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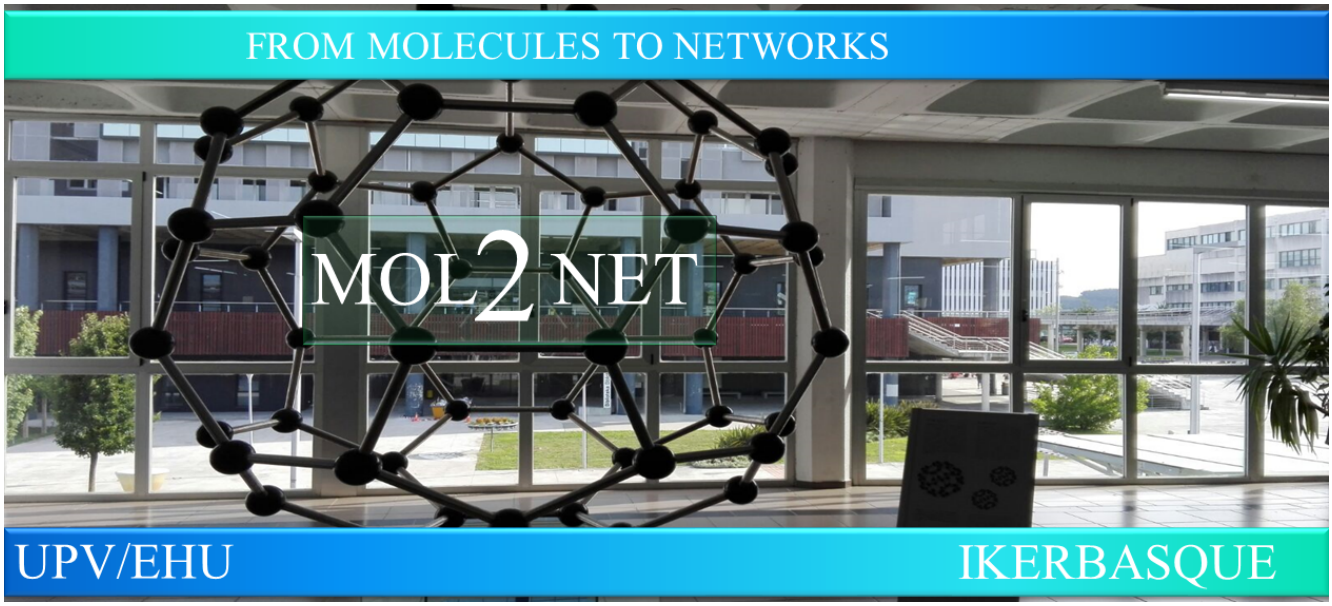

Documentation of medicinal plants used to treat cardiovascular ailments in the Rif region of northern Morocco

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Abstract.

Background: Moroccans have used medicinal plants for centuries to treat various human and cattle health issues. However, there is a need for more research to document and share indigenous ethnopharmacological knowledge. In this study, we aimed to identify medicinal plants indigenous people in the Rif region used to treat cardiovascular problems and assess their ethnomedicinal abilities.

