of 163 individuals were interviewed, including 85 herbalists and 78 cooperative directors. Respondents were mainly males (127 males versus 36 females). Men are usually involved in collecting plants in the field, since some collection areas are usually unsecured, especially in the illegal cannabis cultivation areas in Taounate

(Table 2) (ONUDC & APDN, 2005). In the traditional culture of Morrocco, plant gathering and marketing activities are largely male-dominant tasks, whereas women have more knowledge about plant uses and preparation. However, while herbalists were mostly men (only 2 women out of 85), cooperative directors were more commonly women (34 out of 54). Studies in other Arab countries have also shown that herbal medicine is a male-dominated profession (Boudjelal et al., 2013; Baydoun et al., 2015; Alalwan et al., 2019), while cooperatives are dominated by women (Fadil et al., 2015). In Taounate, herbalists are not so common (Table 2) because of the rural population that has an easy and free access to plant resources. 68% of the informants were over 40 years old, benefiting from a good knowledge of medicinal plants due to accumulated experience and the transmission of this oral family heritage, against low youth involvement (nearly 6% of young people under 30 years were herbalists or cooperative directors). This is consistent with other research showing that ethnobotanical knowledge increases with age (Boudjelal et al., 2013; Mugisha et al., 2014). Furthermore, gender, type of informant and academic level were also correlated. Most herbalists were illiterate or had an average level of education, contrary to the cooperative directors.

2. Distribution of medicinal plants according to the traditional medicinal knowledge of each province

Based on Sorensen indicators, MAPs showed a clear distinction between Taounate and the two other provinces (Figure 2). This reflects both the floristic and biogeographical diversity between the three provinces, and the customs associated with the utilization of MAPs. In addition to variation among provinces, there was also a remarkable difference in knowledge between herbalists and cooperative directors (Figure 2). However, the most remarkable information based on the Sorensen indicators is that the informant by location interaction was significant according to the Permutation test ($p<0.001$). Indeed, herbalists from Meknes and Fez clearly used different species in comparison with cooperative directors within the same region. Furthermore, there was also a marked difference between informants from Taounate

and those from Meknes and Fez (see Figure 2). Herbalists sell both fresh and dried plants, thus offering a diversified panel of plant species and uses. In contrast, cooperatives are mainly interested in plants to produce essential oils, creams, cosmetic products, and other plant extracts. The cooperatives attempt to collect and exploit the traditional knowledge of local women to commercially develop the medicinal plants of the region and improve their living standards (Fadil et al., 2015).

Both herbalists and cooperatives retain substantial local knowledge about the therapeutic use of medicinal plants. But the herbalists seem to be the real repositories of this knowledge. They use a considerable number of medicinal species. In our study, among the 151 plants collected, 144 species were cited and used by herbalists and 123 species cited by cooperatives, the majority of which were rarely or not exploited. In a study performed in Brunei, Kamsani et al. (2020) also showed that healers reported a higher number of medicinal taxa than the non-healers (50 taxa for healers against 11 for non-healers) because of their ancient traditional knowledge and important role in local healthcare. It would be very beneficial to the development of the aromatic and medicinal plant sector in Morocco if herbalists and cooperatives share their medicinal knowledge.

3. Comparison of species collected in each province

3.1. The Diversity of medicinal plants in the three provinces.

A total of 151 plant species (97 in Meknes, 92 in Fez, and 106 in Taounate, Table 3) with 6004 citations (38,18% in Meknes, 31,96% in Fez, and 38,89% in Taounate) were collected. They represented 131 different genera and 64 families. The used species varied from one province to the other, which could be explained by the vegetation diversity. The high diversity in Taounate is explained by the phytogeography (forests and mountains) and the bioclimatic variety of the province. MAP diversity is also influenced by the environment degradation that is caused by intensive human intervention, especially in Fez and Meknes. Indeed, the massive and irrational utilisation of useful species, the growing anthropic pressure, and the absence of monitoring and management have led to the rarefaction, and sometimes extinction,

of medicinal plants and the loss of knowledge and know-how (Tetenyi et al., 2017). The Lamiaceae is the most cited family (14 species and 22.23% of total citations), including the most well-known plants in the study area (e.g. *Origanum compactum*, *Rosmarinus officinalis*, and *Mentha pulegium*). Other families had many citations and few species (such as Apiaceae and Fabaceae) or many species and few citations (such as Asteraceae). The predominance of Lamiaceae and Asteraceae was already reported for the Moroccan medicinal flora of the Rif (Chaachouay et al., 2020), Fez-Boulemane (Jouad et al., 2001) , and Meknes-Tafilalet (Fadil et al., 2015) regions.

