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Traditional medicinal knowledge of Apiaceae at Talassemtane National Park (Northern Morocco)

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ABSTRACT

The Talassemtane National Park (PNTLS) represents a significant biome for flora diversity in Morocco and North Africa. Based on its floristic richness and on the rural lifestyle of its population, we hypothesize that the inhabitants of the park hold a substantial knowledge of medicinal plants. The Apiaceae is one of the 20 largest plant families, and one with the significant higher proportion of medicinal plants. The aim of this study is to deepen the knowledge on the traditional medicinal uses in Morocco within this family. A three-year survey (2014–2017) was conducted following ethnobotanical field-research methods. We identified 31 taxa (species and subspecies) belonging to 16 genera. With a total of 1430 use reports, we have identified 72 medicinal uses to treat 48 conditions or symptoms classified into 15 pathological groups according to the international classification of primary care (ICPC). Highlighted ones are D-digestive system (32% of uses), A-general (12%), S-cutaneous (11%) and U-urological (8%). The most common mode of administration is oral (78%) and the majority of remedies are prepared as a decoction (55%). Original data were found on the medicinal use of several species of genus Eryngium, Stoibrax, Elaeoselinum, Torilis and Apium, which were not previously reported in other territories in Morocco.

1. Introduction

The need for an interdisciplinary approach for enhancing our understanding of the relationship between the plant kingdom and human society has been well discussed (Schultes, 1962; Balick and Cox, 1996; Heinrich et al., 2005; 2006; De Vos, 2010; Touwaide, 2010; Leonti, 2011; Pieroni et al., 2013; Touwaide and Appetiti, 2013). Many authors have reported that in antiquity botany and pharmacology were closely related (Conklin, 1954; Clément, 1998; Posey, 2004; Leonti et al., 2015; Ritter et al., 2015; Totelin, 2016; Pieroni, 2017). As a result, the term ethnobotany was coined, becoming "*the science that studies the relationship between plant and cultural diversity*" (Hamilton, 2002). In fact, ethnobotanical studies document, amongst other things, the evolution of traditional knowledge and the interaction between local populations and surrounding flora. Thus, through the publication of ethno- and agro-pharmacological findings, ethnobotanists contribute to the preservation of traditional, botanical knowledge through successive generations. In this context, the validation of different ethnopharmacological studies is of great importance. According to the World Health Organisation (WHO/IUCN/WWF 1993), 80% of the world's population depends on traditional medicine to meet primary health care needs. However, knowledge regarding traditional medicine is currently held by a limited minority, amongst which, there are high rates of illiteracy (Rivera et al., 1995; 2014; Heinrich et al., 2006; Bellakhdar, 2006; Leonti, 2011). Therefore, it is important to safeguard and translate this traditional know-how into approved scientific knowledge.

The northern part of Morocco, where the Talassemtane National Park (PNTLS) is located, is the African territory closest to Europe. The park exists between two continents, the Atlantic Ocean and the Mediterranean Sea, with a natural and ecological importance that has been well highlighted by Aafi (1995). In the human perspective, the PNTLS represents a location where Eastern and Western civilizations met several times throughout history, and were uniquely influenced by the Mediterranean. Original Berber populations, together with the Eastern Arabic settlers that arrived throughout the 7th and 8th centuries CE, were highly influenced by the Andalusian-Islamic medicine developed and consecrated between the 9th and 13th centuries CE. In this period, agronomists, botanists and doctors developed a

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common therapeutic arsenal based on their extensive knowledge of medicinal plants (Bellakhdar, 1997, 2006; Egea et al., 2015; El-Gharbaoui et al., 2017).

Knowledge of the history of ethnobotany in Morocco is fairly new and only has begun to emerge with the work of Bellakhdar (1978) in the 1970s. Since then, several research studies regarding ethnobotany have been published that have examined different regions of Morocco (Kahouadji, 1995; Merzouki et al., 1997, 2000, A. 2003; Jouad et al., 2001; El Rhaffari, 2002; El-Hilaly et al., 2003; Tahraoui et al., 2007; Lahsissene et al., 2009, 2010; Benkhnigue et al., 2011; Hmamouchi et al., 2012; Ouarghidi et al., 2013; Fakchich and Elachouri, 2014; El Hafian et al., 2014; El Yahyaoui et al., 2015; Hafsé et al., 2015; Hachi et al., 2015; Rhafouri et al., 2015; Zerkani et al., 2015; El Alami et al., 2016; Teixidor-Toneu et al., 2016; Eddouks et al., 2017; El-Gharbaoui et al., 2017). However, there is still a lack of studies investigating the PNTLS, with the exception of the work performed by Benabid (2008), that are based on well-established scientific methodologies. Work of Benabid (2008) provided a catalogue, in the context of the LIFE programme (GEF-RIF), in which all flora of botanical and ethnobotanical interest was classified as either ornamental or medicinal.

In our opinion, unfortunately, current interest in the ethnobotany of Morocco has been comprised of a certain number of studies and publications with no particular relevance. This is especially true for those concerning the northern region of Morocco. Approaches to study ethnobotany, in the broadest sense of the term, have not been well developed. Further, data analysis has suffered from a lack of rigour due, in particular, to a lack of approved scientific methodologies for examining findings.

1.1. The Apiaceae botanical family

Apiaceae Lindley, *nom. cons*. (or Umbelliferae Jussieu, *nom. cons*. et *nom. alt*.) is comprised of about 418 genera and 3257 species (see www.theplantlist.org). The family was described for the first time by John Lindley in 1836 (Lindley, 1836), and the taxonomy of the family has continually undergone revision (Kadereit and Bittrich, 2018; Jimenez-Mejias and Vargas, 2015).

Due to the morphological features of the family (inflorescences in umbels, fruit and mericarp morphology, presence of secretory channels and compound leaves, etc.), and the general presence of essential oil (aromatic features of plants), the family is easily recognisable. Identified by Pliny the Elder (23–79 CE), the family was one of the first to be recognised as a distinct botanical group by Jacques Daleschamps (1513–1588) in his *Historia generalis plantarum* (Daleschamps, 1586). It was also the first group of plants for which a systematic study was published (Morison, 1672). The family is the major group of the order Apiales. The order is comprised of the Apiaceae together with the Araliaceae and other nodes (Stevens, 2018). Comprised of six branches, the anciently family is polyphyletic, with a main branch comprised of the Apioideae forming the main subfamily. It is currently thought to have originated in late Cretaceous, around 69 m.y.o. (Manchester and O'Leary, 2010), and is currently cosmopolitan. Apiaceae range from herbs to trees, are usually aromatic, and possess secretory canals containing essential oils and resins. The essential oil is the most important phytochemical characteristic of the group with respect to the therapeutic usefulness most species within the Apiaceae. Chemical secondary metabolites produced also include (furano-) coumarins (responsible for phototoxic effects), polyacetylens (Heinrich et al., 2012) and, in several species, alkaloids and triterpenoid saponins (Bruneton, 2009). Additionally, the endosperm is rich in petroselinic acid (Kleiman and Spencer, 1982). The Apiaceae is one of the 20-largest plant families, and is comprised of a high proportion of medicinal plants (RBG Kew 2017). Several umbellifers, flowering plants of the Apiaceae family, were known to the ancient Chinese and Mexican Indian civilisations, as well as to ancient Roman and Greeks (Heywood, 1993). Therefore use of the family in traditional medicine has a very rich history. Moreover, the family is comprised of many food and spice plants used worldwide, such as *Anethum graveolens* L. (dill), *Apium graveolens* L. (celery), *Carum carvi* L. (caraway), *Coriandrum sativum* L. (coriander), *Cuminum cyminum* L. (cumin), *Daucus carota* L. (carrot), *Foeniculum vulgare* L. (fennel), *Pastinaca sativa* L. (parsnip), *Petroselinum crispum* (Mill.) Fuss (parsley), and *Pimpinella anisum* L. (anise). However, several other species are extremely poisonous, such as the famous *Conium maculatum* L. (hemlock) and *Cicuta virosa* L. (water hemlock).

