Traditional knowledge and biodiversity of medicinal plants in the Taounate region for treating human diseases: An ethnobotanical perspective

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Research

Abstract

Background: The Taounate region in Morocco boasts a rich diversity of medicinal and aromatic plants. Traditional knowledge, passed down through generations, plays a pivotal role in developing affordable medicines derived from natural products. Our primary objective was to investigate the botanical diversity, comprehend its importance for the local communities, and enhance the value of the plants utilized in this area for the treatment and prevention of various diseases.

Methods: An ethnobotanical study was conducted in Taounate province through semi-structured interviews of 476 individuals from 15 different localities. The data were analyzed using specific ethnobotanical indexes such as the Cultural Importance Index (CI), Fidelity Level (FL), and Relative Frequency of Citation (RFC). Influence and correlation between sociodemographic variables and traditional therapeutic use were performed using a series of bivariate and multivariate tests.

Results: The most frequently used plant parts were leaves (80.66%), followed by seeds (9.03%). Oral ingestion was the most frequently cited way of remedy application (68.23%). The diseases for which plants are most commonly used are Gastrointestinal and Dermatological illnesses. After analyzing the results of the ethnobotanical indices, three plants stand out, namely *Myrtus communis*, *Arbutus unedo* and *Inula viscosa*. Moreover, the statistical analyses revealed significant relationships between various variables. A chi-square test demonstrated a significant association between the methods of preparation of the plants and municipalities (p = 0.032), as well as between plant parts and municipalities (p = 0.0036), but not between gender and types of plants used (p = 0.072). The Kruskal-Wallis test indicated no significant effect of respondents' age on the type of plants used (p = 0.6369). Multiple correspondence analysis (MCA) identified associations among methods, types of plants, and municipalities, accounting for 13.09% of the total variability. Lastly, non-metric multidimensional scaling (NMDS) analysis confirmed significant relationships between plant distribution and municipalities, validated by the PERMANOVA test (p < 0.05).

Conclusion: Knowledge Transmission: Despite the persistence of traditional medicine, gaps exist in knowledge transmission to future generations. Focusing on species like *Myrtus communis*, *Arbutus unedo*, and *Inula viscosa* could enhance short-term community health and pave the way for affordable natural medicines. Our study underscores the need for continued research, conservation, and knowledge dissemination to harness the full potential of Taounate's botanical treasures.

Keywords: Plants, Survey, Ethnobotany, Taounate, Therapeutic use

Background

An ancient bond exists between humanity and the natural world, exemplified by our longstanding use of plants' beneficial properties, especially for medicinal purposes (Šantić *et al.*, 2017). The comprehension of medicinal plant utilization stems from extensive periods of combating diseases, leading to the realization that therapeutic agents can be derived from leaves, seeds, fruits, and other plant parts (Petrovska, 2012). In recent years, there has been a substantial increase in the adoption of these practices, driven by the rising popularity of medicinal plants due to their affordability compared to modern pharmaceuticals (Jaadan *et al.*, 2020).

Currently, slightly exceeding 80% of the world's population relies on medicinal plants as their main form of treatment (Tuli *et al.*, 2023). Plants constitute the foundational elements of a sophisticated traditional medicinal system that has persisted for thousands of years, consistently providing humanity with innovative healing remedies. Over half of all pharmaceuticals used in clinical practice are originate from natural products and their derivatives. Furthermore, approximately 25% of prescribed medications consist of formulations from plants or synthetic analogs inspired by botanical sources (Aidi Wannes *et al.*, 2018).

Medicinal and aromatic plants (MAPs) represent abundant reservoirs of bioactive compounds (Lourenço *et al.*, 2019). In this regard, Morocco stands out due to its remarkable plant diversity, hosting approximately 4,200 species and subspecies, of which 22% are endemic (Rankou *et al.*, 2013). Beyond its rich biodiversity, Morocco possesses a longstanding tradition and expertise in utilizing medicinal plants. Phytotherapy, deeply ingrained in the local culture, is evident through historical and contemporary knowledge (Lemhadri *et al.*, 2023). Conducting this research in the Taounate region is crucial due to its unique geographical and climatic conditions, which create a distinct ecosystem supporting a diverse range of medicinal and aromatic plants. Taounate province, situated on both sides of the Ouargha valley, serves as a transitional zone between the hills of the Pre-Rif and the mountains of the Central Rif. It is characterized by a continental climate with evident Mediterranean influences. The area undergoes distinct seasons characterized by wet and humid winters juxtaposed with hot and arid summers. The average temperature hovers around 16.9°C, with summer temperatures occasionally exceeding 45°C. The average annual rainfall is approximately 790 mm, reaching up to 1 800 mm in specific areas. These climatic conditions contribute to the abundance of plant resources in the region, particularly aromatic and medicinal plants. The region boasts a wealth of traditional medicinal knowledge, which has been passed down through generations over time (Kachmar *et al.*, 2021).

Therefore, the objective of this study was to compile data on the plant species most frequently employed in traditional medicine by the local population of this region for the treatment of human diseases and pathologies.

Materials and Methods

Study area

According to data provided by the Regional Directorate of Water and Forests and the Fight against Desertification, the province of Taounate spans an area of 5,616 km² within the Fez-Meknes region. It is divided among 44 rural municipalities and 5 urban municipalities. As of the 2014 census, the population stands at 660,736 inhabitants. A significant majority, approximately 87% of the population, resides in rural areas, distributed across more than 1600 villages. The religion of the inhabitants is Islam, and Arabic (Moroccan dialect) is the official language of the country (El-Assri *et al.*, 2021).

The province is geographically divided into two distinct parts: a mountainous northern region and a hilly southern area. The northern segment, constituting approximately 40% of the province's total area, is connected to the Rif and primarily characterized by forested terrain, covering an expanse of 40,690.96 hectares. The southern portion, accounting for approximately 60% of the province's surface, is situated within the pre-Rif zone.

Taounate boasts significant hydrographic resources, largely attributed to the Ouergha and Inaouen rivers, along with the presence of reservoirs such as Wahda, Idriss Premier, Bouhouda, Sahla, and Asfalou (Bouarfa *et al.*, 2020).

