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Source: Tropical Conservation Science, 12(1)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/1940082919879315

Research Article

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Tropical Conservation Science
Volume 12: 1–22

DOI: 10.1177/1940082919879315
journals.sagepub.com/home/trc
SAGE

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Abstract

The ethnobotanical importance of the family Piperaceae is recognized mainly for its medicinal properties. A total of 106 species of two genera of this family (*Piper* and *Peperomia*) have been collected in Oaxaca, but only 18 are recorded in scientific publications as medicinal, edible, veterinary, or ritual plants. The objectives of this study are to describe the traditional knowledge and uses of the Piperaceae in areas of high biocultural diversity of Oaxaca and to analyze the relationship between its geographic distribution with ethnobotanical records among ethnic groups. Fieldwork was carried out between 2013 and 2016, and voucher specimens were reviewed in Mexican herbaria. Two multivariate analyses were applied to compare the geographic distribution of Piperaceae with ethnobotanical knowledge in Oaxaca. A total of 13 species of *Peperomia*, and 7 of *Piper* were collected, besides some unidentified species of both genera. Seven use categories were registered, with medicinal and edible being the most important. A high percentage (65%) of the species is named in at least one native language. Most species have a single use, mainly medicinal. *Peperomia* has been collected in Oaxaca since 1980, while *Piper* since 1960. Multivariate analysis indicated the existence of a differentiated ethnobotanical knowledge of this family among ethnic groups, related to the geographic distribution of species. This study evidences that ethnic groups, who maintain areas of higher biodiversity, obtain these species mainly from the wild, from specific microenvironments; hence, conservation practices must be reinforced for them, as for all ecosystems in general.

Keywords

ethnic group, ethnobotany, herbaria, *Piper*, *Peperomia*

Introduction

Mexico is considered among the 10 countries with the highest levels of biological and cultural diversity in the world (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad [CONABIO], 2019). Based on archaeological records, it is known that use and management of natural resources have occurred at least since 10,000 years ago (Flannery, 1986; MacNeish, 1992), which implies accumulative processes of learning, trying, selection, use, and management of those resources that were selected for different purposes. In addition, a philosophical context has evolved, which means that people have developed a cosmovision, in order to link this knowledge and practices with metaphysic concepts to give a sense to their surrounding world (Menzies & Butler, 2006). Ethnobotanical research has tried to understand that complex world, in order to interpret and explain patterns and processes involved in it, and, as a consequence, different studies have been developed in areas of Mexico, attempting to know, understand, and explain that knowledge.

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Received 6 June 2019; Revised 6 September 2019; Accepted 6 September 2019

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Oaxaca is one of the five states with the highest biological richness in Mexico as well as one of the most important in terms of ethnic composition (De Ávila, 2004); hence, traditional knowledge has been recognized in different studies. In terms of floristic records, Oaxaca contains 40% of the Mexican flora, including 8,000 plant species (Pteridophytes, Gymnosperms, Angiosperms), distributed in 26 vegetation types (Mickel & Beitel, 1988; Torres-Colín, 2004) that represent 70% of all type of vegetation present in Mexico (García-Mendoza, Ordoñez, & Briones-Salas, 2004). Culturally, Oaxaca concentrates 30% of the ethnic groups present in Mexican territory. In this context, knowledge and use of plant resources have been part of their evolution and maintenance in different territories, with a range of different ecological, geological, and climatic conditions within this state. These are the reasons to classify Oaxaca in eight different territorial regions (Instituto Nacional para el Federalismo y el Desarrollo Municipal-Secretaría de Gobernación, 2010; Ordóñez, 2000) and in eight Priority Terrestrial Regions (PTRs) (Arriaga et al., 2000). Due to this complex biocultural diversity (Boege, 2008; Toledo et al., 2001), ethnobotanical research in Oaxaca has been developed during decades, focusing on different aspects (Brown & Chase, 1981; Cardoso, 2004; Cruz & Cruz, 1992; Hunn, 2008; Luna-José & Rendón-Aguilar, 2008; Luna-Morales, Aguirre, & Rogelio, 2001; Martin, 1996; Messer, 1978; Rendón-Aguilar, Bernal-Ramírez, & Bravo-Avilez, 2017; Rendoń-Aguilar, Bernal-Ramírez, Bravo-Avilez, & Mendoza-Ruiz, 2017; Van der Wal, 1996; Ventura-Aquino, Rendón-Aguilar, Rebollar, & Hernández, 2008; Zizumbo & Colunga, 1982; among others). This is the case for ethnobotanical studies about traditional knowledge, use and management of different plant families, such as Piperaceae.

Recent floristic data indicate that from the 321 botanical families present in the state of Oaxaca, Piperaceae is among the 20 most species-rich ones, with two genera (*Peperomia* and *Piper*), and 106 species (García-Mendoza & Meave, 2011; Fonseca, 2011; Fonseca & Samain, 2011), which corresponds to 42% of the species of this family collected in Mexico (Villaseñor, 2016), and 2.9% of the total species recorded globally (Frenzke et al., 2015; Quijano-Abril, Callejas-Posada, & Miranda-Esquivel, 2006; Wanke et al., 2007). In addition to these records, a research project including a screening of the ethnofloristic richness in Oaxaca (Rendón-Aguilar, Bernal-Ramírez, & Bravo-Avilez, 2017) reported that the family Piperaceae is one of the 10 most useful families in Oaxaca, of a total of 142 families (Rendón-Aguilar, Bernal-Ramírez, & Bravo-Avilez, 2017; Rendoń-Aguilar, Bernal-Ramírez, Bravo-Avilez, & Mendoza-Ruiz, 2017).

However, relatively few taxa have been reported with a traditional use in scientific literature, mainly in the states of Chiapas, Oaxaca, and Veracruz. In the case of *Piper*, ethnobotanical studies reported only six species: *Piper auritum* Kunth (Aguilar, Chino, Jaquez, & Lopez, 1994; Andrade-Cetto & Heinrich, 2005; Browner, 1985; Estrada-Reyes, Martínez-Laurrabaquio, Ubaldo-Suárez, & Araujo-Escalona, 2013; Frei, Baltisberger, Sticher, & Heinrich, 1998; Garcíá, Leyva, Martíñez & Stashenko, 2007; Geck, 2018; Geck, Reyes-García, Casu, & Leonti, 2016; Joly, 1981; Martíñez, 1969; Picó & Nuez, 2000; Salinas-Espinoza, Vásquez-Dávila, Romero-Santillán, Manzanero-Medina, 2017; Schultes & Hofmann, 2000); *Piper umbellatum* L. (Giovannini & Heinrich, 2009; Roersch, 2010); *Piper sanctum* (Miq.) Schltdl. ex C. DC.; *Piper marginatum* Jacq. (Picó & Nuez, 2000); *Piper amalago* L.; and *Piper unguiculatum* Ruiz & Pav. (Frei et al., 1998; Geck, 2018; Geck et al., 2016).

In the case of the genus *Peperomia*, previous ethnobotanical studies in Mexico reported: *Peperomia hernandiifolia* (Vahl,) A. Dietr., *Peperomia hobbitoides* T. Wendt, *Peperomia peltilimba* C. DC. ex Trel., *Peperomia rotundifolia* (L.) Kunth., and *Peperomia berlandieri* Miq. (Luna-José & Rendón-Aguilar, 2012; Vergara-Rodríguez, Mathieu, Samain, Armenta-Montero, & Krömer, 2017); *Peperomia maculosa*, *Peperomia pellucida* (L.) Kunth, *Peperomia peltata* (L.) A. Dietr., *P. rotundifolia* (L.) Kunth (Giovannini & Heinrich, 2009; Mahiou et al., 1995), and *Peperomia nigropunctata* Miq. (Fournet et al., 1996; Giovannini & Heinrich, 2009).

For these reasons, the objectives of this work are to contribute to the ethnofloristic records of useful Piperaceae in Oaxaca, in areas of high biocultural diversity, and to analyze the relationship between the geographical distribution of this family and its ethnobotanical records among ethnic groups, in order to discard possible bias due to an oversampling during the development of this study within any of the PTRs.

Methods

Study Area

The study area comprised 84 municipalities (Figure 1) belonging to three of the eight PTRs proposed by Arriaga et al. (2000) for the state of Oaxaca, all of them characterized by a very rich ethnic composition and high levels of biodiversity. These municipalities were selected in order to obtain a representative sample of each PTR, trying to include most of the area occupied by each one (Bernal-Ramírez et al., 2019; Rendón-Aguilar, Bernal-Ramírez, & Bravo-Avilez, 2017; Rendoń-Aguilar, Bernal-Ramírez, Bravo-Avilez, & Mendoza-Ruiz, 2017)

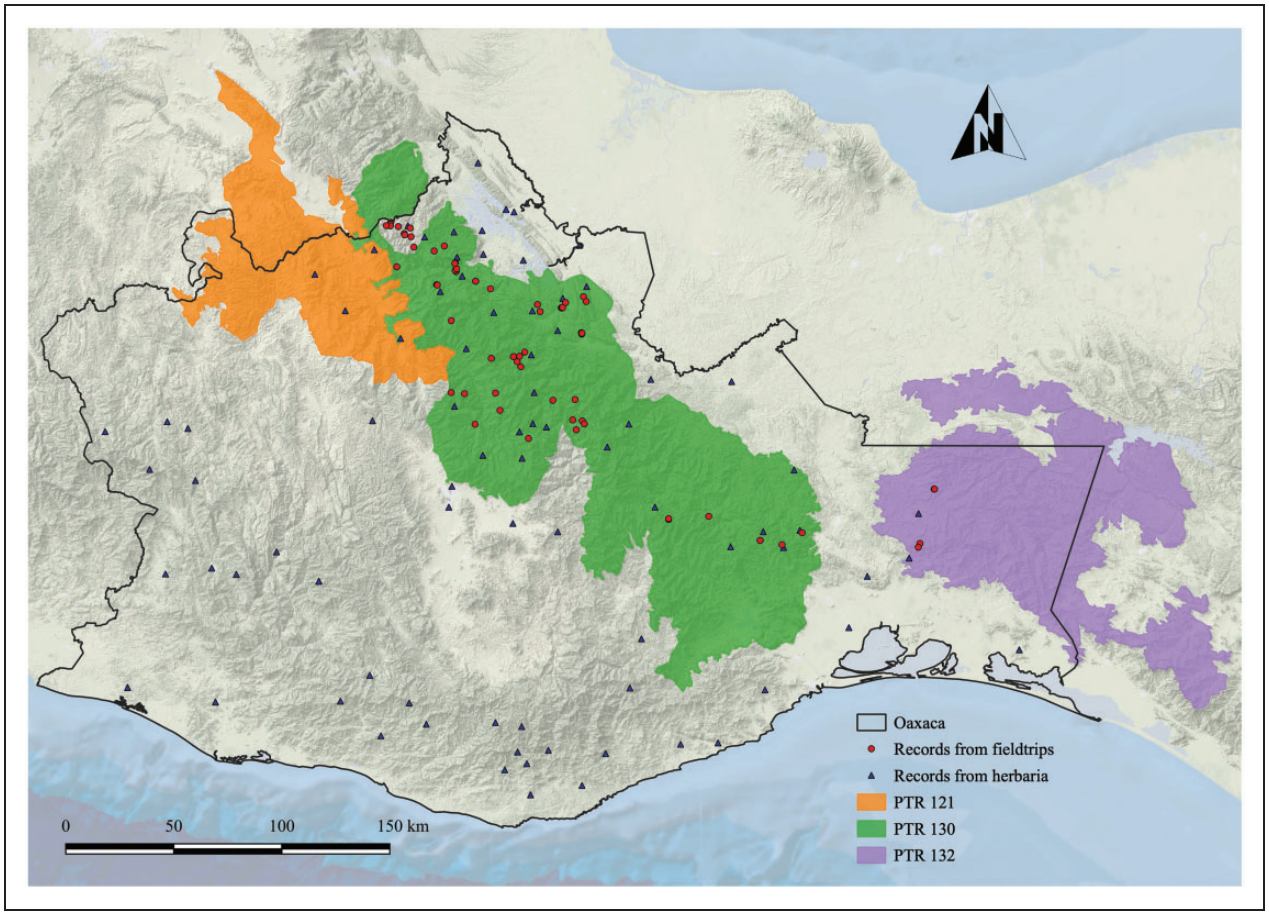

Figure 1. Map showing the study area in three PTRs of Oaxaca: PTR 121, Valle de Tehuacán-Cuicatlán; PTR 130, Sierras del Norte de Oaxaca-Mixe; PTR 132, Selva Zoque-La Sepultura. Red dots indicate localities from fieldtrips, and triangles represent herbarium specimens.