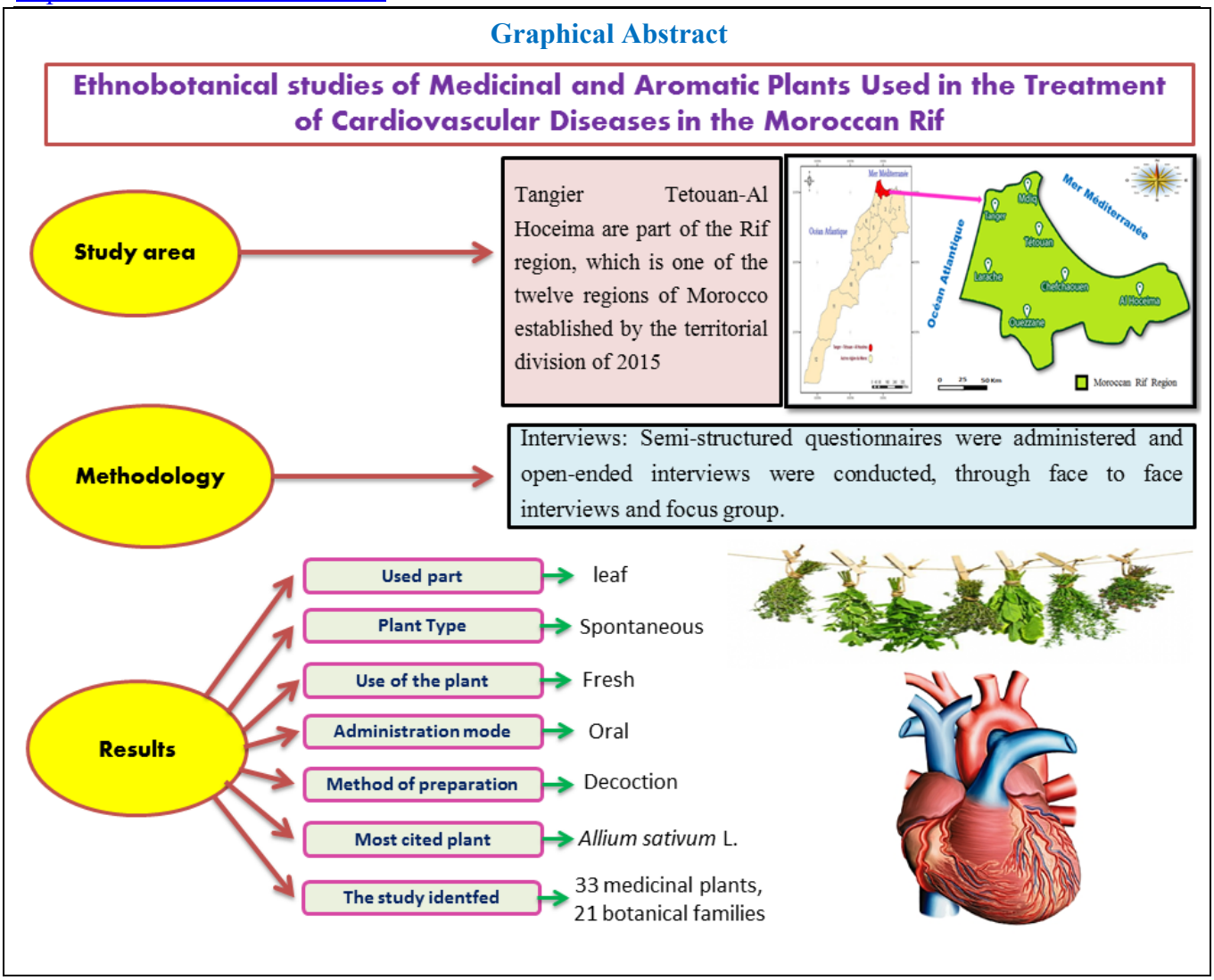
Methods: From 2016 to 2018, we conducted an ethnobotanical study in the Moroccan Rif area, surveying 520 traditional herbalists and consumers. We used quantitative ethnobotanical indicators such as family importance value (FIV), the relative frequency of citation (RFC), plant part value (PPV), fidelity level (FL), and informant consensus factor (ICF) to analyze the data.

Results: Our analysis revealed 33 plant species from 20 families, with Poaceae being the most dominant (7 species). Among the cardiovascular disorders treated, cardiac arrhythmias had the highest ICF (0.98). Leaves were the most frequently used plant part (PPV = 0.353), and decoction was the most common preparation method (31%).

Conclusions: Our study found evidence of indigenous ethnomedicinal knowledge of medicinal plants used to treat cardiovascular illnesses in the Moroccan Rif. We recommend further phytochemistry, pharmacology, and toxicology research to discover new drugs from these documented medicinal plants.

Keywords: Cardiovascular diseases, Ethnobotany, Ethnomedicine, Herbal medicine, Medicinal plant.

Graphical Abstract



Introduction

Cardiovascular disease (CVD) is the number one cause of death worldwide [1, 2]. CVD covers many disorders, including cardiac muscle diseases and the vascular system supplying the heart, brain, and other vital organs. Humans have always used medicinal and aromatic plants (MAPs) to treat themselves and fight against diseases. In all ancient civilizations and all continents, one finds traces of this use [3–5]. Thus, despite the progress of pharmacology, the therapeutic use of plants is very present in some countries, especially in developing countries.