1.2. Aim of the study

As detailed previously, the PNTLS is a region rich in both biodiversity and cultural heritage. Therefore, we hypothesised that the population of the PNTLS will have traditional knowledge regarding the use of local medicinal plants. Within this framework, our objectives are both to document and critically analyse the ethnobotanical knowledge that exists in northern Morocco, focusing on the Apiaceae, one of the largest families of plants, which is also comprised of a high proportion of medicinal plant families. To achieve our aims, we constructed a bibliographic ethnopharmacological and ethnobotanical review of the region.

2. Materials and methods

2.1. Study area

The area studied (the PNTLS) is located in North Morocco. It stretches over the limestone ridge in the Central-Western Rif, an original territory characterised by its unique biodiversity and landscape.

The area is located in the Mediterranean macro-bioclimate according to a classification scheme constructed by Rivas-Martinez and Rivas-Saenz (2018). The area is characterised by a clear summer drought. As it lies within a mountainous range, the geography of the area includes lowlands with high termicity and xericity, as well as humid highlands, and contains peaks with unusual types of vegetation not normally seen in Africa, such as Moroccan fir and black pine forests. This can be explained due to its proximity to the Mediterranean, which causes frequent mists that can partly compensate for the lack of precipitation occurring in the summer, allowing for the growth of these types of vegetation.

The bioclimatic, biogeographic, ecological, and geological features of the area, which is predominantly limestone and dolomite substratum, produce a remarkably diverse set of plant species. The vascular flora checklist is comprised of more than 1380 plant species (Benabid, 2008), with 314 species (+22% of total) endemic to Morocco, of which 86 are endemic exclusively to the PNTLS. The most predominant forestall vegetation includes the previously mentioned Moroccan fir (*Abies marocana* Trab.) and black pine (*Pinus nigra* var. *mauretanica* Maire & Peyerimh.) species, which are present at high altitudes, together with several *Quercus* species (*Q. rotundifolia* Lam., *Q. faginea* Lam., *Q. suber* L.), *Tetraclinis articulata* (Vahl) Mast., and many shrubs and bushes that grow at lower altitude s. Some of the aforementioned species have multiple known traditional uses (Benabid, 2000; 2008).

The PNTLS is boardered to the north by Wadi Tissikiste, douars Amahousse, Arhiniame, and Souk El Had, to the east by Oued Kanar, douars Assimrane and Assifane, to the south by the roads connecting Assifane to Bab Taza, and to the west by douar Benizid, Ain Tissimlane, Tarhzoute, Jble Sidi Salah, and Tamalout. PNTLS was created as a botanical reserve in 1972, considered a National Park in 1995, and officially established, with an area of nearly 60,000 ha, in November of 2004 (Aafi et al., 2002; 2003).

Using Qgis 3.4.2 software, a map of the area studied was created (Fig. 1). We used the 'Carto Antique' plugin as a basis for the creation of the map (a Quick services map plugin available in Qgis software).

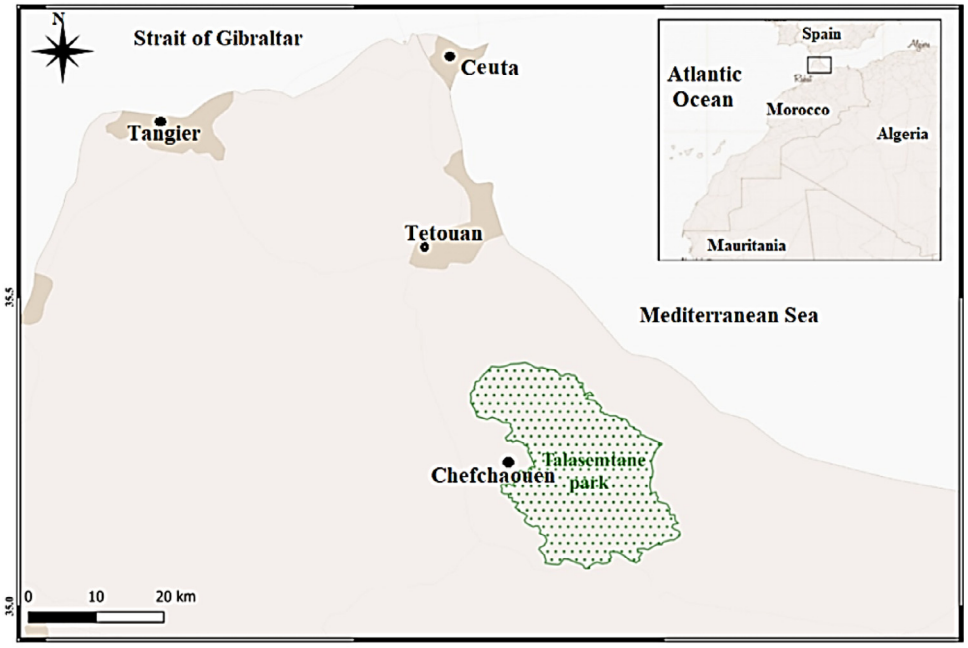

Fig. 1. Situation and delimitation of PNTLS, Strait of Gibraltar, Atlantic Ocean and Mediterranean Sea.

Regarding the socio-economic activities practiced in the park, agriculture is visibly the most representative activity. Of particular importance are the growth of fruit trees and beekeeping. The area studied can therefore be considered a traditional mountain agro-system, based on the use of native resources that include the cultivation of several crops and edible traditional varieties. However, The Rif Mountain area has been undergoing important change in recent decades with respect to the use of the landscape, economic activities and lifestyles of people living in the area. The shift toward increasing levels of *Cannabis* agricultural cultivation versus small-scale cultivation for personal consumption rituals has changed the main socio-economic activity practiced by the population living within the PNTLS. These changes have resulted in the abandonment of traditional agro-systems, which are now being replaced by *Cannabis* crops (Afsahi, 2015; Chouvy and Afsahi, 2014; Meklach et al., 2017; Chouvy and Macfarlane, 2018).

