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Ethnobotanical knowledge of plant species of the North-East of Morocco, with three provinces as a case study: Al Hoceima, Nador, and Jerada

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Abstract. This study focuses on taxa found in the Northeastern part of Morocco and cited in Ibn Al Baytar's book "Al Jam' li-Mufradat al-Adwiya wa'l-Aghdiya" (The Book of Simple Drugs), revealing that 15.78% of the simples in his manuscript are recognized by the local population. A total of 241 taxa were identified during the surveys, with 221 of these referenced in Ibn Al Baytar's manuscript and an additional 20 taxa discovered during the investigation.

The main objective of this study is to determine the recognition of these taxa in three provinces of Northeastern Morocco, and document their traditional uses (medicinal or non-medicinal), their modes of preparation and administration, the plant parts used. The incorporation of Ibn Al Baytar's work serves to provide a historical backdrop, enriching the understanding of this legacy and the evolution of ethnobotanical knowledge in the region. All the data have been collected through conducting an open-ended, semi-structured interviews with randomly selected individuals. The informant consensus factor (FIC) was calculated to identify the level of agreement among informants regarding the use of medicinal plants for specific disease groups.

During these ethnobotanical surveys, 1,177 persons were interviewed. The recorded taxa belong to 66 families with 1,264 uses mentioned in the three provinces. The results obtained confront us with the idea that there is a decline of traditional knowledge. They reveal that 32.12% of the local population considers itself ignorant of the uses of plants to cure illness, and that 66.78% prefer modern medicine despite possessing some knowledge of traditional medicinal plants. However, 790 medicinal uses recorded were classified according to the WHO's international Classification of diseases (ICPC-2, International Classification of Primary Care), and 474 other uses were recorded, along with the transcription of new vernacular names for 107 taxa. Additionally, this study includes a Jaccard Index of similarity with other Moroccan studies, revealing the geographical factor on traditional knowledge. This confirms the importance of ethnobotanical studies as it plays an important role in preserving the reservoir of indigenous knowledge from being lost over time.

Keywords: Morocco, Ethnobotanical surveys, Medicinal plants, ICPC-2, Indigenous knowledge.

Introduction

Ethnobotany aims to understand the relationship between plants, people, and the environment (Gomez-Beloz, 2002; Heinrich, 2014; Balick & Cox, 2020) and has often led to new discoveries in the field of medicine (Tu, 2011; Leonti *et al*., 2015; Atanasov *et al*., 2021; Nguanchoo *et al.*, 2023). Indeed, some modern medicinal research findings are based on people's ethnic knowledge (Balick & Cox, 2020), as ethnobotanical studies can provide valuable information on bioprospecting for medicines and foods (Hoban *et al.*, 2020; Pei *et al.*, 2020; Ulian *et al.*, 2020; Atanasov *et al*., 2021; Yao *et al*., 2021). However, traditional healing nowadays is undervalued due to the development of modern medicine (Fung & Linn, 2015), making traditional knowledge fragile or subject to alteration and modern interpretation (De Beer & Van Wyk, 2011). Moreover, the lack of interest of the younger generations threats the transmission of this body of knowledge (Faruque *et al.*, 2018).

The Moroccan pharmacopoeia dates back to the year 711 AD, when the Muslim influence in Europe was at the height of its expansion (Tahraoui *et al*., 2007) and continues to play an important role in the country's culture and primary healthcare today (Merzouki *et al*., 2000). Herbal preparations have historically been integral to traditional medicine practices in Morocco, used to treat different diseases (Alves-Silva *et al*., 2017; Bouyahya *et al*., 2017; Mohamed *et al*., 2022). This popular medicinal knowledge is a legacy of the Arab-Berber civilization, influenced on one side by the Islamic religion and on the other by the Jewish mores (El-Hilaly *et al*., 2003).

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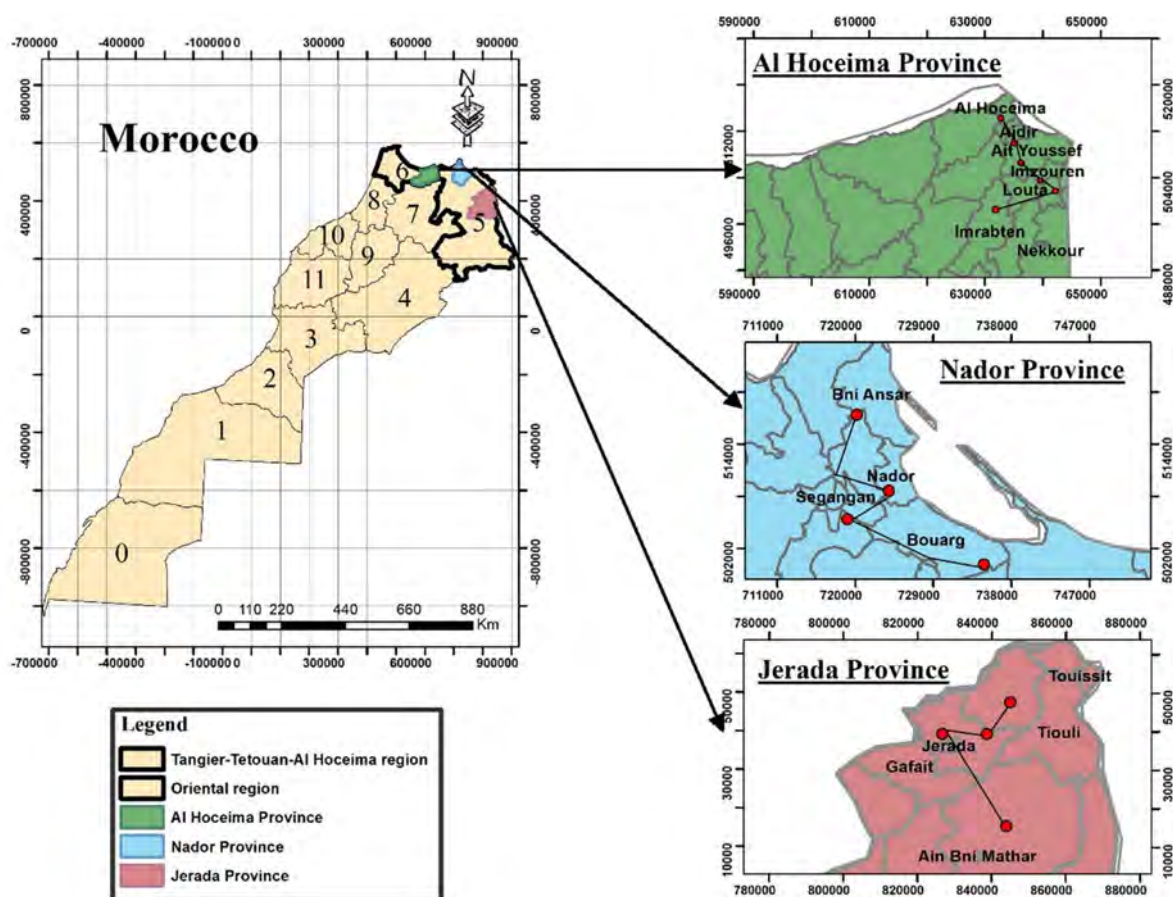
Figure 1. Location map of the Al Hoceima, Jerada, and Nador provinces.

Contrary to the estimation of the World Health Organization (WHO) that 80% of the world's population relies on traditional medicine for their primary health care needs (WHO, 2002, 2015, 2018; Muthu *et al*., 2006; Andrade-Cetto, 2009; Mbuni *et al*., 2020), findings from our recent surveys in three provinces of North-East Morocco reveal an interesting trend (Smaili *et al*., 2023). Only a small percentage of the population in these provinces trust in traditional knowledge, there appears to be a preference for modern healthcare.

The traditional local practices that have existed for centuries around the world are transmitted from generation to generation (Abouri *et al*., 2012; Beltrán-Rodríguez *et al*., 2014; Eoin, 2016) or held individually or tribally (Cordell & Colvard, 2005), but the decline of ethnobotanical knowledge among young people (Awan *et al*., 2021) does not facilitate the task of the conservation of this knowledge. Hence, it is important to save the ethnobotanical and ethnomedical practices of the populations (Reid *et al*., 1993; Cragg *et al*., 1997; Cordell & Colvard, 2005) before they are forgotten forever (Ramirez, 2007; Carrió & Vallès, 2012). Indeed, the recording of local names and traditional use of plants has significant potential biocultural benefit (Polat & Satıl, 2012).

In continuation of our previous research (Smaili *et al*., 2023), which aimed to conduct a comparative study of ethnobotanical knowledge in the provinces of Al Hoceima, Nador, and Jerada in Northeastern Morocco, we aim to further deepen the analysis of traditional knowledge of plants in this present study. The objectives of our work are: first, to analyze plant uses among the local population in this region, and second, to determine the geographical influences on their mention, specifically through a comparative analysis using the Jaccard Index of Similarity with studies in other Moroccan regions. The choice of these provinces was influenced by the lack of extensive ethnobotanical research in these areas, focusing particularly on the unique plant knowledge possessed by specific tribal groups in each province.

