Ethnobotanical study of medicinal plants used by the population of Ain Chkef (North central Morocco)

Khadija Benamar, Saad Ibnsouda Koraichi, Saad Benamar and Kawtar Fikri-Benbrahim

Correspondence

Khadija Benamar[1], Saad Ibnsouda Koraichi[1], Saad Benamar[2] and Kawtar Fikri-Benbrahim[1*]

[1]Microbial Biotechnology and Bioactive Molecules Laboratory, Sciences and Technologies Faculty, Sidi Mohamed Ben Abdellah University, P.O. Box 2202, Imouzzer Road, Fez, Morocco.
[2]High School Teachers-Training Institution, Laboratory of Biotechnology, Environment, Agri-Food, and Health, Sidi Mohamed Ben Abdellah University. P.O. Box 5206 Bensouda, Fez, Morocco.

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

Ethnobotany Research and Applications 26:4 (2023) - http://dx.doi.org/10.32859/era.26.4.1-23
Manuscript received: 27/02/2022 – Revised manuscript received: 14/06/2023 - Published: 18/06/2023

Research

Abstract

Background: Medicinal and aromatic plants (MAPs) use in the folk medicine is widely spread in Morocco. This work aims to study their use in Ain Chkef; a rural area in North central Morocco. It also documents multiples data concerning the ethno-medico-botanical traits of the most cited species.

Methods: An ethnobotanical survey was carried out through the interview of 183 individuals. The responses were analyzed using several plant citation indexes (RFC; FIV; PPV and FL). Correlations between plants and humans of different ages, genders, educational levels, and marital status, were investigated by multiple components analysis (MCA) performed using XLSTAT software.

Results: 93.44% of the studied population use MAPs. Among the 48 used species, belonging to 27 botanical families, the most frequently cited were *Origanum compactum* Benth*. Chenopodium ambrosioides* L, *Cuminum cyminum* L., *Mentha pulegium* L. Leaves were the dominant part used. The infusion and decoction were the principal preparation methods. MCA showed that people not or low using MAPs (< 3) are sharing common traits: Male, not married, high educational level, < 40 years aged. People highly (> 7) or moderately (4 to 7) using MAPs are mainly: Female, married, with low educational level, >40 years aged.

Conclusion: The present study highlighted the spread use of MAPs among the interviewed population in Ain Chkef as traditional remedies. Thus, this work will provide researchers with an important ethnobotanical database which can be exploited in the development of pharmacognosy.

Keywords: Ethnobotanical study; medicinal plants; Ain Chkef; Plant citation indexes; multiple component analysis.

Background

In spite of the development of medicine and the availability of modern therapies, an important interest to traditional pharmacopoeia remains remarkable (Abouri *et al*. 2012).

Medicinal and aromatic plants (MAPs) are widely used in the preparation of herbal remedies especially in rural areas (Abouri *et al*. 2012), since they are affordable, easily accessible and own an efficient healing potential (Al-Adhroey *et al*. 2010).

Morocco is one of countries where the art of healing diseases using MAPs has reigned (Jouad *et al.* 2001). Indeed, thanks to its geographical position (between Sahara in the South, the Atlantic Ocean on the West and the Mediterranean Sea in the North), Morocco presents very rich and diversified ecosystems (Ouhaddou *et al*. 2014). Moreover, Moroccan flora is characterized by more than 7000 species and subspecies including about 800 species of MAPs (Ouhaddou *et al*. 2014).

The knowledge of ethnomedicinal uses of MAPs is extremely important since it constitutes the first pillar of ethnopharmacology (Süntar 2020). In fact, based on traditional uses of MAPs as remedies, many researchers have demonstrated their pharmacological properties as well as their richness in bioactive compounds (Rates 2001), which can therefore be used for the development of natural-based drugs (Zareef *et al*., 2023).

In order to contribute to ethnopharmacology and to preserve Moroccan heritage regarding the preparation of traditional remedies based on MAPs, several ethnobotanical studies have been conducted in different regions of Morocco (Abouri *et al.* 2012*,* Bellakhdar 1997, Jeddi *et al.* 2021*,* Sijelmassi 1993, Tahraoui *et al*. 2007), generally demonstrating the wide use of MAPs in the studied areas. In order to contribute to this research effort, we carried out this work focused on the Ain Chkef area (north central Morocco), where to the best our knowledge, no ethnobotanical survey has been done. The main objectives of the present work were to explore the extent of use of MAPs in this area; to identify the MAPs species used, to determine the diseases treated by these MAPs, and to investigate the existence of determining relationships between those collected data and diverse socio-demographic characteristics (age, gender, educational level...). The study was completed by a bibliographic review documenting the described bioactive molecules and pharmacological properties of the most used MAPs. Furthermore, this work matches with the current global concern related to sustainability. It corresponds to the research of nature-based solutions and the valorization of natural resources and ancestral knowledge linked to human well-being.

Materials and Methods

Study area

Ain Chkef is a rural commune located in the Fez-Meknes region (Figure. 1), precisely in the Moulay Yaacoub province (Kingdom of Morocco) (HCP Morocco 2012). The geographical coordinates of its centre are 33° 57' N, 5° 1' 41'' W, with an altitude of 499 m and a Mediterranean climate (Db-city.com 2023). Ain Chkef (a peri-urban area of Fez city) is covering an area of 146.352 Km^2 with a population density of 238 inhabitants / km^2 (Ministry of urban planning and territory development (MUPTD), 2014). This population benefits from easy access to superior services through the relatively developed urban network of the metropolis (MUPTD 2014).

In addition to the agricultural potentialities residing in the production of cereals and fodder (MUPTD 2014), the studied area is also distinguished by the planted forest Ain Chkef; a green corridor of 60 ha sheltering diverse native and exotic plant species (Benamar 2011).

Data collection

The ethnobotanical survey was carried out at Ain Chkef area.

This study is based on the completion of a questionnaire concerning the socio-demographic profile of the people surveyed (age, gender, level of education, marital status and socio-economic level) on the one hand and the plants they use for medicinal purposes (scientific and local name, parts used, targeted diseases, preparation methods and doses) on the other hand.

The study sample consisted of respondents randomly interviewed at the entrance and exit gate of the main weekly popular market (souk), in the Ain Chkef area. The total number of people interviewed was 183, and the time spent with each interviewee varied between 15 and 20 minutes.

The protocol followed in this work was previously validated by the Council of our Laboratory and applied in several published studies (Jeddi *et al*. 2021, El Hachlafi *et al*. 2020, Benkhaira *et al*. 2021).

Plant species identification

The plant species used by the interviewed population were identified with the help of Moroccan botanical books (Bellakhdar 1997, Fennane *et al*. 1999, Sijelmassi 1993) and through the consultation of other ethnobotanical studies carried out in Morocco (El Hachlafi *et al.* 2020, Jeddi *et al*. 2021, Ouhaddou *et al*. 2014).

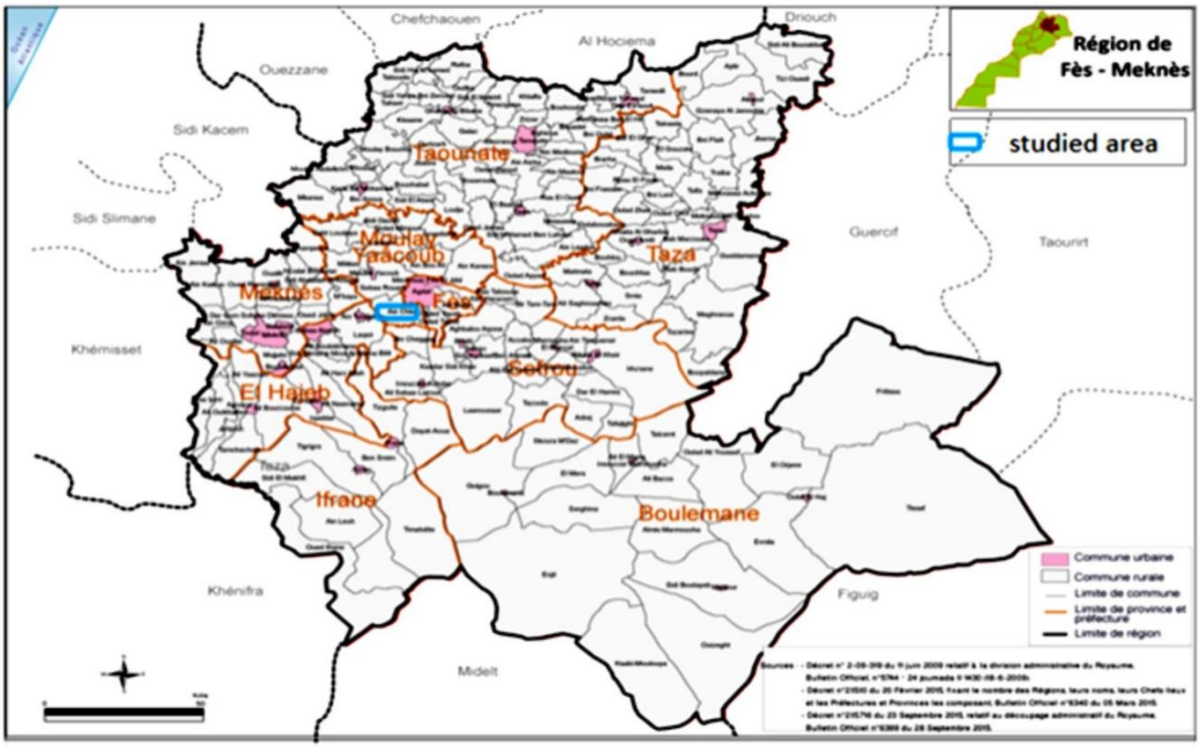

Figure 1. Geographical location of the studied area in Morocco.