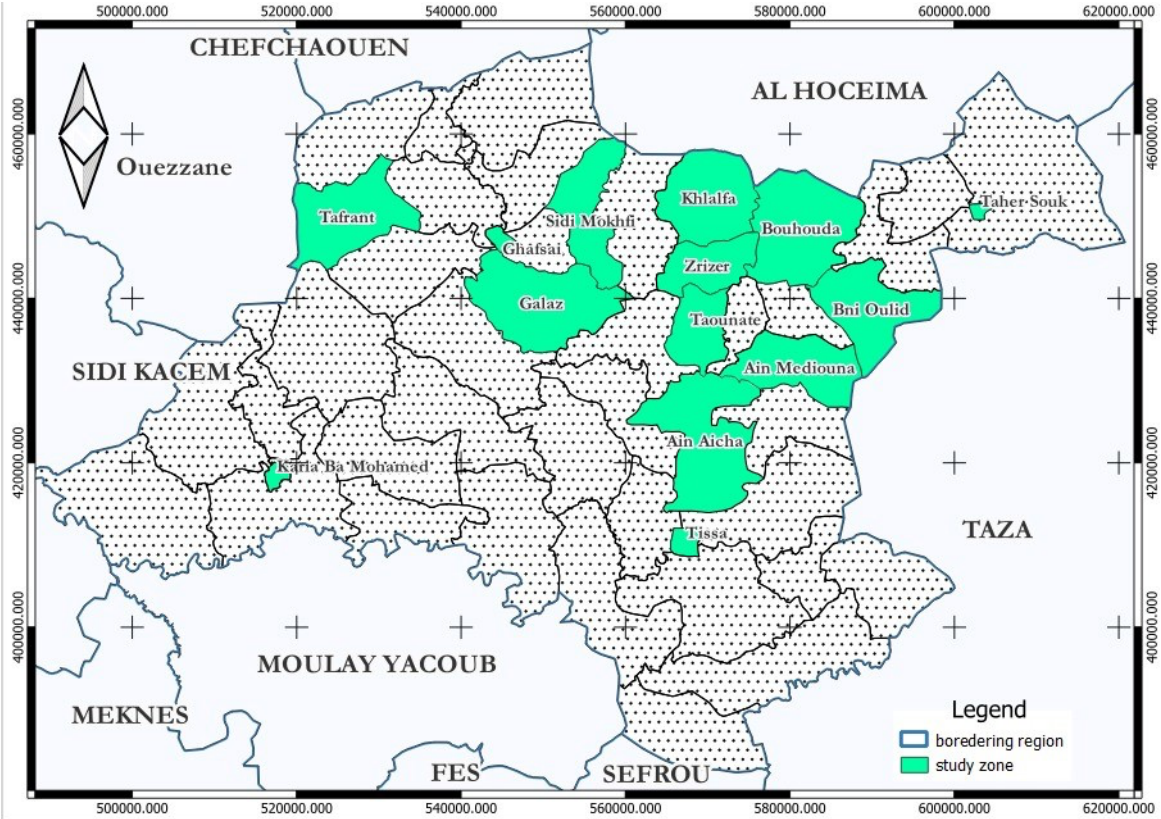

Figure 1. Map of the study area (Qgis software)

Socio-economic aspects of medicinal and aromatic plants

From a socio-economic perspective, the harvesting of medicinal and aromatic plants is a means to diversify agricultural production, providing multiple days of employment and creating income generating activities for local populations (Taleb, 2017).

Data collection

The study was conducted from January to February 2023. The purpose and objectives of the study were communicated to the participants, in advance to obtain their consent. The interview was structured to collect information on the plants used, the diseases they treat, the plant parts employed, and the methods of preparation and administration. The data collection was carried out through semi-structured interviews, conducted in the Arabic language, employing the vernacular names of the plants (Fig. 2). Participants aged 18 years and older were included in the study (Martin, 2010; Nath & Puzari, 2022).

ETHNOBOTANICAL SURVEY

Age:
Gender:
Locality:
Area: ☐ Rural ☐ Urban
Education level: ☐ None ☐ Primary ☐ Secondary ☐ University

Plants	*Parts used*						*Use form*	*Preparation mode*				*Uses*
	Whole	*Leaves*	*Fruit*	*Seeds*	*Flower*	*Roots*		*Infusion*	*Powder*	*Inhalation*	*Other(specify):*	

Origin of knowledge: ☐ Personal experience ☐ knowledge transfer ☐ Bibliography
Satisfaction level: ☐ Disappointed ☐ Not very satisfied ☐ Satisfied ☐ Very satisfied
Undesirable effects: ☐ Yes ☐ No
if yes, which ones: ……………………………………………………………………………………………………
Choice of plant: ☐ Low cost ☐ Efficiency ☐ Other (specify): ………………………………

Data Analysis

Ethnobotanical data were organized using Microsoft Excel spreadsheets.

The parameters analyzed were:

Frequency of citation (FC):

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

$$FC = \frac{\text{Np}}{\text{Nt}} * 100$$

Where Np is the number of times a particular species was mentioned; Nt = total number of times all species were mentioned (Ndhlovu *et al.*, 2023).

Relative Frequency of Citation (RFC):

$$RFC = \frac{Np}{Ni}$$

It was assessed by dividing the number of informants who mentioned the use of the species (Np) by the total number of informants who participated in the survey (Ni). This index ranges from "0," indicating no mention of the plant's utility, to "1," when all informants have mentioned the plant's utility (Faruque *et al.*, 2018). It measures the relative importance of how the species is locally known (Ndhlovu *et al.*, 2023).

The Informant Consensus Factor (ICF):

This value was calculated to assess the degree of homogeneity in knowledge among participants in the study area regarding the use of plants as remedies for diseases. The ICF was calculated using the following formula:

$$ICF = \frac{Npu - N\text{tu}}{N\text{pu} - 1}$$

Where Npu represents the number of use report for a category, and Ntu represents the total number of plants used for that specific category of use by all informants. The closer the ICF is to "1," the more there is a well-defined selection criterion in the community, and/or information is exchanged among informants (Musa *et al.*, 2011).

Fidelity level (FL):

It represents the percentage of informants declaring the use of a specific plant for the same primary purpose, which can be calculated as follows:

$$FL = \frac{Npu}{N} * 100$$

Where "Npu" is the number of informants stating the use of a plant species for a particular purpose, and "N" is the total number of usage reports for that specific purpose (Musa *et al.*, 2011; Reimers *et al.*, 2019).

Use value (UV):

This index, also known as "cultural importance," allows us to determine the relative importance of locally known species and the most frequently reported species in the treatment.

The use value of each species was calculated using the formula diseases:

$$UV = \frac{\sum Ui}{Nt}$$

Where Ui is the number of uses mentioned by each informant for a species, and Nt is the total number of informants (Benkhnigue *et al.*, 2023; Vitalini *et al.*, 2013).

Relative importance index:

This index, created by Pardo-de-Santayana (Pardo de Santayana & Manuel, 2003), only considers usage categories - not subcategories - using the following formula:

$$RI = \frac{\mathrm{RFCs\ (max)} + RNUs\ \mathrm{(max)}}{2}$$

Where RFCs (max) is the relative frequency of citation above the maximum, meaning it is obtained by dividing the frequency of citation of a species by the highest citation value among all species in the study. RNUs (max) is the relative number of uses above the maximum, obtained by dividing the number of uses of the species by the highest usage value among all species in the study (Tardío & Pardo-de-Santayana, 2008).

Cultural value index:

This index, employed by Reyes-Garcia *et al.* (2006) and Thakur *et al.* (2023), relates the number of different uses reported for a specific species to the total number of usage categories considered in the study. It is calculated by multiplying this number by the relative citation frequency and the usage value.

$$CVs = \left(\frac{\mathrm{NUs}}{NUt}\right) * RFC * UVs$$

Where NUs is the number of uses cited for a specific species, and NUt is the total number of uses cited in the study.

Statistical analysis

All data collected from this ethnobotanical survey were transcribed and subjected to descriptive analysis using Excel and in-depth analysis using R software (version 4.3.3). To explore the relationships between different variables and gain insights into the factors influencing our dataset, we conducted a series of bivariate and multivariate tests. Specifically, we performed Pearson's chi-squared tests to determine significant associations between the following pairs of variables:

- Municipalities and Methods
- Municipalities and Plant Parts
- Gender and Plant Types

Furthermore, we employed the non-parametric Kruskal-Wallis test (alternative to the ANOVA test) to evaluate whether there is a statistically significant difference in the age distribution of respondents' and the types of plants used. This test was chosen because it is particularly suitable given the non-normal distribution of the residuals in our data, as indicated by the Shapiro-Wilk normality test. By integrating these various statistical methods, we aimed to achieve a comprehensive understanding of the associations and differences within our dataset.

