Ethnobotanical appraisal of indigenous medicinal plants used in the Taounate region (Northern Morocco): Qualitative and quantitative approaches

Samir Jeddi, Mohamed Ferioun, Nesrine Benkhaira, Mohamed Jeddi, Naoufal El Hachlafi and Kawtar Fikri-Benbrahim

Correspondence

Samir Jeddi[1], Mohamed Ferioun[1,2], Nesrine Benkhaira[1], Mohamed Jeddi[1], Naoufal El Hachlafi[1] and Kawtar Fikri-Benbrahim[1*]

[1]Laboratory of Microbial Biotechnology and Bioactive Molecules, Faculty of Sciences and Technologies Faculty, Sidi Mohamed Ben Abdellah University, P.O. Box 2202, Imouzzer Road, Fez, Morocco.
[2]Laboratory of Natural Resources and Environmental, Faculty of Polydisciplinary of Taza, Sidi Mohamed Ben Abdellah University, Fez, Morocco

*Corresponding Author: kawtar.fikribenbrahim@usmba.ac.ma

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Research

Abstract

Background: For centuries, Moroccan population uses medicinal plants as a primary source of medication to treat different human ailments. However, few investigations have been carried out to properly document and preserve this traditional knowledge. Indeed, this ethnobotanical exploration aims to establish an exhaustive inventory of medicinal plants used by the population of Taounate for the treatment of different diseases.

Methods: Ethnobotanical surveys were carried out with 500 participants distributed equally between different stations. The study participants were selected randomly and subjected to semi-structured interviews, conducted individually over four months from January to April 2023. The socio-demographic features were evaluated using percentages and frequencies in a simple descriptive statistical analysis. However, the ethnobotanical data involved the use of different methods, such as relative frequency of citation (RFC), family importance value (FIV) and plant part value (PPV). In addition, the data analysis was completed using hierarchical cluster analysis to reveal the similarity between plants and rank these plants based on indexes or frequency in treating diseases.

Results: This ethnobotanical survey reported that 112 species of medicinal plants, belonging to 100 genera and 54 botanical families were used for curing a variety of illnesses. Among the 54 families reported, the most predominant are Lamiaceae, with 11 species and a FIV of 22.1%; followed by Apiaceae, with 7 species and a FIV of 1.9% and Asteraceae, with 6 species and a FIV of 8%. Based on hierarchical cluster analysis, Origanum compactum, Rosmarinus officinalis, Salvia officinalis, Pistacia lentiscus and Chenopodium ambrosioides (RFC= 0.366) had the highest values in FC and RFC indexes. Moreover, the heatmap indicates that these plants are primarily used for treating diseases related to the digestive tract (highest ICF values of 0.98). Furthermore, leaves are the most commonly used plant's part (63%), followed by stem (8%), roots (7%), flowers (5%) and

fruit (4%); otherwise, decoction is the most common method (42%), followed by the use of powder (27%) and infusion (13%). The herbal preparation was mainly administered orally (75%).
Conclusion: The current study highlights the widespread use of aromatic and medicinal plants in therapy among the Taounate population, forming an integral part of the traditional healing system. This research aims to enhance Moroccan traditional natural heritage while providing researchers with a valuable ethnobotanical database. The latter can serve as an essential resource for more profound research into phytochemistry and pharmacology.

Keywords: Ethnobotanical survey; medicinal plants; Taounate; Ethnobotanical indexes; clustering dendrogram analysis.

Background

Medicinal plants have been extensively employed as therapeutic agents in folk medicine for numerous years, serving both preventive and curative purposes. Currently, they stand as a significant alternative for treating various diseases and physiological disorders (Tahir *et al*. 2023). In Morocco, traditional healing practices are strongly connected to the history of Arab-Muslim medicine in North Africa's Maghreb region. These practices serve as a historical continuum of Arab-Muslim medicine, with certain applications directly derived from religious texts, remaining relevant to this day. Notable examples include hijâma (Cupping therapy), Ruqyah (Reciting Quran), and phytotherapy (Bouafia *et al.* 2021). In fact, the Moroccan ancestral knowledge regarding medicinal plants plays a pivotal role in shaping the cultural heritage of communities and serves as valuable evidence of their historical connections (Kachmar *et al.* 2021). Consequently, the documentation of this traditional knowledge is an initial phase in discovering novel substances from medicinal plants that can be employed in the development of modern pharmaceutical drugs (El-Assri *et al.* 2021). Besides the insufficient availability of medical services, the prevalence of cultural traditions and the cost-effectiveness of the plant-based remedies were the primary factors contributing to the significant reliance on traditional healing plants in various nations. Indeed, the use of medicinal plants is often influenced by socioeconomic factors, with income levels and education playing pivotal roles in shaping preferences for traditional remedies over conventional healthcare (Edo *et al*. 2023). Due to its unique geographical location, Morocco preserves a remarkably abundant ecological and botanical variety, serving as a genuine repository of plant genetics. It covers about 4.500 species spanning 940 genera and 135 plant families, with the Rif and Atlas mountains are the crucial zones for endemic species (Chaachouay *et al.* 2022). The recording of indigenous knowledge through ethnobotanical studies holds paramount importance for the conservation and effective utilization of biological resources (El Hachlafi *et al.,* 2022). Establishing the local names and indigenous uses of plants carries substantial societal benefits (Benkhaira *et al.,* 2021). A significant portion of Morocco's rural population relies on traditional plant usage, primarily for both nutritional and medicinal purposes (Jeddi *et al*., 2021). Parallel to global trends, there has been a recent surge in research interest focusing on plants traditionally employed for their therapeutic properties in Morocco, mirroring similar developments in other countries across the world.
This work therefore pushes us to establish research questions which are as follows:

- What is the diversity of medicinal plants in the Taounate region, and how are they traditionally utilized to safeguard against various ailments?
- How does the traditional knowledge of medicinal plants in the Taounate region contribute to the cultural heritage of the community?
- What are the factors influencing the reliance on traditional healing plants, considering the insufficient availability of medical services and the cost-effectiveness of plant-based remedies?
- To what extent does the geographical location of Morocco, especially the Rif and Atlas Mountains, contribute to the abundance and uniqueness of medicinal plant species in the Taounate region?
- How do different statistical analysis and quantitative indices help in analyzing and understanding the significance of medicinal plants in the Taounate region?

To answer these questions, this study intends to compile an extensive catalog of medicinal plants used to safeguard against a variety of ailments, according to the traditional knowledge of the Taounate region's inhabitants. Moreover, the data collected are statistically examined using different quantitative indices, including relative frequency of citation (RFC), family importance value (FIV), informant consensus Factor (ICF), plant part value (PPV), and fidelity level (FL).

Materials and Methods

Presentation of the Study area

Taounate, a major city in the Jbala country of Morocco, is home to the Jbala people, characterized as "mountain people." This cultural identity, stemming from their extensive geographical presence, became pronounced despite its geographic origin. Arabized in the 11th century, the Jbalas reflect a pre-Hilalian linguistic heritage. The province boasts a diverse craft industry, including weaving in Oulad Azam, basketry in Moulay Bouchta El Khammar, woodworking in Bni Oulid, and pottery in Aslas. Taounate's economy revolves around natural resources, with agriculture and livestock providing employment for the majority of the rural population. Small businesses, comprising 99.6% of economic units, drive the local economy, employing 95.5% of the permanent workforce. Craft industries, particularly in weaving and basketry, employ a substantial workforce, contributing to the economic vibrancy of the region (Köppen & Geiger 2011).

The Regional Directorate of Water and Forests and Desertification Control of the province of Taounate, located in North-Eastern Morocco, provided the data for the study area. Taounate is a province located in the Pre-Rif region of Morocco, and its geographical coordinates are 34° 32' 9'' N / 4° 38' 24'' W (Figure 1). This region covers an area of 5616 km² within the Fez-Meknes region, encompassing five urban communes and forty-four rural communes. The province has a total population of 662,300, according to the latest census in 2016. The stations studied (Taounate city, Bni Oulid, Zrizer, Bouhouda, Thar Es-Souk and Tamedite) cover an area of 936.47 km², representing almost 0.13% of Morocco's total surface area. The indigenous population is estimated at 124780, giving a population density of 133.24 Inh/km². This density is particularly high for an essentially rural and mountainous region.

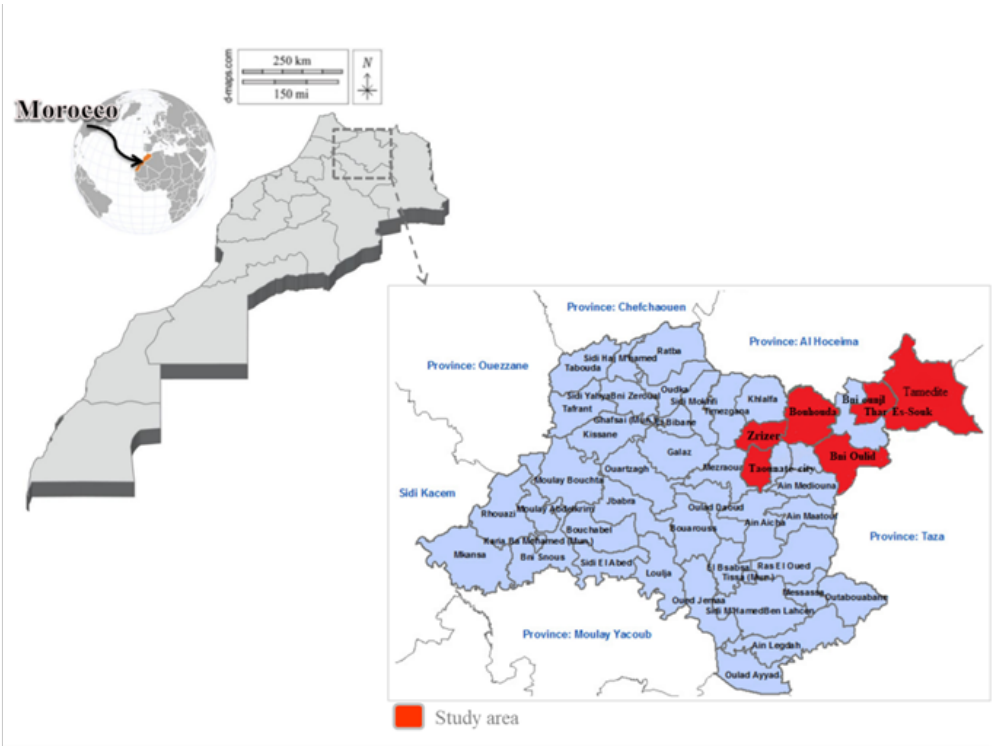

Figure 1. The study area in the North of Morocco.

Most of the inhabitants live in rural areas (90 %), scattered in over 1600 villages. In addition, the inhabitants of this locality share specific customs and traditions that encompass various aspects. The area has a Mediterranean climate, characterized by the cycle of two contrasting periods: a cold and wet winter; and a hot and dry summer. Indeed, temperature averaging 17 °C can surpass 44°C in summer. Jebel Outka can experience a rainfall of 1800 mm, but the average is around 795 mm (Köppen & Geiger 2011).

According to Emberger bioclimatic studies, the province mainly occupies a semi-arid to sub-humid thermo-Mediterranean stage, with cold and rainy winters. However, in the Northern part, Mesomediterranean and even Supramediterranean characteristics can be observed, with conditions ranging from sub-humid to per-humid. The number of months with a dry climate varies between three and five from one year to the next.