3.2. Used plant parts, preparation methods and therapeutic indications

- **Used plant parts**

In the three provinces, leaf is the most used plant part (63.01%), followed by flower (32.88%), diaspore (23.97%), stem (21.58%), root (18.49%) and other parts. This order varies from one province to another (p value = 0.002) (Figure 3). The predominance of the use of leaves can be explained by their easy harvesting (Bitsindou, 1986). In addition, they store secondary metabolites potentially interesting for medicinal effects (Nasution et al., 2018). The predominance of the use of leaves, flowers and diaspores ensure the conservation and sustainability of phytotherapeutic resource, contrary to other collections such as root, since a moderate harvest does not damage the plant (Pandey et al., 2007).

- **Preparation methods**

The methods of preparation are diverse: infusion, decoction, cataplasm, boiling, maceration etc. Infusion is the most common method of use, followed by decoction in all three study provinces (Figure 4). Herbal tea is the most popular as it is an easily prepared and allows the release of the active ingredients that require heat (Barkaoui et al., 2017). It is also the oldest and best-known method of preventive and curative preparations, because the local population, especially in rural areas, believes that heat eliminates the plant toxicity (Chaachouay et al., 2020).

Many active molecules are liposoluble or require dilution in alcohol, and the procedure of extract-alcohol separation is difficult. Therefore, no classical preparation uses alcohol, which implies that these molecules are not extracted and not used.

- **Therapeutic indications**

Most medicinal species are used to treat diseases of the digestive system, followed by skin diseases and respiratory diseases (Figure 5). Gastro-intestinal pathologies are generally the most reported symptoms within the population (OuldEl Hadj et al., 2003). On the other hand, the predominance of digestive, skin, and respiratory disorders treated by local populations is also observed in several Mediterranean countries such as Albania, Algeria, Cyprus, Egypt, Italy and Spain (González-Tejero et al., 2008). Infusion and decoction are the most used preparation methods for the majority of MAP diseases, except for skin diseases where cataplasm is the most commonly used method.

3.3. Comparison of the different indices

- **Use Value Index (UV) and Relative Frequency of Citation (RFC)**

Species from the Meknes province had an RFC between 92% and 5% and a use-value between 5.78 and 0.05 (*Olea europaea* first). Olive tree is the species with the most possible uses (up to 7 in Meknes). Regarding Fez province, an RFC between 86% and 2%, and a UV between 2.53 and 0.03 were registered (*Corrigiola telephiifolia* first). However, in Taounate, the RFC range was between 95% and 2% and the UV between 3.81 and 0.02 (*Origanum compactum* first). Due to the relatively large number of species identified, the present study focused on the top 10 species from each province (Table 4). This study found some common species to the three provinces with high RFC and UV values, such as *Origanum compactum*, *Myrtus communis*, *Rosmarinus officinalis* and *Mentha pulegium*. Others were more common in one province than in the others, such as *Corrigiola telephiifolia*, *Juniperus phoenicea*, *Laurus nobilis* and *Tetraclinis articulata*. These differences are due to the abundance of species in each province and the requirements of the population in each province. The high RFC and

UV values indicate the importance of the plant species, which should be investigated in advanced phytochemical and pharmacological studies (Shaheen et al., 2017).

- **Informant Agreement Ratio (IAR)**

In Fez and Meknes, the maximal value for this index was obtained for respiratory system disorders (0.95 and 0.93 respectively, Table 5) while in Taounate, the categories of neurological, skin, and urogenital diseases showed the highest IAR values (0.93, Table 5). The minimal values were obtained for different pathologies in each province, but they remained greater than 0.80 (Table 5). These results showed the presence of a strong agreement between informants on the therapeutic uses of the reported medicinal plant species, which can be explained by the fact that our survey targeted only two types of informants who are experts in this field.

