

Medicinal flora of Oaxaca, Mexico: a review

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Abstract

Medicinal plants are the first resource for global access to health. In Oaxaca, these resources have been used since pre-Hispanic times. The objective was to integrate the available information on the use of medicinal plants in the state of Oaxaca, including the region and ethnic group that uses them, the conditions they combat, the active compounds they contain, and their conservation status in NOM-059-SEMARNAT-2010. A search was conducted for scientific articles and floristic reports that inform about the presence of medicinal plants in the state in the ScienceDirect, Springer, Google Scholar, and Mendeley databases. The references were sorted and analyzed in Excel. Spearman correlation tests were performed with the SAS statistical package. A total of 1 056 medicinal species were identified, 150 belonging to the family Asteraceae and 69 to the family Fagaceae. A total of 485 were found in the Sierra Norte, and 312 in the Valles Centrales. The Zapotecs are the ones who use them the most, followed by the Chinantecs and Mazatecs. There are 316 species that are used to treat gastrointestinal problems. The state of Oaxaca has a high biological and cultural diversity that is reflected in the number of medicinal species used and the knowledge kept by the communities in which they are located.

Keywords:

active compounds, ethnomedicine, native peoples.



Plants are the resource most used by human beings because they provide ecosystem goods and services as they are used as food, housing, part of rituals, fuel and medicine, among others. Of the non-timber forest resources, medicinal plants are the most employed by man (Aparicio-Aparicio *et al.*, 2021). According to the World Health Organization (WHO), they are used to guarantee global access to health care (Rahman *et al.*, 2022), which is why they are integrated into its strategy to achieve the Millennium Development Goals (MDGs), which are incorporated to improve maternal health, combat HIV/AIDS, and reduce infant mortality and other diseases (Strong *et al.*, 2020).

Due to their importance and frequency of use, in some cases, they have been overexploited since they are marketed in traditional markets as they can also be used as food, ornament or in religious cultural ceremonies that also generate economic income, becoming a means of livelihood for some families in the rural communities where they are collected (Serralta- Batun *et al.*, 2023). According to the International Union for Conservation of Nature (IUCN), there are between 50 000 and 80 000 species of plants with medicinal properties around the world, which are used by 80% of the world's population. Firstly, to meet health needs to some extent (Kujawska and Schmeda-Hirschmann, 2022).

In Mexico, its use has been documented since pre-Hispanic times. It is the second richest country in knowledge and use, only after China (Cruz-Pérez *et al.*, 2021), thanks to the fact that it has been generated and conserved by its 62 ethnic groups, which interact with various ecosystems. The state of Oaxaca has a great biological, cultural and linguistic richness, where 16 native ethnic groups converge (Pérez-Ochoa *et al.*, 2019), which keep a great tradition of the use of their medicinal flora (Martínez-López *et al.*, 2021) and although there are reports of these species traditionally used to treat ailments, these are focused on specific regions with different approaches.

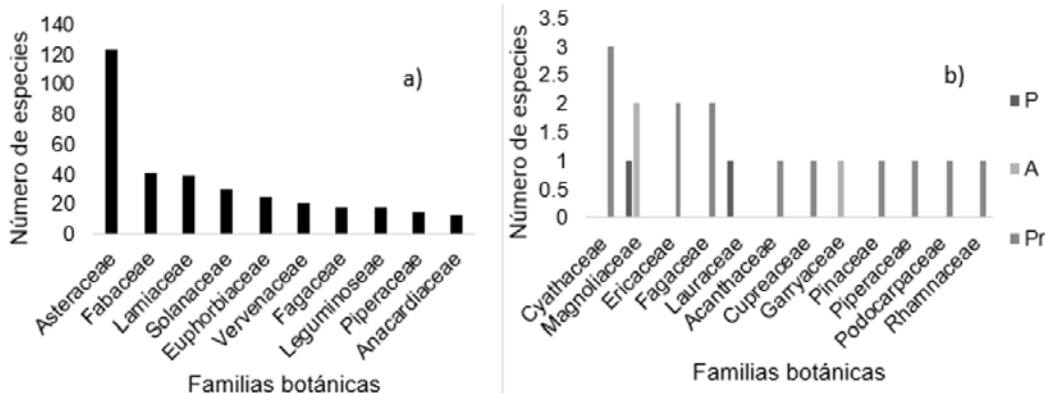
The objective was to integrate the available information on the use of medicinal plants in the state of Oaxaca, including the region and ethnic group that uses them, the conditions they combat, the active compounds they contain, and their conservation status in NOM-059-SEMARNAT-2010. A search was carried out for scientific articles and reports on floristic composition, from 1995 to 2024, that report the use of plants with medicinal properties in the state of Oaxaca in the ScienceDirect, Springer, Google Scholar, Mendeley, and ResearchGate databases, using 'medicinal plants' and 'floristic composition of Oaxaca' as keywords. Once the registry of scientific names was integrated, NOM-059-SEMARNAT-2010 (SEMARNAT, 2010) was consulted to verify if they were in any risk category; likewise, the Plants of the World Online webpage was consulted to verify the synonyms. To identify their use, International Classification of Diseases was taken as a reference (CIE-11, 2019). The common name, scientific name, family to which they belong, region where they are distributed within the state of Oaxaca, ethnic group that uses them, active compound they contain (if there are reports) were concentrated and graphed in Excel. Spearman's correlation tests were also performed between the variables because they did not comply with the assumptions of normality, which were carried out with the SAS 9.0 statistical program.

