# Ethnobotanical study of medicinal plants used to treat microbial infections in the Fez-Meknes region, Morocco

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## Research

## Abstract

*Background*: The Moroccan community is well-known for using medicinal and aromatic plants (MAPs) to treat a variety of illnesses. The purpose of this work is to investigate the use of MAPs in the Fez-Meknes region, located in central-northern Morocco.

*Methods*: An ethnobotanical survey (January-March 2023) interviewed 300 respondents to document the use of MAPs in the treatment of diseases of microbial origin. Data were analyzed using citation indices such as Relative Frequency of Citation (RFC), Family Importance Value (FIV), Plant Part Value (PPV), and Fidelity Level (FL) and Factorial Correspondence Analysis (FCA) performed by PAST software to link socio-demographic factors (age, gender, education, and socio-economic level) with plant use.

*Results*: Among the people interviewed, 90.66% use MAPs. For the treatment of infectious diseases, 68 plant species belonging to 32 families (*Lamiaceae, Myrtaceae, Apiaceae*, etc.) have been recommended, including *Rosmarinus officinalis, Thymus atlanticus, Chamaemelum nobile*, etc. These plants are frequently prepared by decoction. The categories of people most likely to use MAPs are women, the elderly, people with low or average incomes, and those who are illiterate or have only primary schooling.

*Conclusions*: The current study emphasized the widespread usage of MAPs as traditional treatments among the people surveyed in the Fez-Meknes area. As a result, this effort will provide researchers access to a valuable ethnobotanical database that they may use to further pharmaceutical knowledge. In addition, the species identified could constitute a promising resource of new natural antimicrobial agents, offering interesting opportunities in the fight against antibiotic resistance.

*Keywords*: Ethnobotanical study, Medicinal and aromatic plants, Traditional medicine, Phytotherapy, Infectious diseases, Fez-Meknes

## Background

Microbial infectious diseases remain a significant global health burden because antimicrobial agents are steadily losing efficacy against resistant bacteria, fungi and parasites (Papaneophytou *et al.* 2019, Salam *et al.* 2023). Yet the scale and consequences of resistance are strongly context-dependent, and Morocco faces a particularly acute situation due to limited antibiotic stewardship and restricted access to second-line drugs.

In Morocco, recent surveillance (2018 - 2024) has revealed multidrug-resistant (MDR) isolates of *Escherichia coli*, *Klebsiella pneumoniae* and *Staphylococcus aureus* in the tertiary hospitals of the Fez-Meknes region (Al-Selwi and Barkat 2023, Nejjari *et al.* 20). Because many rural households cannot afford or obtain these antibiotics, they continue to rely on traditional medicinal plants as first-line therapy (Ajjoun *et al.* 2021).

Traditional medicinal plants therefore constitute an indispensable, culturally embedded pharmacopeia throughout Morocco. Ethnobotanical inventories list more than 250 medicinal-and-aromatic-plant (MAP) taxa in Fez-Meknes alone, sold in local souks and prescribed by herbalists for infectious ailments (Ait Bouzid *et al.* 2024). Among the most frequently cited species are *Ammi visnaga*, *Inula viscosa*, *Origanum elongatum* and *Thymus zygis*; their dominant flavonoids, polyphenols and terpenoids inhibit Moroccan MDR strains at minimum inhibitory concentrations ≤ 128 µg / mL (Benyahya *et al.* 2023, Khalil *et al.* 2020, Lamine *et al.* 2022).

Despite their widespread use, only a small subset of these plants has been rigorously assessed for efficacy and safety, and the associated empirical knowledge is rapidly eroding under urbanisation and biomedicalization (Dar *et al.* 2023, Katara *et al.* 2023).

Aim of the study. The present ethnobotanical survey documents anti-infective MAPs currently employed in Fez-Meknes, examines how their use varies with age, gender, education and residence, and prioritises the most-cited taxa for subsequent phytochemical and antimicrobial assays. By bridging regional heritage with contemporary science, we seek to generate evidence-based leads for novel therapeutics while preserving intangible cultural knowledge.

## Materials and Methods

#### Study area

The Fez-Meknes region is located in the center of northern Morocco (Fig. 1), extending over the mountain ranges of the Rif and Moyen Atlas and partially encompassing the Sais plain. Its 40.075 km² of surface area makes up 5.7% of the country's total area (Moroccan Ministry of the Interior, 2016). This region includes the provinces of Boulemane, El Hajeb, Ifrane, Moulay Yaacoub, Sefrou, Taounate, and Taza, as well as the prefectures of Fez and Meknes.

With 4,236,892 inhabitants, which represents 13% of the country's total population (Kingdom of Morocco 2016), the Fez-Meknes region has three different types of climates: a continental climate that is hot and dry in the summer, cold and humid in the winter, and snowy in the mountainous areas, and a semi-arid climate in the high Boulemane mountains (Moroccan Ministry of the Interior Wilaya of the Region Fez-Meknes, 2016). According to the primary agricultural sector, Fez-Meknes is one of the most productive regions in the country. The entire area of useful agricultural land is 1,340,826 hectares, or 15% of the country's total useful agricultural land. With an estimated total area of 1,246 255 hectares, the region's forest cover accounts for 14% of the country's total area (Tlemcani *et al.* 2023).

#### Data collection

The present ethnobotanical investigation was carried out in the Fez-Meknes region, following a standardized methodology as described by Martin (2004). Data were collected over a three-month period, from January to March 2023, through structured, face-to-face interviews using a pre-designed questionnaire comprising both demographic and ethnobotanical sections. A total of 300 participants were randomly selected, ensuring representativeness by including both urban (38%) and rural (62%) populations, as well as marginalized groups such as residents of remote villages and traditional healers.

Before the main survey, the questionnaire was pilot-tested on a sample of 20 individuals to assess its clarity, cultural sensitivity, and linguistic appropriateness. Revisions were made accordingly to ensure that all items were comprehensible in both Arabic and local dialects. Prior informed consent was obtained from all participants after clearly explaining the purpose of the study.

Each interview lasted a minimum of 30 minutes and was structured in two parts. The first section collected socio-demographic information, including gender, age, marital status, educational background, and socio-economic level (low/medium/high). The second section focused on the medicinal plants used, covering details such as vernacular names, parts used, methods of preparation, routes of administration, and therapeutic indications. Since participants lacked formal medical training, they were asked to report plants traditionally used to treat symptoms commonly associated with infectious diseases, such as diarrhea, fever, urinary pain, vomiting, and coughing, etc.

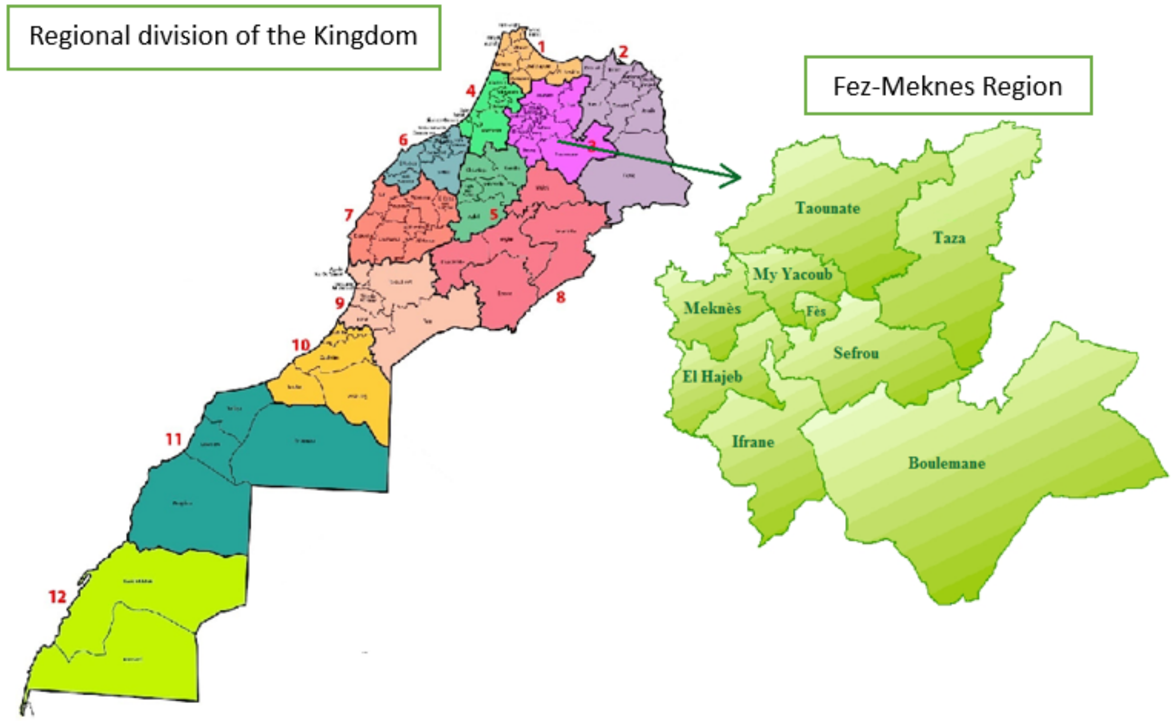


Figure 1. Map of the Fez-Meknes region, Morocco.