In line with these objectives, this study endeavors to answer the following research question: What are the traditional tendencies of plant uses among the local population in this region? Our primary hypothesis is traditional plant knowledge is still influential in the Northeastern region of Morocco. Additionally, a forthcoming paper set to provide a comprehensive analysis of past and present uses, delving into historical sources to enrich our understanding of the traditional uses of medicinal plants in Northeastern Morocco.

Materials and methods

Study area

A field trip was conducted across three provinces located in the Northeastern part of Morocco (Figure 1). The first province, Al Hoceima, covers the central part of the Rif Mountain range (Mchiouer *et al*.,

2022) and is bordered to the west by the province of Chefchaouen, to the east by Driouch, to the south by Taza and Taounate and by 120 km of Mediterranean coastline to the north (HCP, 2017a). This province covers 29% of the natural forests in the Tangier-Tetouan-Al Hoceima region (HCP, 2020) and it is characterized by two main geographic entities: the mountainous region and the Mediterranean coastline, which are known for their numerous small islands and rocky islets, as well as their Mediterranean beaches offering a remarkable range of habitats and ecosystems (Chaachouay *et al*., 2020).

The second province, Nador, is bordered to the east by the province of Berkane, to the south by the provinces of Taourirt and Guercif, to the west by the province of Driouch, to the north by the Mediterranean Sea, and has a coastline of 153 kilometers (HCP, 2017b). Nador province is renowned for its rich biodiversity and varied landscapes that encompass coastal habitats (HCP, 2017b), mountain, plain, and the plateau (HCP, 2017b). It has a coastline of 153 km and covers an area of 3,221 km², or 3.6% of the total area of the Oriental region (90,130 km²) and is approximately 88 km long from north to south and 85 km wide from east to west (HCP, 2017b).

The third province, Jerada, is bounded to the north by the prefecture of Oujda-Angad, to the south by the province of Figuig, to the east by the Moroccan-Algerian border, and to the west by the province of Taourirt (HCP, 2016). It is known for its coal mines, which have been the main source of income for the local population, including its Arabized population.

According to the Köppen-Geiger classification (Kottek *et al*., 2006; Rubel & Kottek, 2010; Hadria *et al*., 2019), the climate in the provinces of Al Hoceima and Nador is: temperate hot-summer dry-summer-hot (code Csa), while in the province of Jerada, the climate is: arid-steppe-cold arid (code Bsk).

As stated in our previous work, these provinces present unique characteristics despite their geographical proximity. Jerada province, predominantly Arabized, is renowned for its coal mines, while Nador and Al Hoceima provinces, situated by the coast, are known for their Amazigh heritage. Our study was focused on the Berber tribes "Aït Waryaghel" in the province of Al Hoceima, the Berber tribes "Guelaya" in the province of Nador, and Arabs in the province of Jerada. In each province ethnobotanical interviews were conducted in several sites in each province; six locations were visited in the province of Al Hoceima and Four in each of the Jerada and Nador provinces (Table 1).

Table 1. Geographic coordinates of study field stations in the provinces of Al Hoceima, Nador, and Jerada.

Province	Station	Latitude	Longitude
Al Hoceima	Al Hoceima city	35°14'42.41"N	3°55'48.668"W
	Ajdir	35°12'13.752"N	3°54'47.617"W
	Boukidane	35°10'26.036"N	3°50'31.52"W
	Imzouren	35°8'36.2"N	3°50'52.072"W
	Tamassint	35°4'10.79"N	3°57'3.614"W
	Souani	35°11'56.9"N	3°52'2.654"W
Nador	Nador city	35°10'2.082"N	2°56'1.456"W
	Bouarg	35°6'33.095"N	2°52'33.98"W
	Segangan	35°9'30.157"N	2°59'58.621"W
	Beni Ensar	35°15'55.951"N	2°56'3.353"W
Jerada	Jerada	34°18'34.643"N	2°10'50.901"W
	Aïn Beni Mathar	34°0'54.05"N	2°1'47.225"W
	Chekhar	34°20'27.175"N	2°4'29.622"W
	Inhabitants living in the vicinity of Jerada "The Road to Jerada"	34°19'56.489"N	2°5'45.999"W

Ethnobotanical field research procedures

The study was initiated by identifying taxa found in Morocco and mentioned in book "Al Jam' li-Mufradat al-Adwiya wa'l-Aghdiya" (The Book of Simple Drugs) by Ibn Al Baytar, an important manuscript listing approximately 1400 simple drugs. The research utilized both versions the complete French edition translated by Leclerc (1877–1883) and the Arabic edition (Ibn Al Baytar, 1992).

After a deep analysis of the ancient manuscript, a total of 363 taxa were identified as existent in Morocco. The purpose of utilizing Ibn Al Baytar's work was to establish a historical baseline that could help in recognizing which of these taxa are still known and used by the local population today.

The field study was conducted between 2017 and 2019 in Al Hoceima, Nador, and Jerada provinces, to document the ethnobotanical knowledge of the local population (Smaili *et al*., 2023). The descriptions and properties of the taxa were also analyzed in various historical sources for the betterment of our understanding of the traditional uses of medicinal plants and to shed light on the historical and cultural importance of Morocco's extensive botanical heritage.

The methodology for this ethnobotanical study was based on the research group's previous work (Merzouki *et al*., 1997, 2000; El-Gharbaoui *et al*., 2017; Yebouk *et al*., 2020; Redouan *et al*., 2020), and it adheres to established standards for ethnopharmacological field research (Weckerle *et al*., 2018). The informants have expressed their agreement to participate, have answered our questions, and assisted in collecting plant samples, which they recognized, at the sites of our investigations.

The taxonomic identification of the species was conducted at the laboratory of the Faculty of Sciences, Abdelmalek Essaadi University of Tetouan, following the recent local botanical checklist (Fennane & Rejdali, 2016). All scientific names were updated to the currently accepted names using the Plants of the World Online (POWO, 2023). Furthermore, plant species were classified into their respective families following the APG IV (The Angiosperm Phylogeny Group, 2016) and PPG I (Schneider *et al*., 2016) classifications. This research adheres to the standards recommended for publishing fieldwork on ethnobotany in Mediterranean Botany (Benítez *et al*., 2023).

A methodology was used to determine the sample size, in order to have meaningful study results (Del Águila & González-Ramírez, 2014). Field data collection focused on specific tribes: Aït Waryaghel in Al Hoceima, Guelaya in Nador, and the Arabs in Jerada, employing a stratified sampling technique (Daget & Godron, 1982; Etikan & Bala, 2017). This method was chosen to ensure a diverse representation of traditional knowledge across different cultural contexts. The selection of participants excluded individuals from outside the area based on their ethnicity.

This strategy remains efficient to gather maximum amount of data (Paniagua-Zambrana *et al*., 2018).

Upon establishing an informant's tribal affiliation, we conducted face-to-face interviews. These interviews combined open and semi-structured formats, allowing for both guided and spontaneous responses. The interview protocol included questions about personal demographic (age, gender, education), local plant names, their traditional uses, the plant parts utilized, and methods of preparation and administration (Appendix S1).

Although the primary data collection method was through interviews, a structured questionnaire was also utilized to gather specific data points and comprised both closed-ended questions to assess informants' knowledge and open-ended questions to explore their preferences for traditional versus modern medicine.

Interviews were primarily conducted in local language. For some older participants in Amazigh tribes, translations were usually provided by younger family members. It is noteworthy that while older informants understood Darija, they preferred to speak in their native tongue, requiring translation assistance.

A total of 1,177 persons were interviewed across three provinces (Table 2): 410 in Al Hoceima, 387 in Nador, and 380 in Jerada. The rate of men interviewed (644 men) is higher than the rate of women interviewed (533 women). The informant's ages ranged from 15 to more than 70 years old, with a dominance of the 35–50 age category (40.7%). Also, the rate of illiterate interviewees (32.8%) is lower than that of the literate interviewees in the three provinces.

Table 2. Sociodemographic characteristics of the surveyed people.

Categories	Characteristic	Statistics (1,177)	Percentages (%)
Gender	Women	533	45.29%
	Men	644	54.71%
Education	Educated	791	67.2%
	Not educated	386	32.8%
Age range	15-30 Years old	373	31.69%
	35-50 Years old	479	40.7%
	55-70 Years old	295	25.06%
	>70 Years old	30	2.55%
Plant knowledge	Positive knowledge of plants	799	67.88%
	No knowledge of plants	378	32.12%

It should be noted that not all of the interviewees provided information about plants. Some were reticent to answer the questions, but their percentage was still low compared to those who were cooperative and were willing to offer their time and answer our questions. Additionally, among those who were ignorant about the uses of plants, there were those who guided us to others who could help us (seniors, housewives, etc.). Thus 67.88% of the respondents provided us with information in the three provinces, out of the 1,177 interviewees (Smaili *et al*., 2023).