4. S

2.4. pecies difference in traditional medicinal uses

Among the 151 species identified, 50 species were mentioned in the three provinces, 13 of them had similar uses: *Ajuga iva*, *Ammi majus*, *Apium nodiflorum*, *Artemisia herba-alba*, *Calendula stellata*, *Eucalyptus globulus*, *Herniaria hirsuta*, *Lavandula multifida*, *Origanum majorana*, *Rhamnus alaternus*, *Rumex acetosa*, *Solanum nigrum*, and *Tanacetum annuum*, while 37 have been used differentially from one province to another (Table 6). Some plant species were used only for specific categories of pathology with the same utilisation among the three provinces: *Apuim nodiflorum* for digestive pathologies, *Calendula stellata* for skin problems, *Eucalyptus globulus* for respiratory problems. *Arbutus unedo* is also specific but its utilisation varied among provinces. In order to explain this difference in use between provinces, the preparation methods and plant parts used of these species were compared. It was found that 9 species have a different preparation method (*Anacyclus pyrethrum*, *Centaurium erythraea*, *Ceratonia siliqua*, *Chamaemelum nobile*, *Nerium oleander*, *Olea europaea*, *Polygonum aviculare*, *Ricinus communis* and *Ziziphus lotus*), 6 species differ in the part used (*Marrubium vulgare*, *Mentha suaveolens*, *Opuntia*

ficus-barbarica, *Origanum compactum*, *Papaver rhoeas* and *Ruta chalepensis*), and 4 species were different both in used part and preparation method (*Capparis spinosa*, *Ferula communis*, *Myrtus communis* and *Pistacia lentiscus*). A medicinal plant may contain several active components that have separate therapeutic effects or act in synergy. Thus, depending on the preparation method, there may be several indications for the same plant because different active constituents will be extracted. Also, each part of the plant can have a different active principle, and consequently a different therapeutic property. Concerning the difference in the use of the remaining 17 plants, it can be explained by traditional medicine practices, which differ from one province to another as they are influenced by culture, history, attitudes, personal philosophy, acquired experience and the efficiency of established practices (Borokini et al., 2014).

Conclusion and recommendations

The present study revealed a diverse medicinal flora as well as a wealth of ethnomedicinal knowledge and know-how, with notable variations in the traditional knowledge between herbalists and cooperative directors and between provinces. However, it also reflected similarities of the used plants and parts, the preparation modes, and the medicinal uses. The use of aromatic and medicinal plants is ancient in Moroccan culture, particularly in rural provinces, and herbalists and cooperatives work to preserve it, despite the young people's scepticism and the scarcity or extinction of some therapeutic species. Otherwise, herbalists and particularly cooperatives continue to require technical and economic assistance to expand this sector and to enhance, in addition to common plants, the plants that are native to each province.

The uncontrolled collection and commerce of these species threaten them. Sustainable management and conservation of endangered medicinal plant species is therefore important. Efforts must be done to enhance understanding of the positive and negative

effects of these plants based on pharmaceutical research and their conservation techniques, in a spirit of collaboration and unity for the sustainable development of this spontaneous flora.

Ethics approval

All participants provided oral prior informed consent.

Consent to publish

The paper does not show any personal data or photographs.

Authors' contribution

The authors confirm contribution to the paper as follows: S. El Amane: Conceptualization, Methodology, Formal analyses, Investigations and Writing-Original draft preparation. E. Imbert: Formal analyses, Writing - review & editing and Supervision. A. Rahou: Supervision and Validation.

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Appendix (Interview sheet)

Sheet number :

Date :

Village/Street surveyed :

- ▲ Informant profile

Informant :

- o Herbalist
- o Cooperative

Gender :

- o Male
- o Female

Age :

- o 20-30
- o 30-40
- o 40-50
- o 50-60
- o 60-70
- o Over 70

Academic level :

- o No academic level
- o Primary
- o Secondary
- o University
- o Other

Marital status :

- o Single
- o Married

- o Divorced
- o Widowed

Experience :

- o <5 years
- o 5-10 years
- o 10-20 years
- o More than 20 years

- Species information:

Common name:

Scientific name:

Use of the plant:

- o Therapeutic
- o Cosmetic

Status of the plant:

- o Common plant
- o Difficult to find

- Use in traditional medicine

Used Part:

- o Stem
- o Flower
- o Fruit
- o Seed
- o Bark
- o Rhizome
- o Bulb
- o Leaf
- o Whole plant

- o Other .....

Form of use:

- o Herbal tea
- o Powder
- o Essential oil
- o Extract

Method of preparation:

- o Infusion
- o Decoction
- o Cataplasm
- o Raw
- o Cooked
- o Boiling
- o Lotion
- o Powder
- o Suppository
- o Other .....

Therapeutic indications .....

