Ethnobotanical Insights into Medicinal Plants usage in Haj Kaddour, Morocco

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Research

Abstract

Background: The use of medicinal and aromatic plants (MAPs) in traditional medicine is integral to Moroccan culture. This study examines their use in Haj Kaddour, a rural area in north-central Morocco, and provides detailed ethnobotanical data on the most frequently cited species.

Methods: A survey was conducted for the first time in Haj Kaddour, with 94 residents of to assess their use of MAPs. The data was analyzed using plant citation indices, and Multiple Correspondence Analysis (MCA) was applied to explore relationships between plant use and the socio-demographic characteristics of participants.

Results: The study found that 68.08% of participants used MAPs. A total of 52 species from 26 families were recorded, with Origanum compactum Benth and Mentha pulegium L. being the most commonly mentioned. Leaves were the most commonly used part, and infusions were the preferred preparation method. Moreover, individuals with low or no MAPs use (<3 species) tended to be male, unmarried, under 20 years old, and highly educated. In contrast, moderate (>4 species) or high (>7 species) users were mainly female, married, over 20, and had lower education levels. A key challenge was the relatively low level of MAPs use among younger, highly educated individuals, which may reflect shifting cultural practices or reduced knowledge transfer across generations.

Conclusions: This study highlights the widespread use of MAPs in Haj Kaddour as traditional remedies. The results provide valuable ethnobotanical insights and establish a foundation for further research in pharmacognosy and the development of natural-based therapies.

Keywords: Haj Kaddour, ethnobotany, multiple component analysis

Background

Despite the advancement of modern medicine and therapies, there remains significant interest in traditional pharmacopoeia (Sen & Chakraborty 2017). Medicinal and aromatic plants (MAPs) continue to play a crucial role in the preparation of herbal remedies, especially in rural regions, due to their affordability, accessibility, and proven therapeutic potential (Benamar *et al.* 2024a). Morocco, with its rich geographical diversity from the Sahara in the south to the Mediterranean Sea in the north and the Atlantic Ocean on the west has long been a center for healing with MAPs (Elachouri *et al.* 2021). The country's flora is home to over 7000 species, including approximately 800 species of MAPs (El Houssine Bouiamrine *et al.* 2017).

Understanding the ethnomedicinal uses of MAPs is vital as it forms the foundation of ethnopharmacology (Süntar 2020). Based on traditional uses, numerous studies have demonstrated the pharmacological properties and bioactive compounds in these plants, supporting their potential in the development of natural-based medications (Benamar *et al.* 2023a, Benamar *et al.* 2024b). To preserve Moroccan heritage and contribute to the field of ethnopharmacology, various ethnobotanical surveys have been carried out across Morocco, often highlighting the widespread use of MAPs (Eddouks & Zeggwagh 2012, Fakchich & Elachouri 2021).

This study aims to fill a gap in the ethnobotanical research by focusing on the rural region of Haj Kaddour in north-central Morocco, a rural area that has not been previously surveyed.Indeed, after conducting extensive bibliographic research across various search engines (Google Scholar, Scopus, ScienceDirect, Web of Science, PubChem), we observed the absence of published work on an ethnobotanical survey in Haj Kaddour. However, it is crucial to conduct an ethnobotanical study in this rural area, as it is well known that rural communities largely rely on traditional therapies rather than modern ones. Furthermore, this area is part of the Fez-Meknes region, where the use of medicinal and aromatic plants (MAPs) has been well documented. A focus on this rural zone could uncover additional plant species with medicinal properties, thereby contributing to the advancement of ethnopharmacology. Hence, The primary objectives of our work were to assess the use of MAPs, identify the species used, explore the diseases they treat, and investigate the relationships between these uses and socio-demographic factors such as age, gender, and education level. A bibliographic review of the bioactive compounds and pharmacological properties of the most frequently used MAPs was also conducted. Additionally, this research aligns with the global movement toward sustainability, highlighting nature-based solutions and the value of natural resources and traditional knowledge for human well-being.

Materials and Methods

Study area

Haj kadour is a Moroccan village located in Fez-Meknes region (Figure 1), more precisely in Meknes prefecture in the rural commune of Sidi Slimane Moul Al kifane . It's altitude is of 633 m, and its geographical coordinates are 33° 50′ N 5° 25′ W. It has an estimated population of around 7.110 inhabitants.

The demographic characteristics of Haj Kaddour, including its relatively small population and rural setting, make it an ideal location for this ethnobotanical study. In small, rural communities like Haj Kaddour, traditional knowledge about the use of plants for medicinal purposes is often preserved across generations. These communities tend to have a stronger reliance on medicinal plants for diseases treatment.

Haj kaddour has a temperate Mediterranean climate, with hot, dry summers according to the Köppen-Geiger classification. Over the year, the average temperature in this area is 17.1°C , and rainfall averages are of 511 mm.

This climate creates an ecosystem that supports a variety of plant species. Hence, it helps to understand the use of some local plants, as the climate plays a pivotal role in the types of plants that thrive and the ways in which they are utilized by the community.

Data collection

The ethnobotanical survey was performed at Haj Kaddour area. A total number of 94 persons were interviewed during April 2024 using semi-structured interviewes regarding the Socio-demographic characteristics of interviewed people (Socio-economic level, marital status, educational level, gender, age) and the plants they use for therapeutical purposes (local name, treated diseases, parts used, and preparation methods).

The questionnaire includes a mix of closed-ended and open-ended questions. The open-ended questions were concerning the age of people, the plant species used, and diseases treated.

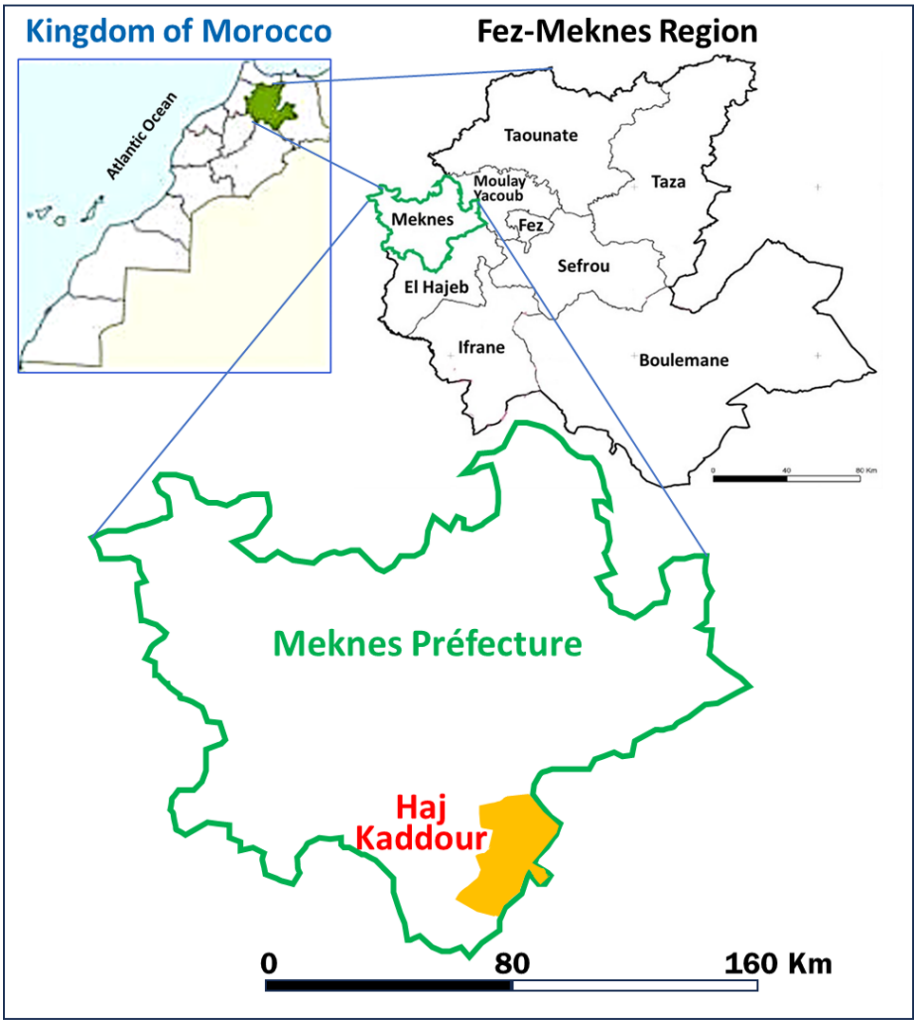

Figure 1. Maps of the geographical location of the studied area in Morocco

The time allotted to each interview was between 15 and 20 minutes.
The study sample consisted of people randomly interviewed in the village lanes.
The protocol used in this work was previously validated and adopted by the council of our laboratory in several published works (Benamar *et al.* 2023b, Benamar *et al.* 2024a, El Hachlafi *et al.* 2020; Jeddi *et al.* 2021).

Figure 2 shows field pictures while interviewing the respondents.

Plant species identification

Plant species cited by respondents were identified based on their local names by referring to some Moroccan botanical books (Bellakhdar 1997, Sijelmassi 1993), as well as through the consultation of other ethnobotanical surveys performed in Morocco (Benamar *et al.* 2023, Jeddi *et al.* 2021, Smaili *et al.* 2023). Specimens of the identified MAPs species are preserved in the national herbarium, at the Scientific Institute in Rabat, Morocco.