Results and Discussion

Demographic Data

A total of 476 participants distributed across 15 municipalities were surveyed, as indicated in the distribution provided in Table 1.

Table 1. Percentage of respondents by municipality

Municipalities	Number of respondents	Percentage
Tafrant	32	6,72 %
Galaz	35	7,35 %
Thar Es-Souk	34	7,14 %
Ain Aicha	37	7,77 %
Ain Mediouna	29	6,09 %
Marnissa	31	6,51 %
Tissa	30	6,30 %
Khlalfa	31	6,51 %
Zrizer	29	6,09 %
Sidi El Mekhfi	36	7,56 %
Kariat Ba Mohamed	38	7,98 %
Ghafsai	32	6,72 %
Bouhouda	27	5,67 %
Beni Oulid	25	5,25 %
Taounate	30	6,30 %

Socio-demographic data of the respondents are presents in table 2. Gender distribution reveals a predominance of females (71.01%) compared to males (28.99%), highlighting the significant role of women as custodians of knowledge on aromatic and medicinal plants in Morocco. This finding aligns with studies conducted by El-Ghazouani *et al.* (2021), Kachmar *et al.* (2021), and Ouhaddou *et al.* (2015). Interviews indicated that older individuals possess a better understanding of medicinal plants usage for various treatments, with 75% of respondents being aged 55 and above. This result is logical, as older generations are expected to hold ancestral knowledge passed down orally. However, the oral transmission of such knowledge is not always assured and is on the declining, as highlighted by Chaachouay *et al.* (2019) and Kachmar *et al.* (2021). Furthermore, the majority of respondents come from rural areas (59.03%), which may be attributed to the lack of infrastructure, limited access to medicines, or a scarcity of medical practitioners (Belhaj & Zidane, 2021; Mandango *et al.*, 2016). The relatively high illiteracy rate (87.34%) could be influenced by various factors, including the prevalence of elderly respondents, low educational rates among rural women (Gender and Development Reports in Rural Areas), socioeconomic status, or the availability and accessibility of educational resources. While this illiteracy rate contradicts the findings of Amrati *et al.* (2021) it aligns with the results reported by Ammor *et al.* (2020), Chaachouay *et al.* (2022), Hafdi Idrissi (2022), and Nait Belaid (2021).

Table 2. Socio-demographic Data of Respondents

Gender		
Women	338	71.01 %
Men	138	28.99 %
Age		
65 and above	138	28.99 %
55 - 64	219	46.01 %
45 - 54	76	15.96 %
under 45	43	9.03 %
Type of locality:		
Rural	281	59.03 %
Urban	195	40.97 %
Level of education:		
None	411	87.34 %
Primary	34	7.14 %
Secondary	22	4.62 %
University	9	1.89 %

Studied Plants and Their Uses

Frequency and Relative Frequency of Citation

A number of 15 plant species were recorded during this survey. Frequency of citations of the various studied plants along with their relative frequency of citation are highlighted in Fig. 2 and Table 3.

It is observed that *Inula viscosa* with 15.36% (131), *Myrtus communis* with 14.30% (122), and *Arbutus unedo* with 13.25% (113) together constitute 42.91% (366) of the total citations (853). These three plants are the most commonly used in the region and are known to the majority of the local population (Bouyahya *et al.*, 2017; El Haouari *et al.*, 2021; Faida *et al.*, 2019). Several plants such as *Calligonum comosum, Aristolochia longa, Apteranthes europaea*, and *Ormenis eriolepis*

are presented with very low percentages, which may be attributed to their non-native origin. Additionally, these plants have been introduced into the traditional medicine of the region due to their relatively rare availability in certain herbalists (Libiad *et al.*, 2011).

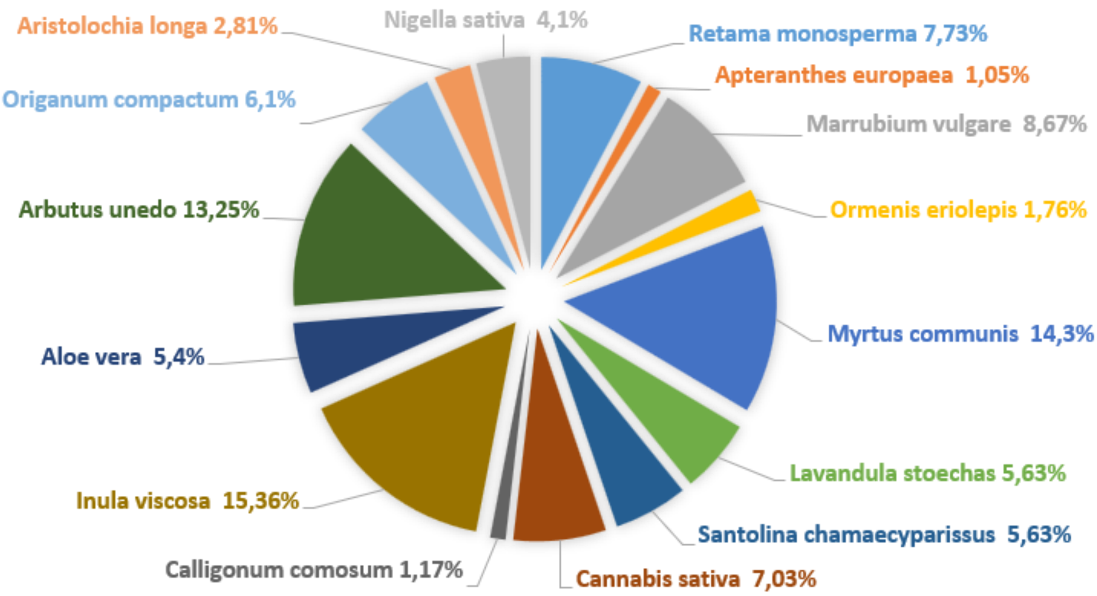

Figure 2. Frequency of citation of the studied plants

Table 3. Relative frequency of citation of the studied plants

Plants	RFC
Inula viscosa (Iv)	0,275
Myrtus communis (Mc)	0,256
Arbutus unedo (Au)	0,237
Marrubium vulgare (Mv)	0,155
Retama monosperma (Rm)	0,139
Cannabis sativa (Cs)	0,126
Origanum compactum (Oc)	0,109
Santolina chamaecyparissus (Sc)	0,101
Lavandula stoechas (Ls)	0,101
Aloe vera (Av)	0,097
Nigella sativa (Ns)	0,074
Aristolochia longa (Al)	0,050
Ormenis eriolepis (Oe)	0,032
Calligonum Comosum (Cc)	0,021
Apteranthes europaea (Ae)	0,019

Plant Parts Used for Treatment

In this study areas, leaves were found to be the predominant plant parts utilized by local residents, accounting for 80.66%, followed by seeds at 9.03 %, and then the use of aerial parts at 3.28 % (Fig. 3). This preference can be explained by the ease of collecting leaves, which require minimal effort for treating various ailments, compared to other plant parts such as flowers, roots, fruits, and seeds. These findings are consistent with previous research by Jeddi *et al.* (2021), indicating that leaves were the most commonly used plant parts due to their pratical application. Furthermore, as noted by Kadir *et al.* (2013), removing leaves causes less harm to plants than other plant parts, which, could significantly impact plant growth and development. Notably, several studies have demonstrated that leaves contain a higher concentration of bioactive compounds effective against specific diseases, thereby playing a crucial role in the formulation of herbal medicines (Barba *et al.*, 2014; Pateiro *et al.*, 2023; Zahoor *et al.*, 2017).