(Figure 1) (Online Appendix 1). These 84 municipalities represented 37% of the total (208) included in these regions (only for the state of Oaxaca):

PTR 121 (Valle de Tehuacán-Cuicatlán) includes 68 municipalities from Oaxaca (45) and Puebla (23). Municipalities of Oaxaca are inhabited by five ethnic groups: Cuicatec, Ixcatec, Mazatec, Nahua, and Mixtec. This region is characterized by the presence of an extensive area of semiarid vegetation in lowlands, such as xerophilous scrub and deciduous tropical forest, with a high proportion of endemism; highlands are represented by pine-oak forest and montane cloud forest. Municipalities of Oaxaca occupy more than half of this region (66.2%). We visited only five of these (11.1%), inhabited by Cuicatec, Mazatec, and Nahua.

PTR 130 (Sierras del Norte de Oaxaca-Mixe) includes 165 municipalities from Oaxaca, Puebla, and Veracruz. Those belonging to Oaxaca (156) are inhabited by Zapotec, Mixe, Chinantec, Nahua, and Mixtec ethnic groups, occupying the highest proportion of this region (94.5%). This region is characterized by a complex landscape, with the presence of different ecosystems with low levels of fragmentation, such as different kinds of temperate and tropical forests (e.g., pine forest, oak forest and subdeciduous tropical forest, among others). Montane cloud forest has its highest area of distribution in this region, and it presents a high level of conservation. We visited 76 municipalities (46%), inhabited by the ethnic groups mentioned earlier.

PTR 132 (Selva Zoque-La Sepultura) includes 17 municipalities from Chiapas, Oaxaca, and Veracruz. Seven municipalities belong to Oaxaca and are inhabited by Zapotec and Zoque groups. It occupies one of the highest extensions of all PTR. It presents a complex mixture of different tropical forests in lowlands, montane cloud forest, and different template forests in highlands. We sampled only three municipalities (17.6%) represented by Zoque ethnic group.

The sampled areas also included four municipalities with Mestizo populations (San Pedro Teutila, Natividad and Santiago Xiacuí in PTR 130, and San Pedro Tapanatepec in PTR 132).

Ethnobotanical Information

In each of the 84 municipalities visited, we explained the purposes of the study to local authorities, asking for support of local guides who knew the area, the plants used currently and in the past, and their names in the local language and in Spanish, as well as for authorization to collect these species. As the project involved an ethnofloristic screening of 84 municipalities, we followed an "accidental sampling," which is a nonprobabilistic sampling technique used in exploratory ethnobiological studies (Albuquerque et al., 2014). Two or three local guides, most of them were men ranging in age between 20 and 65 years, were designated by each municipal authority; female local guides were assigned only in four municipalities (Bernal-Ramírez et al., 2019; Rendón-Aguilar, Bernal-Ramírez, & Bravo-Avilez, 2017; Rendoń-Aguilar, Bernal-Ramírez, Bravo-Avilez, & Mendoza-Ruiz, 2017). Ethnobotanical records came from about 200 local people. We also obtained permission to collect useful plants in preserved or sacred areas and in places with special ecological importance (e.g., near waterfalls, archaeological sites, and glens).

Fieldtrips of 10 to 12 days every 2 months were conducted for 3 years (2013–2016) to collect plants in all proposed municipalities (Rendón-Aguilar, Bernal-Ramírez, & Bravo-Avilez, 2017; Rendón-Aguilar, Bernal-Ramírez, Bravo-Avilez, & Mendoza-Ruiz, 2017). Due to the amplitude of the studied area, and the time restriction, each municipality was visited once (Bernal-Ramírez et al., 2019; Rendón-Aguilar, Bernal-Ramírez, & Bravo-Avilez, 2017; Rendoń-Aguilar, Bernal-Ramírez, Bravo-Avilez, & Mendoza-Ruiz, 2017). As a consequence of these logistical limitations, in many cases, local guides noted useful species that did not show flowers and fruits at the time of the fieldwork, which were neither collected nor recorded.

Each specimen with flowers and fruits which was recognized by local guides as useful was photographed and collected, and ecological and geographical data were recorded, including date, municipality, locality, geographic coordinates, altitude, type of vegetation, visual soil characteristics, biological data of each species (habitat, size, growth form, and characteristics of reproductive structures), common name(s), use(s), use categories, parts of plants used, and descriptions of their use. All specimens were numbered, placed temporarily in brown paper bags, and later processed for transportation. Once in the laboratory, specimens were dried appropriately and distributed to specialists for their taxonomic identification.

Identification and Deposition of Plant Specimens

Herbarium specimens were reviewed and identified with specialized keys, whenever possible. One specimen was labeled, mounted, and deposited in the herbarium UAMIZ of the Metropolitan Autonomous University, Iztapalapa, Mexico City. Duplicates will be distributed to the National Herbarium of Mexico (MEXU) of the National Autonomous University of Mexico, the herbarium OAX, Interdisciplinary Research Center for Integral Development Regional Unit of Oaxaca (CIIDIR-Oaxaca), and the Institute of Ecology Herbarium, Pátzcuaro, Michoacán (IEB).

Ethnobotanical Information of Field Collections During the Project

Field information was systematized in an Excel database in order to analyze traditional knowledge, measured as the species recognized with any use, their names in a local language (De Ávila, 2004) and in Spanish, use categories and the forms of use or preparation. In addition, the information for each specimen was integrated into the database BIÓTICA © 5.0.3 (CONABIO, 2012). Photographs of specimens taken in the field were deposited in the image bank of CONABIO.

Ethnobotanical Information of Herbarium Specimens

All specimens of this family collected in Oaxaca were reviewed in the collection of the National Herbarium of Mexico (MEXU), and the herbaria of the Institute of Ecology, A.C. in Xalapa (XAL), and Pátzcuaro (IEB), and the information of the labels was captured, from which an Excel database was created with the following columns: state, municipality, locality, geographical coordinates, altitude, type of vegetation, and habitat, as well as ethnobotanical information in case of existence. This information was used to compare our findings with those previously reported and to check their geographic distribution. In addition, the electronic database of the National Herbarium of Mexico was reviewed, and the same information was recorded.

Ethical Authorization

The CONABIO (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad), through the Subcoordination of Information and Analysis, provided approval of all results reported in project JF102 "Inventario etnoflorístico en regiones oaxaqueñas con gran biodiversidad" (Of. No. DGP/787/16).

Data Analysis

Data were analyzed to obtain the number of useful species recorded in these genera, common name (local language or Spanish), and use categories. From the 84 municipalities visited during the project, we obtained specimens of Piperaceae from 45 municipalities.

To compare compositional similarity between our field collections of both genera in Oaxaca with the geographic distribution of the family recorded in herbaria specimens in order to discard a possible bias due to oversampling in any of the three PTR during the fieldtrips, we followed a nonmetric multidimensional scaling analysis (nMDS, using Jaccard index in PAST 3.2 software; Ø. Hammer, Harper, & Ryan, 2001). This is a nonparametric rank-based approach for graphically representing relationships between kinds of samples in a multidimensional space through dissimilarity measure (Quinn & Keough, 2002) and is an appropriate ordination method for not normal distribution data or those with a discontinuous or arbitrary scale. In addition, a centered principal component analysis in a correlation matrix was performed to characterize possible clustering through plant species and ethnic groups and vegetation type (Bernal-Ramírez et al., 2019; Rendón-Aguilar, Bernal-Ramírez, & Bravo-Avilez, 2017; Rendoń-Aguilar, Bernal-Ramírez, Bravo-Avilez, & Mendoza-Ruiz, 2017).

Results

Ethnobotanical, ecological, and floristic information about Piperaceae in Oaxaca came from 45 municipalities (53.6% of the total area visited), all of them corresponding to new localities for any of the species collected, and from seven ethnic groups: Cuicatec, Chinantec, Mazatec, Mixe, Nahua, Zapotec, Zoque, as well as the Mestizo group.

Ethnobotanical Aspects of the Piperaceae Family in Oaxaca

Number of useful Piperaceae. Seventy-one specimens were collected corresponding to 20 species, 6 affinities, and 15 specimens identified only to genus level. We found 25 specimens of the genus *Peperomia*, belonging to 13 species, 4 affinities, and 8 specimens identified at genus level. In the case of *Piper*, 16 specimens were collected: seven species, two affinities, and seven identified to genus (Table 1).

Common name (local language or Spanish). Eleven of the 17 species and all affinities of the genus *Peperomia* are named in at least one language, and of these, 7 also have a name in Spanish. Two species receive Spanish names only (Table 1). In the case of *Piper*, of the seven species and the two affinities, almost all are named in a native language and in Spanish, except *Piper* aff. *uhdei* which is named only in Spanish.

Use categories. Seven use categories were recorded. Species of both genera are mainly applied for medicinal purposes; the rest of the uses present variations between both genera. Hence, it is noteworthy that five species of the genus *Peperomia* are used as fresh (vegetable), or processed (seasoning) food, whereas in the genus *Piper*, only *P. auritum* is utilized in this form. In addition, only species of *Piper* are used as firewood, for construction, or for a veterinary purpose, and only three species of *Peperomia* are used as ornamentals (Figure 2(a)).

The medicinal use includes treatments as diverse as acne elimination, childbirth recovery, toothache relief, stomach pain, and erysipelas symptoms, among others (Table 1). Even two species of the genus *Piper* (i.e., *Piper aduncum*, and *P. auritum*) are employed against snakebites.

The ceremonial use corresponds to the species *P. amalago*, *Peperomia obtusifolia*, and *Peperomia quadrangularis* and is related to the treatment of psychosomatic diseases such as evil wind ("mal aire") or evil eye ("mal de ojo"). These ailments include symptoms such as headache, stomach spasms, chest tightness, teary eye, and anxiety. In addition, they usually refer to extreme anxiety or panic attacks ("susto") that can occur when, for example, a snake crosses one's path, or when someone surprises his partner in infidelity. In both cases, people are fatigued, sleepy, and they lose hair and weight, among other symptoms. Moreover, these species are placed on the altars of saints, alone or in association with mosses during and after religious celebrations. Plants used as ornamentals are usually placed in a pot or in the garden of the house (e.g., *P. maculosa*, *Peperomia pseudoalpina*, *P. rotundifolia*). Edible plants can be eaten on their own, such as fresh vegetables, or added to beans or tamales. Such is the case of *P. hernandiifolia*, *P. maculosa*, *Peperomia pecuniifolia*, and *P. quadrangularis*, as well as *P. auritum*. For construction, the stems of *P. aduncum* are used as the support of palm thatch roofs. The veterinary use corresponds to *Piper peltatum*, whose macerated leaves are smeared on the skin of affected dogs to combat scabies. For fuelwood, the thick stems of *Piper lapathifolium* are frequently used (Table 1).

In relation to the number of uses, most species of *Peperomia* have only one, which, as already mentioned, is mainly medicinal, edible, ceremonial, or ornamental. *P. maculosa* and *P. quadrangularis* have two uses: edible-ornamental and edible-ceremonial, respectively. Of the seven species of the genus *Piper*, six have medicinal uses and three have a dual one: *P. aduncum*, medicinal-construction, *P. auritum*, medicinal-edible, and *P. lapathifolium*, medicinal-fuel (Figure 2(b)).

Ethnobotanical Knowledge Recorded on Herbarium Specimens

The information obtained in the herbaria shows that most species of both genera, except for

Table 1. Uses, forms of Use, and Distribution of the Family Piperaceae in Oaxaca (Rendón-Aguilar, Bernal-Ramírez, & Bravo-Avilez, 2017).