The province boasts a wide range of geological formations, including marl, limestone, dolomite, flysch, shale, quartzite, sandstone and gypsum. This geological diversity gives rise to a multitude of soil types in the region, such as feldspathic, calcimagnesic, brown, calcareous, vertic, isohumic, rendzine and even saline soils.

The province of Taounate has a large water reserve, benefiting from the Ouergha and Inaouen rivers, as well as reservoirs such as Asfalou, Idriss 1st, Wahda, Bouhouda and Sahla. This allows the storage of a substantial quantity of water, estimated at around 5.3 billion m^3, in the one hand, and a characteristic abundance of plant resources, including aromatic and medicinal plants, in this area, on the other hand.

The climatic conditions of this region exert a major influence on the development of biodiversity, as well as on the soil's extension and productivity. The predominant plant formations include four Morocco's key forest species: mastic (*Pistacia lentiscus* L.), cedar (*Tetraclinis articulate*.L), the majestic Atlas cedar (*Cedrus atlantica*) and holm oak (*Quercus ilex* L.). These species are complemented by other varieties such as wild fig (*Ficus carica* L.), olive (*Olea europaea* L.), almond (*Prunus dulcis* var.) which are found in association with them.

The selection of six communes and the equitable distribution of interviews were guided by critical considerations. Each commune's representation of distinct ecosystems influencing plant diversity underscored the pivotal role of ecological diversity. To capture unique traditional knowledge, factors such as ethnolinguistic variation and the presence of diverse ethnic groups within each commune were considered. Emphasizing cultural variability aimed to document a spectrum of practices related to medicinal plants. Additionally, geographical factors and accessibility were considered to illuminate the impact of location on plant utilization. Collaborative efforts with engaged communities influenced the selection process, ensuring a comprehensive understanding. The decision to distribute interviews equally aimed at promoting equitable representation and preventing data bias. This survey addressed research gaps in areas with limited ethnobotanical studies, thereby enhancing our understanding of traditional medicinal plant knowledge in the Taounate region.

Ethnobotanical fieldwork

An ethnobotanical survey was carried out using a pre-established questionnaire (Annex 1), covering six communes in the province of Taounate (Taounate city, Bni Oulid, Zrizer, Bouhouda, Thar Es-Souk and Tamedite). 500 participants distributed equally between the different stations (Table 1), were randomly selected and subjected to semi-structured interviews, conducted individually over a four-month period from January to April 2023. During each interview, which generally lasted an hour or more, the questionnaire was structured in two distinct parts; the first section dealt with the informant's profile, addressing such elements as age, family situation, level of education and profession. The second section focused on the plants used, including their nature of use, the parts exploited, methods of diagnosis, preparation, administration and preservation, dosage, toxicity risks, and possible side effects.

Table 1. Distribution of ethnobotanical surveys by station, conducted from January to April 2023.

Province	Survey area	Name of stations	Number of surveys
Taounate	Station 1	Taounate city	83
	Station 2	Bni Oulid	84
	Station 3	Zrizer	83
	Station 4	Bouhouda	84
	Station 5	Thar es-souk	83
	Station 6	Tamedite	83
Total participants			500

Botanical identification of species

Plant identification was carried out by the Botanists of Sidi Mohamed Ben Abdellah University (Fez, Morocco) and then complemented by an extensive literature review (Bellakhdar 1997; Fennane & Ibn Tattou 1999; El-Hilaly et al. 2003; Ajaj et al. 2007; Fakchich & Elachouri 2021). The scientific name of each reported plant was verified using international botanical databases, including The Plant List (https://www.theplantlist.org/) and Encyclopedia of Life (https://eol.org/).

Statistical analysis

After gathering data using field survey forms, the information was manually entered into a database, processed, and statistically analyzed using GraphPad Prism 8.0.1 (GraphPad Software Inc., San Diego, United States) and Microsoft Office

"Excel 2010". Participants' socio-demographic data were evaluated using percentages and frequencies in a simple descriptive statistical analysis. The analysis of ethnobotanical data involved the use of different methods, such as relative frequency of citation (RFC), family importance value (FIV) and plant part value (PPV).

The heatmap clustering figures were created through Euclidean distance to reveal the similarity between plants and rank these plants based on indexes or frequency in treating diseases using Rstudio software (R Core Team, 2018) adopting pheatmap packages. Moreover, principal component analysis (PCA) was carried to reveal the relationship between the use of medicinal plants and sociodemographic characteristics of respondents using XLSTAT statistics version 2016 software.

Relative frequency of citation (RFC)

This index depicts each species' relative importance in the studied area. It is determined by dividing the total number of people interviewed (N) by the number of informants who report the species' use, which corresponds to the frequency of citation (FC). It is calculated according to the formula of Tardio and Pardode-Santayana (1) (Tardío & Pardo-de-Santayana 2008):

$$\mathrm{RFC} = \mathrm{FC}/\mathrm{N} \quad (1)$$

With (0 < RFC < 1)

Family Importance Value (FIV)

The Family Importance Value (FIV) is used to highlight the degree of importance of plant families. It aims to estimate the plants' biological taxonomic value and is calculated as follows (2):

$$\mathrm{FIV} = \mathrm{FC\ family}/\mathrm{NS} \quad (2)$$

FC_{family} = RFC: Number of informants revealing the family

N_s: Total number of species within each family.

Informant Consensus Factor (ICF)

The Informant Consensus Factor (ICF) has been developed to determine the level of concordance between informants regarding the solutions proposed for different sets of diseases (Heinrich et al. 1998; El Hachlafi et al. 2022). This index was determined using the following formula (3):

$$\mathrm{ICF} = \mathrm{Nur} - \mathrm{Nt}/\mathrm{Nur} - 1 \quad (3)$$

Where Nur is the number of reports of a given type of disease, and Nt is the number of plants affected by this type of disease. This index is limited between 0 and 1.

A high ICF value, close to 1, suggests that informants consider the reported plant to be an effective agent against this illness.

Value of the plant part (PPV)

Calculating the plant part value (PPV) makes it possible to assess the frequency of use of each specific plant part. This value is the ratio of the number of uses reported for a given plant part (RUplant part) to the total sum of uses reported for all plant parts (RU) (4) (Gomez-Beloz 2002; Balahbib et al. 2021).

$$\mathrm{PPV} = \mathrm{RUplant\ part}/\mathrm{UR} \quad (4)$$

Fidelity level (FL)

The fidelity level (FL) indicates the effectiveness of a plant species against a specific disease. It is calculated as a percentage based on the number of respondents mentioning the use of a particular plant species to treat a particular disease in the study area (5):

$$\mathrm{FL} = \mathrm{Ip}/\mathrm{Lu} \times 100 \quad (5)$$

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.

The fidelity level (FL) values vary from 0 to 100%. The higher FL (>60%), indicates that the plant is known as single-use. The lower FL (<40%), highlights that the plant is known as multiple-use. Plants with an FL value more than 40% will eventually be taken into account for further preclinical and clinical investigations (Friedman et al. 1986; El Hachlafi et al. 2022).

Results

Sociodemographic characteristics

In the current study, Principal Component Analysis (PCA) was adopted to investigate the relationship between the use of plants and sociodemographic characteristics of respondents. The Biplot created using PCA (Figure 2) showed remarkable variability of the use of plants according to sociodemographic characteristics of respondents. Indeed, the two axes PC1 and PC2 represent 77% (69% for PC1 and 8% for PC2) of the total variation in our data.

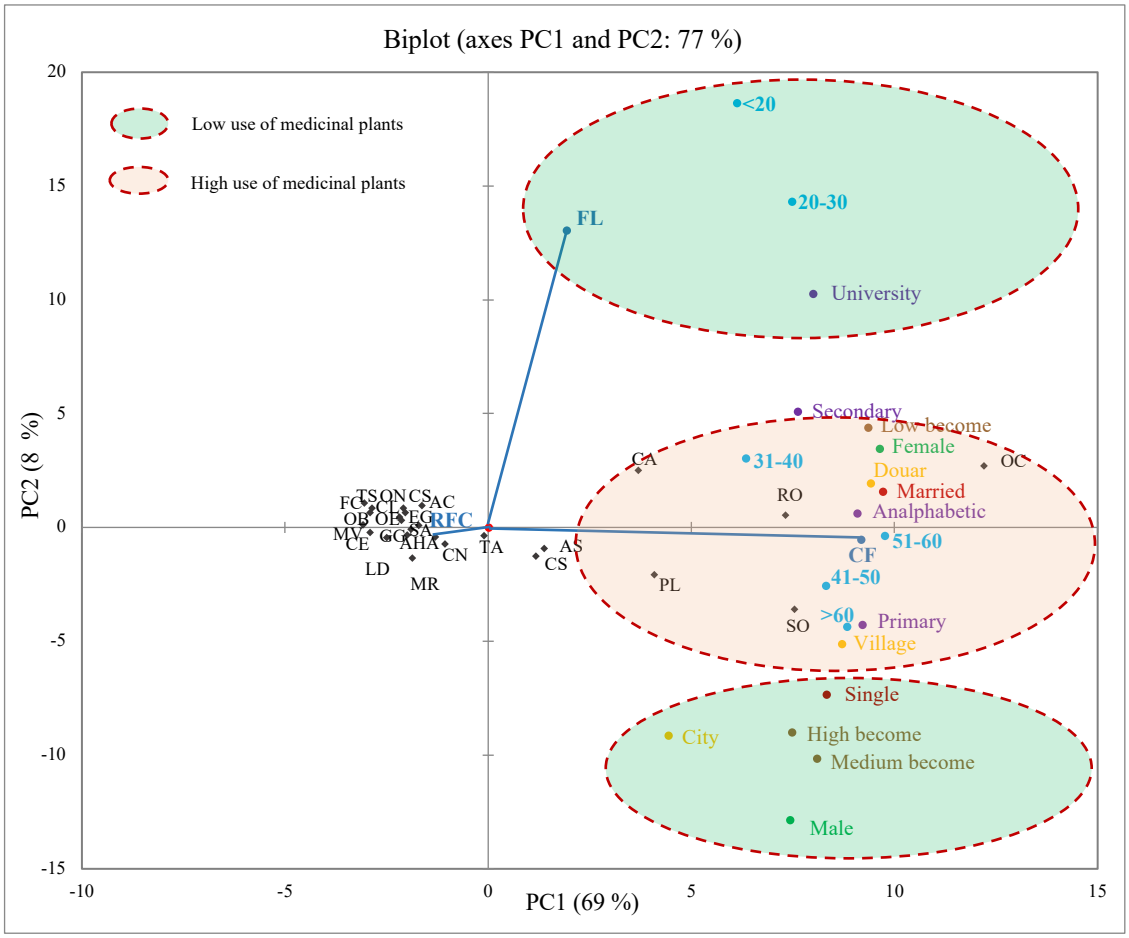

Figure 2. Biplot of Principal component analysis applied to different variables related to the respondents. OC: *O. compactum*, RO: *R. officinalis*, SO: *S. officinalis*, PL: *P. lentiscus*, CA: *C. ambrosioides*, CS: *C. spinosa*, AS: *A. sativum*, AHA: *A. herba-alba*, MR: *M. rotundifolia*, TA: *T. articulata*, EG: *E. globulus*, CN: *C. nobile*, GG: *G. glabra*, MV: *M. vulgare*, TS: *T. satureioides*, CE: *C. erythraea*, ON: *O. natrix*, LD: *L. dentata*, CS: *C. siliqua*, CL: *C. limon*, AC: *A. cepa*, OB: *O. basilicum*, SA: *S. aromaticum*, FC: *F. carica*, OE: *O. europea*.