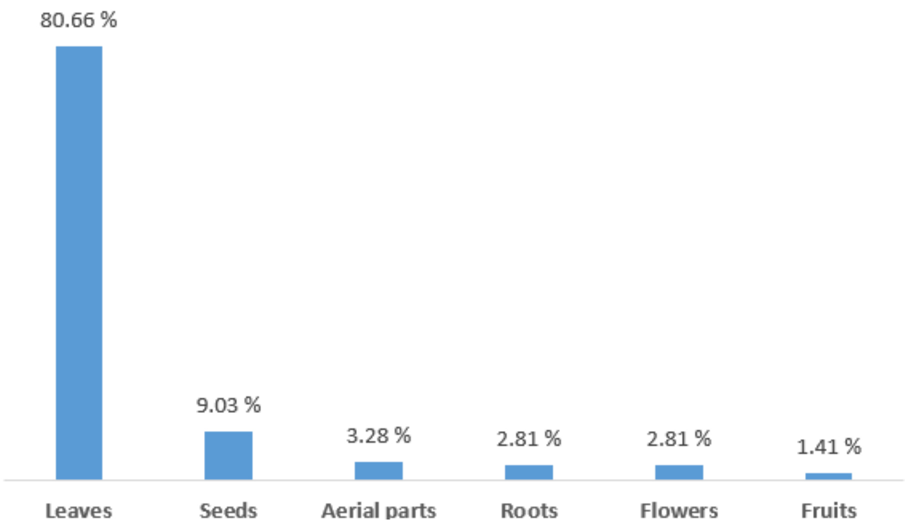

Figure 3. Percentage of the different plant parts used

Preparation Methods and applications

Various therapeutic techniques are employed by local populations, including decoction, infusion, maceration, gel, grinding, raw, and smoking (Fig. 4). The predominant preparation methods are infusion, decoction, and griding, accounting for over 80% of usage. Plant preparations are primarily administered internally, through oral ingestion or inhalation, in 70.34 % of cases, while external application is observed in 29.66% of cases. It is noteworthy that oral ingestion and external application of powder are prevalent among other methods (Table 4). These results appear to be highly similar to those of previous studies conducted in the same region and across Morocco (Achour *et al.*, 2022; Chebaibi *et al.*, 2019; Zeggwagh *et al.*, 2013).

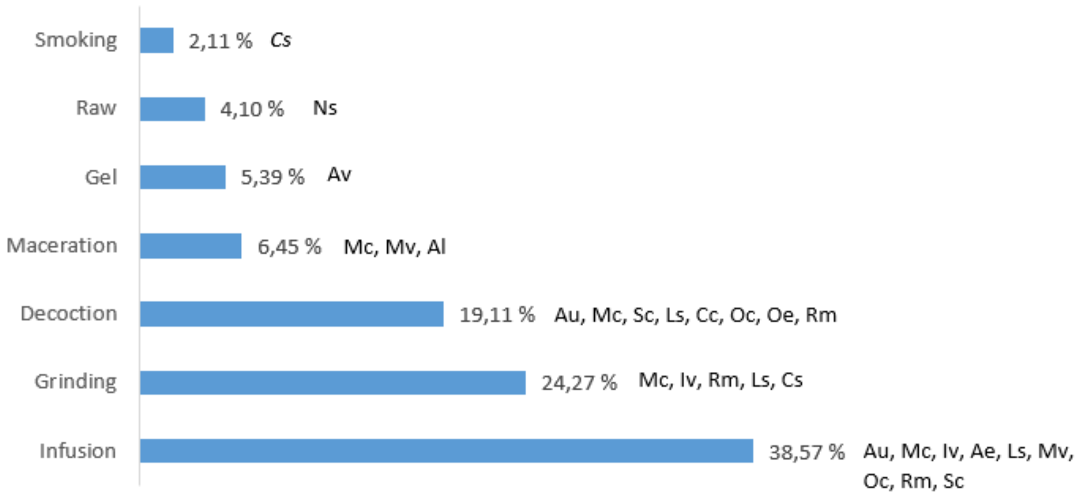

Figure 4. Percentage of different methods of plant preparations

Table 4. Diverse application methods

Internal application	Oral ingestion	68.23 %
	Inhalation	2.11 %
External application	Powder	24.27 %
	Gel	5.39 %

Use of the studied plants

The survey results enabled the identification of 13 different uses of these plants (Table 5). Results reveal a significant prevalence of medicinal plants usage for addressing various ailments, with the highest mention for digestive system issues at 42.28%, followed by dermatological problems at 24.06%, and inflammatory conditions at 17.97%. These findings are supported by the conclusions of Es-Safi *et al.*, 2020 and Musa *et al.*, 2011.

Table 5. Different uses of the studied plants

Use	**Plants used**	**Number of citations**	**Percentage**
Digestive system disorders			**42.28 %**
Aerophagy	4 (Mc, Au, Oc, Oe)	175	20.49 %
Indigestion	3 (Sc, Oc, Ns)	92	10.72 %
Intoxication	3 (Mv, Sc, Au)	76	8.89 %
Hepatitis	2 (Ae, Ls)	19	2.18 %
Metabolic disorders			**9.15 %**
Diabetes	9 (Rm, Ae, Mv, Oe, Sc, Cs, Au, Oc, Ns)	78	9.15 %
Dermatological problems			**24.06 %**
Wound healing	3 (Mc, Ls, Iv)	134	15.69 %
Alopecia (Baldness)	1 (Cs)	37	4.36 %
Burn	1 (Av)	34	4.01 %
Inflammatory problems			**17,97 %**
Fever	5 (Mc, Ls, Sc, Cc, Al)	70	8.20 %
Inflammation	2 (Rm, Cc)	51	6.02 %
Rheumatism	2 (Rm, Ls)	32	3.75 %
Respiratory disorders			**3.14 %**
Asthma / Cough	1 (Mv)	27	3.14 %
Others			**3.40 %**
Venom	2 (Mc, Iv)	29	3.40 %

Use value (UV)

In the present study, the use value (UV) ranges from 0.023 to 0.378 (Table 6). The highest UVs were attributed to *Myrtus communis* (0.378), *Inula viscosa* (0.308), and *Arbutus unedo* (0.283). The high use values (UVs) of these species can be attributed to several factors, with the most significant being their well-documented history of medicinal use in the Taounate region and beyond. This historical context is reflected in their high relative frequency of citation (RFC) values in this study, indicating that these species are extensively recognized and trusted by the local population for their therapeutic properties. Moreover, the high UVs and RFCs of these species underscore their importance in traditional medicinal practices within the Taounate region. These plants are fundamental to local ethnobotanical knowledge and are valued for their demonstrated efficacy in treating a variety of health conditions. The lowest use value was observed in the case of *Apteranthes europaea* (0.023). Comparable findings have been documented in various studies, consistent with the current research, where plants with the highest UV in our study exhibited elevated values in different regions of the country (Chaachouay *et al.*, 2022; Dagni *et al.*, 2023; Katiri *et al.*, 2017; Naceiri Mrabti *et al.*, 2021). The measurement of UV assists in delineating the relative importance of medicinal plant species in a specific geographical area (Hassan *et al.*, 2020). Nevertheless, it is essential to acknowledge the vast diversity of plants and environmental variations across different regions of the country. Therefore, local inhabitants often resort to the use of indigenous and readily available plants for treating common regional illnesses. It is noteworthy that even in neighboring districts within the same country, there persists a subtle disparity in plant utilization values (Usman *et al.*, 2021).

