Concepts and methods: Ethnopharmacological Database for Medicinal plants used in the Northern Morocco

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Research

Abstract

Background: Northern Morocco is rich in biodiversity, notably medicinal plants. which considered the primary source of medicines and drug discovery due to their secondary metabolites and bioactive compounds that are pharmacologically applicable against several diseases. This study aims to design and develop a database to document the therapeutic uses practiced by the population of the PNTLS (catalog of medicinal plants), analyze the information obtained by species and by uses, comparing with recent literature (Andalusia and Sicily), and the historical data from ancient manuscripts, for to compare the conservation of plant knowledge in the space area and over time.

Methods: The survey was carried out between 2014 and 2017 using semi-structured questionnaires in PNTLs. Data were gathered manually from scientific resources such as published scientific articles, books Ibn Al Baytar (13th century), De Materia Medica of Matthioli and Dioscorides of Laguna (16th century). The data were then organized and digitized into a database using: MySQL, PHP, WAMP, JAVA Script, and JavaScript.

Results: The results obtained from the PNTLS (152 medicinal plants with 567 uses) were compared with the same species cited in current works from Andalusia (103 medicinal uses) and Sicily (94 medicinal uses), and with ancient works including Ibn Al Baytar (94 medicinal uses), Matthioli and Laguna (94 medicinal uses).

Conclusion: The fieldwork data, traditional uses cited in the ancient work and an intuitive platform design, it a resource for preserving traditional plant knowledge, supporting scientific research and promoting sustainable use of medicinal plants in the region.

Keywords: Ethnobotanical approach; Database; Medicinal plants; Talassemtane National Park (PNTLS).

Background

Today, ethnobotany and ethnopharmacology connect ancestral knowledge of traditional curative and therapeutic practices and current scientific knowledge, regarding drugs and De Materia Medica through history is a fundamental topic for medicinal plant research, medicinal treatment with medicinal plants holds a strong ground because these plants seem to be safe with least aftereffects (Conklin 1954, Clement 1998, Posey 2004, Leonti *et al*. 2015, Ritter *et al.* 2015, Totelin 2016, Pieroni 2017, Ford 1979, Johns *et al.* 1990, Balick & Cox 1996, Berlin 1992, Endicott & Welsch 2003, Johns 1996, Etkin 2006, Totelin 2009, Heinrich *et al.* 2006, Leonti 2011, Mandal *et al.* 2012, Benítez *et al.* 2009, Harshberger 1896, Nolan & Turner 2011). Traditional medicines are an invaluable resource for mankind, these are above all areas of interdisciplinary research at the interface, on the one hand, of human sciences such as ethnology, history and linguistics, and on the other hand, of natural sciences such as botany, pharmacology, pharmacognosy and medicine. medicinal plants were used in different kinds of current medical systems and also used in ancient medical systems (Schultes 1962, Ford 1979 Balick & Cox 1996, Heinrich *et al.* 2005, 2006, De Vos 2010, Leonti 2011, Touwaide & Appetiti 2013, Pieroni *et al.* 2013, Touwaide 2010, Heywood 1999).

In this sense, we know that the study of the transmission of knowledge about drugs and medical materials throughout history is fundamental for ethnopharmacological research (Touwaide & Appetiti 2013, Volpato *et al.* 2007, Arber 1938, Riddle 1985, Lardos 2006, Weckerle *et al*. 2009, Conklin 1954, Clément 1998, Posey 2004, Leonti *et al*. 2015, Ritter *et al.* 2015, Totelin 2016, Pieroni 2017). Authenticated ancient manuscripts represent a good testimony of knowledge, proof of the transmission of uses and the compilation of knowledge on the curative properties of certain plants (Berlin 1992, Robineau & Soejarto 1986, Frei *et al.* 1998, Leonti *et al.* 2001, Touwaide 2010, Leonti 2011, Leonti *et al.* 2010, Leonti *et al.* 2009, Touwaide & Appetiti 2013, Heinrich *et al.* 2006, de Vos 2010, Staub *et al.* 2016, Van Andel *et al.* 2018, Rivera *et al*. 2017, 2019).

Dioscorides' work is indeed remarkable for its extensive catalog of 550 plants, 80 animals or animal parts, and 90 minerals, showcasing a comprehensive understanding of medicinal substances available during his time. His descriptions laid a foundation for botanical and pharmacological knowledge that influenced generations of herbalists and physicians (Ogilvie 2006). The exploration and colonial expansion of the sixteenth century further enriched European herbalism with a plethora of new species from the Americas and other distant regions, broadening the scope of botanical understanding and medicinal possibilities (Pardo-de-Santayana 2014, Gruner 1930, Pols 2009, Nilsson *et al.* 2001). This historical context highlights the continuous evolution and expansion of pharmacological knowledge throughout the ages (Idolo *et al.* 2010, Altimiras Roset *et al.* 2009, San Miguel 2004).

Indeed, the contributions of Al-Andalusian authors to historical ethnobotany, particularly in Spain, were significant. Ibn al-Baytar's (c. 1180-1248) wrote the "Compendium of Simple Drugs and Food" (al-Jāmiʿ li-mufradāt al-adwiyah wa-l-aghdhiyah) stands out as a monumental work in this regard, this book is translated into French by Leclerc 1877-1883. Compiled around the 13th century, it drew upon a wealth of sources, including the writings of Dioscorides, as well as Ibn al-Baytar's own observations and experiences. This compendium is particularly notable for its extensive catalog of medicinal drugs, with Ibn al-Baytar describing over 1400 substances, 300 of which had not been previously documented (Cabo-González 1999). This demonstrates a remarkable depth of knowledge and a keen understanding of botanical and pharmacological properties. Ibn al-Baytar's work not only contributed to the understanding of medicinal plants during his time but also left a lasting impact on the development of pharmacology and ethnobotany in the region (Abu-Rabia 2005).

