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EALRe and EFC designed the study; EALRo and JMZV conducted the fieldwork; EALRo identified the plant specimens; EALRe, EFC, and LP analyzed the data; EALRe, LP, and ZP wrote the manuscript

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ORIGINAL RESEARCH PAPER

An ethnobotanical study of medicinal plants used in Zacatecas state, Mexico

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Abstract
Despite the fact that Mexico has vast biocultural biodiversity, there are numerous regions where the traditional medicinal use of plants has not yet been studied. We aimed to document, analyze quantitatively, and preserve medicinal plant knowledge among local people living in over 40 communities in the state of Zacatecas. Ethnobotanical information was collected by semistructured interviews with 132 informants. Data were analyzed using standard quantitative indices such as relative frequency of citation, family importance value, cultural importance index, and informant consensus factor. We recorded 168 medicinal plant taxa belonging to 151 genera and 69 botanical families and used to treat 99 health disorders. The most medicinally important plant families were Asteraceae (20 species), followed by Fabaceae and Lamiaceae (12 species) and Cactaceae (five species). The most culturally important species was *Matricaria chamomilla* L., mentioned 140 times, followed by *Arnica montana* L. (62 times) and *Artemisia ludoviciana* Nutt (48 times). The highest consensus for use was for diseases of the reproductive system. The type of disorder for which there was the highest number of references for use (389; 25% of all uses) and plant species (67) were diseases of the digestive and gastrointestinal system. The present study represents the first quantitative medical-ethnobotanical documentation and analysis of the traditional use of medicinal plants in Zacatecas state. Despite the semiarid climate, this region is botanically highly diverse, and its flora have versatile medicinal uses.

Keywords
medicinal plant knowledge; quantitative ethnobotany; health disorders; traditional medicine; herbal remedy

Introduction

Mexico is a megadiverse country, combining one of the richest floras worldwide with high cultural diversity; as a result, it is one of biocultural diversity hotspots of the Earth [1]. Its diverse socioecological systems and traditions of plant use have provided a wealth of ethnobotanical knowledge [2]. From empirical practice to evolution of modern scientific discipline, Mexico's ethnobotany has influenced theories and methods of this science around the world [3]. It is estimated that the Mexican medicinal biota contains approximately 3,000–5,000 plant species with therapeutic potential, and only approximately 1,000 species have been thoroughly studied [4,5]. In Mexico, medicinal plant knowledge is evolving to treat both long-established diseases and recent phenomena

such as diabetes, cancer, necrosis, and hypertension [6]. Much of the research indicates that living far from urban centers, living in poverty, and having low education levels are main drivers of people's preference for traditional medicine [4,7–9]. However, previous studies demonstrated that medicinal plant use is not only limited to rural areas. Even medical institutions in urban areas of many developing countries have adopted and are using folk medicine as a form of complementary medicine to prevent or cure diseases [10–12].

In Mexico, 78% of the population lives in urban areas and 33% live in rural areas. More than half of the people treat their ailments with medicinal plants [13]. Although the use of medicinal plants in the state of Zacatecas plays an important role, particularly in rural areas [14], according to our literature review, Zacatecas remains ethnobotanically unexplored. Several authors stressed that even the biological diversity of Zacatecas is not well documented [15–17]. The majority of the ethnomedicinal studies in Mexico have concentrated on the southern tropical regions (e.g., [18,19]). Therefore, the present study was conducted in semiarid northern Mexico, where little research to date has been conducted.

Previous reviews by Balleza and Enriquez [20] in the herbarium of Zacatecas identified a number of plants with medicinal properties, including 522 species representing 299 genera and 97 botanical families. However, there have been few ethnobotanical analysis of plants' cultural importance. In addition to the absence of ethnobotanical records, factors such as globalization, modernization, migration, and new healthcare system could affect the maintenance of traditional knowledge in Zacatecan population [21,22]. The main objective of the present study was to document medicinal plant knowledge in 40 communities of Zacatecas and identify the most culturally important medicinal plant species and botanical families. We also aimed to compare knowledge between rural and suburban areas and according to different socioeconomic characteristics.