As can be noticed in figure 2, people with low use of traditional remedies are sharing common attributes, including high educational level (university), and gender-male, high and medium become, age-low and are generally living in city. However, people who commonly used medicinal plants have shown other traits, such as, low become, married, gender-female, living in village, age-medium/age-High and low educational levels (analphabetic, primary). These findings were subsequently confirmed through descriptive statistics using frequency and percentages of each sociodemographic characteristic and may be explained by the following reasons:

- Older people have a significant understanding of the use of medicinal plants and their values.
- Women have better know-how about medicinal plants than men, as they tend to have family responsibilities and make greater use of herbal remedies to care for their families.
- Illiterate people are more interested in medicinal plants, while people with a higher level of education possess less traditional knowledge about medicinal plants.
- Middle- and low-income families try to minimize expenditure on expensive medical examinations and symptomatic treatments.
- People living in douars and villages are closely linked to nature due to poverty and lack of access to health facilities.

Age and gender

According to the age distribution results (Figure 3A), the majority of informants belong to the >50 age group (60%), followed by the 31-50 age group (28%). In contrast, the youngest participants (<30 years) showed little interest in traditional medicine using medicinal plants (4% for 20-year-olds and 8% for 21-30 year-olds). These findings could be attributed to the fact that

older people have a substantial understanding of the use of medicinal plants and their values. This is explained by the share of practical knowledge from generation to generation (El Hachlafi *et al.* 2020; Benkhaira *et al.* 2021). National and international ethnobotanical investigations have corroborated these findings (Lee *et al.* 2019; Iqbal *et al.* 2021).

Of the 500 patients surveyed, 78% were women, while men accounted for 22% (Figure 3B). This underlines the fact that women have better know-how about folk medicine than men, as they tend to have family responsibilities and make greater use of herbal remedies to care for their families. These results are in line with the findings of other research carried out in Messiwa (Al-Haouz region, Morocco) (Ghanimi *et al.* 2022), Moulay Yacoub, north-east Morocco (El Khomsi *et al.* 2022

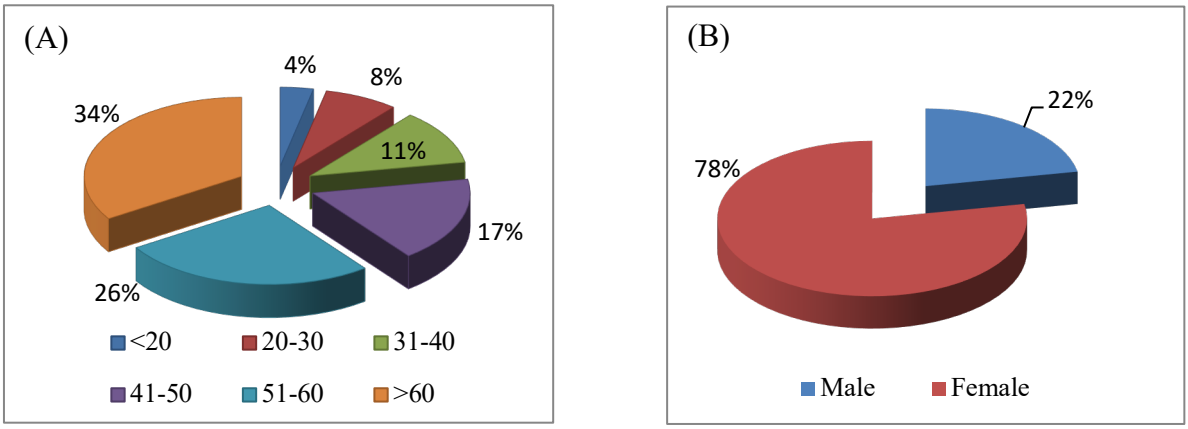

Figure 3. Frequency of medicinal plants used by (A) age value and (B) gender.

In the studied area, illiterate people are more interested in medicinal plants (61%), while 21% of users have a primary education and 14% have a secondary education. On the other hand, people with a higher level of education possess less traditional knowledge about medicinal plants (4%) (Figure 4A). Similar results were obtained in Morocco by El Hachlafi *et al.* (2020), El Yahyaoui *et al.* (2015) ; in Algeria by Boulemtafes *et al.* (2018) and Martin *et al.* (2020); and in Tunisia by Jdaidi and Hasnaoui (2016). Generally, illiterate people often trust on oral traditions and cultural practices for knowledge transfer. Traditional knowledge about medicinal plants is frequently passed down through generations orally. Illiterate individuals may have a closer connection to their cultural heritage, believing and valuing the wisdom embedded in traditional therapeutic practices with the use of medicinal plants. Furthermore, illiterate people typically have limited access to formal education and may lack exposure to modern healthcare system. Without access to scientific information, they may turn to folk medicine, as their primary source of healthcare. Additionally, the lack of awareness about pharmaceutical options and healthcare advancements may contribute to a preference for traditional remedies.

The studied medicinal plants are widely used by married individuals with a significant percentage of 82%, whereas among single people, the use of these plants does not exceed 18%, as shown in Figure 4B. This could be explained by the fact by marriage often involves resource-sharing arrangements. In the context of medicinal plant usage, married individuals may have access to a broader range of resources, including financial means for purchasing plants or the physical resources required for cultivation. This contrasts with the potentially more limited resources available to single individuals. Moreover, married individuals may be part of a cultural context where knowledge about medicinal plants is transmitted more effectively between generations. The passing down of traditional practices within the family unit, especially from older generations to married individuals, could contribute to the observed difference in plant usage. These findings are similar to the majority of previous investigations conducted in different regions of Morocco (El Alami *et al.* 2016; Benkhaira *et al.* 2021; El-Assri *et al.* 2021; Jeddi *et al.* 2021). They suggest that middle- and low-income families try to minimize expenditure on expensive medical examinations and symptomatic treatments, as reported by Hafsé *et al.* (2015); and Chraibi *et al.* (2018).

In this survey, most of the respondents have a low socio-economic level (64%), followed by those with a medium socio-economic level (32%), while only 4% fall into the high socio-economic category (Figure 5A). In terms of locality, the results mentioned in Figure 5B revealed that 74% of informants lived in rural areas (Douar), while 26% lived in urban areas. This result can be explained by the fact that people living in Douars and villages are closely linked to nature due to poverty and lack of access to health facilities (Kharchoufa *et al.* 2021; El Hachlafi *et al.* 2022; Jeddi *et al.* 2023).

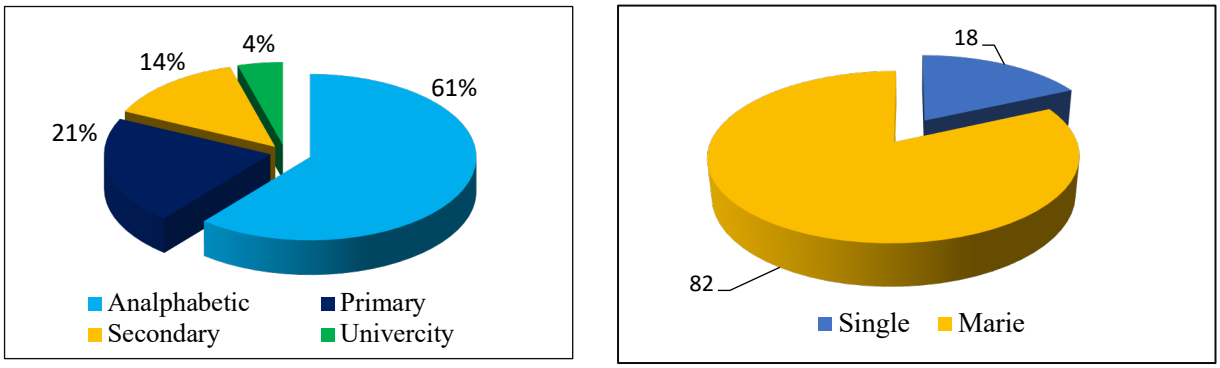

Figure 4. Frequency of medicinal plants used by (A) education level and (B) Family situation.

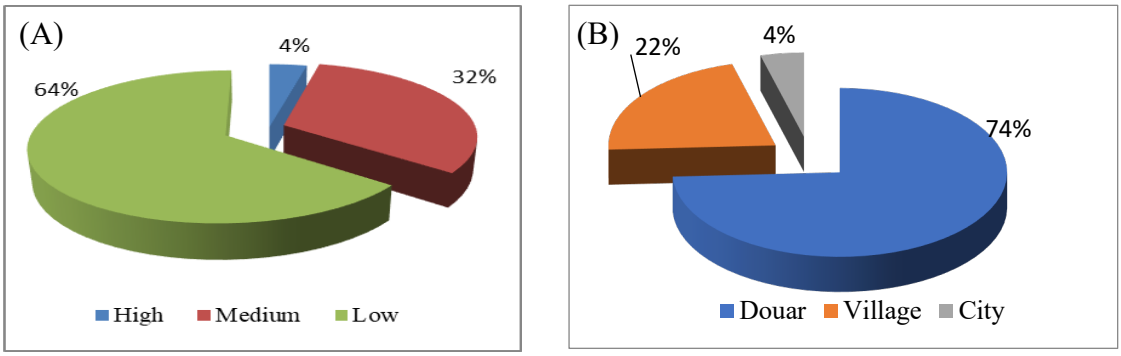

Figure 5. Frequency of medicinal plants used according to (A) income criteria and based (B) on locality.

Floristic analysis

Taounate region is rich in biodiversity and has a large number of medicinal plants. In the current study, the ethnobotanical survey in the Taounate region discovered 112 species of medicinal and aromatic plants utilized for curing a variety of illnesses, belonging to 100 genera and 54 botanical families. All the listed plants are presented in Table 2, including botanical family, scientific name, vernacular name and English name, preparation method, used part, frequency of citation (FC), Fidelity level (FL), family importance value (FIV) and relative frequency of citation (RFC) for each one.

Among the 54 families reported, the most predominant are Lamiaceae, with 11 species and a FIV of 22.1%; followed by Apiaceae, with 7 species and a FIV of 1.9%; Asteraceae, with 6 species and a FIV of 8%; Fabaceae, with 5 species and a FIV of 9.4%; Amaryllidaceae, with 5 species and a FIV of 9.1%; Poaceae, with 4 species and a FIV of 1.4%; and Lauraceae, with 3 species and a FIV of 1.2% (Table 2 and Figure 7). The dominance of these seven families can be explained by their ubiquity and wide distribution in Morocco. Other ethnobotanical studies have confirmed the preponderance of the main families mentioned above (Chaachouay *et al.* 2019; El Hachlafi *et al.* 2020; Fakchich & Elachouri 2021; Numpulsuksant *et al.* 2021).

The RFC expresses the frequency of use of each plant, with values ranging from 0.004 to 0.664. There is a marked predominance of some of the most used species, *Origanum compactum* (RFC=0.664), *Rosmarinus officinalis* (RFC= 0.496), *Salvia officinalis* (RFC= 0.492), *Pistacia lentiscus* (RFC= 0.370), *Chenopodium ambrosioides* (RFC= 0.366), *Chenopodium ambrosioides* L. (RFC= 0.286), *Allium sativum* L. (RFC= 0.274) and *Artemisia herba-alba Asso* (RFC= 0.286).