**Plant species identification**

The identification of the plant species selected through the questionnaire was performed by expert botanists from Sidi Mohamed Ben Abdellah University in Fez, Morocco. For each plant, a voucher specimen was prepared and deposited, with corresponding identification numbers assigned to ensure traceability and reproducibility of the botanical authentication (Table 3).

**Data analysis**

After the collection of data using field survey forms, the information was manually entered into a database, processed, and statistically examined using Microsoft Office "Excel 2019". Informants' sociodemographic information was evaluated using basic descriptive statistics (percentages and frequencies). Ethnobotanical data were interpreted using the quantitative citation indices of RFC, FIV, PPV, and FL. Further, PAST software was used to perform Factorial Correspondence Analysis (FCA) in order to reveal the structure of interactions between humans and plants that differed by age, marital status, gender, and educational level.

***Relative frequency of citation (RFC)***

This index shows the relative importance of each species in the region under study. It is calculated by dividing the number of informants who report the species' use (the frequency of citation, or FC) by the total number of respondents using MAPs (N). It is determined using Tardio and Pardode-Santayana's formula (Tardío & Pardo-De-Santayana, 2008):

$$RFC = FC / N$$

With $(0 < RFC < 1)$

***Family Importance Value (FIV)***
The level of significance of plant families is indicated by the Family Importance Value (FIV). It is computed as follows and attempts to evaluate the biological taxonomic value of the plants (Sreekeesoon & Mahomoodally, 2014).

$$FIV = FC_{family} / Ns$$

$FC_{family}$ = RFC: Number of informants revealing the family
Ns: Total number of species within each family.

***Fidelity level (FL)***
The fidelity level (FL) demonstrates the efficiency of a plant species against a given disease. It is determined as a percentage based on the number of respondents declaring the usage of a particular plant species to treat a particular disease in the research region (Sreekeesoon & Mahomoodally, 2014):

$$FL = Ip / Lu \times 100$$

Ip= The number of informants reporting of the species used in a specific disease treatment.
Lu= the Number of informants who cited the same species as useful.

***Plant part value (PPV)***
The plant part value (PPV) is calculated to determine how frequently a particular plant part is used (Gomez-Beloz, 2002).

$$PPV = RU\ plant\ part / RU$$

RU plant part: the sum of uses reported per a given plants part.
RU: the number of uses reported for all plant parts.

***Factorial Correspondence Analysis (FCA)***
Factorial Correspondence Analysis makes it possible to visualize the underlying trends and investigate the relationships between various qualitative variables. It was performed by PAST software to comprehend the structure of relationships between plants and humans varying by age, educational level, gender, and marital status. Since the FCA is frequently used for qualitative data, the respondents' age—which is a quantitative factor—was converted into qualitative variables using different classes:

For the age:

- Age-Low: Age < 20 years.
- Age-Medium: 20 < Age < 40 years.
- Age- High: Age > 40

***Two parameter's Kolmogorov-Smirnov (K-S) test***
Statistical analysis was carried out to compare the frequencies of MAPs use between different socio-demographic categories, such as gender, age, education level, marital status, and socio-economic status. For each comparison, the frequencies of MAPs usage were calculated and compared between the groups defined by these categories. The two-parameter Kolmogorov-Smirnov test was carried out with PAST software to determine whether the frequency distributions of MAPs use differed significantly between the groups compared. The null hypothesis (equality of distributions) was tested at a significance level of $p = 0.05$.

If the p-value is less than 0.05, the equality hypothesis will be rejected, indicating a significant difference in frequency distribution between the groups compared. Each analysis included all informants aged between 15 and 81 years old, with a total of 66 values per category.

The combination of the FCA and K-S tests ensures a thorough analysis, reliable statistical validation, and effective visual representation.

## Results and Discussion

**Use of MAPs by respondents**

In the Fez-Meknes region, the use of aromatic and medicinal plants by the population exceeds 90%, while the percentage of people choosing not to use MAPs is around 9% (Table 1), which indicates that these plants have a major role to play in the traditional treatment of microbial diseases. These results are very close to those found by Benamar et al who reported a percentage of 93.44% of people using MAPs, which demonstrate the degree to which the population studied is attached to its traditional heritage regarding the use of MAPs (Benamar *et al.* 2023).

Table 1. Distribution of respondents using or not using MAPs according to socio-demographic factors.

| Variable | Categories | Using MAPs (%) | Not Using MAPs (%) |
|---|---|---|---|
| **General use** | - | 90.66% | 9.33% |
| **Age** | <20 years | 8.08% | 53.57% |
| | 20-40 years | 25.73% | 32.14% |
| | >40 years | 66% | 14.28% |
| **Gender** | Male | 41.17% | 64.28% |
| | Female | 58.82% | 35.71% |
| **Education** | Illiterate | 36.76% | 10.71% |
| | Primary | 33.82% | 17.85% |
| | Secondary | 29.41% | 28.57% |
| | Higher education | 7.35% | 42.85% |
| **Socio-economic level** | Low | 45.95% | 10.71% |
| | Medium | 34.55% | 17.85% |
| | High | 19.48% | 71.42% |
| **Marital status** | Single | 31.61% | 60.71% |
| | Married | 68.38% | 39.28% |

**Socio-demographic data of respondents**

***Age***

Table 1 shows that MAPs use in the study area is most widespread among people aged over 40 (66%), followed by those aged between 20 and 40 (25.73%), while the lowest percentage of MAPs use is found among people aged under 20 (8.08%). For people who don't use MAPs, the highest percentage (53.57%) is shown among young people under 20, followed by people between 20 and 40 (32.14%), then people over 40 (14.28%). These results are very similar to other studies that reported a percentage greater than 60% of people over 40 years who frequently use MAPs (Salhi *et al.* 2023, Ed-Dahmani *et al.* 2024). According to the answers, the predominance of MAPs use by the older generation could be explained by the fact that they have a better knowledge of Moroccan plants and the use and preparation of each plant, as well as a strong confidence in the effectiveness of their traditional medicinal use. For people who don't prefer to use MAPs, according to them, either they don't know enough about plants, or they're afraid of their toxicity and the dose to be used. In other side, the low use of medicinal plants among young people is linked to their frequent use of social networks and their confidence in modern medicine (Septiadi *et al.* 2020).

***Gender***

In the Fez-Meknes region, women use MAPs more often than men, indicating a gender-based difference in use. Table 1 shows that 41.17% of informants who use MAPs are men, compared with 58.82% of women, which is very close to the percentage reported in another study showing that 62% of women use MAPs (Habchaoui *et al.* 2023). In our region and according to the informants' responses, many practical, sociological, and cultural variables may be at the source of this difference. It may be that women in this region have more traditional knowledge of how to prepare and administer the therapeutic qualities of these plants. In many cultures, women are more likely to be the primary caregivers and to participate in household health practices, which may explain why they are more familiar with herbal treatments. In addition, given their responsibilities for family health and household management, women may have more time for these activities, which explains the high percentage found among women. However, these interpretations remain hypothetical, as the present study did not include qualitative interviews or direct sociological investigation to substantiate such claims. Further ethnographic or qualitative research would be necessary to confirm these cultural assumptions.

***Educational level***

Table 1 illustrates that, in the region studied, the majority of medicinal plant users are illiterate, followed by those with primary education (36.76% and 33.82% respectively), while 29.41% have secondary education. The lowest percentage (7.35%) corresponds to users with a university educational level. According to a study conducted by El Mekkaoui which also found a high percentage of illiterates using MAPs, this situation could be influenced by a variety of factors, including the low education rate of rural women (Reports on Gender and Development in Rural Areas), the prevalence of elderly people, socio-economic status, or the availability and accessibility of educational resources (El Mekkaoui *et al.* 2024).

***Socio-economic status***

In our region, most people using MAPs have a low socio-economic level (45.95%), followed by those with an average level (34.55%), while 19.48% have a high socio-economic level (Table 1). Our results is similar to others, which showed that people with low and average incomes are the most frequent users of MAPs (El-Ghazouani *et al.* 2024, Benkhaira *et al.* 2021). This can be explained by the fact that people with a low or medium socio-economic level have greater recourse to traditional medicine in the treatment of illnesses, as it is an accessible and effective way, on the other hand, to minimize the cost of treatment. As for those who don't use MAPs, only 10.71% have a low socio-economic level, while the majority (71.42%) have a high level. This result suggests that the latter may be users of modern medical treatments.

***Marital status***

Due to the need for affordable health care, married people (81.28%) use MAPs much more frequently than single people (18.71%), according to the ethnobotanical study (Table 1). Our findings are consistent with other studies conducted in Morocco (Radi *et al.* 2024, Maache *et al.* 2024). Informant responses indicate that families, particularly those with children, frequently use MAPs to save money on the high cost of doctor's visits and treatments. Given that they are usually the primary caregivers and possess a wealth of information on herbal remedies, this practice further underlines the importance of women in Moroccan society. The intensive use of MAPs in the family setting is further reinforced by the important role played by women in managing household health, highlighting the cultural and economic elements in health practices.

**Factorial Correspondence Analysis of collected data**

The results of the FCA test, presented in Figure 2, reveal the relationship between respondents' socio-demographic characteristics and their use of MAPs. In total, the two axes F1 and F2 account for 69.09% of the total variation in the data, with F1 explaining 52.83% and F2 16.26%. These results indicate that the first two factors do indeed represent the key dimensions of MAPs use within the respondent groups.

