Trop J Nat Prod Res, September 2023; 7(9)4016-4025: **ISSN 2616-0684 (Print)**
ISSN 2616-0692 (Electronic)

Tropical Journal of Natural Product Research

Available online at https://www.tjnpr.org

Original Research Article

Plant-based Bioproducts for the Control of Diabetes and Hypertension in Tangier-Tetouan Region (Morocco)

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ARTICLE INFO

Article history:
Received 29 July 2023
Revised 27 August 2023
Accepted 25 September 2023
Published online 01 October 2023

ABSTRACT

Diabetes and high blood pressure are severe chronic metabolic diseases with significant global public health implications. To explore the medicinal plants used by the Moroccan population for treating diabetes and hypertension, a prospective study was conducted through ethnobotanical surveys at various locations, including hospitals and health centers in the cities of Tanger-Tétouan using a semi-structured questionnaire. The study findings indicated that out of the 45 plants mentioned (belonging to 19 different families dominated by the Lamiaceae) by the participants in the ethnobotanical survey, 32 were reported to have anti-diabetic properties. Among these, the most commonly used by diabetic subjects were *Olea europaea* L. (RFC = 16,71%), followed by *Trigonella foenum-graecum* L., *Origanum compactum* Bentham and *Artemisia herba alba* Assac. Additionally, 24 plants were identified as having hypotensive effects. The most popular among them were *Olea europaea* var. sativa, *Trigonella foenum-graecum* L., *Allium sativum* L. and *Origanum compactum* Bentham. Interestingly, eleven plants were found to be used for both diabetes and hypertension treatment, including *Olea europaea* var. sativa, *Trigonella foenum-graecum* L., *Origanum compactum* Bentham, *Rosmarinus officinalis* L., *Nigella sativa* L., *Ajuga iva* (L.) Schreb, *Pistacia lentiscus* L., *Juniperus phoenicea* L., *Eugenia caryophyllata* L., *Arbutus unedo* L., and *Centaurium erythraea* Rafn. Aerial parts of the plants were most commonly used, and the preparation methods mostly involved infusion and decoction. This study holds significant importance for conserving traditional knowledge related to antidiabetic and antihypertensive plants, while also raising the prospect of further scientific research in this field.

***Keywords*:** Medicinal plants, Anti-diabetic, anti-hypertensive, Ethnobotany, bioproducts.

Introduction

Diabetes and high blood pressure are part of highly chronic metabolic diseases, posing a major public health problem globally.[1] Their almost symmetrical or equitable distribution makes them prevalent in both developed and developing countries. According to the WHO, 2020, chronic diseases accounted for 60% of deaths, with 80% of deaths from non-communicable diseases (NCDs) occurring in low- or middle-income countries.[2] In terms of morbidity, Morocco is undergoing an epidemiological transition characterized by a shift in the overall burden of disease from communicable diseases and perinatal problems to chronic diseases, with the most common ones being cardiovascular diseases, diabetes, cancer, chronic respiratory conditions, psychological and psychiatric disorders, as well as emerging and re-emerging diseases, including international public health emergencies according to the Moroccan Ministry of Health (2019).

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Citation: Mabchour I, Houzi G, Beniaich G, Elbattioui F, Kaouia S, El abdali Y, Fadli M, Plant-based Bioproducts for the Control of Diabetes and Hypertension in Tangier-Tetouan Region (Morocco). Trop J Nat Prod Res 2023; 7(9):4016-4025 http://www.doi.org/10.26538/tjnpr/v7i9.25

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Over the past two decades, diabetes and hypertension have become fairly common diseases among the adult population, especially in urban areas. This is why they are included on the list of monitored diseases. The management of hypertensive and diabetic patients requires continuous monitoring and lifelong treatment, which can be costly and involve the combination of multiple therapies.[2] These prohibitive costs, particularly for populations in poor countries who have limited access to modern medicines, lead affected individuals to turn to traditional remedies.

Accordingly, the WHO aims to support Member States in harnessing the potential contribution of traditional medicine (TM)/complementary medicine (CM) to health, well-being, and person-centered healthcare, as well as promoting the safe and effective use of TM/CM through regulation of products, practices, and practitioners. In this regard, an ethnobotanical survey was conducted in the two cities of Tanger-Tétouan (Morocco) to identify medicinal plants with antidiabetic and antihypertensive activities used by patients.

Materials and Methods

Study area

The two cities, Tanger-Tétouan, are part of the Tanger-Tétouan-Al Hoceima region (35° 46′ 00″ N, 5° 48′ 00″ W) located at the junction of two seas in the far northwest of the Kingdom of Morocco, covering an area of 17,262 km². The region is located in the extreme north-west of Morocco, bordered to the north by the Strait of Gibraltar and the

Mediterranean Sea, to the west by the Atlantic Ocean, to the southwest by the Rabat-Salé-Kénitra region, to the southeast by the Fès-Meknès region, and to the east by the Oriental region.