Modern ethnobotany suggests that a practicing herbalist works with considerably less Materia Medica than what premodern botany has recorded in writing. For example, research conducted in Mauritania among 120 informants indicated that, as a group, they worked with a total of 68 plant species, which they applied to 177 different medicinal uses grouped in 14 pathological groups, only 6 of which are also recorded by Ibn al-Baytar. The authors of this study attribute the discrepancy to Ibn al-Baytar's geographic focus: he probably never travelled to Mauritania and was generally focused on the Mediterranean coast of North Africa rather than the Saharan region (Yebouk *et al.* 2020).

Further, modern ethnobotanical practice and what is reported in the ancient sources appear consistent in other ways too: ethnobotanical research in Morocco indicates that most traditional remedies are used for the digestive tract and diseases of the eyes are rarely treated, as is the case with Hippocratic pharmacology (El-Gharbaoui *et al.* 2017, Redouan *et al.* 2022, 2023, Benítez *et al.* 2021).

The history of ethnobotany in Morocco is quite recent and only dates from the 1970s with the important work of Bellakhdar (1978). In this regard, well-referenced ethnobotanical studies have been published covering different regions of Morocco (Kahouadji 1995, Merzouki *et al.* 1997, 2000, 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 & 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, Redouan *et al.* 2019).

This study was part of my PhD dissertation (Redouan 2019), during my stay in Italy and Spain (Erasmus mobility), according to the bibliographic analysis of the uses of medicinal plants in the Mediterranean region, we noted that: the territories of Northern Morocco, eastern Andalusia and Sicily, should now present a high coincidence of medicinal plants and their uses and the know-how of current medicinal plants must be influenced by ancient uses. The current study focuses to create the data base for to document all information concerning the therapeutic uses practiced by the population of the PNTLS (catalog of medicinal plants), analyze the information obtained both by species, by uses, and by origin at the informants, comparing with recent literature (Andalusia and Sicily), and the historical data from ancient manuscripts, for to compare the conservation of plant knowledge in the space area and over time.

Material and Methods

Study area

A field study was performed in Northern Morocco (Talassemtane National Park covers an area of 64,601 ha), including Two-thirds of the park is within the province of Chefchaouen and one-third belongs to the province of Tetouan (see Fig. 1, with main surveyed localities), covering a total area of about 82,820 km^2 between the Mediterranean and Algeria (about 11% of Morocco´s area).

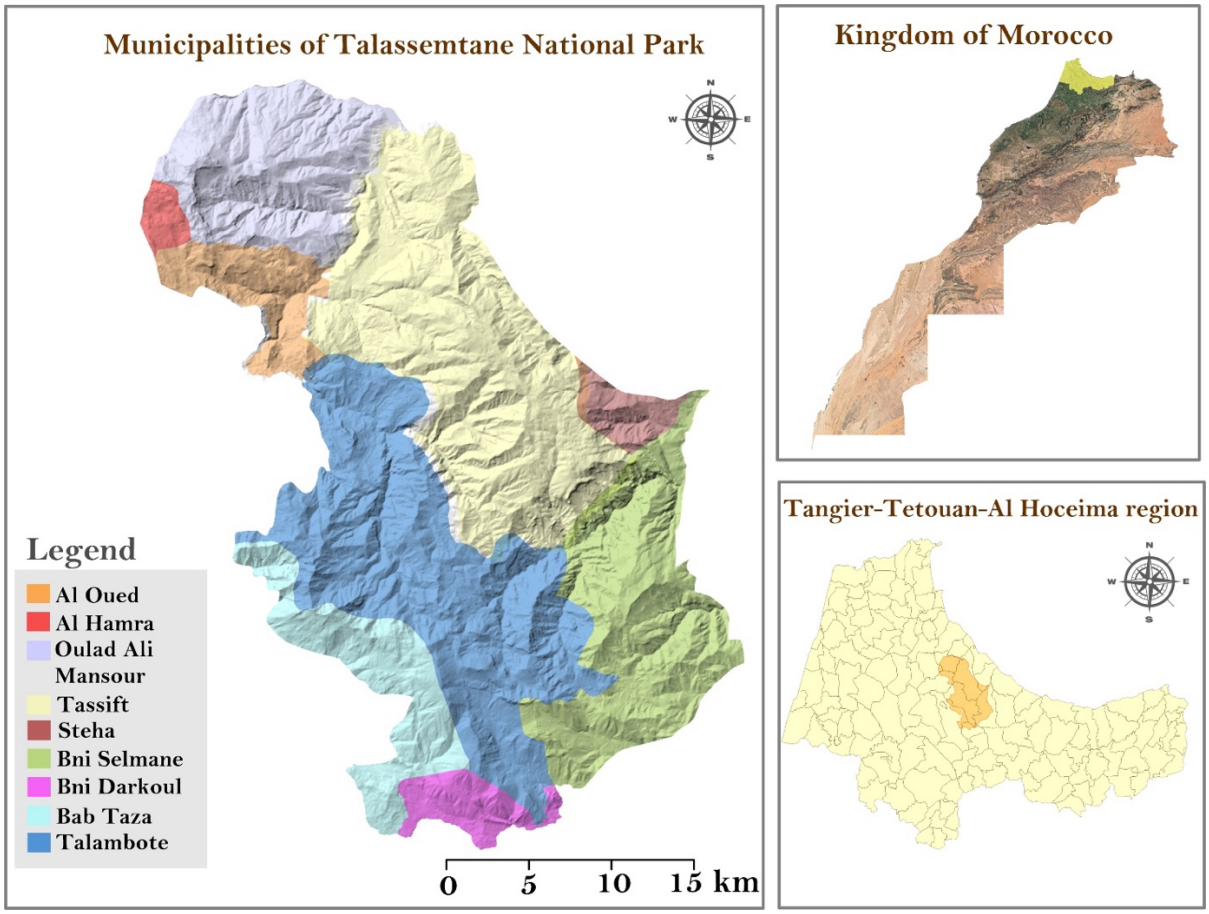

Figure 1. Map of Northern Morocco showing the location of the study area, Talassemtane National Park

Ethnobotanical data collection

Field surveys and research activities were carried out in the Talassemtane National Park (Northern Morocco) from 2014 to May 2017 (Fig. 2). This study area was chosen for its traditional plant use that is still well preserved in the memory of older residents.