The percentages of the most commonly used plant species recorded in the study area vary from 1.1% to 8.7%, with a marked predominance of the following species: *Origanum compactum* (8.7%), *Rosmarinus officinalis* (6.5%), *Salvia officinalis* (6.4%), *Pistacia lentiscus* (4.8%), *Chenopodium ambrosioides* (4.7%), *Capparis spinosa* (3.7%), *Allium sativum* (3.6%) and *Artemisia herba-alba* (2.6%) (Figure 8). The results obtained are similar to those found in other research conducted in Morocco, with only a few small differences (Hseini & Kahouadji 2007; Fadili *et al.* 2017).

Fidelity level (FL)

The fidelity level (FL) was calculated by considering only plants mentioned more than five times to treat a specific disease. Analysis of the data reveals that FL values vary between 6% and 100%. More than 43 species show a level of fidelity of 100%.

These species are used to treat various health problems. For the digestive tract (TD) diseases, there are 17 species, including *Rosmarinus officinalis, Thymus satureioides, Chamaerops humilis, Punica granatum, Pistacia lentiscus, Pistacia atiantica, Cuminum cyminum, Aristolochia longa,* and *Quercus suber*. 15 plants are used for dermatological problems (DR), including *Urginea maritima, Cannabis sativa, Lawsonia inermis, Ruta montana, Vitex agnus-castus, Agave americana, Silybum marianum,* and *Juglans regia.* Four species are used for osteoarticular (OS) disorders: *Carum carvi, Pennisetum glaucum, Cynodon dactylon,* and *Peganum harmala*. Three other plants are used for respiratory problems (RS): *Papaver rhoeas, Elettaria cardamomum* and *Linum usitatissimum.* Only one plant is used for neurological disorders (NR): *Brassica rapa*. For cancer diseases (CN), one species *Cinnamomum camphora* is used. Concerning digestive glands problems (GA), one species is used, *Solanum nigrum*. Finally, *Citrus limon* is implicated in the treatment of otorhinolaryngology ailments (ORL) (Table 2). These findings can be attributed to the relevance and efficacy of the plants in the region. The lowest FL values observed for two species, *Syzygium aromaticum* and *Eucalyptus globulus*, can be explained by their diverse use within the population studied and by their therapeutic versatility.

The heatmap shown in Figure 6 was created to provide an exhaustive overview of the ranking of plants described in the current study based on the variability of FL%, FC, and RFC indexes. *O. compactum, S. officinalis, R. officinalis, P. lentiscus,* and *C. ambrosioides* had the highest values in FC and RFC indexes. *C. spinosa* and *A. sativum* had moderate FC and RFC index values. However, *A. americana, J. regia, A. rubra, Q. suber, C. cyminum, C. ladaniferus, O. natrix, G. glabra, T. satureioides, C. siliqua, C. limon, P. atlantica, A. absinthium, R. alaternus*, and *T. foenum graecum* had important FL% values but scored low in FC and RFC index values.

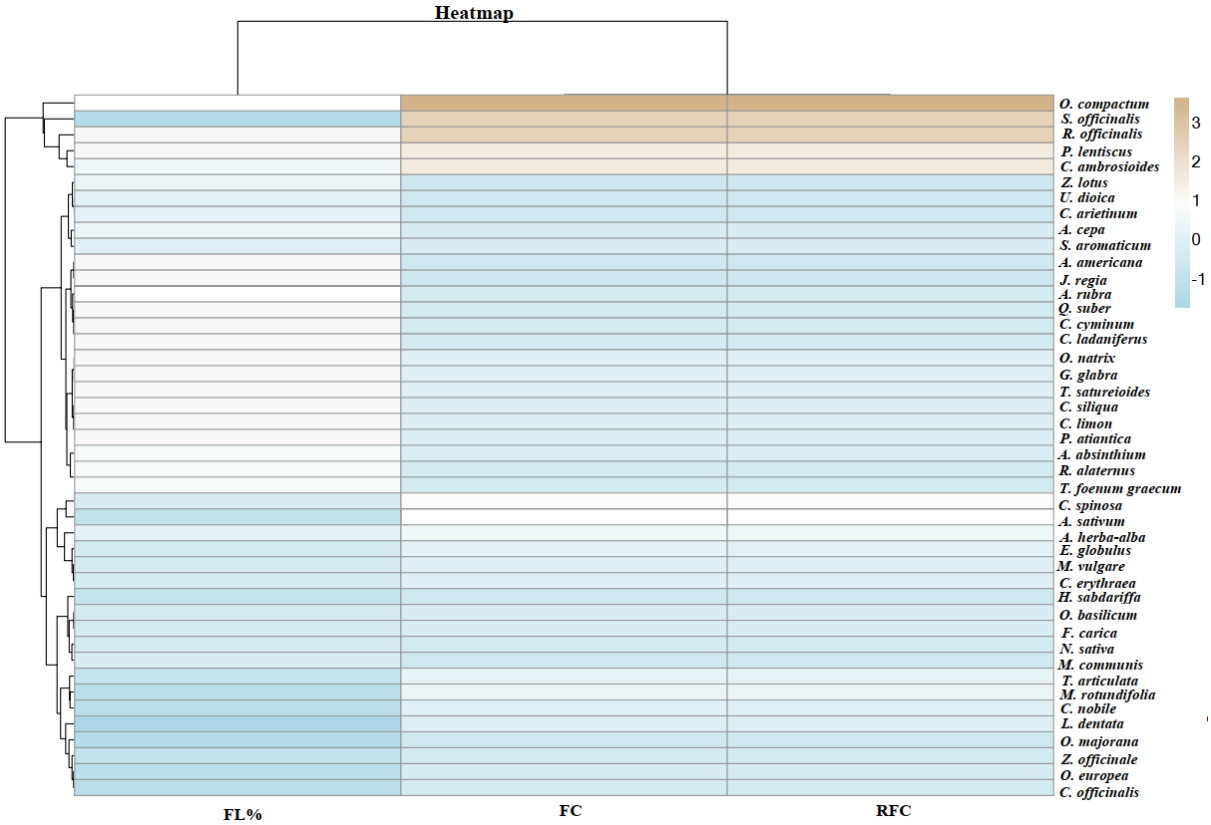

Figure 6. Heat map showing clustering dendrogram based on FL%, FC, and RFC indexes.

Table 2. List of medicinal plants reported in Taounate region.

Family	Scientific name	Vernacular name Arabe (English)	Voucher codes	Preparation methods	Used part	CTD	FC	RFC	FIV	FL(%)
Agavaceae	*Agave americana* L.	Sabra (Century Plant)	BLUMP 397	Juice	Leaves	Spoon	25	0.050	0.050	100%DR
Amaranthaceae	*Beta vulgaris* L.	Lbarba (Beetroot)	BLUMP 398	Dec/Inf/In/Ex	Leaves	Glass	7	0.014	0.014	100%TD
Amaryllidaceae	*Allium cepa* L.	Bessla (Onion)	BLUMP 399	Inf/Dec/In	Bulbs	1 Units	47	0.094	0.091	80%ORL+20%AC
	Allium porrum L.	Kurrat –Borjel (Leek)	BLUMP 400	Inf	Bulbs	3 Units	11	0.022		60%RS+30%AC+20%DR
	Allium sativum L.	Toma (Garlic)	BLUMP 401	Dec/Mac/In	Bulbs	4 Units	137	0.274		45%RS+37%AC+12%OA+8%DR
	Asphodelus microcarpus Salzm.	Berwag (Onion Weed)	BLUMP 402	Inf/Dec/In	Bulbs	1 Units	18	0.036		18%RS+82%DR
	Urginea maritima L.	Bessil (White Squill)	BLUMP 403	Dec/Mac/In	Bulbs	1 Units	15	0.030		100%DR
Anacardiaceae	*Pistacia atiantica* Desf.	Btem (Atlas Pistachio)	BLUMP 404	Pow/Dec/Ex	Leaves / Bark	Handful	52	0.104	0.169	100%TD
	Pistacia lentiscus L.	Drou (Mastic plants)	BLUMP 405	Pow/Dec/Ex	Leaves / Bark	Handful	185	0.370		100%TD
	Rhus pentaphylla Desf.	Teezra (Searsia pentaphylla)	BLUMP 406	Cat	Leaves	Ointment	17	0.034		ND
Apiaceae	*Ammi Majus* L.	Bouchnikha (Bishop's Flower)	BLUMP 407	Inf/Dec/In	Seeds	Glass	6	0.012	0.019	50%DR+25%TD+25%CN
	Apium graveolens L.	Krafess (Celery)	BLUMP 408	Dec	Leaves	Glass	4	0.004		75%TD+25%OA
	Carum carvi L.	Karweya (Caraway)	BLUMP 409	Inf	Seeds	Glass	2	0.004		100%OA
	Coriandrum sativum L.	Kesbour (Coriander)	BLUMP 410	Pow	Roots	Ointment	9	0.018		80%GU+20%TD
	Cuminum cyminum L.	Kamoun (Cumin)	BLUMP 411	Pow/In	Seeds	Spoon	32	0.064		100%TD

	Daucus carota L.	Khizzou (Carrot)	BLUMP 412	Nature	Roots	Units	5	0.010		100%DR
	Foeniculum vulgare L.	Nafaa (Fennel)	BLUMP 413	Dec	Seeds	Seeds	13	0.026		90%TD+10%CN
Apocynaceae	*Nerium oleander* L.	Defla (Oleander)	BLUMP 414	Dec/Ex	Flowers/ Leaves	Handful	13	0.026	0.026	60%DR+40%TD
Arecaceae	*Chamaerops humilis* L.	Doom (European fan palm)	BLUMP 415	Inf	Fruits	Glass	7	0.014	0.014	100%TD
Aristolochiaceae	*Aristolochia longa* L.	Berztem (Pipevine)	BLUMP 416	Dec/Pow/In /Ex	Whole plant	Spoon**/**pin ch	8	0.016	0.016	100%TD
Asteraceae	*Artemisia absinthium* L.	Chiba (Wormwood)	BLUMP 417	Inf	Aerial parts	Glass	52	0.104	0.080	90%TD+10%DR
	Artemisia herba-alba Asso.	Chih (White mugwor)	BLUMP 418	Inf/Dec/In/E x	Aerial parts	Spoon	101	0.202		75%TD+ 25%CN
	Chamaemelum nobile L.	Babonj (Chamomile)	BLUMP 419	Inf/In	Flowers	Spoon	67	0.134		40%TD+30DR+40%NR
	Dittrichia viscosa L.	Baygaman (False yellowhead)	BLUMP 420	Dec/Pow	Aerial parts	Ointment	13	0.026		68%DR+32%TD
	Saussurea costus Falc.	AL-Hindi (Indian costus)	BLUMP 421	Pow/In	Whole plants	Pinch	2	0.004		60%TD+40%OA
	Silybum marianum L.	Taymant (Milk Thistle)	BLUMP 422	Inf/ Dec/In/Ex	Aerial parts	Spoon	7	0.014		100%DR
Brassicaceae	*Brassica rapa* L.	Left (Turnip Rape)	BLUMP 423	Inf/Dec	Leaves	Glass	7	0.014	0.014	100%NR
	Lepidium sativum L.	Hab-errachad (Garden cress)	BLUMP 424	Pow/Mac/In	Seeds/Leav es	Pinch	11	0.022		80%OA+20%TD
	Sinapis arvensis L.	Khardal (Wild Mustard)	BLUMP 425	Inf/Dec	Leaves	Spoon	3	0.006		ND
Cactaceae	*Opuntia ficus-indica* L.	Lhendya (Barbary fig)	BLUMP 426	Dec/Inf/In/E x	Whole plants	Glass	51	0.102	0.102	70%TD+20%DR+15%OA
Cannabinaceae	*Cannabis sativa* L.	El-kif (Hemp)	BLUMP 427	Cat	Seed	Spoon	17	0.034	0.034	100%DR
Capparaceae	*Capparis spinosa* L.	Kebbar (Inders rose)	BLUMP 428	Pow/Ex	Leaves/ fruits	Spoon	143	0.286	0.286	65%OA+18TD+17%GU