Figure 2. Field pictures while interviewing the respondents.

Data Analysis

Collected data were analysed using descriptive statistics based on percentages and frequencies for informations related to the Socio-demographic characteristics of respondents. Whereas for botanical data, different quantitative indices were determined, namely: RFC, FIV, PPV and FL.

Furthermore, multiple component analysis was carried out so that to determine relationships between the socio-demographic features of respondents and their use of plants as natural remedies.

For these statistical analysis, Excel 2013 and XLSTAT softwares were used.

Relative frequency of citation (RFC)

Relative frequency of citation (RFC) reveals the relative importance of cited plant species by informants. It's determined based on on Tardio and Pardode-Santayana (2008) formula,through the division of the number of people mentioning the species use (FC), by the total number of people using MAPs (N):

$$RFC=FC/ N$$

With: $0 < RFC < 1$

Family Importance Value (FIV)

This index reflects the importance of plant families used. It's obtained according to Sreekeesoon and Mahomoodally (2014) formula, by dividing the number of people citing a particular family (FC family) by the number of cited species in this family (Ns):

$$FIV=FC\ family / Ns$$

Plant part value (PPV)

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

PPV=RU plant part/ RU

RU plant part: The overall frequency of recorded uses for a particular plant part.
RU: The number of total uses recorded for all plants parts.

Multiple component analysis (MCA)

Multivariate component analysis (MCA) was conducted using XLSTAT software to explore the relationships between plants and humans categorized by age, educational background, gender, and marital status. MCA, being predominantly suited for qualitative variables, required the transformation of quantitative data namely respondents ages and the number of medicinal and aromatic plants (MAPs) they utilized into qualitative variables by grouping them into distinct classes:

For Age:

-Age-Low: Respondents aged under 20 years.
-Age-Medium: Individuals aged between 20 and 40 years.
-Age-High: Respondents aged above 40 years.

For the Number of MAPs Used:

-MAPs Used-Zero: Individuals who do not use MAPs.
-MAPs Used-Low: Usage of fewer than 3 MAPs.
-MAPs Used-Medium: Usage of 4 to 7 MAPs.
-MAPs Used-High: Usage of more than 7 MAPs.

MCA was chosen for this study because it is particularly well-suited for analyzing categorical data, which is the primary type of data in our ethnobotanical study. The dataset consists of various categorical variables concerning the socio-demographic characteristics of the participants (age, gender, education, socio-economic level, marital status).

MCA allows us to explore medicinal plants use by the interviewed people and its relationships with socio-demographic factors, which are central to understanding the cultural and contextual significance of plant knowledge in the Haj Kaddour community.

Hence, MCA is an appropriate and effective method for revealing how different socio-demographic groups may relate to particular plant species or uses, providing deeper insights into the ethnobotanical practices of the community.

Review study

To emphasize the ethnomedicinal applications of the most frequently cited MAP species, a literature review was conducted. This review focused on recent studies on their pharmacological properties and traditional uses documented in other ethnobotanical research. The databases utilized for this analysis included PubMed, ScienceDirect, Scopus, and Google Scholar. The search was performed using the species' names alongside keywords such as "ethnomedicinal applications," "biological activities," and "pharmacological properties." Additionally, the chemical structures of various bioactive compounds from these species were provided from PubChem database.

Results and Discussion

Use of MAPs by respondents

In the studied area, 68.08% of respondents claimed their use of MAPs for diseases treatment, whereas 31.91% declared not using MAPs for diseases treatment (Figure 3). This results reveals the attachement of the interviewed people to their traditional heritage related to the use of MAPs in folk medicine (Benamar *et al.* 2023b). Moreover, our findings are consistent with other studies revealing the dominant use of MAPs by Moroccan rural people as natural remedies (Benamar *et al.* 2023b).

Socio-demographic data of respondents

Age

Figure 4 shows that MAPs use in the studied area is dominant among people in the age group: between (20-40), and >40 (37.5% and 32.81%), respectively. Whereas its lower (29.68%) among young people belonging to the age group <20. These results are in agreement with previous ethnobotanical studies carried out in different Moroccan areas (Benamar *et al.* 2023b, Jeddi *et al.* 2021).

Besides, the prevalence of MAPs use by elderly, could be related to their high conviction of MAPs efficiency, and their better knowledge on their traditional use for medicinal purposes (Benkhaira *et al.* 2021).

As regard people not using MAPs, they belong to different age groups (Figure 4): < 20 years (50%), 20-40 years (26.66%), > 40 years (23.33%). These people indicated that they dont use MAPs because they fear their toxicity.

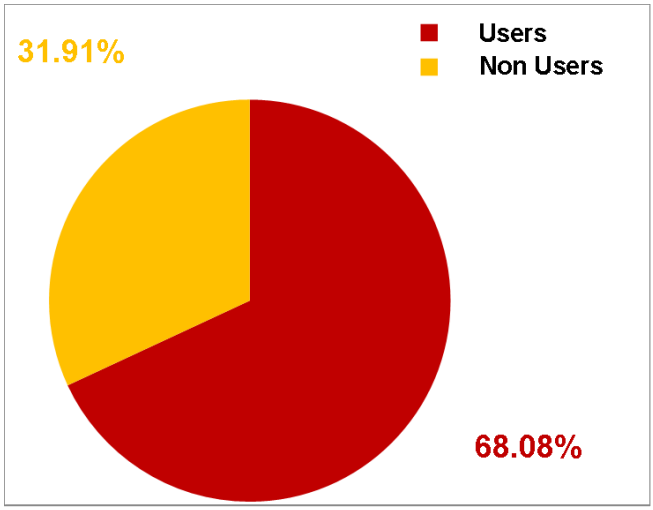

Figure 3. Distribution of respondents according to their use or not of MAPs.

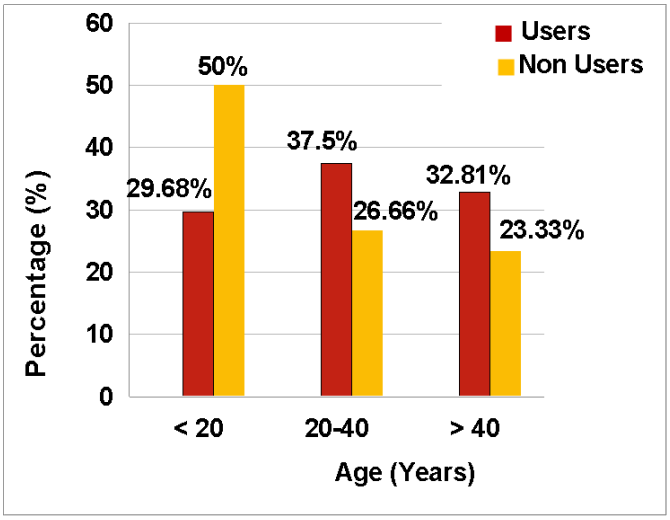

Figure 4. Distribution of respondents using or not MAPs according to their age.

Gender

The utilization of MAPs in the study area varied based on the gender of the informants. Indeed, women were revealed to use MAPs more than men (76.56% and 23.43%) (Figure 5), respectively. This may be related to the higher knowledge that women have in comparison with men, regarding MAPs species efficient against diseases, and their modes of preparation and administration. Furthermore, comparable findings have been reported in various ethnobotanical studies conducted at the national level (Alaoui *et al.* 2018, Benamar *et al.* 2023b, Bencheikh *et al.* 2021).

Concerning people not using MAPs, men and women represent almost the same percentages (56.66% and 43.33%, respectively).

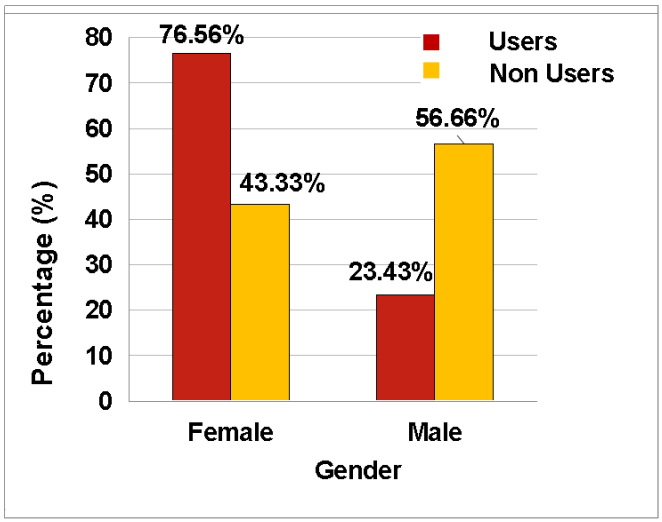

Figure 5. Distribution of respondents using or not MAPs according to their gender

Educational level

Figure 6 shows that the majority of people not using MAPs have a secondary educational level (60 %). This could be attributed to the fact that these individuals have a greater awareness of the risks associated with the random use of medicinal and aromatic plants (MAPs).