Data analysis

Collected data were statistically analyzed using Microsoft Office "Excel 2013". Socio-demographic collected data of respondents were analyzed by descriptive statistics (frequencies and percentages). Concerning ethnobotanical data, they were interpreted through quantitative citation indexes: RFC, FIV, PPV and FL.

Moreover, in order to understand the structure of relationships among plants and humans differing by their age, educational level, gender and marital status, multiple component analysis (MCA) was performed by XLSTAT software.

Relative frequency of citation (RFC)

This index reveals the relative importance of each MAPs species mentioned by respondents. It is calculated by dividing the number of people who mentioned the use of the species (FC), by the total number of respondents using MAPs (N), according to Tardio and Pardode-Santayana (2008) formula:

RFC=FC/ N

With: 0 < RFC < 1

Family Importance Value (FIV)

FIV shows the importance of the families used. It is designed to evaluate the biological taxonomic value of plants; it is calculated by the following formula (Sreekeesoon & Mahomoodally 2014):

FIV=FC family / Ns

Where FC family (FC family=RFC) refers to number of informants citing the family, and Ns is the total number of cited species in each family.

Fidelity level (FL)

Fidelity level reveals the efficiency of a plant species against a particular disease. It was calculated according to the following formula according to Sreekeesoon & Mahomoodally (2014):

FL=IP/ Lu x 100

IP: refers to the citations number of a given plant species used in the treatment of a particular disease.
Lu: indicates the total number of citations of this species used for the treatment of any disease.

Plant part value (PPV)

Plant part value indicates the use frequency of each plant's organ. It is calculated following this formula (Gomez-Beloz 2002):

PPV=RU plant part/ RU

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

Multiple component analysis (MCA)

Multiple component analysis was performed by XLSTAT software to understand the structure of relationships among plants and humans differing by their age, educational level, gender and marital status. Since the MCA is generally applied for qualitative variables, the age of respondents and the number of MAPs they use are quantitative variables, they were converted on to qualitative variables using different classes:

- For the age:
    - Age-Low: Age < 20 years.
    - Age-Medium: 20 < Age < 40 years.
    - Age- High: Age > 40 years.
- For the number of MAPs used:
    - MAPs used zero: People not using MAPs.
    - MAPs used-Low: MAPs used < 3.
    - MAPs used-Medium: 4 < MAPs used < 7.
    - MAPs used-High: MAPs used > 7.

Concerning the educational level (EL), in the MCA, the university level wasn't considered among the modalities of this variable, because of the low number (4) of informants corresponding to this modality. These four cases were added to the number of the secondary level informants.

Two parameter's Kolmogorov-Smirnov test

A statistical analysis of the population distribution was carried out in the context of the comparison of informant populations using and not using MAPs, grouped into age, sex, educational attainment, socio-economic and marital status categories. The two-parameter Kolmogorov-Smirnov test was performed using the XLSTAT software, for each category, to determine whether the two samples came from a population of the same distribution (equality hypothesis accepted) or not (equality hypothesis rejected) at $p = 0.05$. For each category, the samples correspond to the frequency of each of the two parameters (MAPs use or not) for informants of a given age between 12 and 74 years (62 values). For the «age» category, the sample is divided on two parts (< 42 years and ≥ 42 years) of 31 values each one.

Review study

In order to highlight the ethnomedicinal uses of the most cited MAPs species, a literature review was performed regarding the pharmacological properties of these species, as well as their traditional uses reported in other ethnobotanical studies. Data bases used for this purpose were: PubMed, Science Direct, Scopus, and Google Scholar. In addition to the name of the species, the keywords used for this research were: 'ethnomedicinal uses', 'biological activities', and 'pharmacological properties.

Chemical structures of different bioactive compounds of these species were drawn using the ChemDraw software.

Results and Discussion

Use of MAPs by respondents

In the studied area, only 6.55% of respondents have declared not using MAPs for medicinal purposes, while the majority (93.44%) have stated that they use MAPs for the treatment of various ailments (Figure 2). This result could be explained by the attachment of the studied population to its traditional heritage regarding the use of MAPs (Benamar *et al*. 2023).

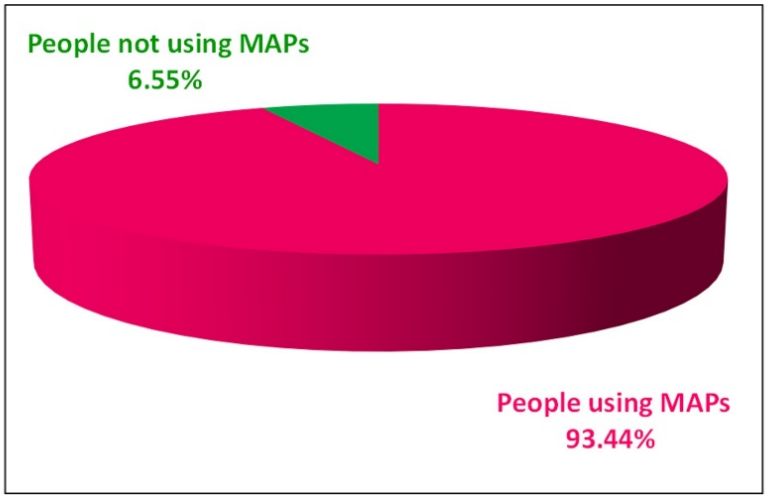

Figure 2. Distribution of respondents according to their statements regarding their use or not of MAPs.

Socio-demographic data of respondents

Age

As shown in figure 3, the use of MAPs in the studied area is widespread among people in the age group > 40 years (47.95%), followed by those who are between 20 and 40 years (41.52%). While the lowest percentage of MAPs use is noted among young people < 20 years (10.52%). Our results are similar to those obtained in other ethnobotanical studies conducted in different regions of Morocco (Jeddi *et al.* 2021, Kachmar *et al*. 2021). The dominance of the use of MAPs by the elderly could be explained by the fact that these people have a better knowledge and highest conviction of the efficiency of the traditional medicinal use of MAPs (Benkhaira *et al*. 2021).

Concerning the people not using MAPs, they belong to different age groups (Figure 3): < 20 years (25%), 20-40 years (50%), > 40 years (25%). These people said that they fear MAPs toxicity.

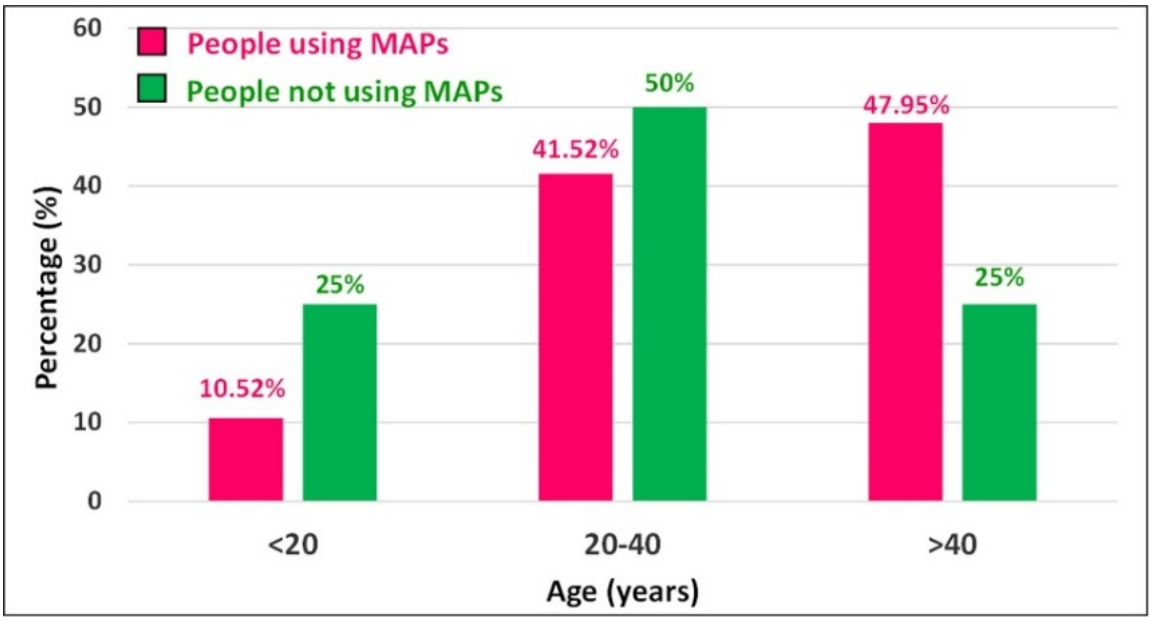

Figure 3. Distribution of respondents using or not MAPs according to their age.

Gender

The use of MAPs in the Ain Chkef area varies according to informant gender (Figure 4); indeed, women (84.21%) use them more than men (15.78%). This could be attributed to the fact that women have more knowledge about MAPs, their preparation and administration modes, in comparison with men. Similar findings were observed in other ethnobotanical studies at national scale (Alaoui *et al*. 2018, Bencheikh *et al*. 2021, Jeddi *et al*. 2021). As for people not using MAPs, women and men represent almost the same percentage: 58.33% and 41.66% respectively (Figure 4).

