Ethnobotany in Morocco from 1990 to 2023: Part I - A critical analysis of researchers' contributions, bibliometric, methodological attributes, and the socio-demographic characteristics of the surveyed population

Khadija Benamar, Kawtar Benelfakir, Saad Benamar

Correspondence

Khadija Benamar[1]*, Kawtar Benelfakir[2], Saad Benamar[2]

[1]Microbial Biotechnology and Bioactive Molecules Laboratory, Sciences and Technologies Faculty, Sidi Mohamed Ben Abdellah University, P.O. Box 2202, Imouzzer Road, Fez, Morocco.
[2]High School Teachers-Training Institution, Laboratory of Scientific Innovation in Sustainability, Environment, Education and Health in the era of AI, Sidi Mohamed Ben Abdellah University. P.O. Box 5206 Bensouda, Fez, Morocco.

* Corresponding Author: Khadija.benamar2@usmba.ac.ma

Ethnobotany Research and Applications 33:18 (2026) - http://dx.doi.org/10.32859/era.33.18.1-18
Manuscript received: 05/01/2026 – Revised manuscript received: 26/01/2026 - Published: 31/01/2026

Review

Abstract

Background: Medicinal and aromatic plants (MAPs) have traditionally been used in Morocco's folk medicine, reflecting the strong cultural and biodiversity background of this country. The present work aims to analyze ethnobotanical research that has been carried out about MAPs use in traditional medicine in Morocco since 1990, with a particular emphasis regarding the scope, methods and data quality.

Methods: A bibliometric and methodological analysis was performed regarding ethnobotanical studies published between 1990 and 2023. Data were gathered from various scientific databases, and analyzed descriptively for publication trends, authorship, institutional contributions, study methods and surveyed populations. International collaboration was analyzed using VOSviewer (v.1.6.20), generating a full-counting country co-authorship network with modularity-based clustering. To perform the networking institutional collaborations map we used the open-source Geographical Information System software QGIS 3.38.2

Results: Ethnobotanical studies conducted in Morocco are characterized by an increase since 2018 and are predominantly undertaken by Moroccan researchers and institutions. Surveys using interviews and questionnaires (69 %) prevail over reviews. Most publications are in English (83 %) and are concentrated in high-impact journals indexed in Scopus and ScienceDirect. However, there are gaps in the reported studies, such as duration of studies, informant demographics and statistical methods. Most informants and MAPs users are women, showing their central role in traditional knowledge transmission.

Conclusions: This review summarizes the growing interest in Moroccan ethnobotany, emphasizing methodological quality and reporting deficiencies. The findings encourage improved rigor and standardized data reporting to support ethnopharmacological development.

Keywords: Ethnobotany; Moroccan Traditional medicine; Knowledge transmission

Background

Since ancient times, many civilizations have used nature, mainly plants, as a source of medicinal treatments (Fakchich and Elachouri, 2021). Until today, a large proportion of the world's population, particularly in developing countries use medicinal and aromatic plants (MAPs) to meet their basic medical needs. In fact, the World Health Organization (WHO) estimates that 80% of the world's population still benefits from herbal traditional medicine (Bachiri *et al.* 2015; Kachmar *et al.* 2021), as accessible and affordable way, and because there is a strong belief in the healing properties of herbal remedies (Fakchich and Elachouri, 2021; Ouarghidi *et al.* 2013). Herbal medicine is rooted in the cultural heritage of populations and is regularly practiced and transmitted from generation to generation over time (Kachmar *et al.* 2021).

In Morocco, the use of MAPs in folk medicine is widely spread. This developing country lies at the crossroads between Africa, Europe and the Middle East, giving it an important strategic position. Over the centuries, this position has attracted many different peoples and civilizations, all of whom have left their cultural imprint on the country. Among the civilizations that have left their mark on Morocco, include the Berbers, who were the indigenous inhabitants of this country before the arrival of Arabs. Morocco was also influenced by the Phoenicians, Punics, Romans and Jews, who lived in the country for centuries. These successive cultural layers have contributed to the transmission and enrichment of traditional botanical knowledge. All these cultural influences have helped to create a mosaic of different cultures, making Morocco a country which benefits from an extremely rich and diversified cultural heritage that includes traditional phytotherapy knowledge (Bellakhdar *et al.* 1991).

This ancestral know-how to use plants in the treatment of different ailments is supported by the presence in Morocco of a high degree of biodiversity, particularly a wide variety of medicinal plants. In fact, Morocco is a North African country bordered by the Atlantic Ocean to the west and the Mediterranean Sea to the north. The landscape is diversified, with mountains (the Atlas Mountains) running from southwest to northeast, and coastal plains to the west. The climate is varying, from hot, dry deserts in the south, to cool, wet winters in the north. This diversity of its climate creates an appropriate environment for an abundant and diverse flora, characterized by 3913 species and 1298 subspecies, belonging to 155 families and 981 genera, as well as 640 endemic species (Jamaleddine *et al.* 2017). Such floristic richness forms the foundation of the country's ethnobotanical traditions.

To illustrate and document the use of MAPS in folk medicine in Morocco, several ethnobotanical studies have been carried out in this context. Thus, the main objective of this study is to analyse in terms of scope, progress, methodology and data collected, the ethnobotanical research carried out regarding MAPs used in traditional phytotherapy in Morocco and published since 1990. Furthermore, the study seeks to evaluate the quality of reporting, assess the methodological consistency across publications, and identify gaps or biases in data collection. We aim also at highlighting the methodological strengths and weaknesses of the publications analysed.

Materials and Methods

Data collection

In order to perform an analysis of ethnobotanical research carried out in Morocco, in terms of scope, progress, methodology and data collected, articles published in this context were selected using different databases, namely Google Scholar, Scopus, Science Direct, Springer, Web of Science, JSTOR and Pub Med. The inclusive and exclusive criteria were characterized by the limitation of selected articles to the years of publication between 1990 and august 2023. This date (1990) was chosen as it represents the starting point for modern ethnobotanical studies in Morocco.

Concerning the language of publication, only articles published in English and French were included in our analytical study. The key words used for the bibliographic research were: "ethnobotanique Maroc", "plantes médicinales Maroc", "usages traditionnels des plantes Maroc", "enquête ethnobotanique", "ethnopharmacologie", "ethnomédecine", "pharmacopée traditionnelle et Maroc"."Medicinal plants of Morocco", "Traditional uses of plants in Morocco", "Ethnobotanical survey ", "Ethnopharmacology", "Ethnomedicine", "Traditional pharmacopoeia and Morocco".

Statistical analysis

The collected data were processed and analyzed using descriptive statistics. Inferential or multivariate analyses (more sophisticated statistical techniques) were not used given the type of data. The work was based on information extracted from previously published articles which do not meet the requirements for such statistical techniques. Thus, the study relies on calculating frequencies, percentages, and distributions so that to emphasize the general tendency and pattern in the ethnobotanical research carried out in Morocco

Results and Discussion

Ethnobotanical studies in Morocco since 1990: progress in relation to the national contributions of researchers and universities

Since 1990, ethnobotanical research in Morocco has experienced significant development, largely driven by the growing involvement of national researchers and universities, whose contributions have played a central role in structuring and expanding this scientific field.