Respondents can be divided into three distinct classes according to their frequency of MAPs use: high MAPs use, medium MAPs use and low MAPs use. These classes were determined by examining respondents' socio-demographic characteristics. On the left-hand side of axis 2, we find those who frequently use MAPs. These are mainly women, illiterate or with a primary level of education, married, elderly and from a low or medium socio-economic level. These respondents tend to make massive use of MAPs to treat illnesses of microbial origin. On the other hand, men, middle-aged people and those with a high level of education make moderate use of MAPs. This group lies towards the center of the graph, reflecting a balanced approach to the use of MAPs. Finally, young people under the age of 20, single people, university-educated people and people of a high socio-economic level rarely use MAPs. This group is located on the right-hand side of the graph, indicating that they tend to prefer modern methods of healthcare and are less likely to turn to MAPs for treatment.

These results indicate that various factors, such as gender, age, level of education, and socio-economic status, influence the use of MAPs. In particular, the use of MAPs for medical purposes is more frequent among older adults, those with lower levels of education, and those from low-income backgrounds. There are many interrelated reasons for this trend. Firstly, accessibility, both financially and geographically, is important, as conventional treatments are often cheaper and easier to find than pharmacological substitutes. In addition, traditional therapeutic methods are maintained, and their continued use is reinforced by the generational transfer of ethnobotanical knowledge. These decisions are also influenced by people's perceptions of contemporary medicine, distrust of formal health systems, whether due to unfavorable experiences in the past or a lack of knowledge, can lead some people to prefer conventional treatments.

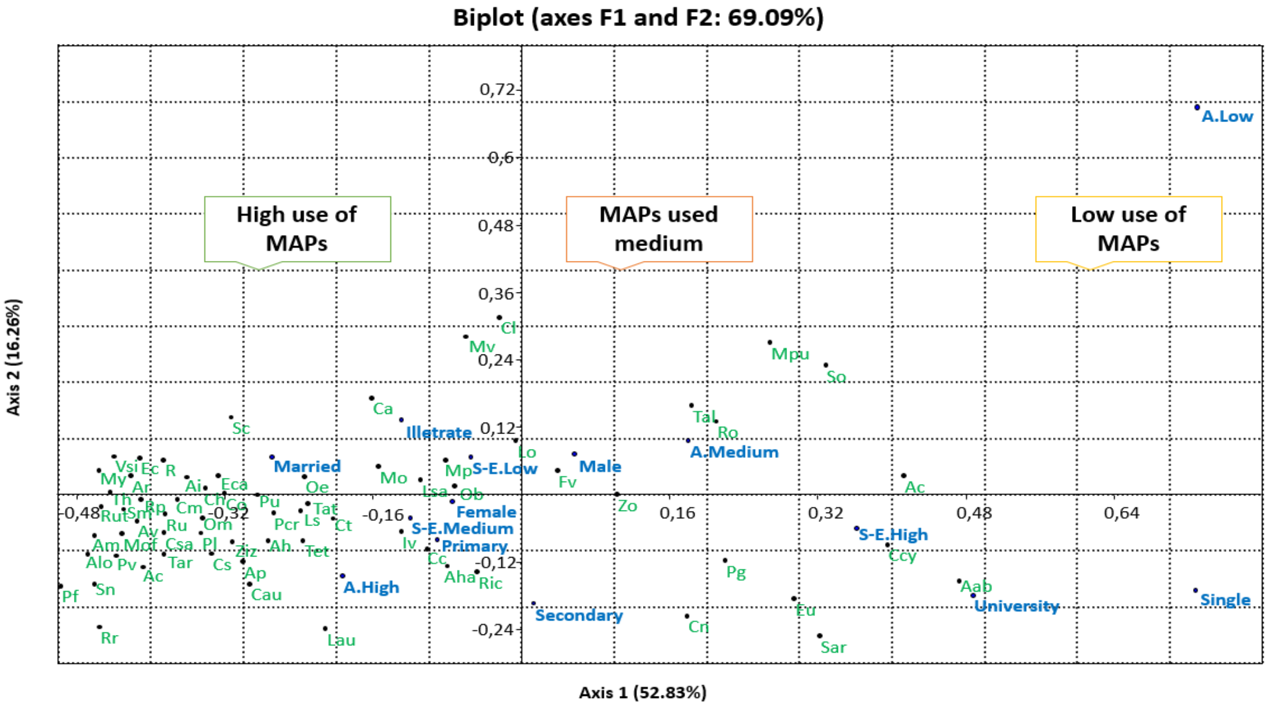


Figure 2. Biplot of multiple component analysis applied to different variables related to the respondents. The first dimension (F1) explains 16.26% of the total variance, and the second dimension (F2) explains 52.83%. A.Low: Age-Low (< 20 years), A.Medium: Age-Medium (20 < age < 40 years), A.High: Age-High (> 40 years), S-E.Low: socio-economic level low, S-E.Medium: socio-economic level Medium, S-E.High: socio-economic level high.

These results are consistent with the information presented in Table 1, highlighting the important role played by women and the elderly in traditional Moroccan medicine and their competence in MAP. In addition, they draw attention to the influence of socio-economic status on healthcare decisions, particularly for middle- and low-income groups seeking affordable treatment options.

***Informant population's socio-demographic and cultural traits analysis by Kolmogorov-Smirnov test***

This ethnobotanical study, based on random sampling of informants, aimed to analyze the factors influencing the use of MAPs. To supplement the results of the FCA test, we carried out a statistical comparison of different population categories, assessing their use or non-use of MAPs in the 15 to 81 age group. To assess differences in plant choice between demographic groups, we used the Kolmogorov-Smirnov test. The null hypothesis ($H_0$) postulates that plant choice distributions are identical between two groups, while the alternative hypothesis ($H_1$) suggests a significant difference. The results, presented in Table 2, indicate that the equal distribution hypothesis was rejected for three categories: gender, socio-economic status and marital status. These results are consistent with those of the FCA (Fig. 2).

Table 2. Results of the two parameters Kolmogorov-Smirnov test applied to the datasets of different categories of informant's populations represented in table 1.

| Figure | Category | Sample size | D (KS statistic) | P-value | Permutation p | Hypothesis |
|---|---|---|---|---|---|---|
| 3 | < 40 and ≥ 40 | 66 | 0.20896 | 0.09306 | 0.0001 | Accepted |
| 4 | Male and Female | 66 | 0.26866 | 0.01255 | 0.0001 | Rejected |
| 5 | Illetrate and Educated | 66 | 0.19403 | 0.142 | 0.0001 | Accepted |
| 6 | SE.Low and SE.High | 66 | 0.25373 | 0.02171 | 0.0001 | Rejected |
| 7 | Married and Single | 66 | 0.23881 | 0.03639 | 0.0001 | Rejected |

Specifically, the test revealed no significant differences in plant choice between age groups (<40 vs ≥40) or education levels (Illetrate vs. educated) ($p > 0.05$), confirming $H_0$. This can be explained by the fact that young and middle-aged people, and those in primary and secondary school, use MAPs moderately, especially plants that are well known and used in Moroccan cuisine. Conversely, significant differences ($p < 0.05$) were observed between men and women, people with high or low socio-economic status, and married or single people, leading to the rejection of $H_0$ in favor of $H_1$.

These results suggest that gender, socio-economic status and marital status influence medicinal plant selection, while age and education level do not appear to be determining factors.

**Floristic analysis**

The ethnobotanical survey carried out in the Fez-Meknes region enabled us to identify 68 species of MAP, belonging to 32 botanical families, used for the treatment of numerous diseases of microbial origin. All the plants selected are presented in Table 3, where the scientific and vernacular names of the species, the botanical families, the parts used, the preparation method and data on FC, RFC, FL, and FIV are given for each one.

Among the 32 families selected from the survey, the most representative are *Amaranthaceae, Lamiaceae, Oleaceae, Myrtaceae, Verbenaceae, Geraniaceae* and *Euphorbiaceae*, with a FIV greater than 0.5 (Fig. 3). Our results are in line with several other studies that have found similar results to ours, particularly for the *Lamiaceae, Myrtaceae, Oleaceae, Fabaceae* and *Apiaceae* families, which are repeated in several studies, confirming the importance and efficacy of plants belonging to these families in traditional medicine (Achour *et al.* 2022, Ghabbour *et al.* 2024). Furthermore, the most frequently cited species are *Chenopodium ambrosioides L., Rosmarinus officinalis, Salvia officinalis, Origanum majorana, Thymus atlanticus, Mentha piperita, Thymus algeriensis, Mentha pulegium L., Lavandula stoechas, Chamaemelum nobile, Artemisia herba alba, Curcuma longa, Zingiber officinale, Olea europaea, Cuminum cyminum L., Syzygium aromaticum, Eucalyptus globulus, Aloysia citrodora, Pelargonium graveolens* and *Ricinus communis* with an RFC greater than 0.2 (Fig. 4).