Methodology

This is a prospective study conducted between March 2021 and December 2022 through ethnobotanical surveys in different locations (hospitals, health centers) in the two cities of Tanger-Tétouan.

Data collection

Prior to the interviews, an initial meeting was held with the patients to provide a brief explanation of the study's objective and the importance of the information they would provide in order to obtain their consent to participate. A total of 335 patients suffering from type 2 diabetes and hypertension were directly interviewed using semi-structured questionnaires for data collection. Each questionnaire consisted of four parts. The first part collected sociodemographic information (age, gender, weight) and clinical information (type of disease, duration, treatment, and complications). The second part included informative questions related to the importance of using antidiabetic and antihypertensive plants by the surveyed population: patients who use plants, reasons for phytotherapy, efficacy of plants according to the interviewed patients, and their knowledge of plant toxicity. The third part focused on gathering information about plants with antidiabetic and antihypertensive activity: identification, indicated pathology, origin, preparation methods (decoction, maceration, infusion, etc.), and plant parts used (stems, roots, leaves, seeds, aerial parts, etc.). The fourth part examined the evolution of the biochemical parameter (glycated hemoglobin) in diabetic patients using plants. The approximate duration of each interview was 45 min.

Data processing

Initially, a list of vernacular names of medicinal plants used by the population was created. Taxonomic identification of the plants and the definitive determination of their botanical names, as well as their names in French and English, were carried out by referring to documents such as the practical flora of Morocco.[3] The plant family names were alphabetically arranged based on the APG III system (Angiosperm Phylogeny Group III).[4] Confirmation and/or determination of their identification was done at the Department of Biology, Faculty of Sciences, Kenitra. To authenticate the reported antidiabetic plants, our documented data was compared with previously published ethnobotanical and pharmacological studies on diabetes worldwide.

Statistical analysis

Subsequently, the data recorded on raw sheets were analyzed using the SPSS Statistics 20 and Excel 2010 software to extract all information related to the toxicity of the medicinal plants used. The local importance of each plant species was calculated based on its relative citation frequency (RFC).[5] This parameter was calculated as follows: the number of informants who mentioned the use of the species (Fc) divided by the total number of informants (N): RFC = Fc / N × 100.

Results and Discussion

Socio-demographic characteristics of patients

The distribution of patients by gender showed a slight predominance of women (234 diabetics and hypertensives, or 69.85% of the total study population) compared with men (101 diabetics and hypertensives, or 30.15%), giving a female/male ratio of 2.3% (Table 1). Risk factors such as obesity and a sedentary lifestyle, which are generally more prevalent in women, may explain this difference between the sexes. However, gender as such is not considered a risk factor for either type of disease.

The average age of the study population was 49, ranging from 20 to 78 years. The frequency of patients in the study population increases with age, with the age group most affected by diabetes and hypertension between 61 and 75 (111 patients, or 34% of those questioned) (Table 1). This number drops significantly after the age of 75 (only 8.95% of patients surveyed).

Table 1: Socio-demographic characteristics of survey respondents

	Tangier-Tetouan region		
	Arterial hypertension	**Type 2 diabetes**	**Total**
Distribution of respondents by gender			
Men	10.45%	19.69%	30.14%
Women	26.87%	42.98%	69.85%
Distribution of respondents by Age			
20 to 30 years	2%	2.68%	4.77%
31 to 45 years	8.67%	13.13%	21.80%
46 to 60 years	12.55%	17.93%	30.48%
61 to 75 years	13.71%	20.29%	34.00%
Above 76 years	3.58%	5.37%	8.95%
Distribution of respondents by level of education			
None	53%		
Primary	21%		
Secondary	17%		
Higher education	9%		
Distribution of respondents by body weight			
<40	9.54%	0%	9.54%
40-60	13.73%	14.03%	27.76%
61-80	14.34%	27%	41.80%
>80	2.98%	17.92%	20.90%

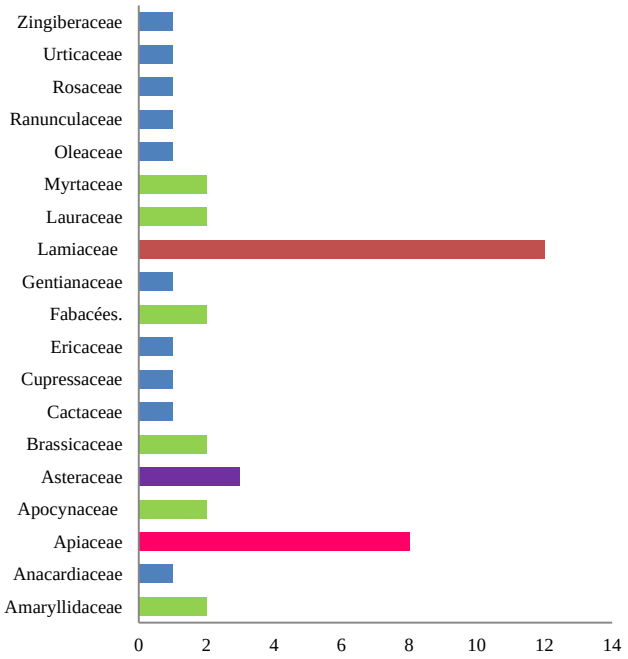

Figure 1: Relative frequency of anti-diabetic and anti-hypertensive botanical families identified during the survey.