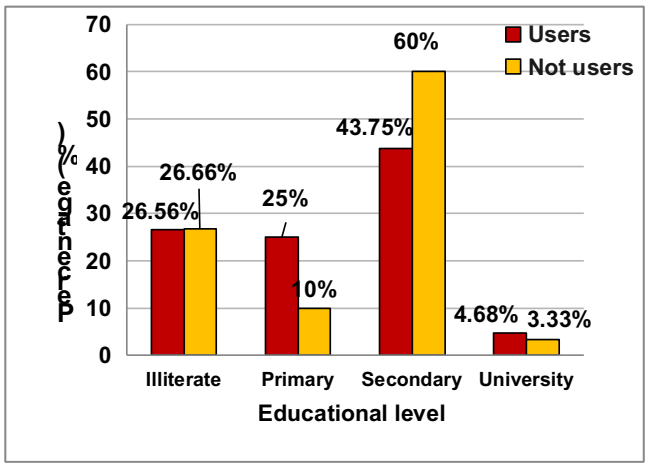

Figure 6. Distribution of respondents using or not MAPs according to their educational level

Socio-economic status

According to figure 7, people using MAPs have either a medium (78.12%) or a low scocio-economic status (21.87%). Whereas 100 % of people not using MAPs have a medium socio-economic level. This result could be explained by the use of MAPs by poor people as an easy and affordable mean in order to treat diseases and suggests the tendency of more rich people to use modern medicines in spite the cost of the treatments. These results agree with those illustrated in other ethnobotanical works (Benamar *et al.* 2023b, Benkhaira *et al.* 2021).

Marital status

Figure 8 reveals that people using MAPs are mostly married (56.25%). This coud be related to the fact that families tend to use MAPs in order to avoid the cost of medical treatments (Benamar *et al.* 2023b, jeddi *et al.* 2021).

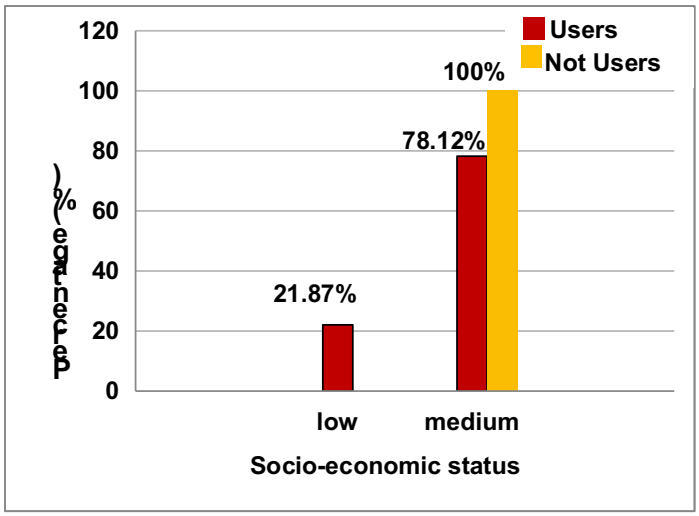

Figure 7. Distribution of respondents using or not MAPs according to their Socio-economic status

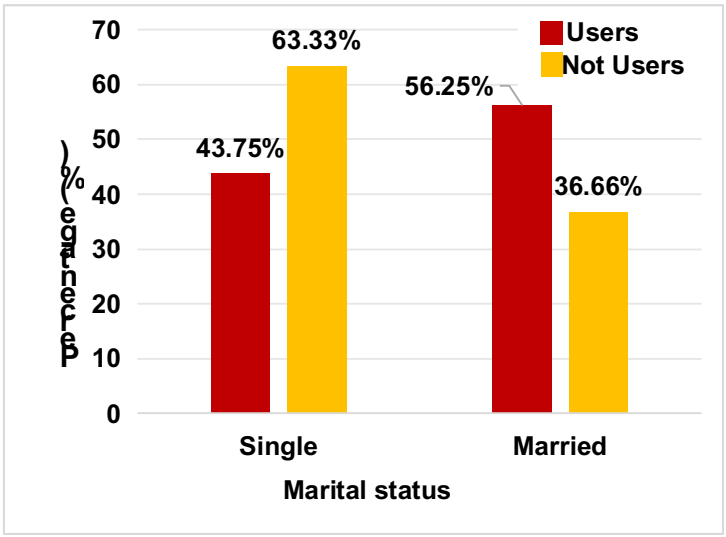

Figure 8. Distribution of respondents using or not MAPs according to their marital status

Multiple component analysis of collected data

The results of MCA are shown in figure 9. The two axes F1 and F2 present 37.44% of the total variation in our analysed data. F1 accounts for 22.67 % of the total variation, whereas F2 presents 14.77 % of this variation. These two axes allowed to separate people according to their use or not of MAPs, as well as according to their socio-demographic features to two main categories as follow:

- People with zero or low use of MAPs, and they exhibit several characteristics: educational level secondary or university, age-low, Gender-male, and marital status-single.
- People with medium or high use of MAPs, and they show the following features: illiterate or with a primary educational level, age-medium or high, gender female, and marital status-married.

These findings allow to draw some conclusions. Indeed, people with high educational level are characterized with zero or low use of MAPs, probably because they are more aware of risks which could result from the random use of MAPs on their health. Whereas people with low educational level, they are associated with high or medium use of MAPs, may be since they are attached to their traditional heritage regarding the use of MAPs.

Besides, the correlation between the medium or high use of MAPs with people having medium or high age could be attributed to their high knowledge on the MAPs species efficient against diseases, and their preparation and administration modes, unlike people belonging to the age group-low, which are young.

Concerning the gender, the MCA results show that women are belonging to the category of people with medium or high use of MAPs. Similarly, married people are belonging to this category. These findings could be justified by the fact that women have more knowledge and expertise regarding herbal remedies, and married people have tendency to use these natural remedies instead of modern treatments, may be in order to avoid their high cost.

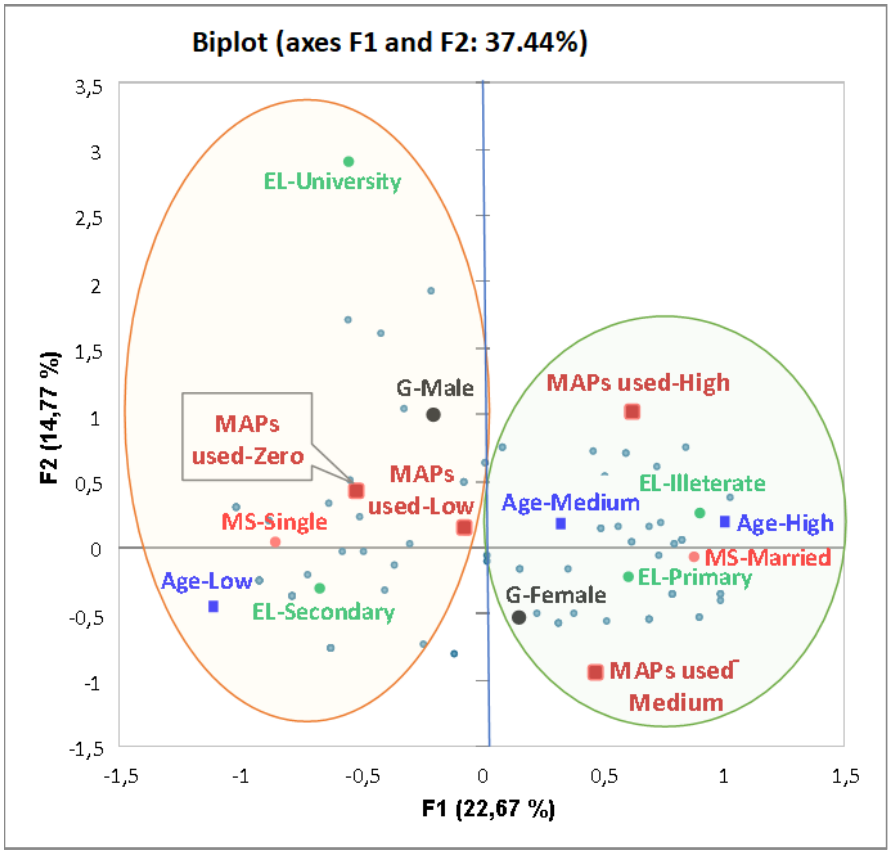

Figure 9. Biplot of multiple component analysis applied to different variables related to the respondents. Age-Low: < 20 years, Age-Medium: 20 < age < 40 years, Age- High: > 40 years; MAPs used zero: People not using MAPs, MAPs used-Low: MAPs used < 3, MAPs used-Medium: 4 < MAPs used < 7, MAPs used-High: MAPs used > 7; G: gender; EL: educational level; MS: marital status.

Floristic analysis

The ethnobotanical study carried out in haj kaddour has enabled as to determine 52 plant species belonging to 26 botanical families used in order to threat different ailments.

All the listed plant species are presented in table 1, in which their scientific and vernacular name, botanical family, pats used, treated diseases, modes of preparation and administration are mentioned, along with their FIV, RFC, and FC.

Among the 27 botanical families corresponding to used species, the most representative are: Amaranthaceae (FIV= 0.276), Verbenaceae (FIV= 0.138), Rutaceae (FIV= 0.106), and Lamiaceae (FIV= 0.092) (Figure 10). The importance of these botanical families has been revealed in other ethnootanical studies (Benamar *et al.* 2023b, Chaachouay *et al.* 2020).

Besides, Origanum compactum Benth (RFC = 0.393), *Mentha pulegium* L. (RFC = 0.287), and *Chenopodium ambrosioides* L. (RFC = 0.276) are the species most frequently utilized by respondents, as indicated by their Relative Frequency of Citation (RFC) values (Figure 11). Similar findings were obtained in other ethnobotanical studies (Benamar *et al.* 2023b, El-Assri *et al.* 2021, jeddi *et al.* 2021). Figure 12 shows pictures of plants having high use value.