The predominance of the *Lamiaceae* and *Myrtaceae* families can be attributed to a number of factors, not least their abundance of bioactive compounds with antimicrobial qualities. The *Lamiaceae*, which include genera such as *Thymus*, *Origanum*, and *Rosmarinus*, are particularly well known for their abundance of essential oils rich in thymol, carvacrol, menthol, and rosmarinic acid, as well as molecules with well-documented antibacterial and antifungal properties (Karpiński, 2020, Khoury *et al.* 2016, Marchese *et al.* 2016). These substances disrupt the integrity of micro-organisms' cell membranes, preventing the development of pathogenic bacteria (Kachur and Suntres 2020). On the other hand, *Myrtaceae*, which include genera such as *Eucalyptus* and *Myrtus*, have a chemistry that is advantageous for medical uses (Nicoletti *et al.* 2018). They include monoterpenes with antiseptic, antiviral, and anti-inflammatory properties, such as myrtenal and eucalyptol (1,8-cineole) (Zielińska-Błajet & Feder-Kubis, 2020).

The predominance of these two families can also be attributed to their wide distribution, their ability to adapt to local climates, and their long-established use in traditional medical practices. The dominance of the *Lamiaceae* and *Myrtaceae* families is not unique to the Fez-Meknes region. In the Rif Mountains, Chaachouay *et al.* (2019) reported 31 medicinal plant species, primarily from *Asteraceae* and *Lamiaceae*, while Myrtaceae were underrepresented. In contrast, Teixidor-Toneu *et al.* (2016) documented 159 taxa in the High Atlas, with *Asteraceae* and *Lamiaceae* again predominant, but *Myrtaceae* accounting for <2% . These differences likely reflect ecological gradients such as altitude, precipitation, and soil type, underscoring the importance of local bioclimatic conditions in shaping ethno-floristic patterns. Several studies have shown that plants belonging to these two families are frequently recommended in traditional medicine across other Moroccan regions, such as the High Atlas and Rif (Hilah *et al.* 2016, Fakchich & Elachouri, 2021).

This regional pattern is confirmed by recent studies. According to Tlemcani *et al.* (2023), the *Lamiaceae* account for approximately 18% of all species used traditionally in the Fez-Meknes region — a proportion significantly higher than the national average. El Oihabi *et al.* (2024) similarly noted the prominence of *Lamiaceae* in adjacent regions like Beni Mellal-Khenifra, where species are employed for their antimicrobial, anti-inflammatory, and digestive properties. *Myrtaceae*, while generally less represented on a national scale, play a notable role locally. For instance, *Myrtus communis* has been frequently cited in the Fez-Meknes region for managing conditions such as diabetes and infections (Mechchate *et al.* 2020).

These findings suggest that both families are not only rich in bioactive secondary metabolites but also deeply embedded in the local ethnobotanical landscape. Their consistent use across regions could be attributed to a combination of cultural transmission, ecological availability, and perceived therapeutic efficacy. However, deeper cross-regional comparisons would help distinguish whether their dominance is driven primarily by pharmacological properties, cultural preferences, or ecological abundance.

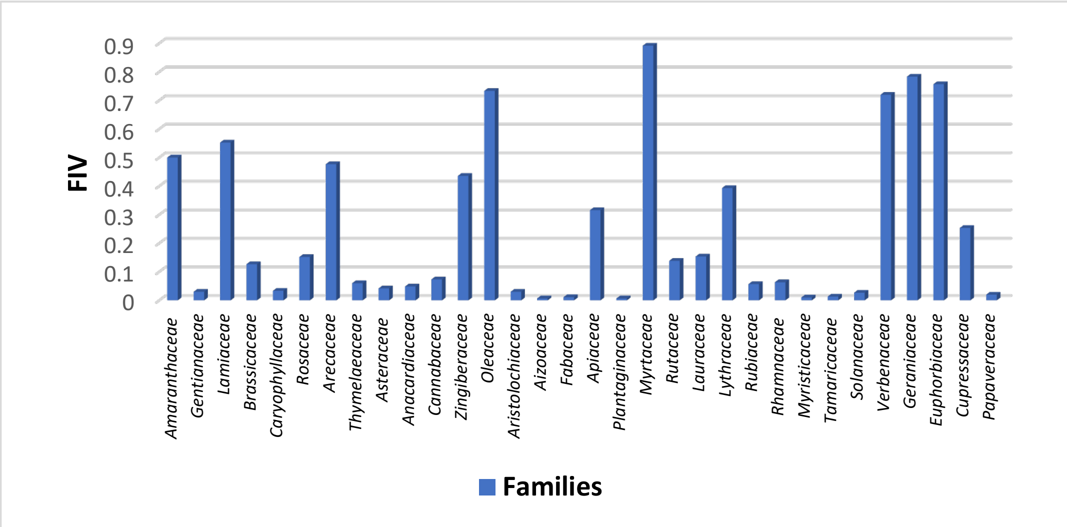


Figure 3. Distribution of cited plant's families according to their FIV

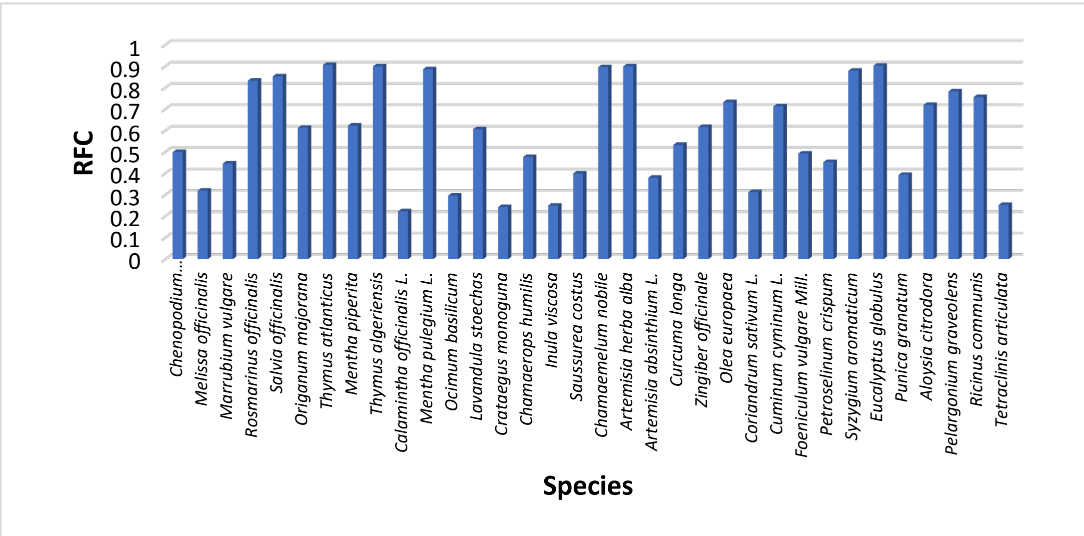


Figure 4. Distribution of the most cited species according to their RFC

For the preparation and use of these plants, people frequently use infusion followed by decoction to extract the plant's compounds, or consume the raw plant in powder form with water or milk. The use of these techniques is explained by their ease and efficiency in extracting and solubilizing the bioactive molecules contained in plants (Checkouri *et al.* 2020). These results are similar to other studies, which have mentioned infusion and decoction as the main techniques for preparing these plants to facilitate administration of their active ingredients (Barkaoui *et al.* 2017, Beniaich *et al.* 2022).

Table 3. Some characteristics of the MAPs used by the people interviewed in the Fez-Meknes region, scientific and vernacular names, parts used, methods of preparation, and citation indexes (FC, RFC, and FIV).

| Family | Botanical name (Vouchers No.) | Local name | Part used | Preparation mode | FC | RFC | FIV | FL |
|---|---|---|---|---|---|---|---|---|
| *Amaranthaceae* | *Chenopodium ambrosioides L.* **BLMUP354** | Mkhinza | Leaves | Infusion | 150 | 0.5 | 0.5 | FV 82% / PI 24% |
| *Gentianaceae* | *Erythraea centaurium* **BLMUP355** | Qesst-Hayya | Whole aerial part | Decoction | 10 | 0.033333 | 0.033333 | FV 70% / DR 40% |
| *Lamiaceae* | *Ajuga iva* **BLMUP356** | Chendgoura | Leaves | Infusion | 12 | 0.04 | 0.552381 | FV 100% |
| | *Melissa officinalis* **BLMUP357** | Marsita | Leaves | Infusion | 98 | 0.326667 | | FV 100% |
| | *Marrubium vulgare* **BLMUP358** | Merriwta/ Marriwa | Leaves | Infusion | 134 | 0.446667 | | FV 50% / ORL 62% |
| | *Rosmarinus officinalis* **BLMUP359** | Azir | Leaves | Infusion | 250 | 0.833333 | | FV 100% |
| | *Salvia officinalis* **BLMUP360** | Salmiya | Leaves | Infusion | 256 | 0.853333 | | FV 100% |
| | *Origanum majorana* **BLMUP361** | Merdedouch | Leaves | Infusion | 184 | 0.613333 | | FV 100% |
| | *Thymus atlanticus* **BLMUP362** | Zîitra | Leaves | Infusion | 272 | 0.906667 | | SD 100% / VO 100% |
| | *Mentha piperita* **BLMUP363** | Nâanâa lâabdi | Leaves | Infusion | 187 | 0.623333 | | SD 60% / FV 47% |
| | *Thymus algeriensis* **BLMUP364** | Zâatar | Leaves | Infusion | 270 | 0.9 | | SD 100% / VO 100% |
| | *Calamintha officinalis L.* **BLMUP365** | Mantha | Leaves | Infusion | 67 | 0.223333 | | SD 100% |
| | *Lavandula officinalis L.* **BLMUP366** | Khzama | Flower | Infusion | 53 | 0.176667 | | FL 100% |
| | *Mentha pulegium L.* **BLMUP367** | Fliyo | Leaves | Infusion | 266 | 0.886667 | | FL 100% |
| | *Ocimum basilicum* **BLMUP368** | Rihane | Leaves | Infusion | 89 | 0.296667 | | SD 100% |
| | *Lavandula stoechas* **BLMUP369** | Al-halhal | Leaves | Infusion | 182 | 0.606667 | | SD 89% / UI 11% |