Figures and Table

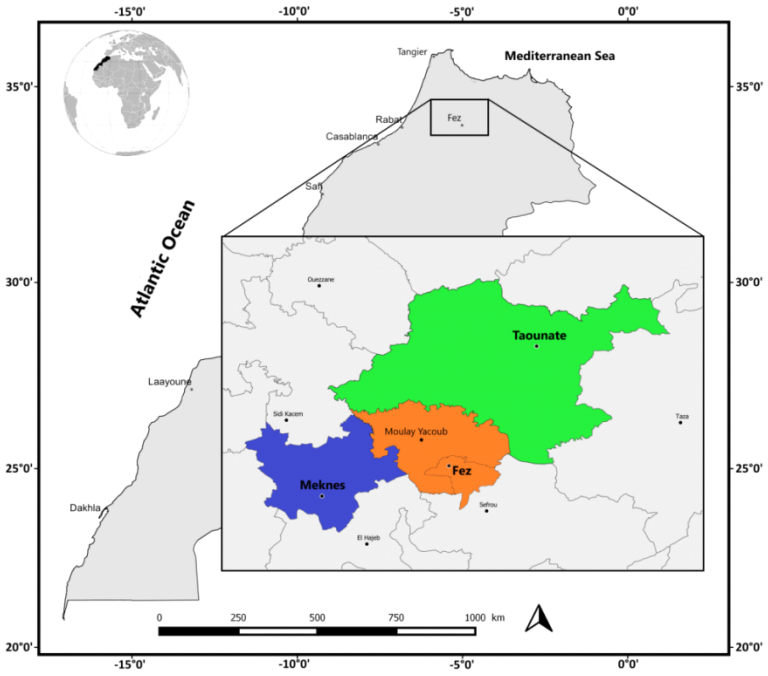

Figure 1 : Location of the provinces (Meknes, Fez and Taounate) in central Morocco where ethnobotanical data on medicinal plants were collected.

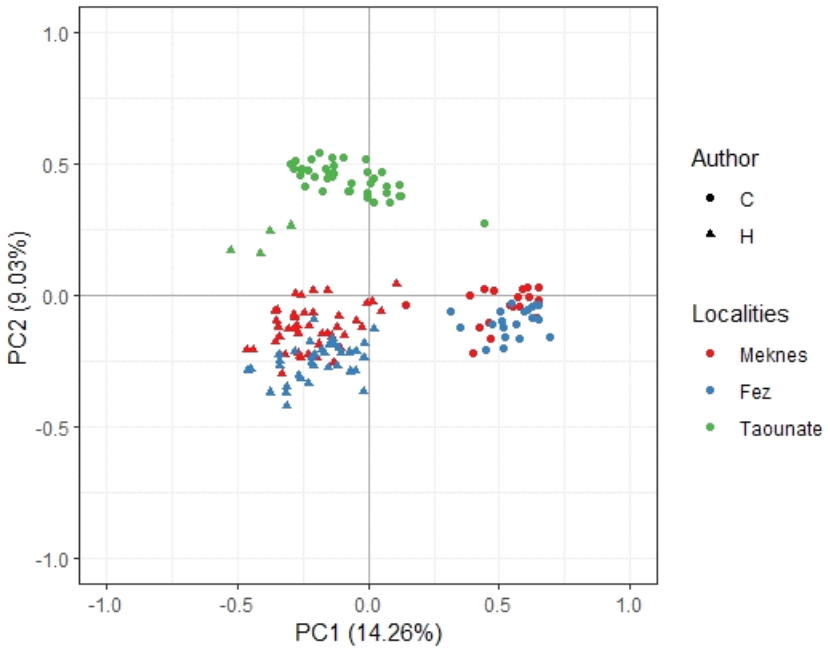

Figure 2 : Projection of the participants to the survey on the basis of the Sorensen index (the closest the participants are, the most plant species they shared) on the first two components. Symbols represent the 2 types of authors (cooperative director and herbalist), while colour represents the province of origin.