Species	Local name (Spanish/local language)	Ethnic group	Category of use	Use	Qualitative appreciation of abundance	Municipalities	Type of vegetation, altitude (m asl)	Municipalities recorded in voucher specimens (MEXU, XAL, IEB)	Uses reported in voucher specimens
Peperomia									
Peperomia alpina (Sw.) A. Dietr.	nr	mi	M	Skin grains	Scarce	Stgo. Zacatepec	PTF 1672–	San Pedro Ocotepec, Stgo. Comaltepec, Totontepec Villa de Morelos	nr
Peperomiablanda (Jacq.) Kunth	nr	cui	M	Anxiety or panic	Scarce	San Andrés Teotilálpam	MCF 1163–	Capulálpam de Méndez, San Jerónimo Coatlán, San Jerónimo Sosola, San José Chiltepec, San Juan Bautista Valle Nacional, San Juan Juquila Vijanos, San Miguel Suchixtepec	nr
Peperomia clavigera Standl. & Steyerm.	sp, ch	ch	M	Stomach ache	Scarce	San Felipe Usila	SDTF 529–	San José Chiltepec, San Lucas Ojitlán	nr
Peperomia hernandiifolia (Vahl) A. Dietr.	sp, mi, ch	mi, ch	F	Fresh leaves eaten or added to cooked beans, tamales and memelas	Scarce to medium	San Miguel Quetzaltepec, San Pedro Sochiápam, San Pedro Teutila, San Pedro Yólox	MCF, PF, PEF 1291–1830	San Miguel del Puerto	nr
Peperomia leptophylla Miq.	ma	ma	M	Teeth ache	Scarce	Sta. Cruz Acatepec	OF 1967–	Asunción Ixtaltepec, Ixtlán de Juárez, San Andrés Chicahuastla, San Juan Evangelista Analco, San Martín de las Peras, San Miguel Suchixtepec, Sta. Ma. Yavesía, Stgo. Textitlán, Stgo. Yosondúa, Totontepec Villa de Morelos	nr
Peperomia maculosa (L.) Hook.	sp	mi, za	F, O	Fresh leaves	Scarce to medium	Guevea de Humboldt, San Miguel Quetzaltepec	OF, MCF 1164–1314	Guevea de Humboldt, San Miguel Chimalapa, Sto. Domingo Tehuantepec	nr
Peperomia obtusifolia (L.) A. Dietr.	sp, za	za	C	To decorate saints´ altars.	Medium	Sta. Ma. Guienagati	MCF 1274–	Acatlán de Pérez Figueroa, Guevea de Humboldt, Huautla de Jiménez, Ixtlán de Juárez, Jesús Carranza, Juchitán de Zaragoza, Nuevo Soyaltepec, San Bartolomé Ayautla, San Felipe Usila, San Jerónimo Coatlán, San Juan Bautista Valle	nr

(continued)

Table 1. Continued.

Species	Local name (Spanish/local language)	Ethnic group	Category of use	Use	Qualitative appreciation of abundance	Municipalities	Type of vegetation, altitude (m asl)	Municipalities recorded in voucher specimens (MEXU, XAL, IEB)	Uses reported in voucher specimens
								Nacional, San Juan Comaltepec, San Miguel del Puerto, San Miguel Soyaltepec, San Pedro Ocotepec, Sta. Ma Chimalapa, Sta. Ma. Guienagati, Sta. Ma. Jacatepec, Stgo. Comaltepec, Stgo. Lachiguiri, Sto. Domingo Tehuantepec, Totontepec Villa de Morelos, Vista Hermosa	
Peperomia pecuniifolia Trel. & Standl	sp, za	za	F	Added to cooked beans	Medium	Sta. Ma. Jaltianguis	POF 3020–	**Without record in herbarium** **Reported only for Oaxaca, without specification (Villaseñor, 2016)**	nr
Peperomia peltilimba C. DC. ex Trel	ch	ch	M	Inflamed feet	Medium	Sta. Ma. Jacatepec	PTF 320–	Guevea de Humboldt, Ixtlán de Juárez, San Felipe Usila, San José Tenango, San Juan Bautista Valle Nacional, Sta. Ma. Zacatepec, Stgo. Comaltepec, Stgo. Lachiguiri, Totontepec Villa de Morelos	F: edible leaves V: remove worms in cows
Peperomiapseudoalpina Trel.	sp	za	O	Nr	Medium	Guevea de Humboldt	MCF 1164–	San José Tenango, Stgo. Comaltepec	nr
Peperomia quadrangularis (J. V. Thomps.) A. Dietr.[a]	za, ma	za, ma	F, C	Fresh leaves are eaten; For bad air	Scarce to High	San José Tenango, San Miguel Abejones, San Miguel Aloápam, Stgo. Xiacuí	OPF, POF, SDTF 1424–2941	**Without record**	nr
Peperomia quadrifolia (L.) Kunth	nr	ma	nr	Nr	Not indicated	San Francisco Huehuetlán	MCF 2200–	Guevea de Humboldt, Huautla de Jiménez, Ixtlán de Juárez, San Felipe Usila, San Jerónimo Coatlán, San Juan Bautista Cuicatlán, San Juan Comaltepec,	F, C

(continued)

Table 1. Continued.

Species	Local name (Spanish/local language)	Ethnic group	Category of use	Use	Qualitative appreciation of abundance	Municipalities	Type of vegetation, altitude (m asl)	Municipalities recorded in voucher specimens (MEXU, XAL, IEB)	Uses reported in voucher specimens
								San Juan Guichicovi, San Mateo Río Hondo, San Miguel Aloápam, San Miguel Yotao, San Pedro Tapanatepec, San Pedro Teutila, Sta. Catarina Ixtepeji, Sta. Cruz Itundujia, Sta. Ma. Ixcatlán, Sta Ma. Zacatepec, Stgo. Comaltepec, Stgo. Lachiguiri, Stgo. Textitlán, Stgo. Yaitepec, Tanetze de Zaragoza, Tepelmeme Villa de Morelos, Totontepec Villa de Morelos	
Peperomia rotundifolia (L.) Kunth	nr	cui	O	**Decoration of saints**´altars, Niño Dios (along with moss)	Medium	San Andrés Teotilálpam	MCF 1163–	Huautla de Jiménez, San Felipe Usila, San José Tenango, Stgo. Comaltepec, Sta. Ma. Chimalapa	M
P. aff. *blanda* (Jacq.) Kunth	sp, ma, ch	ma, ch	M	To eliminate mud; **for** labor recovery	Scarce	San Juan Quiotepec, San Lorenzo Cuanecuiltitla	MCF, POF 2052–2354	[b]	
*Peperomia*aff. *glabella* (Sw.) A. Dietr.	sp, ch	ch	M	Erysipelas	Scarce	San Juan Bautista Valle Nacional	PTF 617–	[b]	
*Peperomia*aff. *glabra* C. DC.	sp, cui	cui	O	To decorate houses	Scarce	San Andrés Teotilálpam	MCF 1163–	[b]	
*P.*aff. *leptophylla* Miq.	ch	ch	M, C	Rheumatism, dysentery, anxiety or panic	Scarce	San Juan Quiotepec	MCF 2354–	[b]	
Piper									
Piper aduncum L.	sp, ch, za	ch, za	CO, M	Cold, snakebite, roof support	Scarce to medium	San Cristóbal Lachirioag, San Ildefonso Villa Alta, San Pedro Yólox, Sta. María Jacatepec, Stgo. Comaltepec	OF, MCF, PTF, SDTF 265–1332	Acatlán de Pérez Figueroa, Guevea de Humboldt, Ixtlán de Juárez, Jamiltepec, Jamiltepec-Pinotepa Nacional, Pochutla y Candelaria Loxicha, Putla Villa de Guerrero, San Gabriel Mixtepec, San Jerónimo	nr

(continued)

Table 1. Continued.

Species	Local name (Spanish/local language)	Ethnic group	Category of use	Use	Qualitative appreciation of abundance	Municipalities	Type of vegetation, altitude (m asl)	Municipalities recorded in voucher specimens (MEXU, XAL, IEB)	Uses reported in voucher specimens
								Coatlán, San Juan Comaltepec, San Mateo Piñas, San Miguel del Puerto, San Miguel Soyaltepec, San Pedro Ixcatlán, San Pedro Juchatengo, San Pedro Teutila, San Sebastián Coatlán, Sta. Cruz Itundujia, Sta. Ma. Chimalapa, Sta. Ma. Ecatepec, Sta. Ma. Tlalixtac, Stgo. Comaltepc, Stgo. Astata, Stgo. Juxtlahuaca, Stgo. La Galera, Soyaltepec, Soyolapan, Temascal, Tuxtepec - Jalapa de Díaz, Totontepec Villa de Morelos	
Piperamalago L.	sp, mi	mi	C	Evil eye	Medium	Stgo. Ixcuintepec	SDTF 624–	Eloxochitlán de Flores Magón, Huautla de Jiménez, San Bartolo Yautepec, San Felipe Jalapa de Díaz, San Jerónimo Coatlán, San José Chiltepec, San Juan Bautista Valle Nacional, San Juan Comaltepec, San Juan Guichicovi, San Lucas Ojitlán, San Miguel del Puerto, San Miguel Soyaltepec, San Miguel Suchixtepec, San Pedro Huamelula, San Pedro Teutila, Sta. Ma. Chimalapa, Sta. Ma. Ecatepec, Sta. Ma. Jacatepec, Stgo. Comaltepec, Stgo. Jamiltepec, Stgo. Juxtlahuaca, Sto.	M: To relief fever, scare, body pain, dry caught C: "bad eye"

(continued)

Table 1. Continued.

Species	Local name (Spanish/local language)	Ethnic group	Category of use	Use	Qualitative appreciation of abundance	Municipalities	Type of vegetation, altitude (m asl)	Municipalities recorded in voucher specimens (MEXU, XAL, IEB)	Uses reported in voucher specimens
								Domingo Petapa, Sto. Domingo Tehuantepec	
Piper auritum Kunth	sp, cui, zo, ma, mi, na, za	cui, ma, mi, na, za	F, M	Leaves added to different dishes: chicken and fish soup, mole, tamales, chilatole, mixiotes, tezmole. Fresh stem is eaten. Hemorrhage, diarrhea, Anger, snakebite, pressure in the ears	Scarce to high	Huautepec, Mazatlán Villa de Flores, San Francisco Chapulapa, San Juan Cotzocón, San Miguel Chimalapa, San Pedro Teutila, Sta. Cruz Acatepec, Sta. María Teopoxco, Stgo. Camotlán, Stgo. Texcalcingo, Sto. Domingo Roayaga, Teococuilco de Marcos Pérez	OF, OPF, GV, POF, MCF, PTF, DTF, SDTF 342–1928	Asunción Ixtaltepec, Eloxochitlán, Ixtlán de Juárez, Oax. de Juárez, San Felipe Jalapa de Díaz, San José Tenango, San Juan Bautista Valle Nacional, San Juan Comaltepec, San Juan Guichicovi, San Juan Mixtepec, San Juan Quiotepec, San Lorenzo Albarradas, San Lucas Ojitlán, San Miguel Soyaltepec, Sta. Cruz Itundujia, Sta. Cruz Xoxocotlán, Sta. Ma. Huatulco, Sta. Ma. Ixcatlán, Stgo. Camotlán, Stgo. Comaltepec, Stgo. Juxtlahuaca, Stgo. Pinotepa Nacional, Stgo. Textitlán, Sto. Domingo Petapa, Sto Domingo Roayaga, Sto. Domingo Tehuantepec, Sto. Domingo Yodohino, Santos Reyes Tepejillo, Tlacolula de Matamoros, Totontepec Villa de Morelos	M: To relief fever, to relief hot body after a dead person is charged; skin and vaginal infections F: edible buds, stems, and leaves and seasoningf
Piper lapathifolium (Kunth) Steud.	sp, ch	ch	M, FU	Diarrhea, fuel		San José Chiltepec, San Juan Bautista Valle Nacional	PTF 430–461	San Juan Bautista Valle Nacional, San Felipe Usila, San José Tenango, San Lucas Ojitlán, Santa María Jacatepec, Yaveo	nr
Piper peltatum L.	sp, ch	ch	V	Scabies	Medium	Sta. Ma. Jacatepec	PTF 219–	Sta. Ma. Huatulco	nr
Piper schiedeanum Steud.	sp, ch	ch	M	Rheumatism	Medium	Sta. Ma Jacatepec	PTF 78–	San José Chiltepec, San Juan Bautista Valle Nacional, San Miguel Soyaltepec,	M: snakebite

(continued)

Table 1. Continued.

Species	Local name (Spanish/local language)	Ethnic group	Category of use	Use	Qualitative appreciation of abundance	Municipalities	Type of vegetation, altitude (m asl)	Municipalities recorded in voucher specimens (MEXU, XAL, IEB)	Uses reported in voucher specimens
Piper umbellatum L.	sp, ch, ma, za	ch, ma, za	M	Skin grains; muscular pain; stomach ache; clean skin	Scarce	Eloxochitlán de Flores Magón, Huautla de Jiménez, San José Chiltepec, San Juan Yaeé	MCF, OF, POF, PTF 227–1632	Sta. Ma. Chimalapa, Sta. Ma. Jacatepec, Yecuatla Acatlán de Pérez Figueroa, Candelaria Loxicha, Ixtlán de Juárez, Pluma Hidalgo, San Bartolo Yautepec, San Felipe Usila, San Jerónimo Coatlán, San José Tenango, San Juan Lalana, San Miguel Chimalapa, San Miguel del Puerto, San Miguel Soyaltepec, San Pedro Ixcatlán, Sta. Cruz Itundujia, Sta. Ma. Huatulco, Stgo. Textitlán	nr
P. aff. *schiedeanum* Steud.	sp, ch	ch	M	Stomach ache	Scarce	Sta. Ma Jacatepec	PTF 320–	**Reported only for Oaxaca, without specification (Villaseñor, 2016)[b]**	
*Piper*aff. *uhdei* C. DC.	sp	zo	FU	Fuel	High	Sta. Ma Chimalapa	PTF 405–	**Reported only for Oaxaca, without specification (Villaseñor, 2016)[b]**	

Note. MEXU = National Herbarium of Mexico; XAL = the herbaria of the Institute of Ecology, A.C. in Xalapa; IEB = Institute of Ecology Herbarium, Pátzcuaro, Michoacán; SDTF = subdeciduous tropical forest; PTF = perennial tropical forest; MCF = montane cloud forest; POF = pine-oak forest; OF = oak forest.