Material and methods

Study area

Zacatecas is a landlocked state in the northcentral region of Mexico that borders the states of Durango, Coahuila, and Nuevo Leon to the north and Aguascalientes, Guanajuato, and Jalisco to the south. The study area falls within the area of Sierra Madre Occidental mountain range, Mesa del Centro, and Eje Neovolcanico. The state is somewhat mountainous, with lateral ranges of the Sierra Madre Occidental in the west and an average elevation of about 2,300 m a.s.l. Agricultural production is seasonal and irrigation is limited due to low precipitation. The climate is dry and semidry (dry 73%, temperate 17%, very dry 6%, and warm subhumid 4% of the time). The average annual temperature is 17°C. Average annual precipitation is approximately 510 mm [22,23]. Zacatecas is divided into 58 municipalities. The majority of people live in urban areas (59% urban, 41% rural). The main industries are tourism (47.2%), mining and manufacturing (45.4%), and agriculture (7.5%). The population is 1,579,209 and the average life expectancy is 75 years. The percentage of the population living in moderate to extreme poverty is 52.3% [14,22]. Small herbal stores and a variety of indigenous and introduced exotic plants are commonly found throughout the state. Hospitals and medical services are not readily available outside urban areas, and there is a shortage of specialists, clinics, and medicine in these remote areas (e.g., [19]).

Data collection

Fieldwork was carried out from January to October 2016 in 40 communities (12 urban and 28 rural) in Zacatecas (Fig. 1). All the informants were permanent residents of the respective communities and sampling was based on the snowball method [24]. This method was employed in order to find people who have a rich traditional knowledge of using medicinal plants. Informants gave permission for their knowledge to be used in the study and gave their ethical approval of this research. After the informants gave their

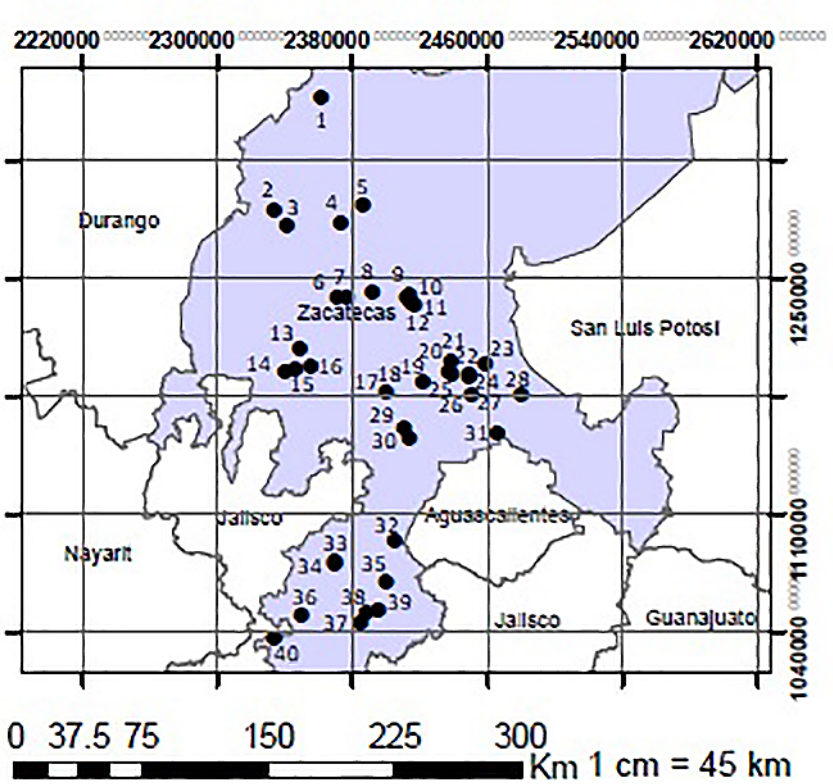

Fig. 1 Map of Zacatecas state with sampling points: 1 – Juan Aldama; 2 – Loma de Cruz; 3 – Tapias de Sana Cruz; 4 – Nuevo Sain Alto; 5 – Cazaderos; 6 – Refugio Abrego; 7 – Emiliano Zapata; 8 – El Salto; 9 – Fresnillo; 10 – El Verguel; 11 – San Rafael; 12 – San Elena; 13 – San Mateo; 14 – Santa Potencia; 15 – Valparaiso; 16 – Mala Noche; 17 – Leobardo Reynoso; 18 – El Capulin; 19 – San Miguel; 20 – San José; 21 – Hacienda Nueva; 22 – Zacatecas; 23 – 6 de Enero; 24 – Guadalupe; 25 – Sauceda de la Borda; 26 – Tacoaleche; 27 – San Jeronimo; 28 – Pozo de Jarillas; 29 – Cuenca Lechera; 30 – Coyotes; 31 – Cosio; 32 – Tabasco; 33 – Santa Ana; 34 – Tlaltenango; 35 – Jalpa; 36 – Ortega; 37 – Juchipila; 38 – Palma Cuata; 39 – Apozol; 40 – Milpillas.