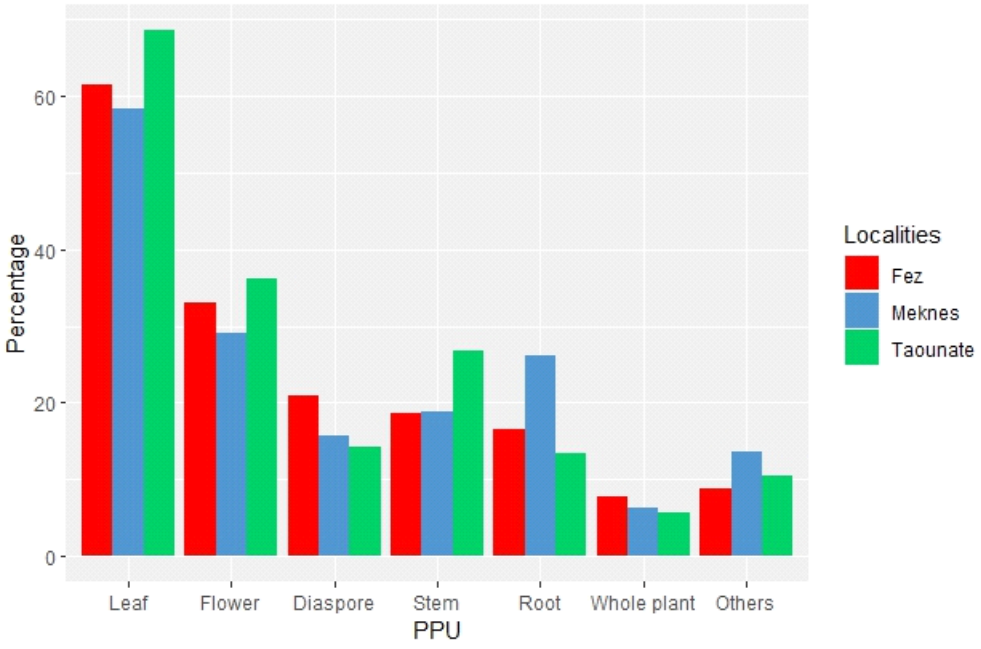

Figure 3 : Percentage of each plant part used (PPU) in the 3 study areas. The last class (others) correspond to belowground structures such as bulbs, rhizoms… and aboveground structures such as wood, bark, resin...

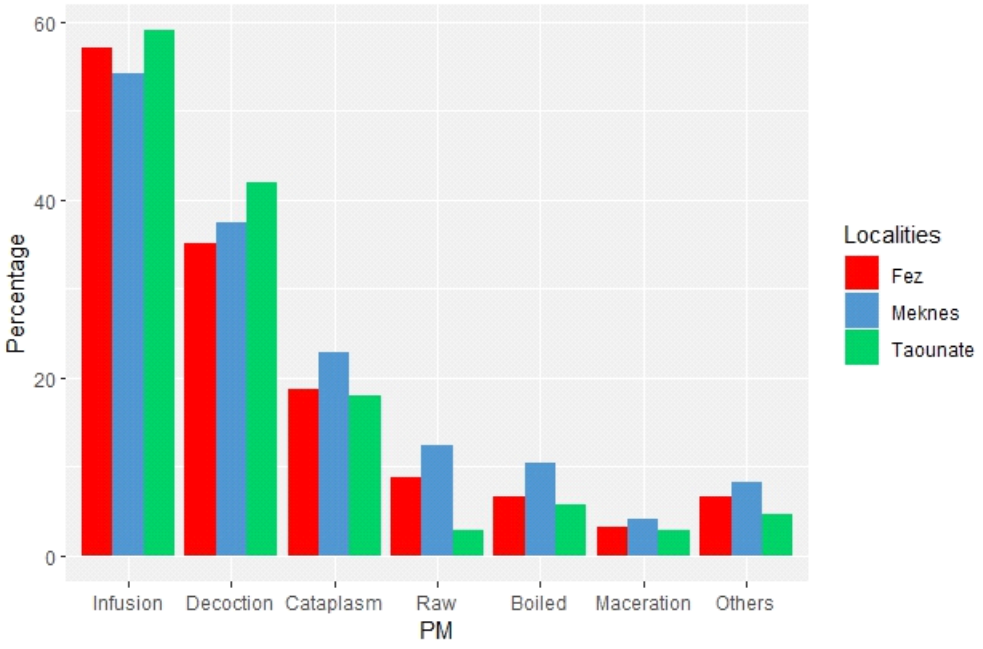

Figure 4 : Percentage of each method of preparation (PM) of medicinal plants used in the 3 study areas. The "Others" class correspond to digestion, poultice, powdered and extracted juice.