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|---|---|---|---|---|---|---|---|---|
| *Brassicaceae* | *Anastatica hierochuntica* **BLMUP370** | Keff-Meryem | Whole aerial part | Decoction | 20 | 0.066667 | 0.126667 | IN 100% |
| | *Lepidium sativum* **BLMUP371** | Heb Arrechad | Grains | Decoction | 56 | 0.186667 | | SD 100% |
| *Caryophyllaceae* | *Arenaria rubra L.* **BLMUP372** | Herras-Lahjar | Whole aerial part | Decoction | 5 | 0.016667 | 0.033333 | UI 60% / KD 40% |
| | *Corrigiola telephiifolia* **BLMUP373** | Serghina | Roots | Decoction | 15 | 0.05 | | RI 100% |
| *Rosaceae* | *Crataegus monoguna* **BLMUP374** | Admam | Leaves | Infusion | 73 | 0.243333 | 0.151667 | ND |
| | *Sanguisorba minor* **BLMUP375** | Hayat-Nofous | Whole plant | Decoction | 18 | 0.06 | | FV 80% / DR 60% |
| *Arecaceae* | *Chamaerops humilis* **BLMUP376** | Aghaz | Fruit | Infusion | 143 | 0.476667 | 0.476667 | RI 100% |
| *Thymelaeaceae* | *Thymelaea hirsuta* **BLMUP377** | Mathnan | Whole plant | Decoction | 16 | 0.053333 | 0.06 | IN 100% |
| | *Aquilaria malaccensis* **BLMUP378** | Aoud Aghris | Roots | Decoction | 20 | 0.066667 | | ND |
| *Asteraceae* | *Inula viscosa* **BLMUP379** | Magramane | Leaves | Infusion | 75 | 0.25 | 0.041667 | SI 100% |
| | *Saussurea costus* **BLMUP380** | Quisst-Lhindi | Roots | Decoction | 122 | 0.406667 | | RI 100% |
| | *Anacyclus pyrethrum* **BLMUP381** | Taquandicht | Roots | Decoction | 18 | 0.06 | | ND |
| | *Chamaemelum nobile* **BLMUP382** | Babounj | Leaves | Decoction | 269 | 0.896667 | | DR 23% / SD 77% |
| | *Artemisia herba alba* **BLMUP383** | Chih | Leaves | Infusion | 270 | 0.9 | | FV 80% / PI 20% |
| | *Artemisia absinthium L.* **BLMUP384** | Chiba | Leaves | Infusion | 114 | 0.38 | | SD 85% / SI 15% |
| *Anacardiaceae* | *Pistacia lentiscus* **BLMUP385** | Drou | Leaves | Infusion | 23 | 0.076667 | 0.048333 | SD 100% |
| | *Rhus pentaphylla* **BLMUP386** | Tizgha | Fruit | Infusion | 6 | 0.02 | | SD 100% |
| *Cannabaceae* | *Cannabis sativa* **BLMUP387** | Lkif | Seeds | Decoction | 22 | 0.073333 | 0.073333 | ND |
| *Zingiberaceae* | *Elettaria cardamonum* **BLMUP388** | Hab Al-hal | Seeds | Decoction | 47 | 0.156667 | 0.435556 | SD 100% |

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|---|---|---|---|---|---|---|---|---|
| | *Curcuma longa* **BLMUP389** | Kharkoum | Roots | Decoction | 160 | 0.533333 | | SD 90% / IN 10% |
| | *Zingiber officinale* **BLMUP390** | Zenjabil | Roots | Decoction / Raw | 185 | 0.616667 | | SD 14% / IN 46% / CO 100% |
| *Oleaceae* | *Olea europaea* **BLMUP391** | Zitoun El-berri | Leaves | Infusion | 220 | 0.733333 | 0.733333 | SI 100% |
| *Aristolochiaceae* | *Aristolochia longa* **BLMUP392** | Barztem | Leaves | Infusion | 9 | 0.03 | 0.03 | UI 80% / KD 33% |
| *Aizoaceae* | *Rabiea sp* **BLMUP393** | Rebiit-Sem | Leaves | Infusion | 2 | 0.006667 | 0.006667 | ND |
| *Fabaceae* | *Melitolus officinalis* **BLMUP394** | Azroud | Grains | Decoction | 3 | 0.01 | 0.011111 | SD 100% |
| | *Retama raetam* **BLMUP395** | Rtem | Leaves | Infusion | 5 | 0.016667 | | RI 100% |
| | *Prosopis farcta* **BLMUP396** | Tasslbout | Roots | Decoction | 2 | 0.006667 | | RI 100% |
| *Apiaceae* | *Ptychotis verticillata* **BLMUP397** | Nanoukha / Nankha | Seeds | Decoction | 5 | 0.016667 | 0.315714 | UI 100% / SD 60% |
| | *Carum carvi L.* **BLMUP398** | Karwiya | Seeds | Decoction | 33 | 0.11 | | SD 100% |
| | *Coriandrum sativum L.* **BLMUP399** | Kasbour | Seeds | Decoction | 94 | 0.313333 | | SD 100% |
| | *Cuminum cyminum L.* **BLMUP400** | Kamoun | Seeds | Raw | 214 | 0.713333 | | SD 100% |
| | *Foeniculum vulgare Mill.* **BLMUP401** | Nafaâ | Seeds | Raw | 148 | 0.493333 | | SD 100% |
| | *Petroselinum crispum* **BLMUP402** | Mâadnouss | Leaves | Infusion | 136 | 0.453333 | | UI 100% |
| | *Ammi visnaga* **BLMUP403** | Bechnikha | Seeds | Decoction | 33 | 0.11 | | KD 100% |
| *Plantaginaceae* | *Verbascum sinuatum* **BLMUP404** | Mousshandar | Leaves | Infusion | 2 | 0.006667 | 0.006667 | RI 100% |
| *Myrtaceae* | *Syzygium aromaticum* **BLMUP405** | Queranfel | Flower | Raw | 264 | 0.88 | 0.891667 | SI 10% / FL 100% |
| | *Eucalyptus globulus* **BLMUP406** | Eucalyptus | Leaves | Infusion | 271 | 0.903333 | | RI 10% / CO 17% / FL 100% |
| *Rutaceae* | *Citrus aurantium* **BLMUP407** | Renj | Fruit | Infusion | 30 | 0.1 | 0.138333 | SD 100% |
| | *Ruta chalepensis* L. **BLMUP408** | Lfijel | Leaves | Infusion | 20 | 0.066667 | | ORL 100% |

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|---|---|---|---|---|---|---|---|---|
| | *Ruta graveolens* **BLMUP409** | Rota | Leaves | Infusion | 33 | 0.11 | | ORL 100% |
| *Lauraceae* | *Laurus nobilis* **BLMUP410** | Chajrat Sidna Moussa | Leaves | Infusion | 46 | 0.153333 | 0.153333 | RI 26% / SD 76% |
| *Lythraceae* | *Punica granatum* **BLMUP411** | Remman | Peel | Decoction | 118 | 0.393333 | 0.393333 | PI 11% / IN 94% |
| *Rubiaceae* | *Rubia tinctorum* **BLMUP412** | Fowa / Fessa | Leaves | Infusion | 17 | 0.056667 | 0.056667 | UI 100% |
| *Rhamnaceae* | *Ziziphus jujuba* **BLMUP413** | Zefzouf | Fruit | Infusion | 19 | 0.063333 | 0.063333 | SD 100% |
| *Myristicaceae* | *Myristica fragrans* **BLMUP415** | Gouza Sahraouiya | Leaves | Infusion | 3 | 0.01 | 0.01 | SD 100% |
| *Tamaricaceae* | *Tamarix articulata* **BLMUP416** | Tara Sahraouiya | Leaves | Infusion | 4 | 0.013333 | 0.013333 | UI 100% |
| *Solanaceae* | *Solanum nigrum L.* **BLMUP417** | Bouqnina | Leaves | Infusion | 8 | 0.026667 | 0.026667 | DR 75% / SD 50% |
| *Verbenaceae* | *Aloysia citrodora* **BLMUP418** | Lwiza | Leaves | Infusion | 216 | 0.72 | 0.72 | SD 100% |
| *Geraniaceae* | *Pelargonium graveolens* **BLMUP419** | Lâatercha | Leaves flower | Infusion | 235 | 0.783333 | 0.783333 | RI 100% |
| *Euphorbiaceae* | *Ricinus communis* **BLMUP420** | Lkharwâa | Leaves | Infusion | 227 | 0.756667 | 0.756667 | ND |
| *Cupressaceae* | *Tetraclinis articulata* **BLMUP421** | Âarâar | Leaves | Infusion | 76 | 0.253333 | 0.253333 | SI 100% |
| *Papaveraceae* | *Papaver rhoeas L.* **BLMUP422** | Belaaman | Leaves flower | Infusion | 6 | 0.02 | 0.02 | FV 100% |

**Legend:**

**Diseases:** FV: Fever, DR: Diarrhea, SD: Stomach disorder, UI: Urinary infection, SI: Skin infection, ORL: Otorhino-laryngologie, RI: Respiratory infection, FL: Flu, PI: Parasitological infection, CO: Cough, VO: Vomiting, KD: kidney, IN: Infections, ND: Not determined.