Diversity of medicinal plants in the state of Oaxaca

A total of 26 scientific articles reporting the use of medicinal species in the state of Oaxaca were reviewed, from which a record of 1 056 species was obtained, 33 more than those reported by Cruz-Pérez *et al.* (2021) for the state of Oaxaca, of which 725 are native, 192 endemic and 136 exotic, and three exotic-invasive (CONABIO, 2025). The family Asteraceae had the highest number of medicinal plants, contributing 14.19% of the total (Figure 1a).



Figure 1. a) Proportion of medicinal species reported in botanical families of Oaxaca and b) medicinal plants of Oaxaca in the risk category. Pr= special protection; A= threatened; P= danger of extinction.



This is to be expected because it is one of the most abundant, made up of 1 600 genera with a total of 25 037 species, representing more than 10% of all vascular plants in the world (Rolnik *et al.*, 2022). Their abundance was attributed to their excellent method of seed dispersal; in addition, they are present in the different types (Leyva-Castañeda *et al.*, 2020). The family Fabaceae ranked second, representing 6.52% of the total, with a difference of 82 species compared to the family Asteraceae. Worldwide, it ranks third in angiosperm diversity, has 730 genera, and is made up of 19 400 species, so this family is usually dominant (Pérez-Lara *et al.*, 2019). It should be noted that it is the second most reported family in traditional Chinese medicine with more than 490 species, and it also stands out in Brazil for the number of species that are used for the same purpose (Macêdo *et al.*, 2018).

In the above order, Lamiaceae is the third family with the highest diversity, with 49 medicinal species reported, 20 less than Fabaceae, which is because it is the sixth largest family of angiosperms in the world, with more than 245 genera and 7 886 species (Zhao *et al.*, 2021). In addition, it has taken on economic importance because they have been widely used in cosmetics, culinary art and medicine, and they are used for the extraction of essential oils due to their content of secondary metabolites. Despite the existing diversity of species with medicinal properties, they face challenges for their conservation, so much so that 30 are in some risk category according to NOM-059-SEMARNAT, of which 13 are under special protection (Pr), 11 are threatened (A), and six are in danger of extinction (P), (Figure 1b) (SEMARNAT, 2010).