[a]Means new records for Oaxaca.

[b]No information of herbaria was included for specimens with *affinis*, due to the absence of taxonomic classification. Cuicatec (cui); Chinantec (ch); Mazatec (ma); Mixe (mi); Náhuatl (na); Spanish (sp); Zapotec (za); Zoque (zo); Not recorded (nr). Ceremonial (C); Construction (CO); Food (F); Fuel (FU); Medicine (M); Ornament (O); Veterinary (V). MEXU (National Autonomous University of Mexico); XAL (Institute of Ecology-Xalapa); IEB (Herbarium of the Regional Center of the Bajío, Institute of Ecology).

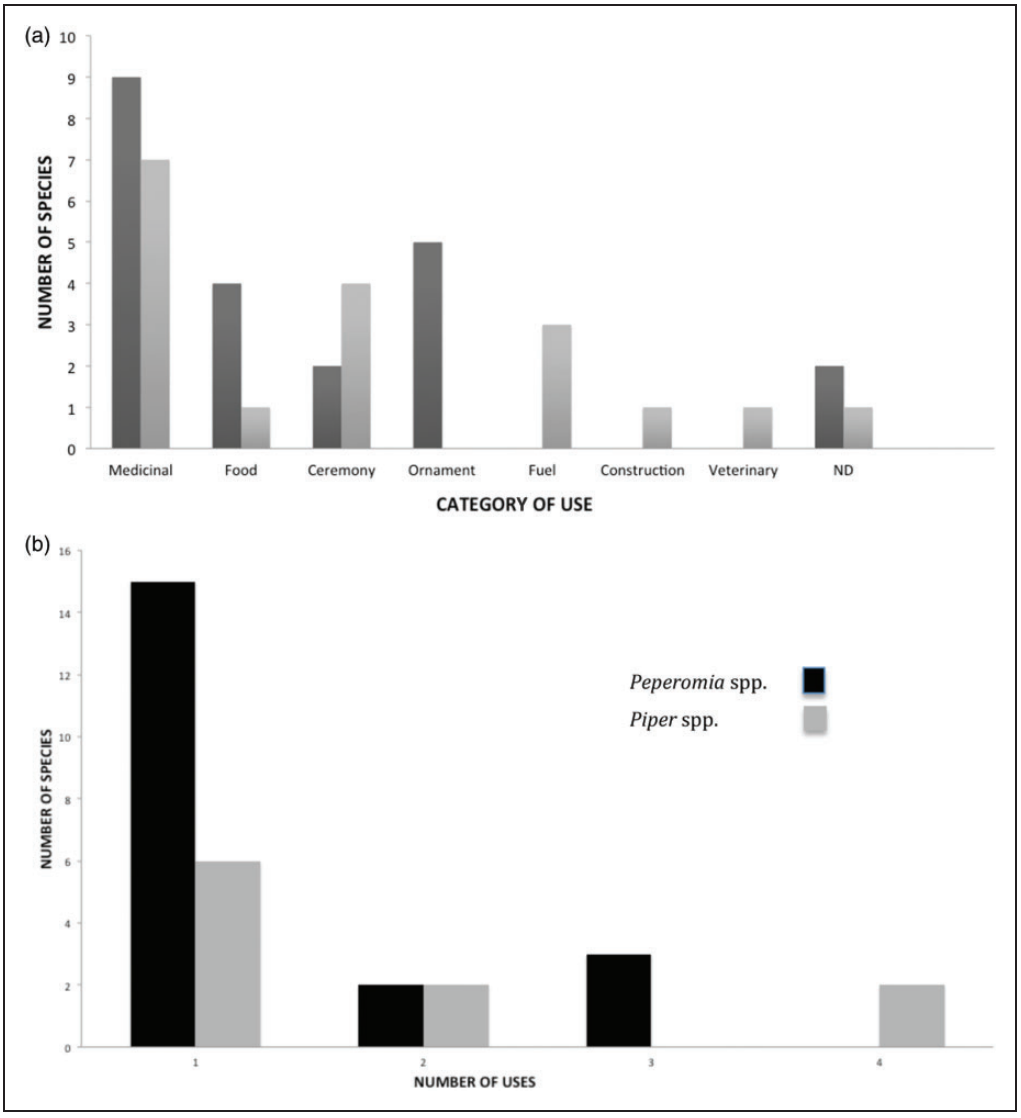

Figure 2. Uses of the family Piperaceae in the state of Oaxaca: (a) Use categories recorded during field trips and (b) number of uses.

P. quadrangularis, have previously been collected in several municipalities of the state, either in one to three municipalities (e.g., *Peperomia alpina*, *P. hernandiifolia*, *P. maculosa*, *P. pseudoalpina*, *P. lapathifolium*, and *P. peltatum*) or with more than 20 records (e.g., *P. obtusifolia* and *Peperomia quadrifolia*, *P. aduncum*, *P. amalago*, *P. auritum*). However, all the specimens collected in this study represent new records within the area sampled during this study (Table 1). It is worth mentioning that of the 11 species with herbarium records of the genus *Peperomia* exclusively for the state of Oaxaca, a little more than 70% were collected from the 1980s onwards. In the case of *Piper*, almost 60% of the species were collected from the decade of the 1960s onwards.

The ethnobotanical information available on herbarium specimens is scarce. As indicated, only three species of *Peperomia* recorded food, veterinary, ceremonial and medicinal use (*P. peltilimba*, *P. quadrifolia*, *P. rotundifolia*) and only three species of *Piper* recorded some use (*P. amalago*, *P. auritum*, *Piper schiedeanum*), mainly medicine and food (Table 1).

The nMDS analysis shows that the voucher specimens, as well as our records from fieldwork of the two genera of Piperaceae, do mainly overlap on the plot (Figure 3). Dots outside the 95% confidence ellipses correspond to geographic areas of northeast Oaxaca that were visited and sampled for the first time. The principal component analysis displays at least two groups of Piperaceae species (Figure 4). With respect to the first component, the left

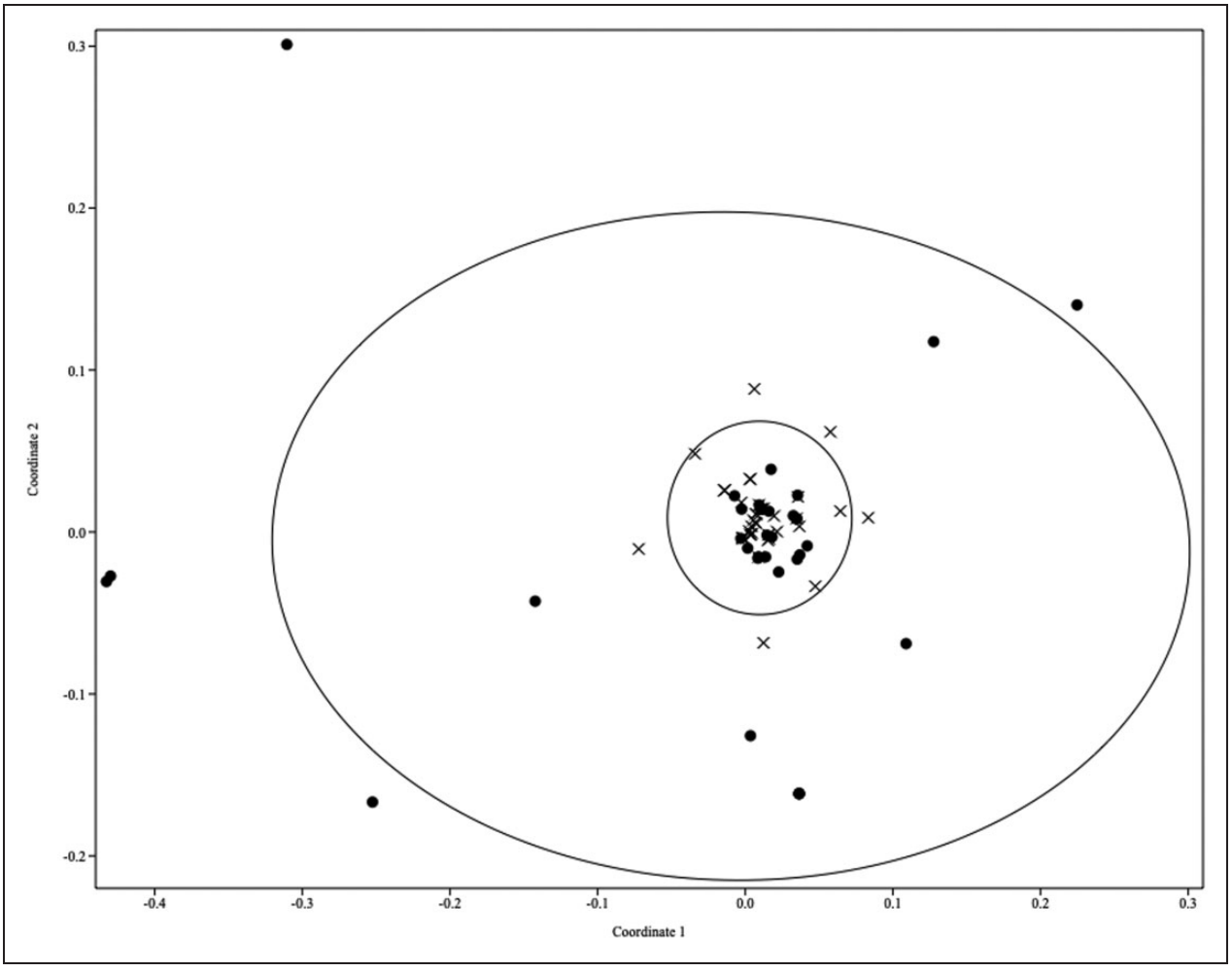

Figure 3. The nMDS scatter plot using Jaccard index. Dots represent plants collected during field trips, and crosses refer to herbarium specimens (stress = 0.689).

section shows species used by Chinantec and Zoque ethnic groups, associated to perennial tropical forest (PTF) and subdeciduous tropical forest, and distributed in lowlands below 1,000 m a.s.l.; the section at the right groups species distributed in temperate zones, with pine-oak forest, oak-pine forest, and oak forest, used by Zapotec and Mazatec ethnic groups. The second component separates, in the lower right section, those useful species collected in montane cloud forest, which are not associated with a specific ethnic group. This means that montane cloud forest in Oaxaca is a germplasm reservoir to the different ethnic groups, and even when they frequently gather natural resources from this type of vegetation, it still remains as one of the most important plant cover areas in Oaxaca (CONABIO, 2010).

Discussion

This study resumes ethnobotanical knowledge of 26 useful species and affinities of family Piperaceae in Oaxaca, as well as new records of 17 species (5 species from *Piper* and 12 from *Peperomia*), collected in 45 municipalities, from the 84 visited between 2013 and 2016, in different biocultural regions of this state, inhabited by seven ethnic groups, and four municipalities conformed by the Mestizo group. These records represent more than those existing in previous literature for Oaxaca (from 1982 to the present). In addition, this is the first record of five useful species of Piperaceae within Mixe communities (*P. alpina*, *P. hernandiifolia*, *P. maculosa*; *P. amalago*, and *P. auritum*).