oral informed consent, they were interviewed on general demographics and ethnobotanical knowledge. The interviews were conducted in Spanish (the local language) and a total of 132 informants between 20 and 86 years (mean age = 49 years) participated. Demographic characteristics are presented in Tab. 1. The ethnobotanical information included sources of traditional knowledge, uses of the plants, mode of administration, plant parts harvested, and dosage for each remedy. The interview included an open discussion of the status of traditional knowledge and the perception of current trends. Plants were also collected over the course of several visits. All plant material was collected by the first author, and specimens were identified taxonomically with the aid of Biblioteca Digital de la Medicina Tradicional Mexicana (http://www.medicinatradicionalmexicana.unam.mx/index.php), in cooperation with the Department of Agronomy and the Herbarium of the Autonomous University of Zacatecas. The botanical names of species were verified with The Plant List (http://www.theplantlist.org). The voucher specimens were deposited in the aforementioned herbarium (SNIB-CONABIO).

Quantitative data analysis

Each index specifically evaluates different parameters of the plants (accuracy of use, relative importance, and cultural importance). The indices are calculated from the responses and degree of consensus among informants, and they were used to establish statistically different parameters to evaluate the knowledge and serve as a qualitative reference.

Tab. 1 Demographic characteristics of the 132 informants.

Demographic variable	Demographic category	Number of informants	%	Mean number of plant species cited
Gender	Female	73	55	7.2
	Male	59	45	6.5
Age	20–30	10	8	6.8
	31–40	19	14	6.6
	41–50	38	29	7.1
	51–60	36	27	7.2
	Above 61	29	22	6.6
Residence location	Rural	69	52	5.8
	Suburban	63	48	8.2
Occupation	House wives	54	41	6.9
	Farmers	21	16	5.2
	Public workers	9	7	6.3
	Traders	17	13	9.5
	Students and professors	7	6	6.7
	Labourers and others	24	18	7.1
Public health insurance	Insured	139	83	7.0
	Uninsured	29	17	6.0

All the ailments described by the informants were organized in 12 main categories, based on the International Classification of Diseases used by the World Health Organization [25].

The ethnobotanical information was converted into a use report (UR) [26]. The data were then tabulated and analyzed according to the quantitative ethnobotanical indices described in the following sections.

Relative frequency of citation (RFC)

The quantitative index relative frequency of citation (RFC) was calculated as follows to assess the local importance of particular plant species:

$$RFC_S = \frac{FC_S}{N} = \frac{\sum_{i=i_1}^{i_N} UR_i}{N} \ (0 < RFC < 1)$$

This index represents the frequency of plant citations (*FC*, the number of informants who mentioned the use of the species), divided by the total number of informants participating in the survey (*N*), regardless of use [27]. In essence, it assesses the cultural importance of individual species.

Relative importance index (RI)

Developed by Tardío and Pardo-de-Santayana [28], this index takes into account both the number of informants who mentioned the species and the different uses for it:

$$RI_S = \frac{RFC_{S(max)} + RNU_{S(max)}}{2}$$

$RFC_{S(max)}$ is the relative frequency of citation over the maximum. It is obtained by dividing FC_S by the maximum value in all the species of the survey, $RFC_{S(max)}$ (FC_S = max *FC*). $RNU_{S(max)}$ is the relative number of use categories over the maximum, obtained by dividing the number of use categories of the species (NU_S) by the maximum number of use categories obtained by any other species in the survey, $RN_{S(max)}$ (NU_S = max *NU*).

Cultural importance index (CI)

The cultural importance index [29] reflects a measure of relative importance per plant use. This index considers not only the spread of the use (number of informants) for each species, but also its versatility (i.e., the diversity of its uses). The index is calculated using the following formula:

$$CI_s = \sum_{u=u_1}^{u_{NC}} \sum_{i=i_1}^{i_N} UR_{ui}/_N$$

The theoretical maximum value of the index is the total number of different use-categories (*NC*), reached in the unlikely case that all the informants mention the use of a particular species for all the use categories considered in the survey. In the case of a species with only one use, this index would be equal to the RFC index.

Family importance value (FIV) index

This index represents the cultural significance of particular botanical families in the ethnobotanical context. It reflects the proportion of informants who cite a particular family with respect to the total number of informants:

$$FIV = \frac{FC(FAMILY)}{N}\ 100$$

FC is the number of informants mentioning the family, while *N* is the total number of informants participating in the study.