2.2. Ethnobotanical approach and surveys

The ethnobotanical approach is based on the previous work by our research group (Merzouki et al., 1997, 2000, 2001; El-Gharbaoui et al., 2017), which consider the recommended standards for ethnopharmacological field studies (Weckerle et al., 2018). First, in order to locate informants, we made several visits to areas containing main population centers within the study area and administered closed questionnaires (as described in Merzouki et al., 1997; 2000). These questionnaires contained questions regarding both the informant (including gender, age, education level, and family situation), and use of medicinal plants (vernacular name, therapeutic use, etc.). After analysis, using obtained data as a basis, we later developed both open and semi-structured interviews with informants (Cotton, 1996; Martin, 2004). Other conventional methods of determining informant location, such as the snowball method and participant observation, were also followed.

Ethnobotanical data was collected using interviews of local inhabitants of the National Park, which were based on a semi-structured survey sheet. These interviews were previously based on questionnaires containing direct questions including demographic information about the interviewee (including gender, age, education level, and family situation), the local vernacular name of plants, and the information regarding the therapeutic use of plants (including preparation methods used, mode of administration, parts used, and diseases treated). Interviews were performed individually in the field using local Arabic dialects (*darija).* The Arabic vernacular names of species were transcribed to the Latin alphabet according to the methods described by Bellakhdar (1997).

The association of an ethnobotanical use with a scientific plant name was always established after the identification of the plant material, which was provided by our informants or gathered from the field to be shown to informants during the interview. The taxonomic identification of the species was carried out in the laboratory of the Sciences School of the University of Tetouan (Abdelmalek Essaâdi University) based on the local botanical chequelist and catalogue of Benabid (2008) and the available Flora in the area studied (Maire, 1952-1987; Fennane et al., 1999, 2007, 2014). All scientific names were reviewed using the plant list database (www.theplantlist.org), as suggested by Rivera et al. (2014). Collected samples, with associated identification vouchers, were deposited in the Abdelmalek Essaâdi University Herbarium. Voucher numbers have been provided in the results section of this paper. After the database containing plants used and the above-mentioned data was compiled, we performed a bibliographical review of previous ethnobotanical works in surrounding territories to enhance our understanding of previously-reported ethnobotanical work and glean local insights. To this end, the works of Bellakhdar (1997), Merzouki et al. (2000), El-Hilaly et al., (2003) and Fakchich and Elachouri (2014) were mainly used. El-Gharbaoui et al. (2017) was also consulted for information regarding field methods.

2.3. Data analysis

Once obtained, the data were compiled using Microsoft Excel and presented in the form of graphs and tables. The database also includes emic categories for the classification of diseases (as they were recorded in the interviews) and an etic category for the classification of diseases into pathological groups, followed by the international classification of diseases (International Classification of Primary Care (ICPC)) used by the WHO (as suggested by Staub et al., 2015).

Table 1
Demographic and socio-educational features of the interviewees.

Categories		Statistics (200)	Percentages (%)
Age	<20	11	5.5
	[20–40]	99	**49.5**
	[40–60]	67	33.5
	>60	23	11.5
Gender	F	87	43.5
	M	113	**56.5**
Status	Divorced	2	1
	Married	150	**75**
	Single	42	21
	Widow	6	3
Education	**Illiterate**	94	**47**
	Koranic School	32	16
	Literacy center	4	2
	Primary School	28	14
	Secondary School	21	10.5
	High School	3	1.5
	University	18	9

3. Results and discussion

3.1. Analysis of ethnobotanical surveys

A total of 200 informants were interviewed during our fieldwork within the geographic area studied. The main demographic features of individuals interviewed have been summarized in Table 1.

Demographic analysis of our informants revealed that men are slightly more highly represented than women (56.5%). Regarding the age of participants, the most highly represented age groups were 20–40 and 40–60 years old. It is important to highlight that 47% of our interviewees were illiterate and their knowledge on medicinal plant use had, therefore, originated from the oral transmission of information.

3.2. Ethnobotanical analysis of medicinal plants

3.2.1. Plants

The ethnobotanical analysis of medicinal plants was able to identify 31 taxa (including subspecies) belonging to 30 different species and 16 genera of the Apiaceae family that had been used for medicinal purposes by populations living within the PNTLS region. The list of species identified has been provided in Table 2. We also have included local vernacular names (Arabic and Roman alphabets), and information regarding diseases and/or symptoms treated (with ICPC-2 codes), the part of the plant used, the mode of preparation of the plant, mode of administration of medicine and reported uses. Previously reported uses have been cited, as well as a short review regarding the chemical composition of plant identified, when such information was known. Pharmacological evidence for the use of some plants has also been provided for cases in which that information was available.

Our findings show that, with respect to the number of species of medicinal use, *Eryngium* is the richest genus, having eight species reported to be useful medicinally (*E. caespitiferum* Font Quer & Pau, *E. bourgatii* Gouan, *E. glaciale* Boiss., *E. huteri* Porta, *E. ilicifolium* Lam., *E. mohamedanii* Font Quer & Pau, *E. tricuspidatum* L., *E. triquetrum* Vahl). The second-most-highly represented genus was *Apium*, which had three medicinally useful species (*A. inundatum* (L.) Rchb. f., *A. nodiflorum* (L.) Lag., *A repens* (Jacq.) Lag.). In addition, *Torilis arvensis* (Huds.) Link includes two subspecies of medicinal importance.

In comparison with other studies examining other Moroccan territories (El-Hilaly et al., 2003; Fakchich and Elachouri, 2014; Hachi et al., 2015; Eddouks et al., 2017; El Haouari et al., 2018), we found that the genus *Eryngium* has been used only very rarely. Although cultivated celery (*Apium graveolens*) is frequently used for medicinal purposes in Morocco, no native *Apium* species were previously cited in ethnobotanical works investigating the identity of medicinal plants within the country. The phytochemical and ethnopharmacological review (Table 2) includes information regarding only 24 plants. For seven plants, no information was found, either in general pharmacognosy books (Heinrich et al., 2012; Bruneton, 2009) or published journals in the field. These species included: *Apium inundatum, Apium repens, Bunium bulbocastanum* L., *Eryngium caespitiferum, Eryngium huteri, Stoibrax pomeliana* (Maire) B.L. Burtt, and the hybrid *Eryngium* × *mohamedanii*. Although in some cases information provided is preliminary and incomplete, 16 of the plants included in Table 2 have uses that can be pharmacologically explained on the basis of the demonstrated activities of chemical compounds that they produce. In particular, most of the traditional uses of fennel (all but one) can be explained using knowledge regarding the activities of compounds produced by the plant. Further analysis of chemicals produced and their demonstrated activities could increase this number of medicinal plants with activities that can be explained in this way.

3.2.2. Plant parts used, modes of preparation and administration of plant-based medicine

Our analysis has shown that fruits (mericarps) are the most used part of plants (39%), followed by roots (35%), leaves (10%) and flowers (7%) (see Fig. 2). The high percentage of fruits used within the PNTLS is in accordance with other studies in nearby territories such as those by El-Hilaly et al. (2003); Fakchich and Elachouri (2014); Hachi et al. (2015) and El Haouari et al. (2018).