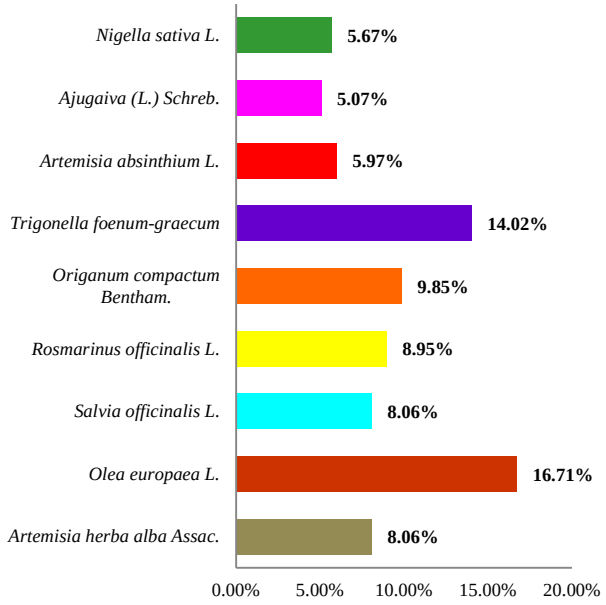

Figure 2: Ranking of anti-diabetic plants most frequently mentioned by patients surveyed (RFC<20%).

In Table 1, the frequency of diabetes mellitus and hypertension as a function of body weight shows that excess weight is often associated with type 2 diabetes and hypertension, since one of the symptoms characterizing the latter is weight gain.

In terms of educational level, 53% of the study population had no schooling, while the remaining 47% of patients were divided between primary (21%) and secondary (17%) schooling. Only 9% of the patients had a higher level of education (Table 1).

According to the results obtained when the questionnaire was distributed to 335 patients, 99 of them were type 2 diabetics and 136 hypertensives (i.e. 40.60% of the population questioned), 234 were female (i.e. 70%), and almost 62.09% lived in urban areas. This coincides with a national survey carried out by the Ministry of Health on Common Risk Factors for Non-Communicable Diseases 2017 - 2018, which showed that the manifestation of diabetes and hypertension differs significantly between urban and rural areas. Whereas in 2000 data from the latest risk factor study concluded that 33.6% of Moroccans aged 20 and over have high blood pressure and 6.6% have diabetes.

Over 46% of the cases questioned had diabetes and hypertension for more than 10 years. Similarly, we found that most of the patients surveyed suffer from more than one chronic complication, for example, hypertension is among the macroangiopathic complications of diabetes, so hypertension constitutes a secondary disease.[6]

According to the survey carried out, the high percentage of medicinal plant use wins the female population over the male population (67.40% versus 32.60%). The same finding has been observed in other ethnobotanical studies conducted nationwide.[7,8,9,10] This difference between the two sexes can be explained by women's attachment to all that is traditional, their vigilance in balancing illness - indeed, it's women who provide substances and care for their families in the event of illness. And by the illiteracy rate among women in our society, which means that most women are homemakers. The high frequency in the female population is due to the obesity detected in Moroccan women, because for diabetics first of all, overweight caused by dieting reduces the efficiency of insulin use by the body, which implies an increase in insulin production by the pancreas. Obesity is also a major risk factor for high blood pressure. Adipose tissue releases numerous substances that act on the pathophysiological mechanisms of blood pressure.

Our survey also showed that the average age of this population was 53, with the age group most affected by diabetes and hypertension being between 46 and 75 years old. The same results were obtained from the 2018 National Population and Family Health Survey, which reported that the frequency of hypertension and diabetes increases progressively with age, rising from 0.1% for hypertension in the 10-19 age group to 34% in the 60 and over age group, as does the frequency of diabetes.

The age groups 50-59 and 60 and over record prevalences of 13.4% and 20% respectively. 41.80% of them are at risk of obesity (weight between 61 and 80kg), and 20.9% of those questioned are overweight (>80kg). This result can be explained by the fact that one of the symptoms characterizing diabetes and hypertension is weight gain.