Quantitative progress of ethnobotanical studies in Morocco since 1990

One of the relevant indicators for answering one of the main research questions of this work, estimating the evolution of interest of national and international scientific community to Morocco's ethnomedicinal heritage over the last three decades, is the annual number of publications of ethnobotanical studies carried out in Morocco. The data in Figure 1 show a significant increase in this indicator between 1990 and 2023 and allow us to distinguish two phases in its evolution: a fluctuation from 1990 to 2017 and an exponentially increasing from 2018 to 2023. This remarkable increase in the number of publications reflects the growing number of researchers carrying out research on Morocco's ethnobotanical heritage. But could the high number of publications also be explained by the multiplicity of publications by each author?

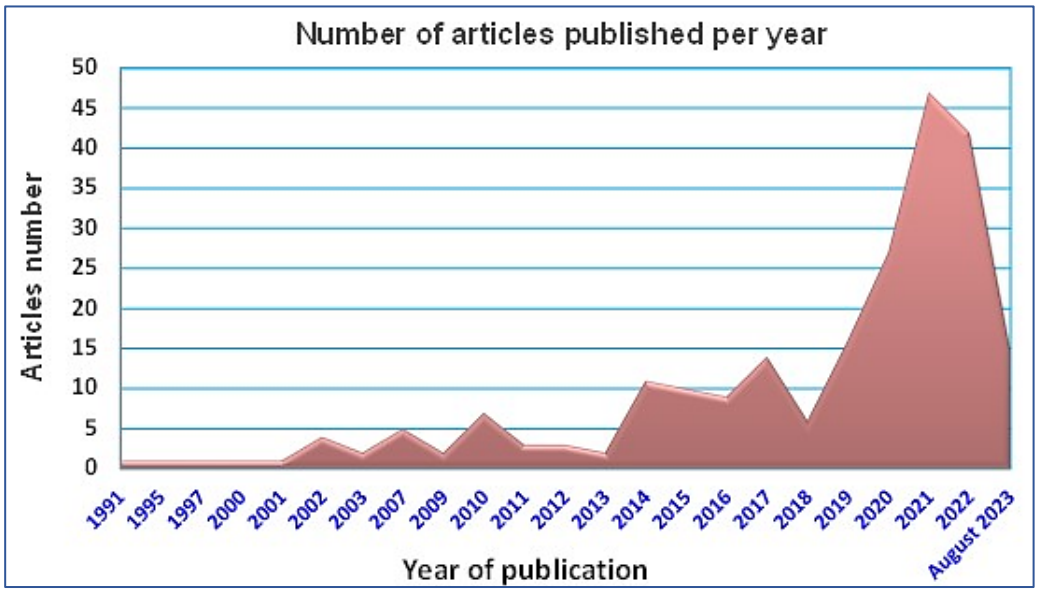

Figure 1. Number of articles published per year from 1990 to 2023

Multiple contributions from authors to the studied publications

The data in Figure 2 help to answer the question posed at the end of the previous paragraph (Fig. 1). They show that 69.47 % of authors have published one article on the ethnomedicinal use of MAPs in Morocco. The Other authors showed greater interest in this type of study, publishing 2 articles (15.42 %) or more: 3, 4, 5, 6 to 32 articles (7.02, 2.75, 1.68, and 4.12 %, respectively). Table 1 presents examples of publications of authors having published 2 to 7 articles. These results demonstrate the significant involvement of these authors in the conservation of Morocco's ethnobotanical medicinal heritage.

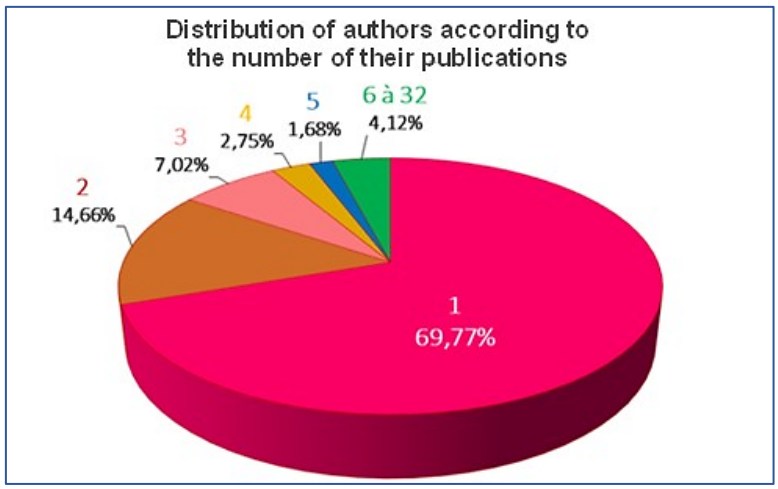

Figure 2. Distribution of authors according to the number of their publications

Table 1. Examples of publications of authors having published 2 to 7 articles.

Number of articles published by the author	Author (References)
2	**-Ait-Haj-Said A** (Arrout *et al.* 2022; Bourhia *et al.* 2019) **-Ajebli M** (Ajebli *et al.* 2019; Eddouks *et al.* 2017) **-Amrati F** (Amrati *et al.* 2021; Slighoua *et al.* 2020)
3	**-Aanniz T** (El Menyiy *et al.* 2021; El Omari *et al.* 2021; Taha *et al.* 2022) **-Aboufaras M** (Aboufaras *et al.* 2023; Aboufaras *et al.* 2022; Aboufaras *et al.* 2021) **- Benkhaira N** (Benkhaira *et al.* 2021a; Benkhaira *et al.* 2021b; El Hachlafi *et al.* 2022) **- Bouiamrine E** (Bouiamrine *et al.* 2017; Najem *et al.* 2019; Najem *et al.* 2018) **-Bouissane L (**Khatib *et al.* 2023; Khatib et al.,2022)
4	**-Chamkhi I** (Bouyahya *et al.* 2021; Bouyahya *et al.* 2020; El Menyiy *et al.* 2021; El Omari *et al.* 2021) **- Cherifi K** (Abouri *et al.* 2012; Idm'hand *et al.* 2020a; Idm'hand *et al.* 2020b Idm'hand *et al.* 2019)
5	**-Alami-Merrouni I** (Ajjoun *et al.* 2022; Alami-Merrouni *et al.* 2021a; Alami-Merrouni *et al.* 2021b; Bencheikh *et al.* 2021; Kharchoufa *et al.* 2018) **- Boubaker H** (Abouri *et al.* 2012; Barkaoui *et al.* 2022a; Barkaoui *et al.* 2022b; Barkaoui *et al.* 2017; Ouhaddou *et al.* 2014) **- Fakchich J** (Bencheikh *et al.* 2023; Elachouri *et al.* 2021; Fakchich *et al.* 2022; Fakchich and Elachouri, 2021; Fakchich and Elachouri, 2014) **- Guaouguaou FE** (Bouyahya *et al.* 2021; Bouyahya *et al.* 2020; El Menyiy *et al.* 2021; El Omari *et al.* 2021; Khouchlaa *et al.* 2021) **- Mesa JM** (Benítez *et al.* 2021; El-Gharbaoui *et al.* 2017; Merzouki *et al.* 2000; Redouan *et al.* 2020a; Redouan *et al.* 2020b).
6	**- Teixidor-Toneu I** (Montanari and Teixidor-Toneu I, 2022).
7	**-Eddouks M** (Ajebli *et al.* 2019; Eddouks *et al.* 2017; Eddouks *et al.* 2009; Eddouks *et al.* 2007; Eddouks *et al.* 2002; Jouad *et al.* 2001; Khallouki *et al.* 2017) **- Kahouadji A** (Chebat *et al.* 2014; Hseini and Kahouadji, 2007; Hseini *et al.* 2007; Khouchlaa *et al.* 2017; Lahsissene and Kahouadji, 2010a; Lahsissene and Kahouadji, 2010b; Mehdioui and Kahouadji, 2007) **- Ouhammou A** (Ghanimi *et al.* 2022a; Ghanimi *et al.* 2022b; Ghanimi *et al.* 2022c; Teixidor-Toneu *et al.* 2021; Teixidor-Toneu *et al.* 2017; Teixidor-Toneu *et al.* 2016a; Teixidor-Toneu *et al.* 2016b) **-Rochdi A** (Akka *et al.* 2016 ; Bachar *et al.* 2021; Bachar *et al.* 2016; Benkhnigue *et al.* 2010; Benlamdini *et al.* 2014 ; Hachi *et al.* 2016 ; Tahrı *et al.* 2012)