Table 6. Use value of the studied plants

Plants	Use value
Inula viscosa (Iv)	0.378
Myrtus communis (Mc)	0.309
Arbutus unedo (Au)	0.284
Marrubium vulgare (Mv)	0.235
Retama monosperma (Rm)	0.204
Cannabis sativa (Cs)	0.183
Origanum compactum (Oc)	0.166
Santolina chamaecyparissus (Sc)	0.164
Lavandula stoechas (Ls)	0.160
Aloe vera (Av)	0.099
Nigella sativa (Ns)	0.097
Aristolochia longa (Al)	0.048
Ormenis eriolepis (Oe)	0.036
Calligonum Comosum (Cc)	0.025
Apteranthes europaea (Ae)	0.023

Informant Consensus Factor (ICF)

In the conducted survey, Informant Consensus Factor (ICF) was examined for 13 distinct uses, and all mentioned plants exhibited high consensus, with ICF values exceeding 0.95. This suggests a very high level of uniformity in knowledge regarding the use of medicinal plants in the region. Some plants, such as *Aloe vera*, achieved an ICF of 1, indicating that they were the only plants mentioned for a specific use. Excluding plants with an ICF of 1, the remaining values ranged from 0.923 to 0.988 (Table 7).

Table 7. ICF for the various cited ailments

Maladies	ICF	Most used species
Asthma	1	*Marrubium vulagre*
Burn	1	*Aloe verra*
Baldness	1	*Canabis sativa*
Wound healing	0.988	*Inula viscosa*
Aerophagy	0.987	*Myrtus communis / Arbutus unedo*
Inflammation	0.985	*Retama monosperma*
Indigestion	0.983	*Origanum compactum*
Intoxication	0.98	*Marrubium vulagre*
Rheumatism	0.976	*Lavandula Stoechas / Retama monsperma*
Venom	0.973	*Myrtus communis*
Hepatitis	0.958	*Lavandula stoechas*
Fever	0.956	*Santolina chamaecyparissus*
Diabetes	0.923	*Cannabis Sativa*

Fidelity level

The fidelity level (FL) serves as a crucial indicator for assessing the effectiveness of a particular plant species for a specific ailment. In this study, FL values ranged from 4.17% to 100%. The survey identified four plant species with a fidelity value of 100%, indicating that they were primarily used for a single category of ailment by multiple informants (Table 8). Specifically, a fidelity level of 100% for a given plant means that all use reports consistently endorsed the same method of using the plant in treatment (Srithi *et al.*, 2009). These findings suggest that informants in the Taounate region prefer relying on specific plant species for the treatment of particular ailments rather than using them for various health issues.

Plant species with a fidelity level exceeding 80% warrant thorough examination and further studies to gather additional data on their effectiveness and authenticity, as advocated in previous research (Chaachouay, *et al.*, 2019). However, plants with lower FL percentages should not be overlooked, as neglecting them poses the risk of losing valuable knowledge, potentially leading to the gradual disappearance of traditional wisdom for future generations (Chaudhary *et al.*, 2006).

Table 8. Fidelity level of the studied plants for the various ailments

Plants	Ailments	Fidelity level
Retama monosperma	Diabetes	18.18 %
	Inflammation	95.45 %
	Rheumatism	33.33 %
Apteranthes europaea	Diabetes	33.33 %
	Hepatitis	88.89 %
Marrubium vulgare	Diabetes	8.11 %
	Asthma	48.65 %
	Intoxication	94.59 %
Ormenis eriolepis	Diabetes	42.86 %
	Aerophagy	78.57 %
Myrtus communis	Aerophagy	90.91 %
	Healing	24.79 %
	Venom	18.18 %
	Fever	16.51 %
Lavandula stoechas	Hepatitis	36.17 %
	Fever	42.55 %
	Rheumatism	44.68 %
	Healing	42.55 %
Santolina chamaecyparissus	Diabetes	18.37 %
	Intoxication	4.17 %
	Indigestion	85.42 %
	Fever	56.25 %
Cannabis sativa	Diabetes	59.68 %
	Baldness	80.65 %
Calligonum comosum	Inflammation	60 %
	Fever	60 %
Inula viscosa	Healing	100 %
	Venom	13.08 %
Aloe verra	Burn	100 %
Arbutus unedo	Diabetes	8.77 %
	Aerophagy	83.33 %
	Intoxication	26.32 %
Origanum compactum	Diabetes	19.23 %
	Indigestion	90.38 %
	Aerophagy	36.54 %
Aristolochia longa	Fever	100 %
Nigella sativa	Diabetes	34.29 %
	Indigestion	100 %

Relative importance index

Results of the Relative Importance Index provide a quantitative perspective on the use of plants in the studied context (Fig. 5). *Myrtus communis* emerges prominently with a notable index of 0.965, suggesting significant prevalence in local practices. *Arbutus unedo* closely follows with an index of 0.813, also indicating substantial importance. Other species such as *Inula viscosa*, *Santolina chamaecyparissus*, and *Lavandula stoechas* display high indices. Even species with relatively lower indices, like *Cannabis sativa*, retain some significance in the ethnobotanical context.

However, it is important to understand that this index was conceptualized as a comprehensive measure of usage diversity, considering both the versatility of use categories and more specific applications, without consideration for the number of informants and the likelihood of assignment to one of the categories. While a simple count of different usage categories and applications is insufficient to assess the versatility of usage (Leonti, 2022).

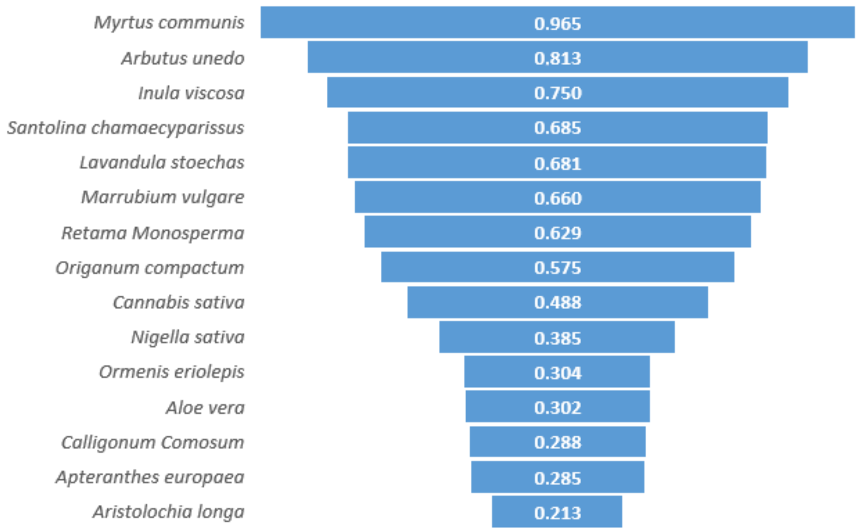

Figure 5. Relative importance index of the studied plants

Cultural value index

The Cultural Value Index allows for the assessment of the cultural importance of plants within a particular community. Results for each plant in our study provide meaningful insights, although the values are relatively low in numerical terms. It is important to note that, in the context of Cultural Value, a low value should not necessarily be interpreted as an indication of the plant's low cultural importance. On the contrary, even with modest numerical values, the cultural significance of these plants can be high within the specific context of our study (Pieroni, 2001; Tardío & Pardo-de-Santayana, 2008; Turner, 1988). The results of the Cultural Value Index demonstrate significant diversity in the cultural importance of plants within the studied community, ranging from 8.22E-05 to 4.40E-02. It is notable that *Myrtus communis* stands out distinctly with the highest value (4.40E-02), indicating a marked predominance in cultural practices. Similarly, plants *Arbutus unedo* and *Inula viscosa* display substantial values, although slightly lower than *Myrtus communis*.