***PPV***

According to the plant part value presented in the figure 5, people in the Fez-Meknes region use different parts of MAPs to prepare their traditional medicines. Leaves constituted the most frequently used plant part (68.95%), likely due to their year-round availability and high concentrations of secondary metabolites, as observed in Mediterranean ethnobotanical studies (El Khomsi *et al.* 2022). In addition, Leaves are more widely used in traditional medicine because of their high essential oil content and their ease of harvesting (Ngoule *et al.* 2015). They are followed by seeds with a percentage of 9.85% and flowers with 8.39% then roots with 7.85%, while fruits, the whole aerial part, the whole plant and peels represent just a percentage of use of 2.83%, 1.04%, 0.51% and 0.018%, respectively.

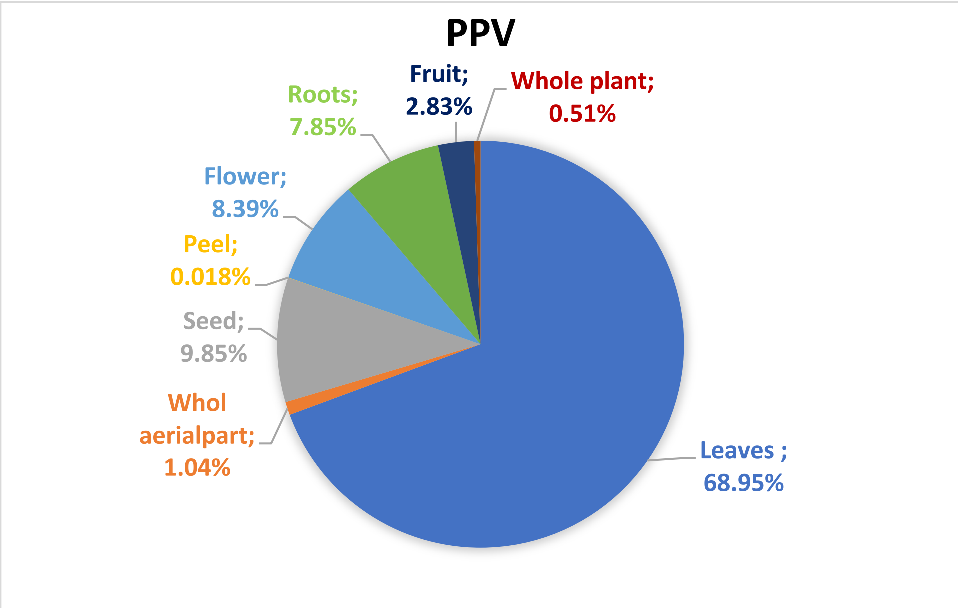


Figure 5: Parts of plants used in traditional medicine by people interviewed.

***Fidelity level***

The FL of the selected plants ranges from 10% to 100%, according to Table 3, reflecting the degree of agreement among informants regarding their medicinal uses. The presence of 47 species with a FL of 100% indicates that these plants are unanimously cited for treating specific microbial infections, suggesting their strong cultural significance and high perceived efficacy in traditional medicine. This high level of consistency implies that these plants have likely been used repeatedly over generations, reinforcing their symbolic and practical value in local health traditions.

However, it is important to note that a FL of 100% does not imply scientifically validated therapeutic efficacy. It reflects a consensus of use among informants, rather than clinically demonstrated effectiveness. Caution should be taken when interpreting FL values as indicators of pharmacological performance. Further phytochemical and pharmacological studies are needed to confirm the bioactivity and safety of these plants.

On the other hand, species with lower FL values are probably used for multiple health ailments, scattering their recognition among informants. This suggests that while some plants have a well-established and exclusive therapeutic role, others are known for their broader medicinal multi-functionality, treating a variety of affections rather than being associated with a single, specific use. The variation in FL values highlights the complexity of traditional medicinal knowledge, where some plants are highly specialized while others are versatile, depending on local healthcare needs and practices.

**Plant Safety and Toxicity Considerations**

Although MAPs are essential to traditional health care, their use is not without its dangers. Some of the species identified in this research contain potentially toxic bioactive compounds, especially when improperly prepared or consumed in excessive doses. For example, *Ricinus communis*, commonly used in traditional Moroccan medicine, contains ricin, an extremely toxic protein contained in the seeds, which can be fatal if ingested even in small doses (Franke *et al.* 2019). Similarly, *Punica granatum* (pomegranate) bark, commonly used as a decoction, contains alkaloids and tannins that can cause adverse effects if consumed over a long period or in large doses (Ge *et al.* 2021). Despite promising traditional uses, the toxicological safety of certain species remains underexplored. *Aristolochia longa*, used for urinary tract infections, contains aristolochic acids with nephrotoxic and carcinogenic potential (Debelle *et al.* 2008). Although its RFC in this study is low (0.03), its high-fidelity level (FL = 80%) highlights the need for caution. Any pharmacological development must therefore include toxicity screening—including cytotoxicity and genotoxicity—to ensure the safe use of these plants.

Traditional preparation methods, such as decoction, infusion or maceration, modify the chemical composition of plant extracts and can either reduce or increase toxicity. For example, decoction can denature certain toxic compounds, while concentrating other active substances (Guo *et al.* 2022).

One of the main limitations of ethnobotanical studies is the lack of systematic evaluation of the toxicity of the species used. It is therefore crucial to conduct in-depth research into the safe use of the most commonly cited species, particularly those with a high-fidelity index (FL) or widespread use. In addition, it would be desirable to encourage awareness campaigns on the potential risks, contraindications and toxicity of certain plants among users, with the aim of promoting preventive public health.

**Conservation and Sustainability**

Among the 68 medicinal plants recorded, 33 species—almost half—are collected exclusively from wild environments. On-site surveys revealed particularly intensive foraging of *Thymus atlanticus* and *Chamaemelum nobile*, both listed as Near Threatened in Morocco’s Red List (Lamrani-Alaoui and Hassikou, 2018). This level of extraction raises serious conservation concerns. To mitigate these risks, we propose a threefold approach:

- First, promote cultivation at the community level, guided by agroecological principles.
- Second, apply rotational harvesting systems, enforcing minimum cutting heights. This method is consistent with FairWild sustainability standards (Wolf *et al.* 2014).
- Third, establish micro-reserves in sites facing excessive plant pressure.

This model has shown success in the Arganeraie region, where genetic diversity conservation has been implemented (El Mousadik and Petit, 1996).

These actions align with SDG 15, aiming to halt biodiversity loss and foster sustainable use of ecosystems.

## Conclusion

Medicinal and aromatic plants (MAPs) play a major role in traditional Moroccan medicine, particularly in the Fez-Meknes region, for the treatment of diseases of microbial origin. Our results confirm this importance, revealing that 90.66% of the population studied uses MAPs. The ethnobotanical survey identified 68 plant species belonging to 32 families, of which *Lamiaceae, Myrtaceae, Euphorbiaceae, Geraniaceae, Verbenaceae, Apiaceae,* and *Oleaceae* are the most commonly reported.

Socio-demographic characteristics directly affect the use of MAPs, as well as the choice of species employed. The results show that the elderly, married people, women, individuals with low or no educational level, and those with low or middle socio-economic level are the categories most likely to use these plants. This can be explained both by economic factors and by the transmission of traditional knowledge about the therapeutic uses of plants.

In conclusion, this study highlights the traditional medical knowledge of the inhabitants of the Fez-Meknes region and represents a valuable source of ethnobotanical data for the development of new plant-based medicines. In accordance with the Sustainable Development Goals (SDGs) such as SDGs 3, 11 and 15 (https://fr.unesco.org/sdgs), these results contribute to:

- SDG 3 (Good health and well-being), by promoting therapeutic solutions derived from local biodiversity, potentially exploitable in the fight against microbial infections.
- SDG 11 (Sustainable cities and communities) by encouraging the conservation of ethnobotanical knowledge and the integration of MAPs into public health practices adapted to the needs of local populations.

- SDG 15 (Life on Earth) by emphasizing the need to preserve medicinal plants and their natural habitats while promoting the sustainable use of plant resources.

Finally, further research is required to further examine these findings. Specifically, a phytochemical and pharmacological analysis of the most often cited species would enable the identification and scientific validation of their antimicrobial properties. Furthermore, research into the possible interactions and modes of use with conventional treatments may encourage the rational integration of MAPs into public health strategies. In addition, Create conservatories for endangered species (e.g. *Chamaemelum nobile*) in collaboration with local communities

## Declarations

**List of abbreviations:** MAPs: medicinal and aromatic plants, RFC: Relative Frequency of Citation, FIV: Family Importance Value, PPV: Plant Part Value, FL: fidelity level Index, FC: frequency of citation, N: total number of people using MAPs, Ns: total number of cited species in each family. FV: Fever, DR: Diarrhea, SD: Stomach disorder, UI: Urinary infection, SI: Skin infection, ORL: Otorhino-laryngologie, RI: Respiratory infection, FL: Flu, PI: Parasitological infection, CO: Cough, VO: Vomiting, KD: kidney, IN: Infections, MDR: multidrug resistant, ND: Not determined.