Surveys were conducted in order to preselect informants, together with conventional methods of informant location, such as the snowball method and participant observation. Data on the use of plants were gathered by open and semi-structured interviews performed in Darija, the Moroccan Arabic dialect, usually individually (although group discussions and team interviews were also performed). Informants gave their prior verbal informed consent. We interviewed a total of 200 people ranging in age from 20 and above 66 years, with 87 men and 113 women. The regulations by the International Society of Ethnobiology (available at https://www.ethnobiology.net, accessed on 1 December 2021) were followed during the whole study and for data compilation. All the information obtained through the interviews were stored in an excel file, where we reported the following: Latin name, botanical family, life form, vernacular name, part used, ethnobotanical category, claimed uses, native or exotic status.

Figure 2. Photos (A, B, C, D) from the field research team in PNTLS

With regard to the plant material, it is comprised by dry plant material, which was donated by our informants or directly bought in markets while performing the interviews. In all cases we obtained all the needed structures for the proper identification of the species: fruits, leaves, calices, corollas, etc. using local floras in order to identify the plant material (Fennane *et al.* 1999, 2007, 2014, Valdés *et al.* 2002, Castroviejo 1986-2005). Vouchers were deposited in the University of Tetouan *Herbarium*, and codes are included in the results (Fig. 3). General standards and recommendations for ethnopharmacological studies were followed (Martin 1995, Alexiades *et al.* 1996, Weckerle *et al.* 2018).

Figure 3. Photos of herbarium preparation (Parts used)

The figure 4 is a summary diagram of an ethnobotanical survey of medicinal plants in the PNTLS area, would typical outline key steps, methodologies, and results involved in the ethnobotanical survey process. The diagram structured in a method that provides a visual representation of the various steps of the survey and how they interconnect.

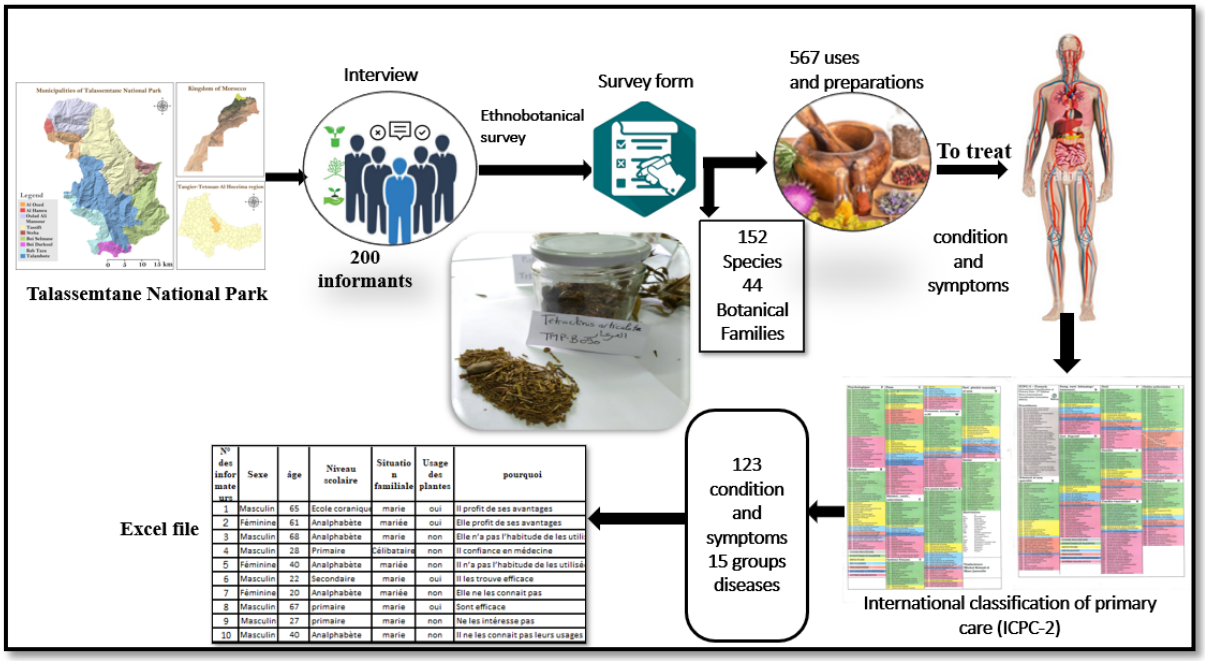

Figure 4. Schema of an ethnobotanical survey in PNTLS area

Literature Review

Phytochemical Data

Pharmacological properties as well as the major phytochemical constituents were compiled manually from published literature using several research engines and web sources, such as Science Direct, Scopus, Web of Science, PubMed, and Google Scholar.

Ethnobotanical review works

During this study, the results of investigation of the ethnobotanical data that were collected in the PNTLS using surveys of the local population, were compared with those of different geographical spaces (Eastern Andalusia and Sicily) (Fig. 4 and 5).

In this aspect, we compare the results of our ethnobotanical survey which were collected at the PNTLS with recent bibliographic data in Mediterranean Europe (Andalusia and Sicily) in order to contrast the conservation of traditional know-how of medicinal plants between these countries.