The predominant use of one plant organ over another in the therapeutic field could be related to the location in which secondary metabolites are likely to be concentrated. As is known, the Apiaceae commonly produce essential oils within their fruits, which have secretory channels, and leaves. Therefore, the high level of use of fruits is not surprising and may be explained by the high concentrations of essential oils present in fruits. Other secondary metabolites may also be important, however. In this family, there are high concentrations of bitter substances, such as petroselinic acid, in the endosperm (Avatoa et al., 2001; Lopes et al., 2012; Eyup, 2013). Furthermore, some secondary metabolites can also be found in the Apiaceae roots, such as furanocumarins (Wink, 2015).

As is typical for ethnobotanical research studies of plants used in traditional medicine, simple modes of preparation were preferred. In our study, decoction was the most frequent mode of preparation (55%, see Fig. 2), followed by powder (17%) and fresh (11%) categories. Other methods of preparation (infusion, fumigation, boiling, maceration, and juice) combine to account for 17% of the total (Fig. 2).

Decoction was a highly appreciated mode of preparation because our informants were convinced that it allowed for the extraction of the most active plant ingredients, while simultaneously serving to disinfect the plant parts used, and warm the body. The widespread appreciation of decoction has also been observed by other authors investigating Moroccan ethnobotany (Merzouki et al., 2000; El-Hilaly et al., 2003; Fakchich and Elachouri, 2014; Hachi et al., 2015; El Alami et al., 2016; Eddouks et al., 2017; El Haouari et al., 2018) and other parts of the world (Benítez et al., 2010; Leto et al., 2013). Our report showed that remedies were generally consumed orally (78%) but the use of inhalation (3%), poultice (8%), massage (4%), gargle (3%), lotion (3%) and exposure to smoke (1%) were also reported (Fig. 3).

Although our informants had not been familiarised with chemical compounds, extraction forms, etc., we observed some cases in which the same plant was administrated in different ways to treat differing conditions. For example, *Ammi majus* is administered orally after decoction of the fruits to mitigate flatulence, however, for the treatment of vitiligo a poultice is prepared using dried roots that is applied externally. The use of this plant in the treatment of vitiligo has been previously pharmacologically studied (Al-Snafi, 2013).

Table 2
List of medicinal Apiaceae used in the PNTLS with local names, treated diseases, used parts, modes of preparation and administration, Previous reported references in Morocco, use reports, chemical composition and pharmacological evidence.

Species (Vouchers)	Local names in Arabic (Roman alphabets)	Treated diseases & symptoms codes	Used parts	Modes of preparation	Mode of administration	Previous references(*)	Use reports	Chemical composition (references)	Pharmacological evidence
Ammi majus L. (TMP-B001)	اتريلال Atrillal	Vitiligo S08	Stems	Powder	Poultice	Bellakhdar, 1997	25	Furanocoumarins (xanthotoxins, imperatorin, bergaptens), coumarins (umbelliprenin, glycosides of quercetin, luteolin), flavonoids (quercetin and kaempferol), essential oil (carvone, 1,8-cineole),fatty acids (Al-Snafi, 2013; Akhtar et al., 2009)	Several researches with vitiligo (Al-Snafi, 2013)
		Flatulence D08	Fruits	Decoction	Oral	Tahri et al.. 2012	15		_
		Indigestion D07	Fruits	Decoction	Oral	_	27		_
		Absence of menstruation X05	Fruits	Decoction	Oral	Tahri et al., 2012	7		_
Ammi visnaga (L.) Lam. (TMP-B002)	البشنيخة Bùchenikha	Bronchitis R78	Fruits	Decoction	Oral	_	22	Furanochromones (khellin, visnagin, khellinol and more), fixed oils, coumarins (visnadin), flavonoids, essential oil (2,2-di methylbutanoic acid, isobutyl isobutyrate, croweacin, linalool, etc.) (Al-Snafi, 2013; Satrani et al., 2004)	_
		Mouth symptom D20	Fruits	Decoction	Oral	Bellakhdar, 1997	64		Antimicrobial (Al-Snafi, 2013)
		Teeth ache D19	Fruits	Decoction	Gargling	Bellakhdar 1997; El-Hilaly et al., 2003	69		_
		Oral abscess D83	Fruits	Powder with water	Gargling	Bellakhdar, 1997	78		_
		Diabetesnon-insulin dependant T90	Fruits	Powder with water	Oral	El-Hilaly et al., 2003	19		_
		Palpitations K04	Fruits	Decoction	Oral	Bellakhdar, 1997	15		Vasodilatator, nonspecific inhibition of vascular smooth muscle (Duarte et al., 1995), decreases blood pressure (Duarte et al., 2000)
		Kidney symptom U14	Fruits	Decoction	Oral	Bellakhdar, 1997	10		Preventive effect of kidney stone formation (Vanachayangkul, 2008)
		Bladder pain U13	Fruits	Decoction	Oral	Bellakhdar, 1997	18		_
		Dizziness N17	Fruits	Fumigation	Inhalation	Bellakhdar, 1997	9		_
		Cluster headache N90	Fruits	Fumigation	Inhalation	_	11		_
		Prostate symptom Y06	Fruits	Decoction	Oral	Bellakhdar, 1997	7		_
Apium inundatum (L.) Rchb. f. (TMP-B003)	كرفس Krafess	Urine retention U08	whole plant	Decoction	Oral	_	5	_	_
Apium nodiflorum (L.)Lag. (TMP-B004)		Eczema S87	Roots	Decoction	Poultice	_	13	Essential oil (myristicin, dillapiol, Limonene, p-cymene, myristicine, β-pinene) (Maxia et al., 2012; Menghini et al., 2010)	Antimicrobial, antifungal (Maxia et al., 2012; Menghini et al., 2010)
Apium repens (Jacq.) Lag. (TMP-B005)		IntoxicationA86	Roots	Decoction	Oral	_	5	_	_
Athamanta sicula L. *(TMP-B047)*	شكوثة الحجر Chkotat elhjar	Leprosy A78	Whole plant	Powder	Poultice	Bellakhdar, 1997	13	Essential oil (apiol, myristicin, elemicin) (Camarda et al., 2008)	_
Bunium alpinum Waldst. & Kit. (TMP-B007)	تالغودي Talghodi	Warts S03	Tubers	Cooked	Oral	Bellakhdar, 1997	15	Flavonoids, essential oil (caryophyllene oxide, humulene epoxide I, n-pentacosane) (Hayet et al., 2017; Lefahal et al., 2017)	_
Bunium bulbocastanum L. (TMP-B008)		Warts S03	Tubers	Cooked	Oral	Bellakhdar, 1997	19	_	_

(*continued on next page*)

Table 2 (*Continued*)