In the last few decades, plants have been necessary sources of preventive and healing traditional medication preparations for human beings and livestock. Plants are also significant in global commerce today [6, 7]. The day-to-day demand for medicinal plants is growing in developing and developed countries without an excellent medical system.

By its biogeographical position, Morocco offers a vibrant ecological and floristic diversity constituting an actual plant genetic reserve, with about 4,500 species belonging to 940 genera and 135 families, the mountainous regions of Rif and Atlas being the most critical areas for endemism [8]. This biodiversity is characterized by considerable endemism [9], allowing it to occupy a privileged place among the

Mediterranean countries with a long medical tradition and traditional know-how based on medicinal and aromatic plants [10]. Indeed, herbal medicine has always occupied an important place in medication practices in Morocco, and the Rif region is a concrete example.

We conducted an ethnobotanical study in the Moroccan Rif, known for its various lithological, structural, biological, and floristic features resulting from its topography, relief, and geographical location. This investigation aimed to assess the medicinal plants growing in the region to enhance the knowledge of indigenous MAPs and analyze their potential relationship with cardiovascular diseases. It is crucial to convert traditional knowledge into scientific knowledge to sustainably appreciate, conserve, and utilize it.

Materials and Methods

Study area

The study area was conducted in the Rif, in Northern Morocco, within the Tangier-Tetouan-Al Hoceima region. This region spans from 34° to 36° of latitude in the North and 4° to 6° of longitude in the East, bordered by the Mediterranean Sea and the Strait of Gibraltar to the North, the Fez-Meknes region and Rabat-Sale-Kenitra region to the South, the Eastern Region to the East, and the Atlantic Ocean to the West (Figure 1). The total area of the Rif is 11,570 km², and the population is approximately 3,549,512 people, with a population density rate of 222.2/km² [11].

The study area experiences a Mediterranean climate, with temperatures ranging from over 45°C during summer (July-August) to below 0°C during winter (December-January). The average yearly precipitation falls between 700 and 1300 mm, primarily between October and February [12]. The region is mountainous, with elevations ranging from 145 to 2,456 meters above mean sea level, dominated by species such as *Abies marocana* Trab., *Pinus halepensis* Mill., *Cannabis sativa* L., *Cedrus atlantica* (Endl.), *Quercus suber* L., *Quercus ilex* L., and *Quercus canariensis* Willd. The inhabitants of the Rif rely heavily on subsistence agriculture, livestock, and, to a lesser extent, forest reserves for their livelihood [13].