Informant consensus factor (ICF)

The informant consensus factor expresses whether there is agreement among informants on the use of plant species in particular ailment categories [30]:

$$ICF = \frac{n_{\mathrm{UR}} - n_{\mathrm{t}}}{n_{\mathrm{UR}} - 1}$$

In this formula, n_{UR} is the number of use reports for a particular ailment category, and n_{t} is the number of species used for that ailment category by all the informants. The range of the index is between 0 and 1, with a higher number (close to 1) reflecting agreement among the informants that the plant is used to cure a particular ailment category [31].

Results

The popularity of herbal medicine among the studied communities

Despite the high percentage of people holding health insurance (Tab. 1), 96.3% of the total participants used traditional medicine to solve health problems. Due to high expense and length of time required to access care, 26.5% do not typically access medical facilities as the first resource for treatment of diseases. Furthermore, 25.7% use plants in combination with conventional medicine.

The majority of survey participants were between the ages of 41 and 50 (29%). Only 14% of informants contacted traditional healers to treat illnesses. Medicinal plants were mostly used by women, with the exception of the youngest group (ages 21–30 years) in which men more often used plants than women. Participants in different age classes did not significantly differ regarding the number of plants and use reports (Tab. 1). The greatest knowledge of plant use, as demonstrated by number of species cited, was shown by participants aged 51–60 years (average 7.2 species) and 41–50 years (average 7.1 species). Women cited slightly more species (average 7.2 species) than men (average 6.5 species). With regard to occupation, traders reported the highest

number of species (average 9.5 species). Remarkably, the informants in suburban areas mentioned a significantly higher number of species (average 8.2 species) than did their rural counterparts (average 5.8 species). This result might be due to the purchase of new natural products (often exotic species) in markets which people assume represent traditional knowledge.

Medicinal plant species diversity and cultural importance

A total of 168 medicinal plant taxa were reported by their common names. Of these, 163 were identified down to species level, and five taxa were identified only to the genus level (*Gnaphalium* sp., *Calendula* sp., *Rosa* sp., *Casimiroa* sp., and *Agave* spp.), resulting in a list representing 151 genera and 69 botanical families (Tab. S1). The family Asteraceae was the most represented family, with 20 species (11%), followed by Fabaceae and Lamiaceae with 12 species each (7.1%). The list of species (Tab. 2) shows 10 of the most cited plants by number of informants and those that obtained the highest quantitative index values for CI, RFC, and RI. *Matricaria chamomilla* L. ranked first, representing the highest number of all indices (CI = 1.15, RFC = 0.55, RI = 0.73) and use reports (140 UR). This plant was cited by 59% of the informants and has tremendous medicinal importance with multiple uses. The leaves and flowers are used for a wide range of conditions, such as ailments of the respiratory and digestive systems, colic pains, fever, and eye problems. *Arnica montana* L. scored second place for CI (0.49) and 0.39 for RFC, with 62 UR. *Arnica montana* is predominantly used for skin infections, burns, stretch mark, vaginal infections, gastritis, stomachache, rheumatism, urinary tract infection, wounds, and bruises. It was followed by *Mentha* ×*verticillata* L. (0.48), *Aloe vera* (L.) Burm f. (0.46), and *Ruta chalepensis* L. (0.44).

Tab. 2 Top 10 most culturally important species according to the quantitative measures.

Scientific name	Use reports	% of informants	CI	RFC	RI
Matricaria chamomilla	140	59	1.15	0.55	0.73
Arnica montana	62	39	0.49	0.39	0.66
Mentha ×*verticillata*	55	27	0.48	0.27	0.51
Aloe vera	53	23	0.46	0.23	0.71
Ruta chalepensis	51	27	0.44	0.27	0.62
Gnaphalium sp.	35	27	0.42	0.27	0.36
Artemisia ludoviciana	48	32	0.36	0.32	0.48
Eryngium heterophyllum	40	13	0.30	0.13	0.31
Larrea tridentata	33	25	0.26	0.15	0.54
Origanum vulgare	31	14	0.23	0.14	0.25

RFC results indicate the order of medicinal significance. After *M. chamomilla* and *A. montana*, the third-highest RFC value was for *Artemisia ludoviciana* (0.32) with just 48 UR. This plant is used for flu, headache, nerves, stress, and gastrointestinal problems. *Mentha* ×*verticillata*, *R. chalepensis*, and *Gnaphalium* sp. all had the same RFC value (0.27), and all are commonly applied to combat gastrointestinal disorders by preparing an infusion from the leaves.

After *M. chamomilla*, *A. vera* had the second highest RI value (0.71) with 53 UR. *Arnica montana* was in third place (0.66) with 55 UR, followed by *R. chalepensis* (0.62) with 51 UR, *Larrea tridentata* (Sessé & Moc. ex DC.) Coville (0.54) with 33 UR, and *Mentha* ×*verticillata* (0.51) with 55 UR.