Caryophyllaceae	*Arenaria rubra* L.	Herras lehjar	BLUMP 429	Pow	Leaves	Glass	37	0.074	0.037	96%GU+5%DR
	Corrigiola telephiifolia Pourr.	Sarghina (Corrigiola)	BLUMP 430	Dec/In	Whole plants	Spoon	14	0.028		100%TD
	Saponaria officinalis L.	Tighicht/Saponia (Soapwort)	BLUMP 431	Cat	Leaves/ Roots	Ointment	5	0.010		ND
Chenopodiaceae	*Chenopodium ambrosioides* L.	Mkhinza (Sweet pigweed)	BLUMP 432	Dec/In/Ex	Leaves	Spoon	183	0.366	0.366	82%MT+20%NR
Cistaceae	*Cistus ladaniferus* L.	Touyalte (Gum Rockrose)	BLUMP 433	Inf/ Dec	Leaves	Glass	32	0.064	0.064	ND
Cucurbitaceae	*Citrullus colocynthis* L.	Hantel (Colocynth Colocynth)	BLUMP 434	Inf	Seeds	Glass	13	0.026	0.026	36%TD+27%CN+33%OA
Cupressaceae	*Tetraclinis articulata* Vahl.	El A'râr (Arartree)	BLUMP 435	Pow/Inf	Leaves	Coffee spoon	80	0.160	0.160	50%OA+30%NR+20%TD
Ephedraceae	*Ephedra alata* Decne.	Andla (Ephedra)	BLUMP 436	Pow/Cat/In/ Ex	Leaves	Spoon	3	0.006	0.006	50%CN+50%MT
Ericaceae	*Arbutus unedo* L.	Bakhano, Sasno (Strawberry Tree)	BLUMP 437	Dec	Roots	Spoon	7	0.014	0.014	60%TD+20%RS+20%GU
Fabaceae	*Ceratonia siliqua* L.	El kharob (Carob)	BLUMP 438	Pow	Fruit	Spoon	56	0.112	0.094	100%TD
	Cicer arietinum L.	Hemmes (Chickpea)	BLUMP 439	Pow	Seeds	Spoon	23	0.046		ND
	Glycyrrhiza glabra L.	Araq-sus (Licorice)	BLUMP 440	Pow/Dec	Roots/Stems	Handful	63	0.126		100%DR
	Ononis natrix L.	Afezzaz (Yellow restharrow)	BLUMP 441	Inf/Dec	Aerial parts	Spoon	61	0.122		100%DR
	Trigonella foenum graecum L.	Holba (Fenugreek)	BLUMP 442	Pow	Seeds	Spoon	32	0.064		90%TD+15%CN
Fagaceae	*Quercus suber* L.	Bellout (Cork Oak)	BLUMP 443	Pow/Dec	Flower/ Seeds	Spoon	36	0.072	0.047	100%TD
	Quercus ilex L.	Korrich (Holm Oak)	BLUMP 444	Dec	Roots	Coffee spoon	11	0.022		100%TD
Gentianaceae	*Centaurium erythraea* Rafn.	Kost lhaya (Common centaury)	BLUMP 445	Pow	Flowers	Ointment	62	0.124	0.124	63%DR+45%CN

Iridacées	*Crocus sativus* L.	Safran (Saffron)	BLUMP 446	Pow/In/Ex	Roots	Spoon	14	0.028	0.028	100% TD
Juglandaceae	*Juglans regia* L.	Sswâk, Gargae (walnut)	BLUMP 447	Other	Bark	Pinch	21	0.042	0.042	100%DR
Juncaceae	*Juncus acutus* L.	Azlaaf (Spiny Rush)	BLUMP 448	Pow/Cat/In/ Ex	Rhizomes	Glass	15	0.030	0.030	46%TD+20%DR+40%OA
Lamiaceae	*Ajuga iva* L.	Chendgora (Bugle)	BLUMP 449	Dec/Inf/In	Leaves	Pinch	12	0.024	0.221	10%RS+62%TD+30%OA
	Calamintha officinalis L.	Manta (Calamint)	BLUMP 450	Dec/In/Ex	Aerial parts	Glass	37	0.074		40%RS+35%TD+20%OA
	Lavandula dentata L.	Lakhzama (Fringed lavender)	BLUMP 451	Dec/In	Leaves	Spoon	58	0.116		27%RS+16%TD+22%OA
	Marrubium vulgare L.	Merriwta (White horehound)	BLUMP 452	Dec/In/Ex	Aerial parts	Glass	63	0.126		60%TD+20%CR+10%RS
	Mentha rotundifolia Muds.	Marseta (round leaved mint)	BLUMP 453	Inf/Dec	Leaves	Spoon	89	0.178		20%RS+34%TD+40%OA
	Ocimum basilicum L.	Lahbak (Basil)	BLUMP 454	Inf	Leaves	Glass	47	0.094		60%NR+20%DR+30%TD
	Origanum compactum Bentham.	Zaatar (Oregano)	BLUMP 455	Dec/ Inf/In	Aerial parts	Handful	332	0.664		10%RS+95%TD
	Origanum majorana L.	Merdedûch (Marjoram)	BLUMP 456	Inf/ Dec	Whole plante	Glass	23	0.046		33%GU+33%OA+33%NR
	Rosmarinus officinalis L.	Iklil aljabal, Azir (Rosemary)	BLUMP 457	Dec/Inf/In	Aerial parts	Pinch	248	0.496		100%TD
	Salvia officinalis L.	Ssâlmya (Sage)	BLUMP 458	Inf/ Dec/In	Leaves	Glass	246	0.492		15%RS+20%TD+20%OA+35%CN
	Thymus satureioides Coss.	Z'îtra (Thyme)	BLUMP 459	Inf	Leaves	Glass	62	0.124		100%TD
Lauraceae	*Cinnamomum camphora* L.	Kafour (Camphor)	BLUMP 460	Fum/Ex	Whole plant	Spoon	4	0.008	0.012	100%CN
	Cinnamomum zeylanicum Nees.	Kerffa (Cinnamon)	BLUMP 461	Pow	Bark	Spoon	12	0.024		60%AC+20%+25%CN
	Laurus nobilis L.	Rrend (Laurel)	BLUMP 462	Inf/Dec	Leaves	Glass	3	0.006		50%TD+50%NR

Linaceae	*Linum usitatissimum* L.	Zeriit-lktan (Flax seed)	BLUMP 463	Pow/In/Ex	Seeds	Spoon	3	0.006	0.006	100%RS
Lythraceae	*Lawsonia inermis* L.	Henna (Henna plant)	BLUMP 464	Pow	Leaves	Pinch	16	0.032	0.029	100%DR
	Punica granatum L.	Rummân (Pomegranate)	BLUMP 465	Dec	Bark	Glass	13	0.026		100%TD
Malvaceae	*Hibiscus sabdariffa* L.	Karkadi (Roselle)	BLUMP 466	Inf	Flower	Glass	23	0.046	0.035	ND
	Malva sylvestris L.	Khobbeysa (Mallow)	BLUMP 467	Cat	Leaves	Ointment	12	0.024		64%TD+36%DR
Moraceae	*Ficus carica* L.	Karmous-Chriha (Fig)	BLUMP 468	Pow/In	Fruits	Spoon	45	0.090	0.090	35%RS+62%TD+5%DR
Myrtaceae	*Eucalyptus globulus* Labill.	Kalitos (Blue Gum)	BLUMP 469	Dec/Inf/In	Leaves	Glass	73	0.146	0.094	60%RS+15%NR+6%CN+15%TD
	Myrtus communis L.	Rihan (Myrtle)	BLUMP 470	Dec	Leaves	Pinch	23	0.046		65%NR+15%DR+40%TD
	Syzygium aromaticum L.	Qronfel (Clove)	BLUMP 471	Inf/Dec	Seeds	4 Units	46	0.092		72%RS+21%DR+6%NR
Oleaceae	*Olea europea* L.	Berri (Olive tree)	BLUMP 472	Cat	Leaves /Seed	Spoon	42	0.084	0.084	16%TD+20%AC+8%DR+40%CN
Papaveraceae	*Glaucium flavum* Crantz.	Merzak Halabi (Yellow-horned poppy)	BLUMP 473	Inf	Flower	Glass	2	0.004	0.011	ND
	Papaver rhoeas L.	Bela'man (Red Poppy)	BLUMP 474	Inf	Flower	Glass	9	0.018		100%RS
Pinaceae	*Cedrus atlantica* Endl.	Arze (Atlas Cedar)	BLUMP 475	Cat	Leaves	Ointment	4	0.008	0.016	100%DR
	Pinus halepensis Mill.	Taydâ (Aleppo Pine)	BLUMP 476	Cat	Leaves	Ointment	18	0.036		35%TD+30%NR+35%OA
	Pinus pinaster Aiton.	Tayda (Cluster Pine)	BLUMP 477	Cat	Leaves	Ointment	3	0.006		35%TD+30%NR+35%OA
Poaceae	*Avena sativa* L.	Khortal (Oat Straw)	BLUMP 478	Pow/ Dec	Seeds	Spoon	2	0.004	0.014	43%MT+57%TD
	Cynodon dactylon L.	Nejm (Bahama Grass)	BLUMP 479	Inf	Rhizome	Glass	5	0.010		100%OA