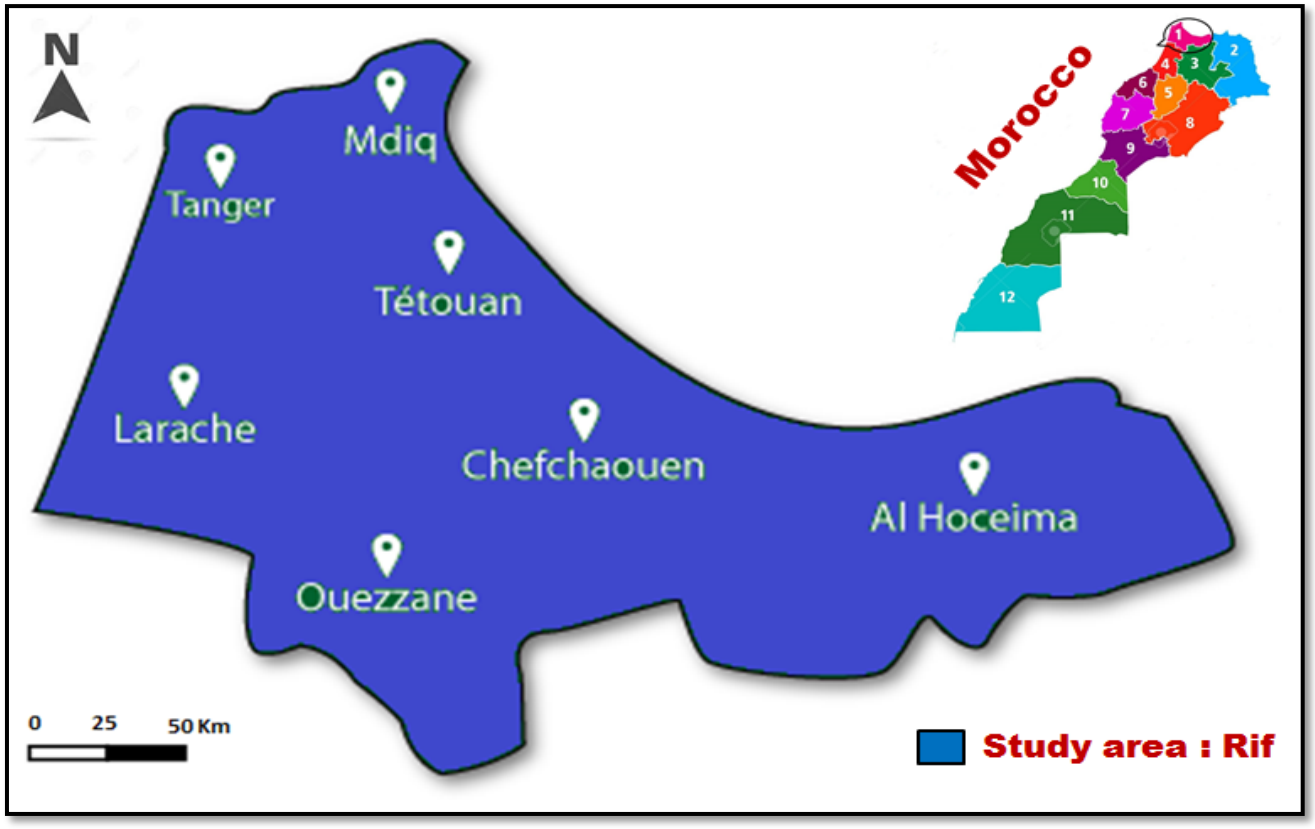


Figure 1: Map of the study area.

Methodology

Data collection

Ethnomedicinal investigations were carried out from June 30th, 2016, to June 1st, 2018, to collect knowledge on plant species used to manage cardiovascular diseases in the Rif **[14, 15]**. The techniques employed for data collection were semi-structured interviews **[16]**, open-ended, group discussion, free listing, and noted and recorded with a digital voice recorder. Five hundred twenty interviewees aged 17 to 81 were randomly chosen for meetings in the study area (houses, pharmacies, weekly markets, hospitals, and mosques). A stratified random sampling **[17]** formed samples in each of the 28 strata, including seven urban communes. They were put together to make up the overall sample of 520 informants. The number of people surveyed varies from one stratum to another, depending on the abundance of medicinal plants sought. The period spent on every interview was approximately 20 minutes to one hour. The information collected concerning the profile of the interviewee and the ethnomedicinal data for each plant include the common local name, the route of administration, the method of preparation, the dosage, the part used, the condition of the plant used and the diseases treated. The people in the Rif speak Amazigh or Arabic dialects; accordingly, interviews were conducted in Amazigh or Arabic dialects.

Medicinal plants identification and preservation

We recorded the gathering of plant substances and then dehydrated, positioned, prepared, and preserved plant parts **[18]**. Based on ethnomedicinal information provided by our informants, specimens were numbered, collected, dried, pressed, poisoned, and mounted standard herbarium sheets

for identification. The plants were arranged systematically by local name, scientific name, family, plant parts used, mode of preparation, relative abundance, and geographical distribution. The plant species mentioned by the informants were taxonomically identified using local flora accessible, including "The medicinal plants of Morocco" [19], "Practical flora of Morocco" [20–22], and "Catalog of vascular plants of north Morocco tomes I and II" [23]. Finally, the voucher specimens were deposited in the Herbarium, Department of Biology, Ibn Tofail University, Morocco, for future reference.

Results and Discussion

Socio-demographic features of the informants

In total, 600 local informants, including 311 females and 289 males (with a sex ratio female/male of 1.08), were interviewed. In the Moroccan Rif, both sexes are affected by traditional herbal medicines (Table 1). However, women have a more excellent knowledge of the plant species and their use, with a predominance of 51.8% against a percentage of 48.2% among men though the test (independent sample t-test) did not show a significant difference (P = 0.053) between male and female informants on the number of medicinal plant species they listed and associated uses reported. Women's vigilance can explain this predominance of females for the balance of the disease and their attachment to all that is traditional; indeed, women give sustenance and healthcare to their families in case of an illness. These results confirm the results of other ethnobotanical work carried out nationally [29–33].