In this study, an in-depth analysis was conducted of the categories of diseases most treated and the repeated mentions of certain taxa for their therapeutic

value. It also presents the vernacular names cited by informants, written in Arabic and in Tifinagh for Berber names, and was compared with those reported in other research works. This comparison allowed us to identify vernacular names that were not transcribed or mentioned in those previous works.

Data analysis

Microsoft Excel was used to compile the recorded data, and the treated diseases mentioned by the informants were classified according to the WHO's International Classifications of diseases (ICPC-2, International

Classification of Primary Care) (as suggested by Staub *et al.*, 2015). Additionally, non-medicinal uses of taxa were classed into 11 categories of the Hierarchical Categories use Classification (de Santayana *et al.*, 2014).

It has been demonstrated that ethnobotanical indices often fall short accurately representing the true importance of plants (Leonti, 2022). However, we consider two indices of interest for this study, the first one being the informant consensus factor that quantifies the relationship between the number of use-reports in each category (nur) minus the number of taxa used (nt) and the number of use-reports in each category (nur) minus 1 (Heinrich *et al.*, 1998). It helps to identify the level of agreement among informants regarding the use of medicinal plants for specific diseases groups. In this study, a use-report (UR) is defined as each specific mention of a plant species by an informant for a particular medicinal use. Each unique citation was recorded, as this data is crucial for analyzing the informant consensus factor.

$$FIC = \frac{(nur - nt)}{(nur - 1)}$$

The second one is the Jaccard index, a commonly used measure in ethnobotanical research (González-Tejero *et al.*, 2008, El-Gharbaoui *et al.*, 2017), was calculated to assess the similarity of species mentioned by the population in the Northeast of Morocco in our study and the species mentioned by the population of different regions in Morocco in other works (El-Hilaly *et al.*, 2003; Ajjoun *et al.*, 2021; Aboukhalaf *et al.*, 2022; El Khomsi *et al.*, 2022; El Finou *et al.*, 2023). The measure of similarity ranges from 0% to 100%, where 0% indicates no similarity and 100% indicates complete similarity.

$$JI = [\frac{C}{(A + B - C)}] \times 100$$

Where "A" represents the number of species mentioned by the local population in the Northeast of Morocco in our study; "B" represents the number of species mentioned by the population in different regions of Morocco in other works; "C" represents the number of species that are mentioned in both our study and other works.

The Report Frequency (RF) was calculated as the total number of times a plant species is mentioned by all informants. This includes mentions for both medicinal and non-medicinal uses, as well as the local names of the plants.

Results and Discussion

Ethnobotanical analysis

General results about species

The investigation reveals that among 363 taxa cited in Ibn Al Baytar's manuscript and found in Morocco, the local population recognizes 221 of these taxa (15,78% of Ibn Al Baytar's simples). Additionally, 20 taxa were mentioned during the survey but were not cited in Ibn Baytar's manuscript (Figure 2).

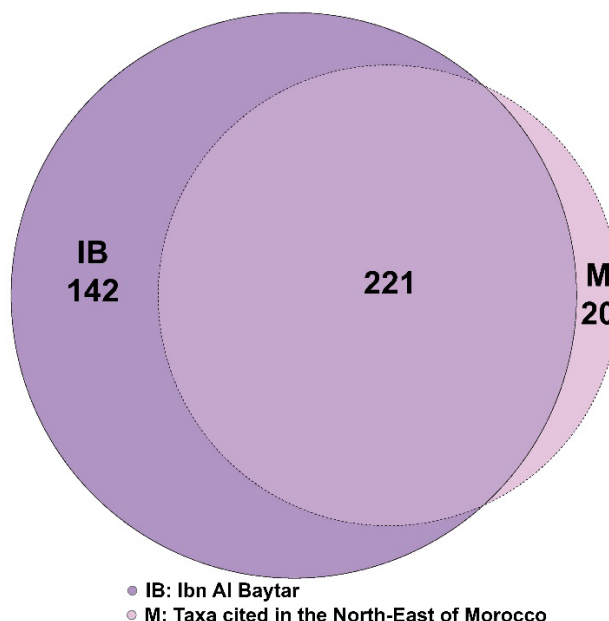● IB: Ibn Al Baytar
● M: Taxa cited in the North-East of Morocco

Figure 2. Venn diagram of the number of taxa cited in Ibn Al Baytar's manuscript (IB) and mentioned by the local population of the North-East of Morocco.

A total of 241 taxa belonging to 66 families were recorded across the three provinces. Among these taxa, a notable portion, 19.08%, are cited without any therapeutic use; the population mentions them for their vernacular name (6.63%) or because it is a plant that they use in daily life for non-medicinal purposes (12.44%). Out of the 241 taxa, 57.68% are spontaneous, 31.54% are cultivated, and 9.54% are introduced taxa.

Additional details such as vernacular names, treated diseases, mode of preparation and administration, parts used, and other uses for each taxon can be accessed in Appendix S2. This information was initially presented in a more localized manner in Annexes A-C in a previous article (Smaili *et al.*, 2023). The aim of this paper is to provide a synthesized overview, offering a comprehensive understanding of the diverse flora across the Northeastern region of Morocco.

Families and species

The most mentioned families in the three provinces are: Apiaceae, Asteraceae, Fabaceae, and Lamiaceae (Figure 3; Appendix S2). This tendency to use plants belonging to these families has been well demonstrated in previous studies concerning the Mediterranean (Bonet *et al.*, 1992; Camejo-Rodrigues *et al.*, 2003; Novais *et al.*, 2004; Guarrera *et al.*, 2005; Scherrer *et al.*, 2005; González-Tejero *et al.*, 2008); the plants belonging to these families are also easily identifiable due to their strong aromas, flavors and notable flowers (González-Tejero *et al.*, 2008)
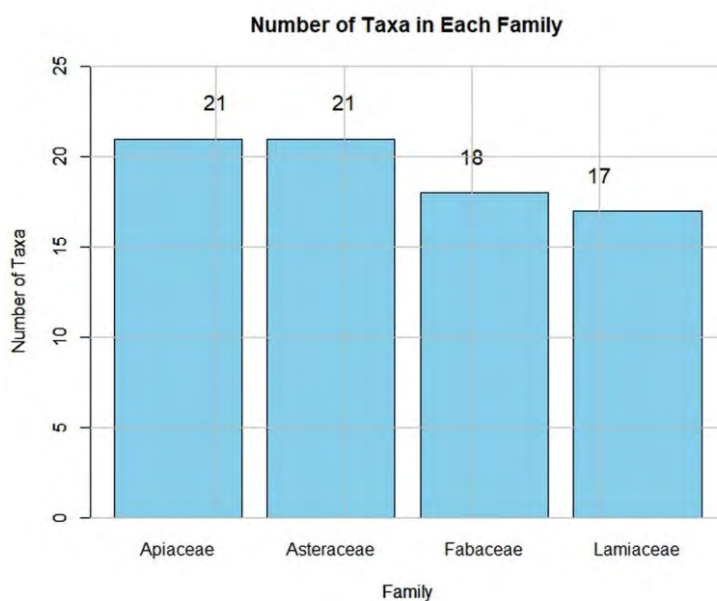
Number of Taxa in Each Family

Figure 3. Most cited families in the three provinces by informants.

The most frequently cited species by the population of the North-East of Morocco (Appendix S2) include *Lavandula stoechas* L. (RF=681), *Hordeum vulgare* L. (RF=638), *Zingiber officinale* Roscoe (RF=634). These plants are highly cited due to their diverse applications, from medicinal to culinary uses, reflecting their importance in daily life.

Zingiber officinale Roscoe, commonly used daily as a condiment to season dishes, is also cited for treating various diseases, notably the common cold (UR=398). Its regular use in preparing coffee and tea likely helps the population maintain awareness of the plant's medicinal benefits.

Lavandula stoechas L., grow spontaneously along the edges of Al Hoceima province. The local population attributes the origin of the name "Al Hoceima" to this plant, Known locally as "L-Khzama" or "L-Halhal".

Although this association between the name of the province and the plant is widely recognized by the local population, it has not been documented in other scientific works. Additionally, this plant is often placed in sachets to absorb humidity in highly humid areas.

Hordeum vulgare L., a key ingredient in daily bread-making, many informants attest to its beneficial effects digestive health, particularly against diarrhea (UR=185). Its role in the local diet is recognized not only for its nutritional contributions but also for its health benefits.