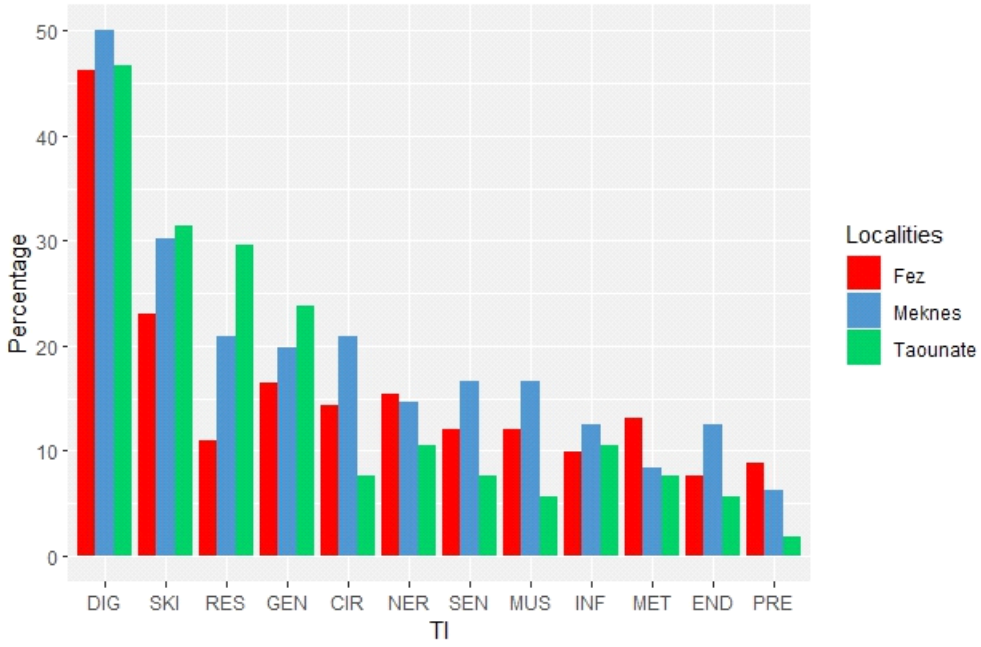

Figure 5 : Distribution of each therapeutic indication (TI) in the 3 study areas. (DIG: digestive system disorders, SKI: skin/subcutaneous cellular tissue disorders, RES: respiratory system disorders, GEN: genitourinary system disorders, CIR: circulatory system disorders, NER: nervous system disorders, SEN: sensory system disorders, MUS: musculoskeletal system disorders, INF: infections, MET: metabolic system disorders, END: endocrine system disorders and PRE: pregnancy/ birth disorders).

Table 1 : Area, geographical, climatic and population information of the study area (values for 2019, www.climate-data.org)(HCP & RGPH, 2017).

Province	Area(km^2)	Mean altitude (m)	Annual Precipitation (mm)	Number of rainfall days	Range temperature (°C)	Urban population	Rural population	Illiteracy rate (%)	Unemployment rate (%)
Meknes	1786	546	509	53	9.3 to 26.3	687 575	14 812	21.5 - 44.5	20.8 - 7.9
Fez	2032	414	549	60	9.2 to 27.7	1 154 843	169 367	26.1- 40.3	19.7 - 13.1
Taounate	5585	566	701	56	9.8 to 28.4	86 222	576 024	28.9 - 50.7	18.6 - 10.2

Table 2 : Socio-demographic characteristics of the informants and general population in the three study areas.

Variable		Meknes(%) N=63	Fez(%) N=58	Taounate(%) N=42	Total(%) N=163
Authors	Herbalist	69.84	62.50	9.52	52.15
	Cooperative director	30.16	37.50	90.48	47.85
Gender	Female	25.39	10.34	33.33	22.08
	Male	74.60	89.65	66.66	77.91
Marital status	Single	15.87	17.24	14.28	15.95
	Married	79.36	82.76	85.71	82.21
	Divorced	4.76	0	0	1.84
Academic level	Illiterate	19.05	15.52	11.90	15.95
	Primary school	23.81	18.97	14.28	19.63
	Secondary school	22.22	18.97	4.76	16.56
	High school	26.98	24.14	35.71	28.22
	University	7.94	22.41	33.33	19.63
Age (year)	20-30	4.76	6.89	7.14	6.13
	30-40	23.81	27.59	26.19	25.77
	40-50	23.81	32.76	23.81	26.99
	50-60	26.98	18.96	28.57	24.54
	60-70	12.70	86.21	11.90	11.04
	>70	7.94	5.17	2.38	5.52
Experience (year)	<5	15.87	6.89	14.28	12.27
	5-10	14.28	22.41	21.43	19.02
	10-20	20.63	31.03	35.71	28.22
	20-30	26.98	22.41	26.19	25.15
	>30	22.22	17.24	2.38	15.34

Table 3 : The most species-rich plant families recorded in Meknes, Fez and Taounate, their percentage of citation and their FUV.