At the level of the study area, the majority of respondents were in the age range between 40 and 60 (45.7%), followed by informants who were more than 60 years (25.8%) and informants who were between 20 and 40 years (22.3%). Finally, informants younger than 20 come in the last position (6.2%). ANOVA One-way between age groups and indigenous knowledge obtained significant differences (P = 0.000). The highest age respondents provide more reliable information because they hold much of the ancestral knowledge that is part of the oral tradition. So, there is a need for more details on MAPs, which can be explained by the mistrust of confident young people, who tend to be disinterested in this herbal medicine due to the influence of modernization and exotic cultural influence. The traditional medical knowledge transmitted from generation to generation is in danger because transmission between old and younger generations is only sometimes assured [34]. These values confirm the results obtained in other regions of Morocco [35–38].

The analysis of the collected data shows that MAPs are much more used by married (80.3%) than by divorced (10.3%), knowing that widowers have a percentage of 7.3% and only 2.1% for singles because married people can avoid or minimize the material charges required by the doctor and the pharmacist. The difference between family status and indigenous knowledge of the treatment of cardiovascular diseases was statistically significant (P = 0.000). Those findings coincide with those of a similar study conducted in other regions of Morocco [6, 39, 40].

Regarding the level of education, 75.2% of the respondents are illiterate, followed by the category of primary, with a percentage of 20.3%. Nevertheless, people with a secondary level education use little medicinal plants, with a rate of 4.5%. Thus, the difference between educational level and indigenous knowledge was significant (P = 0.000). The use of MAPs decreases as the level of study increases. This result is similar to the findings reported in other studies [40–44].

In our study, (63.4%) were unemployed, 26.1% of the interviewees had a low socio-economic level, (10%) with an average level, and only 0.5% with a higher level. The difference between income/month and indigenous knowledge was significant (P = 0.000). The high cost of modern medical treatments and their side effects are among the main reasons respondents used herbal medicine. The use of plants increases with the increase in the monthly income of these informants. These results are similar to those obtained in Moyen Moulouya of Morocco [45].

Table 1: Sociodemographic details of the informants in the Moroccan Rif area.

Variables	Categories	Number of informants N=600	Percentages (%)	P-values
Gender	Female	311	51.8	.0053
	Male	289	48.2	
Age groups	< 18 years	37	6.2	
	20-40	134	22.3	
	40-60	274	45.7	0.000
	> 60 years	155	25.8	
Family situation	Married	482	80.3	
	Divorced	62	10.3	0.000
	Widower	44	7.3	
	Single	12	2.1	
Educational level	Illiterate	451	75.2	
	Primary	122	20.3	
	Secondary	27	4.5	0.000
	University	0	0.0	
Income/month	Unemployed	380	63.4	
	250 - 1500 DH	157	26.1	
	1500 - 5000 DH	60	10	0.000
	> 5000 DH	3	0.5	

Medicinal plant species of the study area

A total of 33 medicinal plant species belonging to 21 botanical families, including 15 from di-cotyledons and five from mono-cotyledons, were used to treat cardiovascular diseases in the study area. The information gathered during this survey included the local name of the medicinal plants, their scientific method of preparation and the part of the plant used, and the therapeutic indication for which it is used. The data are arranged in alphabetical order according to the family name, and the FIV, RFC, FL, and ICF data are shown in Table 2.

The most botanical family of medicinal plant species, used to treat cardiovascular diseases based on the number of species and FIV index, was Poaceae, the leading family with seven species (FIV 0.02), followed by Fabaceae (03 species with FIV 0.035). In comparison, only one or two species represented

other families. This high proportion of Poaceae could be explained by the increased representation of this family in the Rif's flora because of the ecological factors that favor the development and adaptation of the majority of the species of this family. This representation has also been observed, with some differences, in other ethnomedicinal surveys conducted in different regions of the country [30, 32, 46–48].