In addition, the information presented in Figure 3 also show the authors' strong commitment to this type of study. Indeed, 19.2% of authors have contributed to the publication of an ethnobotanical study as 1st author, 20.2% as 2nd author, while 80.50% of authors have not been last authors in any article (Fig. 3). This shows the great motivation of the authors to complete a good contribution to these ethnobotanical studies in Morocco.

Furthermore, it is important to note that these ethnobotanical scientific productions are the result of efforts deployed by not only Moroccan researchers but also by their colleagues from a numerous worldwide country (fig. 4). The question then arises as to whether these efforts are also the fruit of commitment of academic institutions? And if so, what is the contribution of institutions particularly national universities?

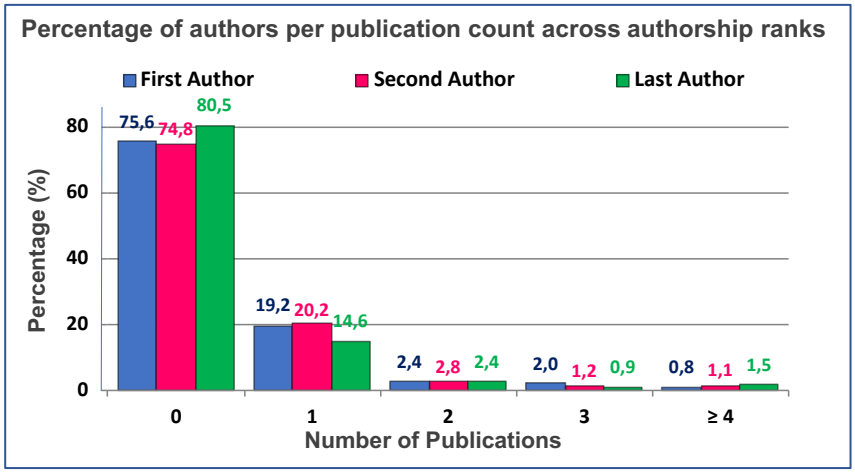

Figure 3. Distribution of authors by publication count and authorship position

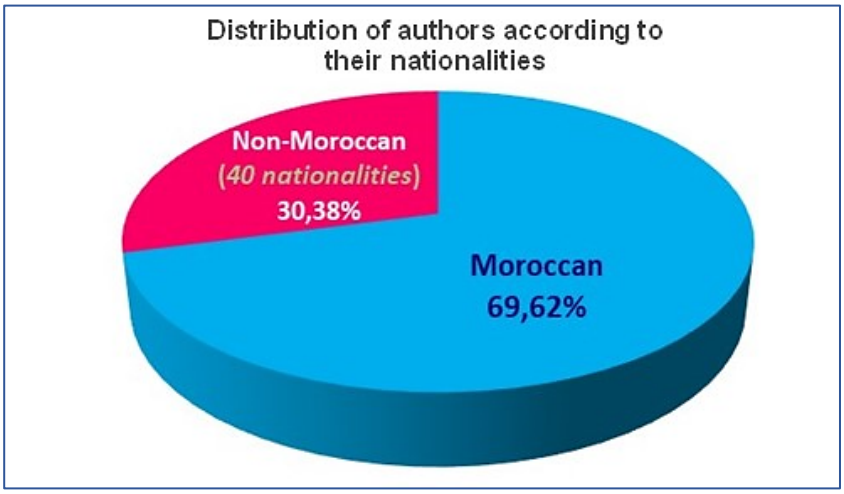

Figure 4. Distribution of authors according to their nationalities

University and research institutions contributions to the published ethnobotanical studies

The map (Fig. 5) illustrates the global distribution of countries whose research institutions have published articles on Moroccan ethnobotany. It highlights the strong international interest in this field, reflected by contributions originating from 40 countries across all five continents (Africa, Europe, Asia, the Americas, and Australia). European countries, in particular, exhibit a high involvement, revealing their ongoing academic collaboration and research patterns in ethnobotanical investigations. Meanwhile, important contributions from African, Asian, American, and Oceanian institutions indicate that Moroccan ethnobotany extends far beyond regional or continental limits. The strong geographic spread of contributing countries indicates that Moroccan ethnobotany is a research area of international importance.