Species (Vouchers)	Local names in Arabic (Roman alphabets)	Treated diseases & symptoms codes	Used parts	Modes of preparation	Mode of administration	Previous references(*)	Use reports	Chemical composition (references)	Pharmacological evidence
Cachrys libanotis L. (TMP-B016)	شبشابة Chebchaba	Joint symptom L20	Roots	Fresh smashed in olive oil	Massage	Bellakhdar, 1997	21	Furocoumarines, germacrene, γ-terpinene, p-cymene, caryophyllene oxide, limonene (Bouderdara et al., 2008)	_
Daucus carota L. (TMP-B020)	جعدة Djaâda	Urinary infection U71	Fruits	Fresh	Oral	Bellakhdar, 1997; Fakchich et al., 2014;.Tahri et al., 2012	12	Essential oil (carotol, -pinene, myrcene, limonene in subsp. *sativus;* Verma et al., 2014); sesquiterpenes, chromones, flavonoids, coumarins, anthocyanins (Fu et al., 2010), carotenes or carotenoids (Heinrich et al., 2012)	_
Daucus muricatus (L.) L. (TMP-B021)	خيزو البري Khizo berri	Care of the face S01	Fruits	Juice	Lotion	Bellakhdar, 1997	35	Essential oil (limonene, α-Pinene, trans-Sabinyl acetate, Undecane, Myrcene, Citronellol (umbels; Bendiabdellah et al., 2012)	Antimicrobial activity (Bendiabdellah et al., 2012)
		Burns S14	Fruits	Fresh smashed in olive oil	Poultice	Bellakhdar, 1997	25		_
		Abdominal pain epigastric D02	Roots	Fresh	Oral	_	12		_
		Sweating problem A09	Roots	Fresh	Oral	_	7		_
		Diabetesnon-insulin dependant T90	Roots	Fresh	Oral	_	10		_
		Sexual desire reduced P07	Roots	Fresh	Oral	_	6		_
		Weakness of vision F28	Roots	Fresh	Oral	_	29		_
Elaeoselinum foetidum (L.) Boiss. (TMP-B022)	الكلخ El kellikh	Cluster headache N90	Aerial part	Powder with henna (Lawsonia inermis) on the forehead	Poultice	–	13	Diterpenes (foetidin, ent-kaur-l6-en-19-oic acid) and diterpenoid acids (Pinar et al., 1983; Pinar and Galan, 1986; Mongelli et al., 2002)	_
Eryngium bourgatii Gouan (TMP-B023)	الشوكة الزرقا Al chuka zaraka	IntoxicationA86	Leaves	Infusion	Oral	_	6	Essential oil (phyllocladene, bicyclogermacrene in the inflorescences, phyllocladene, γ-muurolene and (E)-caryophyllene in leaves, γ-muurolene and phyllocladene in roots (Palá-Paúl et al., 2005a), flavonols, flavanones, organic acids (Cádiz-Gurrea et al., 2013), triterpenoid glycosides, coumarins, acetylenes (Wang et al., 2012)	_
		Post-partum symptom W18	Roots	Decoction	Oral	_	8		_
		Constipation D12	Leaves	Infusion	Oral	_	11		_
Eryngium caespitiferum Font Quer & Pau (TMP-B023)		Intoxication A86	Roots	Decoction	Oral	_	6	_	_
Eryngium glaciale Boiss. (TMP-B025)		Constipation D12	Roots	Decoction	Oral	_	9	Essential oil (phyllocladene, (E)-caryophyllene, valencene and linalool (Palá-Paúl et al., 2005b)	_
Eryngium huteri Porta (TMP-B026)		Constipation D12	Roots	Decoction	Oral	_	5	_	_
Eryngium ilicifolium Lam. (TMP-B027)		Absence of menstruation X05	Roots	Decoction	Oral	_	4	Coumarins (Pinar and Galan, 1985)	_

(*continued on next page*)

Table 2 (*Continued*)

Species (Vouchers)	Local names in Arabic (Roman alphabets)	Treated diseases & symptoms codes	Used parts	Modes of preparation	Mode of administration	Previous references(*)	Use reports	Chemical composition (references)	Pharmacological evidence
Eryngium x mohamedanii Font Quer &Pau (TMP-B028)		Infertility Y10	Roots	Decoction	Oral	_	7	_	_
Eryngium tricuspidatum L. (TMP-B029)		Urine retention U08	Leaves	Infusion	Oral	Bellakhdar, 1997	16	Essential oil (α-bisabolol, α-curcumene (Merghache et al., 2014); phenolic glucosides Benmerache et al., 2016	Antibacterial and antifungal activities (Merghache et al., 2014)
Eryngium triquetrum Vahl (TMP-B030)		Intoxication A86	Roots	Decoction	Oral	_	9	Polyacetylenes, lignans, flavonoids (Khalfallah et al., 2014; Bouzergoune et al., 2016)	_
Foeniculum vulgare Mill. (TMP-B031)	البسباس –النافع Besbass- Annafaà	Abdominal pain epigastric D02	Fruits	Decoction	Oral	Bellakhdar, 1997; El-Hilaly et al., 2003; Fakchich et al., 2014; Hachi et al., 2015; Lahsissene et al., 2009; El Haouari, et al., 2018	77	Aerial parts with essential oil (trans-anethole and fenchone), fatty oil, proteins (Heinrich et al., 2012)	Analgesic (Choi and Hwang, 2004); carminative (Heinrich et al., 2012)
		Indigestion D07	Fruits	Decoction	Oral	El-Hilaly et al., 2003; Fakchich et al. 2014; Merzouki et al., 2000; El Haouari, et al., 2018	62		Antiinflammatory (Choi and Hwang, 2004); antibacterial activity (Diao et al., 2014), carminative (Heinrich et al., 2012)
		Asthma R96	Fruits	Decoction	Oral	Hachi et al., 2015; Lahsissene et al., 2009	20		_
		Flatulence D08	Fruits	Decoction	Oral	Bellakhdar, 1997; Fakchich et al., 2014; Hachi et al., 2015; Salhi et al., 2010	52		Antiinflammatory (Choi and Hwang, 2004); antibacterial activity (Diao et al., 2014)
		Mouth symptom D20	Fruits	Decoction	Oral	Bellakhdar, 1997	32		Antiinflammatory (Choi and Hwang, 2004); antibacterial activity (Diao et al., 2014)
		Swallowing problem D21	Fruits	Decoction	Oral	Bellakhdar, 1997	54		Antiinflammatory (Choi and Hwang, 2004); antibacterial activity (Diao et al., 2014)
		Colon pains D93	Roots	Decoction	Oral	Fakchich et al. 2014;	87		Analgesic (Choi and Hwang, 2004)
Kundmannia sicula (L.) DC. (TMP-B032)	الزياتة Ziyata	Swelling A08	Roots	Fumigation	Exposure to smoke	Bellakhdar, 1997	8	Essential oil (spathulenol, caryophyllene oxide, salvial-4(14)en-1-one, Germacranene D (Djarri et al., 2008; Casiglia et al., 2017)	_
		Abdominal pain epigastricD02	Roots	Decoction	Oral	_	10		Antiinflammatory (Rimbau et al., 1999)
		Colon pains D93	Roots	Decoction	Oral	Bellakhdar, 1997	16		Antiinflammatory (Rimbau et al., 1999)
Magydaris pastinacea (Lam.) Paol (TMP-B033)	فريفرة Frifra	Head pains N01	Fruits	Powder	Oral	_	12	Coumarins, furancoumarins (Cerri et al., 1995)	_
		Hair care S23	Fruits	Decoction	Lotion	Bellakhdar, 1997	23		_
		Icterus D13	Fruits	Decoction	Oral	Bellakhdar, 1997	10		_