Ethnobotanical, taxonomic, and ecological relevance of this family for Oaxaca is remarkable due to the fact that many species are gathered from the wild. The ecological statuses of most of them are unknown; nevertheless, they grow in specific microhabitats, or on specific phorophytes, and our qualitative evaluation indicates that their populations are scarce (Table 1), so it is possible they are at risk due to deforestation, habitat fragmentation, or over-gathering, as indicated in other

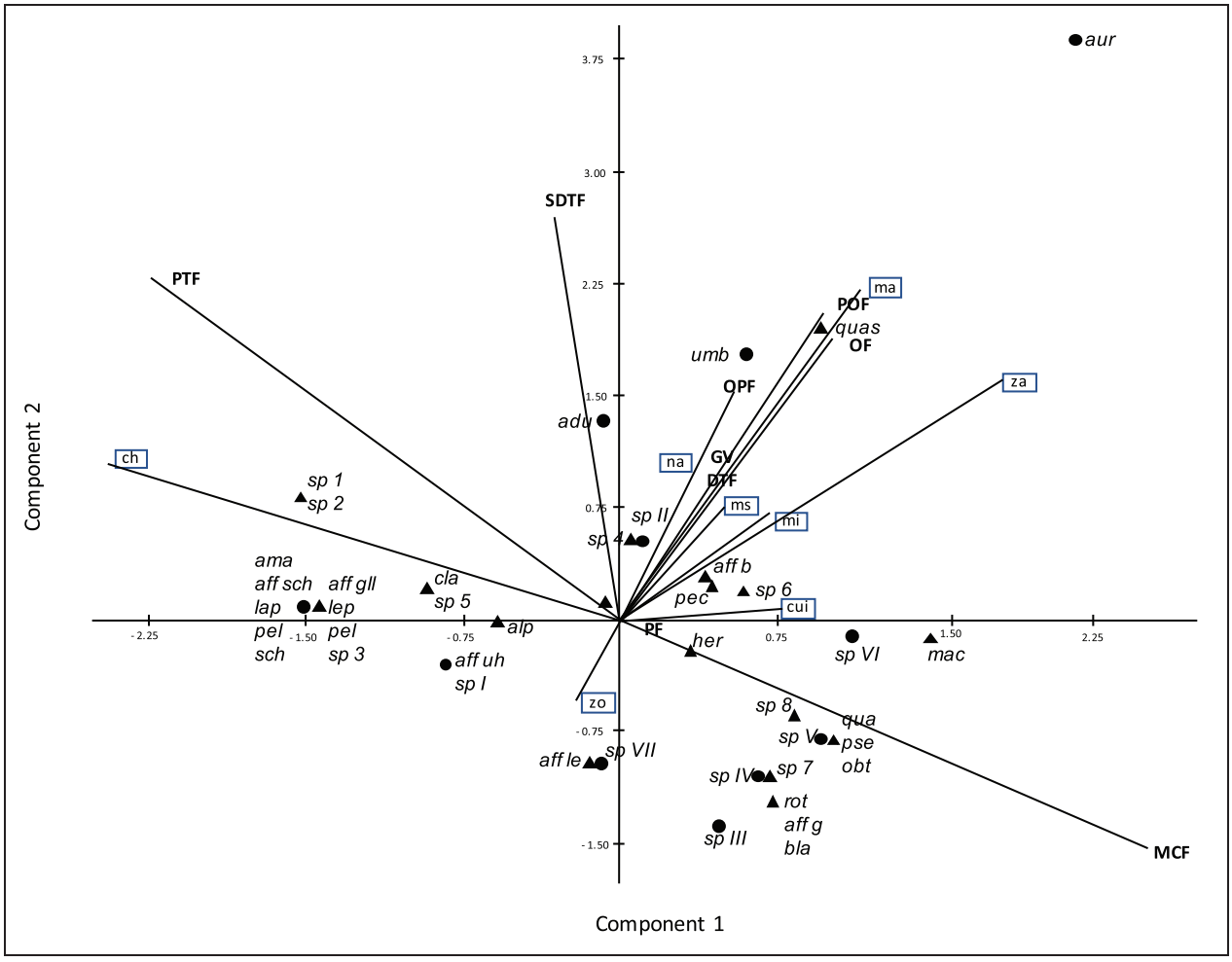

Figure 4. Principal component analysis scatter plot for plant species and ethnic group—vegetation type. The first two axes explained 42.6% of the variance, exhibiting two weak grouping. Abbreviations and acronyms: *Peperomia* aff. *blanda (aff b), Peperomia* aff. *glabella (aff gll), Peperomia* aff. *glabra (aff g), Peperomia* aff. *leptophylla (aff le), Peperomia alpina (alp), Peperomia blanda (bla), Peperomia clavigera (cla), Peperomia hernandiifolia (her), Peperomia leptophylla (lep), Peperomia maculosa (mac), Peperomia obtusifolia (obt), Peperomia pecuniifolia (pec), Peperomia peltilimba (pel), Peperomia pseudoalpina (pse), Peperomia quadrangularis (quas), Peperomia quadrifolia (qua), Peperomia rotundifolia (rot), Peperomia* sp.*1 (sp 1), Peperomia* sp.*2 (sp 2), Peperomia* sp.*3 (sp 3), Peperomia* sp.*4 (sp 4), Peperomia* sp.*5 (sp 5), Peperomia* sp.*6 (sp 6), Peperomia* sp.*7 (sp 7), Peperomia* sp.*8 (sp 8), Piper aduncum (adu). Piper* aff. *schiedeanum (aff sch), Piper* aff. *uhdei (aff uh), Piper amalago (ama), Piper auritum (aur), Piper lapathifolium (lap), Piper peltatum (pel), Piper schiedeanum (sch), Piper umbellatum (umb), Piper* sp.*1 (sp I), Piper* sp.*2 (sp II), Piper* sp.*3 (sp III), Piper* sp.*4 (sp IV), Piper* sp.*5 (sp V), Piper* sp.*6 (sp VI), Piper* sp.*7 (sp VII).* ▲ = *Peperomia,* ● = *Piper.* PTF = perennial tropical forest; MCF = montane cloud forest; SDTF = subdeciduous tropical forest; PF = pine forest; POF = pine-oak forest; OF = oak forest; OPF = oak-pine forest; GV = gallery vegetation; DTF = deciduous tropical forest; MV = meadow vegetation; OyF = oyamel forest; XS = xerophilous scrub; cui = Cuicatec; ch = Chinantec; ma= Mazatec; mi= Mixe; na = Náhuatl; ms = Mestizo; za = Zapotec; zo = Zoque.

studies (Arellanes et al., 2013; Blancas, Casas, Pérez-Salicrup, Caballero, & Vega, 2013; Vergara-Rodríguez et al., 2017). Commercialization could be another important cause of increasing over-gathering practices. *P. peltilimba* is commercialized in regional markets in the Tehuacán Valley, which indicates its high demand, and the high risk of wild populations because of the absence of management practices (Arellanes et al., 2013), due to the difficulty to propagate it, which is the main reason to continue gathering it from the wild (Blancas et al., 2013). Nevertheless, the same species is under some kind of management in the homegardens of Camotlán, Oaxaca (Pérez-Nicolás, Vibrans, & Romero-Manzanares, 2018), where its risk perception is different. Ixcatec people in Oaxaca gather *P. quadrifolia* from wild populations but also protect it leaving part of the plant in order for it to continue to grow and propagate. Some efforts have been done to propagate it ex situ, but "it does not like a different environment" (Rangel-Landa, Casas, Rivera-Lozoya, Torres-García, & Vallejo-Ramos, 2016; Rangel-Landa, Casas, García-Frapolli, & Lira, 2017). This human management, such as transplanting in

homegardens, is also reported for *P. auritum* (Browner, 1985; Blancas et al., 2013; Rangel-Landa et al., 2016), *P. sanctum* (Solis-Rojas, 2006), and *P. unguiculatum* (Geck, 2018). This variable information about different forms of management, and use intensity, stresses the need to develop studies focused on the evaluation of ecological parameters of wild populations of many of these species (density, microhabitat distribution), as well as to evaluate the effects of extraction from wild and to analyze the socioeconomic context of the localities where it occurs. In this study, *P. quadrangularis*, *P. auritum*, and *P.* aff. *uhdei* were recorded with high abundance in their wild populations, or at least in one of them. The rest of the species were recorded with scarce abundance. This evidence shows the relevance of forest management by the ethnic groups.

Even when some of the species are relevant in many ethnic and Mestizo groups because of their medicinal, food, or condiment uses, previous studies only reported one or few species (Arellanes et al., 2013; Blancas et al., 2013; Browner, 1985; Caballero, Cortés, Martínez-Alfaro, & Lira-Saade, 2004; Frei et al., 1998; Geck, 2018; Geck et al., 2016; Giovannini & Heinrich, 2009; Luna-José & Rendón-Aguilar, 2008; Salinas-Espinoza et al., 2017; Solis-Rojas, 2006), and they correspond to 19 of the 106 species (Villaseñor, 2016) reported for this state (Caballero et al., 2004; Frei et al., 1998; Geck, 2018; Geck et al., 2016; Giovannini & Heinrich, 2009; Luna-José & Rendón-Aguilar, 2012; PeŕezNicolaś et al., 2017, 2018; RangelLanda et al., 2016, 2017; Vergara-Rodríguez et al., 2017). Among these, the most mentioned is *P. auritum* and in minor proportion *P. peltilimba*; the rest of the species are named only once (Table 2). These previous studies were developed in eight ethnic groups, which is 50% of the total ethnic diversity of this state. In addition, few specimens in the consulted herbaria have ethnobotanical information, only *P. schiedeanum*, *P. auritum*, and *P. amalago*, and *P. peltilimba*, *P. quadrifolia* and *P. rotundifolia*. Especially the genus *Peperomia* has been less collected in the state.

Hence, this study represents a first synthesis about traditional use in several municipalities of Oaxaca, with great ethnic representation. A similar ethnobotanical relevance of this plant family has been reported for the Ecuadorian Amazon, with seven species used for medicinal purposes (Caballero-Serrano et al., 2019).

Including our records and those reported in literature, 35 species and 6 affinities of Piperaceae have some use (Table 2). Compared with the 106 species recorded for Oaxaca (Fonseca & Samain, 2011), 33% of the species are used. However, given the aromatic and palatability properties of the family (a more conspicuous aspect in *Peperomia*, Figure 2(a)), it is to be expected that additional species and uses will be recorded in future ethnobotanical expeditions.

The main uses of *Peperomia* and *Piper* species found in this study are as medicinal and edible plants. In the case of medicinal applications, this high richness of useful species is in accordance with those reported in literature for Mexico and for Oaxaca (Aguilar et al., 1994; Andrade-Cetto & Heinrich, 2005; Estrada-Reyes et al., 2013; Fournet et al., 1996; Frei et al., 1998; García et al., 2007; Geck, 2018; Geck et al., 2016; Giovannini & Heinrich, 2009; Mahiou et al., 1995; Martíınez, 1969; Roersch, 2010; Schultes & Hofmann, 2000).

However, this is not the case for food or condiment uses, because only *P. peltilimba* (Arellanes et al., 2013; Peŕez-Nicolaś et al., 2018), *P. quadrifolia* (Rangel-Landa et al., 2016, 2017), and *P. hernandiifolia* (Luna-José & Rendón-Aguilar, 2012) are reported in literature, while in this study, we recorded five species.

Ceremony or ritual use is another well-represented category in this study, with six species. However, *P. amalago* and *P. unguiculatum* are the only species mentioned in the literature (Frei et al., 1998; Geck, 2018; Geck et al., 2016).

In the case of veterinary use, we added another record with *P. peltatum*, because the only species mentioned for this application in literature was *P. auritum* (Salinas-Espinoza et al., 2017).

Some species used in Oaxaca in at least one category are also reported in other countries, such as *P. aduncum*, whose record in the municipality of San Pedro Yólox (Table 1) to reduce bleeding caused by a cut, has also been observed in Cuba (Abreu, Sánchez, Pino, & Barreto, 2015) and Brazil (Vianna & Akisue, 1997). *P. umbellatum*, mentioned to alleviate stomachache in San Juan Yaeé, has the same use in Nigeria (Ejele, Duru, Oze, Iwu, & Ogukwe, 2012), and its use to clean skin rash in Eloxochitlán de Flores Magón is similar to that given in Brazil, where it is applied for the treatment of skin lesions (Brohem et al., 2009). This consistency in the use of the same species in distant geographic localities indicates the soundness of traditional knowledge, as well as the empirical recognition of specific properties of plants. These evidences of patterns of knowledge and use of specific plant species to satisfy specific needs are every time more forceful (Caballero et al., 2004; Weckerle et al., 2012).

Based on the multivariate analysis, it was determined that there is no bias in species composition between voucher specimens of herbaria and our records in the study area. Moreover, it indicates that there are many regions of Oaxaca that have not been explored yet for the family.

This study also reinforces the previously reported pattern (Bernal-Ramírez et al., 2019; Rendón-Aguilar, Bernal-Ramírez, & Bravo-Avilez, 2017; Rendoń-Aguilar,

Table 2. Useful species of Piperaceae **in Oaxaca, Mexico at present**. The contribution of the present study is indicated in bold. Cuicatec (Cui); Chinantec (Ch); Ixcatec (Ix); Mazatec (Ma); Mixtec (Mix); Nahua (Na); Zapotec (Za); Zoque (Zo). Condiment (Co); Food (F); Medicine (Me); Veterinary (Ve); Not indicated (ni).