Anti-diabetic and anti-hypertensive plants reported in Tangier-Tetouan

The results of the survey are presented in Table 2. Plant families are listed in alphabetical order. The ethnobotanical characteristics for each plant are provided as follows: botanical family, scientific name, vernacular name, RFC for each plant, and the most commonly used plant parts. Therapeutic uses, preparation and administration methods are also listed.

According to our study, hypertensives use medicinal plants less than type 2 diabetics, with percentages of 27.4% and 72.60% respectively. This is explained by the fact that hypertension causes cardiovascular attacks in patients and cannot be cured, but it can be controlled, which means that current treatments can bring the figures down to a normal level. The aim of the various treatments is to normalize blood pressure at rest and during exercise. Treatment should be initiated as early as possible, as soon as the first symptoms appear.

Most patients (79.26%) using medication for their disease (hypertension and type 2 diabetes) may sometimes combine it with certain herbal preparations. Only 20.74% of subjects mentioned using herbs alone. These results do not allow us to assess the impact of herbal medicines on diabetes mellitus and hypertension. This can be seen as one of the major limitations of this study, the results of which enabled us to understand traditional anti-diabetic and anti-hypertensive practice much more in terms of patients' knowledge and attitudes towards the plants used, than to study their actual effects on diabetes and hypertension.

Among plant users, a large percentage (59.26%) report no change at all. This is explained by the fact that patients do not follow the

instructions for use and recommended doses when preparing plant remedies.

Botanical family/species/RFC of plants surveyed

A total of 45 plant species that serve as remedies for antidiabetic and antihypertensive purposes were identified. These species belong to 19 different families. The most represented were: Lamiaceae (12 species), Apiaceae (8 species), Asteraceae (3 species), Amaryllidaceae, Apocynaceae, Brassicaceae, Lauraceae and Myrtaceae (2 species), while the remaining eight families have only one species (Figure 1). This high number could be explained by the representation of these families in the flora of the Rif, due to the ecology that favors the development and adaptation of most of their species.

The predominance of these families has already been observed in other studies,[10,11,12,13,14] while a study in another region of Morocco showed the predominance of other families such as Asteraceae, Apiaceae (5 species each) and Fabaceae with the exception of Lamiaceae (8 species), which is also represented in this study for the treatment of diabetes mellitus.[9]

Of the forty-five (45) plants cited by participants in this ethnobotanical survey, thirty-two (32) were declared to be anti-diabetic, and the most commonly used by diabetic subjects were: *Olea europaea* L., with the highest RFC (16.71%), followed by *Trigonella foenum-graecum*, *Origanum compactum* Bentham, *Artemisia herba alba* Assac, *Salvia officinalis* L., *Rosmarinus officinalis* L., *Artemisia absinthium* L., *Ajugaiva* (L.) Schreb and *Nigella sativa* L., with RFC values between 14% and 5% (Figure 2).

Twenty-four anti-hypertensive plants most frequently requested by patients participating in the survey, where their FRC<20%: *Olea europaea* L. (16.71%), *Trigonella foenum-graecum* (14.02%), *Allium sativum* L. (10%), *Origanum compactum* Bentham. (9.85%), *Rosmarinus officinalis* L. (8.95%), *Origanum majorana* L. (8.35%), *Carum carvi* L. (6.86%), *Lepidium sativum* L. (5.97%), *Nigella sativa* L. (5.67%), *Ajugaiva* (L.) Schreb. (5.07%), *Ammodaucus leucotrichus* Coss and Dur (4.17%) (Figure 3).

However, 11 plants were found to treat both diabetes and hypertension: *Olea europaea* L. (16.71%), *Trigonella foenum-graecum* (14.02%), *Origanum compactum* Bentham (9.85%), *Rosmarinus officinalis* L. (8.95%), *Nigella sativa* L. (5.67%), *Ajugaiva* (L.) Schreb. (5.07%), *Pistacia lentiscus* L. (3.88%), *Juniperus phoenicea*, *Eugenia caryophyllata* (2.68%), *Arbutus unedo* L (2.38%) and *Centaurium Erythraea* Rafn (0.89%) (Figure 4).

Our results confirm those obtained in the study carried out in northern Morocco in the Izarène region,[10] which found that *Trigonella foenum-graecum*, *Artemisia herba-alba*, *Olea europaea*, *Rosmarinus officinalis* and *Marrubium vulgare* are the plants most frequently used by the population to combat diabetes. However, the most popular anti-hypertensive plants are: *Allium sativum*, *Olea europaea*, *Rosmarinus officinalis*, *Nigella sativa*, *Petroselinum sativum*, *Ajuga iva*, *Tetraclinis articulate* and *Thymus vulgaris*. On the other hand, thirteen plants are used to treat both diabetes and hypertension: *Ajuga iva*, *Centaurium Erythraea*, *Origanum compactum*, *Rosmarinus officinalis*, *Nigella sativa*, *Pistacia lentiscus*, *Tetraclinis articulate*, *Arbutus unedo*, *Trigonella foenum-graecum*, *Lavandula dentata*, *Salvia officinalis*, *Eugenia caryophyllata*, and *Olea europaea*.