Significance of plant families in local medicine

The most common botanical families, according to their FIV, were Asteraceae (FIV = 15.2), Fabaceae, and Lamiaceae (both FIV = 6.1). The 10 most frequently cited families were Asteraceae (261 UR), Lauraceae (139 UR), Rutaceae (61 UR), Fabaceae (54 UR), Xanthorrhoeaceae (30 UR), Amaranthaceae (27 UR), Cactaceae (26 UR), Apiaceae (25 UR), Nyctaginaceae (22 UR), and Zygophyllaceae (20 UR) (Fig. 2).

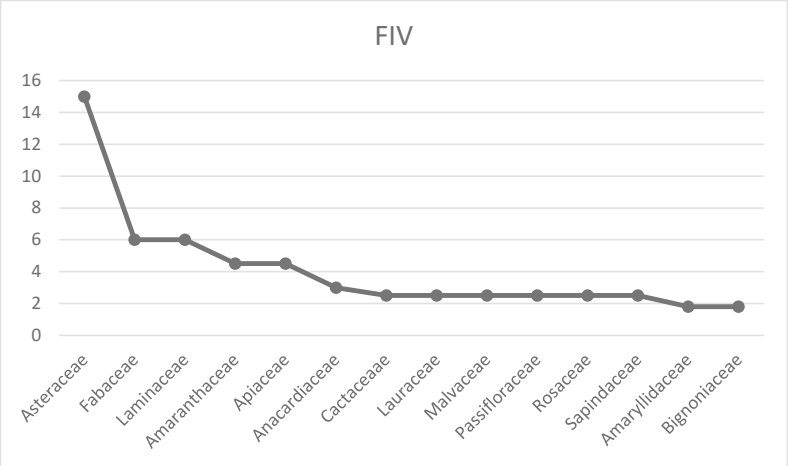

Fig. 2 Family importance value (FIV).

Modes of preparation and administration and plant parts used

Leaves (43%) were the most commonly used plant part, followed by the whole plant (11%) and stems (9%) (Fig. 3). Only 18% of informants cultivated plants. Freshly harvested and directly processed plant parts were used in 44% of cases, dried plant material was used in 27% of the cases, and the remaining 29% of the reported remedies were prepared from both dried and fresh plant material. Most plant parts (leaves, fruits, flowers, and stems) are ingested raw, but some plants (mainly roots, seeds, and bark) need to be boiled before consumption in order to degrade some toxic properties (alkaloids). Due to the limited accessibility of some plants, a few species were stored in order to increase availability of the herbal material.

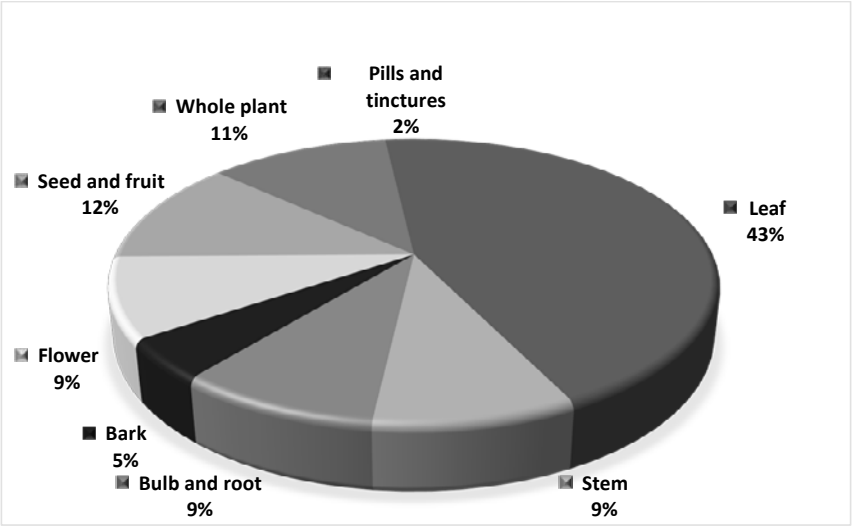

Fig. 3 Plant parts used to prepare herbal remedies.

Oral application (76.8%) was used most often, followed by topical application (24.2%). Most of the plants were consumed the day after they are gathered in the form of herbal teas (infusion 52.2%, decoction 10.2%). Wounds were usually treated with a paste or cataplasm in topical form. Baths and tinctures were mostly used to control herpes and skin disorders (Fig. 4).