In Eastern Andalusia, we performed a review of the ethnobotanical works of this area. It includes all the ethnobotanical field works performed in the Spanish provinces of Grenade (González-Tejero 1986, Benítez 2009), Almería (Martínez-Lirola 1996), Jaén (Guzmán *et al.* 1986, Fernández Ocaña 2000, Casado Ponce 2003) et Cordoba (Galán 1993, Triano 1998). Covered territories can be seen in Figure 5.

Most of these works were performed using the same data gathering methods and within the same research group (except Galan Soldevilla 1993, Triano *et al.* 1998, Casado Ponce 2003). Thus, any new field work was performed in Andalusia, and data for this territory come from this literature review.

In Sicily (Italy) we refer to current ethnobotanical data from, in order to obtain these data, an exhaustive bibliographic review of ethnobotanical work carried out in different regions of Sicily (Fig. 6) (González-Tejero 1989, Martínez-Lirola 1996, Guzmán-Tirado 1997, Galán-Soldevílla 1993, Fernández Ocaña 2000, Casado Ponce 2003, Benítez 2009, Triano 1998).

Figure 5. Map of the study area in the East Andalusian territories used for bibliographical comparison. PNTLS: main localities for the field study, Number A1-A7: Andalusian territories for bibliographical comparison (Benítez *et al.* 2021)

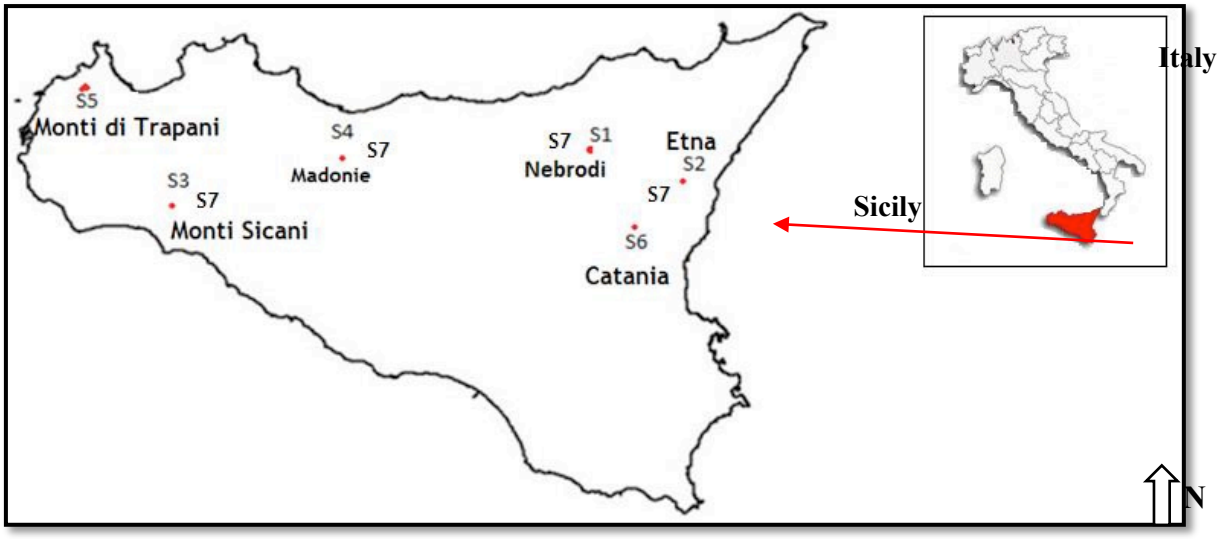

Figure 6. Map of the study area in Sicily territories used for bibliographical comparison. Number S1-S7: Sicily territories for bibliographical comparison

Historical use of plants

Ibn al-Baytar (IB)

Diya al-Din Abu Muhammad Abdullah Ibn Ahmed Ibn al-Baytar (1197-1248), was a physician, pharmacologist and botanist born in Malaga (South Spain). He studied in the Islamic school of the Nasri Kingdom of Granada, and focused on botany and pharmacology as complementary disciplines for medicine (Cabo- González 1999, Sankary 1984, 1991, Sterpellone & El sheikh 1995, Bellakhdar 1997, Guardi 1999). After this, he travelled through the Islamic world learning the use of medicinal plants and compiled in Damascus, where he died, the most important Compendium of medicinal plants of his age. The Compendium, entitled Kitab al-Yami' li-mufradat aladwiyawa-l-aghdiya (the Compendium of Simple Medicaments and Foods) is one of the major works in Arabic on this issue (Alvarez-de-Morales 1986, Bellakhdar 1978, 1997). For the analysis we mainly used the French translation (Leclerc, 1877-1883) with the author's comments providing information on the correlation of mentioned plants with scientific and French vernacular names.

Laguna's Dioscorides (DL)

Andres Laguna de Segovia (1499-1559) was a Spanish physician, who worked as doctor for Pope Julius III and later for the Spanish Kings Carlos I and Felipe II. Several papers deal with his biography and bibliography (e.g. Kousoulis *et al.* 2011, Lahiff 2012, Morales 2015, Andretta & Tomas 2017), but his most known work was the commented Spanish translation of Dioscorides' Materia Medica (Laguna, 1555). It was only few years after Matthioli's first one in Italian (Matthioli 1544). Several ethnobotanical historical studies focused on Matthioli's work (Leonti *et al.* 2009, Leonti *et al.* 2010, Leonti 2011, Staub *et al.* 2016).