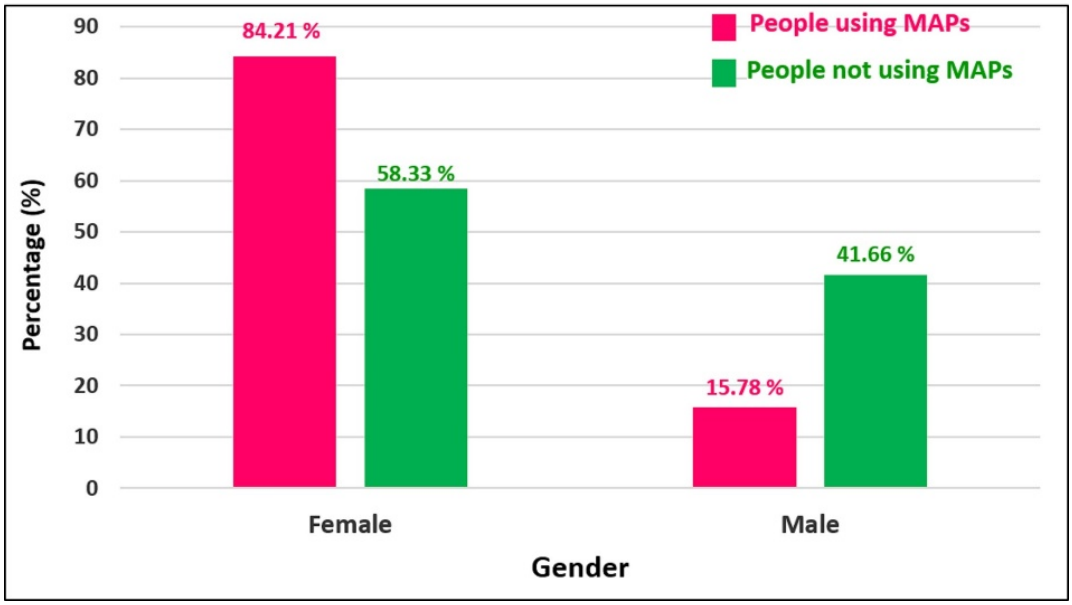

Figure 4. Distribution of respondents using or not MAPs according to their gender.

Educational level

In the studied area, among the medicinal plant users, the majority (57.89%) are illiterate, while 23.39% of them have a primary educational level and 16.37% have a secondary level. The lowest percentage (2.33%) correspond to users having a university level (Figure 5). Similar results were obtained in Morocco by Bencheikh *et al*. (2021), El Hachlafi *et al*. (2020) and Jeddi *et al.* (2021). As regard people not using MAPs, they are composed equally (50%) of illiterate and educated individuals.

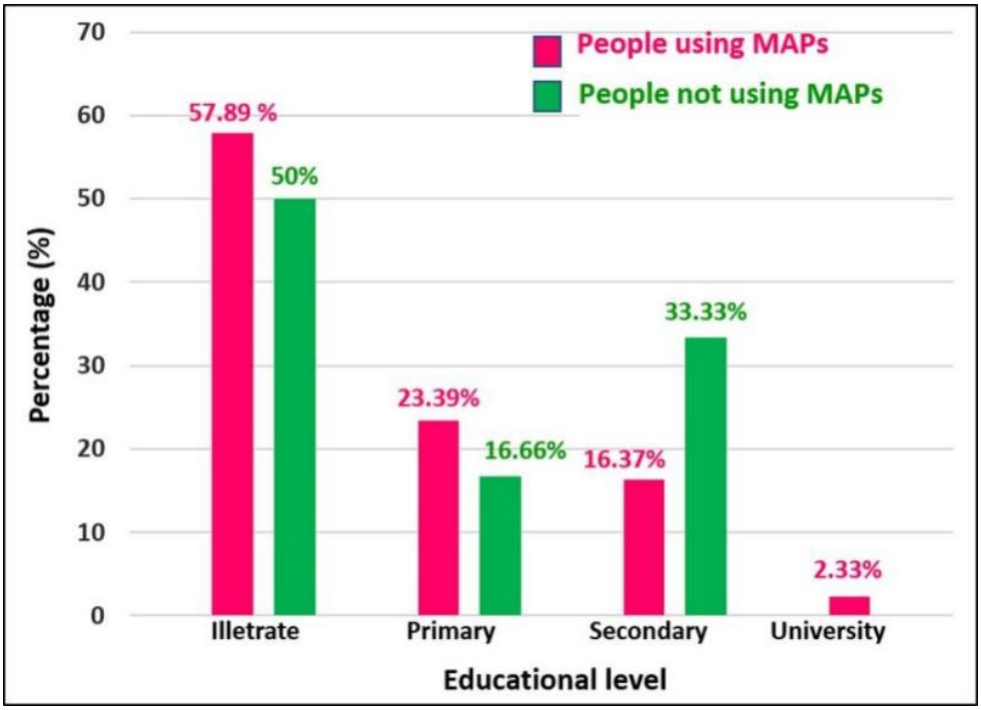

Figure 5. Distribution of respondents using or not MAPs according to their educational level.

Socio-economic status

In Ain Chkef area, most of people using MAPs have a medium socio-economic level (81.28%) followed by those with a low level (36%), while only 1.75% have a high level (Figure 6). This may explain the use of herbal medicine by the indigenous population in the treatment of diseases as an accessible and effective mean. Our findings are consistent with those obtained in other ethnobotanical surveys (Benkhaira *et al*. 2021, Jeddi *et al.* 2021).

As for people not using MAPs, they are composed of only 16.66% of individuals having a low socio-economic level, while the majority of them (83.33%) have a medium level. This result suggest that the latter may be users of modern medical treatments in spite of their cost.

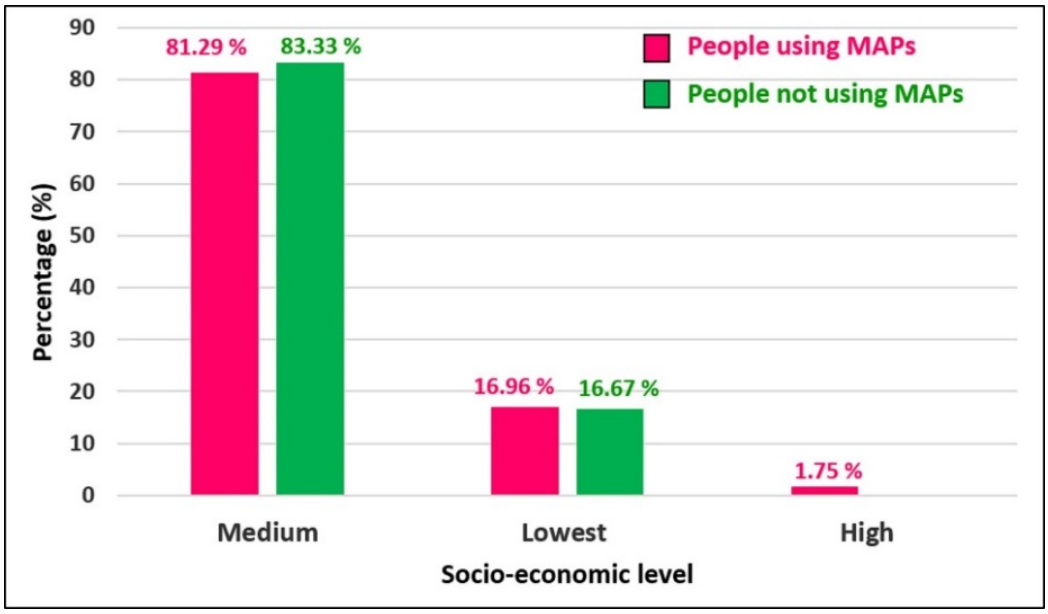

Figure 6. Distribution of respondents using or not MAPs according to their Socio-economic level.

Marital status

According to the present ethnobotanical survey (Figure 7), MAPs are used much more by married people (81.28%), than by single people (18.71%). This could be explained by the fact that families with medium or low incomes tend to use MAPs in order to reduce or avoid the high costs of medical visits and treatments (Benkhaira *et al*. 2021, Jeddi *et al.* 2021).

Regarding people not using MAPs, they include married and single persons with percentages of 66.66% and 33.33% respectively.

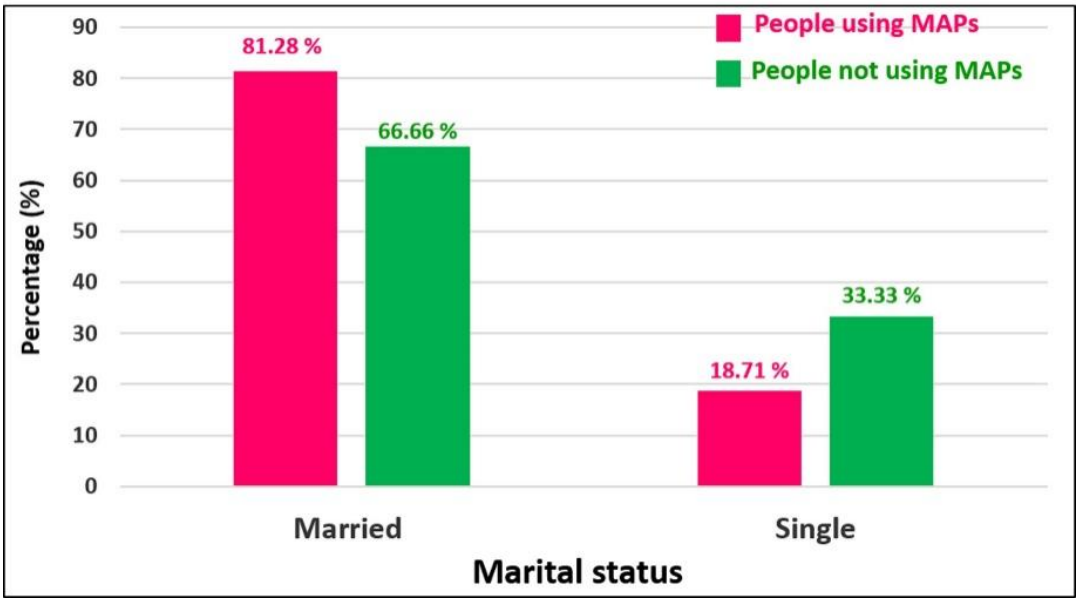

Figure 7. Distribution of respondents using or not MAPs according to their marital status.