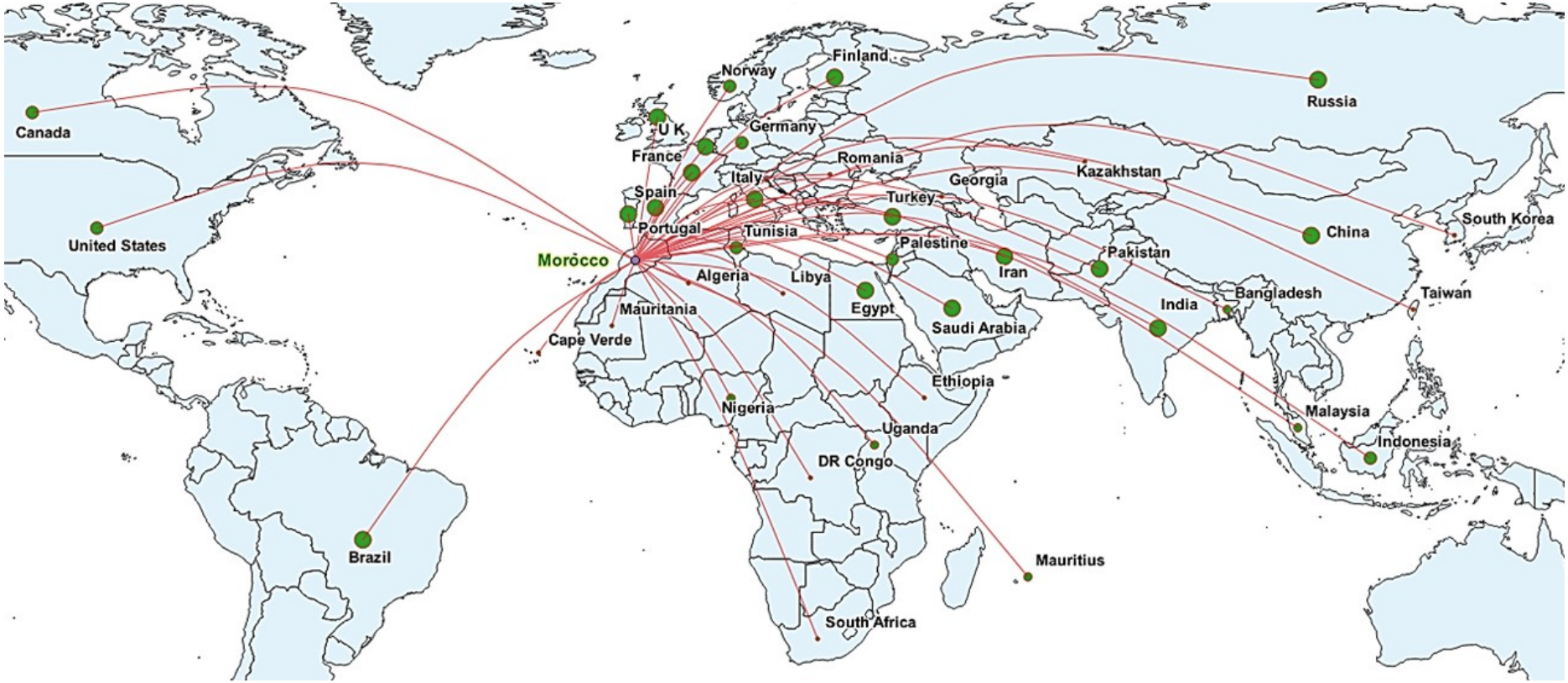

Figure 5. Map showing the geographical distribution of countries whose research institutions have contributed to the analyzed publications on Moroccan ethnobotany. The size of the points on the map is proportional to the number of publications from institutions in each country relative to the total number of publications analyzed.

The analysis of the co-authorship network using VOSviewer (Fig. 6) identified five separate collaboration clusters that are indicative of the structure and dynamics of global research collaborations in Moroccan ethnobotany. Morocco is a central and highly influential node, sharing very strong direct relationships with Western European countries (France, Spain, Italy, and Portugal) as well as Middle Eastern partners, including Saudi Arabia and Egypt. The precisely central location on this map is symbolic of the key bridging role that Morocco plays as a connector of research activity between Europe, the Middle East, and, to some extent, Africa. A second cluster is led by Western European countries such as France, Spain, Italy, Belgium, Germany, and the Netherlands, and is characterized by dense intra-European collaborations that reflect long-standing academic relationships and geographical proximity. A third cluster combines Middle Eastern and North African countries (Saudi Arabia, Egypt, Iran, and Turkey), which show frequent connections with Morocco, denoting the relevance of regional and South–South collaborations, probably driven by shared research priorities. The 4th cluster corresponds to an emerging Asia–Pacific network, with China, Australia, Pakistan, and Bangladesh, as the core countries connected to more peripheral nodes, indicating that the research network is increasingly becoming global in scope beyond traditional Euro-Mediterranean relationships. Finally, a few peripheral countries (e.g., Congo, and Kazakhstan) feature relatively poor connectivity, meaning that these relationships are occasional or project-oriented collaborations rather than sustained scientific partnerships.

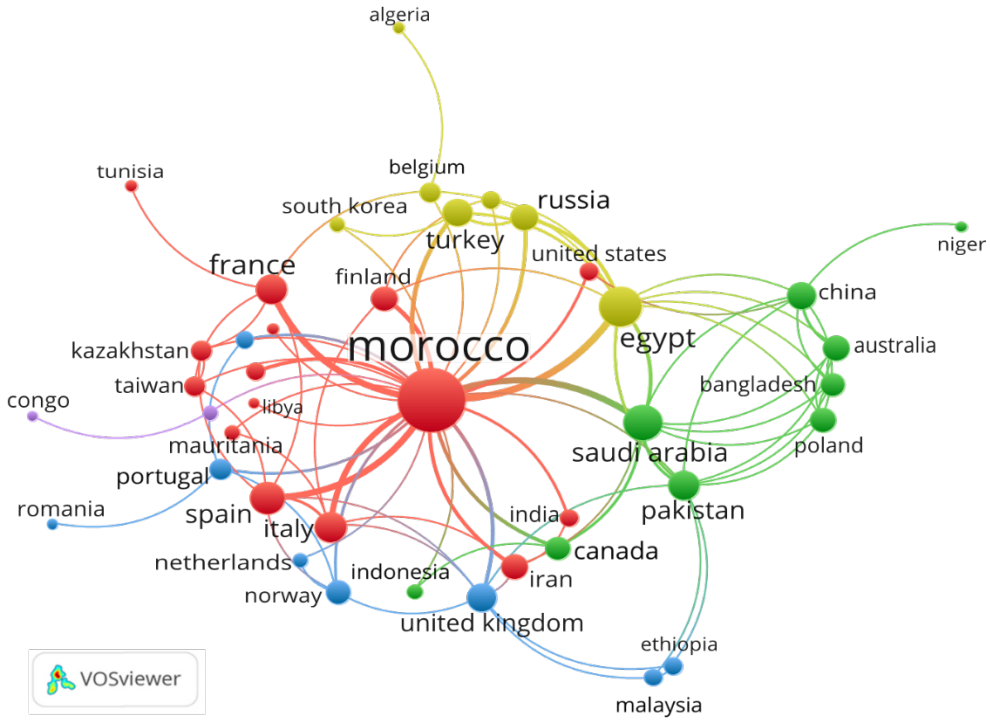

Figure 6. Network visualization of collaborations carried out in the studied ethnobotanical articles among countries worldwide.

Furthermore, Figure 7 reveals the importance of the contribution of different universities and research institutions to the publications analyzed in our work.

It clearly appears contribution dominance of 5 Moroccan universities to the analyzed ethnobotanical studies with at least 20 published articles, and a total contribution of 37.13%; Ibn Tofail and Sidi Mohamed Ben Abdellah Universities (44 articles; 9.28%), Mohamed V University (41 articles; 8.65%), Moulay Ismail University (27 articles; 5.70%) and Mohamed I University (20 articles; 4.22%). The other universities present a less contribution, with a maximum published articles of 20, and they are dominated by Moroccan Universities; Cadi Ayyad University (19 articles), Abdelmalek Essadi and Hassan I Universities (18 articles), Ibn Zohr University (14 articles), then Saudi University: King Saud University (11 articles).

Bibliometric attributes of the studies analyzed

The bibliometric attributes of the analyzed studies provide an overview of their publication patterns as well as scientific visibility, accessibility, and academic impact.