(*continued on next page*)

Table 2 (*Continued*)

Species (Vouchers)	Local names in Arabic (Roman alphabets)	Treated diseases & symptoms codes	Used parts	Modes of preparation	Mode of administration	Previous references(*)	Use reports	Chemical composition (references)	Pharmacological evidence
Ridolfia segetum (L.) Moris (TMP-B042)	سليلي - سليلو Slilo- Slili	DyspepsiaD07	Whole plant	Infusion	Oral	Bellakhdar, 1997	14	Essential oil (dillapiole, myristicin in roots; Jabrane et al., 2010; α-phellandrene piperitenone oxide and terpinolene in flowers; with p-cymene in flowers; Fleisher and Fleisher, 1996)	_
Smyrnium olusatrumL. (TMP-B044)	الحيار Al hayar	Chills A02	Fruits	Powder	Oral	Bellakhdar, 1997. Tahri et al., 2012	10	Essential oil (isofuranodiene, α-pinene, β-phellandrene in fruits; furanoeremophil-1-one, isofuranodiene, myrcene in basal leaves; Quassinti et al., 2013)	_
		Antepartum bleeding W03	Fruits	Powder	Oral	Bellakhdar, 1997	9		_
		Abdominal pain epigastric D02	Leaves	Powder	Oral	_	11		_
		Intestinal pain D01	Leaves	Powder with honey	Oral	_	16		_
Stoibrax pomeliana (Maire) B.L. Burtt (TMP-B006)	كرفس البري Krafess berri	Mumps D71	Flowers and leaves	Decoction	Oral	_	15	_	_
		Ear pain H01	Flowers and leaves	Decoction	Oral	_	35		_
		Kidney symptom U14	Roots and fruits	Decoction	Oral	_	31		_
		Abdominal pain epigastric D02	Fruits	Powder	Oral	_	20		_
Thapsia transtagana Brot. (TMP-B045)	الدرياس Deriass	Bronchitis R78	Roots	Decoction	Oral	Bellakhdar, 1997	7	Sesquiterpenoids (guaianolides: thapsigargin and thapsigargicin, transtaganolides $A-D$; Saouf et al., 2005; Christensen et al., 1997), coumarins (scopoletin, 6-methoxy-7-geranyloxycoumar; Rasmussen et al., 1981)	_
Thapsia villosa L. (TMP-B046)		Cough R05	Roots	Decoction	Oral	Bellakhdar, 1997	8	Sesquiterpenoids (guaianolides: thapsigargin, trilobolide, thapsivillosin A, B, C, D, E, F), coumarins (scopoletin, 6-methoxy-7-geranyloxycoumar; Rasmussen et al., 1981), essential oil (limonene, methyl eugenol; Avato et al., 1996)	_
		Joint symptom L20	Roots	Powder with oliveoil	Massage	Bellakhdar, 1997	22		_
		Bites of poisonous animals S13	Roots	Powder with oliveoil. mixed with flour	Poultice	Bellakhdar, 1997	13		_
		Allergies A92	Roots	Macerated in oliveoil	Massage	_	7		_
		Infertility W15	Roots	Cooked with barley	Oral	_	4		_
Torilis arvensis (Huds.) Link subsp. *neglecta* (Schult.) Thell. (TMP-B048)	قميلة Qumila	Sexual desire reduced P07	Flowers	Decoction	Oral	_	9	Essential oil ((E)-β-farnesene, arcurcumene different subspecies; Bigdeli et al., 2004)	_
Torilis arvensis (Huds.) Link subsp. p*urpurea* (Ten.) Hayek (TMP-B049)		Sexual desire reduced P07	Flowers	Decoction	Oral	_	8	Essential oil ((E)-β-farnesene, arcurcumene different subspecies; Bigdeli et al., 2004)	_
Torilis japonica (Houtt.) DC. (TMP-B053)		Sexual desire reduced P07	Flowers	Decoction	Oral	_	11	Sesquiterpenes (torilin, opositane; Itokawa et al., 1983), essential oil (β-eudesmene, α-selinene, eudesm-7(11)-en-4-ol, β-elemene; Chen et al., 2013)	Inhibition of testosterone 5α-reductase by torilin (Kim et al., 1998)

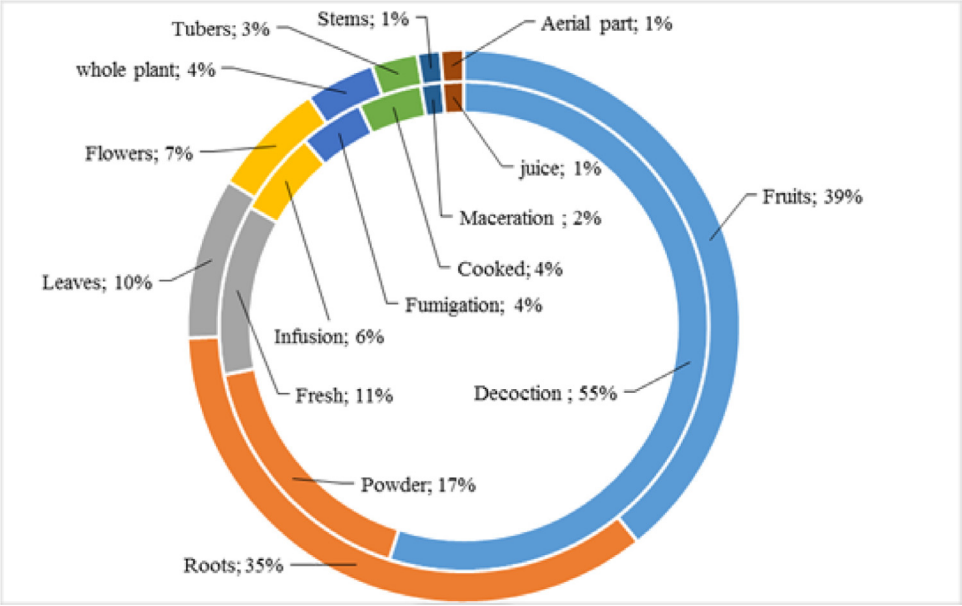

Fig. 2. Frequencies of used part (outer circle) and preparation modes (inner circle) of Apiaceae species in PNTLS.

3.2.3. Conditions and pathological groups

In this study, 72 medicinal uses were identified for the 31 included taxa, and a total of 1430 use reports (UR) were produced. Although some uses were not highly reported (e.g., the decoction of the roots of *Eryngium ilicifolium* against absence of menstruation with only 4 UR, see Table 2) in general, we have obtained very high numbers of UR for most types of uses. Most reported UR are reported for the decoction of fennel (*Foeniculum vulgare*) roots against colon pain (87 UR) or of its fruits to treat abdominal pain (78 UR) and indigestion (62 UR). The fruits of bisnaga (*Ammi visnaga*) are prepared as a powder with water and administrated by gargling to treat oral abscess (78 UR), or by decoction to treat toothaches (69 UR).