Pietro Andrea Matthioli (M)

The most relevant annotated version of Dioscorides' book Materia Medica was that of the doctor of Siena, Pietro Andrea Matthioli (1500-1577), initially published in Italian in 1544, then in Latin, expanded considerably in 1554 (I Discorsi Nei I Sei Libri Della Materia Medicinale di Pedacio Dioscoride Anazarbeo). This work, constantly expanded, both in commentaries and illustrations, continued to be printed until the 18th century, reaching 17 editions. Matthioli not only commented on the chapters of Dioscorides presenting different uses and observations, but also introduced new species from other authorities. Andrea Matthioli tolerated neither his rivals nor their corrections and those who dared to disagree with him were mistreated (Osbaldeston 2000). In the version of Materia Medica that we used in this study, there are chapters and each chapter begins with the corresponding title, adapted by Matthioli. This is then numbered with Roman numerals. Comments usually begin with a discussion of the identity of the plant, any doubts there might be about their identification, adding comments on related species or others considered under that name. In addition, the opinions of different classical authors (Galen, Theophrastus, etc…) are included, always ending with their own opinion. Sometimes other species related by similar uses are also included. The names of the plants discussed in the text appear alongside these annotations. In addition, they comment and present their own experiences on each plant.

The figure 6 illustrate the comprehensive process of conducting an ethnobotanical survey in the PNTLS area while highlighting the comparative analysis with ancient manuscripts and actual data in Andalusia (Spain) and Sicily (Italy). It would be a useful implement for illustrating the interconnection of modern and ancient knowledge in ethnobotanical research (preservation of knowledge of medicinal plants).

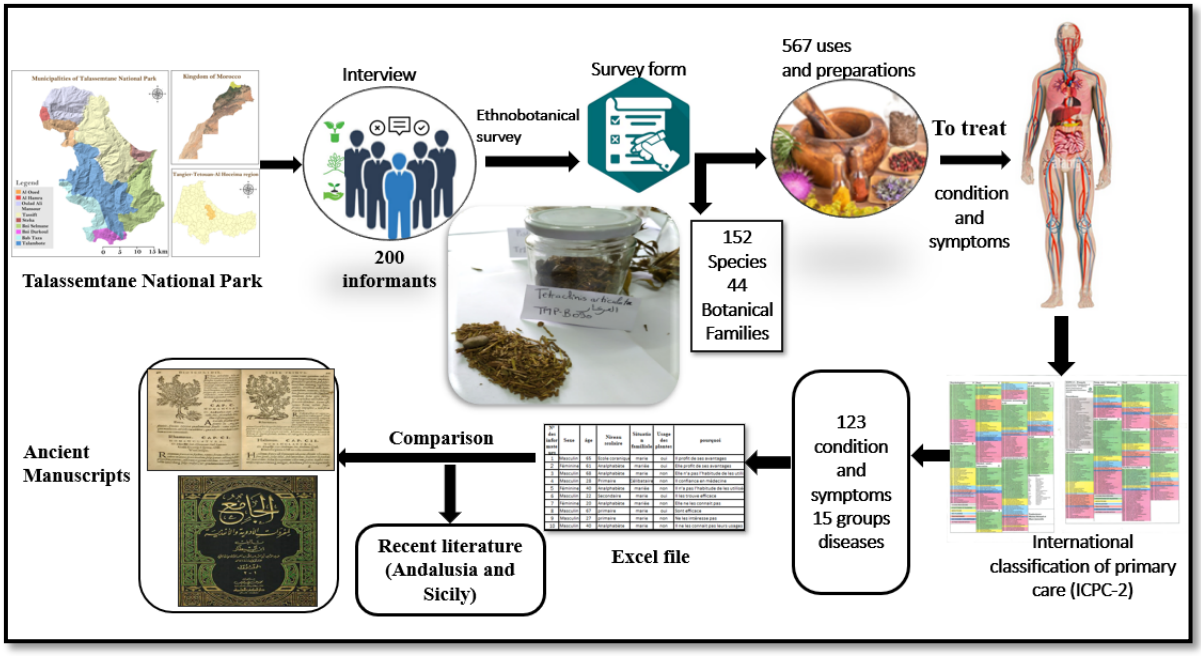

Figure 6. Schema of an ethnobotanical survey in PNTLS area with a comparative study of ancient manuscripts (Ibn Al Baytar, Matthioli, Laguna) and data actual (Andalusia and Sicily)

Database creation

Data collected previously were gathered and organized manually into a table using Microsoft Excel (surveys, interviews, field visits, identification of plant material, historical documentation, etc.). Afterward, all scientific information were converted into a digital platform using the following Software and programming languages: MySQL, HTML, CSS, JAVA, and JavaScript (Fig. 7).