**Ethics approval and consent to participate:** The data were collected with respect to confidentiality, anonymity and consent of the respondents who were informed about the aim of this study before the interviews.

**Consent for publication:** Not applicable

**Availability of data and materials:** Not applicable

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**Author contributions:** Soufyane Yassara: carried out data collection, literature survey, data analysis, interpretation, and prepared the first draft of the manuscript. Samira Jaouhar: writing-review and editing. Ikrame Zeouk: writing-review and editing. Khadija Bekhti: supervision and validation.

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## Literature cited

Achour S, Mohamed C, Hanane E, Mohammed B, Lahcen O, Ahmad MS, Mourad AMAS, John PG. 2022. Ethnobotanical Study of Medicinal Plants Used as Therapeutic Agents to Manage Diseases of Humans. Evidence-Based Complementary and Alternative Medicine. doi: 10.1155/2022/4104772

Ait Bouzid H, Mohamed I, Aicha H, Samira O, Abderrahim A, Otmane Ha, Laila B, Jamal K, Khalid M, Said G. 2024. Moroccan Aromatic and Medicinal Plants: A Review of Economy, Ethnobotany, Chemical Composition, and Biological Activities of Commonly Used Plants. Food and Humanity 2:100259. doi: 10.1016/J.FOOHUM.2024.100259

Al-Selwi AGM, and Amina B. 2023. Antibiotic Resistance of *Streptococcus Pneumoniae, Neisseria meningitidis, Haemophilus influenzae* and *Staphylococcus aureus* in Morocco, National Data: Meta- Analysis. Biomedical and Pharmacology Journal 16 (1): 251-263. doi: 10.13005/BPJ/2607

Barkaoui MA, Katiri H, Boubaker, Msanda F. 2017. Ethnobotanical Survey of Medicinal Plants Used in the Traditional Treatment of Diabetes in Chtouka Ait Baha and Tiznit (Western Anti-Atlas), Morocco. Journal of Ethnopharmacology 198: 338-350. doi: 10.1016/j.jep.2017.01.023

Bellakhdar J. 1997. Contribution à l’Étude de La Pharmacopée Traditionnelle Au Maroc : La Situation Actuelle, Les Produits, Les Sources Du Savoir (Enquête Ethnopharmacologique de Terrain Réalisée de 1969 à 1992). PhD dissertation, University of Université Paul Verlaine - Metz.

Benamar K, Saad IK, Saad B, Kawtar FB. 2023. Ethnobotanical Study of Medicinal Plants Used by the Population of Ain Chkef (North Central Morocco). Ethnobotany Research and Applications 26. doi: 10.32859/era.26.4.1-23

Beniaich G, Rajae S, Elhachmia E, Fadoua E, Zakia R, Abdelfattah A, Mustapha T. 2022. Ethnobotanical Survey about Medicinal Plants Used in Traditional Treatment of Insomnia, Asthenia, and Oral and Gum Infections in the Region Fez-Meknes, Morocco. Environmental Science and Pollution Research 29:133-145. doi: 10.1007/s11356-021-14439-8

Benkhaira N, Nisrine E, Kawtar FB. 2021. Ethnobotanical Survey on the Medicinal Usage of Two Common Medicinal Plants in Taounate Region: *Artemisia herba-alba* Asso and *Ormenis mixta* (L.) Dumort. Ethnobotany Research and Applications 22. doi: 10.32859/ERA.22.48.1-19

Benyahya H, Hicham M, Lhoussaine E, 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

Chaachouay N, Ouafae B, Mohamed F, Hamid E, and Lahcen Z. 2019. Ethnobotanical and Ethnopharmacological Studies of Medicinal and Aromatic Plants Used in the Treatment of Metabolic Diseases in the Moroccan Rif. Heliyon 5 (10): e02191. doi: 10.1016/j.heliyon.2019.e02191

Checkouri E, Franck R, Christine RDS, Olivier M. 2020. Evaluation of Polyphenol Content and Antioxidant Capacity of Aqueous Extracts from Eight Medicinal Plants from Reunion Island: Protection against Oxidative Stress in Red Blood Cells and Preadipocytes. Antioxidants 9:1-21. doi: 10.3390/antiox9100959

Dar RA, Mohd S, Muzaffer AA, Irfan UM. 2023. Exploring the Diverse Bioactive Compounds from Medicinal Plants: A Review. The Journal of Phytopharmacology 12:189-195. doi: 10.31254/phyto.2023.12307

Debelle FD, Jean LV, and Joëlle LN. 2008. Aristolochic Acid Nephropathy: A Worldwide Problem. Kidney International 74 (2): 158-169. doi: 10.1038/ki.2008.129

Ed-Dahmani I, Insaf M, Aziza L, Fatima ZB, Mustapha T, Abdelfattah A. 2024. Ethnobotanical Study of Potentially Toxic Plants of Fez-Meknes Region, Eastern Middle Atlas, Morocco. Tropical Journal of Natural Product Research 8:6115-6133. doi: 10.26538/tjnpr/v8i2.9

El Mousadik A, and Petit RJ. 1996. High Level of Genetic Differentiation for Allelic Richness among Populations of the Argan Tree [*Argania Spinosa* (L.) Skeels] Endemic to Morocco. Theoretical and Applied Genetics 92 (7): 832-839. doi: 10.1007/BF00221895/METRICS

El Oihabi K, Abdellatif B, Taha E, El Houssine B, Issam E, and Abdellatif B. 2024. Ethno-Pharmacological Study on Medicinal and Aromatic Plants Commonly Used in the Fez-Meknes and Beni Mellal-Khenifra Regions: Insights from Pharmacy-Based Surveys. Tropical Journal of Natural Product Research 8 (2): 6279-6290. doi: 10.26538/tjnpr/v8i2.28

El-Ghazouani F, Rachid B, Bouchra Y, Abderrahmane Z. 2024. Ethnobotanical Study of Medicinal Plants Used in the Rural Area of the Western High Atlas (Morocco). Ethnobotany Research and Applications 29. doi: 10.32859/era.29.15.1-26

Fakchich J, Mostafa E. 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

Franke H, Reinhold S, and Achim A. 2019. Ricin and Ricinus Communis in Pharmacology and Toxicology-from Ancient Use and 'Papyrus Ebers' to Modern Perspectives and "poisonous Plant of the Year 2018. Naunyn Schmiedebergs Archives Pharmacology 392(10):1181-1208. doi: 10.1007/S00210-019-01691-6

Ge S, Lan D, Junqi W, Gegen Z, Jingfan Y, Zhiyong L, and Ya T. 2021. A Unique Understanding of Traditional Medicine of Pomegranate, *Punica Granatum* L. and Its Current Research Status. Journal of Ethnopharmacology 271. doi: 10.1016/J.JEP.2021.113877

Ghabbour I, Nabil G, Abdelmajid K, Said L, Khalil H. 2024. Checklist of the Medicinal Flora Used by the Local Population in the Province of Taza (North-Eastern Morocco) through an Ethnobotanical Study. Botanical Sciences 102:854-877. doi: 10.17129/botsci.3420

Gomez-Beloz A. 2002. Plant Use Knowledge of the Winikina Warao: The Case for Questionnaires in Ethnobotany1. 56:231-241. doi: 10.1663/0013-0001(2002)056

Guo Y, Zejun M, Yuanyuan G, Weinan L, Shuang S, Qiuhong W, and Haixue K. 2022. HPLC-MS/MS Analysis of Primary Alkaloids in Rat Plasma after Oral Administration of 'Nux Vomica - Glycyrrhiza Glabra Decoction': A Pharmacokinetic Study. Journal of Ethnopharmacology 298: 115588. doi: 10.1016/J.JEP.2022.115588

Habchaoui J, Ilham S, Mostafa E, Mohamed F, Brahim B. 2023. Tropical Journal of Natural Product Research Ethnobotanical Study of Medicinal Herbs in the Saïss Urban Commune (Region Of Fez/Morocco). Tropical Journal of Natural Product Research Available 7:5034-5039

Hachlafi N, Abderrahim C, Rachida SB, Kawtar FB. 2020. Ethnopharmacological Study of Medicinal Plants Used for Chronic Diseases Treatment in Rabat-Sale-Kenitra Region (Morocco). Ethnobotany Research and Applications 20:1-23. doi: 10.32859/era.20.2.1-23

Hilah FE, Fatiha BA, Rachid B, Atmane R, Lahcen Z. 2016. Étude Ethnobotanique Des Plantes Médicinales Utilisées Dans Le Traitement Des Affections Dermatologiques Dans Le Plateau Central Marocain. Journal of Applied Biosciences 98:9252-9260. doi: 10.4314/JAB.V98I1.2

Jeddi S, Mohamed F, Nesrine B, Mohamed J, Naoufal EH, Kawtar FB. 2024. Ethnobotanical Appraisal of Indigenous Medicinal Plants Used in the Taounate Region (Northern Morocco): Qualitative and Quantitative Approaches. Ethnobotany Research and Applications 28. doi: 10.32859/era.28.34.1-26