Table1: MAPs used by respondents in Haj Kaddour and their Scientific and vernacular names, parts used, treated diseases, use and preparation modes and citation indexes (FC, RFC and FIV).

Scientific name	Vernacular name	Voucher codes	Parts used	Treated diseases	Mode of		Indices		
Families Species					**Preparation**	**Use**	**FC**	**RFC**	**FIV**
Amaranthaceae									**0.276**
Chenopodium ambrosioides L.	Mkhinza	BLUMP 515	L	DD, F, Dy, Co, H, Dt	R, I, D; Ct	O;E	26	0.276	
Apiaceae									**0.023**
Apium graveolens L.	**Krafès**	BLUMP 5035	L	UD	D	O	1	0.010	
Coriandrum sativum L.	**Kasbour**	K002730185	S	Dt	I	O	3	0.031	
Cuminum cyminum L.	**Kamoun**	K002730445	S	DD	I, D, R	O	5	0.053	
Foeniculum vulgare Mill.	Nafaâ,Besbass	K001737150	S	DD	I		1	0.010	
Petroselinum crispum (Mill.) Nyman ex A.W.Hill	**Maâdnous**	BLUMP5050	S	DD, Dy	D	O	2	0.021	
Pimpinella anisum L.	**Habat hlawa**	K002754127	S	DD	I	O	1	0.010	
Apocynaceae									**0.010**
Calotropis procera (Aiton) Dryand	**Krnka**	BLUMP 2288	L	W	Ct	E	1	0.010	
Arecaceae									**0.010**
Chamaerops humilis L.	**Doum**	BLUMP 1206	L	Ch, C, Dt, DD	R	O	1	0.010	
Asteraceae									**0.028**
Artemisia absinthium L.	**Chiba**	BLUMP 3429	L	Den	D	E	1	0.010	
Artemisia herba alba Asso	**Chih**	BLUMP 3454	L	DD, Co, Dt	D, I	O	5	0.053	
Chamaemelum nobile (L.) All.	**Babounj**	K002709897	FL	ND	I	O	2	0.021	

Cupressaceae									**0.010**
Tetraclinis articulata (Vahl) Mast	**El'ar'ar**	BLUMP 677	L	DD	D	O	1	0.010	
Fabaceae									**0.021**
Lens culinaris Medik.	**Adas**	K001051437	S	A	Coo	O	1	0.010	
Retama raetam (Forssk.) Webb	**Rrtem**	K003012442	L	Co	Fu	E	1	0.010	
Trigonella foenum graecum L.	**L-halba**	K000998676	S	Dt, O, DD	I, R, D	O	4	0.042	
Juglandaceae									**0.010**
Juglans regia L.	**Sswâk, el-gargae**	K000809183	S	DD, Dy, Co	D	O	1	0.010	
Lamiaceae									**0.092**
Calamintha officinalis L.	**Manta**	K005907235	L	DD, Dy	I	O	1	0.010	
Lavandula officinalis L.	**Lakhzama**	BLUMP 1317	Fl	DD, Co, Dy; H	I; Ct	E	5	0.053	
Lavandula stoechas L.	**halhal**	BLUMP 1313	Fl	SD, Co	I	O	1	0.010	
Marrubium vulgare L.	**Merriwta**	BLUMP 1312	L	Co, Den, C	R, I, D; Ct	O; E	6	0.063	
Mentha pulegium L.	**Fliyyo**	BLUMP 1341	L	DD,Th, Dy,H, F, Dt; Co	D, I, Coo, Ma; Fu	O; E	27	0.287	
Mentha rotundifolia Muds	**Marseta**	BLUMP 1344	L	DD, Th, Dy, Co,Dt, Hl	D, I	O	5	0.053	
Origanum compactum Benth	**Zaâter**	BLUMP 1368	L	DD, Th,Dy, H, F, Dt; Co	D, I; Fu	O;E	37	0.393	
Origanum majorana L.	**Merdeduch**	BLUMP 1363	L	DD, Co	I	O	1	0.010	
Peganum harmala L.	**L-harmel**	K000630425	S, R, Ba	Co	Fu	E	1	0.010	

Rosmarinus officinalis L.	**Azir**	BLUMP 730	L	DD, Th, Dy, Co, H,ND,Hl	D,I	O	10	0.106	
Salvia officinalis L.	**Ssâlmya**	BLUMP 695	L	DD,Dy, Co	D,I	O	2	0.021	
Lauraceae									**0.010**
Cinnamomum verum Berchtold & J.S. Presl	**Qarfa**	K002235088	Ba	Dy	I	O	1	0.010	
Liliaceae									**0.037**
Allium cepa L.	**Bassala**	K000365501	Bu	ND,F,H	D,I, Ct	O; E	5	0.053	
Allium sativum L.	**Touma**	K003718508	Bu	Hy,DD	R	O	2	0.021	
Linaceae									**0.010**
Linum usitatissimum L.	**Zarrî'at l-kettân**	K000374179	S	OD	R	O	1	0.010	
Lythraceae									**0.015**
Lawsonia inermis L.	**Henna**	BLUMP 4847	L	H	Ct	E	1	0.010	
Punica granatum L.	**Er-rummân**	BLUMP 4848	Pe	DD, Th, Co, F	D	O	2	0.021	
Myrtaceae									**0.021**
Eucalyptus globulus Labill.	**kalitous**	K005298248	L	Co	R		2	0.021	
Syzygium aromaticum (L.) Merr. &Perry	**Qronfel**	K001110734	Fl	Co, Den	I, D	O	2	0.021	
Oleaceae									**0.074**
Olea europea L. var. *oleaster*	**zeitoun berri**	BLUMP 2268	L	Dt, DD	I, D	O	2	0.021	
Olea europea L. var. *sativa*	**zeitoun**	BLUMP 2268	L	DD, Dy, Co, Dt, , Hy, Den	D, I, R, Ma, Ct		12	0.127	
Piperaceae									**0.010**
Piper nigrum L.	**Ibzar**	K000731955	S	Co	I	O	1	0.010	
Poaceae									**0.015**
Hordeum vulgare L.	**Chaâir**	K001117218	S	Dt, Ch	Coo	O	1	0.010	
Panicum miliaceum L.	**Illan**	K003366849	S	DD, OD	D, R	O	2	0.021	

Ranunculaceae									**0.010**
Nigella sativa L.	**Haba ssawda**	K000694416	S	DD	D	O	1	0.010	
Rosaceae									**0.010**
Prunus amygdalus Stokes var.Amara L.	**Louz lhar**	K004471658	S	C, Co	R	O	1	0.010	
Rosa centifolia L.	**El-ward**	K004566859	Fl	Co	D	E	1	0.010	
Rutaceae									**0.106**
Citrus limon (L.) Burm. f.	**El-hammed**	K005864354	FR	F, Th, DD, Dt, Co; Der	R, I; Ct	O, E	10	0.106	
Salicaceae									**0.010**
Populus alba L.	**Safsaf**	BLUMP 1536	L	Den	D	E	1	0.010	
Solanaceae									**0.015**
Solanum melongena L.	**Bdnjane**	K000414129	Fr	Co, F, Dt, Ch	Coo, D	O	2	0.021	
Solanum tuberosum L.	**Btata**	BLUMP 1735	Tu	F	Ct	E	1	0.010	
Theaceae									**0.010**
Camellia sinensis (L.) Kuntze	**Atây**	K005466426	L	DD	I	O	1	0.010	
Urticaceae									**0.010**
Parietaria officinalis L.	**Khawi laachoub**	K003634509	Ae	W	Ct	E	1	0.010	
Verbenaceae									**0.138**
Aloysia citrodora Palau	**Lwiza**	K004949525	L	DD, Dy, Co, ND	D, I	O	13	0.138	
Zingiberaceae									**0.063**
Zingiber officinale Roscoe	**Skenjbîr**	K002428505	Rh	DD, Co	D, I	O	6	0.063	

Legend

Treated diseases: UD: Urinary diseases; Dt: Diabete; Dy: Dysmenorrhea; Ch: Cholesterol; C:Cancer; DD: Digestive disorders;ND: Nervous diseases;F: Fever; Co: Cold; H:Headache; A: Anemia; O: Obesity; Den: Dental; Th: Throat; Hl:Hair loss; Hy: Hypertension; OD:Osteoarticular diseases;Der: Dermatological

Preparation mode: D: Decoction; I: Infusion; Ct: Cataplasm; R: Raw; Coo: Cooked; Fu: Fumigation; Ma: Maceration

Administration mode: O: oral; E: externally;

Parts used: S:Seeds; R: Roots; Ba: Bark; Fl:Flower;Fr: Fruits; Ae: aerial parts; Rh: rhizome; Tu: tubercule; L: Leaves; Pe: peeling; Bu: bulb

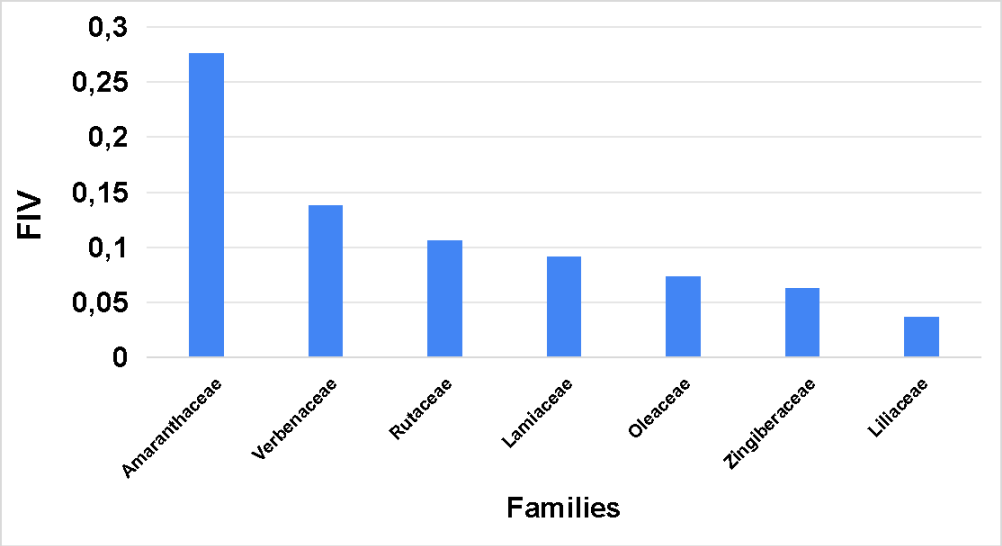

Figure 10. Distribution of cited plant's families according to their Family Importance Value (FIV).