A comparison of medicinal plants used to treat diabetes and hypertension in the Tangier-Tetouan region, with those reported from other regions of Morocco, has shown that 70% of species are cited at least once.[7,11,13,15,16] This similarity can be interpreted by the fact that, on the one hand, the populations of the same country share the same traditional customs and, on the other, the climate, flora and geographical position are points in common between certain regions such as the Rif,[7] and the study carried out in the three cities of Tangier, Tétouan and Chefchaouen.[17]

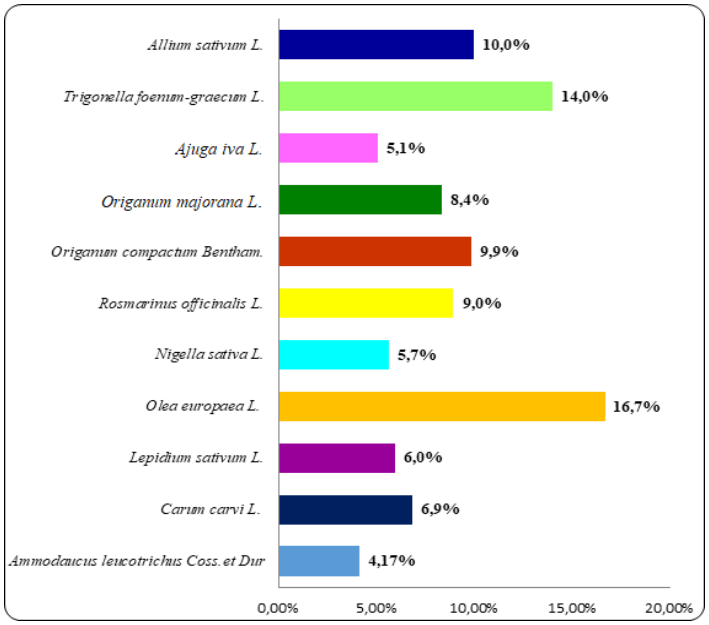

Figure 3: Ranking of anti-hypertensive plants most frequently mentioned by patients surveyed (RFC<20%).

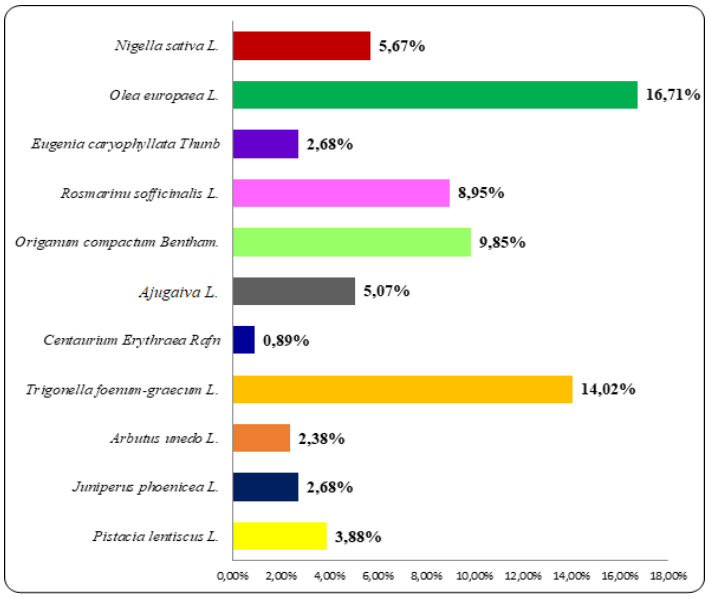

Figure 4: Relative frequency of anti-diabetic and anti-hypertensive herbs identified by patients participating in the survey (RFC <20%).

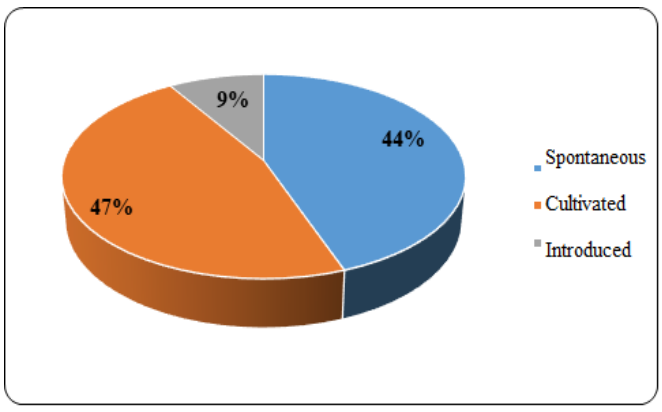

Figure 5: Distribution of plants used by origin.