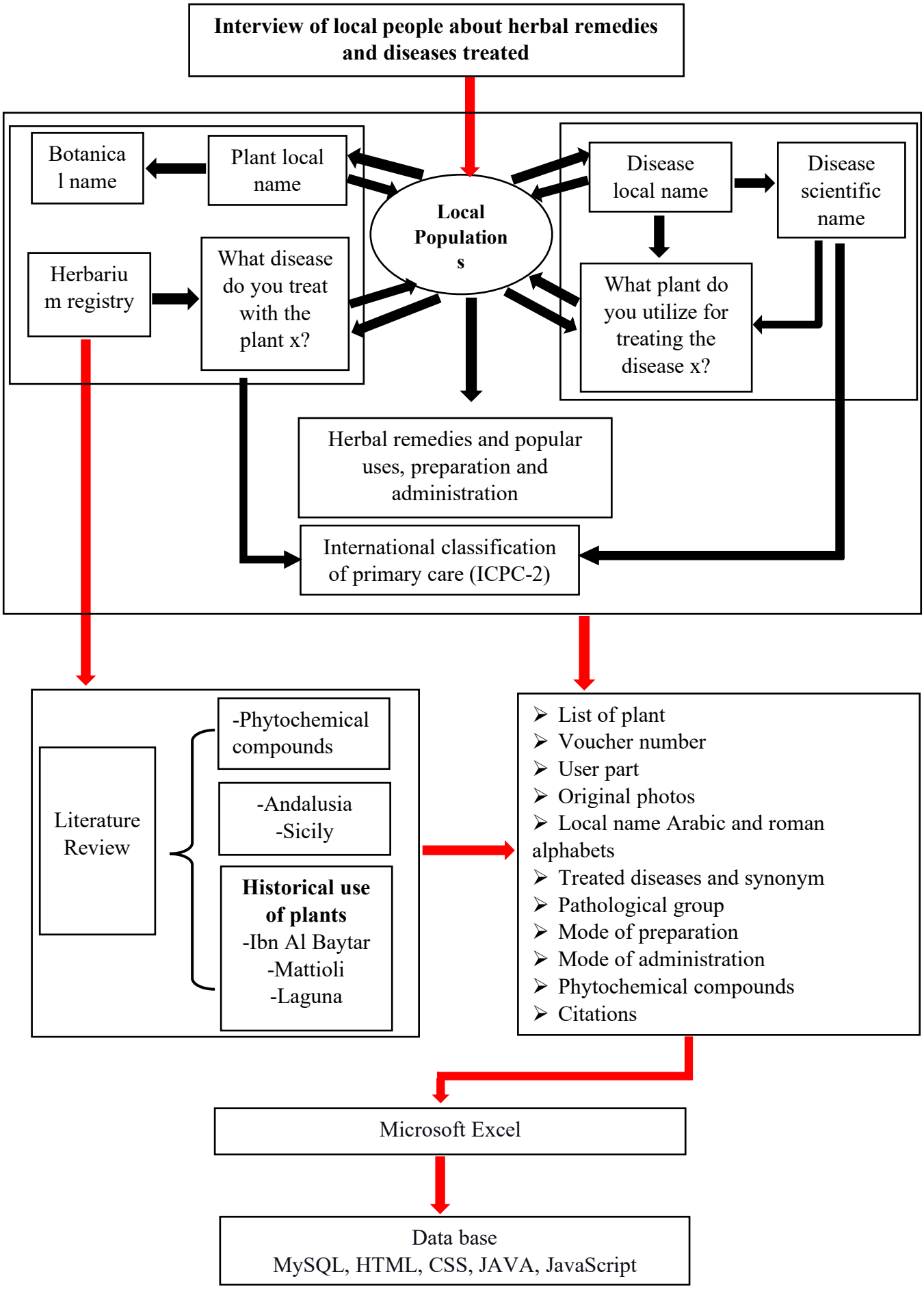
Interview of local people about herbal remedies and diseases treated
Botanical name
Plant local name
Herbarium registry
What disease do you treat with the plant x?
Local Populations
Disease local name
Disease scientific name
What plant do you utilize for treating the disease x?
Herbal remedies and popular uses, preparation and administration
International classification of primary care (ICPC-2)
Literature Review
-Phytochemical compounds
-Andalusia
-Sicily
Historical use of plants
-Ibn Al Baytar
-Mattioli
-Laguna
List of plant
Voucher number
User part
Original photos
Local name Arabic and roman alphabets
Treated diseases and synonym
Pathological group
Mode of preparation
Mode of administration
Phytochemical compounds
Citations
Microsoft Excel
Data base
MySQL, HTML, CSS, JAVA, JavaScript

Figure 7. Methodology step of database (based on previous work of Merzouki *et al.* 1997)

MySQL: is a Database Management System (DBMS) operating on Linux and Windows. SQL (Structured Query Language) is the most popular language for adding. MySQL is essential for managing large or small volumes of data. We used MySQL for its simplicity of management through the phpMyAdmin graphical interface, and for its ability to be easily interfaced (via PHP among others).
PHP is a free scripting language primarily used for producing dynamic web pages via an HTTP server, but can also function like any locally interpreted language, executing programs on the command line. PHP is an imperative language that has had complete object model features since version 5, due to the richness of its library. PHP is sometimes referred to as a platform more than a simple language.

WAMP is not in itself software, but an environment including everything necessary for local PHP development: two servers (Apache and MySQL). A script executor (PHP), as well as SQL administration (PhpMyAdmin). It has an administration interface allowing you to manage aliases (virtual folders available under Apache), and starting/stopping servers.

JavaScript: is a scripting language embedded in an HTML document. Historically, it is even the first scripting language for the web. This language is a programming language that makes it possible to make improvements to the HTML language by allowing commands to be executed on the client side, that is to say at the browser level and not the web server. Thus, the JavaScript language strongly depends on the browser calling the web page in which the script is incorporated, but in return it does not require a compiler. Unlike the Java language, with which it has long been confused. In our application it will be used most in error management.

Results and Discussion

Once the data collection work (surveys, interviews, field visits, identification of plant material, historical documentation, etc.) was completed, we planned the phase of ordering the information obtained and its transcription into computer support, creating a database with the MySQL program. The database includes tables (all interrelated), with fields. An example of relationships between fields is given in the figure 8.

The information for plant species available in the database could be accessed through the keyword search tab by assigning the scientific name or the voucher number of a specific medicinal plant. Otherwise, by exploring the botanical families regrouped in the menu list (Fig. 10).

Our medicinal plant database provides information on scientific name, family, vernacular name, vouchers, medicinal uses in PNTLS, chemical composition, The images of the plants are given in JPEG file format, and comparison with recent literature (Andalusia and Sicily), and the historical Books (Ibn al Baytar, Matthioli and Laguna). In this database we have included information on ethnopharmacological data from the terrain of PNTLS, revised data of the same plants in Eastern Andalusia and Sicily, and the uses that were made of them by Ibn Al-Baytar, Matthioli and Laguna (Fig. 10).

This format not only facilitates its processing for the analysis and discussion of the results, but also the incorporation of new subsequent data by extending the territory or integrating it into other databases.

Conclusion

The database of medicinal and aromatic plants of the PNTLS Northern Morocco encompasses 152 species used by the population of the studied region to relieve and treat multiple diseases traditionally. This group of plants was gathered through an ethnobotanical survey conducted in this region. Meanwhile, an in-depth interdisciplinary bibliographic study was carried out to fulfill all the information on this group of plants to reveal a complete scientific profile for each plant recorded, including Ethnobotany, Botany, Ecology, Pharmacology, and Phytochemistry.