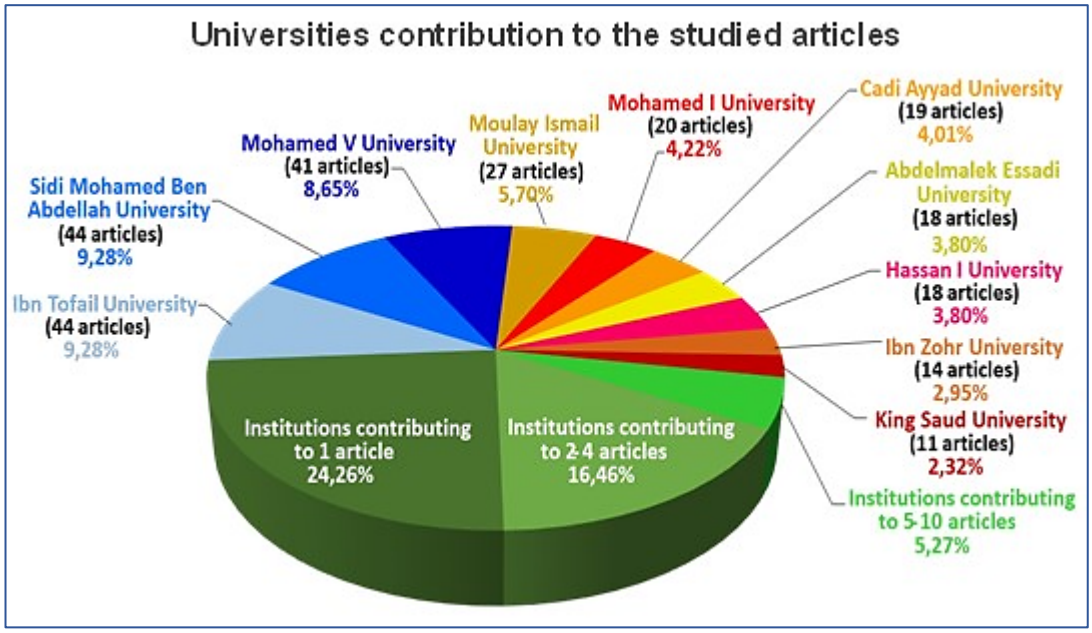

Figure 7. Contribution of universities to the publications studied

Journal Indexing Databases and Quality Distribution

Journal indexing databases reveal the quality of publications. It was therefore interesting to know the distribution of the analyzed studies on different indexing databases (Scopus, ScienceDirect, Springer, Web of Science, Pub Med, Jstor and Google Scholar).

Figure 8 shows the high contribution of Scopus-indexed journals (31.74%), followed by those indexed in ScienceDirect (23.48%), then those indexed in three databases with almost similar contributions, namely Springer (13.91%), PubMed (12.61%) and Google scholar (10.43%). The contribution of journals indexed in Web of science and Jstor is much more modest (5.65 and 2.17 %, respectively). These indexing databases present several articles from various journals. The question is whether there is a correlation between the contribution of indexing databases and the frequency of ethnobotanical publications in certain journals?

To delve deeper, Figure 8 also aims to provide an overview of journal quality and their distribution across different indexing platforms. Indeed, it indicates the predominance of high-impact journals, as revealed by their classification in high-ranked journals; Q1 (41%). Journals with undetermined quartile are also dominant (25%), which reflects newer or non-ranked journals. Moreover, we note a decrease in ethnobotanical studies published in journals with lower ranks, as presented by low percentages (19%) in Q2, 5% in Q3, and 10% in Q4.

Furthermore, Figure 8 shows the distribution of articles according to the indexing database and journal quartile. Of particular note, Scopus and ScienceDirect hold a high proportion of Q1 journals, maintaining these databases as sources of quality content. Scopus also contains a high proportion of Q2 journals, as well as Q3, Q4, and non-ranked journals. In contrast, Google Scholar is dominated by non-ranked journals, possibly reflecting their low scientific robustness. Although Web of Science and PubMed are less represented, they are characterized by a high proportion of Q1 journals. These findings provide evidence that the databases Scopus and ScienceDirect host not only a great number of articles but also a high proportion of Q1 journals, reinforcing their robustness in ethnobotanical investigations. On the other hand, databases like Google Scholar and Jstor offer broader accessibility, but they index a wider diversity in journal quality, including a significant proportion of non-ranked journals.

Distribution of journals according to the number of published papers per journal

Figure 9 shows that journals which published one or two ethnobotanical studies are the most preponderant (83.33 %). However, 16.67 % of journals have published from three to forty articles in ethnobotanical specialized journals. This distribution demonstrates how ethnobotanical research is extremely dispersed among many journals, the vast majority of which have published only one or two articles. A few journals (16.67%) show sustained interest in the topic, publishing more

than one article, suggesting that while ethnobotanical research is growing, it lacks strong concentration in a limited number of specialized journals.

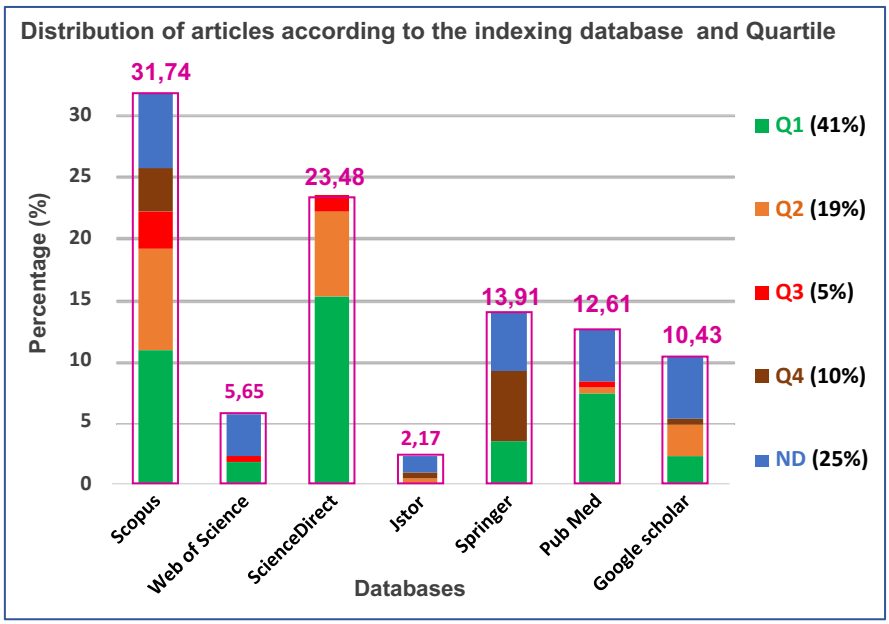

Figure 8. Distribution of articles according to the indexing database and quartile; ND: not determined; The percentage shown in parentheses to the right of the quartile legends represents the total percentage of the analyzed articles belonging to that quartile.