These three species emerge as the most culturally important within the studied area. The cultural value ranged from 8.22E-05 to 4.40E-02 (Table 9). However, it is worth noting that this index indicates values that may not appear as high as logic might suggest.

Table 9. Cultural Value Index of the studied plants

Plants	Cultural value index
Inula viscosa (Iv)	4.40E-02
Myrtus communis (Mc)	1.86E-02
Arbutus unedo (Au)	1.47E-02
Marrubium vulgare (Mv)	1.28E-02
Retama monosperma (Rm)	9.58E-03
Cannabis sativa (Cs)	8.48E-03
Origanum compactum (Oc)	8.26E-03
Santolina chamaecyparissus (Sc)	5.88E-03
Lavandula stoechas (Ls)	5.14E-03
Aloe vera (Av)	1.50E-03
Nigella sativa (Ns)	7.18E-04
Aristolochia longa (Al)	1.96E-04
Ormenis eriolepis (Oe)	1.80E-04
Calligonum Comosum (Cc)	9.78E-05
Apteranthes europaea (Ae)	8.22E-05

Statistical analysis

The collected data underwent Principal Component Analysis (PCA) to assess the influence of

Chi-square test

To test the null hypothesis (H0) asserting the absence of a significant relationship between the variables "Municipalities" and "Methods," we employed a chi-square test. The results yielded a p-value of 0.032, which is below the conventional significance threshold of 0.05. Consequently, we reject the null hypothesis. This indicates that there is a significant relationship between the methods applied to the plants and the municipalities from which the interviews were conducted.

In contrast, the result of Pearson's chi-squared test for the variables "Municipalities" and "Parts" yielded a p-value of 0.0036. Since this p-value is below the conventional significance threshold of 0.05, we reject the null hypothesis in favor of the alternative hypothesis. This indicates a statistically significant relationship between the "Municipalities" and "Parts" variables. Moreover, the Pearson's chi-squared test was conducted to evaluate the relationship between the variables "Gender" and "Plants." The test resulted in a p-value of 0.072. Given that this p-value is greater than the conventional significance threshold of 0.05, we fail to reject the null hypothesis. Consequently, this indicates that there is no significant association between "Gender" and the types of plants used.

Kruskal-Wallis test

The Shapiro-Wilk normality test conducted on the residuals of the model yielded a Shapiro-Wilk statistic (W) of 0.90366 and an extremely low p-value (< 2.2e-16), indicating that the residuals are not normally distributed. Subsequently, a Kruskal-Wallis rank sum test was performed to assess the relationship between age and the types of plants used. The Kruskal-Wallis test resulted in a p-value of 0.6369. This suggests that there is no significant difference in the type of plant used based on age of the interviewees.

The multiple correspondence analysis (MCA)

We will examine the associations between the variables Municipalities, Plants, Parts, and Methods without a specific hypothesis regarding their relationships.

The multiple correspondence analysis (MCA) performed on the variables Plants, Parts, Methods, and Municipalities resulted in a scatter plot of individuals across two factorial axes (Fig. 6). The first two axes of the analysis account for 13.09% of the total inertia of the dataset, meaning that 13.09% of the total variability of the data cloud is represented in this plane. Although this is a relatively low percentage, indicating that the first plane captures only a small portion of the variability contained in the active dataset, it is higher than the reference value of 7.21%. This suggests that the variability explained by this plane is significant. The reference inertia is the 0.95-quantile of the distribution of percentage inertias obtained by simulating 579 random datasets of comparable dimensions based on a uniform distribution.

Furthermore, the associations between variables were identified by calculating the chi-square distance between different variable categories and respondents. The data points are displayed in Euclidean space to illustrate these associations. Variables that are close to each other at the periphery of the graph are positively associated, orthogonal variables are independent, and variables that are 180 degrees apart are negatively associated. The strength of the association between variables increases as they move closer to the graph's periphery. This visualization helps in understanding the relationships between different variables within the dataset.

The squared correlation ratios of variables across the two dimensions (Fig. 6) reveal that the variables contributing most significantly to the construction of the first dimension, in descending order, are Plants, Parts, and Methods. Conversely, the variable Municipality shows a low contribution to the second dimension. To gain a more comprehensive understanding of these relationships, a detailed representation of the categories is essential (Fig. 7). This detailed representation allows us to classify all modalities into four distinct groups in dimension 1 and two groups in dimension 2.

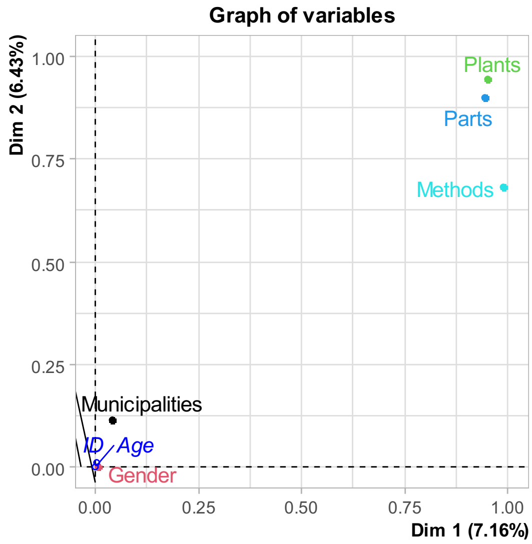

Figure 6. Map of categorical variables

In Dimension 1: The first group comprises individuals characterized by a high frequency of using the Raw (Brute) method, *Nigella sativa* plants, and seeds. They exhibit a low frequency of leaf parts, *Cannabis sativa* and *Aloe vera* plants, Gel, Grinding, and Smoking (Incense) methods. The second group consists of individuals who frequently use the Grinding method, *Cannabis sativa* plants, seeds, and have a low frequency of using leaf parts, *Aloe vera* plants, Gel methods, *Nigella sativa* plants, Brute methods and Incense methods. The third group, with a negative coordinate on the axis, shares traits like a high frequency of using the Incense method, *Cannabis sativa* plants, leaf parts, and being female. They show a low frequency of using seeds, *Aloe vera* plants, Gel methods, grinding methods, *Nigella sativa* plants, Brute methods, and being male. The fourth group, also with a negative coordinate on the axis, includes individuals who frequently use the Gel method, *Aloe vera* plants, and leaf parts. They exhibit a low frequency of using seeds, *Cannabis sativa* plants, Grinding methods, *Nigella sativa* plants, Brute methods, and Incense methods. Notably, the seed factor is highly correlated with this dimension (correlation of 0.95), which could alone summarize Dimension 1.