Species reported in previous literature of Oaxaca	Reference	Ethnic group	Use	Species reported in the present study
Piper				
Piper aduncum L.	*Solis-Rojas, 2006*	*Cui*	*ni*	*P. aduncum* L.
Piper amalago L.	*Frei et al., 1998*	*Za*	*Me, C*	*P. amalago* L.
Piper auritum Kunth	*Frei et al., 1998*	*Za*	*Me*	*P. auritum* Kunth
P. auritum	*Geck et al., 2016*	*Zo*	*Me*	***Piper lapathifolium* (Kunth) Steud.**
P. auritum	*Geck, 2018*	*Zo*	*Me*	***Piper peltatum* L.**
P. auritum	*Salinas-Espinoza et al., 2017*	*Mix*	*Ve*	***Piper schiedeanum* Steud.**
P. auritum	*Browner, 1985*	*Ch*	*Me*	*P. umbellatum* L.
P. auritum	*Blancas et al., 2013*	*Na*	*F*	***Piper* aff. *schiedeanum* Steud.**
P. auritum	*Rangel-Landa et al., 2016*	*Ix*	*F*	
P. auritum	*Pérez-Nicolás et al., 2017, 2018*	*Za*	*Me*	
Piper dioica L.	*Frei et al., 1998*	*Za*	*ni*	***Piper* aff. *uhdei* C. DC.**
Piper hispidum Sw.	*Solis-Rojas, 2006*	*Cui*	*ni*	
Piper sanctum (Miq.) Schltdl. ex C.DC.	*Caballero y Cortés, 2004*	*NI*	*ni*	
P. sanctum	*Solis-Rojas, 2006*	*Cui*	*F*	
Piper scabrum Lam.	*Luna y Rendón, 2008*	*Za*	*Me*	
Piper tuberculatum Jacq.	*Frei et al., 1998*	*Za*	*Me*	
Piper unguiculatum Ruiz y Pavon	*Geck et al., 2016*	*Zo*	*Me, C*	
	Geck, 2018	*Zo*	*Me*	
Piper umbellatum L.	*Giovannini y Heinrich, 2009*	*Ma*	*Me*	
	Luna y Rendón, 2008	*Za*	*Me, F*	
Previous records = 10				**Records added = 5 (indicated in bold)**
Peperomia				
Peperomia campylotrofa Hill	*Solis-Rojas, 2006*	*Cui*	*Me*	***Peperomia alpina* (Sw.) A. Dietr.**
Peperomia donaguina (C).DC	*Solis-Rojas, 2006*	*Cui*	*ni*	***Peperomia blanda* (Jacq.) Kunth**
Peperomia hernandiifolia (Vahl) A. Dietr.	*Luna y Rendón, 2008*	*Za*	*Me, Co*	***Peperomia clavigera* Standl. & Steyerm.**
Peperomia nigropunctata Miq.	*Giovannini y Heinrich, 2009*	*Ma*	*Me*	*P. hernandiifolia* (Vahl) A. Dietr.
Peperomia peltilimba C. DC. ex Trel	*Arellanes et al., 2013*	*NI*	*F*	***Peperomia leptophylla* Miq.**
P. peltilimba	*Blancas et al., 2013*	*Na*	*F*	
P. peltilimba	*Pérez-Nicolás et al., 2017, 2018*	*Za*	*Me*	***Peperomia maculosa* (L.) Hook.**
Peperomia quadrifolia (L.) Kunth	*Rangel-Landa et al., 2016, 2017*	*Ix*	*F*	***Peperomia obtusifolia* (L.) A. Dietr.**
Peperomia rotundifolia (L.) Kunth	*Giovannini y Heinrich, 2009*	*Ma*	*Me*	
Peperomia ubilicata Ruiz y Pavon	*Solis-Rojas, 2006*	*Cui*	*Me*	***Peperomia pecuniifolia* Trel. & Standl**
				P. peltilimba C. DC. ex Trel
				***Peperomia pseudoalpina* Trel.**
				***Peperomia quadrangularis* (J. V. Thomps.) A. Dietr.**
				P. quadrifolia (L.) Kunth

(continued)

Table 2. Continued.

Species reported in previous literature of Oaxaca	Reference	Ethnic group	Use	Species reported in the present study
				P. rotundifolia (L.) Kunth
				***Peperomia* aff. *blanda* (Jacq.) Kunth**
				***Peperomia* aff. *glabella* (Sw.) A. Dietr.**
				***Peperomia* aff. *glabra* C. DC.**
				***Peperomia* aff. *leptophylla* Miq.**
Previous records = 8				**Records added = 13 (indicated in bold)**

Note. The contribution of this study is indicated in bold. Cuicatec (Cui); Chinantec (Ch); Ixcatec (Ix); Mazatec (Ma); Mixtec (Mix); Nahua (Na); Zapotec (Za); Zoque (Zo). Condiment (Co); Food (F); Medicine (Me); Veterinary (Ve); Not indicated (ni).

Bernal-Ramírez, Bravo-Avilez, & Mendoza-Ruiz, 2017) that there is a differentiated ethnobotanical knowledge and use of this family among ethnic groups, which is the case mainly for Chinantec and Zoque people for lowland and tropical species, as well as Mazatec and Zapotec people for species of temperate zones. This concordance among distribution of this family, traditional knowledge, and uses are basic aspects that reinforce the proposal that areas of higher biodiversity are related with ethnic groups (Pretty et al., 2009), and that they maintain and take care of the plant cover areas that provide them with the natural resources they rely on in their daily activities.

The traditional uses preserved and transmitted over the years have led to studies with scientific approaches of some species. In the case of *Peperomia*, these are focused on phytochemistry, pharmacology, ecology, phytopathology, germination, and plant physiology of few species such as *P. obtusifolia* (Alfieri & Knauss, 1973; Horner, 2012; Rivas et al., 2003; Strojny, 2000); *Peperomia blanda* (Jardim et al., 2015), and *P. rotundifolia* (Lans, 2006, 2007).

Scientific approaches are more numerous in *Piper* than in *Peperomia*, and in more species, such as *P. auritum* (Estrada-Reyes et al., 2013; Lepe & Jimenez, 1972; López-Barreiro, García-Hernández, Boucourt-Rodríguez, & Morejón-Rodríguez, 2014; Martínez-Padrón, Palmero-Álvarez, Gómez-Zayas, & Domínguez-Sardíñas, 2011), *P. aduncum* (Abreu et al., 2015; Da Silva et al., 2010; Kidd, 1996; Orjala, Erdelmeier, Wright, Rali, & Sticher, 1993; Rocha et al., 2011; Siges, 2005), *P. umbellatum* (Bidla, Titanji, El-Ghazali, Bolad, & Berzins, 2004; Bonaccorso, Winkelmann, Dumont, & Thibault, 2002; De Carvalho-Ricardo, Uieda, Fonseca, & Rossi, 2014; M. L. A. Hammer & Johns, 1993; Hartemink, 2002; Hiratsuka, Toma, Diana, Hadriyanto, & Morikawa, 2006; Nghiem, Tan, & Corlett, 2015; Quimio & Quilario, 2007; Roersch, 2010), *P. amalago*, and *P. peltatum* (Da Silva et al., 2010; Sosa et al., 2002; Valadeau et al., 2009). These scientific studies also reinforce the traditional knowledge and value of this family.

Even when our ethnobotanical methodology consisted on an exploratory sampling technique, based on the selection by municipal authorities of local guides which are recognized as knowledgeable people within their community, there is no doubt that this article contributes to the record of traditional knowledge of this family in Oaxaca.

Ethnofloristic records of plants are a primary aspect of any ethnobotanical research. Basic information such as "which plants do you know," "what are they used for," "how do you use them," and "how are they named" represents the starting point of future research, in order to answer specific questions about the traditional knowledge, uses, cultural value, and management of plant resources.

Implications for Conservation

Piperaceae is one of the 10 most species-rich botanical families in Oaxaca (García-Mendoza & Meave, 2011) and is also one of the most useful families in different ethnic groups in this state (Rendón-Aguilar, Bernal-Ramírez, & Bravo-Avilez, 2017; Rendoń-Aguilar, Bernal-Ramírez, Bravo-Avilez, & Mendoza-Ruiz, 2017), as they satisfy daily needs. Because most of these plant resources are collected from wild populations, it is necessary to conserve forested areas in order to continue the access to these vegetal resources.

Some of them come from particular microenvironments (e.g., rocks, specific phorophytes, wet canyons)

and are conformed by small populations that, when drastically modified, could disappear. This is frequently observed in the different species of *Peperomia*, whose microhabitats are highly specific and habited by small populations. Even when some species have been propagated in home gardens, or traditional shade coffee plantations, many species can be found only in wild conditions, so an additional effort is needed in order to preserve natural populations, meaning that their habitat should also be preserved. Furthermore, the increased number of useful species registered for this family in this study suggests that more records could be added in future research. A notable aspect is that traditional knowledge is deep, persistent, and dynamic, and it currently has been recognized as a sustainable way to preserve these areas of high diversity in Oaxaca.

Acknowledgments

The authors thank the municipal authorities as well as Ejidal and Communal Lands of the 84 municipalities that were visited during the development of the project and the local guides who helped us during the fieldwork. We are also grateful to the Universidad Autónoma Metropolitana Iztapalapa for the logistic support.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This project was financially supported by the CONABIO (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad), through the project "Inventario Etnoflorístico en regiones oaxaqueñas con gran biodiversidad" (JF102), by the logistic support of the Universidad Autónoma Metropolitana, and personal resources of the authors.

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Supplementary Material

Supplementary material for this article is available online.

References

Abreu, O. A., Sánchez, I., Pino, J., & Barreto, G. (2015). Antimicrobial activity of *Piper aduncum* subsp. *ossanum* essential oil. *International Journal Phytomedicine*, *7*(2), 205–208.

Aguilar, C. A., Chino, J. R., Jaquez, P. S., & Lopez, M. E. (1994). *Herbario Medicinal del Instituto Mexicano del Seguro Social*. México D.F., Mexico: Instituto Mexicano del Seguro Social [Medicinal Herbarium of the Mexican Social Security Institute. Mexico D.F., Mexico: Mexican Social Security Institute].

Albuquerque, U. P., de Lucena, R. F. P., & Neto, E. M. de F. (2014). Selection of Research Participants. In: Albuquerque, U. P., L. V. F., Cruz, R. F. P., Lucena, & Alves, R. R. N. (Eds.). *Methods and Techniques in Ethnobiology and Ethnoecology*. (pp. 1–14). Springer, New York.

Alfieri, S. A., & Knauss, J. F. (1973). Stem and leaf rot of Peperomia incited by *Sclerotium rolfsii*. In Proceedings of the 85th Annual Meeting. *Florida State Horticultural Society* (vol. 85, pp. 352–357).

Andrade-Cetto, A., & Heinrich, M. (2005). Mexican plants with hypoglycemic effect used in the treatment of diabetes. *Journal of Ethnopharmacology*, *99*, 325–348.

Arellanes, Y., Casas, A., Arellanes, A., Vega, E., Blancas, J., Vallejo, M., … Pérez-Negrón, E. (2013). Influence of traditional markets on plant management in the Tehuacán Valley. *Journal of Ethnobiology and Ethnomedicine*, *9*, 38. doi:10.1186/1746-4269-9-38

Arriaga, L., Espinoza, J. M., Aguilar, C., Martínez, E., Gómez, L., & Loa, E. (2000). *Regiones terrestres prioritarias de México*. México D.F., Mexico: Comisión Nacional para el Conocimiento y uso de la Biodiversidad. [Priority land regions of Mexico. Mexico City, Mexico: National Commission for the Knowledge and Use of Biodiversity].

Bernal-Ramírez, L. A., Bravo-Avilez, D., Fonseca-Juárez, R. M., Yáñez-Espinosa, L., Gernandt, D. S., & Rendón-Aguilar, B. (2019). Usos y conocimiento tradicional de las gimnospermas en el noreste de Oaxaca, México [Uses and traditional knowledge of gymnosperms in northeastern Oaxaca, Mexico]. *Acta Botanica Mexicana*, *126*, e1471. doi:10.221829/abm126.2019.1471

Bidla, G., Titanji, V. P. K., El-Ghazali, G., Bolad, A., & Berzins, K. (2004). Antiplasmodial activity of seven plants used in African folk medicine. *Indian Journal of Pharmacology*, *36*(4), 245–246.

Blancas, J., Casas, A., Pérez-Salicrup, D., Caballero, J., & Vega, E. (2013). Ecological and socio-cultural factors influencing plant management in Náhuatl communities of the Tehuacán Valley, Mexico. *Journal of Ethnobiology and Ethnomedicine*, *9*, 39. doi:10.1186/1746-4269-9-39

Boege, E. (2008). El patrimonio biocultural de los pueblos indígenas de México. Hacia la conservación in situ de la biodiversidad y agrobiodiversidad en los territorios indígenas. *Instituto Nacional de Antropología e Historia: Comisión Nacional para el Desarrollo de los Pueblos Indígenas*. México, D. F., México. [The biocultural heritage of the indigenous people of Mexico. Towards the in situ conservation of biodiversity and agrobiodiversity in indigenous territories] (pp. 49–70).