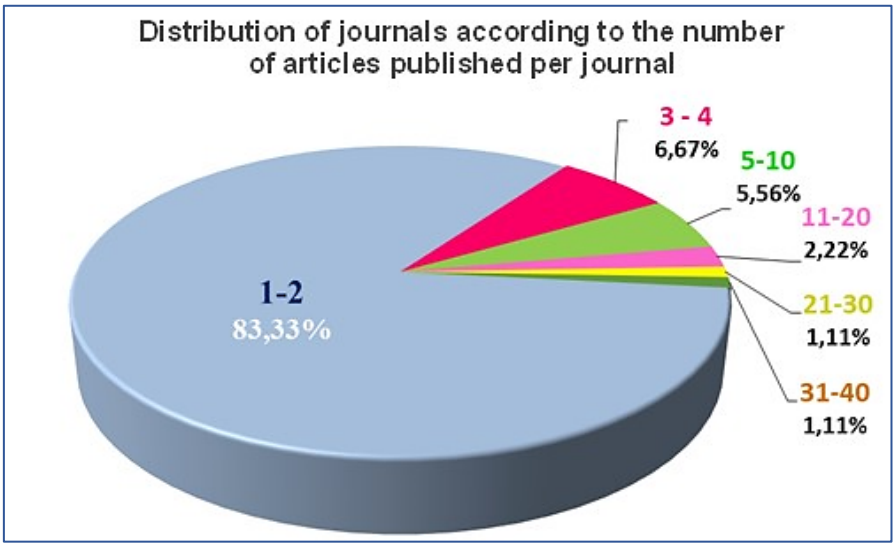

Figure 9. Distribution of journals according to the number of published papers per journal.

General characteristics of studied articles

Figure 10 illustrates general characteristics of studied articles, namely, the language of publication, study type, and data collection method.

Indeed, it appears that articles in English constitute the vast majority (83%), followed by articles written in French (17%). This pattern reflects an overall predominance of English as the language of scientific exchange in the area of ethnobotany, which might be related to more extensive international spreading as well as to higher visibility and accessibility in global databases. The smaller proportion of French publications may also be due to regional or national dissemination, which, although important, can reduce the global readership and impact of such studies.

Moreover, Figure 10 indicates the dominance of surveys (69.1%) in comparison with reviews (30.9%). These findings explain the frequent use of questionnaires (61%) and interviews (34%) as methods for data collection (Fig. 10).

Furthermore, this figure highlights the quality of the analysed ethnobotanical studies from a methodological point of view, since it reveals the prevalence of Direct methods for data collection through surveys. However, it's important to realize if the collected data are subjected to standards of scientific rigor required.

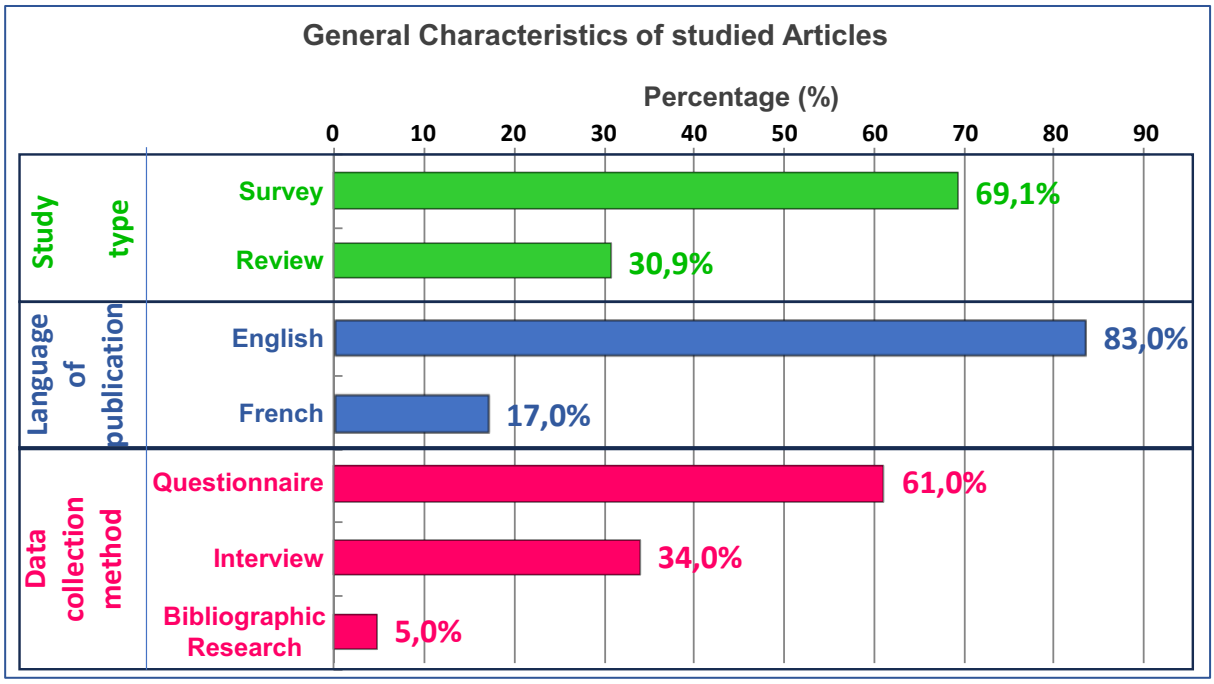

Figure 10. General characteristics of studied articles; Study type, language of publication and data collection method.

Methods of data processing

Figure 11 represents statistical methods used in the studies selected in our work. It appears that descriptive statistics are the most prevalent (80.00%) in comparison with analytical statistics (20%). Moreover, analyse of variance (ANOVA) is used more frequently (10.43 %) in comparison with ACP/ACM (2.61%).

Due the importance of analytical statistics in the relevant exploitation of research data in all scientific fields, the obtained results underline the need of ethnobotanical publications improvement through greater use of analytical statistics (Leonti, 2022).

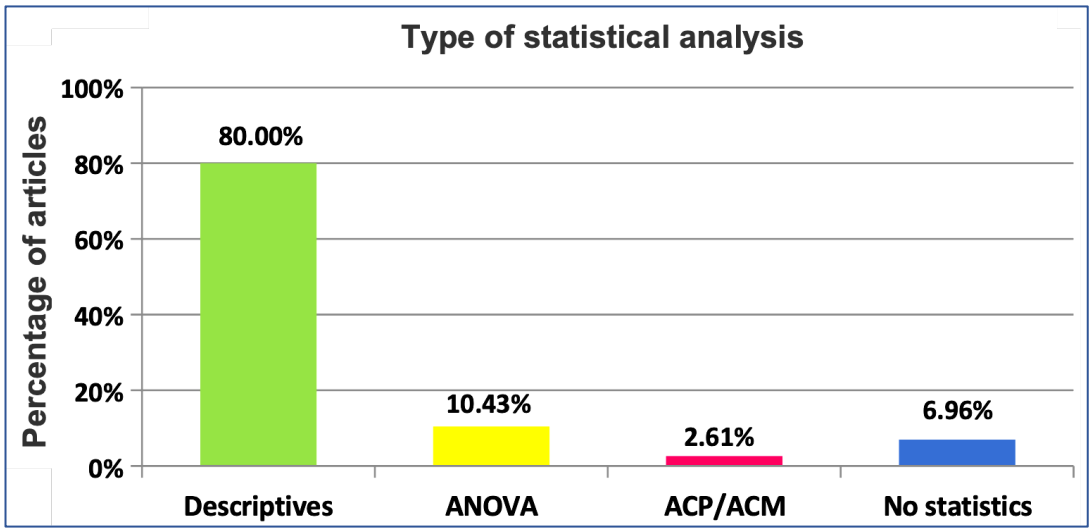

Figure 11. Statistical methods used for data processing on the selected articles.