Multiple component analysis of collected data

The results of the MCA are presented in figure 8. Overall, the two axes F1 and F2 account for 41.06 % of the total variation in our data. F1 presents 25.73 % of the total variation and reveals two categories of people according to their use of MAPs: people not using MAPs (MAPs used zero), or with a low use of MAPs (MAPs used < 3) and people with a medium (4 < MAPs used < 7) or a high (MAPs used > 7) use of MAPs. The second axis F2 accounts for 15.34 % of the total variation and separates people according to their gender (male and female). It can be noted from this figure that people with zero or low use of MAPs are sharing common traits: marital status (MS-Single), educational level (EL-Secondary), age group-Low and gender-Male. As regard people with a medium or a high use of MAPs, they have other characteristics: MS-Married, EL-illiterate and EL-Primary, Age-Medium / Age-High and gender-Female. These findings are suggesting the following explanations:

People with low educational level who are associated with a medium or high use of MAPs (Figure 8) are tightly attached to their traditional heritage and have high trust on the efficiency of MAPs. However, it must be noticed that these people are probably not aware of MAPs danger when used at high doses. As for people with higher educational level (EL-Secondary), they are associated with zero of low use of MAPs, may be because they are more conscious of health risks that can result from the random use of MAPs. The correlation between the medium and the high use of MAPs with people of medium or high age can be attributed to the high knowledge of these persons of MAPs uses modes in the treatment of several diseases and their attachment to their traditional heritage, unlike the case of young people. Regarding the gender, the MCA allows also to note that women are associated with medium or high use of MAPs unlike men. This can be justified by the fact that women have more expertise in the preparation of different MAPs recipes that are appropriate for the treatment of various ailments.

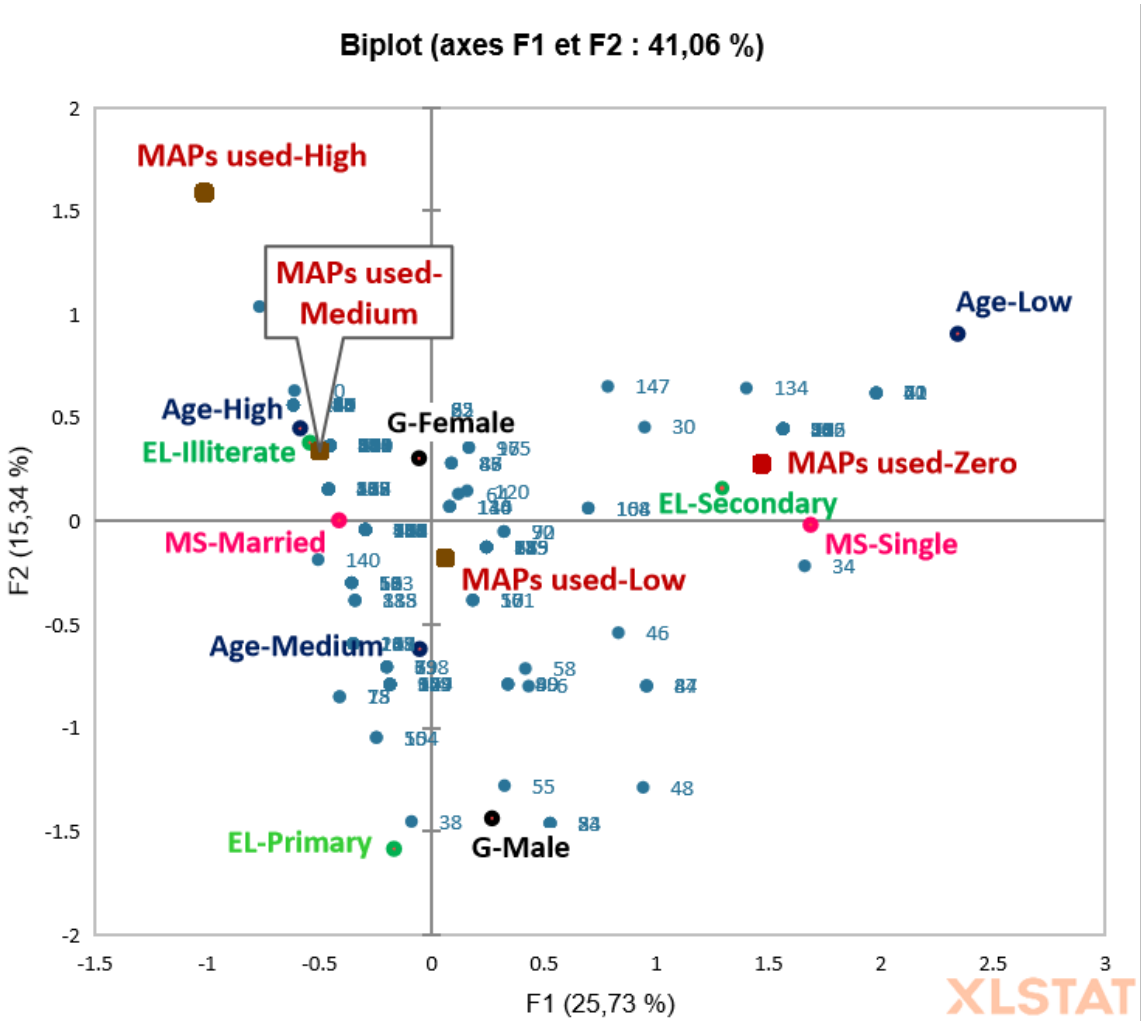

Figure 8. Biplot of multiple component analysis applied to different variables related to the respondents.
Age-Low: < 20 years, Age-Medium: 20 < age < 40 years, Age- High: > 40 years; MAPs used zero: People not using MAPs, MAPs used-Low: MAPs used < 3, MAPs used-Medium: 4 < MAPs used < 7, MAPs used-High: MAPs used > 7; G: gender; EL: educational level; MS: marital status.

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

Although the current ethnobotanical study was based on a randomized sampling of informants, we considered interesting to supplement the MCA results by a statistical comparison of the distribution of the different population categories according to the frequency of their use or non-use of MAPs at each age between the minimum and maximum encountered (12-74 years). The results of this analysis performed by the two parameter Kolmogorov-Smirnov test, presented in Table 1, show that the hypothesis of equal distribution of the populations of informants using or not the MAPs (MAPs-using and MAPs-not-using) was rejected for three categories based on age, gender and educational level, which is in conformity consistent with the MCA results (Figure 8) showing for example that Medium or High-age is associated with other characteristics of the population highly or moderately using MAPs, particularly gender-Female; MS-Married; EL-illiterate and EL-Primary. This means that populations using MAPs in these categories could not have an an age distribution equal to that of populations not using MAPs. In contrast, the Kolmogorov-Smirnov test shows that the hypothesis of equal distribution of populations using or not MAPs is accepted for "low socioeconomic level" and "unmarried" categories.

Thereby, these results corroborate with those of multiple component analysis, which support the findings that age, gender, marital status, socio-economic and education levels are important demographic variables affecting the use of herbal medicinal plants, in the studied area.

Table 1: Results of the two parameters Kolmogorov-Smirnov test applied to the datasets of different categories of informant's populations represented in figures 3-7. The nul hypothesis was that the two samples come from a population of the same distribution (p = 0.05).

Figure	**Category**	**Two samples** Using MAPs :	**Sample size**	**D-stat** Max Deviation	**Ks** (Kolmogorov-Smirnov test statistic)	**P value**	**Hypothesis**
3	**< 42 years**	Yes *vs* No	31	0.774194	3.048003	0.000000	Rejected
	≥ 42 years	Yes *vs* No	62	0.612903	2.413002	0.000018	Rejected
4	**Female**	Yes *vs* No	62	0.612903	3.412501	0.000000	Rejected
	Male	Yes *vs* No	62	0.258065	1.436842	0.032197	Rejected
5	**Educated**	Yes *vs* No	62	0.435484	2.424672	0.000016	Rejected
	Illiterate	Yes *vs* No	62	0.467742	2.604277	0.000003	Rejected
6	**SEL-Low)**	Yes *vs* No	62	0.209677	1.167434	0.130950	Accepted
	SEL-Medium	Yes *vs* No	62	0.612903	3.412501	0.000000	Rejected
7	**Married**	Yes *vs* No	62	0.612903	3.412501	0.000000	Rejected
	Single	Yes *vs* No	62	0.161290	0.898027	0.395461	Accepted

Floristic analysis

The ethnobotanical survey conducted in Ain Chkef area has allowed us to identify 48 species of MAPs, belonging to 27 botanical families, used for the treatment of various ailments.

All the plants listed are presented in table 2 where are indicated for each of them: The scientific name of species and botanical families, the vernacular name, parts used, targeted diseases, preparation method and the data related to FC, RFC and FIV; for each of them. Among the 27 botanical families cited by respondents, the most representative are Chenopodiaceae (FIV=0.251), Verbenaceae (FIV=0.181), Lamiaceae (FIV=0.110), Apiaceae (FIV=0.078) (Figure 9). Other studies have also showed the preponderance of ethnomedicinal use of plant species belonging to these families (Alaoui *et al*. 2018, Chaachouay *et al.* 2020*,* El Hachlafi *et al*. 2020).

It's important to note that the MAPs used by the population of Ain Chkef area include only one species which is endemic in a large area including Morocco and Iberian Peninsula: *Origanum compactum* Benth (Fennane *et al*., 2007). Furthermore, the listed MAPs are in majority under LC IUCN status, which means a least concern (Fennane 2021). The only two cited MAPs considered as threatened species according to IUCN criteria are: *Artemisia absinthium* L. (endangered 'EN') *Origanum compactum* Benth (vulnerable 'VU') (Fennane 2021).