RFC and FL plant species

To evaluate the relative importance of reported medicinal plants, the relative frequency of citation (RFC) was calculated based on the informants' sources for specific understudy plants; its value ranged from 0.002 to 0.205. Results of this study depicted that *Rubia peregrina* L. exhibited a higher RFC (0.205), followed by the *Allium sativum* L. (RFC = 0.197), *Daucus carota* L. (RFC = 0.17), and *Laurus nobilis* L. (RFC = 0.152). The least RFC was exhibited by 13 plant species (RFC = 0.002 each). These species had the highest RFC index because many informants mentioned these plants, and RFC directly depends on the number of informants saying the use of a specific plant. Those medicinal plant species with high RFC must be further assessed for phytochemical and pharmaceutical analysis to identify their active constituents for drug extraction [49]. These species should also be prioritized for conservation as their preferred uses may threaten their populations due to over-harvesting.

To determine the most frequent species used for each ailment category, we calculated the FL. According to our results, twenty-two species that had the highest FL of 100% were used in the treatment of cardiovascular diseases by the interviewees (Table 2). The highest value of FL indicates that plant species are mostly preferred for the study population to treat a given condition. The MAPs with high fidelity levels have better healing potential in the Moroccan Rif region and possess more natural products (tannins, flavonoids, and alkaloids).

Plant parts used to treat cardiovascular problems

People of the Moroccan Rif harvest different plant parts of preparing traditional remedies (e.g., seed, root, flower, bulb, fruit, leaf, and whole plant). Based on the plant part value PPV index, the leaf was reported as the dominant plant part for cardiovascular remedy preparation in the study area (PPV 0.353), followed by root (PPV 0.213), bulb (PPV 0.201), fruit (PPV 0.103), seed (PPV 0.102) and whole plant (PPV 0.027) respectively. The preference for leaves was due to their easy availability, effortless harvesting, and simplicity in remedy preparation. Besides, the leaves are the seat of photosynthesis and sometimes the storage of the secondary metabolites responsible for the biological properties of the plant. Our results on the proportions of diverse plant parts used in this research agree with the largest of the previous ethnomedicinal investigations carried out in several other countries [50–56] that have shown the predominance of the leaf as signifying used in the preparation of herbal medicines.

Remedies preparation method and routes of administration

To facilitate the administration of the active principles of the plant, several modes of preparation are employed to know the decoction, infusion, cataplasm, raw, maceration, fumigation, and cooked. In the study area, decoction remains the most dominant mode of preparation (31%), followed by infusion (29%), cooked (17.9%), and raw (10.7%) cataplasm (6.2%). The percentage of the other modes of preparation grouped (fumigation, maceration) is at most 5.2%. The frequent use of the decoction can be explained by the fact that the decoction makes it possible to collect the most active ingredients and attenuates or cancels out the toxic effect of specific recipes. Ethnobotanical research surveys conducted elsewhere in Morocco showed the majority of the interviewees prepared the remedy by decoction [6], **[31, 40, 44, 57, 58]**. This confirms a perpetual exchange of information on the use of medicinal and aromatic plants between the people of Morocco. A decoction is mentioned as the principal method of preparation at the continental level. The route of administration also varies depending on the disease and materials used. In general, most of the prepared recipes are orally prescribed (84%), followed by massage (5.7%), other modes of administration (5%), swabbing (4%), and rinsing (1.3%). The predominance of oral administration may be explained by a high incidence of internal ailments in the region **[63]**. On the other hand, the oral route is the most acceptable for the patient. The predominance of oral administration of the different medicinal plants in the Moroccan Rif is in total agreement with most of the ethnobotanical studies carried out in Africa **[38, 50, 64, 65]**.

Conditions of medicine preparation

Most commonly, the local people asserted that they prefer the fresh plant part to the dried part for remedy preparation. The majority of the remedies (62%) in the study area were prepared from fresh parts of medicinal plants, followed by dried form (35.4%) and (2.6%) prepared either from dry or fresh plant parts. The study **[66]** indicated that 86% of preparations were in fresh form, and this investigation **[67]** reported that most (64%) medicinal plants were used in fresh form and 36% in dried form. The dependency of Moroccan Rif people on fresh materials is primarily due to the effectiveness of fresh medicinal plants in treatment, as the contents are not lost before use compared to the dried forms.