Study duration

Another indication of ethnobotanical studies quality is the time devoted to their completion. Figure 12 shows that analysed ethnobotanical studies were conducted in different durations, varying from less than three months (4%) to more than one year (32%). These results highlight therefore the importance and the colossal amount of work devoted to most of the conducted studies. However, in 37% of selected articles, the study duration was not mentioned, which reflects a defect and a lack in collection data presentation section of these studies.

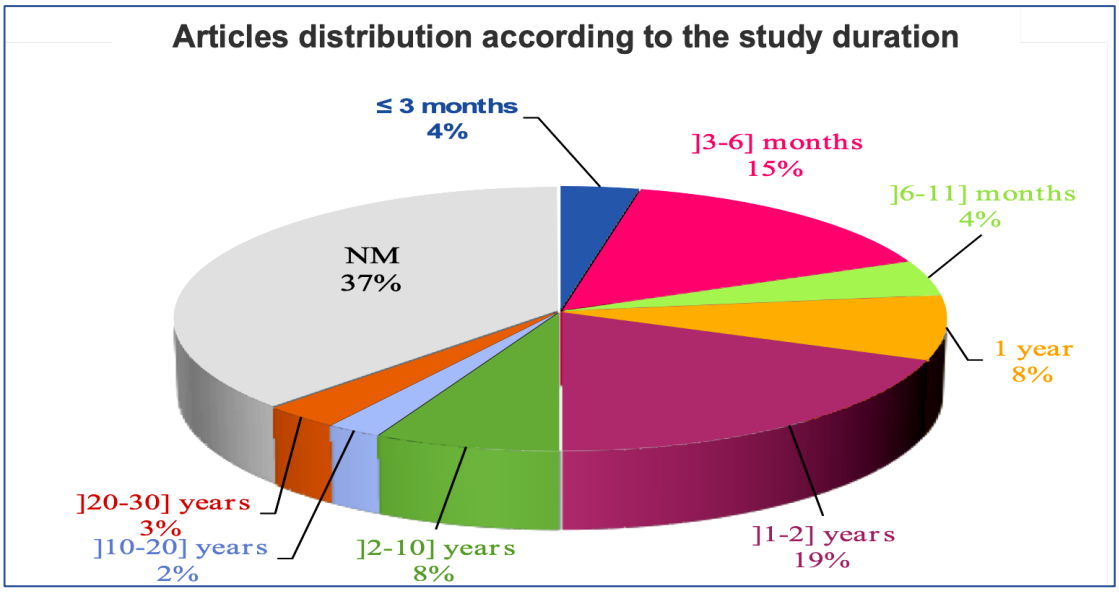

Figure 12. Articles distribution according to study duration; NM: not mentioned.

Geographical scope of studies

Another important parameter of the performed ethnobotanical studies is the geographical zone they have concerned. Data presented in figure 13 show that most of ethnobotanical studies were performed either in one city (29 %) or in one administrative region (19 %), whereas few ethnobotanical studies have been dedicated to more than one city, or more than one administrative region (5% and 2%, respectively). Moreover, it appears that high mountains were also concerned by an important number of ethnobotanical studies (11%). Indeed, it was claimed that rural communities and areas far from cities are characterized by a more use of herbal remedies than civilized areas where the access to hospitals and the consumption of pharmaceutical medicines is more emerging (Abouri *et al.* 2012). Thus, further ethnobotanical studies in more rural areas will be of a great interest for the development of ethnopharmacology.

Besides, it's noticed that in 22% of analysed studies, the geographical areas were not mentioned. In fact, these studies lie on reviews declaring the ethnomedicinal use of different plants species by Moroccan people, without indicating their living areas.

Characteristics of the surveyed population

Articles distribution according to the number of all informants

Figure 14 gives an insight on the study sample size of the analyzed ethnobotanical studies. Indeed, most surveys have included more than 100 informants (52.61 %). This percentage involves 35.22 %, 12.61 % and 4.78 % of studies characterized by 101 to 500, 501 to 100 and 1001 to 3151 of informants, respectively. As regard studies with a low number of informants (not exceeding 100), they represent a low percentage (10.87 %). Studies targeting a high number of informants were probably conducted in a long time period and concerned wide geographical zones.

Furthermore, Figure 14 reveals that in 36.52 %, the number of informants was not indicated, which doesn't comply with an appropriate presentation of ethnobotanical studies results.

The next obvious question is: what proportion of the study samples are women?

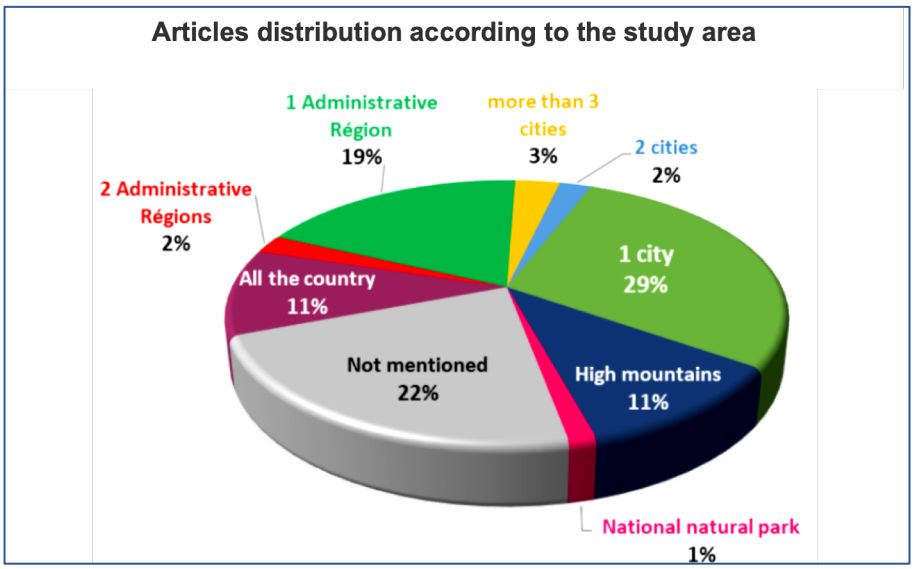

Figure 13. Articles distribution according to the study area.