Kachur K, Zacharias S. 2020. The Antibacterial Properties of Phenolic Isomers, Carvacrol and Thymol. Critical Reviews in Food Science and Nutrition 60:3042-53. doi: 10.1080/10408398.2019.1675585

Karpinski TM. 2020. Essential Oils of Lamiaceae Family Plants as Antifungals. Biomolecules 10. doi: 10.3390/biom10010103

Katara K, Kruti C, Himanshu P, Bharat M. 2023. The Review On Ethnobotanical Concept, History And Traditional Knowledge Of Indigenous Communities Of India And Its Threats. International Association of Biologicals and Computational Digest 2:71-74. doi: 10.56588/IABCD.V2I1.120

Khalil N, Mokhtar B, Samar D, Osama S. 2020. *Ammi visnaga* L., a Potential Medicinal Plant: A Review. Molecules 25:1-18. doi: 10.3390/molecules25020301

Khomsi M, Yousra D, Noureddine C, Driss H. 2022. Ethnobotanical Study of Plants Used for Medicinal, Cosmetic, and Food Purposes in the Region of Moulay Yacoub, Northeast of Morocco. Journal of Pharmacy and Pharmacognosy Research 10:13-29. doi: 10.56499/jppres21.1084_10.1.13

Khoury M, Didier S, Véronique E, Naïm O, Marc EB. 2016. Report on the Medicinal Use of Eleven *Lamiaceae* Species in Lebanon and Rationalization of Their Antimicrobial Potential by Examination of the Chemical Composition and Antimicrobial Activity of Their Essential Oils. Evidence-Based Complementary and Alternative Medicine. doi: 10.1155/2016/2547169

Kingdom of Morocco: Ministry of Interior. Fez-Meknes Regional Direction, Regional Statistical Directory Fez Meknes, Regional Direction; 2016.

Lamine B, Khaldi A, Maghdouri N, Elkadi Z, Benattouche Z, Abbouni B. 2022. Antibacterial Activity of Essential Oils of Inula Viscosa against Some Multi-Resistant *Pseudomonas aeruginosa* ATCC 27853 and *Staphylococcus aureus* ATCC 25923. Egyptian Academic Journal of Biological Sciences. C, Physiology and Molecular Biology 14:399-407. doi: 10.21608/eajbsc.2022.236997

Lamrani-Alaoui M, and Rachida H. 2018. Rapid Risk Assessment to Harvesting of Wild Medicinal and Aromatic Plant Species in Morocco for Conservation and Sustainable Management Purposes. Biodiversity and Conservation 27 (10): 2729-2745. doi: 10.1007/S10531-018-1565-3/METRICS

Maache S, Adel T, Ghizlane N, Yissam L, Karima E, Ilham E, Badiaa L. 2024. Ethnobotanical Knowledge of Medicinal Plants in Fez-Meknes Region: Origin of Used Species, Plant-Disease Associations, Used Parts, and Preparation Forms. Ethnobotany Research and Applications 29. doi: 10.32859/era.29.4.1-20

Marchese A, Ilkay EO, Maria D, Ramona B, Arianna DL, Seyed FN, Olga G, Morteza I, Seyed MN. 2016. Antibacterial and Antifungal Activities of Thymol: A Brief Review of the Literature. Food Chemistry 210:402-414. doi: 10.1016/j.foodchem.2016.04.111

Martin GJ. 2004. Ethnobotany: A Methods Manual. Ethnobotany: A Methods Manual. 1-268. doi: 10.4324/9781849775854

Mechchate H, Imane E, Fatima Zahra J, Amina B, Andriy G, and Dalila B. 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. doi: 10.32859/era.19.12.1-28

Mekkaoui A, Khamar M, Benlakhdar S, Ngadi M, Slimani C, Louafi B, Nounah A, Cherkaoui E, Balafrej T, Rais C. 2024. Traditional Knowledge and Biodiversity of Medicinal Plants in the Taounate Region for Treating Human Diseases: An Ethnobotanical Perspective. Ethnobotany Research and Applications 29. doi: 10.32859/era.29.30.1-22

Mohammed A, Fakchich J, and Elachouri M. 2021. First Insight on Ethnobotanical Appraisal of Plants Used Traditionally as Medicine by Berber Community (Amazigh-Speaking), Living in Driouch Province (North-Eastern Morocco). Ethnobotany Research and Applications 22. doi: 10.32859/ERA.22.24.1-71

Moroccan Ministry of the Interior Wilaya of the Region Fez-Meknes, Monograph of the Region Fez-Menkes, Thèses et Mémoires, C28613/14, Thèse No. DL 1987/489; 2016

Nejjari C, Youness E, Amina B, and Chakib A. 2021. Antimicrobial Resistance among GLASS Pathogens in Morocco: An Epidemiological Scoping Review. BMC Infectious Diseases 22 (438). doi: 10.1186/s12879-022-07412-4

Ngoule CC, Jean-Pierre N, Marie-Cathérine KP, Rosette CN, Siegfried DD, Emmanuel MM. 2015. Inventaire et Caractérisation Floristiques Des Plantes Médicinales à Huiles Essentielles Des Marchés de Douala Est (Cameroun). International Journal of Biological and Chemical Sciences 9:874-889. doi: 10.4314/IJBCS.V9I2.26

Nicoletti R, Maria MS, Pasquale F, Anna A. 2018. Structures and Bioactive Properties of Myrtucommulones and Related Acylphloroglucinols from *Myrtaceae*. Molecules 23. doi: 10.3390/molecules23123370

Nikam K, Sachin B, Mohini S, Pravin W. 2024. An Overview of Techniques for Extracting Bioactive Components from Naturals Sources. Research Journal of Pharmacy and Technology 17:1874-1880. doi: 10.52711/0974-360X.2024.00297

Papaneophytou C, Ilias G, Catalin D. 2019. Resistance of Bacteria, Fungi, and Parasites to Antibiotics or Natural Substances of Botanical Origin. Feed Additives: Aromatic Plants and Herbs in Animal Nutrition and Health. Elsevier Inc. doi: 10.1016/B978-0-12-814700-9.00019-4

Radi M, Said B, Atika A, Fatima ZA, Taha B, Asmaa BA, Nadia H. 2024. Ethnobotanical Study of Medicinal Plants with Therapeutic Interest in the Province of Khemisset, Morocco. Ethnobotany Research and Applications 29. doi: 10.32859/era.29.43.1-22

Salam Md, Abdus Md, Yusuf A, Moushumi TS, Jogendra SP, Naseem A, Ali AR, Mohammed AAA. 2023. Antimicrobial Resistance: A Growing Serious Threat for Global Public Health. Healthcare 11:1-20. doi: 10.3389/fvets.2023.1167847

Salhi N, El Finou H, Halmoune A, Zaid A, El Rhaffari L. 2023. Traditional Knowledge of Medicinal Plants Used for Cosmetic Purposes in The Fez-Meknes Region. Tropical Journal of Natural Product Research 7:5135-154. doi: 10.26538/tjnpr/v7i11.17

Septiadi D, Mohammad AM, Arif W. 2020. The Use Of Medicinal Plants During The Covid-19 Pandemic: Perspective Of Literacy A Nd Consumption Interests For Millennial Generation. JURNAL AGRIBISNIS TERPADU 13:205. doi: 10.33512/JAT.V13I2.9867

Sreekeesoon DP, Fawzi MM. 2014. Ethnopharmacological Analysis of Medicinal Plants and Animals Used in the Treatment and Management of Pain in Mauritius. Journal of Ethnopharmacology 157:181-200. doi: 10.1016/J.JEP.2014.09.030

Tardío J, Manuel PDS. 2008. Cultural Importance Indices: A Comparative Analysis Based on the Useful Wild Plants of Southern Cantabria (Northern Spain). Economic Botany 62:24-39. doi: 10.1007/S12231-007-9004-5

Teixidor-Toneu I, Gary JM, Ahmed O, Rajindra KP, and Julie AH. 2016. An Ethnomedicinal Survey of a Tashelhit-Speaking Community in the High Atlas, Morocco. Journal of Ethnopharmacology 188: 96-110. doi: 10.1016/J.JEP.2016.05.009

Tlemcani S, Amal L, Noureddine E, Ahmed B, Anouar H, Hicham B. 2023. Ethnobotanical Study of Medicinal Plants in the Fez-Meknes Region of Morocco. Journal of Pharmacy and Pharmacognosy Research 11:137-159. doi: 10.56499/jppres22.1459_11.1.137

Wolf D, Thomasina EEO, Uwe S, Noel M, and Danna JL. 2014. CITES Non-Detriment Findings: Guidance for Perennial Plants. A Nine-Step Process to Support CITES Scientific Authorities Making Science-Based Non-Detriment Findings (NDFs) for Species Listed in CITES Appendix II. BfN-Skripten 358. doi: 10.19217/skr716

Zeouk I, Abdelhakim EL, Khadija B. 2019. In Vitro Antibacterial Activity of Medicinal Plants in the Central North of Morocco: A Possible Source of Alternative Drugs Against Methicillin-Resistant *Staphylococcus aureus*. Asian Journal of Pharmaceutical and Clinical Research 12:285-292. doi: 10.22159/ajpcr.2019.v12i3.30395

Zielińska-Błajet M, Joanna FK. 2020. Monoterpenes and Their Derivatives—Recent Development in Biological and Medical Applications. International Journal of Molecular Sciences 21. doi: 10.3390/ijms21197078