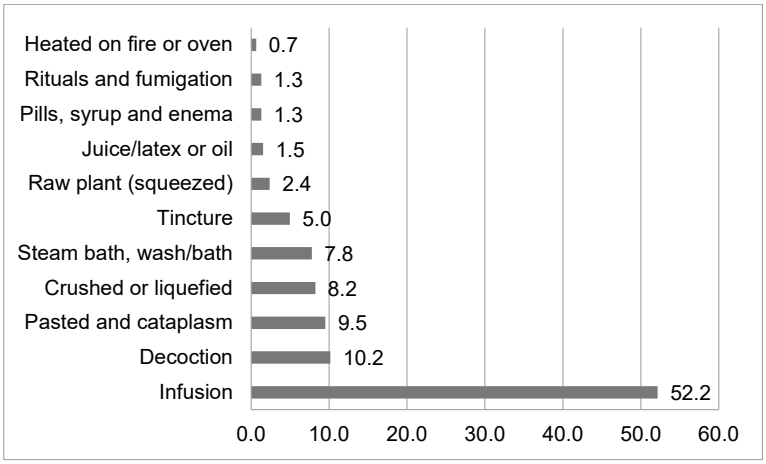

Fig. 4 Different modes of preparation.

Consensus on the treatment of ailment categories

A total of 99 ailments were reported, divided into 12 categories (Tab. 3). Disorders of the reproductive system reached the highest ICF value (0.81). The second highest ICF value was for gastrointestinal conditions (0.80). Next were disorders of the respiratory system (0.79), and diseases of the musculoskeletal system (0.78).

The highest ICF values represent a concordance among the informants about the use of certain plants for specific ailments. The high consensus on those categories indicates that the use of these medicinal plants to treat these disorders is well established. The most frequently treated ailments (diseases of the digestive and gastrointestinal system, diseases of the respiratory system, and disorders of the musculoskeletal system, respectively) were present with a high incidence among the population. In Zacatecas, women primarily used traditional knowledge to solve reproductive and maternal problems.

Discussion

According to Mshana et al. [7], the combination of traditional and modern medicine (multitreatment) has become a strategy for people who live in places where modern healthcare is not easily accessed. In fact, the most common health problems in rural areas in Mexico are related to the high cost of medicine, the shortage of supplies of medicinal products, and the perceived ineffectiveness of modern medicines for resolving chronic diseases (e.g., [9,32,33]). These factors drive the communities in the study area to continue using medicinal plants and to combine both traditional and modern medicine. The high acceptance of complementary medicine (traditional medicine) was demonstrated by Romero-Cerecero and Tortoriello [33], who studied the local Family Medical Care Unit of the Mexican Institute of Social Security (about 83% acceptance by personnel and 75% acceptance by patients).

According to Ceuterick et al. [34], higher family incomes are generally associated with less knowledge about medicinal plants and less use of plants for medicinal purposes [34]. In addition to income, other demographic factors such as age, gender, education, and occupation are important determinants of knowledge. There was slightly higher knowledge among women than men, and in suburban areas compared with rural areas. Worldwide, the traditional knowledge is also related to labor divisions within the

Tab. 3 Types of ailments with consensus on their treatment.

No.	Ailments category	Description of ailments	ICF	No. of species	No. of UR	% of total UR
1	Diseases of the reproductive system	Colic, sinus pain, contraceptive, reduction of breastfeeding, sexual impotence, lactation suppression, childbirth preparation, vaginal infections	0.81	17	86	6.53
2	Diseases of the digestive and gastrointestinal system	Anemia, bile, bitter mouth, bleeding ulcers, diarrhea, digestion, stomach ache, dysentery, gastric ulcer, gastritis, gastrointestinal problems, hemorrhoids, indigestion, intestinal parasites, amoebae, intestinal gases, liver problems	0.80	67	329	24.96
3	Diseases of the respiratory system	Asthma, bronchitis, chest pain, cough, flu, chest pain, pneumonia, laryngitis, respiratory system, sore throat	0.79	54	257	19.50
4	Diseases of the musculoskeletal system	Antibacterial, anti-inflammatory, arthralgia, back pain, general pain of the body, rheumatism, pain of muscles, body analgesic	0.78	29	130	9.86
5	Diseases of the nervous system	Anxiety, insomnia, epilepsy (spasm)	0.74	15	55	4.17
6	General symptoms	Colitis, ear ache, fever, headache, irritated eyes, lack of energy, migraine, motion sickness, ear problems, sight problems, body strength, stress, toothache, weak gums	0.69	52	168	12.75
7	Diseases of the urinary tract	Problems of urinary tract system, urinary tract infection, kidney stones, diuretic	0.67	30	89	6.75
8	Chronic – degenerative diseases	Diabetes, hormonal problems, cancer	0.63	15	39	2.96
9	Auto-immune diseases	Antibiotic, rheumatoid arthritis, hematopoietic, strengthening immunity defense	0.60	5	11	0.83
10	Diseases of the cardiovascular system	Blood cholesterol, circulatory system, hypertension, inflammation, weight reduction, anginas	0.58	28	66	5.01
11	Diseases of the skin	Allergies, acne problems, baldness, external blows and bruises, burns, calluses, chickenpox (varicella), dry skin, foot fungus, sores, wounds, grains of the skin, genital herpes, injures in the mouth, gums, herpes, lice, rashes in the skin, measles, skin allergies, sore and wounds, skin blemishes, skin and hair problems, stretch marks, warts	0.58	36	85	6.45
12	Antidotes	Antidote for insect bite (arlomo) and snakebite	0.00	3	3	0.23