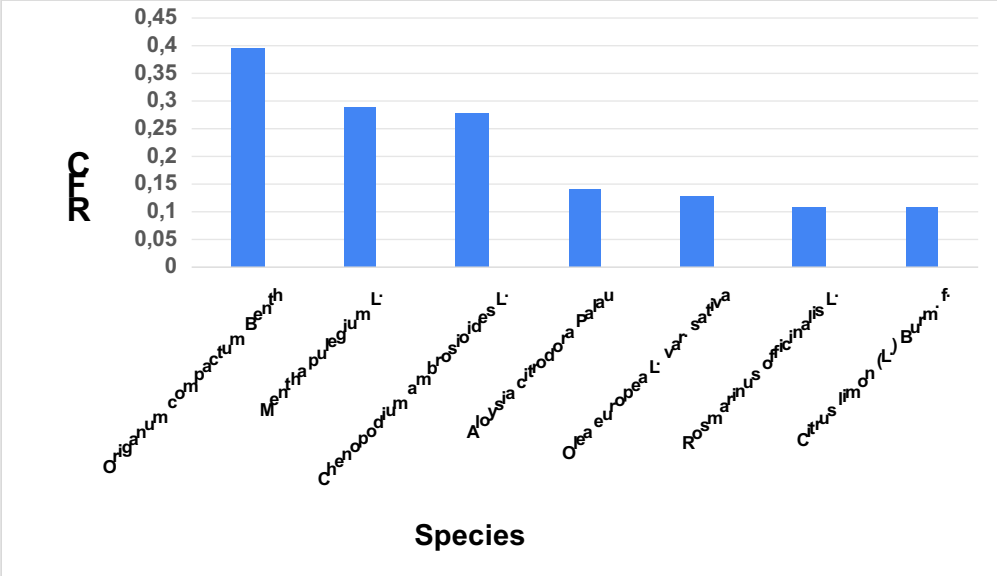

Figure 11. Distribution of the most cited species according to their Relative frequency of citation (RFC)

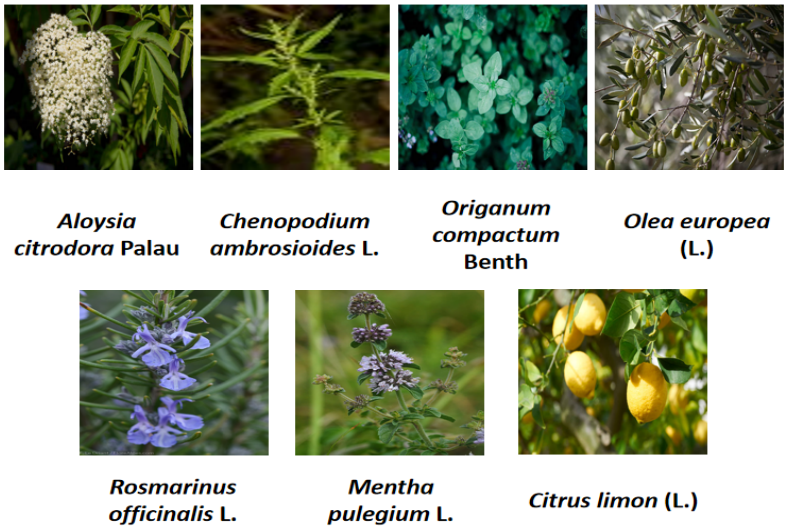

Figure 12. Pictures of plants having high use value

Recent ethnobotanical and pharmacological studies regarding the cited species

Numerous in vitro and in vivo investigations have previously highlighted the pharmacological potential of MAPs utilized in the surveyed region. Table 2 provides an overview of various ethnomedicinal applications documented in other recent ethnobotanical studies for the cited species. Additionally, it outlines their pharmacological activities as identified in various scientific research. The chemical structures of the primary bioactive compounds found in these species are illustrated in Figure 13.

Table 2. Literature data on ethnomedicinal uses and pharmacological properties of the cited species in this study.

Families Species	**Ethnomedicinal uses for the treatment of various ailments according to literature**	**Pharmacological properties and Main bio-active compounds**	**Reference**
Amaranthaceae			
Chenopodium ambrosioides L.	Treat infections such as arthritis, gastrointestinal disorders including dysentery and intestinal catarrh, and to manage menstrual disorders and serve as an emmenagogue (to stimulate menstrual flow).	Saponins: anti-inflammatory and immunomodulating; quercetin: antioxidant and anti-inflammatory; Ascaridol: antiparasitic.	(Kandsi *et al.* 2022, Kasali *et al.* 2021)
Apiaceae			
Apium graveolens L.	Anti-inflammatory and antioxidant/ Cardiovascular support/ Neuroprotective effects/ Antibacterial and antifungal properties/ Diabetes management	3-n-butylphthalide/ Ligustilide/ Sedanolide and Sedanenolide/ Cnidilide/ Limonene/ β-Selinene/ Ocimene/ Myrcene/ γ-Terpinene/ Luteolin	(Turner et al., 2021)
Coriandrum sativum L.	Treatment of digestive disorders/Natural hypotensive/Use to treat arthritis and muscle pain/Use against urinary tract and gastrointestinal infections.	Apigenin, luteolin, quercetin/Limonene, myrcene, β-selinene/Falcarinol, falcarinone/β-sitosterol	(Mahleyuddin et al., 2021)
Cuminum cyminum L.	Diuretic properties/ Anti-inflammatory/ Hypoglycemic effects/ Antimicrobial and antifungal/ Antispasmodic	apiin, apigenin, luteolin/ bergapten, xanthotoxin/ limonene, myrcene and β-selinene	(Mughal, 2022)
Foeniculum vulgare Mill.	Dermatological problems/ Respiratory disorders/ Gastrointestinal disorders/ Nervous system disorders	Estragole/ Fenchone/ Limonene/ α-pinene and p-cymene/ 3-O-caffeoylquinic acid/ Quercetin glucoside	(Jadid et al., 2023)
Petroselinum crispum (Mill.) Nyman ex A.W.Hill	Antioxidant/ Nephroprotective/ Anti-inflammatory/ Antispasmodic/ Mild laxative	Monoterpenes/ Monoterpenes/ Coumarins/ Xanthines/ Glycosides	(Nouioura et al., 2023)
Pimpinella anisum L.	Dysmenorrhea (menstrual pain)/ Polycystic ovary syndrome (PCOS)/ Anxiolytic and antidepressant properties	Trans-anethole/ Estragole/ Limonene and pinenes/ Flavonoids (quercetin, flavonols)	(Mahboubi and Mahboubi, 2021)
Apocynaceae			
Calotropis procera (Aiton) Dryand	Rheumatism and muscle aches/ Fever and infections/ Respiratory diseases (asthma, bronchitis) / Malaria	Saponins/ Tannins/ Proteases (Calotropin, Procerain, Syriogenin)/ Cardenolides	(Dogara, 2023)
Arecaceae			
Chamaerops humilis L.	Urinary and kidney disorders/ Anti-inflammatory effect/ Digestive disorders	Tannins/ Saponins/ Lipids and waxes/ Phenolic acids	(Atoui et al., 2024)
Asteraceae			
Artemisia absinthium L.	Diabetes and blood sugar control/ Antioxidant and anti-inflammatory properties/ Use as a dewormer and parasite repellent/ Treatment of fevers and infectious diseases	Caffeic acid/ p-hydroxybenzoic acid/ p-coumaric acid/ Quercetin/ Ferulic acid/ Naringenin/	(Hbika et al., 2022)