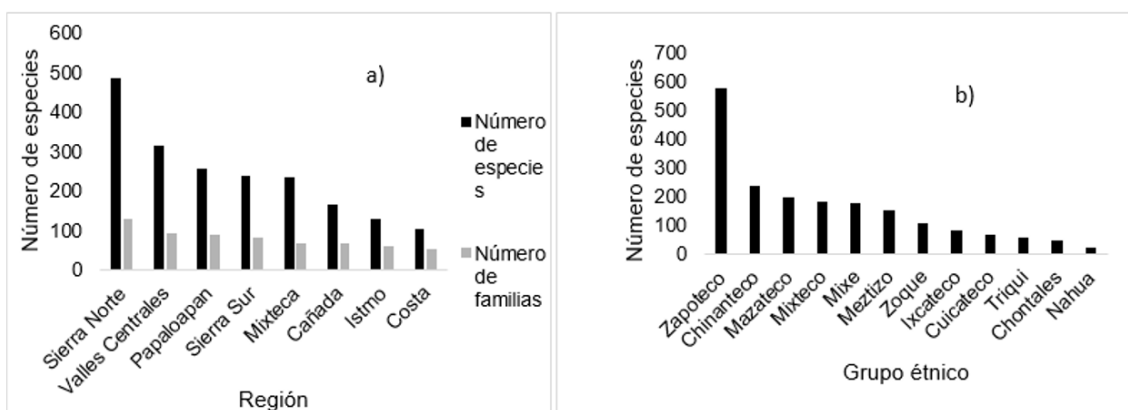
These are distributed in 12 botanical families, with the families Cyathaceae and Magnoliaceae having the most species at risk. Some examples include *Litsea glaucescens* and *Magnolia dealbata*; *Litsea glaucescens* is intensively used by the ethnic groups of Mexico to treat various diseases and as a food condiment (López-Caamal and Reyes-Chilpa, 2021). On the other hand, *Magnolia dealbata*, distributed in cloud forests in several states of Mexico, has been studied for its antimicrobial and antifungal properties. Despite this, both species face threats due to intensive use and habitat loss (Alonso-Castro *et al.*, 2014).

Use of medicinal plants by ethnic groups and their distribution by region

The highest concentration of medicinal plants is found in the Sierra Norte, representing 45.9% of the total species reported for the state, due to its cloud forest ecosystems, which are home to a great diversity of flora and fauna, which is why various studies have been conducted in this region

in the state (Perez-Ochoa *et al.*, 2019). Followed by the Valles Centrales, it represented 29.55% of the total. In this region, there are oak pine forests, temperate forests, low rainforest and grasslands, which makes the landscape contrast abruptly in a very short distance (García-Mendoza and Meave, 2011), and it is the region with the best accessibility. In Papaloapan, it ranks third with 24.33% of the total (Figure 2a).

Figure 2. a) distribution of species and families in the eight regions of Oaxaca and b) use of medicinal plants by the different ethnic groups in Oaxaca.



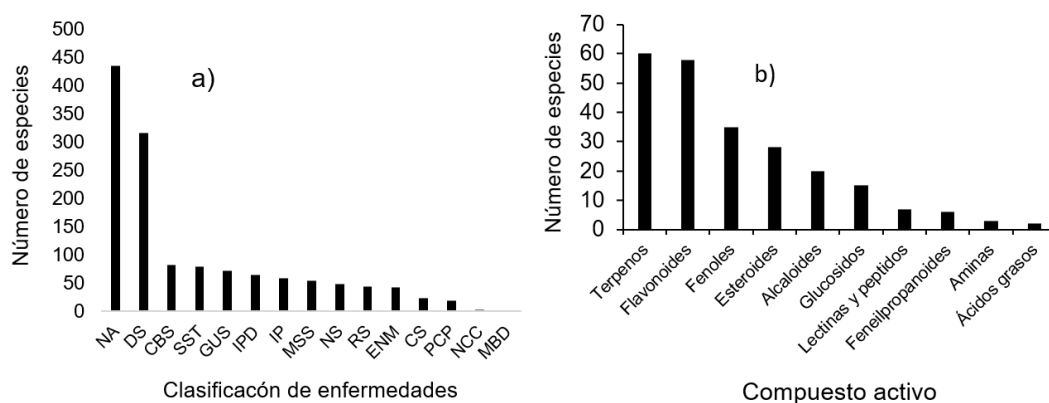
The Zapotecs are the ethnic group that uses the largest number of medicinal species, reporting 574 species, more than 50% of the species reported in this review, because they occupy the largest area of territory since they are settled in the Valles Centrales, the Sierra Sur, the Sierra Norte and the Istmo (Nodar, 2020); in addition, they have extensive knowledge of the use of plants in traditional medicine since pre-Hispanic times, they were used for hygiene and therapeutic practices in ceremonial centers, such as Monte Albán (Fernandez-Flowers *et al.*, 2020). On the other hand, the Chinantecs use 22.44% of the total medicinal species. Located in the Sierra Norte, which is characterized by its temperate ecosystems that are home to a great diversity of species; furthermore, due to its type of vegetation and its easy access and proximity to the city, it is a widely studied region (Valdivia-Correa *et al.*, 2016). After the Zapotecs and Chinantecs, the Mazatecs are the ethnic group that uses 18.75% of medicinal plants (Figure 2b). They are located in the Mazatec mountains, one of the emblematic places where this group is located is Huautla de Jiménez, a magical town known for the rituals with medicinal plants and entheogenic mushrooms performed by the healer María Sabina Magdalena García (Piña-Alcántara, 2019).