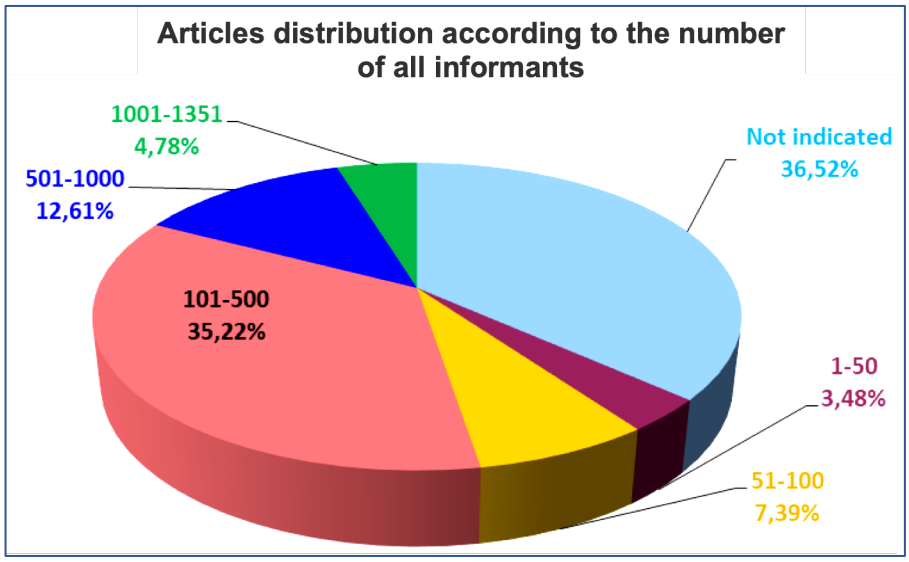

Figure 14. Articles distribution according to the number of all informants

Articles distribution according to the percentage of women informants

Figure 15 shows that the answer to the question posed at the end of the previous paragraph can only be partial, since in almost half of the studies (49%), respondents' gender is not specified.

However, it should be noted that in the other half of articles, the major proportion (27%) of articles is characterized by the dominance of women informants (51-75%), which reveals the interest attributed to interviewing women, in view of their attachment to herbal medicinal recipes, as well as their important role in preserving the ethnomedicinal heritage (Bencheikh *et al.* 2021).

The question that arises is what is the proportion of respondents using MAPs in the analysed studies?

Proportion of informants using MAPs and their gender

As showed in Figure 16, the precision of informants using MAPs percentage is lacking in a significant proportion (71.30 %) of articles. This result gives us only a partial answer to the question posed at the end of the previous paragraph. Moreover, a high proportion of informants using MAPs (84.37 %) is revealed in the articles specifying the rate of MAPs use by respondents. Furthermore, among respondents using MAPs, women represent the majority (52.33 %), which reflects the attachment of women to their traditional heritage regarding the use of MAPs as remedies for different ailments, and their more knowledge on herbal therapeutical recipes than men (Jeddi *et al.* 2021).

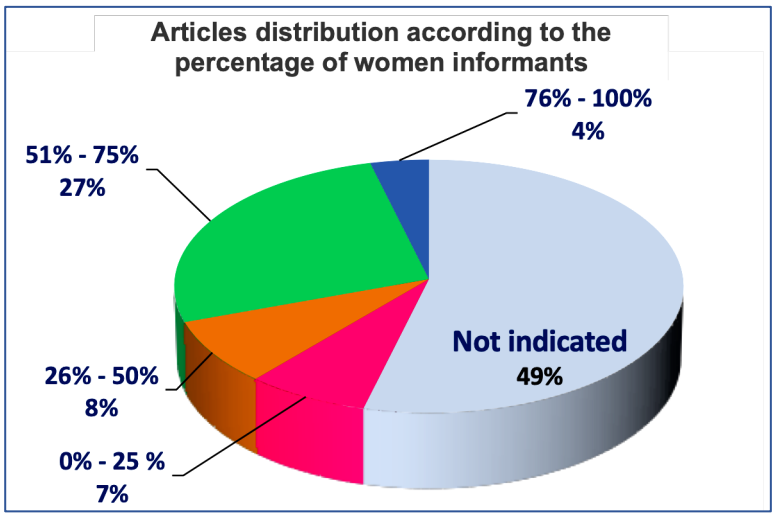

Figure 15. Articles distribution according to the percentage of women informants.

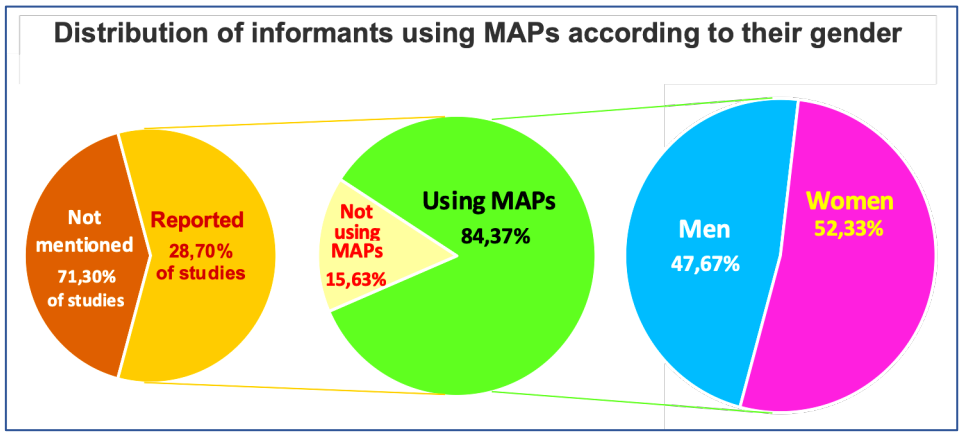

Figure 16. Articles distribution according to the informant's gender.

Conclusion

This work, which is a global review of ethnobotanical field studies conducted in Morocco between 1990 and 2023, shows a clear increase of research activity in relation to the increase in the scientific interest for the pharmacological potential of the rich Moroccan medicinal and aromatic plant heritage. The dominance of Moroccan researchers and institutions reflects the country's dedication to the conservation and documentation of traditional knowledge. Most research methods are based on survey with interview and questionnaires, and the descriptive statistics are the main tools of analysis. However, there are still significant gaps in the consistent reporting of certain key study factors, such as duration, geographic scope, and demographic information about informants.

The major role that women play as knowledge bearers and being the main users of MAPs is elucidated, which highlights their significance in the process of cultural transmission. In addition, although many publications appear in esteemed indexing databases, ethnobotanical research is distributed among various journals and has little focus in specialized journals. Addressing these methodological and reporting constraints, the scientific validity and comparability of future research can be improved. In conclusion, this review gives an insightful state of ethnobotanical studies in Morocco and contributes to providing a solid basis for advancing the ethnopharmacological research and the sustainable valorization of Morocco's medicinal plant biodiversity.

Declarations

List of abbreviations: MAPs- Medicinal and Aromatic plants

Ethics approval and consent to participate: Not applicable.

Consent for publication: Not applicable.

Availability of data and materials: All the data utilized for the study and included in the manuscript were obtained from Google Scholar, Scopus, Science Direct, Springer, Web of Science, JSTOR and Pub Med databases.
Competing interests: The authors declare no conflict of interest.
Funding: Not applicable
Authors' contributions: K. B carried out data collection, and prepared the first draft of the manuscript. K. B carried out data collection, and prepared the first draft of the manuscript. S.B. Prepared the first draft of the manuscript, Supervised the research and improved the manuscript.

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