Table 2. Some traits of MAPs used by respondents in Ain Chkef: Scientific and vernacular names, parts used, preparation and use modes and citation indexes (FC, RFC and FIV).

Scientific name	Vernacular name	Parts used	Treated diseases	Modes of :		Indices	
Families *Species*				**Prepar.**	**Use**	**FC**	**RFC**	**FIV**
Aloeaceae								**0.011**
Aloe vera L.	**Aloe vera**	L	OAD, DT	R (Juice)	O	2	0.011	
Apiaceae								**0.078**
Carum carvi L.	**Karwiya**	S	SD	R, Dc, In	O	7	0.040	
Coriandrum sativum L.	**Kasbour**	S	SD	R	O	5	0.029	
Cuminum cyminum L.	**Kamoun**	S	SD	R, Dc, In	O	40	0.233	
Foeniculum vulgare Mill.	**Nafaâ, besbass**	S	NSD, SD	R, Dc, In	O	11	0.064	
Petroselinum crispum (Mill.) Nyman ex A.W.Hill	**Maâdnous**	AP, L	KD, UD, SD	Dc, In, R	O	4		
Arecaceae								**0.017**
Chamaerops humilis L.	**Doum**	L	I, DD	Fu	E	3	0.017	
Asparagaceae								**0.005**
Asparagus albus	**Sekkoum**	L	SD	In	O	1	0.005	
Asteraceae								**0.030**
Artemisia absinthium L.	**Chiba**	L	OD, SD	Dc, In	O, E	3	0.017	
Artemisia herba alba Asso	**Chih**	L	SD	R, Dc, In	O	13	0.076	
Chamaemelum nobile (L.) All.	**Babounj**	Fl	SD	Dc	O	1	0.005	
Dittrichia viscosa (L.) Greuter	**Magraman**	L	DD, DT, BP, SD	Ct, In, R (Juice)	O, E	4	0.023	
Brassicaceae								**0.005**
Lepidium sativum L	**Habb er- chad (l'horf)**	S	CO, COU	R	O	1	0.005	
Cannaceae								**0.005**
Canna indica	**Soussane**	L	H	Ct	E	1	0.005	
Caryophyllaceae								**0.011**
Arenaria rubra L.	**Harass elhajer**	L	KD	R	O	2	0.011	
Chenopodiaceae								**0.251**
Chenopodium ambrosioides L.	**Mkhinza**	L	OD, SD, F	Dc, In, Ct, R (Juice)	O, E	43	0.251	
Fabaceae								**0.032**
Trigonella foenum graecum L.	**Halba**	S	SD	R, Ma, In, Dc	O	10	0.058	
Vicia faba L.	**Fûl**	S	COU	R	O	1	0.005	
Juglandaceae								**0.005**
Juglans regia L	**Sswâk, el-gargae**	S	NSD	R	O	1	0.005	

Lamiaceae								**0.110**
Calamintha officinalis L.	**Manta**	L	CO, SD	In, Dc	O	4	0.023	
Lavandula officinalis L.	**Lakhzama**	Fl	UD, SD	Fu, Dc, In	E, O	13	0.076	
Marrubium vulgare L.	**Merriwta**	L	SD, DT, OD, OAD, CO, UD, DD, CA	R, Dc, In, D, Ma	E, O	15	0.087	
Melissa officinalis	**Mersita**	L	F	Dc	O	2	0.011	
Mentha pulegium L.	**Fliyyo**	L	SD, CO, COU	In, Dc	O	38	0.222	
Mentha viridis L.	**Liqamâ**	L	F	R (Juice)	O	1	0.005	
Ocimum basilicum L.	**Lahbaq**	L	SD	Dc	O	1	0.005	
Origanum compactum Benth.	**Zaâter**	L	SD, OD, OAD, DT	In, Dc, R	O, E	92	0.538	
Origanum majorana L.	**Merded-douch**	L	SD	In	O	1	0.005	
Rosmarinus officinalis L.	**Azir**	L	SD, OAD	Dc, In	O	33	0.192	
Salvia officinalis L.	**Ssâlmya**	L	SD	Dc, In	O	8	0.046	
Lauraceae								**0.064**
Cinnamomum verum Berchtold & J. S. Presl	**Qarfa**	Ba	SD, T	In, Dc	O	11	0.064	
Liliaceae								**0.040**
Allium cepa L.	**Bassala**	Bu	DD, F	Ct, R	E, O	5	0.029	
Allium sativum L.	**Touma**	Bu	SD	R , C	O	9	0.052	
Linaceae								**0.005**
Linum usitatissimum L	**zarrî'at l-kettân**	S	SD	R	O	1	0.005	
Lythraceae								**0.023**
Punica granatum L.	**Rummân**	Pel	SD, OD	Dc	O, E	4	0.023	
Moraceae								**0.011**
Ficus carica L.	**Karmôss, Chriha**	Fr	COU	R	O	2	0.011	
Myrtaceae								**0.017**
Eucalyptus spp *(Eucalyptus globulus* Labill.; *E. polybractea* R.T. Baker)	**Kalitos, Kalitous**	L	F, CO	Dc, Fu	E, O	4	0.023	
Syzygium aromaticum (L.) Merr. & Perry	**Qronfel**	Fl	H, SD	Ct, In	E, O	2	0.011	

Oleaceae								**0.058**
Olea europea L. var. sativa	**Zeitoun**	L	OD, SD, DD, DT, BP	Dc, In, Ct	E, O	10	0.058	
Ranunculaceae								**0.011**
Nigella sativa L.	**Sanouje, hapa ssawda**	S	CO, COU, SD	R, In	O	2	0.011	
Rhamnaceae								**0.029**
Ziziphus lotus (L.) Lam.	**Nnbeg**	Fr	SD, KD	R	O	5	0.029	
Rosaceae								**0.005**
Prunus amygdalus Stokes var. Amara L.	**Louz lhar**	S	DT	R	O	1	0.005	
Rutaceae								**0.040**
Citrus limon (L.) Burm. f.	**El-hammed**	Fr	H, ST, CO	Ct, R (Juice)	E, O	7	0.040	
Solanaceae								**0.005**
Solanum nigrum L.	**Boqnîna**	L	I	Ma	O	1	0.005	
Solanum tuberosum	**Btata**	Tu	H	Ct	E	1	0.005	
Theaceae								**0.058**
Camellia sinensis (L.) Kuntze	**Atây**	L	SD	Dc	O	10	0.058	
Verbenaceae								**0.181**
Aloysia citrodora Palau L.	**Lwiza**	L	NSD, SD	In, Dc	O	31	0.181	
Zingiberaceae								**0.017**
Zingiber officinale Roscoe	**Skenjbîr**	Rh	SD, CO	R, Dc	O	3	0.017	

L: leaves; S: seeds; AP: aerial parts ; Rh: rhizome; Tu: tuber; Fl: flower; Pel: peelings (Pericarp) ; Bu: bulb; Ba: bark; OAD: osteoarticular disease; DT: diabetes; SD: stomach disorder; NSD: nervous system disease; KD: kidney; UD: urinary disease; I: icterous; DD: dermatological disease; OD: oral disease; BP: blood pressure; CO: cold; COU: cough; H: headache; F: fever; CA: cancer; T: tiredness; ST: sore throat; R: raw; Dc: decoction; In: infusion; Ct: cataplasm; Ma: maceration; Fu: fumigation; C: cooked; O: oral; E: externally; Prepar.: preparation.

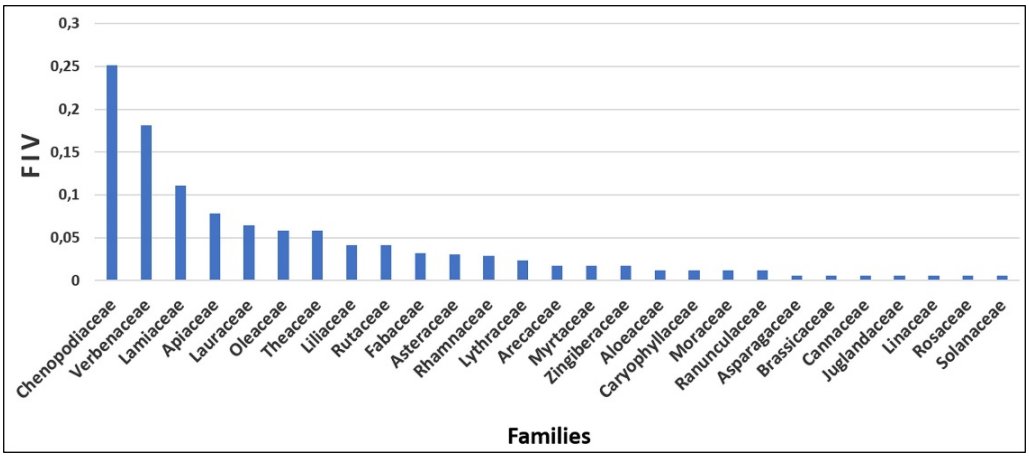

Figure 9. Distribution of cited plant's families according to their Family Importance Value (FIV).

According to RFC which indicates the use frequency of each plant, the most used species are *Origanum compactum* Benth. (RFC=0.538), *Chenopodium ambrosioides* L. (RFC=0.251), *Cuminum cyminum* L. (RFC=0.233), *Mentha pulegium* L. (RFC=0.222) (Figure 10). Similar results were found in other ethnobotanical studies (Ben Akka *et al*. 2019, El-Assri *et al*. 2021, Jeddi *et al*. 2021).