Vernacular names

Vernacular names were carefully noted as pronounced by the population during the recording of plants information, and informants were consulted to ensure accurate transcription of these names. The Arabic names were recorded using Arabic letters and the Berber names were transcribed using Tifinaghe-IRCAM (Ameur *et al*., 2004). To enhance understanding and readability, especially for those not familiar with Arabic or Amazigh languages, a simplified transcription was utilized. 99 taxa had only one vernacular name, 142 taxa had several names and for 107 taxa new vernacular names not previously published were found (Appendix S2) in comparison with previous studies (Kahouadji, 1995; Bellakhdar, 1997; El-Hilaly *et al*., 2003; Fennane & Rejdali, 2016; Teixidor-Toneu *et al*., 2016; Barkaoui *et al*., 2017; Ajjoun *et al*., 2021; Merrouni & Elachouri, 2021), including Amazigh names such as "Zoy" (ⵣⴰⵢ) which for the population refers to the male and "Zoyt" (ⵣⴰⵢⵜ) which refers to the female, and indicating *Origanum* spp. These novel findings highlight the unique linguistic richness associated with plant biodiversity in the Northeastern region of Morocco, expanding our understanding of local plant knowledge and emphasizes the importance of documenting indigenous names to preserve cultural knowledge.

Medicinal uses

Treated diseases and Informant Consensus Factor (FIC)

In our study, a total of 790 medicinal uses for various diseases were recorded across the three provinces of Al Hoceima, Nador, and Jerada (Table 3). This number includes all instances where a specific medicinal use was mentioned in multiple provinces, to reflect provincial aspect. It is important to note that a "medicinal use" is defined as each specific application of a plant to treat a distinct disease, categorized according to the International Classification of Primary Care (ICPC-2). However, when unique or non-repetitive medicinal uses were considered, where each distinct disease treated mentioned in the three provinces was counted only once, the total is 693 medicinal uses in the Northeastern region of Morocco. The results (Table 4) show that the Informant Consensus Factor (FIC) ranges between 0.97 and 0.99. This reflects a high degree of consensus among the interviewees for certain taxa for the 16 WHO diseases categories (Kufer *et al*., 2005).

Table 3. International classification of primary care categories assigned to reported diseases in the Northeastern.

International classification of primary care (2nd edition)	Diseases reported	Use-report (UR)	Number of species
General and Unspecified (A)	General health (A01)	646	10
	Fever (A03)	825	9
	Weakness (A04)	362	8
	Swelling (A08)	13	1
	Hemorrhage (A10)	82	2
	Anesthetic (A29)	28	1
	Antiseptic (A29)	47	1
	Body toxins (A29)	136	1
	Children's diseases (A29)	87	3
	Coldness (A29)	1467	3
	Contamination (A29)	146	3
	For all diseases except death (A29)	122	18
	General diseases (A29)	87	2
	Heat stroke sun (A29)	61	1
	Inflammation (A29)	115	4
	Refreshing (A29)	310	4
	Sedative (A29)	104	1
	Tumors (A29)	40	2
	Warms the body (A29)	39	1
	Measles (A71)	156	2
	Infectious disease (A78)	168	4
	Cancer (A79)	536	14
	Poison (A86)	95	3
	Allergy (A92)	92	6
Blood, Blood forming organs and immune mechanism (B)	Swollen lymph nodes (B02)	61	1
	Blood circulation (B04)	25	1
	Blood toxins (B04)	267	7
	Anemia (B78)	772	9
Digestive (D)	Abdominal pain (D01)	959	10
	Colic (D01)	84	1
	Stomachache (D01)	3058	30
	Heartburn (D02)	79	1
	Indigestion (D07)	346	6
	Gas (D08)	938	7
	Jaundice (D13)	129	2
	Bowels movement (D18)	1615	15
	Diarrhea (D11)	1324	13
	Constipation (D12)	1534	17
	Dental hygiene (D19)	163	2
	Dental pain (D19)	176	3
	Gum disease (D19)	228	4
	Strengthen the gums (D19)	86	1
	Toothache (D19)	155	3
	Whitened teeth (D19)	321	1
	Bad breath (D20)	192	3
	Swollen abdomen (D21)	39	1
	Coldness in stomach (D29)	88	1
	Gallbladder problem (D29)	131	2
	Stomach wound (D29)	53	1

International classification of primary care (2nd edition)	Diseases reported	Use-report (UR)	Number of species
	Typhoid (D70)	427	7
	Hepatitis A (D72)	62	2
	Mouth diseases (D83)	77	1
	Gastric ulcers (D87)	182	1
	Intestinal worms (D96)	323	2
	Hepatitis (D97)	193	3
	Liver diseases (D97)	225	5
	Digestive system diseases (D99)	196	1
Eye (F)	Eye pain (F01)	81	3
	Visual disturbance (F05)	98	1
	Eye allergy (F29)	53	1
	Eye disease (F29)	48	1
Ear (H)	Earache (H01)	225	4
	Ear allergy (H29)	47	1
Cardiovascular (K)	Heart pain (K01)	109	3
	Tightness of heart (K02)	29	1
	Vein problems (K29)	138	3
	Blood pressure (K85)	273	5
	Hypertension (K86)	695	10
	Hemorrhoid (K96)	379	11
Musculoskeletal (L)	Back pain (L02)	125	1
	Joint inflammation (L20)	34	1
	Joint pain (L20)	590	9
	Torsion of the joints (L20)	63	1
	Articular pain (L29)	63	1
	Strengthens the bone (L29)	58	2
	Fracture (L76)	534	2
	Sciatica (L86)	135	4
	Rheumatism (L99)	132	4
Neurological (N)	Headache (N01)	876	12
	Spasm (N08)	124	3
	Vertigo (N17)	218	3
	Nervous system diseases (N29)	114	2
	Relaxes the neurons (N29)	140	1
	Migraine (N89)	44	1
Psychological (P)	Nervousness (P01)	75	2
	Stress (P02)	368	1
	Nightmare (P06)	28	1
	Sleep disturbance (P06)	389	4
	Sexual desire reduced (P07)	10	1
	Loss of focus (P20)	125	1
	Memory disturbance (P20)	411	3
	Against fears (P29)	27	2
	Calm (P29)	229	6
	Madness (P29)	24	1
Respiratory (R)	Cough (R05)	791	10
	Nasal congestion (R07)	95	1
	Throat pain (R21)	99	2
	Common cold (R29)	3652	26
	Diseases of the respiratory system (R29)	84	1

International classification of primary care (2nd edition)	Diseases reported	Use-report (UR)	Number of species
	Pulmonary problems (R29)	84	1
	Whooping cough (R71)	72	1
	Sinusitis (R75)	72	1
	Tonsilitis acute (R76)	111	2
	Bronchitis (R78)	69	1
	Influenza (R80)	589	5
	Asthma (R96)	664	10
	Lung diseases (R99)	86	1
Skin (S)	Redness (S07)	54	1
	Facial brown spots (S08)	29	1
	Melasma (S08)	79	3
	Furuncle (S10)	112	3
	Skin infection (S11)	44	1
	Scorpion stings (S12)	29	2
	Snake stings (S12)	47	1
	Burn (S14)	1019	12
	Blisters on the feet (S17)	25	1
	Anti-infectious wounds (S18)	48	1
	Wound (S18)	870	16
	Corn at feet (S20)	51	1
	Alopecia areata (S23)	121	3
	Hair loss (S23)	402	11
	Dandruff (S24)	50	1
	Hair care (S24)	661	13
	Baby's skin irritation (S29)	52	1
	Beautifies the skin (S29)	81	1
	Brown spot (S29)	52	2
	Facial spots (S29)	27	1
	Itching (S29)	60	2
	Lighten the complexion (S29)	341	2
	Pus (S29)	22	1
	Remove all impurities from the face (S29)	37	1
	Skin complaint (S29)	74	1
	Skin inflammation (S29)	61	1
	Tones the skin (S29)	123	2
	Sunburns (S80)	421	5
	Eczema (S87)	189	4
	Acne (S96)	356	8
Endocrine/Metabolic and Nutritional (T)	Excessive thirst (T01)	54	2
	Excessive appetite (T02)	40	1
	Loss of appetite (T03)	522	6
	Weight gain (T07)	276	3
	Weight loss (T08)	740	8
	Sweating problem (T09)	68	1
	Diabetes (T90)	1087	15
	Hyperglycemia (T90)	95	3
	Gout (T92)	145	2
	Cholesterol (T93)	162	4
	Hyperthyroidism (T85)	61	1
	Hormonal disturbance (T99)	44	2

International classification of primary care (2nd edition)	Diseases reported	Use-report (UR)	Number of species
	Hormonal problem (T99)	229	4
Urological (U)	Dysuria (U01)	106	2
	Bladder weakness (U05)	108	3
	Diuretic (U08)	153	2
	Bladder complaint (U13)	523	10
	Kidney complaint (U14)	56	1
	Kidney lithiasis (U14)	660	5
	Kidney pain (U14)	67	1
	Kidney problem (U14)	395	3
	Renal toxins (U14)	36	1
	Cystitis (U71)	95	2
	Urinary calculus (U95)	182	3
	Urinary infection (U99)	115	1
Pregnancy, childbearing, Family planning (W)	Infertility (W15)	369	6
	Lactation problem (W19)	199	3
	Constipation in Pregnancy (W29)	41	1
	Complication of pregnancy (W29)	64	2
	Pregnancy (W78)	53	4
	Miscarriage (W82)	39	1
	Childbirth (W90)	374	7
Female genital (X)	Menstrual pain (X02)	232	4
	Menstruation irregular (X07)	222	5
	Menopausal complain (X11)	14	1
	Vaginal infection (X15)	51	1
	Breast cancer (X76)	30	2
	Genital swelling (X29)	26	1
	Uterus complaint (X29)	191	5
	Ovarian cyst (X80)	47	2
Male genital (Y)	Prostate complaint (Y06)	23	1
	Genital swelling (Y29)	26	1

Regarding the treated diseases, it appears that the Lamiaceae family is the most frequently used in popular medicine, treating the highest number of diseases. This observation can be explained by the fact that it is the family that in the territory includes taxa that are common, and it is known that the more common a plant is, the more likely it is to acquire local use (Benítez *et al*., 2010). The catalog includes very polyvalent taxa, used for the treatment of different pathologies, in this case the top-ranking are *Clinopodium nepeta* (L.) Kuntze and *Rosmarinus officinalis* L. (see Figure 4).