	Hordeum vulgare L.	Chaaiir (Barley)	BLUMP 480	Pow	Seeds	Spoon	3	0.006		90%GU+10%DR
	Pennisetum glaucum L.	Yellan (Pearl millet)	BLUMP 481	Pow	Seeds	Pinch	19	0.038		100%OA
Polygonaceae	*Emex spinosa* L.	Houmida (Spiny emex)	BLUMP 482	Inf/Dec/In	Root	Spoon	7	0.014	0.014	ND
Ranunculaceae	*Clematis flammula* L.	Nar el-barda (Sweet Autumn Clematis)	BLUMP 483	Pow/Dec/In /Ex	Leaves	Spoon	3	0.006	0.034	50%DR+50%OA
	Nigella sativa L.	Sanouj (Black cumin)	BLUMP 484	Pow/Dec	Seeds	Spoon	31	0.062		60%TD+40%RS
Rhamnaceae	*Rhamnus alaternus* L.	Sedra dlbhar (Alaternus)	BLUMP 485	Pow/ Dec	Root/Seeds	Spoon	32	0.064	0.053	90%TD+10%DR
	Ziziphus lotus L.	Sedra, Nbeg (Lotus Jujube)	BLUMP 486	Pow/Dec/In /Ex	Leaves/See ds	Spoon	21	0.042		80%TD+15%OA+5%DR
Rosaceae	*Prunus amygdalus* Dulcis.	Louz lmer (Almond)	BLUMP 487	Pow/Dec/Ex	Seeds	Spoon	12	0.024	0.022	50%CN+30%TD+16%
	Prunus persica L.	Lkhokh (Peach)	BLUMP 488	Inf/Dec/In	Leaves	Glass	4	0.008		ND
	Rosa centrifolia L.	Lwerd lbeldi (Cabbage Rose)	BLUMP 489	Pow/ Inf/ Ex	Flower	Glass	17	0.034		30%TD+46%DR+25%NR
Rutaceae	*Citrus limon* L.	Limon, Elhamed (Lemon)	BLUMP 490	Juice	Fruits	Glass	53	0.106	0.062	100%ORL
	Ruta montana L.	Fiijel (Mountain Rue)	BLUMP 491	Inf/Dec/In	Leaves	Glass	9	0.018		100%DR
Salicaceae	*Populus alba* L.	Sefsaf (White Poplar)	BLUMP 492	Dec	Leaves	Spoon	13	0.026	0.015	50%DR+50%CN
	Populus nigra L.	Sefsaf (Black Poplar)	BLUMP 493	Dec	Leaves	Spoon	2	0.004		80%DR+20%CN
Sapotaceae	*Argania spinosa* L.	Argane (Argan)	BLUMP 494	Pow/Cat/In/ Ex	Fruits	Glass	7	0.014	0.014	100%DR
Solanaceae	*Solanum melongena* L.	Denjal (Aubergine)	BLUMP 495	Cooked	Fruits	1Units	5	0.010	0.011	100%DR
	Solanum nigrum L.	Boqnîna (Nightshade)	BLUMP 496	Inf	Leaves	Spoon	6	0.012		100%GA

Theaceae	*Camellia sinensis* L.	Atay (Tea)	BLUMP 497	Inf	Leaves	Glass	4	0.008	0.008	100%TD
Thymelaeaceae	*Thymelaea lythroides* Murb.	Metnane (Spiny Spurge)	BLUMP 498	Inf	Aerial parts	Glass	13	0.026	0.026	90%RD+10%NR
Urticaceae	Urtica dioica L.	L-hurrîga (Common nettle)	BLUMP 499	Dec/Cat/In/ Ex	Aerial parts	Handful	25	0.050	0.050	75%AC+25%OA
Verbenaceae	*Lippia citriodora* H.	Lwiza (Lemon Verbena)	BLUMP 500	Inf	Leaves	Glass	11	0.022	0.015	46%NR+32%OA+23%TD
	Vitex agnus-castus L.	ELkharwaâ (Chaste Tree)	BLUMP 501	Inf	Leaves	Glass	4	0.008		100%DR
Viscaceae	*Viscum cruciatum* Sieber.	Lenjbar (European Mistletoe)	BLUMP 502	Pow/In	Aerial parts	Pinch	3	0.006	0.006	100%DR
Vitaceae	Vitis vinifera L.	Dalya (Grapevine)	BLUMP 503	Inf	Leaves	Glass	5	0.010	0.010	100%TD
Zingiberaceae	*Curcuma xanthorrhiza* Roxb.	Kharcoum (Javanese Turmeric)	BLUMP 504	Pow	Rhizomes	Spoon	17	0.034	0.036	100%TD
	Elettaria cardamomum L.	Qaaqella (Cardamom)	BLUMP 505	Dec	Seeds	Spoon	3	0.006		100%RS
	Zingiber officinale Roscoe.	Skinjbir (Ginger)	BLUMP 506	Pow/In	Rhizomes	Glass	35	0.070		35%RS+45%TD+15%NR
Zygophyllaceae	*Peganum harmala* L.	Lharmel (Syrian Rue)	BLUMP 507	Cat	Seeds	Spoon	2	0.004	0.004	100%OA

RS: Respiratory diseases;TD: Digestive diseases; DR: Dermatological diseases; OS: Osteoarticular diseases; MT: Metabolic disorder; NR: Neurological diseases; GU: Genito-urinary diseases; CN: Cancer; GA: Glands of the Digestive diseases; ORL: Otorhino-laryngologie; CV: Cardiovascular diseases; AC: Cirulatory system; ND= Not Determined; Dec: Decoction; Cat: Cataplasm; Pow: Powder; In: Inhalation; Ex: Extration; Inf: Infusion; Mac: Maceration; CTD= Common traditional dosages.

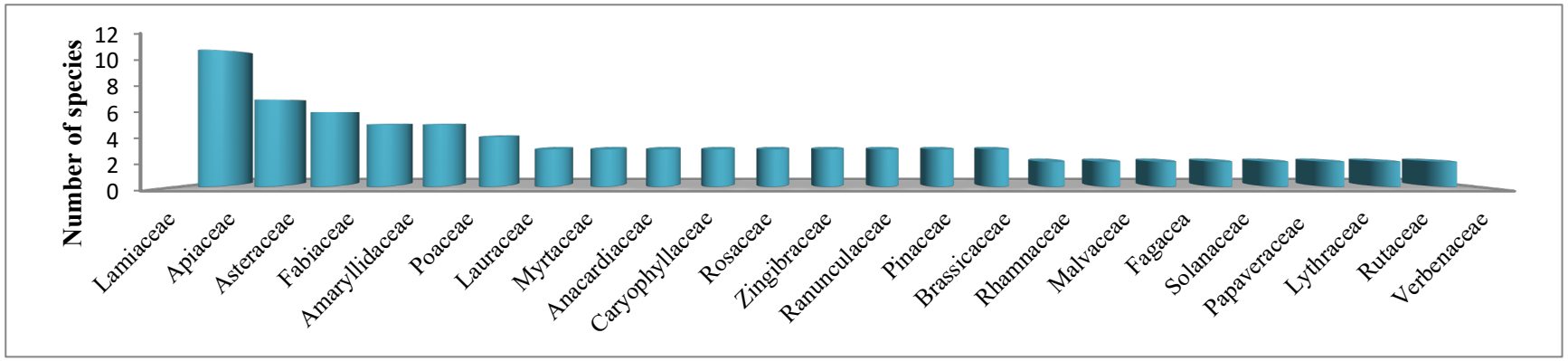

Figure 7. Number of species declared by family.

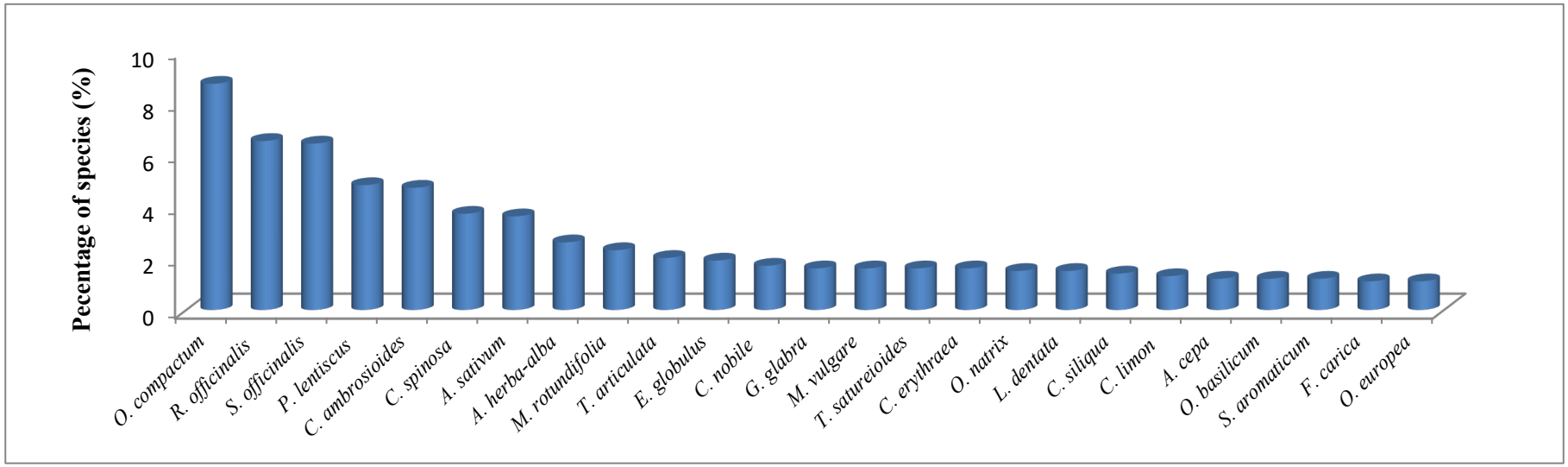

Figure 8. percentage of the most used species in the stations.

Alternative and complementary medicine based on scientific evidence

Plants parts used

In order to facilitate the ethnobotanical study of plants in different stations of Taounate, we noted that the interviewers use a total of 10 plant parts. Leaves are the most commonly used part (63%), followed by stems (8%), roots (7%), flowers (5%) and fruits (4%). Other parts such as bark, seeds, rhizomes, the whole plant and others are used less frequently, with percentages ranging from 1% to 3% (Figure 9). These results are consistent with other studies conducted in Morocco and Algeria, which have also shown that the leaves are the most commonly used part (Bouasla & Bouasla 2017; El-Assri *et al.* 2021). In the Taounate region, people prefer to use the leaves because they believe they are rich in active ingredients. In addition, the leaves are the site of photosynthesis and thereby the storage of various bioactive molecules with promising pharmacological properties (El Hachlafi *et al.* 2022).

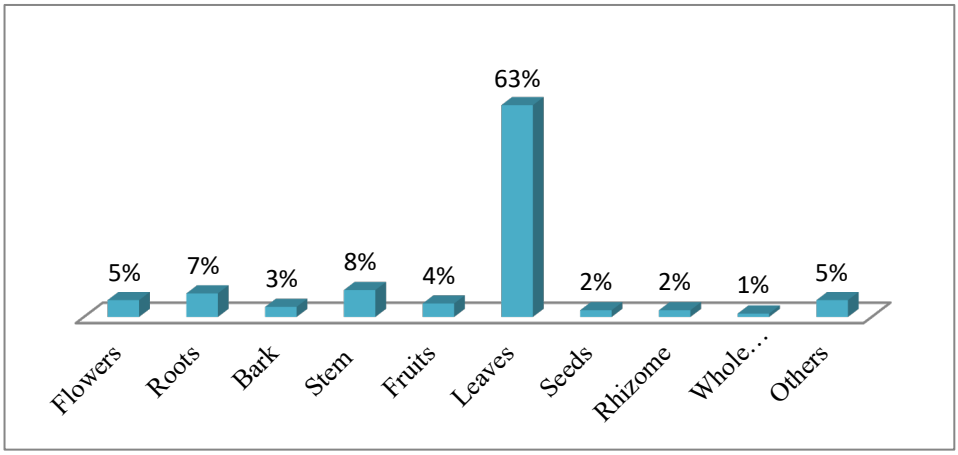

Figure 9. Utilization rates of various plants parts used.

Methods of preparation

According to the participants in our current ethnobotanical study, various methods are used to prepare treatments. Table 3 showed that decoction is the most common method (42%), followed closely by the use of powder (27%) and infusion (13%). Other methods such as cataplasm, maceration and fumigation are used less frequently by the population studied, accounting for less than 10%. These results could be substantiated by the observation that the process of decoction facilitates a more effective extraction of the most potent ingredients, while concurrently diminishing or eliminating the potential toxicity associated with specific polyherbal formulations. The predominance of decoction in our results is consistent with national research (Chaachouay *et al.* 2019; El Hachlafi *et al.* 2020; Benkhaira *et al.* 2021; Benkhaira *et al.* 2021).