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

Table 2: General ethnobotanical characteristics of anti-diabetic and anti-hypertensive plants used in Tangier-Tetouan.

N°	Family	Scientific name	Arabic vernacular name	TD[c]		Origin	PU[d]	PM[e]	MA[f]	RFC
				D[a]	H[b]					
1	Amaryllidaceae	*Allium sativum* L.	Thouma		X	Cultivated	Bulb	Cru	Oral	10%
2		*Allium cepa* L.	Al'Bassla	X		Cultivated	Bulb	Cru	Oral	4.17%
3	Anacardiaceae	*Pistacia lentiscus* L.	Adru	X	X	Spontaneous	Leaves	Decoction, Perfusion	Oral	3.88%
4		*Ammi visnaga* (Lam)	Bachnikha	X		Spontaneous	Fruits	Decoction	Oral	3.58%
5		*Ammodaucus leucotrichus* Coss.et Dur	Kamoun sooufi		X	Cultivated	Seeds	powder, Decoction, Perfusion	Oral	4.17%
6		*Carum carvi* L.	El-qarwiya		X	Cultivated	Seeds	Decoction	Oral	6.86%
7	Apiaceae	*Coriandrum sativum* L.	Qasbur	X		Cultivated	Seeds, aerial part	Decoction, Cru	Oral	4.76%
8		*Cuminum cyminum* L.	Kamoun		X	Cultivated	Seeds	powder, Decoction	Oral	2.98%
9		*Foeniculum vulgare* Gaertn	Nafaâ		X	Cultivated	Seeds	powder, Decoction	Oral	3.28%
10		*Petroselinum sativum* Hoffm.	Maâdanous	X		Cultivated	Seeds, aerial part	Decoction, Cru	Oral	3.58%
11	Apocynaceae	*Caralluma europea* L.	Deghmous	X		Spontaneous	Aerial part	Perfusion	Oral	2.08%
12		*Nerium oleander* L.	Defla	X		Spontaneous	Leaves	Decoction, Perfusion	Oral	2.38%
13		*Artemisia absinthium* L.	Chiba	X		Cultivated	Aerial part	Decoction, Perfusion	Oral	5.97%
14	Asteraceae	*Artemisia herba alba* Assac.	Chih	X		Spontaneous	Stem, Leaves, Roots	powder, Decoction, Perfusion	Oral	8.059%
15		*Cynara cardunculus* L.	Khourchouf	X		Cultivated	Roots	Decoction	Oral	2.38%
16	Brassicaceae	*Raphanus sativus* L.	Lfjel	X		Cultivated	Roots	Cru	Oral	1.49%

17		*Lepidium sativum* L.	Hab Rchad		X	Cultivated	Seeds	Decoction	Oral	5.97%
18	Cactaceae	*Opuntia ficus-indica* (L.) Mill.	hindiya	X		Spontaneous	Fleur, Fruits	Decoction, cru	Oral	0.89%
19	Cupressaceae	*Juniperus phoenicea*.L.	Araar	X	X	Spontaneous	Leaves	powder, maceration	Oral	2.68%
20	Ericaceae	*Arbutus unedo* L	Sasnou	X	X	Spontaneous	Leaves, Roots	Decoction	Oral	2.38%
21	Fabaceae	*Trigonella foenum-graecum*	Helba	X	X	Spontaneous	Seeds	Decoction, powder, and maceration	Oral	14.02%
22		*Lupinus albus* L.	Termis	X		Introduced	Seeds	Decoction maceration powder	Oral	4.17%
23	Gentianaceae	*Centaurium Erythraea* Rafn	GossatAl'Hayya	X	X	Cultivated	Aerial part	Decoction, Perfusion	Oral	0.89%
24		*Ajugaiva* (L.) Schreb.	Chendgora	X	X	Spontaneous	Aerial part	Decoction	Oral	5.07%
25		*Calamintha officinalis* Moench	Manta	X		Spontaneous	Aerial part	Decoction, Perfusion	Oral	3.58%
26		*Marrubium vulgare* L.	Merriwta	X		Spontaneous	Aerial part	Decoction	Oral	2.26%
27		*Mentha pulegium* L.	Fliyou		X	Spontaneous	Aerial part	Decoction, Perfusion	Oral	2.38%
28	Lamiaceae	*Ocimum basilicum* L.	Lahbak		X	Spontaneous	Aerial part	Decoction, Perfusion	Oral	0.89%
29		*Origanum compactum* Bentham.	Zaâtar	X	X	Spontaneous	Leaves	Perfusion	Oral	9.85%
30		*Origanum majorana* L.	Merdedoûch		X	Cultivated	Leaves	Perfusion	Oral	8.35%
31		*Lavandu lastoechas* L.	Al'Halhal		X	Spontaneous	Leaves	Decoction, Perfusion	Oral	0.59%
32		*Rosmarinus officinalis* L.	Azir	X	X	Spontaneous	Leaves	Decoction	Oral	8.95%
33		*Salvia officinalis* L.	salmiya	X		Cultivated	Leaves	Perfusion	Oral	8.059%
34		*Salvia verbenaca* L.	Al'khiyata		X	Spontaneous	Aerial part	Decoction, Perfusion	Oral	0.59%