Among the diseases mentioned, the most common ones are: "common cold", "stomachache", and "bowels movement". Furthermore, the most cited category (Figure 5) in the three provinces is the digestive group (D); 98 taxa were mentioned to have treated 157 digestive diseases, with a consensus factor of 0.99. Indeed, when inquiring about any instances where diseases were successfully treated through the use of plants, informants were always quick to cite problems related to the digestive system, and this is reflected in the number of mentions of this category during the survey, 13,409 times (Table 4), with "stomachache" as the most cited diseases, with 3,058 mentions (Table 3). Coincidentally, other studies in Morocco (El-Hilaly *et al*., 2003; Merzouki *et al*., 2000; Fakchich & Elachouri, 2014; Jaadan *et al*., 2020; Redouan *et al*., 2020) and in the Mediterranean (Raja *et al*., 1997; Novais *et al*., 2004; Benítez *et al*., 2010) have cited similar results.

The prevalence of digestive system problems can be explained by the population's interest in digestive diseases, by the fact that many symptoms of various diseases are related to the digestive system, and the tendency to use plants more frequently for treating digestive aliments than other more severe diseases.

The second most frequently mentioned category is group (A), covering a wide range of general and unspecified diseases (Figure 5), with a total of 77 taxa mentioned for their effectiveness in treating 107 general diseases. This group encompasses common health issues such as fever or pain, which can explain the
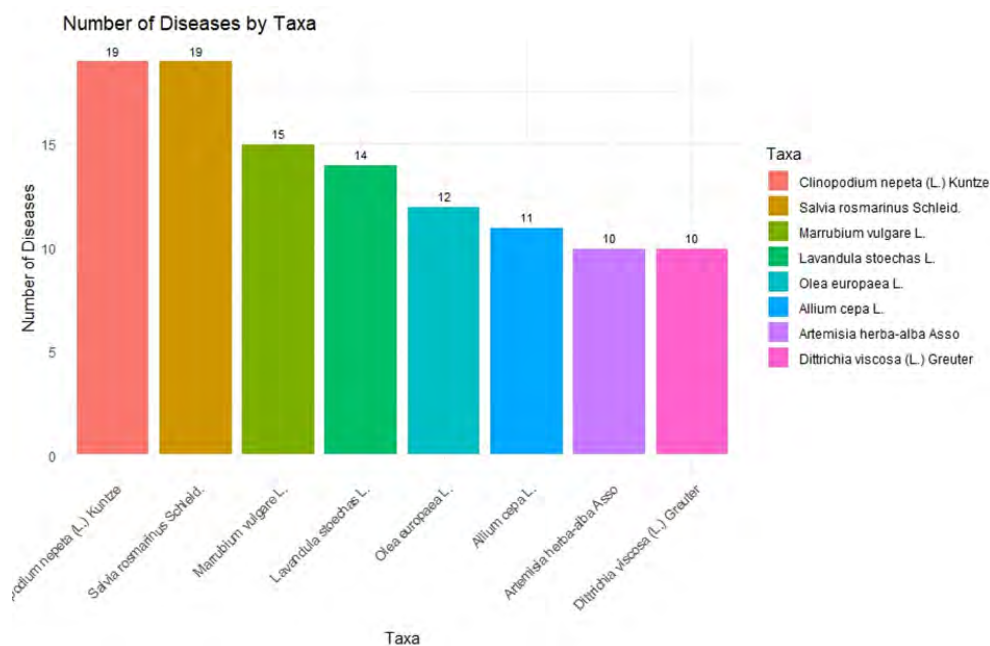
Number of Diseases by Taxa

Figure 4. More polyvalent taxa cited in the three provinces by informants.
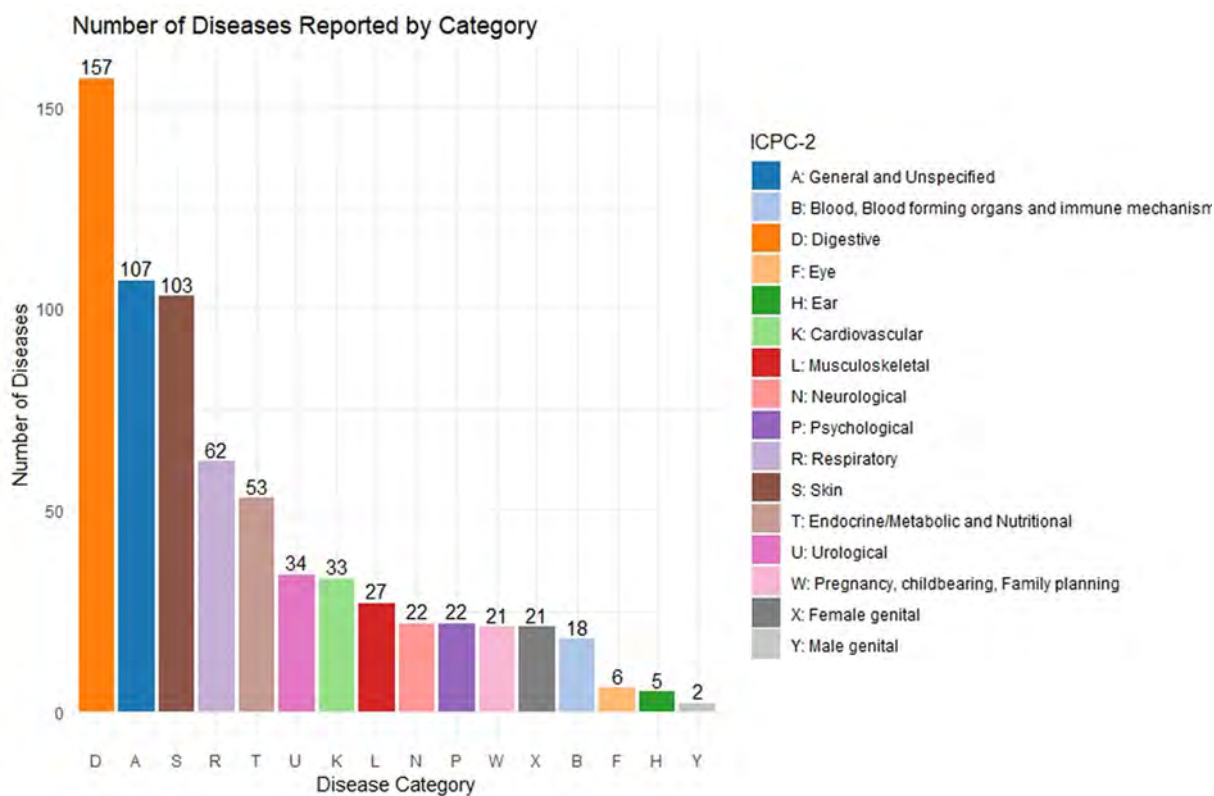
Number of Diseases Reported by Category

Figure 5. International classification of primary care categories assigned for reported diseases by informants.

high frequency of the mentions of this category, 6,481 mentions (Table 4) with "coldness" standing as the most frequently mentioned disease, with 1,467 citations (Table 3). In Moroccan health traditions, the concept of "coldness" is more than a feeling of being physically cold. It is perceived as a symptomatic manifestation of various diseases, believed to be caused by the accumulation of cold within the body. This accumulation is thought to harm the body, leading to symptoms such

as fatigue and bones pain. Moreover, it is considered to have a significant impact on women's health with conditions like infertility or menstrual pain.

The skin group (S) is the third most cited group (Figure 5), with 68 taxa mentioned for treating 103 skin diseases. The high consensus factor of 0.98 underscores the reliability and agreement among informants regarding the use of these plant-based treatments. This category mentioned 5,537 times during the survey

(Table 4), with "burns" being the most frequently cited disease, mentioned 1,019 times (Table 3). This highlights the strong reliance on traditional remedies to address dermatological issues in Northeastern region of Morocco, given that skin problems affect all age groups and genders (Grice *et al*., 2009) and can be challenging to treat (Ashraf *et al*., 2010). These findings also align with various studies that have focused on skin diseases in Morocco (Makbli *et al*., 2016; Salhi *et al*., 2019), and in Mediterranean (Vitalini *et al*., 2013; Fortini *et al*., 2016; Menale *et al*., 2016).