Table 3. The various methods of preparation plants used.

Methods of preparation	Percentage
Decoction	42%
Powder	27%
Infusion	13%
Cataplasm	10%
Maceration	6%
Fumigation	2%

Mode of the administrations

Most herbal remedies are administered orally (75%) because this is the most common and widely used method among patients (Salhi *et al.* 2010; Hafsé *et al.* 2015; Benarba 2016; Uzun & Koca 2020). Additionally, other methods like inhalation, ointment and massage have been used in some traditional medicinal practices (Figure 10). These results are also corroborated by traditional national and international pharmacopoeias, confirming that these methods are widely used.

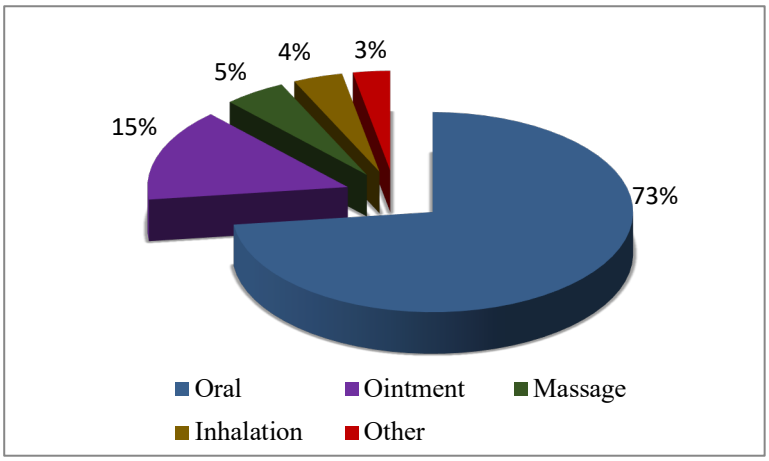

Figure 10. Distribution of the administration methods

Dose and duration of use

In Taounate stations, most of the people interviewed used medicinal plants without following precise doses. They did not consider high doses to be toxic or even fatal. The ethnobotanical study reveals that most medicinal plants are used in various doses, including 37.5% by spoonful, 32.2% by glass, 10.7% by pinch, 7.2% by ointment, 5.4% by handful, and other forms (3.6%) (Figure 11A). In terms of duration of use, 45% of interviewed people use plants for one day, 25% for one week, 6% for one month, and 24% of people use medicinal plants to treat ailments until they are cured (Figure 11B). However, the administration of phytochemical compounds at non-precise and irrational doses in the autochthon population can lead to harmful effects on human health, as there is frequently a relationship between dose and toxicity (Bellakhdar 1997; Sreekeesoon & Mahomoodally 2014).

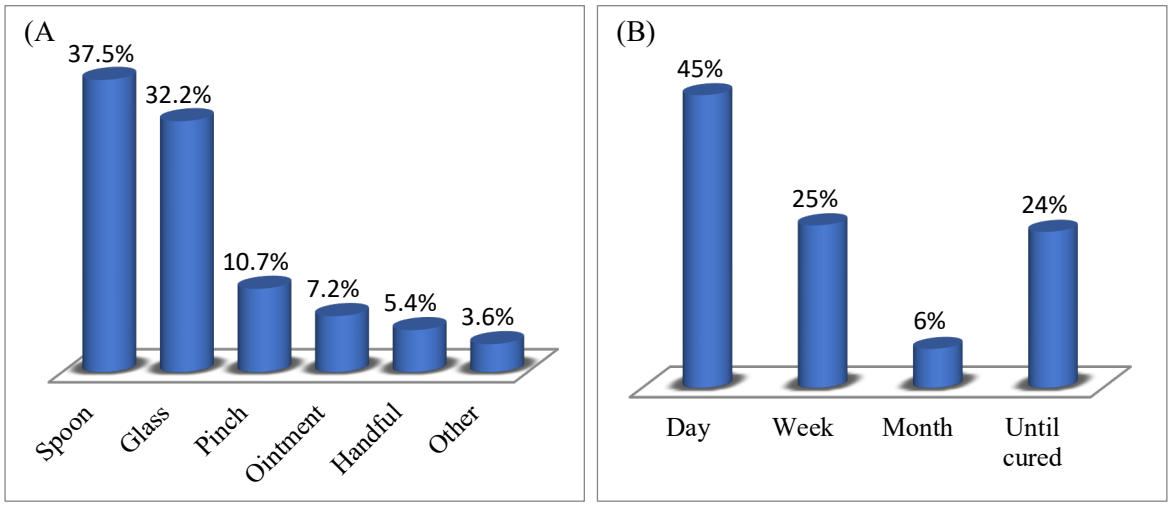

Figure 11. Distribution of medicinal plant users according to (A) dosage and (B) duration of use.

Diagnostic and care results

According to the results obtained in Figure 12A, 45% of respondents believe that medicinal plants can cure the illnesses they treat, while 53% believe that they merely provide relief from the illness. Only 2% of the indigenous population believe that medicinal plants are ineffective and have no effect on human health. Nevertheless, in the study region, the majority of respondents (83%) diagnosed their health problems themselves, while only 12% consulted a doctor (Physician). On the other hand, a small percentage of respondents (5%) obtained a diagnosis from herbalists (Figure 12B).

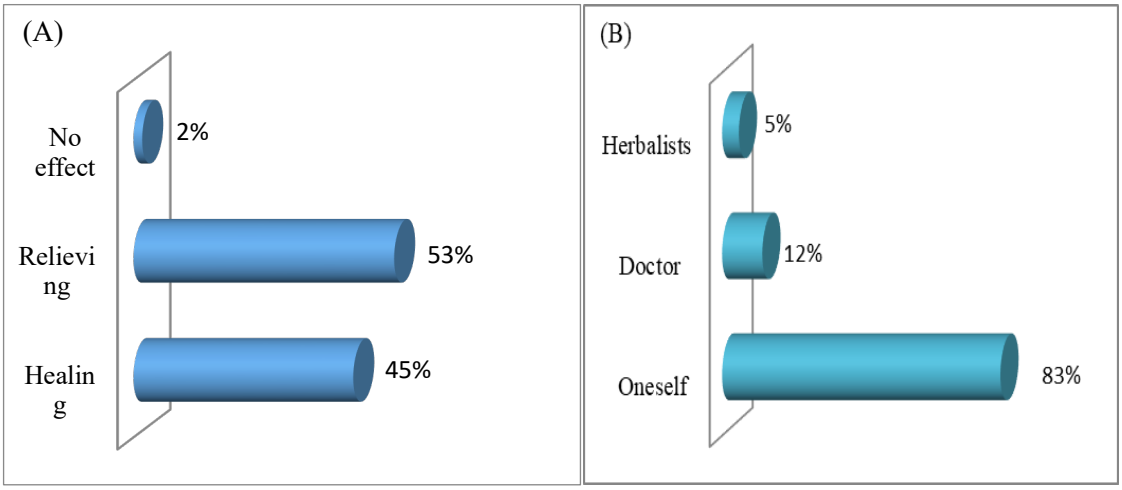

Figure 12. Percentages of (A) care results and (B) disease diagnoses.

Diseases treated

The ethnobotanical survey shows that the majority of the medicinal species identified in the Taounate region are used to treat or relieve a large number of diseases or symptoms (Figure 13). Pathologies treated with medicinal plants mainly include disorders of the digestive tract (37%), followed by respiratory ailments (15%), dermatological problems (12%), osteo-articular/orthopedic ailments (10%), metabolic disorders (7%), neurological ailments (5%), cardiovascular ailments (6%), and genitourinary ailments (4%). Other diseases, such as otorhino-laryngological problems, ophthalmological disorders, disorders of the glands annexed to the digestive tract and cancer, are less frequently mentioned, with a rate of only 1% each.

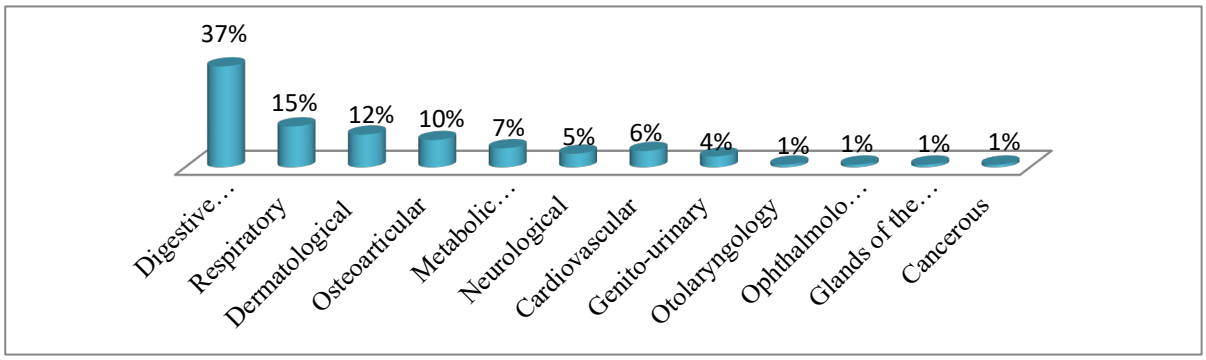

Figure 13. Percentage of different diseases treated.

Folk medicine has been applied in various regions in Morocco. The conclusions of this study are similar to those obtained in the other regions such as the province of Taounate (Northern Morocco) (Chaachouay *et al.* 2019), the Gharb region (El Hachlafi *et al.* 2020), the province of Laayoune (El Yahyaoui *et al.* 2015), and the Mediterranean region (El Khomsi *et al.* 2022). In these various regions, it has been noted that digestive tract disorders are in the first position in terms of the use of medicinal plants.

The heatmap in Figure 14 illustrates the frequency of medicinal plant usage as revealed in the current study for the treatment of various diseases. The heatmap indicates that these plants are primarily used for treating diseases related to the digestive tract. The highest frequency was recorded for *O. compactum*, followed by *S. officinalis* with a moderate frequency. Additionally, *L. dentata, A. sativum, A. herba-alba, G. glabra, P. atlantica, A. absinthium, C. spinosa, C. silva, P. lentiscus, C. ambrosioides,* and *M. rotundifolia* were found to be used with low frequency. *M. vulgare* was found to be used with a moderate frequency for treating dermatological problems. *T. satureioides* and *C. erythraen* were found to be used with a low frequency. *P. lentiscus* was shown to be used with a low frequency for treating metabolic and neurological disorders. *C. ambrosioides* and *M. rotundifolia* were revealed to be used with a low frequency for treating osteoarticular problems. However, the use of these plants for treating other disorders was shown to have very low frequencies.