Bonaccorso, F. J., Winkelmann, J. R., Dumont, E. R., & Thibault, K. (2002). Home range of *Dobsonia minor* (Pteropodidae): A solitary, foliage-roosting fruit bat in Papua New Guinea. *Biotropica*, *34*(1), 127–135.

Brohem, C. A., Sawada, T. C. H., Massaro, R. R., Almeida, R. L., Rivelli, D. P., Ropke, C. D., … Maria-Engler, S. S.

(2009). Apoptosis induction by 4-nerolidylcatechol in melanoma cell lines. *Toxicology in Vitro*, *23*(1), 111–119.

Brown, C. H., & Chase, P. K. (1981). Animal classification in Juchitan Zapotec. *The Journal of Anthropological Research*, *37*(1), 61–70.

Browner, C. H. (1985). Plants used for reproductive health in Oaxaca, México. *Economic Botany*, *39*(4), 482–493.

Caballero, J., Cortés, L., Martínez-Alfaro, M. A., & Lira-Saade, R. (2004). Uso y manejo tradicional de la diversidad vegetal. In A. J. García-Mendoza, M. J. Ordoñez, & M. Briones-Salas (Eds.), *Biodiversidad de Oaxaca* [Traditional use and management of plant diversity. In A. J. García-Mendoza, M. J. Ordoñez, & M. Briones-Salas (Eds.), Oaxaca Biodiversity] (pp. 541–564). México D. F., México: Instituto de Biología, Universidad Nacional Autónoma de México-Fondo Oaxaqueño para la Conservación de la Biodiversidad-World Wildlife Fund.

Caballero-Serrano, V., McLaren, B., Carrasco, J. C., Alday, J. G., Fiallos, L., Amigo, J., & Onaindia, M. (2019). Traditional ecological knowledge and medicinal plant diversity in Ecuadorian Amazon home gardens. *Global Ecology and Conservation*, *17*, e00524. doi:10.1016/j.gecco.2019.e00524

Cardoso, J. (2004). *Estudio etnobotánico del agroecosistema milpa en la localidad de Candelaria Loxicha*. Oaxaca, Mexico. Informe Final de Servicio Social, Universidad Autónoma Metropolitana Iztapalapa [Ethnobotanical study of the milpa agroecosystem in the town of Candelaria Loxicha. Oaxaca, Mexico. Final Social Service Report].

Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. (2010). *El Bosque Mesófilo de Montaña en México: Amenazas y oportunidades para su conservación y manejo sostenible*. México D. F., Mexico: Author [The Mesophyllous Mountain Forest in Mexico: Threats and opportunities for its conservation and sustainable management].

Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. (2012). *Sistema de Información Biótica. Manual de usuario. Versión 5.0.3[Biotic Information System. User manual. Version 5.0.3]*. México D. F., Mexico: Author.

Comisión Nacional para el Conocimiento y Uso de la Biodiversidad [What is a megadiverse country?]. (2019). Retrieved from https://www.biodiversidad.gob.mx/pais/quees.html

Cruz, S., & Cruz, R. (1992). Zoología zapoteca de Santiago Xanica sierra sur de Oaxaca. In A. Gonzalez, & M. A. Vaśquez (Coords.), *Etnias, desarrollo, recursos y tecnologías en Oaxaca* [Zapotec zoology of Santiago Xanica Sierra south of Oaxaca. In A. González, & M. A. Vásquez (Coord.), Ethnic groups, development, resources and technologies in Oaxaca. Centro de Investigaciones y Estudios Superiores en Antropología Social CIESAS, Oaxaca, Mexico] (pp. 117–136). CIESAS - Gobierno del Estado de Oaxaca.

Da Silva, A. C., Maia, F. C., dos Santos, P. A., Nunez, C. V., Tadei, W. P., & Pohlit, A. M. (2010). *Piper peltatum*: Biomass and 4-nerolidylcatechol production. *Planta Medica*, *76*(13), 1473–1476.

De Ávila, A. (2004). Clasificación de las lenguas de Oaxaca. In A. J. García-Mendoza, M. J. Ordoñez, & M. Briones-Salas (Eds.), *Biodiversidad de Oaxaca* [Classification of the languages of Oaxaca. In A. J. García-Mendoza, M. J. Ordoñez, & M. Briones-Salas (Eds.), *Oaxaca Biodiversity*] (pp. 481–539). México D. F., México: Instituto de Biología, Universidad Nacional Autónoma de México- Fondo Oaxaqueño para la Conservación de la Biodiversidad-World Wildlife Fund.

De Carvalho-Ricardo, M. C., Uieda, W., Fonseca, R. C. B., & Rossi, M. N. (2014). Frugivory and the effects of ingestion by bats on the seed germination of three pioneering plants. *Acta Oecoligica*, *55*, 51–57.

Ejele, A. E., Duru, I. A., Oze, R. N., Iwu, I. C., & Ogukwe, C. E. (2012). Comparison of antimicrobial potential of *Piper umbellatum*, *Piper guineense*, *Ocimum gratissimum* and *Newbouldia laevis* extracts. *International Research Journal of Biochemistry Bioinformatics*, *2*(2), 35–40.

Estrada-Reyes, R., Martínez-Laurrabaquio, A., Ubaldo-Suárez, D., & Araujo-Escalona, A. G. (2013). Neuropharmacological studies of *Piper auritum* Kunth (Piperaceae): Antinociceptive and anxiolytic-like effects. *Journal of Medicinal Plants Research*, *7*(23), 1718–1729.

Flannery, K. V. (1986). *Guilá Naquitz. Archaic foraging and early agriculture in Oaxaca, Mexico*. New York, NY: Academic Press.

Fonseca, R. M. (2011). Piperaceae, *Piper*. In A. J. García-Mendoza, & J. A. Meave (Eds.), *Diversidad florística de Oaxaca: De musgos a angiospermas [Floristic diversity of Oaxaca: From mosses to angiosperms]* (pp. 271–272). México D. F., México: Instituto de Biología, Universidad Nacional Autónoma de México, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Instituto Estatal de Ecología y Desarrollo Sustentable.

Fonseca, R. M., & Samain, M. S. (2011). Piperaceae, *Peperomia*. In A. J. García-Mendoza & J. A. Meave (Eds.), *Diversidad florística de Oaxaca: De musgos a angiospermas [Floristic diversity of Oaxaca: From mosses to angiosperms]* (pp. 270–271). México D. F., México: Instituto de Biología, Universidad Nacional Autónoma de México, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Instituto Estatal de Ecología y Desarrollo Sustentable.

Fournet, A., Ferreira, M. E., Rojas de Arias, A., Fuentes, S., Torres, S., Inchausti, A., … Cavé, A. (1996). *In vitro* and *in vivo* leishmanicidal studies of *Peperomia galioides* (Piperaceae). *Phytomedicine*, *3*, 271–275.

Frei, B., Baltisberger, M., Sticher, O., & Heinrich, M. (1998). Medical ethnobotany of the Zapotecs of the Isthmus-Sierra (Oaxaca, Mexico): Documentation and assessment of indigenous uses. *Journal of Ethnopharmacology*, *62*, 149–165.

Frenzke, L., Scheiris, E., Pino, G., Symmank, L., Goetghebeur, P., Neinhuis, C., … Samain, M. S. (2015). A revised infrageneric classification of the genus *Peperomia* (Piperaceae). *Taxon*, *64*, 424–444.

García-Mendoza, A. J., Ordoñez, M. J., & Briones-Salas, M. (2004). Introducción. In A. J. García-Mendoza, M. J.

Ordoñez, & M. Briones-Salas (Eds.), *Biodiversidad de Oaxaca* (pp. 19–26). México D. F., México: Instituto de Biología, Universidad Nacional Autónoma de México-Fondo Oaxaqueño para la Conservación de la Biodiversidad-World Wildlife Fund.

García-Mendoza, A. J., & Meave, J. A. (2011). Introducción. In A. J. García-Mendoza & J. A. Meave (Eds.), *Diversidad florística de Oaxaca: De musgos a angiospermas [Floristic diversity of Oaxaca: From mosses to angiosperms]* (pp. 13–20). México D. F., México: Instituto de Biología, Universidad Nacional Autónoma de México, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Instituto Estatal de Ecología y Desarrollo Sustentable.

García, R. A., Leyva, M. A., Martíńez, M. J. R., & Stashenko, E. E. (2007). Determinación de la composición química y actividad antioxidante *in vitro* del aceite esencial de *Piper auritum* Kunth (Piperaceae) difundida en la costa Colombiana. *Scientia et Technica*, [Determination of the chemical composition and in vitro antioxidant activity of the essential oils of Piper auritum Kunth (Piperaceae) distributed on the Colombian coast] *13*, 439–442.

Geck, M. S. (2018). *Medicina tradicional y herbolaria zoque* (Primera edición). [*Traditional and herbal Zoque medicine*] (First edition). Chiapas, México: Taller editorial de La Cosecha.

Geck, M. S., Reyes-García, A. J., Casu, L., & Leonti, M. (2016). Acculturation and ethnomedicine: A regional comparison of medicinal plant knowledge among the Zoque of southern Mexico. *Journal of Ethnopharmacology*, *187*, 146–159.

Giovannini, P., & Heinrich, M. (2009). Xki yoma' (our medicine) and xki tienda (patent medicine)-Interface between traditional and modern medicine among the Mazatecs of Oaxaca, Mexico. *Journal of Ethnopharmacology*, *121*, 383–399.

Hammer, M. L. A., & Johns, E. A. (1993). Tapping an Amazonian plethora: Four medicinal plants of Marajó Islands, Pará (Brazil). *Journal of Ethnopharmacology*, *40*(1), 53–75.

Hammer, Ø., Harper, D. A. T., & Ryan, P. D. (2001). Past: Paleontological statistics software package for education and data analysis. *Paleontologia Electronica*, *4*(1), 1–9.

Hartemink, A. E. (2002). The invasion of *Piper aduncum* in Papua New Guinea: Friend or foe? *Flora Malesiana Bulletin*, *13*(1), 66–68.

Hiratsuka, M., Toma, T., Diana, R., Hadriyanto, D., & Morikawa, Y. (2006). Biomass recovery of naturally regenerated vegetation after the 1998 forest fire in East Kalimantan, Indonesia. *Japan Agricultural Research Quarterly*, *40*(3), 277–282.

Horner, H. T. (2012). *Peperomia* leaf cell wall interface between the multiple hypodermis and crystal containing photosynthetic layer displays unusual pit fields. *Annals of Botany*, *109*, 1307–1315.

Hunn, E. (2008). *A Zapotec natural history. Trees, herbs, and flowers, birds, beasts, and bugs in the life of San Juan Gbëë*. Tucson, AZ: The University of Arizona Press.

Instituto Nacional para el Federalismo y el Desarrollo Municipal-Secretaría de Gobernación. (2010). *Enciclopedia de los municipios y delegaciones de México. Estado de Oaxaca [Encyclopedia of the municipalities and delegations of Mexico. Oaxaca state]*. Mexico City, Mexico: Author.

Jardim, A. C., Igloi, Z., Shimizu, J. F., Santos, V. A., Felippe, L. G., Mazzeu, B. F., … Rahal, P. (2015). Natural compounds isolated from Brazilian plants are potent inhibitors of hepatitis C virus replication in vitro. *Antiviral Research*, *115*, 39–47.

Joly, L. G. (1981). Feeding and trapping fish with *Piper auritum*. *Economic Botany*, *35*(4), 383–390.

Kidd, S. B. (1996). A note on *Piper aduncum* in Morobe Province, Papua New Guinea. *Science in New Guinea*, *22*(3), 121–123.

Lans, C. A. (2006). Ethnomedicines used in Trinidad and Tobago for urinary problems and diabetes mellitus. *Journal of Ethnobiology and Ethnomedicine*, *2*, 45. doi:10.1186/1746-4269-2-45

Lans, C. A. (2007). Comparison of plants used for skin and stomach problems in Trinidad and Tobago with Asian ethnomedicine. *Journal of Ethnobiology and Ethnomedicine*, *3*, 3. doi:10.1186/1746-4269-3-3

Lepe, B. G., & Jimenez, E. (1972). Germination of the seed of two secondary tropical plant species: *Heliocarpus donnell-smithii* and *Piper auritum*. *Anales Del Instituto de Biología (Serie Biología Experimental), Universidad Nacional Autónoma de México*, *43*(1), 17–34.