The respiratory group (R) is the fourth most cited group (Figure 5), aligning with the global rise in respiratory diseases affecting all age groups and leading to increased treatment costs (WHO, 2020). Consequently, traditional medicinal practices have become common in many regions of the world for treating respiratory issues (Kayani, 2014). Our study identifies 46 taxa used to treat 62 respiratory diseases, with a high consensus factor of 0.99, indicating strong

agreement among informants regarding the use of these taxa (Table 4). Respiratory health issues encompass a wide range of diseases, from simple allergies to chronic asthma and even cancer (Chaachouay *et al*., 2019). Additionally, research suggests that climate change may exert potential influence on global respiratory health (d'Amato *et al*., 2020). This explains the 6,468 mentions of this group during the survey (more than skin category, despite the respiratory category having fewer reported diseases). "common cold" is the most cited diseases, with 3,652 mentions (Table 3). These results reveal a reliance on traditional remedies based on plants to address respiratory diseases in the Northeastern region of Morocco, and are consistent with other studies where the respiratory group is one of the most cited in Morocco (Ouhaddou *et al*., 2014; Jaadan *et al*., 2020; Idm'hand *et al*., 2020; Ajjoun *et al*., 2021), and in Mediterranean (Benítez *et al*., 2010; Vitalini *et al*., 2013; Güzel *et al*., 2015; Sargin *et al*., 2015; Fortini *et al*., 2016; Menale *et al*., 2016).

Table 4. Categories of diseases, diseases reported, number of use-reports in each category (Nur), number of taxa (Nt), Informant consensus factor (FIC).

Disease categories	Diseases reported	Nur	Nt	FIC
General and Unspecified (A)	107	6481	77	0,98
Blood, Blood forming organs and immune mechanism (B)	18	1125	14	0,98
Digestive (D)	157	13409	98	0,99
Eye (F)	6	280	7	0,98
Ear (H)	5	272	5	0,98
Cardiovascular (K)	33	1623	25	0,98
Musculoskeletal (L)	27	1734	21	0,98
Neurological (N)	22	1516	17	0,98
Psychological (P)	22	1686	17	0,99
Respiratory (R)	62	6468	46	0,99
Skin (S)	103	5537	68	0,98
Endocrine/Metabolic and Nutritional (T)	53	3523	39	0,98
Urological (U)	34	2496	27	0,98
Pregnancy, childbearing, Family planning (W)	21	1139	17	0,98
Female genital (X)	21	813	16	0,98
Male genital (Y)	2	49	2	0,97

Preparation and administration

Concerning the mode of preparation (Figure 6A), 14.9% of citations related to decoction, 12.7% to grind, 11.2% to infusion, 10.7% to consumption, and 10.2% to a mixed way. The modes of administration (Figure 6B) varied as well, with 56.9% of citations related to oral administration, 21.4% to external use, 10.1% to cataplasm, 5.07% to inhalation and 6.52% to other methods of administration. These findings align with other studies conducted in Morocco (El Amri et *al*., 2014; Merzouki *et al*., 2000; El Hilaly *et al*., 2003; Ammor *et al*., 2020; El Hachlafi *et al*., 2020; Es-Safi *et al*., 2020; Jaadan *et al*., 2020; Benkhnigue *et al*., 2023), which have also reported similar preferences for preparation methods. The preference for oral administration is also

reported in other studies in Morocco (Teixidor-Toneu *et al*., 2016; Benkhnigue *et al*., 2019; El Hachlafi *et al*., 2020; Ajjoun *et al*., 2021; Aboukhalaf *et al*., 2022; Benkhnigue *et al*., 2023).
The mode of preparation and of administration depends on what part is used by the population, we can cite some particular examples mentioned through our surveys:
Prunus persica (L.) Stokes: In Al Hoceima, we were told that they put the leaves of this plant in any part of the body and, if holes start to form on the leaves, it means that the patient is suffering from intestinal worms.
Opuntia ficus-indica (L.) Mill.: In Al Hoceima, they rub the belly or the feet with a young glochid in case of stomachache.
Medicago sativa L.: In Jerada, informants said, they grind it and mix the powder with camel grease to treat
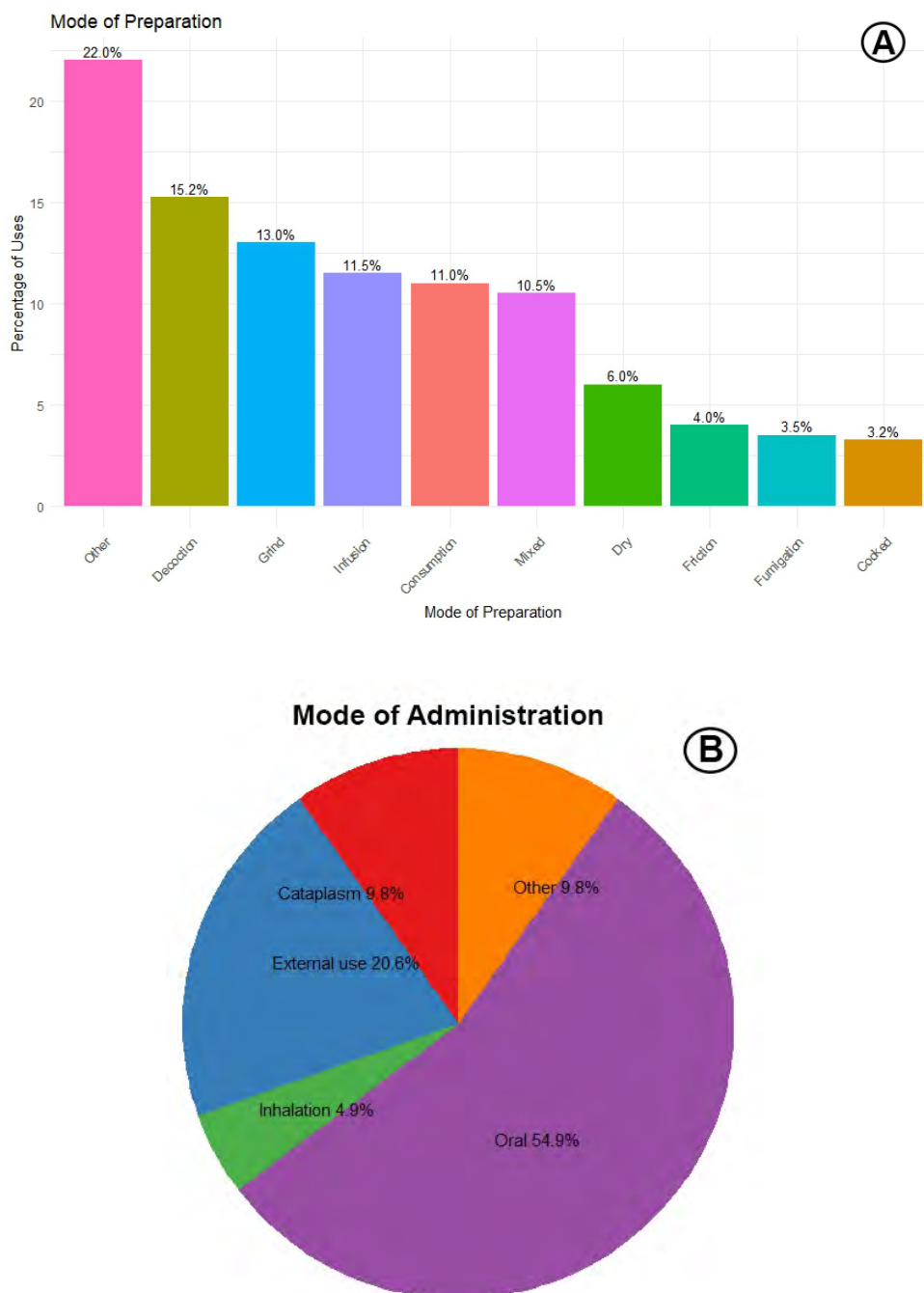
Figure 6. Mode of preparation (A), and mode of administration (B) reported by informants.

nervousness; the patient must eat this mixture and drink a glass of water, and go visit the Hammam two days later.
Dittrichia viscosa (L.) Greuter: In Nador, they fry or boil the plant and put it on the head of a teething child to relieve his or her pain.