This shows the importance of these plant species in the treatment of various ailments such as diabetes, osteoarticular diseases, fever, stomach disorder, cold, cough etc (Table 2).

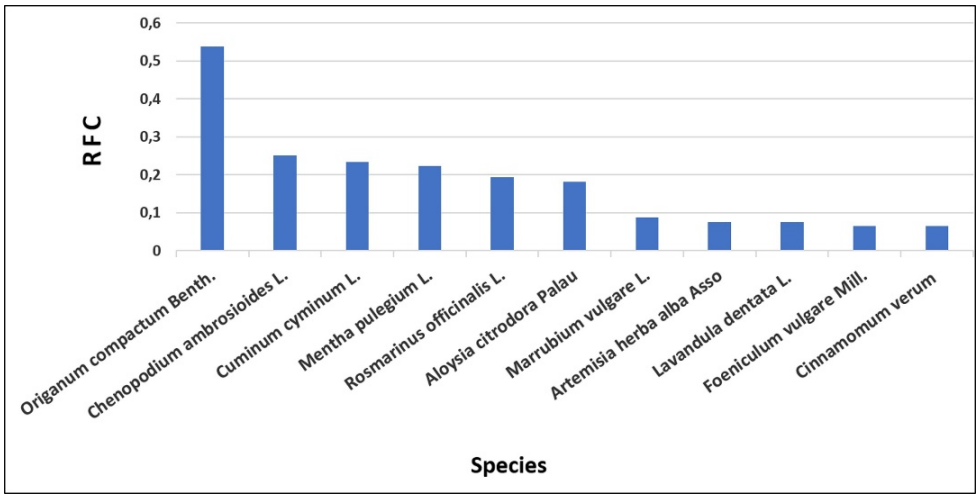

Figure 10. Distribution of the most cited species according to their Relative frequency of citation (RFC).

Ethnopharmacological plants traits

Several *in vitro* and *in vivo* studies have previously demonstrated the pharmacological potential of MAPs used in the studied area. Table 3 shows different ethnomedicinal uses reported in other ethnobotanical works of the most cited species. Moreover, it highlights their pharmacological properties according to different scientific studies. Chemical structures of the main bioactive compounds present in these species are given in Figure 11.

Table 3. Literature data on ethnomedicinal uses and pharmacological properties of the most cited species in this study.

Plant species	**RFC**	**Ethnomedicinal uses for the treatment of various ailments according to literature**	**Pharmacological properties / Main bio-active compounds**
Origanum compactum Benth.	0.538	-Stomach disorders and febrifuge (Bouyahya *et al*. 2017). - Emmenagogue, nausea, food poisoning, asthma, colds, appetite stimulant (Idm'hand *et al*. 2020). - Pyelonephritis, kidney stones (Bencheikh *et al*. 2022). - Skin infection, dandruff (Ajjoun *et al*. 2022). - Diabetes (Nawel *et al*. 2019).	- Antifungal/Carvacrol thymol, p-cymene, γ-terpinene (Santamarina *et al*. 2015). - Antibacterial (Boutahiri *et al*. 2022). - Antioxidant/Carvacrol (Ridaoui *et al*. 2022). - Cercaricide/carvacrol, p-cymene (Lahlou 2002). - Anticancer/ Betulinic acid (Chaouki *et al.* 2010).
Chenopodium ambrosioides L.	0.251	- Fever, Carminative, Diarrhea, rheumatism, female infertility, sexual impotence (Idm'hand *et al*. 2020). - Hair loss, skin infection (Ajjoun *et al*. 2022). - Dermal wound, Eczema (Chaachouay *et al*. 2022). - Obesity (Aumeeruddy & Mahomoodally 2021).	- Vasodilatory/ kaempferol and quercetin (Assaidi *et al*. 2019). - Immunomodulatory, antiparasitic (Rodrigues *et al*. 2021). - Bone regenerater (Pinheiro Neto *et al*. 2017). - Hypotensive (Assaidi *et al*. 2014) - Antiproliferative (Wang *et al*. 2016). - Antifungal /kaempferol and quercetin (Zago *et al*. 2019). - Anti-leishmanial, Antispasmodic /4-carene and o-cymene (Niaz *et al*. 2021).

		- Sickle cell disease (Amujoyegbe *et al*. 2016).	
Cuminum cyminum L.	0.233	- Diarrhea (Bouyahya *et al*. 2017). - Kidney pain (Bencheikh *et al*. 2022). - Skin disease (Ajjoun *et al*. 2022). - Diabetes, cardiovascular diseases and pathologies of the digestive system (Bouyahya *et al*. 2017).	- Antibacterial/ cuminic aldehyde, α,β-dihydroxyethylbenzene, 2-caren-10-al, γ-terpinene (Sharifi *et al*. 2021) - Antioxidant, antifungal/3-caren-10-al and cumina (Ghasemi *et al*. 2019). - Anti-inflammatory/Cuminaldehyde (Tomy *et al*. 2014). - Antinociceptive, Antineuropathic/ Cuminaldehyde (Koohsari *et al*. 2020). - Analgesic/ 4-isopropylbenzyl alcohol (Sheikholeslami *et al.* 2021).
Mentha pulegium L.	0.222	- Stomach disorders, cooling and respiratory diseases such as influenza, colds and bronchitis (Bouyahya *et al*. 2017). - Appetite stimulant, Colds, fever (Idm'hand *et al*. 2020). - Kidney pain, pyelonephritis, diuretic (Bencheikh *et al*. 2022). - Skin disease, burn (Ajjoun *et al.* 2022).	- Vasorelaxant, Antihypertensive (Ajebli *et al*. 2021). - Antifungal / pulegone (Piras *et al*. 2021). - Antioxidant, antiproliferative and antibacterial (Jebali *et al*. 2022). - Anticoagulant, anticancer/ Chrysoeriol, kaempferol, 7-OH flavone (Al-Rajhi *et al*. 2022). - Anti-inflammatory (Ângelo *et al*. 2021).
Rosmarinus officinalis L.	0.192	- Gastric disorders, cold and to facilitate childbirth (Bouyahya *et al*. 2017). - Carminative, constipation, urinary infections, painful periods, gastralgia, rheumatism, colds (dm'hand *et al*. 2020). - Renal colic, pyelonephritis, kidney stones, diuretic (Bencheikh *et al*. 2022).	- Antioxidant, hepatoprotective/ 1,8-cineole, camphor, and α-pinene (El-Demerdash *et al*. 2021). - Anticancer (Gezici *et al*. 2017). - Antidiabetic/ verbenone, 1,8-cineol, α-pinene (Ahamad *et al*. 2019). - Anti-inflammatory, Anti-arthritic (Wei *et al*. 2021). - Antibacterial, analgesic/ Rosmarinic acid, luteolin, quercetin and apigenin (Karadağ *et al*. 2019)
Aloysia citrodora Palau L.	0.181	- Sedative, hypertension, colds (Idm'hand *et al*. 2020). - Kidney pain (Bencheikh *et al*. 2022). - Burn, hair loss (Ajjoun *et al.* 2022). - Obesity (Aumeeruddy *et al*. 2021). - Diabetes (Nawel *et al*. 2019).	- Antibacterial (Dildar *et al*. 2012). - Antioxidant, Antifungal / luteolin 7-diglucuronide, apigenin 7-glucuronide, chlorogenic acid and verbascoside (Casanova *et al*. 2008). - Anti-inflammatory, wound healing, gastroprotective (Speroni *et al*. 2007). - Analgesic (Calvo 2006). -Anticonvulsant, anxiolytic, sedative activities (Khan *et al*. 2016). - Sleep promoting activity (Jawaid *et al*. 2015). - Neuroprotective (Lai *et al*. 2006). - Anticancer (Encalada *et al*. 2015).