family. Men generally possess significant knowledge about plants used for construction, handicrafts, and animal feed because they often perform labor-intensive work, whereas women usually know more about edible and aromatic medicinal plants because they have the responsibility for domestic activities [16,18,19]. In Zacatecas, women are usually in charge of gardening, selling plants in local markets, and child rearing. The slightly greater number of medicinal plants cited on average by respondents in suburban areas might be explained by the use of a higher number of species (often exotic) and new natural products commonly purchased in markets. The influence of markets on accessibility of new plant resources is well known (e.g., [33]).

Generally, species with high cultural importance were used frequently and had versatile uses. Numerous culturally important plants in our study, such as *M. chamomilla*, *Mentha* ×*verticillata*, *A. montana*, *Citrus sinensis*, and *Bougainvillea glabra*, are used to cure the same ailments as in other parts of Mexico [18]. Moreover, there have been numerous pharmacological studies reporting that use of these species leads to a significant reduction of anxiety, depression, sedative effects, anti-inflammatory effects,

colic-related pain, headaches, gastrointestinal disorders, diarrhea, and fright [35,36,38]. *Matricaria* spp. are recommended and used by the health professionals in Mexico, due to the wide medicinal effect against many diseases in respiratory and gastrointestinal system (e.g., [18,38]). The medicinal use of *A. montana* L. has been confirmed to be efficacious for the treatment of bruising, injuries, rheumatism, fractures, inflammation in the throat and muscles, and insect bites, as well as accelerating postoperative healing and preventing skin fungal infections [39,40]. The plant is also used to inhibit root rot fungi (*Fusarium oxysporum*, *Rhizoctonia solani*, and *Macrophomina phaseolina*) in seeds [41]. The significance of another important species, *A. vera*, could be explained by its trend of popular usage to cure the most common conditions. In Central America, *A. vera* is used for a wide range of conditions, such as diabetes, skin problems, and kidney diseases [42]. The juice has long been used as a sugar substitute for patients who have problems associated with triglycerides in the blood [42]. These examples indicate that the culturally important medicinal plants of Zacatecan communities are known to be effective pharmacologically, suggesting that the traditional knowledge is well founded, and that other medicinal plants used in the area are likely to be efficacious as well. The medicinal importance of neglected and underutilized species cited by fewer informants should also be investigated.

The fact that Asteraceae was the most culturally important family may indicate that the Zacatecan pharmacopoeia is not a random selection of flora but includes over-representation by some taxonomic groups (see [43]). After comparing four Mexican indigenous groups, Heinrich et al. [30] suggested that cultures use well-defined criteria to select medicinal plants. Balleza and Villaseñor [44] found that the Asteraceae is the most widely distributed and diverse family among the flowering plants throughout Zacatecas. They recorded 191 species (42% of the total) of weeds in this family, including 59 species that are endemic to Mexico. The Asteraceae family is apparently a crucial component of the floristic richness of the xeric environment in central Mexico [45–47]. The importance of this family is widely supported by different studies [45] reporting a rich number of species and uses (medicinal, agricultural, and industrial). The phytochemical components present in flavonoids, sapogenins, mucilage, essential oils, and glucoalcohols are used in folk medicine to treat condition fever and rheumatism [48,49] and used as a diuretic, an antispasmodic, a general tonic, a stimulating agent, and an antidepressant [49,50]. After Asteraceae, Fabaceae and Laminaceae were the most dominant families used for medicine by Mexican communities [16,18], as well as in other parts of the world (e.g., Ethiopia [51], Pakistan [27]).