Most important medicinal species

Various taxa were mentioned in our surveys for treating a single disease, with significant use-report numbers ranging from 71 to 462. In treating fractures, *Cenchrus americanus* (L.) Morrone (Pearl Millet - Ilân) stands out, with 462 informants reporting its efficacy. Its

seeds are commonly used to prepare a soup for a fast recovery. *Cuminum cyminum* L. (Cumin - Kemmûn) is not only widely known as a culinary condiment, but also for its effectiveness to treat stomachache, with 229 informants mentioning its efficacity. It can be consumed as a decoction or in powder form. For kidney problems, *Petroselinum crispum* (Mill.) Fuss subsp. *crispum* (Curly Parsley - Imzzi) was reported by 152 informants for its effectiveness. A decoction of its leaves and steam is employed as a remedy for this health issue. *Crataegus* spp. (Âdmâm) was mentioned by 107 informants for its effectiveness against diarrhea, with its fruits consumed orally. *Ammi visnaga* L. (Tbichnikht/Bachnikha) was cited for dental hygiene by 89 informants, with various parts used, including the umbels and fruits. It can be used

as a powder for gargling, or as a toothpick. *Carthamus tinctorius* L. (Safflower - Zo'fer), employed in the treatment of jaundice, a decoction of its flowers in milk is administered orally as mentioned by 86 informants. *Echinops spinosissimus* Turra (Chdeg Ej-Jmel/Tasekra/Chouk L-Hmir) is recognized for its role in healing diarrhea by with 79 informants. Its roots are decocted and taken orally. *Fraxinus* spp. (Tozalet/Lessan Etter) used by diabetics, its leaves and aerial part of the plant are infused and taken orally, as mentioned by 71 informants.

Other use categories

Our study compiled a total of 474 non-medicinal uses across the three provinces of Al Hoceima, Nador, and Jerada. This count encompasses all instances where a specific use was cited across these provinces. However, when unique or non-repetitive non-medicinal uses were considered, each use was counted only once, resulting in a total of 251 non-medicinal uses in the Northeastern region of Morocco (Figure 7). Non-medicinal uses of plants were listed in 11 categories following the Hierarchical Classification of Categories. The most frequently cited category across the three provinces is "Human Food", followed by "Industry and crafts", and by "Animal Feed".

Human Food. In Morocco, the use of spontaneous plants as food is common, especially in rural area (Aboukhalaf *et al*., 2020) where they play a crucial role in food insecurity (Aboukhalaf *et al*., 2022). Therefore, 45 of spontaneous plants recorded in this study are mentioned as edible by the local population. It is worth noting that the consumption of spontaneous plants is primarily a seasonal tradition, often linked to the spring season when the availability of wild food plants is at its peak (Nassif & Tanji, 2013).

Industry and crafts. The population of Al Hoceima mentioned that they put the fruit of *Pinus halepensis* Mill. (Sanuwbar, صنوبر) with "Leben" (Buttermilk), but they don't know what the exact reason is; some say that maybe it is to give strength when they prepare the Leben, while others think that maybe it is to keep Leben in good conditions.

The leaves of *Origanum elongatum* (Bonnet) Emb. & Maire (Za'tar, زعتر), helps to preserve the figs. They put them in a traditional bag that they call "Ahhmâr" أحمَّار.

Animal Feed. The province of Jerada is known for animal husbandry, so the population cited many plants that serve as fodder, such as *Medicago sativa* L. (Fassâh, فصة), the seeds of *Mercurialis* divers (L-Hriqa Lmelssa, الحريقة الملسا) are good fodder for birds, *Silybum marianum* (L.) Gaertn. (Chouk L-Hmir, شوك الحمير) is a fodder for camels while *Panicum turgidum* Forssk. (Zaymo, زايمو; Tafoust, تافوست) for horses.

Veterinary. Although nowadays the population turns more to the veterinarian, population in the province of Jerada still use *Trigonella foenum-graecum* L. (L-Helba, الحلبة) and *Urtica* divers (l-Hurrayqa, l-htrrîga, الحريقة) to stimulate milk in cows, and *Peganum harmala* L. (L-Hermel, الحرمل) against cattle scabies. They take the plant once a year and burn it, and let their cattle inhale the smoke that is released into the air. *Rosmarinus officinalis* L. (Azîr, أزير) is known to cure cattle, and *Allium cepa* L. (L-Bessla, البصلة) and *Retama* spp. (Er-Ttem, الرطم) to cure rabies in dogs.

In Al Hoceima they mentioned that *Magydaris* spp. (Fafra, فافرة) increases milk production in cows, but only plants one year old (Fafra dyal 'am, فافرة ديال عام) or seven years old (Fafra dyal 7 snine, فافرة ديال 7 سنين) both should be exposed to the sunlight.

Social, Symbolic, and Ritual Uses. The presence of *Avena sativa* L. (Tmsikhth, تمسيخت) in the home protect from the evil eye, while *Raphanus sativus* L. (Lfjel, لفجل) and *Ziziphus lotus* (L.) Lam. (Sedra, السدرة) are used against demoniac possession.
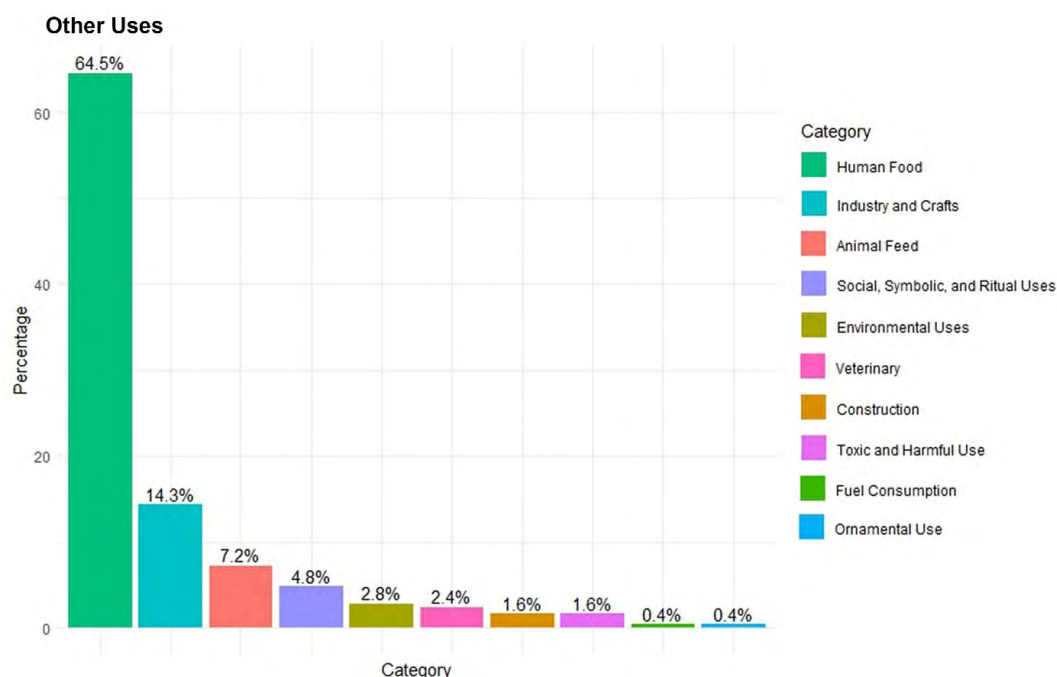

Figure 7. Other Uses reported by informants.

Plant parts used

It was observed that various plant parts were used by the local population for both medicinal and non-medicinal purposes (Figure 8), with 22.1% of citations related to leaves, 16.7% to fruits, 14.4% to seeds, and 10.4% to the whole plant. The predo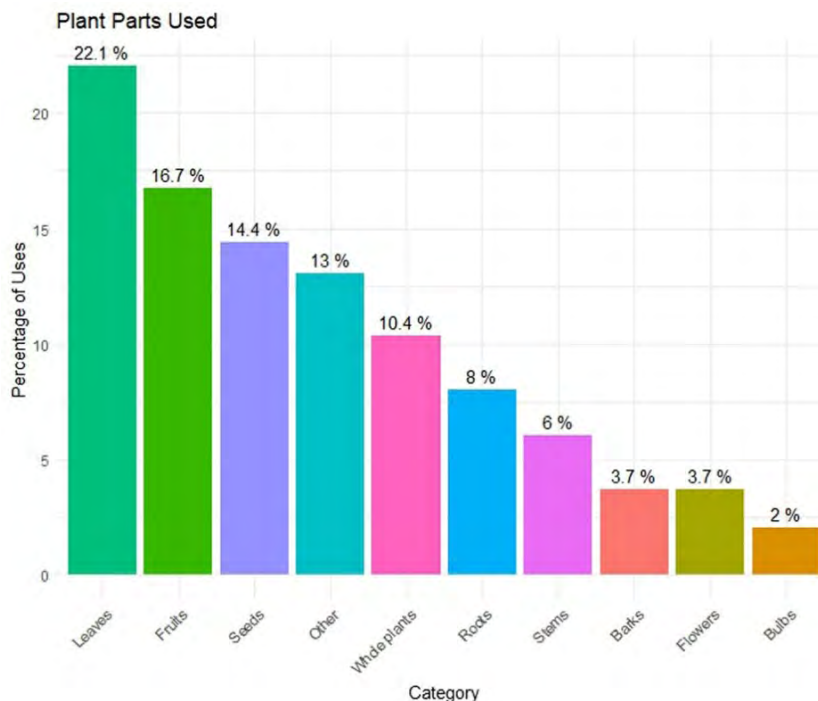minance of leaves, fruits, and seeds can be attributed to their ease of identification, collection, and also conservation, making them well-known. This aligns with findings from several other studies conducted in Morocco, where leaves have been identified as the most used part (Bouayyadi and Zidane, 2020; El Hachlafi *et al*., 2020; Jaadan *et al*., 2020; Ajjoun *et al*., 2021; Aboukhalaf *et al*., 2022; Benkhnigue *et al*., 2023).