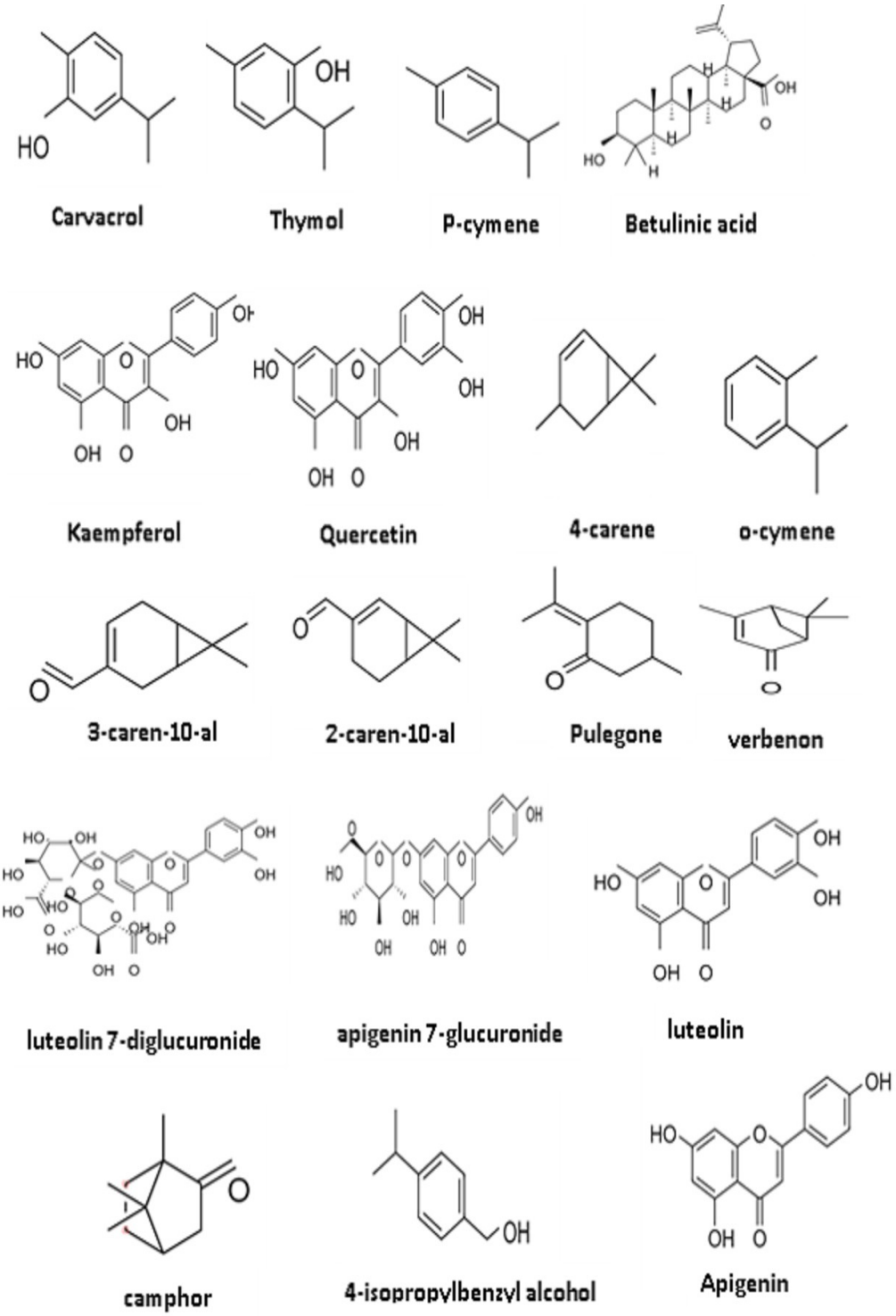

Figure 11. Chemical structures of the main bioactive compounds of MAPs having the highest RFC values.

Plant parts used

According to the results obtained from our ethnobotanical survey, the population of Ain Chkef uses different parts of MAPs for traditional remedies preparation. The PPV values of the different parts used are shown in figure 12. From this figure, it's noted that leaves are the most used part (PPV=52.08%), followed by seeds (PPV=20.83%), flowers (PPV=6.25%), fruits (PPV=6.25%), Bulb (4.17%) peelings, (2.08%), bark (2.08%), tuber (2.08%), rhizome (2.08%) and aerial parts (2.08%).

The frequent use of leaves was also observed in other ethnobotanical studies (Belhaj & Zidane 2021, Jaadan *et al*. 2020, Jeddi *et al*. 2021,) and it could be justified by the ease of their harvest (Salhi *et al*. 2010), as well as by their richness in bioactive compounds (Belhaj & Zidane 2021, El Hachlafi *et al*. 2020, Salhi *et al*. 2010).

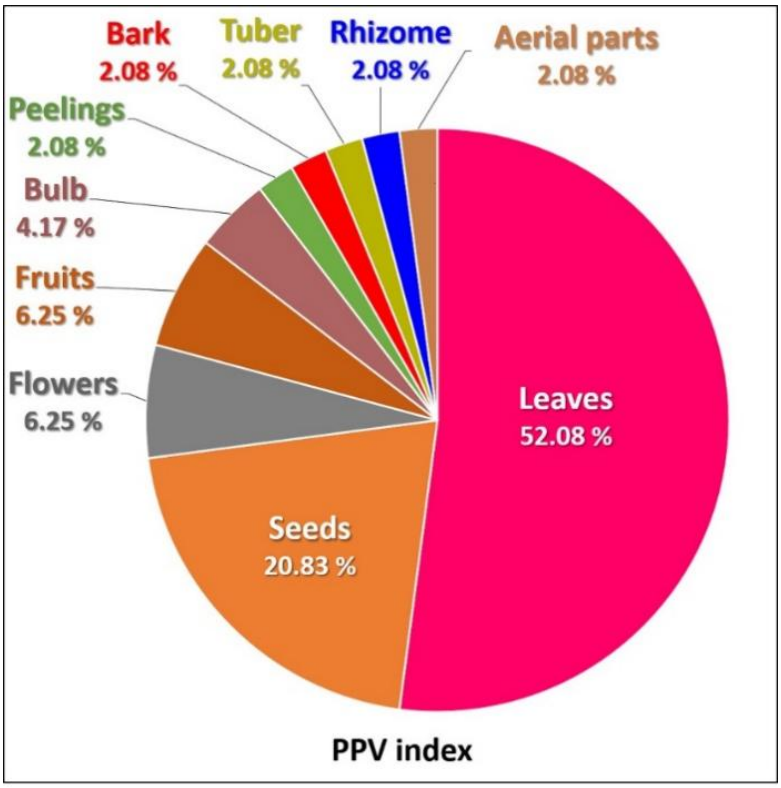

Figure 12. Plant parts used by respondents in treatment of various ailments.

Preparation mode

In order to extract and benefit from bioactive compounds present in MAPs, several preparation methods are used by the studied population. According to figure 13, Infusion (38.20%) and decoction (33.26%) represent the most used preparation methods, followed by other modes; raw (23.39%), cataplasm (3.43%), maceration (0.86%), fumigation (0.64%) and cooked preparations (0.21%). The frequent use of infusion and decoction can be explained by the fact that these two methods allow the extraction of the maximum of active substances and reduce or cancel the toxic effect of plant remedies (Benaiche *et al*. 2019, Salhi *et al.* 2010).

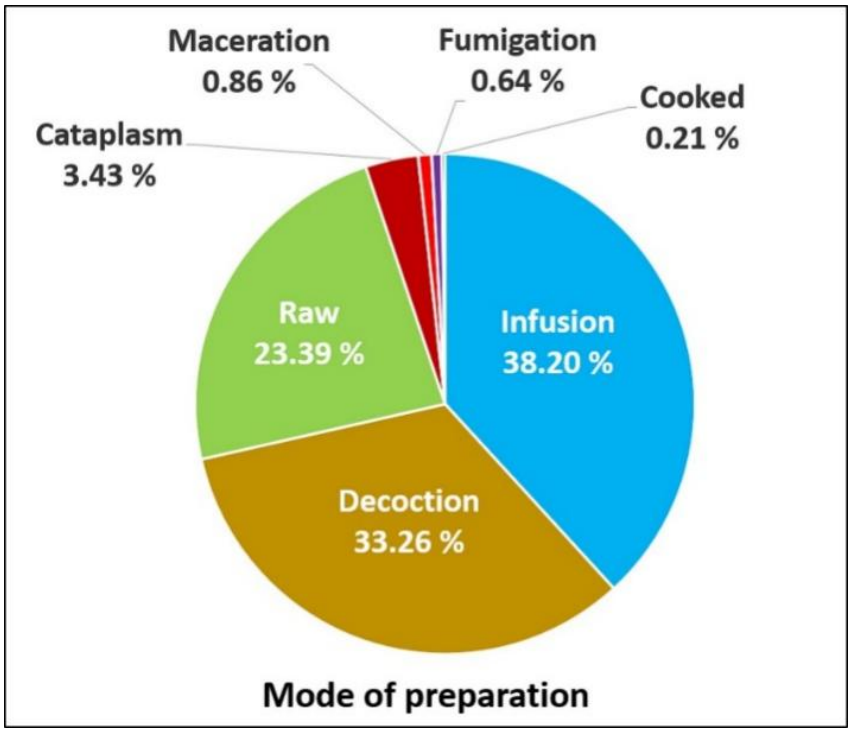

Figure 13. Frequency of preparation methods of the used MAPs by respondents.

Dose used and duration of treatment

Concerning doses of MAPS used, among informants, 74.51% use spoons of MAPs, 18.57% use handle and 0.86% use pinch (Figure 14). As for the duration of treatment, the majority of people (85.96%) use MAPs for one day, whereas 8.42% use them until recovery and 5.62% for one week (Figure 15). These results revealed that MAPs are used randomly in the studied area with different quantities. Unfortunately, this can threaten life of the indigenous population, since the administration of phytochemicals at unspecified and non-rational doses may lead to adverse effects on human health (Benkhnigue *et al*. 2010, Jeddi *et al*. 2021).

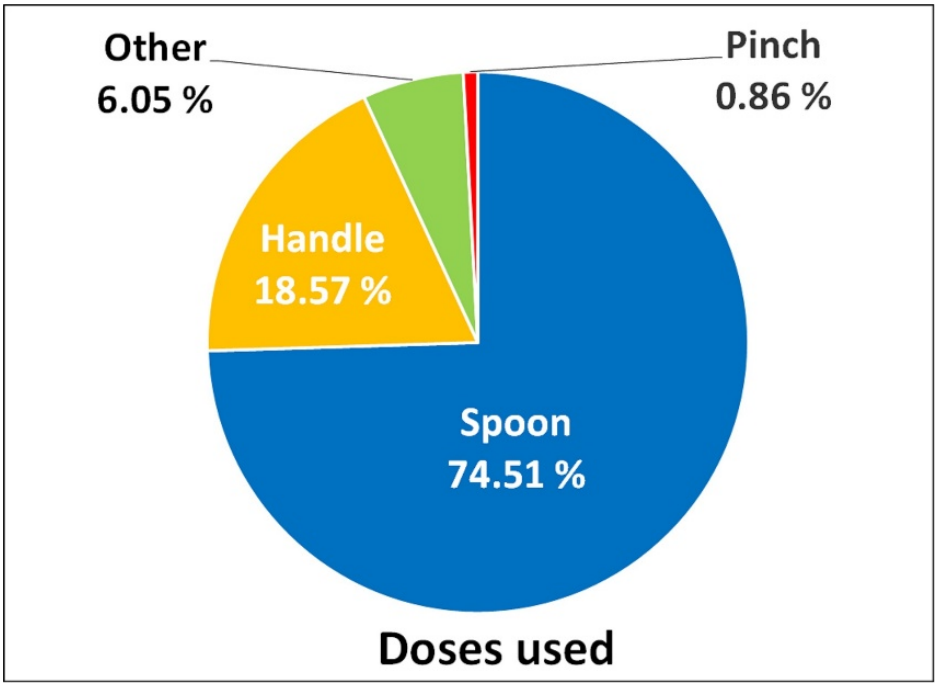

Figure 14. Used doses of MAPs for the preparation of traditional remedies by respondents.