Undoubtedly, this database needs more attention, and the information provided in it needs to be updated continuously. We believe that this work is the first and the only one of its kind within the Northern region and may be in the entire country since that are no databases founded in the Moroccan published literature. However, it is worth to mention that this work needs funding to be released as a website. Overall, the database can be of great support and interest to academic researchers, Medical Sciences, Environment, and Agronomy, albeit to the general public.

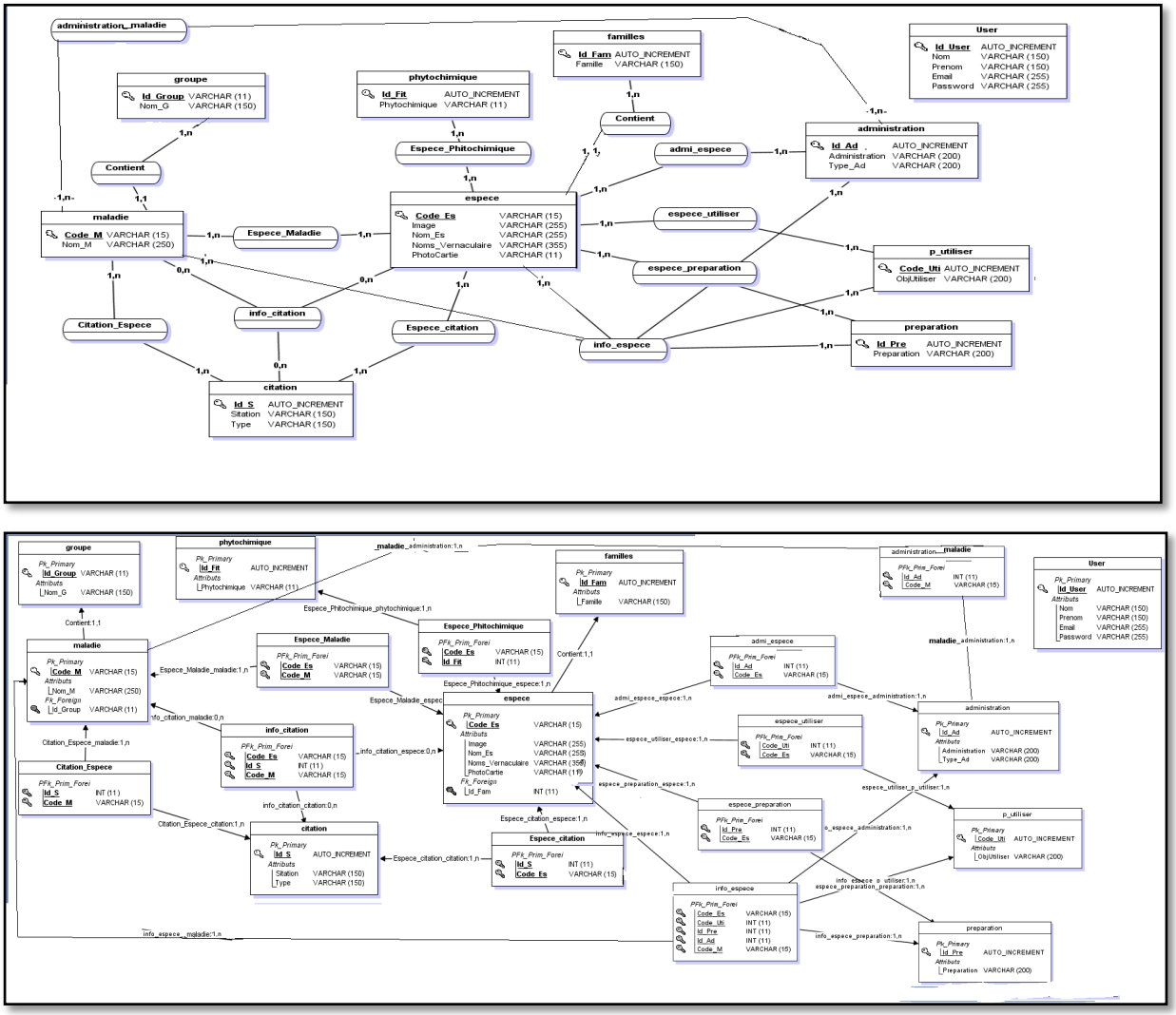

Figure 9. Diagram of relationships between different database tables (table of species in families, parts used, method of preparation, method of administration, diseases treated, phytochemistry, use cited by (Ibn Al Baytar, Matthioli, Laguna), use cited in Andalusia and Sicily)