Figure 8. Plant Parts Used reported by informants.

Comparison with other studies in Morocco

Finaly, the comparison with existing ethnobotanical studies conducted in different regions of Morocco (Figure 9; Table 5) reveals that the first study listed (study 1) by El-Hilaly *et al*. in 2003, conducted in Taounate province showed a JI of 27% indicating a moderate level of similarity. The second study (study 2) by Ajjoun *et al*. in 2021 conducted in Driouch province had a higher JI of 41% suggesting a relatively higher degree of similarity. The third study (study 3) by Aboukhalaf *et al*., in 2022 in Sidi Bennour region, had a JI of 10%, indicating a lower level of similarity. The fourth study (study 4) by El Khomsi *et al*., in 2022 conducted in Moulay Yacoub region had a JI of 28% suggesting a moderate level of similarity. Lastly, the fifth study (study 5) by El Finou *et al*., in 2023 conducted in Fez-Meknes region had a JI of 25% indicating a moderate level of similarity.

It is important to note that the geographical distance between our study area and the other studies (Table 5) varied from approximately 61.6 km to 787 km. As the distance between study areas increased, there was a higher probability of having a low similarity index due to variation in environmental conditions. Therefore, the influence of geographical distance on the observed differences in Jaccard Index of Similarity (JI) highlights the variability of plants species among different regions of Morocco.

Conclusions

This study provides a complete data on the tendencies of plants uses among the local population in the Northeastern part of Morocco. Through surveys conducted with 1,177 persons in three provinces (Al Hoceima, Nador, and Jerada), the study found that a significant portion of respondents (32.12%) consider themselves ignorant about the uses of medicinal plants. However, a notable majority (67.88%) retain local knowledge passed down through generations. Interestingly, despite this rich heritage of traditional knowledge, 66.78% of the population prefer modern medicine. This highlights the importance of ethnobotanical studies in preserving the traditional knowledge of the indigenous population.

Our research has also led to the transcription of 107 new vernacular names, not previously recorded, reflecting the linguistic diversity in this region. A total of 241 taxa, classified into 66 families, were cited, with families like Apiaceae, Asteraceae, Fabaceae, and Lamiceae being predominant, likely due to their varied applications and availability. Furthermore, 19.08% of these taxa are cited without therapeutic applications, known for their vernacular names or everyday non-medicinal uses, highlighting their cultural value.

The study recorded 1,264 uses, including 790 medicinal uses and 474 non-medicinal uses, underscoring the rich diversity of traditional practices. The high
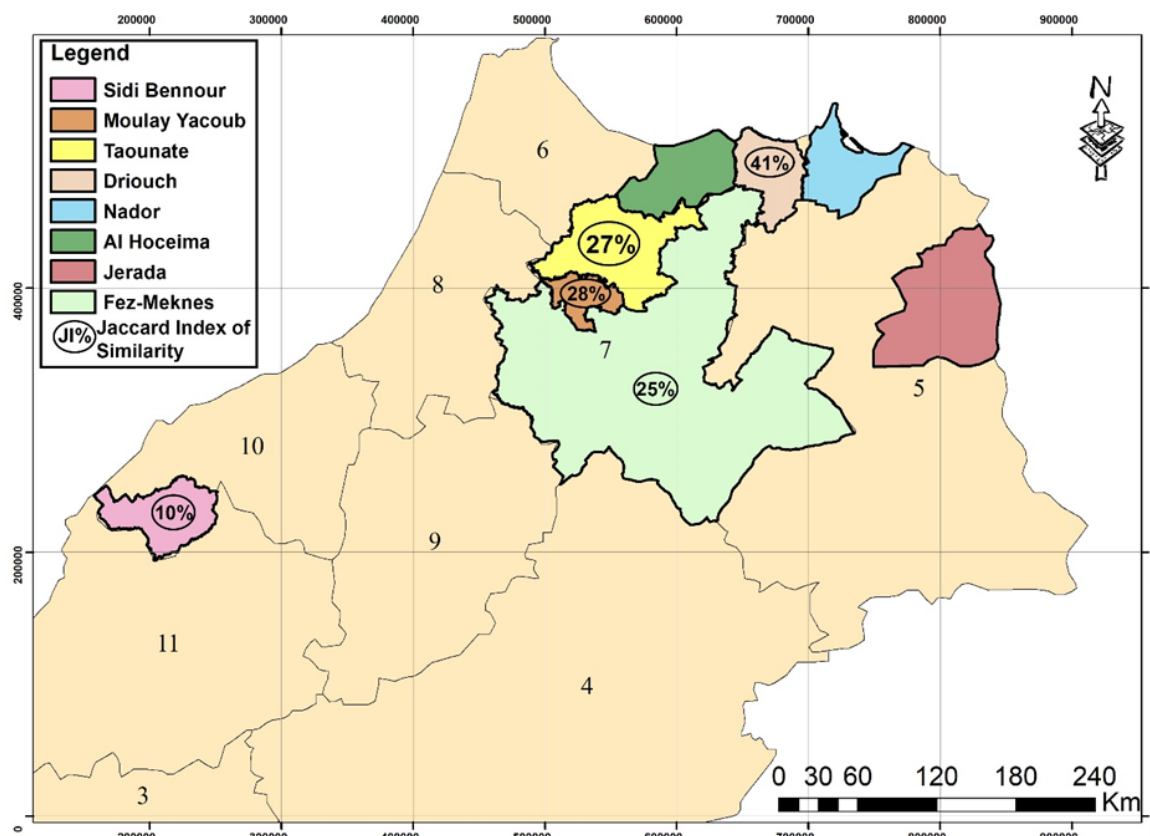
Figure 9. Location map of regions of other studies in Morocco with Jaccard Index (JI) values.

Table 5. Jaccard Index of Similarity with other studies conducted in different regions of Morocco.

N.	Studies	Study Area	Total Species	Common Species	Jaccard Index of Similarity	Geographical distance
1	El-Hilaly et al. (2003)	Taounate province (Northern Morocco)	102	73	27%	Al Hociema province: 188,5 km Nador province: 313,5 km Jerada province: 337,5 km
2	Ajjoun et al. (2021)	Driouch province (North-eastern Morocco)	158	117	41%	Al Hociema province: 88,0 km Nador province: 61,6 km Jerada province: 183,8 km
3	Aboukhalaf et al. (2022)	Sidi Bennour region (Central Morocco)	56	28	10%	Al Hociema province: 770,8 km Nador province: 763,1 km Jerada province: 787,0 km
4	El Khomsi et al. (2022)	Moulay Yacoub region (Northeast of Morocco)	104	76	28%	Al Hociema province: 272,8 km Nador province: 322,6 km Jerada province: 346,5 km
5	El Finou et al. (2023)	Fez-Meknes region	81	66	25%	Al Hociema province: 88,0 km Nador province: 61,6 km Jerada province: 183,8 km

Informant Consensus Factor (FIC) for diseases indicates a possible potential for developing new treatments based on these traditional practices. Commonly, taxa are used in the treatment of digestive, skin, respiratory, and unspecified diseases categories. These uses represent home remedies and daily practices that are still being used by some members of the population.

Our comparative analysis using the Jaccard index of Similarity with the comparison with existing ethnobotanical studies in other regions in Morocco provides a deeper understanding of the variation plants species and shows clearly the influence of the geographical factor, the probability of having a low similarity index is higher as the distance between study areas increased.

In summary, this study not only reinforces the importance of traditional plant knowledge in Northeastern region of Morocco but also highlights the dynamic nature of this knowledge, varying over regions. A forthcoming work will delve deeper into comparing the uses cited by the local population with those documented in Ibn Al Baytar's work. Such a comparative analysis aims to provide a more nuanced understanding of the complex relationship between ancient and contemporary ethnobotanical practices.

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Authorship

F-ZM: Conceptualization, Data curation, Formal analysis, Research, Software, Visualization, Writing original draft preparation, review and editing.

HS: Conceptualization, Data curation, Formal analysis, Research, Software, Visualization, Writing review and editing.

AM: Conceptualization, Methodology, Project Management, Resources, Supervision, Visualization, Writing review and editing.

Conflict of interest

None.

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Supplementary Material

Appendix S1. Survey Form used in the ethnobotanical study.

Appendix S2. Taxa recorded in three provinces of Northeastern region of Morocco.