35		*Thymus ssp (vulgaris)*	Zaîtra		X	Spontaneous	Aerial part	Decoction	Oral	4.77%
36		*Cinnamomum cassia* Lour.	El Korfa	X		Introduced	Bark	Decoction	Oral	0.89%
37	Lauraceae	*Laurus nobilis* L.	Ourak moussa	X		Cultivated	Leaves	Decoction, Perfusion	Oral	0.89%
38		*Eucalyptus globulus* Labill.	Al' Kalitouss	X		Cultivated	Leaves, Fruits	Decoction	Oral	3.58%
39	Myrtaceae	*Eugenia caryophyllata* L.	Qronfel	X	X	Introduced	Leaves	Decoction, powder, and maceration	Oral	2.68%
40	Oleaceae	*Olea europaea* L.	Zitoun,	X	X	Cultivated	Leaves, Fruits	Decoction, Perfusion	Oral	16.71%
41	Ranunculaceae	*Nigella sativa* L.	Assanouj	X	X	Cultivated	Seeds	Decoction, powder	Oral	5.67%
42		*Mallus communis*	Teffah		X	Cultivated	Fruits	Cru	Oral	2.98%
43	Rosaceae	*Prunus dulcis* Mill.	Louzhar	X		Cultivated	Seeds	Decoction, Perfusion	Oral	1.79%
44	Urticaceae	*Urtica dioîca* L.	Hourrika	X		Spontaneous	Aerial part	Perfusion	Oral	1.79%
45	Zingiberaceae	*Zingiber officinal* Rosc.	Sekinjbir	X		Introduced	Rhizome	Decoction, powder, maceration	Oral	4.47%

a: Diabetes; b: Hypertension; c: Treated disease; d: Part used; e: Preparation mode; f: Mode of administration

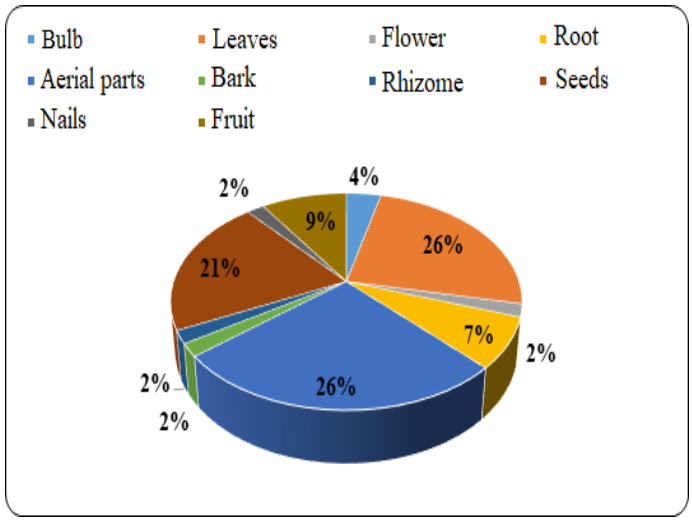

Figure 6: Proportion of different parts used from the plants surveyed.

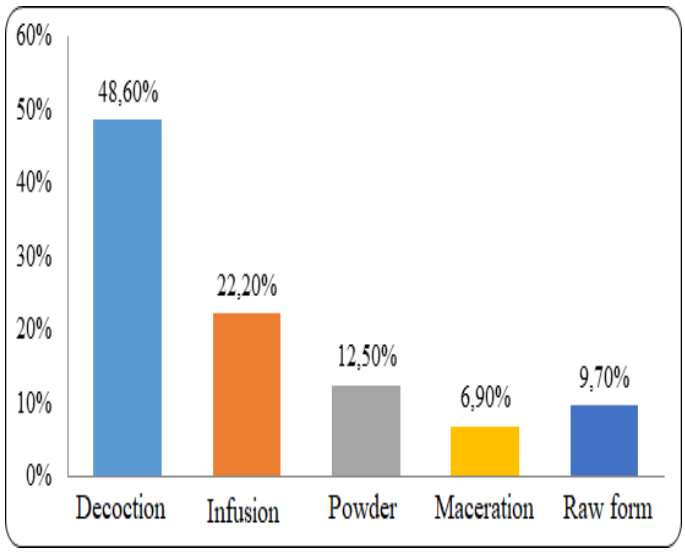

Figure 7: Proportion of different preparation modes for medicinal plants used.