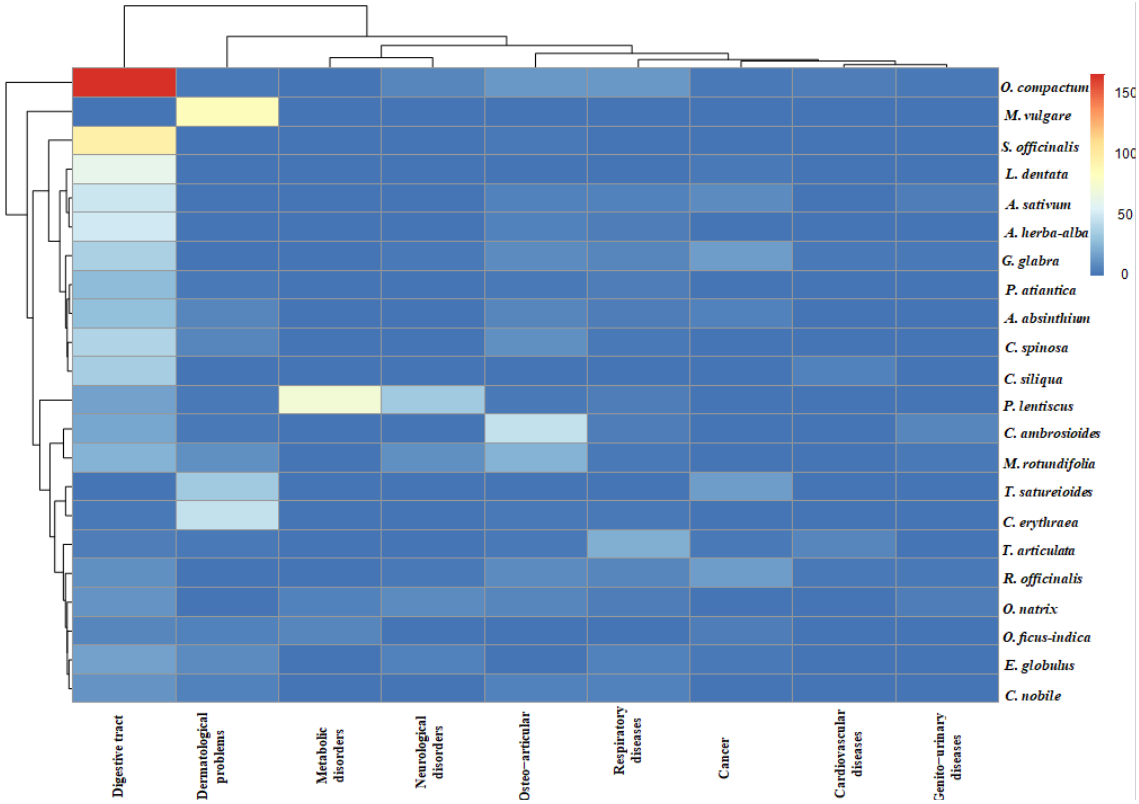

Figure 14. Heat map showing clustering dendrogram based on the frequency of medicinal plant usage to treat various ailments.

Informant Consensus Factor (ICF)

The Informant Consensus Factor evaluates the consistency of information provided by different informants regarding the use of medicinal plants to treat the most common ailments. The ICF results for different categories of use are listed in Table 4. There are nine distinct categories, namely respiratory disorders, dermatological conditions, osteoarticular problems, metabolic disorders, neurological disorders, cardiovascular conditions, genitourinary disorders, and cancer. The ICF values obtained for these categories indicate the extent to which knowledge about the efficacy and use of medicinal plants is shared among informants.

The ICF values vary between 0.73 and 0.98 for each category of use. More specifically, ICF values of 0.98 and 0.96 were successively recorded for the "Digestive disorders" category with 22 species and the metabolic disorders category with 4 species, suggesting a high prevalence of these illnesses in Taounate region. These high ICF values indicate the reasonable credibility of informants regarding the use of medicinal plants, as indicated by Chaachouay *et al.* (2019), Salhi *et al.* (2010), Ramdane *et al.* (2015), Benarba (2016),and Uzun & Koca (2020).

Table 4. ICF values by category for the treatment of the most frequent diseases.

Categories	**List of plant species most used and number of citations**	**Total number of Species**	**Use citations**	**ICF**
Digestive disorders	*Origanum compactum* (225), *Rosmarinus officinalis* (166), *Salvia officinalis* (10), *Pistacia lentiscus* (95), *Chenopodium ambrosioides* (17), *Capparis spinosa (*19), *Allium sativum* (39), *Artemisia herba-alba* (49), *Mentha rotundifolia* (51), *Tetraclinis articulate* (24), *Eucalyptus globulus* (24), *Chamaemelum nobile* (17), *Marrubium vulgare* (12), *Thymus satureioides* (37), *Centaurium erythraea* (1), *Ononis natrix* (3), *Lavandula dentata* (12), *Ceratonia siliqua* (63), *Pistacia atlantica* (36), *Artemisia absinthium* (28),*Opuntia ficus-indica* (29),*Ocimum basilicum* (7).	22	944	0.98

Respiratory disorders	*Origanum compactum* (26), *Rosmarinus officinalis* (14), *Salvia officinalis* (8), *Pistacia lentiscus* (1), *Chenopodium ambrosioides* (4), *Capparis spinosa* (4), *Allium sativum* (2), *Artemisia herba-alba* (5), *Mentha rotundifolia* (4), *Tetraclinis articulate* (3), *Eucalyptus globulus* (23), *Chamaemelum nobile* (5), *Marrubium vulgare* (5), *Thymus satureioides Coss* (7), *Ononis natrix* (2), *Lavandula dentata* (4), *Artemisia absinthium* (4), *Opuntia ficus-indica* (4).	18	125	0.86
Dermatological disorders	*Origanum compactum* (2), *Rosmarinus officinalis* (2), *Chenopodium ambrosioides* (2), *Capparis spinosa* (3), *Allium sativum* (7), *Tetraclinis articulate* (10), *Eucalyptus globulus* (2), *Chamaemelum nobile* (9), *Marrubium vulgare* (5), *Centaurium erythraea* (34), *Ononis natrix* (46), *Lavandula dentata* (1), *Artemisia absinthium* (2), *Opuntia ficus-indica* (7), *Ocimum basilicum* (5), *Glycyrrhiza glabra* (85).	17	222	0.93
Osteo-articular disorders	*Origanum compactum* (6), *Rosmarinus officinalis* (14), *Salvia officinalis* (9), *Pistacia lentiscus* (2), *Chenopodium ambrosioides* (3), *Capparis spinosa* (45), *Allium sativum* (10), *Artemisia herba-alba Asso* (5), *Mentha rotundifolia Muds* (5), *Tetraclinis articulate* (24), *Eucalyptus globulus* (2), *Marrubium vulgare* (6), *Thymus satureioides* (9), *Centaurium erythraea* (1), *Ononis natrix* (2), *Lavandula dentata* (8), *Artemisia absinthium* (3),*Opuntia ficus-indica* (8).	18	162	0.89
Metabolic disorders	*Rosmarinus officinalis* (1), *Pistacia lentiscus* (72), *Lavandula dentata* (6), *Ocimum basilicum* (7).	4	86	0.96
Neurological disorders	*Origanum compactum* (5), *Rosmarinus officinalis* (7), *Salvia officinalis* (3), *Chenopodium ambrosioides* (34), *Capparis spinosa* (1), *Mentha rotundifolia* (1), *Tetraclinis articulate* (11), *Chamaemelum nobile* (5), *Marrubium vulgare* (1), *Thymus satureioides* (3), *Lavandula dentata* (9).	11	80	0.87
Cardiovascular disorders	*Origanum compactum* (1), *Rosmarinus officinalis* (4), *Salvia officinalis* (2), *Tetraclinis articulate* (1), *Eucalyptus globulus* (8), *Thymus satureioides* (2), *Pistacia atiantica* (5).	7	23	0.73
Genito-urinary disorders	*Origanum compactum* (4), *Rosmarinus officinalis* (3), *Salvia officinalis* (2), *Capparis spinosa* (7), *Artemisia herba-alba* (4), *Tetraclinis articulate* (2), *Thymus satureioides* (2), *Lavandula dentata* (4).	8	28	0.74
Cancer	*Origanum compactum* (2), *Rosmarinus officinalis* (3), *Salvia officinalis* (15), *Artemisia herba-alba* (9), *Eucalyptus globulus* (2), *Chamaemelum nobile* (2), *Thymus satureioides* (15), *Centaurium erythraea* (15), *Ceratonia siliqua* (3), *Opuntia ficus-indica* (5),*Ocimum basilicum* (4).	11	75	0.86

Conclusion

This study revealed that the indigenous population of Taounate possess substantial knowledge about the actual use of medicinal plants as a source of medications to treat different pathologies. These traditional practices reflect the rich and varied floristic patrimony of Taounate region.

In this survey, 112 species of medicinal plants were reported, belonging to 100 genera and 54 botanical families. Among the 54 families reported, the most predominant are Lamiaceae (11 species, FIV= 22.1%), followed by Apiaceae (7 species and FIV=1.9%) and Asteraceae (6 species and FIV= 8%). The most used species are *Origanum compactum* (RFC=0.664), *Rosmarinus officinalis* (RFC= 0.496), *Salvia officinalis* (RFC= 0.492), *Pistacia lentiscus* (RFC= 0.370), *Chenopodium ambrosioides* (RFC= 0.366). Additionally, based on the reported findings and proposed discussions, it appears that certain medicinal plants show

promise in potentially treating different diseases, including but not limited to digestive, respiratory, dermatological articular/orthopedic, metabolic, neurological, cardiovascular and genitourinary illnesses. In fact, the identified plants may hold untapped potential for the development of pharmaceuticals or herbal medicines. This investigation opens avenues for further exploration into the bioactive compounds and therapeutic properties of these plants, potentially contributing to the discovery of novel treatments. This has implications for both local healthcare practices and broader medical and pharmaceutical advancements.

In terms of community health and well-being, the study indicates the interconnectedness between traditional medicine and the overall health of the population in the Taounate region. Integrating traditional knowledge into modern healthcare systems could enhance the effectiveness and accessibility of healthcare services. This recognition of traditional practices could lead to a more holistic and culturally sensitive approach to health, raising a collaborative and inclusive healthcare environment.

As the ethnobotanical survey bridges the gap between traditional knowledge and scientific understanding, it suggests opportunities for cultural exchange and collaboration. Facilitating dialogue between traditional healers, local communities, and scientific researchers is essential for mutual learning and respect. The study encourages a collaborative approach to further research, ensuring that the benefits of ethnobotanical knowledge are shared and applied in a culturally sensitive manner.

Furthermore, the implications of this exploratory study extend beyond cultural aspects to include conservation and sustainable use. With certain medicinal plant species potentially at risk due to overharvesting or habitat loss, the study emphasizes the urgent need for conservation efforts. Indeed, recommendations for sustainable harvesting practices, cultivation initiatives, and the establishment of protected areas are vital for preservation of the biodiversity and safeguarding the availability of these medicinal resources for future generations.

Declarations

List of abbreviations: RFC: Relative Citation Frequency, FIV: Family Importance Value, PPV: Plant Part Value, FL: Fidelity Level, ICF: Informant Consensus Factor, FC: citation frequency, N: total number of people surveyed, Nur: number of use citations for a disease category, Nt: number of species used by informants in a given use category, RS: Respiratory diseases;TD: Digestive diseases; DR: Dermatological diseases; OS: Osteoarticular diseases; MT: Metabolic disorder; NR: Neurological diseases; GU: Genito-urinary diseases; CN: Cancer; GA: Glands of the Digestive diseases; ORL: Otorhino-laryngologie; CV: Cardiovascular diseases; AC: Cirulatory system; ND= Not Determined; Dec: Decoction; Cat: Cataplasm; Pow: Powder; In: Inhalation; Ex: Extration; Inf: Infusion; Mac: Maceration.

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

Consent for publication: Not applicable.

Availability of data and materials: The data was not deposited in public repositories.

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