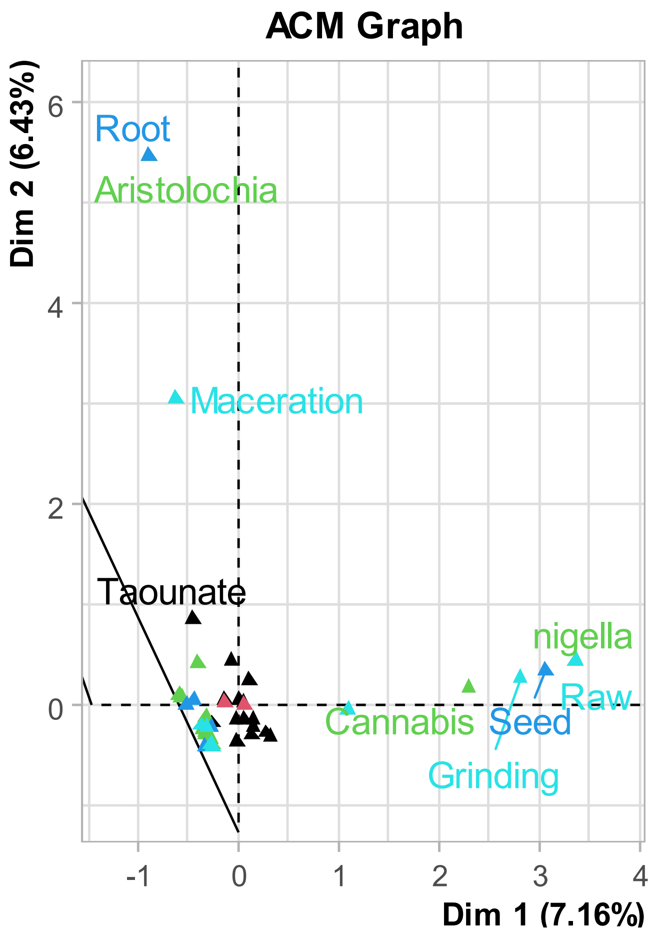

Figure 7. Visualization of Multiple Correspondence Analysis (MCA)

In Dimension 2: Dimension 2 contrasts two groups of individuals. The first group, with a strongly positive coordinate, shares characteristics such as a high frequency of using the Gel method, *Aloe vera* plants, and leaf parts, and a low frequency of using seeds, *Cannabis sativa* plants, Grinding methods, *Nigella sativa* plants, Brute methods, and Incense methods. The second group, with a strongly negative coordinate (at the bottom of the graph), shares traits like a high frequency of using the Brute method, *Nigella sativa* plants and seeds, and a low frequency of using leaf parts, *Cannabis sativa* plants, *Aloe vera* plants, Gel methods, Grinding methods, and Incense methods.

Dissimilarity Analysis of Samples across Plants in Different Municipalities Using NMDS.

The non-metric multidimensional scaling (NMDS) plot in Fig. 8 reveals distinct patterns that are pivotal to our understanding of the relationships between plants and geographical locality (Municipalities).

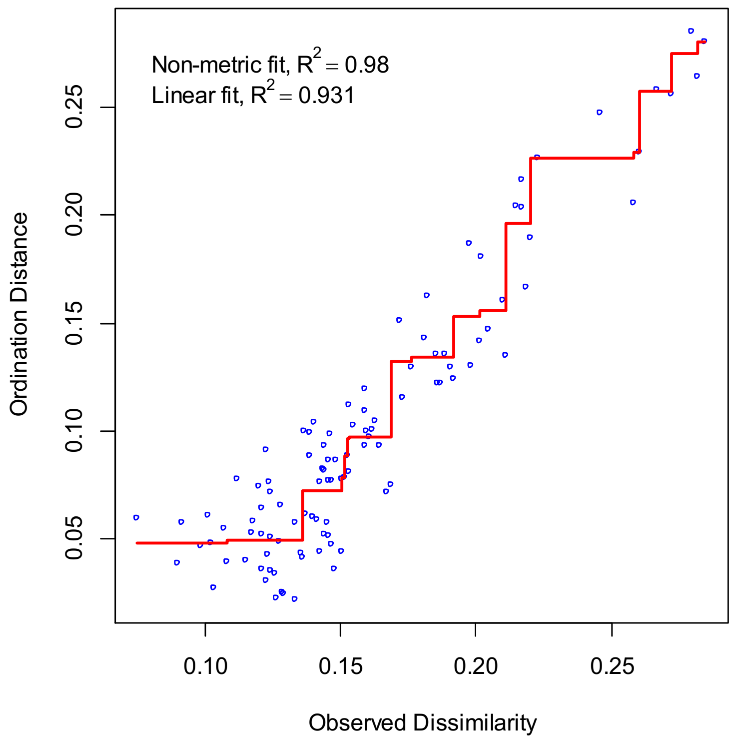

Figure 8. Shepard stress plot. Relationship between NMDS ordination distance and original observed distance

The Shepard diagram (Freveals a significant correlation between the observed distances and the distances calculated by the ordination, with a coefficient of determination R2 equal 0.98. This strong correlation attests to the reliability of the adjustment carried out by the NMDS method. Furthermore, the low value of stress, measured at only 0.13, also confirms the high quality of adjustment achieved by the NMDS (Fig. 8). This combination of results underlines the relevance of the two-dimensional representation of the similarities between objects in the analysis, as well as the robustness of the method used for this study.

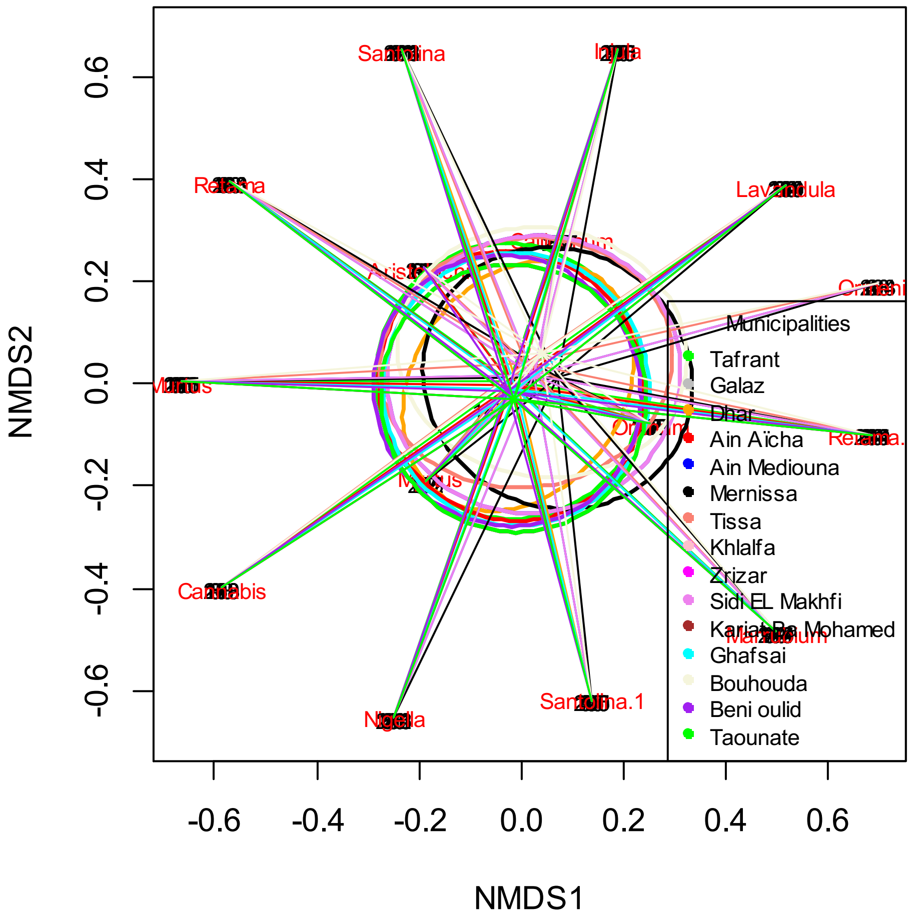

Figure 9. Non-metric multidimensional scaling (NMDS) plot based on Bray-Curtis dissimilarity indices. (Each axis represents a studied plant marked in red and each colored line corresponds to a specific municipality)