The plants are identified within the area studied are reportedly used to treat 48 conditions or symptoms classified within 15 pathological groups, according to the classification of diseases scheme (International Classification of Primary Care (ICPC)). The main pathological groups treated were digestive symptoms (D: 32%), which were related to 23 conditions. For the treatment of digestive symptoms, 11 plants were reportedly used, including *Ammi majus, Ammi visnaga* (L.) Lam., *Stoibrax pomeliana, Daucus muricatus* (L.) L., *Eryngium bourgatii, Eryngium glaciale, Eryngium huteri, Foeniculum vulgare, Kundmannia sicula* (L.) DC., *Ridolfia segetum* (L.) Moris, and *Smyrnium olusatrum* L. The group "general and unspecified conditions" (A: 12%) includes five unique conditions that are treated with eight different

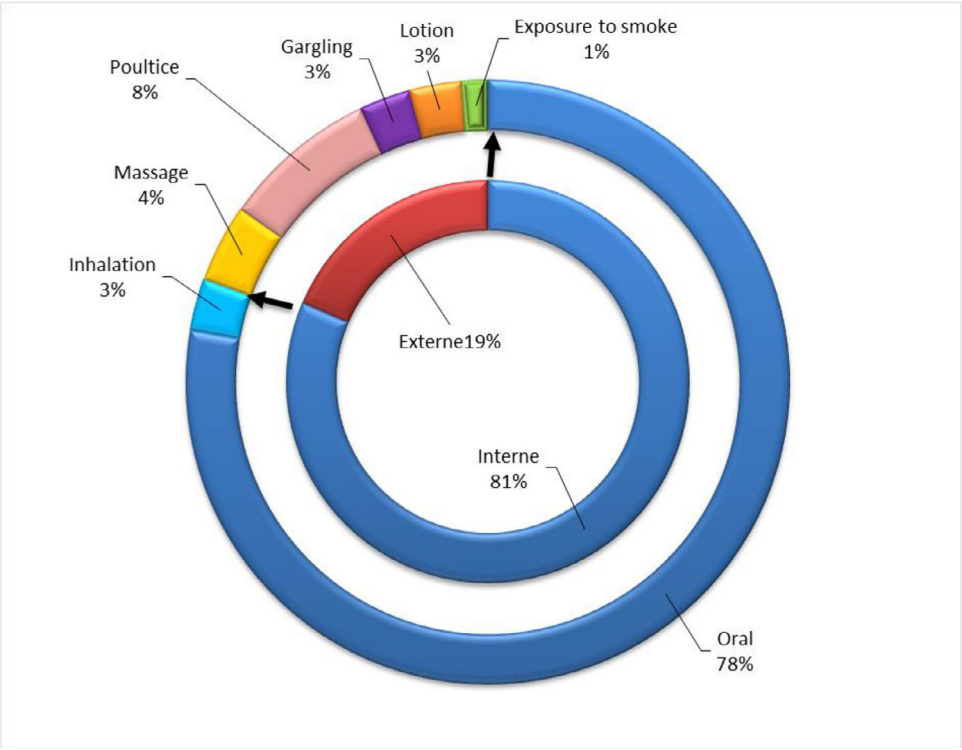

Fig. 3. Frequencies of administration modes of Apiaceae species in PNTLS.

Table 3
Number of conditions per pathological group treated with the Apiaceae genera.

	Pathological Groups (PG)															
Genus	A	D	F	H	K	L	N	P	R	S	T	U	W	X	Y	Total citation per Genera
Ammi	–	5	–	–	1	–	2	–	1	1	1	2	–	1	1	**15**
Apium	1	–	–	–	–	–	–	–	–	1	–	1	–	–	–	3
Athamanta	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Bunium	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	2
Cachrys	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1
Daucus	1	1	1	–	–	–	–	1	–	2	1	1	–	–	–	**8**
Elaeoselinum	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	1
Eryngium	3	3	–	–	–	–	–	–	–	–	–	1	1	1	1	**10**
Foeniculum	–	6	–	–	–	–	–	–	1	–	–	–	–	–	–	**7**
Kundmannia	1	2	–	–	–	–	–	–	–	–	–	–	–	–	–	3
Magydaris	–	–	–	–	–	–	1	–	–	1	–	–	–	–	–	2
Ridolfia	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Smyrnium	1	2	–	–	–	–	–	–	–	–	–	–	1	–	–	4
Stoibrax	–	2	–	1	–	–	–	–	–	–	–	1	–	–	–	4
Thapsia	1	–	–	–	–	1	–	–	2	1	–	–	1	–	–	6
Torilis	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	3
Total citationper PG	**9**	**23**	**1**	**1**	**1**	**2**	**4**	**4**	**4**	**8**	**2**	**6**	**3**	**2**	**2**	**72**

plant species. Skin symptoms (S: 11%) resulted from seven unique conditions that were treated using seven species, whereas urological ones (U: 8%) were related to four conditions that were remedied by five species.

Polyvalence was observed in several plants, in which the same plant could be used to treat conditions of different groups. In this study, the highest level of polyvalence was shown for *Ammi visnaga*, which can be used to treat digestive (D), respiratory (R), nutritional and endocrine metabolism (T), cardio-vascular (K), urological (U), neurological (N), and male genital (Y) symptoms.

Forty-three% of the uses included in Table 2 were not previously reported in the work consulted for the purpose of comparison to this study (mentioned in Table 2). Regarding the remaining uses uncovered here, we have found that Bellakhdar (1997) identified a high number of conditions (32 in total) that could be treated using traditional medicine. This means that, with the work of Bellakhdar (1997) as a starting point, in-depth field studies should enrich our knowledge of traditionally used plants in north of Morocco. Table 3 shows the number of conditions treated with the Apiaceae plant genera, sorted by pathological groups. The genus used for treating the greatest number of diseases in the PNTLS is *Ammi,* which has been reportedly used to treat 15 different ailments, followed by *Eryngium* (10), *Daucus* (8), *Foeniculum* (7) and *Thapsia* (6).

The inhabitants of the PNTLS use the Apiaceae mainly to cure digestive symptoms (23 different uses for treating 13 digestive conditions, with a relative frequency D of 32%; see Fig. 4). Further, five general (unspecified) symptoms were reportedly treated (9 uses in this category; A: 12%), followed by the 7 skin conditions (S: 11% of uses), and urological ones (with 4 conditions, U: 8% of uses).