Due to the differences in geography and biodiversity in many countries, the species listed are proven to be different, but this does not prevent each country's heritage from representing a non-negligible source of medicinal plants. As in the case of Allium, which is a different species in other African countries: *Alium cepa* (Cameroon, Togo),[18,19] *Hibiscus sabdariffa* (Cameroon, Mali, Côte d'Ivoire),[18,20,21] *Olea europea* L. and *Crataegus monogyna* (Mali),[20] and *Mentha spicata* (Bangui).[22] The same observation was made in other surveys carried out in Pakistan,[23] Togo,[24] and Kenya[25], which identified species different from those found in the region of the two cities of Tangier-Tetouan.

Morocco enjoys a highly diverse climate, with plants growing in abundance in coastal, mountain and Saharan regions. These plants are potential natural remedies that can be used for both curative and preventive treatment. Medicinal plants still find their therapeutic indications in the treatment of several chronic diseases in Morocco, including diabetes and high blood pressure, but this traditional treatment remains limited by patients and herbalists alike.

Several reasons have been put forward to explain the increased use of traditional medicine. Among them, the inability of modern medicine to treat certain problems: The high cost of modern medicine and their side effects.[7]

According to the testimonies of survey participants, traditional medicine is a therapeutic complement because it is less costly and reduces the share of drug treatments, as well as the positive experience reported by other patients in the same situation. Other reasons were linked to the psychic state of the subjects.[26] Based on our field observations, we found that patients who were dissatisfied with their doctors were more likely to turn to traditional medicine as an alternative, due to the relatively short consultation time and doctors' differing views on recommended treatments.

In this study, the use of medicinal plants for the control or treatment of diabetes mellitus and hypertension was 40.30% in the two cities of Tangier-Tetouan. In contrast, an ethnobotanical study carried out in south-eastern Morocco (Tafilalet) found that 80% of the population studied used plants.[13]

This low percentage reflects the population's easy access to expensive drugs from pharmacies in Ceuta (a Spanish-occupied territory). Another important point is that the method of use and the recommended doses are not respected by patients, hence the mistrust and refusal of doctors to use them for fear of the patient's health. As a result, even diabetics who treat themselves with anti-diabetic plants do so without seeking medical advice.[27]

Origin, parts used, method of preparation and administration of plants

With regard to the origin of the plants surveyed, 46.7% of the cultivated medicinal plants recorded in this survey are the most widely used for medicinal purposes. Whereas 44.40% grow spontaneously in the wild, reflecting the social importance of local floristic resources. However, only 8.90% are species introduced from outside Morocco (*Eugenia caryophyllata, Zingiber officinal* Rosc., *Cinnamomum cassia* Lour., *Lupinus albus* L.) (Figure 5).

The aerial parts of the plant are the most widely used, with a percentage of 26.4%, followed by leaves (24.50%), seeds (20.80%), fruits (9.4%) and roots (7.5%). However, flowers, bark, nails and rhizomes were rarely used (1.90%) (Figure 6).

Decoction is the main method of preparing medicinal plants, with a percentage of 48.60%, followed by infusion with 22.2% of cases, or in raw form with a percentage of 9.7%, and only 6.9% for preparation by maceration (Figure 7).

The high frequency of use of the aerial parts can be explained by the ease and speed of harvesting, as well as the ease of preparation (infusion, decoction). Recent ethnopharmacological studies reporting leaves as the most widely used part of the plant.[7,10] Indeed, leaves and aerial parts are responsible for photosynthesis and are easy to collect.[28] They also provide the majority of active ingredients such as alkaloids, flavonoids and essential oils.[29,30] Nevertheless, excessive harvesting of these species can lead to their disappearance. Therefore, it is necessary to exploit them in a reasonable way to preserve the native flora.

Conclusion

The study revealed that herbal therapy is still widely used by the Moroccan population to treat diabetes and hypertension, which are frequent and serious chronic diseases that threaten public health worldwide, due to their serious morbid consequences and progressive nature.

The results of this ethnobotanical survey identified 45 medicinal plant species belonging to 19 families, with thirty-two (32) plants declared to be anti-diabetic, twenty-four (24) hypotensive and eleven plants used to treat both diabetes and hypertension. These medicinal plants can provide a broad response to the complex problem of diabetes and hypertension, and offer therapeutic prospects for better management, as well as the discovery of new drugs for the pharmacological treatment of diabetes and hypertension. However, the use of these remedies must be based on the results of well-conducted scientific studies, specifying the plant's mechanism of action, and the therapeutic and toxic dose, since medicinal plants are undoubtedly a potential source of hypoglycemic and hypotensive substances, as well as toxic side-effects, hence the need for constant vigilance.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

Acknowledgments

The authors would like to thank Dr. Nguyen Quoc Binh from the Vietnam National Museum of Nature, Vietnam Academy of Science and Technology to conduct sample identification. This research was funded by Tay Nguyen Unversity under Grant [number T2023-CBTĐ].

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