Source of knowledge about medicinal plants

In our ethnobotanical survey, 69.3% of the population acquired knowledge about the medicinal use of plants as a remedy for cardiovascular diseases through others' experiences. This reflects the relative transmission of traditional practices from one generation to the next one. 19% practice herbal medicine according to herbalists' advice, (10.3%) of respondents their information is reflected from a pharmacist, and only 1.6% had built this knowledge by reading books about traditional Arab medicine, watching television programs, or by their own experience with a large number of medicinal plants in their surroundings. Therefore, the environment and others' experiences remain the most effective means to transmit knowledge about the medicinal purposes of plants.

Table 2: List of medicinal and aromatic plant actives on the cardiovascular diseases in the Moroccan Rif region.

Family and Scientific name	Vernacular name	Part used	Mode of Preparation	Medicinal uses	FL	FC	RFC	FIV
Apiaceae								0.17
Daucus carota L.	Khizou	Leaf	Decoction	HA	100	102	0.17	
Amaryllidaceae								0.12
Allium porrum L.	Borro	Bulb	Infusion	HA	100	72	0.12	
Araliaceae								0.002
Hedera hebernica (G.Kirchn.) Carrière.	Louwaya	Leaf	Infusion	BP	100	01	0.002	
Arecaceae								0.076
Phoenix dactylifera L.	Tmar, Tazdayet	Fruit	Other	HA, AG	78	46	0.076	
Asteraceae								0.017
Carduus getulus Pomel.	Lssan Maghribi	Leaf	Other	AG	100	01	0.002	
Cynara scolymus L.	Lqoq	Whole plant	Decoction	HA	100	09	0.015	
Cactaceae								0.031
Opuntia ficus indica (L.) Mill.	Sbar, Zaâboul	Fruit	Infusion	BP	100	01	0.002	
Opuntia ficus-barbarica A.Berger	Hendya	Seed	Decoction	HA	100	36	0.06	
Cannabaceae								0.018
Cannabis sativa L.	Lkif	Seed	Cataplasm	AG	100	11	0.018	
Amaranthaceae								0.093
Spinacia oleracea L.	Sabanikh, Selq	Leaf	Raw	HA	100	56	0.093	
Dryopteridaceae								0.002
Dryopteris filix-mas (L.) Schott.	Sarkhs Dakar	Leaf	Decoction	BP	100	01	0.002	
Fabaceae								0.035
Lens culinaris Medik.	Aaddes	Seed	Cooked	HA	100	48	0.08	
Medicago polymorpha L.	Fessa	Whole plant	Decoction	AG	100	14	0.023	
Vicia sativa L.	Guersana	Whole plant	Infusion	BP	100	01	0.002	
Geraniaceae								0.005
Erodium cicutarium (L.) L'Hér.	Rakma Chokrania	Leaf	Cooked	AG	100	03	0.005	
Iridaceae								0.002
Gladiolus italicus Mill.	Dalbout Itali	Leaf	Other	AG	100	01	0.002	
Lauraceae								0.105
Laurus nobilis L.	Wrak Sidnamossa,	Leaf	Decoction	HA, AG, BP	0.89	91	0.152	
Persea gratissima C.F.Gaertn.	Avocat	Fruit	Cataplasm	HA	100	35	0.058	
Amaryllidaceae								0.197

Allium sativum L.	Touma, Tishert	Bulb	Cooked	HA	100	118	0.197	
Malvaceae								0.002
Hibiscus sabdariffa L.	Karkadé	Leaf	Decoction	BP	100	01	0.002	
Poaceae								0.02
Zea mays L.	Dra	Fruit	Decoction	HA	100	08	0.013	
Phragmites communis Trin.	Kseb	Root	Infusion	HA	100	74	0.123	
Glyceria fluitans (L.) R.Br.	Aaima	Whole plant	Other	BP	100	01	0.002	
Miscanthus sinensis Andersson.	Kseb Chinwa	Leaf	Decoction	BP	100	01	0.002	
Pennisetum setaceum (Forssk.) Chiov.	Dyl Ethaalab	Seed	Decoction	BP	100	01	0.002	
Hordeum murinum L.	Chaair El Firan	Leaf	Infusion	AG	100	01	0.002	
Avena barbata Pott ex Link.	Chofan Barri	Whole plant	Raw	AG	100	01	0.002	
Polygonaceae								0.043
Rumex sanguineus L.	Hommida	Leaf	Decoction	AG	100	26	0.043	
Ranunculaceae								0.003
Ranunculus bullatus L.	Wden Elhallouf	Root	Decoction	AG	100	02	0.003	
Rosaceae								0.082
Rubus ulmifolius Schott.	Oualik, Tabgha	Leaf	Raw	HA	100	49	0.082	
Rubiaceae								0.104
Rubia peregrina L.	Fûwa, Tarubya	Root	Infusion	HA	100	123	0.205	
Galium aparine L.	Lsak	Leaf	Infusion	AG	100	01	0.002	
Solanaceae								0.001
Solanum sodomaeum Dunal.	Tfah Lfar	Fruit	Cataplasm	BP	100	07	0.001	