		Rutin/ Kaempferol/ Vanillin	
Artemisia herba alba Asso	Digestive disorders/ Respiratory diseases/ Diabetes/ Antioxidant and anti-inflammatory effect	Thujone (trans- and cis-)/ Camphor/ Davanone/ Eucalyptol (1,8-cineole)/ Camphene/ Santolina and Yomogi alcohol	(El Ouardi et al., 2024)
Chamaemelum nobile (L.) All.	Relaxing and sedative effects/ Anti-inflammatory and analgesic effects/ Diuretic and hypoglycemic effects	3-Methylpentyl angelate/ Isobutyl angelate/ Isoamyl angelate/ Isoamyl tiglate/ Artemisia ketone/ α-Pinene/ Camphene/ Chamazulene	(Filipović et al., 2024)
Cupressaceae			
Tetraclinis articulata (Vahl) Mast	Microbial and fungal infections/ Anti-inflammatory properties/ Dermatoprotective and anti-hyperpigmentation effect/ Antioxidant properties	Bornyl acetate/ α-Pinene/ Camphor/ Limonene/ Camphene/ Verbenone/ Borneol/ β-Pinene/ 3-Carene/ Caryophyllene	(El Hachlafi et al., 2024)
Fabaceae			
Lens culinaris Medik.	Reduce blood cholesterol/ Lower blood pressure/ Improve digestion	Saponins/ Tannins/ Total phenolics/ Phytic acid	Kaale et al., 2023)
Retama raetam (Forssk.) Webb	Antihypertensive and diuretic effect/ Antioxidant properties/ Antibacterial and antifungal activity/ Anti-inflammatory activity	Eugenol/ Alpinumisoflavone/ Licoflavone C/ Ephedroidin/ Anagyrine/ Isoprunétine/ Genistein-8β-C-glucoside	(Kamel et al., 2024)
Trigonella foenum graecum L.	Diabetes treatment/ Cholesterol reduction/ Immunomodulatory effect/ Fat metabolism/ Neuroprotection	Trigonelline, choline, gentianine, carpaine/ Diosgenine, yamogenine, tigogenine, neotigogenine/ Quercetin, rutin, vitexin, isovitexin/ Galactomannans	(Visuvanathan et al., 2022)
Juglandaceae			
Juglans regia L.	Scrofula, eczema, excessive hand and feet perspiration, dermal inflammation	Tocopherol, linoleic acid, oleic acid	(Sharma et al., 2022)
Lamiaceae			
Calamintha officinalis L.	Digestive disorders, Respiratory disorders, Antiseptic and healing properties	Saponins, Coumarins, Tannins	(Laftouhi et al., 2023)
Lavandula officinalis L.	Treatment of bacterial and fungal infections/ Care of skin disorders	Terpenes and terpenoids/ Terpene oxides	(Nacef et al., 2022)
Lavandula stoechas L.	Antiseptic & healing/ Sedative & relaxing/ Anti-inflammatory/ Antimicrobial/ Antihypertensive/ Neuroprotective	luteolin, acacetin, vitexin, apigenin 7-glucoside/ β-sitosterol, α-amyrin, lupeol/ Coumarins/ Leucoanthocyanins/ Mucilages	(Şahinler et al., 2022)
Marrubium vulgare L.	Digestive disorders/ Inflammatory and joint disorders/ Cardiovascular disorders/ Antidiabetic drugs	Alkaloids/ Terpenoids/ Saponins/ Catecholic tannins/ Anthocyanins	(Al-Snafi et al., 2021)
Mentha pulegium L.	Digestive disorders, Pain relief, Menstrual and reproductive health	Carvone, menthol, pulegone, hesperidin, narirutin, luteolin: antioxidant, anti-inflammatory, anticancer potential effects	(Amtaghri *et al.* 2024, Jebali *et al.* 2022)
Mentha rotundifolia Muds	Antiemetic, antidiarrhea, analgesic	Menthal, isomenthal	(Salamatullah, 2022)
Origanum compactum Benth	Antiseptic, Skin infection, respiratory and digestive infections/ gastrointestinal pain	Thymol and Carvacrol: Antifungal, insecticidal,	(Hayani *et al.* 2022, Ouknin *et al.* 2024)

		antioxidant and antibacterial against various strains such as Staphylococcus aureus	
Origanum majorana L.	Respiratory disorders/ Digestive disorders/ Anti-inflammatory and analgesic effect/ Antidiabetic properties/ Antihypertensive and cardioprotective effect	Carvacrol, thymol, γ-terpinene, terpinen-4-ol, α-terpinene, sabinene, α-terpineol, limonene, linalool, myrcene, camphene/ β-caryophyllene, bicyclogermacrene, spathulenol/ Luteolin, apigenin, diosmetin, quercetin, catechin, arbutin, hesperetin	(Bouyahya et al., 2021)
Peganum harmala L.	Infectious diseases/ Neurological and neurodegenerative diseases/ Gastrointestinal disorders	Harmine/ Harmaline/ Harmalol/ Harmane/ Harmol/ Pegaharmines A-F	(Zhu et al., 2022)
Rosmarinus officinalis L.	To promote hair growth and improve scalp health, treat respiratory conditions like coughs and bronchitis due to its anti-inflammatory and antimicrobial properties, and to stimulate the mind and enhance mental clarity.	Carnosic acid: antioxidant and anti- inflammatory, potential neuroprotective effects; Carnosol: Anti-cancer and anti-inflammation; Rosmarinic acid: Anti- inflammatory and antiviral	(De Oliveira et al. 2019, Kamli *et al.* 2022)
Salvia officinalis L.	Antioxidant and anti-inflammatory effect/ Neuroprotective properties/ Digestive support/ Use in dermatology	α-Thujone/ 1,8-Cineole/ α-Humulene/ Camphor/ β-Pinene/ Bornyl acetate/ Epi-manool	(Belcadi et al., 2023)
Lauraceae			
Cinnamomum verum Berchtold & J.S. Presl	Treatment of diabetes/ Digestive disorders/ Antimicrobial effect/ Relief of pain and inflammation	Cinnamaldehyde/ Eugenol/ Coumarin/ Cinnamic acid/ Polyphenols	(Yang et al., 2022a)
Liliaceae			
Allium cepa L.	Antioxidant activity/ Antimicrobial properties/ Anti-inflammatory effects/ Anti-obesity activity	Onionin A/ cycloalliin, isoalliin, methiin, propiin/ Thiosulfinate/ Quercetin/ Rutin/ Anthocyanes/ Saponins	(Zhao et al., 2021)
Allium sativum L.	Treatment of bacterial and fungal infections/ Oral health/ Antioxidant and anti-inflammatory effect/ Anti-cancer properties	Alliin/ Allicin/ S-allylcysteine/ S-allylcysteine/ Diallyl sulfide/ Diallyl disulfide/ Ajoene/ Pyrogallol/ Quercetin/ Diosgenin/ Gitogenin/ β-chlorogenin	(Sasi et al., 2021)
Linaceae			
Linum usitatissimum L.	Cardiovascular disease prevention/ Diabetes/ Hormonal support and menopause	alpha-linolenic acid/ Lignans/ Proteins and bioactive peptides	(Stavropoulos et al., 2023)
Lythraceae			
Lawsonia inermis L.	Skin care and treatment of skin infections/ Hair health/ Anti-inflammatory and analgesic effects/ Hepatoprotective	Apigenin, kaempferol, quercetin, catechin, epicatechin/ lawsone, 2-hydroxy-1,4-naphthoquinone/ Xanthones and polyphenols/ Tannins	(Batiha et al., 2024)

Punica granatum L.	Gastrointestinal diseases/ Cardiovascular diseases/ Endocrine and metabolic disorders/ Infections and inflammatory diseases	Punicalagine/ Punicaline/ Gallic acid/ p-Coumaric acid/ Chlorogenic acid/ Cyanidin-3-glucoside/ Catechin/ Epicatechin/ Quercetin/ Pseudopelletierine	(Eghbali et al., 2021)
Myrtaceae			
Eucalyptus globulus Labill.	Respiratory problems/ Antimicrobial properties/ Anti-inflammatory and analgesic effect/ Antioxidant properties	1,8-cineole/ α-pinene/ β-pinene/ Limonene/ p-cymene/ Globulol and spathulenol/ quercetin, luteolin, catechin, gallic acid, ellagic acid	(Shala and Gururani, 2021)
Syzygium aromaticum (L.) Merr. &Perry	Analgesic and anesthetic/ Anti-inflammatory and healing/ Antimicrobial and antifungal	Eugenol/ Eugenyl acetate/ β-Caryophyllene/ α-Humulene	(Haro-González et al., 2021)
Oleaceae			
Olea europea L. var. *oleaster*	Diabete, hypertension, urinary problems	Oleoside, verbascoside, hydroxytyrosol	(Benamar et al., 2024b)
Olea europea L. var. *sativa*	Enhancing cardiovascular health by lowering high blood pressure and improving cholesterol levels, maintaining blood sugar levels with antidiabetic and antihyperglycemic properties, and utilized in skin care products for hydration and protection.	Oleuropein, Ligstroside, Oleuropein aglycone; Ligstroside aglycone, Oleacein,Oleacanthal: Anti-inflammatories and antioxidants	(Elhrech et al. 2024, Filardo et al. 2024)
Piperaceae			
Piper nigrum L.	Antioxidant/ Antimicrobial and antibacterial/ Anti-inflammatory/ Anti-obesity/ Antidiabetic	β-caryophyllene, Limonene, Sabinene, α-pinene, β-bisabolene, α-copaene/asechin, Myricetin, Quercetin/ Lutein, β-carotene	(Zeriouh et al., 2017)
Poaceae			
Hordeum vulgare L.	Effects on oxidative stress and ageing/ Improving the digestive system/ Regulating metabolism and diabetes	Melatonin/ β-glucan/ γ-aminobutyric acid/ Polyphenols and carotenoids	(Ashokkumar et al., 2021)
Panicum miliaceum L.	Type 2 diabetes and cardiovascular disease/ Digestive disorders/ Celiac disease (gluten intolerance)	leucine, phenylalanine and methionine	(Rajasekaran and Francis, 2021)
Ranunculaceae			
Nigella sativa L.	Respiratory diseases/ Immune system and infections/ Dermatological disorders	Thymoquinone, Thymohydroquinone, Thymol, Carvacrol, α-Pinene, p-Cymene/, Nigellicimine, Nigellicimine-N-oxide, Nigellidine, Nigellicine	(Yang et al., 2022b)
Rosaceae			
Prunus amygdalus Stokes var.Amara L.	Diabetes treatment/ Hepatoprotective/ Antioxidant effect/ Antitumor and antiangiogenic effect	Cucurbitacin B, E/ Luffein/ Oleanolic acid/ Luffangulin/ Acutosides A, B, C, D, E, F and G	(Kumar et al., 2021)
Rosa centifolia L.	Respiratory and immune problems/ Digestive problems/ Dermatological and skin problems	Geraniol,Nerol, Citronellol, Linalool/ Phenylethanol, Eugenol/ Sesquiterpenoids and triterpenoids	(Dashora et al., 2013)
Rutaceae			
Citrus limon (L.) Burm. f.	Lemon has antibacterial properties, reduces inflammation, combats fever, and	Eriocitrin: Anti-oxidant; Neoeriocitrin: Anti-	(Poddar *et al.* 2020, Posadino *et al.*