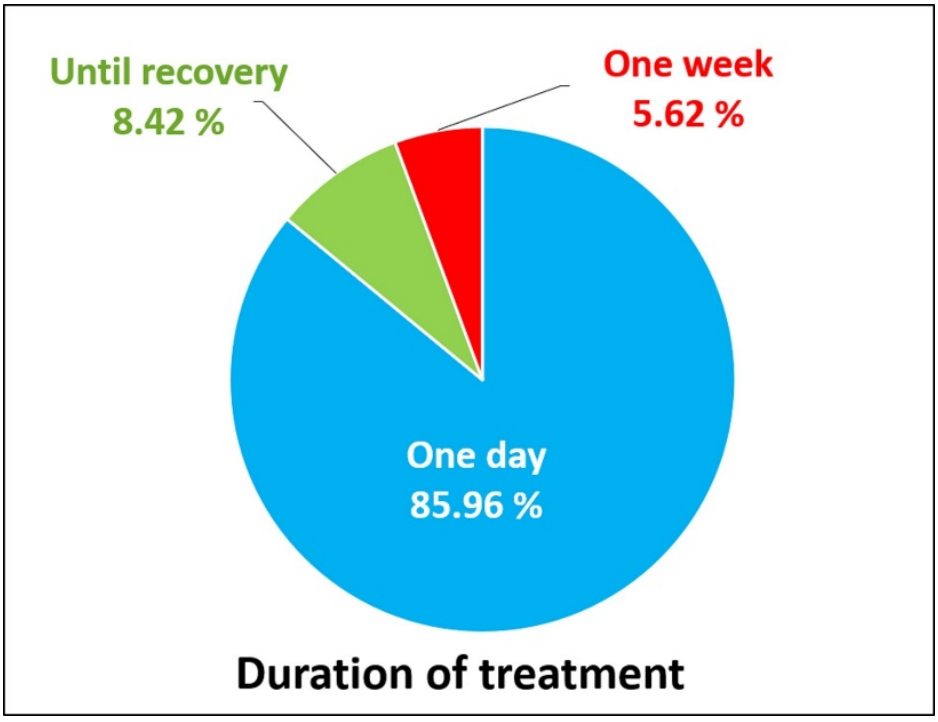

Figure 15. Duration of treatment using MAPs by the studied population.

Fidelity level

For the calculation of FL, only plant species declared to be used for the treatment of a given disease more than twice were considered. As presented in Table 4, values of FL vary between 26.31% and 100%. Eight species, namely *Allium sativum* L.*, Artemisia herba alba* Asso*, Camellia sinensis* (L.) Kuntze*, Carum carvi* L.*, Coriandrum sativum* L.*, Cuminum cyminum* L.*, Salvia officinalis* L.*, Trigonella foenum graecum* L. present a FL=100% against SD. Other species have been characterized by a high FL; four species against stomach disease. *Rosmarinus officinalis* L. (FL=96.96%), *Origanum compactum* Benth. (FL=96.73%), *Lavandula officinalis* L. (FL=92.30), *Cinnamomum verum* Berchtold & J.S. Presl (FL=81.81%). Two species against fever: *Chenopodium ambrosioides* L. (FL=95.34%) and *Allium cepa* L. (FL=80%), and one species against kidney: *Ziziphus lotus* (L.) Lam. (FL=80%). Thus, these results reveal the effectiveness of each of these species against a specific disease.

The lowest FL value was obtained for *Marrubium vulgare* L. (FL=26.31%). This can be explained by the multiple uses of this species by the studied population for the treatment of different ailments. Moreover, *Marrubium vulgare* L. has been found according to many studies to exhibit a multitude of pharmacological properties, such as antioxidant, hepatoprotective, antiproliferative, immunomodulatory, antidiabetic and anti-inflammatory activities (Aćimović *et al*. 2020).

Table 4. Efficiency of the most used plants species by the respondents against a given disease according to their FL.

Plants species	**Treated diseases**	**FL (%)**
Allium cepa L.	F	80
Allium sativum L.	SD	100
Aloysia citrodora Palau L.	SD	64.51
	NSD	35.48
Artemisia herba alba Asso	SD	100
Camellia sinensis (L.) Kuntze	SD	100
Carum carvi L.	SD	100
Chenopodium ambrosioides L.	F	95.34
Cinnamomum verum Berchtold & J.S. Presl	SD	81.81
Citrus limon (L.) Burm. f.	H	42.85
Coriandrum sativum L.	SD	100
Cuminum cyminum L.	SD	100
Foeniculum vulgare Mill.	NSD	54.54
	SD	45.45
Lavandula officinalis L.	SD	92.30
Marrubium vulgare L.	SD	31.57
	DT	26.31
Mentha pulegium L.	SD	60.52
	CO	36.84
Olea europea L. var. sativa	OD	27.27
	SD	27.27
	DT	27.27
Origanum compactum Benth.	SD	96.73
Rosmarinus officinalis L.	SD	96.96
Salvia officinalis L.	SD	100
Trigonella foenum graecum L.	SD	100
Ziziphus lotus (L.) Lam.	KD	80

F: fever; SD: stomach disorder; NSD: nervous system disease; H: headache; DT: diabetes; CO: cold; OD: oral disease; KD: kidney.

Conclusions

The use of MAPs plays a very important role in the therapy of the indigenous population of Ain Chkef area and is considered as an alternative to synthetic medicines. In fact, 93.44% of people resort to MAPs for the preparation of traditional remedies. Among MAPs used, 48 species were identified belonging to 27 botanical families.

As regard relationships among plants used and population studied, people with no or low use of MAPs (MAPs used < 3) are sharing common traits: marital status (MS-Single), educational level (EL-Secondary), age group-Low (< 40 years) and gender-Male. Whereas people with a medium or a high use of MAPs (4 < MAPs used < 7 and MAPs used > 7 respectively), have other characteristics: MS-Married, EL-illiterate and EL-Primary, Age-Medium (40 < Age < 60 years) and Age-High (Age > 60 years) and gender-Female.

The most cited plant species are *Origanum compactum* Benth. (RFC=0.538), *Chenopodium ambrosioides* L. (RFC=0.251), *Cuminum cyminum* L. (RFC=0.233), *Mentha pulegium* L. (RFC=0.222) and the dominant families are Chenopodiaceae (FIV=0.251), Verbenaceae (FIV=0.181), Lamiaceae (FIV=0.110), Apiaceae (FIV=0.078). Leaves are the most used plants parts (PPV=52.08%) while infusion (38.20%) and decoction (33.26%) are the dominant preparations methods. Doses of MAPs are not precise and vary between people. Several species were reported to be effective against a given disease, among which eight species present a FL of 100%: *Allium sativum* L.*, Artemisia herba alba* Asso*, Camellia sinensis* (L.) Kuntze*, Carum carvi* L.*, Coriandrum sativum* L.*, Cuminum cyminum* L.*, Salvia officinalis* L.*, Trigonella foenum graecum* L.

In conclusion, the results of this study enabled to discover and illustrate traditional medicinal knowledge of the population of Ain Chkef. Besides, they constitute an important ethnobotanical database which can be exploited by researchers in the development of herbal medicines. Furthermore, this article matches with several sustainable development goals (SDGs) such as SDG 3, 11, and 15 (https://fr.unesco.org/sdgs).

Declarations

List of abbreviations: MAPs: medicinal and aromatic plants, RFC: Relative Frequency of Citation, FIV: Family Importance Value, PPV: Plant Part Value, FL: fidelity level Index, FC: frequency of citation, N: total number of people using MAPs, Ns: total number of cited species in each family. L: leaves, S: seeds, AP: aerial parts, Rh: rhizome, Tu: tuber, Fl: flower, Pel: Peelings (Pericarp), Bu: bulb, Ba: bark, OAD: osteoarticular disease, DT: diabetes, SD: stomach disorder, NSD: nervous system disease, KD: kidney, UD: urinary disease, I: icterous, DD: dermatological disease, OD: oral disease, BP: blood pressure, CO: cold, COU: cough, H: headache, F: fever, CA: cancer, T: tiredness, ST: sore throat, R: raw, Dc: decoction, In: infusion, Ct: cataplasm, Ma: maceration, Fu: fumigation; C: Cooked, O: Oral, E: Externally; Prepar: preparation; G: gender; EL: educational level; MS: marital status; MCA : multiple component analysis; EN: endangered; VU: vulnerable; SDGs: sustainable development goals; IUCN: International Union for Conservation of Nature; G: gender; MS: marital status; EL: educational level; SEL: socio-economic level

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

Consent for publication: Not applicable.

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

Competing interests: The authors declare no conflict of interest.

Funding: This research was supported by fellowship grant (5USMBA2022) provided by the National Center for Scientific and Technical Research (CNRST), Morocco.

Authors' contributions: Khadija Benamar: carried out data collection, literature survey and prepared the first draft of the manuscript. Saad Ibnsouda Koraichi: Supervised the research. Saad Benamar: performed the statistical analysis part concerning the multiple component analysis and improved the manuscript. Kawtar Fikri-Benbrahim: Supervised the research and improved the manuscript.

Acknowledgements

Acknowledgments to CNRST (National center for scientific and technical research, Morocco) for supporting this research by fellowship grant.

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