Medicinal practices with plants in the state of Oaxaca

Twenty-nine point nine percent of the medicinal species reported are used to treat gastrointestinal diseases due to the importance of this system, which is closely related to general well-being (Cheema and Singh, 2021); on the other hand, there are syndromes linked to culture, for which 83 medicinal species (7.57%) are reported to treat the evil eye, scares, nerves, cholera or magical rituals (Pérez-Nicolás *et al.*, 2018) (Figure 3a).



Figure 3. a) Frequency of plant species used by type of disease in Oaxaca. NA= not available; DS= digestive system; CBS= culture-bound syndromes; ENM= endocrine, nutritional and metabolic diseases; GUS= genitourinary system; IP= injuries and poisoning; IPD= infectious and parasitic diseases; MBD= mental and behavioral disorders; MSS= musculoskeletal system; NS= nervous system; PCP= pregnancy, childbirth, and puerperium; RS= respiratory system; SST= skin and subcutaneous tissue disorders, NCC= neoplasms, carcinoma and cancer; and b) active compounds present in different species of medicinal plants.



Of the total medicinal plants reported in this study, 11.17% report the presence of some secondary metabolite, terpenes being found in 6.08% of medicinal plants (Figure 3b). This could be because there are more than 4 000 molecules of this type, which are found in various plants that have been used in human medicine to treat diseases, such as Alzheimer's, diabetes mellitus, cancer, skin problems, and SARS-CoV-2, among others (Tang *et al.*, 2023). Flavonoids are present in 5.49% of the plants reported in this study, which are used to treat or prevent diseases, such as lung cancer, Alzheimer's, anti-aging therapies, cardiovascular diseases, microbial infections, inflammatory diseases, and varicose and gastrointestinal diseases (Sathishkumar *et al.*, 2018). Phenols rank third with 16.6% of medicinal species, they are widely distributed in the plant kingdom and have gained interest in recent times due to their use to treat skin diseases, cancer, and gastrointestinal diseases, among others (Madhavan y Tharakan, 2020).

Relationship between the use of medicinal plants reported in the state of Oaxaca and the ethnic group and region where they are found

Pearson's correlation analysis showed positive relationships ($p \leq 0.01$) between use and ethnic group, use and region, region and ethnic group that use medicinal plants (Table 1), and although the relationships shown are low, they indicate the trend of association of the different factors. Because traditional knowledge about the use of medicinal plants has been preserved in various parts of the world, including countries such as Malaysia, Australia, Morocco, Thailand and Mexico, it is logical that there is a relationship between the use they give to their medicinal plants and the societies that use them because this information is transmitted from generation to generation (Kachmar *et al.*, 2021; Pascual-Mendoza *et al.*, 2022).



Table 1. Relationship between the use given to medicinal plants with the region, ethnic group and active compounds they contain.

	Use	Risk category	Region	Ethnic group
Use	1	0.004ns	0.16504**	0.55187**
Risk category		1	0.09985*	0.00744ns
Region			1	0.4344**
Ethnic group				1

In each correlation value, ns= not significant, *= significant, **= highly significant ($p \leq 0.01$).

Conclusions

The biological and cultural biodiversity of the state of Oaxaca has generated extensive knowledge about the use of vegetation for medicinal purposes, which has been transmitted from generation to generation in its 16 ethnic groups, which has allowed them to treat different ailments, making it an independent resource that gives them sovereignty in health due to the diversity of secondary metabolites that these plants contain; despite this, there are still information gaps because only 9.8% of plants have phytochemical reports. Nevertheless, the intensive use and sale of species in regional markets coupled with the degradation of ecosystems due to climate change and land use change, among others, has caused some of these species to be at risk.

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