	prevents scurvy, ulcers, and urinary diseases. It acts as an antidote to poison, helps prevent bad breath and body odor, lowers blood pressure, alleviates vomiting and liver disorders, boosts immunity, promotes glowing skin.	inflammatory and antioxidant, Hesperidin: Vasoprotective and anti-inflammatory	2024, Zahr*et al.* 2023)
Salicaceae			
Populus alba L.	Analgesic and anti-inflammatory properties/ Treatment of rheumatism and joint pain/ Dermatological care	Catechins, quercetin, kaempferol/ β-sitosterol/ Condensed tannins	(Gateva et al., 2024)
Solanaceae			
Solanum melongena L.	Diabetes/ Hypertension/ Hyperlipidemia/ Obesity	Delphinidine/ Tyramine and its derivatives/ Acetylcholine/ Flavonoids and Saponins	(Wei et al., 2023)
Solanum tuberosum L.	Treatment of burns and skin irritations/ Anti-ulcer effect/ Anti-inflammatory action	Solanine and chaconine/ Chlorogenic acid, flavonoids (quercetin, kaempferol), anthocyanins	(Yarmohammadi et al., 2021)
Theaceae			
Camellia sinensis (L.) Kuntze	Oxidative stress/ Cardiovascular disorders/ Diabetes/ Cancer/ Neuroprotection (Alzheimer's, Parkinson's)	Catechin/ Epicatechin/ Epigallocatechin-3-gallate/ Epicatechin gallate/ Caffeine, Theanine	(Djaman et al., 2021)
Urticaceae			
Parietaria officinalis L.	Diuretic and blood purifier/ Treatment of urinary tract infections/ Relief of bronchitis and respiratory ailments	Acétate de géranyle/ Viridiflorol/ Trans-β-Ionone/ Oxyde de caryophyllène/ Acétone d'hexahydrofarnesyl/ Angélique de bornyle	(Governa et al., 2022)
Verbenaceae			
Aloysia citrodora Palau	Antibacterial and antifungal effects/ Anticancer effects/ Traditional use in natural medicine	Geranial/ Neral/ α-Curcumene/ Spathulenol/ Caryophyllene oxide/ Limonene/ 1,8-Cineole	(Fikjvar et al., 2024)
Zingiberaceae			
Zingiber officinale Roscoe	Neurodegenerative diseases (Alzheimer's, Parkinson's, multiple sclerosis)/ cardiovascular diseases/ Diabetes and metabolic disorders	Gingerols/ Shogaols/ Paradols/ Gingerdiones et gingerdiols/ 6-dehydrogingerol/ 12-gingero	(Arcusa et al., 2022)

Plant parts used

The results of our ethnobotanical study show that the population of Haj Kaddour prepare herbal remedies using various plant parts.

The PPV values of different MAPs parts are presented in figure 14. According to this figure, the most used parts are leaves (PPV= 70.12%), followed by seeds (PPV= 9.95%), fruits (PPV= 6.06%), bulb (3.03%), rhizome (2.59%), peelings (1.29%), bark (0.86%), and tuber (0.86%).

The dominant use of leaves was also reported in several ethnobotanical studies, and it could be explained by their richness in bioactive compounds, in addition to their easy harvest (Belhaj & Zidane 2021, El hachlafi *et al.* 2020, Jaadan *et al.* 2020, Salhi *et al.* 2010).

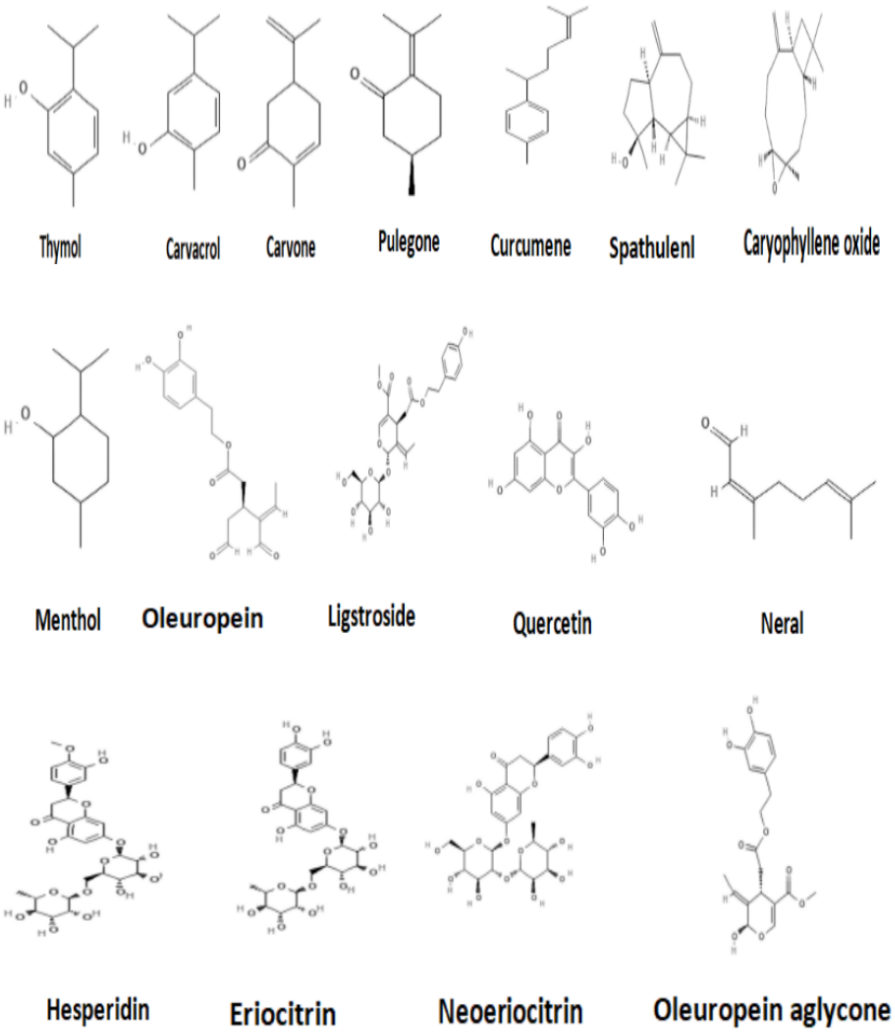

Figure 13. Molecular structures of key bioactive constituents in the cited MAPs species.

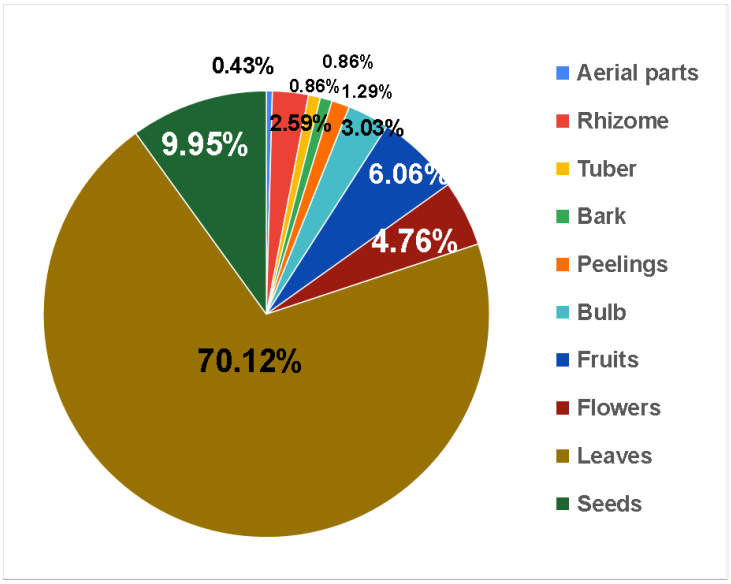

Figure 14. Plant parts used by informants in treatment of different ailments.

Preparation mode

Our study revealed that people of haj Kaddour area use different methods for MAPs based remedies preparation. Indeed, Figure 15 shows that the most frequent preparation modes used are Infusion (48.18%) and decoction (30%). Other modes are used less frequently, namely raw (10.90%), cataplasm (6.36%), cooked (1.81%), and fumigation (1.81%).