The remaining 11 pathological groups (R, N, P, T,W, L, X, Y, F, K, and H) represent a total of 37% of the conditions reported, with individual percentages varying between 6% and 1%. These groups generally include more complicated health conditions such as cardiovascular, respiratory, neurological, and psychological abnormalities. These results are similar to those obtained by Mehdioui and Kahouadji (2007) in the province of Essaouira. In this study,

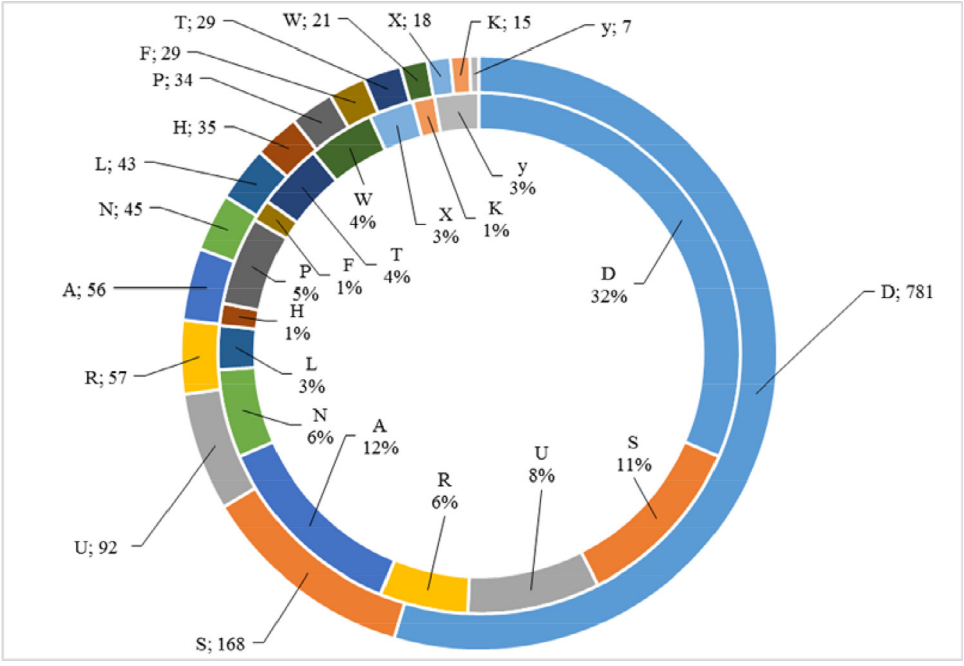

Fig. 4. Frequencies of the pathological groups treated (outer circle) and ethnobotanical uses (inner circle). Codes for pathological groups are according to ICPC-2.

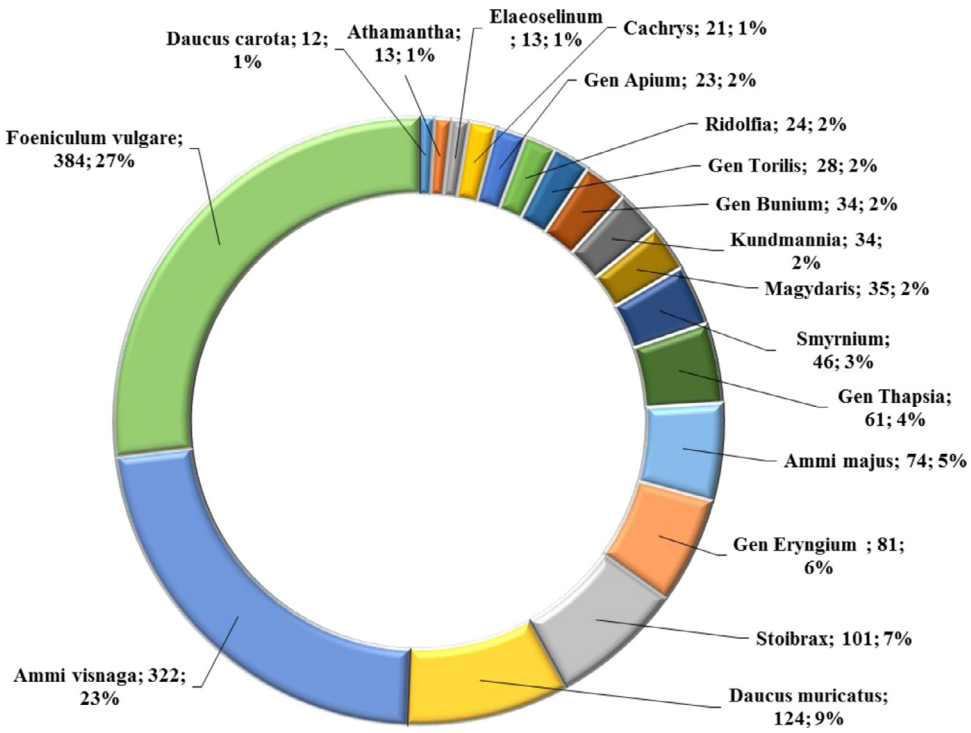

Fig. 5. The Apiaceae use reports according to the used taxa.

researchers reported that digestive disorders are most commonly treated using medicinal plants. In fact, digestive disorders are typically the most-reported conditions treated by traditional, plant-based medicine in the Mediterranean (Benítez et al., 2010; Benlamdini et al., 2014; El Haouari et al., 2018). The high (although not surprising) importance of traditional medicine in the treatment of digestive conditions can be better observed based on percentages documented in UR. Up to 54.6% of UR were recorded for conditions in this pathological group (781 UR; see Fig. 4).

As mentioned in the results section, a total of 1430 UR were obtained for the different species. *Foeniculum vulgare* was the most cited species by our informants, with 384 UR (27% of the total UR recorded; Fig. 5). The species was especially important for the treatment of digestive symptoms (D; see Table 3). *Ammi visnaga* was the second most reported species, with 322 UR (23%), most of which were also for the treatment of digestive complaints (D). The species accumulating the third most URs was *Daucus muricatus,* with 124 UR (9%). This species was used primarily for treating skin diseases (S). Finally, we have identified specific uses of some plants. The three species of the genus *Torilis* included here are used to combat reductions in sexual desire, therefore the genus is considered an aphrodisiac by people of the PNTLS. Another plant used in a specific manner was is *Athamanta sicula* L., which was solely used to treat leprosy and, further, was the only herbal remedy for this condition uncovered in this study.

4. Conclusions

People from the PNTLS use up to 31 medicinal plants belonging to the genus Apiaceae. We have found original data regarding the use of several species belonging to the genera *Eryngium, Stoibrax, Elaeoselinum, Torilis* and *Apium* which, to our knowledge, have not previously been reported in Morocco. We have registered 1430 UR for 72 medicinal uses to treat 48 symptomatic conditions associated with 15 pathological groups. The most highly referenced conditions have digestive symptoms. The preferred preparation methods used by individuals in the area are decoction and are mostly administrated orally. The part of the plant anatomy most used to treat symptoms are the fruits. Seven species lack any phytochemical or pharmacological study. Remaining species have been surveyed, although an in-depth assessment of the pharmacological properties of the plants are not available in most cases. The most reported species by traditional healers of PNTLS was *Foeniculum vulgare,* a plant mainly used to treat digestive symptoms. In general, we have obtained high numbers of UR for most symptoms.

Finally, the study revealed an important pool of ethnopharmacological information and knowledge embedded in the cultural and traditional heritage of the PNTLS that requires further investigation. Even using some previous research investigating the use of medicinal plants in the Rif Mountains and other territories of Morocco, nearly half of the included uses had not been previously reported. These results encourage us to continue performing field-work and documenting the ethnopharmacological knowledge of Morocco, either by expanding our focus so that multiple, non-related individuals are interviewed, or by studying expanding geographically to other interesting territories. Undoubtedly the safeguarding of the traditional pharmacopoeia requires the preservation of biomes in the PNTLS, as well as the conservation of this important and interesting traditional knowledge.

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