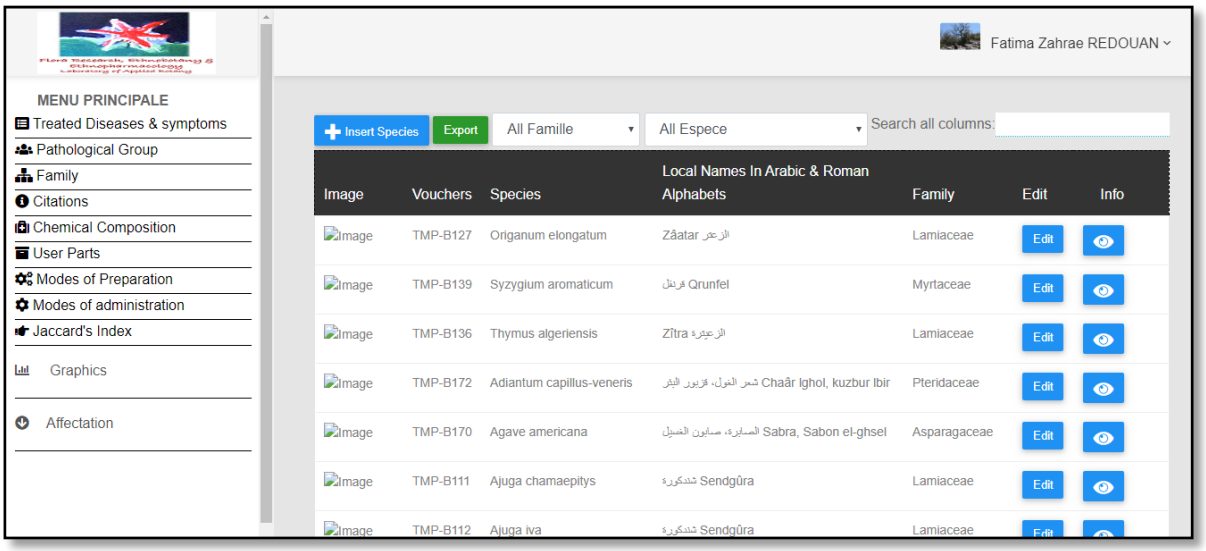

Figure 10. Menu principal interface of Database and list of plant species per botanical family

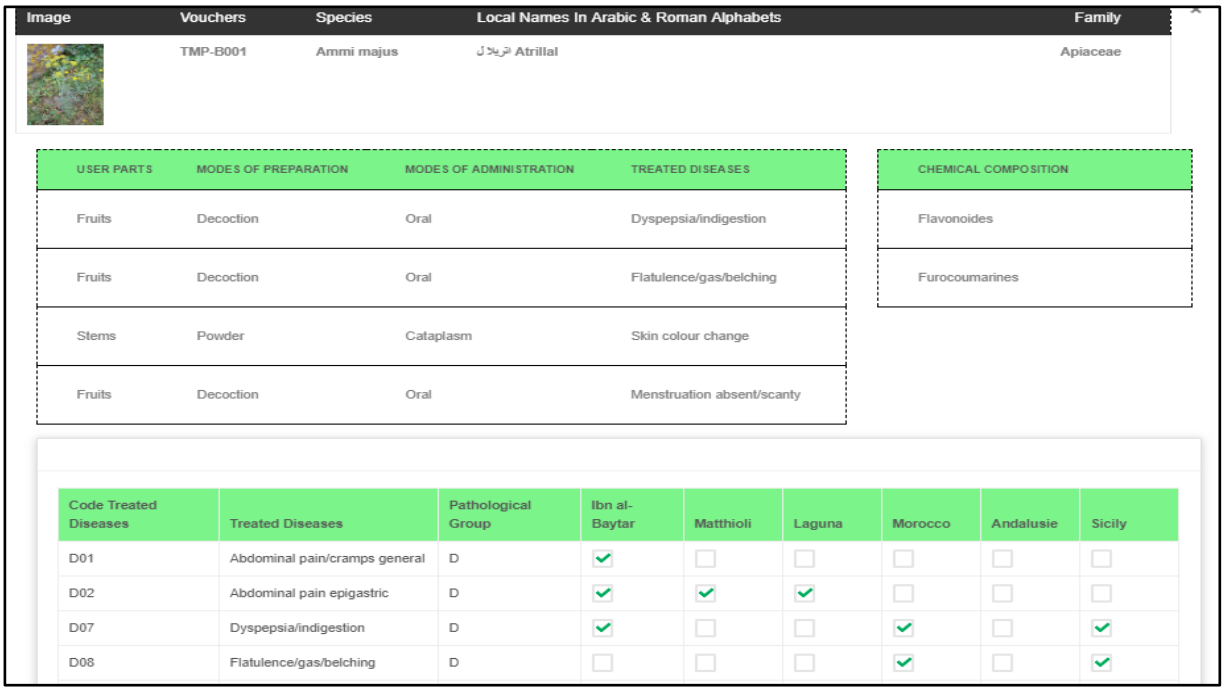

Image	Vouchers	Species	Local Names In Arabic & Roman Alphabets	Family
	TMP-B001	Ammi majus	الترياك Atrillal	Apiaceae

USER PARTS	MODES OF PREPARATION	MODES OF ADMINISTRATION	TREATED DISEASES
Fruits	Decoction	Oral	Dyspepsia/indigestion
Fruits	Decoction	Oral	Flatulence/gas/belching
Stems	Powder	Cataplasm	Skin colour change
Fruits	Decoction	Oral	Menstruation absent/scanty

CHEMICAL COMPOSITION
Flavonoides
Furocoumarines

Code Treated Diseases	Treated Diseases	Pathological Group	Ibn al-Baytar	Matthioli	Laguna	Morocco	Andalusie	Sicily
D01	Abdominal pain/cramps general	D	✓					
D02	Abdominal pain epigastric	D	✓	✓	✓			
D07	Dyspepsia/indigestion	D	✓			✓		✓
D08	Flatulence/gas/belching	D				✓		✓

Figure 11. Scientific information for each plant species provided by Database (Example: *Ammi majus* L. (Apiaceae))

Declarations

List of abbreviations: PNTLS: Park National Talassemtane

Consent for publication: Not applicable.

Availability of data and materials: All the data are presented in figures, tables and appendix in the manuscript and are available with the corresponding author.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: **Fatima Zahrae Redouan:** Conducting field surveys of the work, Drafting the work, Analysis and interpretation of data for the work, Corresponding author and submission. **Cheikh Yebouk, Ghizlane Merzouki, Rachid Ouhtit**: Participated in the drafting of work, Analysis and interpretation of data for the work.

Alessandro Crisafulli, Rosa Maria Picone, Gaetano Gargiulo Maurizio: Revising the content.

Abderrahmane Merzouki: Drafting and conception and design of the work, Revising and critically of the content; Final approval of the version to be published.

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