The predominant use of infusion and decoction could be attributed to the efficiency of these methods in the extraction of bioactive compounds, and their role in reducing or eliminating the toxic effects of herbal remedies (Benaiche *et al.* 2019, Benamar *et al.* 2023b, Benamar et al., 2024d, Salhi *et al.* 2010).

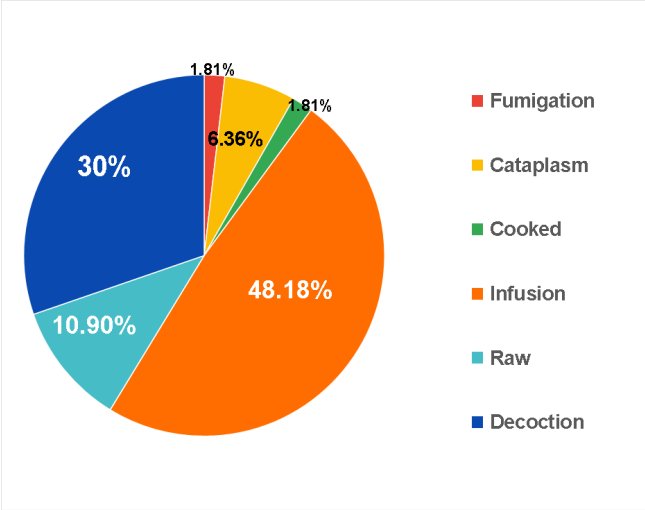

Figure 15. MAPs preparation methods and their frequency of use by respondents

Doses used of MAPs and duration of treatment

Regarding doses of MAPs used, the majority of respondents (64.17%) use spoons, 26.86% use handle, and 5.97 % use pinch (Figure 16).

Concerning the treatments duration (Figure 17), most of respondents (68.75%) use MAPs for one day, whereas 18.75% use them for one week, 10.93% use them until recovery, and 1.56% stated that they rely on MAPs use for one month in order to threat some chronicle diseases such as certain cancers. These findings show that the use of MAPs in the studied area is a random, this practice could pose health risks, since the use of MAPs at unspecified doses and for random durations may cause undesirable effects and constitutes therefore a a threat to life users (Benamar *et al.* 2023b, Benkhnigue *et al.* 2010).

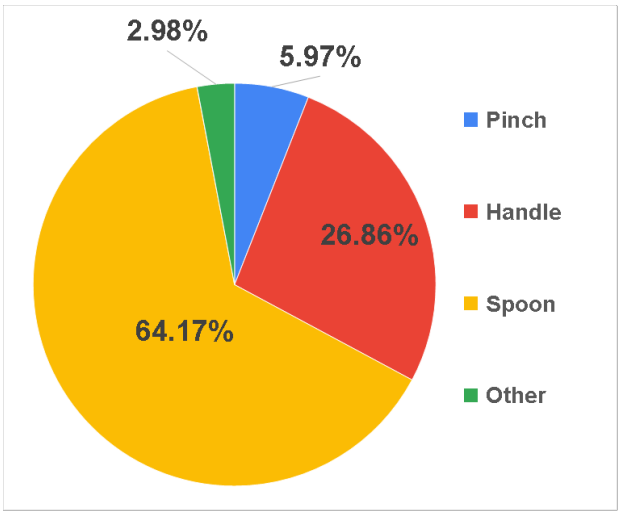

Figure 16. Doses of MAPs used by respondents for the preparation of traditional remedies

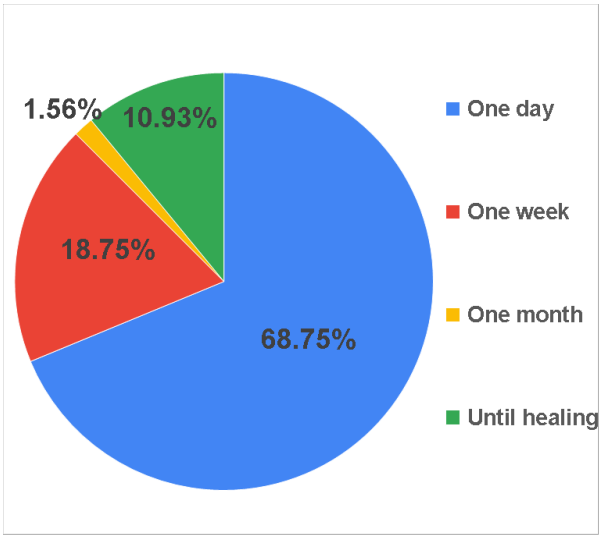

Figure 17. Duration of treatment using MAPs by respondents .

Implications of our findings on healthcare practices or policymaking in Morocco

The high use of MAPs in Haj Kaddour highlights the need for integrating traditional knowledge with modern healthcare practices, especially in such rural areas with limited access to formal medical infrastructure. Local heritage could be respected by training healthcare practitioners in both modern and traditional medicinal practices, which would ensure patient safety together with heritage protection and sustainability.

Furthermore, Since MAPs are found common therapeutic agents for a vast proportion of the studied population (including the elderly and women), policymakers may consider a path forward to ensure the safe use of these plants through development of regulatory frameworks. This may lead to developing guidelines for appropriate doses, ways of preparing them, and toxic effects, thus helping to make the herbal remedies used by rural people safer.

Policymakers could also explore the potential for these plants to be used in public health campaigns for the treatment of common diseases, where appropriate, while ensuring that the treatments are scientifically validated and regulated.

Besides, the integration of traditional knowledge into national health systems could also stimulate the local economy by creating local markets for MAPs based products, benefiting rural areas economically, while guaranteeing the safety of these products. Additionally, to reduce the health risk of MAPs use, seeking advice from a healthcare professional before using MAPs, may be beneficial.

Study limitations

A limitation of our study is the small sample size. In fact, some community members were hesitant towards participating in interviews or had difficulty in replying to questions during the data gathering process, which contributed to the small sample size. This hesitation is likely the outcome of several factors, such as: distrust of the researchers, discomfort about talking about their own health practices or a desire for privacy. Consequently, the final sample might not adequately reflect the variety of attitudes and practices associated with the use of medicinal plants in the region.

However, our study identifies the patterns and practices of the use of medicinal plants by the local population in the region which may assist in grounding future studies with larger and better diverse sample sizes. Future studies might try to overcome some of these limitations through trust-building strategies in the community and broadening participation to a larger group.

Conclusion

The use of medicinal and aromatic plants (MAPs) is a significant aspect of therapeutic practices among the indigenous population of the Haj Kaddour region, serving as a viable alternative to synthetic pharmaceuticals. Notably, 68.08% of individuals rely on MAPs to prepare traditional remedies. A total of 52 plant species from 26 botanical families were identified as being used in this context.

Demographic analysis revealed distinct trends in MAPs usage. Individuals with limited use of MAPs (fewer than three plants) often shared specific characteristics: they were predominantly male, single, younger than 20 years, and had attained secondary education. In contrast, moderate and extensive users of MAPs (those using 4–7 plants or more than 7, respectively) were generally married, female, older (>20 years), and had lower education levels, such as being illiterate or having only primary education.

The most frequently cited plant species included Origanum compactum Benth. (RFC = 0.393), Mentha pulegium L. (RFC = 0.287), and Chenopodium ambrosioides L. (RFC = 0.276). Among the dominant botanical families, Amaranthaceae (FIV = 0.276), Verbenaceae (FIV = 0.138), Rutaceae (FIV = 0.106), and Lamiaceae (FIV = 0.106) were prominent. Leaves were the most commonly utilized plant part (PPV = 70.12%), with infusion (48.18%) and decoction (30%) being the primary preparation methods. However, the dosages of MAPs were often imprecise and varied among users.

The results of this study contribute valuable insights into the traditional use of MAPs in the Haj Kaddour region and their potential for further development in the field of ethnopharmacology. These findings can inform future research into the bioactive properties of the medicinal plant species used and guide the formulation of new, natural-based therapeutic approaches.

In conclusion, this work underscores the importance of MAPs in traditional healing practices in the Haj Kaddour region, highlighting its significant role in the development of ethnopharmacology.

Declarations

List of abbreviations: RFC - Relative Frequency of Citation; FIV - Family Importance Value; PPV - Plant Part Value; FC - Frequency of citation; N - Total number of people using MAPs; Ns - Total number of cited species in each family; MAPs - Medicinal and Aromatic Plants; L - Leaves; S - Seeds; Fl - Flower; Bu - Bulb; Fr - Fruit; B - Bark; R - Raw; C - Cooked; O - Oral; F - Fumigation; I -Infusion; D - Decoction; M - Maceration; E - Externally; Prepar - Preparation; Admin - Administration; G - Gender; EL - Educational level; MS - Marital status; MCA - Multiple component analysis.

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: All participants shown in images gave their permission to have these images published.

Availability of data and materials: Not applicable

Competing interests: Not applicable

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Authors' contributions: K.B. carried out data collection, literature survey and prepared the first draft of the manuscript. I. D. performed data analysis and preparation of the first draft of the manuscript. M.A. carried out data collection and data analysis. Y.L. performed data analysis and preparation of the first draft of the manuscript. R.L. Supervised the research. S. I. K. Supervised the research. S. B. performed the statistical analysis and improved the manuscript. K. F. B. Supervised the research and improved the manuscript.

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