The similarities were clearly evident in the non-metric multidimensional scaling (NMDS) plot, as depicted in Fig. 9. The analysis reveals that certain plants are more closely associated with specific municipalities. Additionally, the overlapping ellipses at the center indicate that some plants share common characteristics across multiple municipalities, suggesting a similarity in the presence of these plants (e.g., *Santolina chamaecyparissus*, *Marrubium vulagare*, *Aristolochia longa* and *Ormenis eriolepis*).

In light of the visually suggestive results from the nMDS graph, the imperative need for rigorous statistical validation of our hypothesis becomes clear. To achieve this, we utilized permutational multivariate analysis of variance (PERMANOVA) with the adonis2 function in the R package vegan (Oksanen *et al.*, 2022), based on Bray-Curtis dissimilarity (distance). The significance of these results was assessed through a Monte Carlo permutation test (permutations = 999). Testing the null hypothesis, which posits that there is no significant relationship between the dispersal of plants and the municipalities, is detailed in Table 10.

Table 10. Permutational multivariate analysis of variance (PERMANOVA) results based on Bray-Curtis dissimilarities

Plants	Df	Sum Sq	R^2	F.Model	P
Locality	14	284.35	0.73753	168.2	0.001
Residual	838	101.19	0.26247		
Total	852	385.54	1.00000		

Df: degrees of freedom; Sum Sq: Sum of squares; F.Model: F value by permutation. R2: the effect size. Boldface indicates statistical significance with $p < 0.05$

The results reveal a significant relationship between the dispersal of plants and the municipalities in which they are found. This relationship suggests that the distribution patterns of various plant species are not random but are influenced by specific characteristics of the municipalities ($P < 0.05$).

Conclusion

This ethnobotanical survey has unveiled remarkable biodiversity in the Taounate region, highlighting a wide array of medicinal and aromatic plants. The results underscore the substantial potential of traditional knowledge for developing affordable medicines from natural product derivatives. However, it is evident that more in-depth explorations are needed to fully harness this botanical wealth.

The collected data demonstrates a strong reliance of the local community on herbal remedies, often sought from local herbalists or used based on transmitted knowledge. The emphasis placed on the elderly during our survey has facilitated the extraction of comprehensive and valuable ethnobotanical knowledge regarding medicinal plants.

Our analysis identified the plants *Myrtus communis*, *Arbutus unedo*, and *Inula viscosa* as particularly interesting and widely used by the community. These species appear to play a central role in local traditional medicine, emphasizing their potential importance for the development of new derivative products. Notably, these plants are both cultivated by the local community and harvested from the wild, reflecting a deep-rooted knowledge and sustainable use of local botanical resources.

However, despite the persistence of traditional medicine in the region, it is concerning to note that knowledge and practices are not always transmitted to future generations.

Our study suggests that the valorization and preservation of local biodiversity, with a focus on plants like *Myrtus communis*, *Arbutus unedo*, and *Inula viscosa*, could not only contribute to short-term community health but also offer promising prospects for the future development of natural and affordable medicines.

Declarations

Lists of abbreviations: UV: Use Value, FL: Fidelity Level, ICF: Informant Consensus Factor*, Mc: Myrtus communis, Au: Arbutus unedo, Oc: Origanum compactum, Oe: Ormenis eriolepis, Sc: Santolina chamaecyparissus, Ns: Nigella sativa, Mv: Marrubium vulgare, Ae: Apteranthes europaea, Ls: Lavandula stoechas, Rm: Retama monosperma, Cs: Cannabis sativa, Iv: Inula viscosa, Av: Aloe vera, Cc: Calligonum comosum, Al: Aristolochia longa*

Ethics approval and consent to participate: Prior to the survey, we obtained oral informed consent from each participant.

Consent for publication: Not applicable

Ethics approval and consent to participate: All interviewees gave their informed consent prior to the start of the interview. All data were collected with respect for confidentiality, anonymity and consent.

Availability of data and materials: The article contains the supporting figures and tables for the study's results, while the original datasets can be obtained from the primary author upon request.

Competing interests: The authors declare that there are no conflicts of interest in this article.

Funding: Authors have not received any funding during this research.

Author's contribution: AEM designed the questionnaire. AEM, MN, TB and BL conducted the personal interviews. SB did the statistical analysis. MK, AN, CE and CR supervised the study. AEM wrote the original draft of the manuscript. CS and CR critically revised the manuscript. All the authors approved the final draft of manuscript after revision.

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Table 11. List of medicinal and aromatic plant species used by the local population in the province of Taouante

Botanical name (Citation)	Vernacular name	Parts used	Application method	Mode of preparation	Therapeutic use
Inula viscosa	Magramane	Leaves	External application	Grinding	Wound healing
			Oral ingestion	Infusion	Venom
Myrtus communis	Rayhan	Leaves	Oral ingestion	Decoction	Aerophagy
				Infusion	Fever
				Maceration	Venom
		Aerial Parts	External application	Griding	Wound healing
Arbutus unedo	Sasnou	Leaves	Oral ingestion	Decoction	Diabetes
				Infusion	Aerophagy Intoxication
Retama monosperma	R'tem	Leaves	Oral ingestion	Infusion	Inflammation
				Decoction	Diabetes
		Fruits	External application	Grinding	Rheumatism
Marrubium vulgare	Merriwa / Merriwta	Leaves	Oral ingestion	Maceration	Diabetes
				Infusion	Intoxication Asthma / Cough
Cannabis sativa	Kif	Leaves	Inhalation	Smoking	Diabetes
		Seeds	External application	Grinding	Alopecia (Baldness)
Origanum compactum	Zaatar	Leaves	Oral ingestion	Infusion	Diabetes
				Decoction	Aerophagy Indigestion
Santolina chamaecyparissus	Gartoufa	Leaves	Oral ingestion	Decoction	Diabetes
				Infusion	Intoxication Indigestion Fever
Lavandula stoechas	khouzama	Leaves	Oral ingestion	Infusion	Rheumatism
				Decoction	Fever Hepatitis
		Flowers	External application	Grinding	Wound healing
Aloe vera	Sabra	Leaves	External application	Gel	Burn
Nigella sativa	Habba Sawda	Seeds	Oral ingestion	Raw	Diabetes Indigestion

Aristolochia longa	Bereztem	Roots	Oral ingestion	Maceration	Fever
Ormenis eriolepis	Hellala	Flower	Oral ingestion	Maceration	Diabetes Aerophagy
Calligonum comosum	Arta	Aerial parts	Oral ingestion	Decoction	Inflammation Fever
Apteranthes europaea	Darmouss	Leaves	Oral ingestion	Infusion	Diabetes Hepatitis