Infusions and decoctions were the most common preparation modes and leaves were the most commonly used plant parts used in various countries [8,27,51–53]. Numerous plants store highly active compounds in the leaves, the most important plant part in the present study, and these compounds confer significant antibacterial and antioxidant effects [54–56]. Teas containing infusions are among the most common medicinal preparations globally. In Mexico, a variety of traditional fermented beverages are also made for religious or medicinal purposes from maize (atole, pozol, and tesgüino) or agave (pulque). These beverages contain beneficial probiotic microorganisms that reduce gastrointestinal problems [57]. Although these beverages exist in Zacatecas, they are not perceived as explicitly medicinal, but rather are drunk in a recreational-food context.

External applications were used only for the treatment of wounds or rheumatism by processing raw plant parts into a paste or cataplasm. According to Neves et al. [58], raw materials such as roots and stems are not frequently applied to skin. In Zacatecas, baths and tinctures applied externally are mostly used to control herpes and skin disorders, and these methods of application were also mentioned in correspondence of García-Hernandez et al. [59]. They reported that bathing (e.g., steam baths, foot baths, vaginal steam baths, sweat lodges) is commonly recommended by healers, who perceive baths to be more effective than oral infusions [59].

Gastrointestinal illnesses are often mentioned in ethnomedicinal studies. In the Maya and Nahua communities in southern Mexico, gastrointestinal illnesses had one of the highest consensus values [30], as was the case in our study. Diarrhea, stomachache, and vomiting are symptoms that are frequently treated with homemade remedies in southern Mexico [60]. The use of medicinal plants to solve gastric problems in rural and suburban communities that have access to public healthcare in Mexico may be

caused by the short supply of pills in health centers [61]. Similar values of ICF in other regions of Mexico suggest that digestive problems are common, as well as respiratory, musculoskeletal, and integumentary system issues [18].

Diseases of the reproductive system obtained the highest ICF value. Reproductive health issues are common in indigenous communities in Mexico, and locals are accustomed to applying traditional medicine to treat them [18–20,35,62]. Smith-oka [62] confirmed the wide use of plants by indigenous Mexican women to treat reproductive hormone problems, complications during labor, and pre-/postpartum problems [62]. In Zacatecas, 17 species are used traditionally for those purposes, and there is great consensus on them. However, the present study noticed that reproductive system problems have serious health consequences and are not controlled easily by the local communities.

Spiritual treatments are also frequently used in the study area. *Schinus molle* L., *Ocimum basilicum* L., *Mentha ×piperita* L., *Thymus vulgaris* L., and *Rosmarinus officinalis* L. are used in a traditional ritual for cleaning the spirit.

Most of the informants gathered plants from the wild (82%), as these plants are easily accessible and are perceived to have a high level of medical effectiveness. Some informants have recently started cultivating medicinally important plants to increase their availability. According to a study in southern Mexico [30], cultivation of selected medicinal plants is spreading through the regions because these plants are perceived to be effective and are grown close to the settlements. The cultivation of plants could also affect the compounds in the plants and may homogenize them, thus making it easier to provide a consistent dose to active users (e.g., [63]). Differences in nutritional and chemical composition between wild and cultivated plants are still widely debated, and this issue deserves further investigation [32]. It is important to mention that the most versatile plant species are often the exotic ones. These non-native plant species were introduced, cultivated, spread, and commercialized in Spanish American territories, and nowadays they are common in many ecosystems in the Americas [64].

Conclusions

Our survey showed that there is a rich store of traditional knowledge on medicinal plants in Zacatecas. Although we did not find significant differences in traditional knowledge among different demographic groups, some informants had more knowledge than others.

The present study is the first ethnobotanical inventory of medicinal plants used in Zacatecas. The results showed that the region is an important reservoir of medicinal plant knowledge. Surprisingly, respondents from suburban areas showed richer plant knowledge than their rural counterparts. This may be because they have better market access and can purchase mostly exotic medicinal species, which gives them more knowledge of plants. Women were slightly more knowledgeable than men. The highest informant consensus was reached for reproductive system disorders (ICF = 0.81), as local women commonly exchange knowledge on the use of plants to treat postdelivery complications. Gastrointestinal disorders were the category most frequently treated by plants and were treated by the highest diversity of species (67).

In terms of acquisition of plant resources, the majority of medicinal plants were obtained in the forest or the surrounding areas. This activity may cause the exhaustion of certain plant species in the future, and culturally sensitive development projects should be developed in the region to sustainably cultivate medicinal and aromatic plants.

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Supplementary material

The following supplementary material for this article is available at http://pbsociety.org.pl/journals/index.php/asbp/rt/suppFiles/asbp.3581/0:

Tab. S1 Medicinal uses and cultural importance of plants in Zacatecas state, Mexico.

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