López-Barreiro, M., García-Hernández, A. I., Boucourt-Rodríguez, E., & Morejón-Rodríguez, Z. (2014). Acute topical toxicity and dermal irritability of decoction of *Piper auritum* Kunth (caisimón de anís.). *Revista Cubana de Plantas Medicinales*, *19*(4), 443–450.

Luna-José, A. L., & Rendón-Aguilar, B. (2008). Recursos vegetales en diez comunidades de la Sierra Madre del Sur, [Plant resources in ten communities of the Sierra Madre del Sur] Oaxaca, México. *Polibotánica*, *26*, 193–242.

Luna-Jose, A. L., & Rendón-Aguilar, B. (2012). Traditional knowledge among Zapotecs of Sierra Madre Del Sur, Oaxaca. Does it represent a base for plant resources management and conservation? *Journal of Ethnobiology and Ethnomedicine*, *8*(1), 24. doi:0.1186/1746-4269-8-24

Luna-Morales, C. C., Aguirre, R., & Rogelio, J. (2001). Clasificación tradicional, aprovechamiento y distribución ecológica de la pitaya mixteca en México. [Traditional classification, use and ecological distribution of the Mixtec pitaya in Mexico] *Interciencia*, *26*(1), 18–24.

MacNeish, R. S. (1992). *The origins of agriculture and settled life*. Norman, OK: University of Oklahoma Press.

Mahiou, V., Roblot, F., Hocquemiller, R., Cave, A., Angelo-Barrios, A., Fournet, A., & Ducrot, P. H. (1995). Piperogalin, a new antiparasitic prenylated phenolic from *Peperomia galioides* (Piperaceae). *Journal of Natural Products*, *58*, 324–328.

Martin, G. (1996). *Comparative ethnobotany of the Chinantec and Mixe of the Sierra Norte, Oaxaca, Mexico* (PhD Thesis). University of California, USA.

Martínez, M. (1969). *Las plantas medicinales de México* [The medicinal plants of Mexico]. México D. F., México: Ediciones Botas.

Martínez-Padrón, A., Palmero-Álvarez, R., Gómez-Zayas, O., & Domínguez-Sardíñas, N. (2011). Deep cutaneous necrosis caused by the local application of *Piper auritum* Kunth. (caisimón de anis) leaves. *Revista Cubana de Plantas Medicinales*, *16*(2), 209–215.

Menzies, C. R., & Butler, C. (2006). Understanding ecological knowledge. In C. R. Menzies (Ed.), *Traditional ecological knowledge and natural resource management* (pp. 1–20). London, England: University of Nebraska Press.

Messer, E. (1978). Zapotec plant knowledge: Classification, uses and communication about plants in Mitla, Oaxaca, Méxco. Memoirs of the Museum of Anthropology, núm. 10, University of Michigan, Ann Arbor, MI, USA.

Mickel, J. T., & Beitel, J. M. (1988). *Pteridophyte flora of Oaxaca*. Bronx, NY, USA: Mexico Memoirs of the New York Botanical Garden *46*, 1–568.

Nghiem, L. T. P., Tan, H. T. W., & Corlett, R. T. (2015). Invasive trees in Singapore: Are they a threat to native forests? *Tropical Conservation Science*, *8*(1), 201–214.

Ordóñez, M. J. (2000). El territorio del estado de Oaxaca: Una revisión histórica [The territory of the state of Oaxaca: A historical review]. *Investigaciones Geográficas*, *42*, 67–86.

Orjala, J., Erdelmeier, C. A. J., Wright, A. D., Rali, T., & Sticher, O. (1993). Five new prenylated p-hydroxybenzoic acid derivatives with antimicrobial and molluscicidal activity from *Piper aduncum* leaves. *Planta Medica*, *59*(6), 546–551.

Peŕez-Nicolaś, M., Vibrans, H., Romero-Manzanares, A., Saynes-Vaśquez, A., Luna-Cavazos, M., Flores-Cruz, M., & Lira-Saade, R. (2017). Patterns of knowledge and use of medicinal plants in Santiago Camotlań, Oaxaca, Mexico. *Economic Botany*, *71*(3), 209–223.

Peŕez-Nicolaś, M., Vibrans, H., & Romero-Manzanares, A. (2018). Can the use of medicinal plants motivate forest conservation in the humid mountains of Northern Oaxaca, Mexico? *Botanical Sciences*, *96*(2), 267–285.

Picó, B., & Nuez, F. (2000). Minor crops of Mesoamerica in early sources (II). Herbs used as condiments. *Genetic Resources and Crop Evolution*, *47*, 541–552.

Pretty, J., Adams, B., Berkes, F., Ferreira, S., Dudley, N., Hunn, E., … Pilgrim, S. (2009). The intersections of biological diversity and cultural diversity: Towards integration. *Conservation and Society*, *7*(2), 100–112.

Quijano-Abril, M. A., Callejas-Posada, R., & Miranda-Esquivel, D. R. (2006). Areas of endemism and distribution patterns for Neotropical *Piper* species (Piperaceae). *Journal of Biogeography*, *33*, 1266–1278.

Quimio, J. M., & Quilario, N. L. (2007). Species and structure of forests in Tampakan Highlands, South Cotabato, Philippines. *Annals of Tropical Research*, *29*(2), 47–65.

Quinn, G. P., & Keough, M. J. (2002). *Experimental design and data analysis for biologist*. Cambridge, England: Cambridge University Press.

Rangel-Landa, S., Casas, A., Rivera-Lozoya, E., Torres-García, I., & Vallejo-Ramos, M. (2016). Ixcatec ethnoecology: Plant management and biocultural heritage in Oaxaca, Mexico. *Journal of Ethnobiology and Ethnomedicine*, *12*(1), 30–83. doi:10.1186/s13002-016-0101-3

Rangel-Landa, S., Casas, A., García-Frapolli, E., & Lira, R. (2017). Sociocultural and ecological factors influencing management of edible and non-edible plants: The case of Ixcatlań, Mexico. *Journal of Ethnobiology and Ethnomedicine*, *13*(1), 59–43. doi:10.1186/s13002-017-0185-4

Rendón-Aguilar, B., Bernal-Ramírez, L. A., & Bravo-Avilez, D. (2017). *Inventario etnoflorístico en regiones oaxaqueñas con gran biodiversidad* (Informe final SNIB-CONABIO proyecto JF102) [*Ethnofloristic inventory in Oaxaca regions with great biodiversity (Final report SNIB-CONABIO project JF102)*]. Ciudad de México, México: Universidad Autónoma Metropolitana, Unidad Iztapalapa.

Rendoń-Aguilar, B., Bernal-Ramírez, L. A., Bravo-Avilez, D., & Mendoza-Ruiz, A., (2017). Ethnobotany of lycophyta and polypodiophyta in priority terrestrial regions of Oaxaca, México. *American Fern Journal*, *107*(4), 200–218.

Rivas, E. B., Koenig, R., Duarte, L. M. L., Alexandre, M. A. V., Galleti, S. R., & Bandetini, E. P. T. (2003). Identification of Eggplant mosaic virus isolated from *Peperomia obtusifolia*. *Summa Phytopathologica*, *29*, 313–316.

Rocha, L. F., da Silva, A. C., Pohlit, A. M., Jacques, E. L., Ribero, P. P., Tadei, W. P., … de Andrade-Neto, V. F. (2011). *In vivo* and *in vitro* antimalarial activity of 4-nerolidylcatechol. *Phytotherapy Research*, *25*, 1181–1188.

Roersch, C. M. F. B. (2010). *Piper umbellatum* L.: A comparative cross-cultural analysis of its medicinal uses and an ethnopharmacological evaluation. *Journal of Ethnopharmacology*, *131*(3), 522–537.

Salinas-Espinoza, S., Vásquez-Dávila, M. A., Romero-Santillán, F., & Manzanero-Medina, G. I. (2017). Medicina veterinaria tradicional para caprinos y ovinos en Coixtlahuaca, Oaxaca, México (traditional Veterinary medicine for goats and sheep in Coixtlahuaca, Oaxaca, México). *Actas Iberoamericanas en Conservación Animal*, *10*, 277–281.

Schultes, R. E., & Hofmann, A. (2000). *Plantas de los dioses: Orígenes del uso de los alucinógenos* (Plants of the Gods: origins of the use of hallucinogens). México, D. F., México: Fondo de Cultura Económica.

Siges, T. H. (2005). The invasive shrub *Piper aduncum* and rural livelihoods in the Finschhafen area of Papua New Guinea. *Human Ecology*, *33*(6), 875–893.

Solis-Rojas, L. (2006). *Etnoecología cuicateca en San Lorenzo Pápalo, Oaxaca. Tesis de Maestría en Ciencias Biológicas (Biología Ambiental) [Cuicatec ethnoecology in San Lorenzo Papalo, Oaxaca. Master thesis in Biological Sciences (Environmental Biology)]*. Mexico City, México: Posgrado en Ciencias Biológicas, Ciudad Universitaria.

Sosa, S., Balick, M. J., Arvigo, R., Esposito, R. G., Pizza, C., Altinier, G., & Tubaro, A. (2002). Screening of the topical anti-inflammatory activity of some Central American plants. *Journal of Ethnopharmacology*, *81*(2), 211–215.

Strojny, Z. (2000). Use rockwool as a substrate for *Peperomia obtusifolia*, *Streptocarpus hybridus* and *Spathiphyllum floribundum*. *Acta Agrobotanica*, *53*, 23–29.

Toledo, V. M., Alarcón-Chaires, P., Moguel, P., Olivo, M., Cabrera, A., Leyequien, E., & Rodríguez-Aldabe A. (2001). El atlas etnoecológico de México y Centroamérica: Fundamentos, métodos y resultados [The ethnoecological atlas of Mexico and Central America: Fundamentals, methods and results]. *Etnoecológica*, *6*(8), 7–41.

Torres-Colín, R. (2004). Tipos de vegetación [Vegetation types]. In A. J. García-Mendoza, M. J. Ordoñez, & M. Briones-Salas (Eds.), *Biodiversidad de Oaxaca [Oaxaca Biodiversity]* (pp. 105–117). México D. F., México: Instituto de Biología, Universidad Nacional Autónoma de México-Fondo Oaxaqueño para la Conservación de la Biodiversidad-World Wildlife Fund.

Valadeau, C., Pabon, A., Deharo, E., Albán-Castillo, J., Estevez, Y., Lores, A., … Bourdy, G. (2009). Medicinal plants from the Yanesha (Peru): Evaluation of the leishmanicidal and antimalarial activity of selected extracts. *Journal of Ethnopharmacology*, *123*(3), 413–422.

Van der Wal, H. (1996). Modificación de la vegetación y el suelo por los chinantecos de Santiago Tlatepusco, Oaxaca, México [Modification of vegetation and soil by the Chinantecos of Santiago Tlatepusco, Oaxaca, Mexico]. *Etnoecológica*, *3*, 37–57.

Ventura-Aquino, Y., Rendón-Aguilar, B., Rebollar, S., & Hernández, G. (2008). Use and conservation of forest resources in the municipality of San Agustin Loxicha, Sierra Madre del Sur, Oaxaca, Mexico. *Agroforestry Systems*, *73*(3), 167–180.

Vergara-Rodríguez, D., Mathieu, G., Samain, M. S., Armenta-Montero, S., & Krömer, T. (2017). Diversity, distribution, and conservation status of *Peperomia* (Piperaceae) in the state of Veracruz, Mexico. *Tropical Conservation Science*, *10*, 1–28.

Vianna, W. O., & Akisue, G. (1997). Caracterização morfológica de *Piper aduncum* L. *[Morphological characterization of Piper aduncum L.] Lecta*, *15*, 11–62.

Villaseñor, J. L. (2016). Checklist of the native vascular plants of Mexico. *Revista Mexicana de Biodiversidad*, *87*, 559–902.

Wanke, S., Vanderschaeve, L., Mathieu, G., Neinhuis, C., Goetghebeur, P., & Samain, M. S. (2007). From forgotten taxon to a missing link? The position of the genus *Verhuellia* (Piperaceae) revealed by molecules. *Annals of Botany*, *99*, 1231–1238.

Weckerle, C. S., Cabras, S., Castellanos, M. E., & Leonti, M. (2012). An imprecise probability approach for the detection of over and underused taxonomic groups with the Campania (Italy) and the Sierra Popoluca (Mexico) medicinal flora. *Journal of Ethnopharmacology*, *142*, 259–264.

Zizumbo, D., & Colunga, P. (1982). Aspectos etnobotaínicos entre los Huaves de San Mateo del Mar, Oaxaca, Méxíco [Ethnobotanical aspects among the Huaves of San Mateo del Mar, Oaxaca, Mexico]. *Biótica*, *7*(2), 223–270.