HA: Heart arrhythmia, **AG:** Angina, **BP:** Blood pressure.

Medicinal use and informant consensus factor (ICF)

Cardiovascular diseases in the study area are grouped into three ailment categories, and informant consensus factor (ICF) analyses were computed. In the present study, the ICF values ranged from 0.44 to 0.98 per use category. A total of 33 species were identified to treat cardiovascular diseases. The informant consensus factors have been calculated for each type (Table 3). The highest ICF (0.98) value was obtained for heart arrhythmia-related illnesses, and the least (ICF = 0.44) was associated with blood pressure. The ICF results of the study proved that diseases that were frequent in the Moroccan Rif area have a higher informant consensus factor (0.98). These high ICF values indicated informants' reasonable reliability on medicinal plant species use **[68]**. The informant consensus values also indicated that the people share the knowledge of the most important medicinal plant species to treat the most frequently encountered diseases in the study area. Therefore, species with high ICF will be prioritized for further pharmacological toxicological and phytochemical studies.

Table 3: ICF values by categories for treating cardiovascular diseases

Categories	List of plant species used and number of citations	Total number of		ICF
		Species	Use citations	
Heart arrhythmia (HA)	*Daucus carota* L. (102), *Allium porrum* L. (72), *Cynara scolymus* L. (9), *Opuntia ficus-barbarica* A.Berger. *(36), Spinacia oleracea* L. (56), *Lens culinaris* Medik. (48), *Laurus nobilis* L. (81), *Persea gratissima* C.F.Gaertn. (35), *Allium sativum* L. (118), Zea mays L. (8), *Phragmites communis* Trin. (74), *Rubus ulmifolius* Schott. (49), *Rubia peregrina* L. (123), *Phoenix dactylifera* L. (10)	14	821	0.98
Angina (AG)	*Phoenix dactylifera* L. (36), *Carduus getulus* Pomel. (1), *Cannabis sativa* L. (11), *Medicago polymorpha* L. (14), *Erodium cicutarium* (L.) L'Hér. (3), *Gladiolus italicus* Mill. *(1), Hordeum murinum* L. (1), *Avena barbata* Pott ex Link. (1), *Rumex sanguineus* L. (26), *Ranunculus bullatus* L. (2), *Galium aparine* L. (1), *Laurus nobilis* L. (7)	12	104	0.88
Blood pressure (BP)	*Hedera hebernica* (G.Kirchn.) Carrière. (1), *Opuntia ficus indica* (L.) Mill. (1), *Dryopteris filix-mas* (L.) Schott (1), *Vicia sativa* L. (1), *Hibiscus sabdariffa* L. (1), *Glyceria fluitans* (L.) R.Br. (1), *Miscanthus sinensis* Andersson. (1), *Pennisetum setaceum* (Forssk.) Chiov. (1), *Solanum sodomaeum* Dunal. (7), *Laurus nobilis* L. (3)	10	18	0.44

Conclusions

The study conducted an ethnobotanical survey in the area and found a significant amount of biodiversity, including medicinal and aromatic plants. Further exploration is needed to understand the extent of this diversity fully. This abundance of flora suggests that traditional knowledge could be utilized to create affordable medicines from natural sources. The local people in the Moroccan Rif region still rely heavily on these plants, but there is a lack of evidence supporting their use in treating cardiovascular diseases. Based on these findings, it is recommended that future pharmaceutical and phytochemical studies and conservation efforts focus on the medicinal plant species with higher use value, preference ranking scores, and fidelity level values. It is also essential to preserve the traditional medicinal plants and the associated indigenous knowledge in the Moroccan Rif area to ensure their sustainability in the future.

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