Families		Meknes			Fez			Taounate		
	Total species	No of species	Citations (in %)	FUV	No. of species	Citations (in %)	FUV	No. of species	Citations (in %)	FUV
Lamiaceae	14	13	22.23	1.31	13	25.06	1.20	12	19.15	1.79
Asteraceae	16	13	9.94	0.73	12	11.24	0.74	11	8.01	0.69
Apiaceae	13	8	6.46	0.49	9	4.91	0.29	8	5.62	0.62
Fabaceae	10	5	3.48	0.56	6	5.17	0.53	5	3.57	0.58
Brassicaceae	6	0	0	0	1	1.21	0.79	5	1.95	0.28
Solanaceae	5	2	0.88	0.43	3	2.40	0.70	3	0.83	0.30
Euphorbiaceae	4	3	2.79	0.71	2	2.03	0.34	3	3.71	1.11
Boraginaceae	3	0	0	0	2	0.21	0.04	2	1.42	0.50
Cistaceae	3	0	0	0	1	0.68	0.22	2	1.47	0.49
Oleaceae	3	2	3.33	3.14	2	2.45	1.25	2	2.78	2.29
Ranunculaceae	3	3	1.32	0.22	0	0	0	0	0	0
Rhamnaceae	3	2	3.13	1.18	3	3.39	0.64	3	2.93	1.17
Rosaceae	3	3	3.13	0.98	2	3.24	1.19	3	3.61	1.53
Myrtaceae	2	2	4.95	2.21	2	4.23	1.49	2	3.12	1.19
Cupressaceae	2	1	1.76	1.14	1	1.83	0.60	2	2.93	2.86
Others	61	40	38.18	_	33	31.96	_	43	38.89	_
Total	151	97	_	_	92	_	_	106	_	_

Table 4 : Relative frequency of citation (RFC) values and use value index (UV) for the most mentioned species in Meknes, Fez and Taounate.

	Meknes		Fez		Taomnate	
Medicinal plants	**RFC$_{(\%)}$**	**UV**	**RFC$_{(\%)}$**	**UV**	**RFC$_{(\%)}$**	**UV**
Chamaemelum nobile(L.) All.	84	2.52	74%	1.48	67%	2
Clinopodium nepeta (L.) Kuntze	41	1.24	60%	1.81	83%	1.67
Corrigiola telephiifolia Pourr.	30	0.6	84%	0.53	31%	0.62
Crataegus monogyna Jacq.	37	1.46	24%	0.72	79%	2.36
Juniperus phoenicea L.	_	_	_	_	67	2.67
*Laurus nobilis*L.	52	2.1	52	2.07	_	_
Lavandula dentata L.	56	0.56	78	2.33	45	1.36
*Mentha pulegium*L.	87	2.62	84	1.69	93	2.79
Myrtus communis L.	92	3.68	79	2.38	86	1.71
Olea europaea L.	83	5.78	29	1.47	93	3.71
Origanum compactum Benth.	89	2.67	86	1.72	95	3.81
*Papaver rhoeas*L.	46	1.84	43	1.29	71	2.14
Pistacia lentiscus L.	46	0.92	40	0.79	86	2.57
*Rosa canina*L.	46	0.92	83	1.66	69	1.38
*Rosmarinus officinalis*L.	86	3.43	83	2.48	86	1.71
*Ruta chalepensis*L.	49	1.48	55	1.66	55	2.19
*Ruta chalepensis*L.	49	1.48	55	1.66	55	2.19
Tetraclinis articulata (Vahl) Mast.	57	1.14	_	_	76	3.05
Thymus bleicherianus Pomel	60	1.81	66	0.66	88	1.76
*Urtica urens*L.	54	2.16	48	0.97	88	2.64
Ziziphus lotus L. Lam.	68	1.37	69	0.69	81	2.43

Table 5 : Informant agreement ratio (IAR) values for 12 different use categories of illnesses treated according to 63 informants in Meknes, 58 in Fez and 42 in Taounate. For each province, minimal and maximal values are underscored.

Use categories (Pathologies)	IAR		
	Meknes	**Fez**	**Taounate**
Circulatory system disorders	0.91	0.89	0.92
Digestive system disorders	0.88	0.91	0.90
Endocrine system disorders	0.85	0.86	0.87
Genitourinary system disorders	0.88	0.90	0.93
Infections	0.89	0.92	0.91
Metabolic System disorders	0.87	0.88	0.86
Musculoskeletal system disorders	0.81	0.89	0.89
Nervous system disorders	0.86	0.91	0.90
Pregnancy/ birth disorders	0.85	0.83	0.93
Respiratory system disorders	0.93	0.95	0.91
Skin/subcutaneous cellular tissue disorders	0.87	0.92	0.93
Sensory system disorders	0.88	0.93	0.87

Table 6 : Differences in the use of common species between Meknes, Fez and Taounate.

Scientific name	Meknes	Fez	Taounate
***Anacyclus pyrethrum* (L.) Lag.**	NER, DIG, INF, MET, SEN	NER, DIG	SEN, DIG
***Arbutus unedo* L.**	DIG	CIR	GEN
***Aristolochia baetica* L.**	DIG, MET, PRE	DIG, INF	DIG, PRE, MET
***Capparis spinosa* L.**	MUS, GEN	GEN, DIG, SKI	GEN
***Centaurium erythraea* Rafn.**	DIG	MET, NER	DIG
***Ceratonia siliqua*L.**	DIG, CIR	DIG	GEN, DIG
***Chamaemelum nobile*(L.) All.**	SKI, SEN, DIG	SKI, DIG	SKI, DIG, GEN
***Clinopodium nepeta* (L.) Kuntze**	GEN, CIR, INF	DIG, NER, GEN	DIG, SKI
***Corrigiola telephiifolia* Pourr.**	DIG, MET	NER, MUS, SKI	DIG, MUS
***Crataegus monogyna* Jacq.**	DIG, PRE, CIR, NER	DIG, GEN, NER	DIG, NER, GEN
***Daphne gnidium*L.**	DIG	DIG, CIR	DIG, SKI
***Dittrichia viscosa* (L.) Greuter**	MUS, DIG , RES, SKI, END	MUS, DIG, SKI, SEN	RES, DIG
***Ferula communis* L.**	MUS, PRE, DIG	PRE, DIG	SKI
***Fraxinus angustifolia* Vahl.**	CIR, MUS	NER, GEN	CIR, GEN
***Lavandula dentata*L.**	RES	CIR, INF, GEN	NER, MUS, SKI
***Lavandula stoechas*L.**	SKI, RES	RES	SKI, RES
***Marrubium vulgare*L.**	RES	RES	SKI, RES
***Melilotus officinalis* (L.) Pall.**	CIR, MUS	CIR	NER
***Mentha pulegium*L.**	RES, MET, INF	NER, DIG	RES, NER, DIG
***Mentha suaveolens* Ehrh.**	DIG	DIG	DIG, PRE
***Myrtus communis* L.**	CIR, RES, NER, DIG	CIR, RES, NER	RES, NER

***Nerium oleander* L.**	RES, SKI	RES, INF, SKI	RES, SKI
***Olea europaea* L.**	CIR, DIG, END, RES, NER, SEN, INF	CIR, DIG, END, RES, MUS	DIG, END, RES, SEN
***Opuntia ficus-barbarica* A. Berger**	DIG, SKI, GEN	DIG, SKI	MUS, GEN
***Origanum compactum* Benth.**	DIG, CIR, RES	DIG, RES	DIG, RES, INF, NER
***Papaver rhoeas*L.**	RES, NER, INF, SEN	RES, INF, PRE	RES, NER, INF
***Pistacia lentiscus* L.**	DIG, SKI	DIG, SEN	DIG, RES, SKI
***Polygonum aviculare* L.**	SKI, DIG, MUS	DIG, MUS	DIG, RES, SKI
***Ricinus communis*L.**	INF, SKI	SKI	INF, SKI
***Rosmarinus officinalis*L.**	RES, CIR, NER, DIG	INF, RES, SEN	DIG, CIR
***Ruta chalepensis*L.**	CIR, INF, NER	CIR, SEN, INF	INF, MET, NER, SKI
***Silybum marianum* L.**	GEN	DIG, MET, END	GEN
***Tetraclinis articulata* (Vahl) Mast.**	END, RES	MUS	DIG, RES, END, CIR
***Thymus bleicherianus* Pomel**	DIG, CIR, NER	DIG	DIG, RES
***Urtica urens*L.**	CIR, END, SEN, SKI	MET, SEN	CIR, SKI, DIG
***Verbena officinalis*L.**	INF, NER	NER, SEN	INF
***Ziziphus lotus*L. Lam.**	GEN, SEN	SEN	DIG, RES, SKI