DOI: https://doi.org/10.29298/rmcf.v9i50.240

Article

Diversidad de macromicetos en bosques de pino en el municipio Madera, Chihuahua

Diversity of macromyctes in pine forests at the municipality of *Madera*, *Chihuahua*

Elena Flores Cavada[1], Artemio Carrillo Parra[1], Christian A. Wehenkel[1], Fortunato Garza Ocañas[2]* y José Ciro Hernández Díaz[1]

Resumen:

El municipio Madera cuenta con una gran diversidad de ecosistemas que albergan una alta riqueza de especies fúngicas, de las cuales se tiene poco conocimiento debido a la falta de investigación para esa zona. El objetivo del presente estudio fue determinar y comparar la diversidad, hábitos y comestibilidad de los macromicetos. El muestreo se realizó en siete parcelas de 100 m × 100 m, en seis ejidos del municipio Madera, Chihuahua, durante los meses de julio y agosto del año 2016; se determinó número efectivo de especies, abundancia de frutos y diversidad alfa, mediante los índices de *Shannon* (H') y *Margalef* (D_{MG}). Los resultados mostraron un total de 69 taxa de macromicetos, pertenecientes a 27 familias y 46 géneros; de acuerdo al hábito de desarrollo, 53.62 % son saprobias, 43.50 % micorrízicas y 2.90 % patógenas. En cuanto a la comestibilidad, 28.98 % tienen potencial alimenticio. La mayor diversidad se presentó en el ejido Socorro Rivera (H’=2.44 y D_{MG}=3.58). Las especies con mayor distribución en las localidades de estudio pertenecen a *Amanita*; el porcentaje más alto de similitud de especies se registró en los ejidos Nicolás Bravo (paraje El Pedregoso) y Madera, con 18 %. Los taxones fúngicos registrados se suman a los citados previamente; con ello, aumenta el conocimiento para el estado de Chihuahua.

Palabras clave: Comestibilidad, fúngicas, hábito, potencial alimenticio, recurso forestal, saprobios.

Abstract:

The *Madera* municipality has a great diversity of ecosystems that harbor a high richness of fungal species of which there is little knowledge due to insufficient research on that area. The objective of the present study was to determine and compare the diversity, habits, and edibility of macromycetes. The sampling was carried out in 100 m × 100 m seven plots, in six *ejidos* of the *Madera* municipality, *Chihuahua*, during the months of July and August, 2016. Effective number of species, abundance of sporocarps, and alpha diversity were determined using the Shannon (H) and Margalef (D_{MG}) indices. The results obtained showed a total of 69 species of macromycetes belonging to 27 families and 46 genera. According to their growth habit, 53.62 % of the species are saprobic, 43.50 % are mycorrhizal, and 2.90 % are pathogenic. As for their edibility, 28.98 % have nutritional potential. The greatest diversity was presented in *Socorro Rivera ejido* (H '= 2.44 and D_{MG} = 3.58). The species with greatest distribution in the study localities belong to the genus *Amanita*; the highest percentage of similarity of species was found in *Nicolás Bravo* (*El Pedregoso* site) and *Madera ejidos*, with 18 %. The registered fungal species have been added to those previously reported, increasing the knowledge for the state of *Chihuahua*.

Keywords: Edibility, fungal, habit, nutritional potential, forest resource, saprobes.

Fecha de recepción/Reception date: 15 de marzo de 2018
Fecha de aceptación/Acceptance date: 24 de octubre de 2018

[1]Instituto de Silvicultura e Industria de la Madera. Universidad Juárez del Estado de Durango. México.
[2]Facultad de Ciencias Forestales, Universidad Autónoma de Nuevo León. México. Correo-e: fortunatogo@gmail.com

Introduction

Chihuahua is the largest state in Mexico; its surface area is 247 460 km², *i.e.* it covers 12.6 % of the national territory. It has various ecosystems, distributed along the *Sierra Madre Occidental*; this mountain complex has a great ecological importance, as it contributes to water capture for the phreatic mantles and is a significant source of water supply for northwestern Mexico (González-Elizondo *et al*., 2012).

There is a great vegetal diversity in the *Sierra Madre Occidental*, which is therefore a biological corridor for the various species of boreal and tropical tree species (Rzedowski, 2006). The numerous microclimates existing in it favor a variegated vegetal cover, which includes temperate forests formed by pine and pine-oak species on the mountains, and oak and pine-oak-checkerbark juniper forests, shrubs and other types of vegetation in its lower parts (Conabio, 2017).

Forests are an important source of economic resources in the state of *Chihuahua* and contribute to its industrial development, for they occupy the second place in timber production (Quiñónez and Garza, 2003). The forest industry of the state is concentrated in the *Madera*, *Parral*, *Bocoyna* and *Chihuahua* municipalities. The first is part of the north-west forest supply basin, the *El Largo-Madera* sub basin; this occupies 3.5 % of the surface area of the state (Inegi, 2010) and has the most abundant forest production.

Macromycetes are a scarcely exploited non-timber forest resource and play a major role in the ecosystems (Heredia and Arias, 2014; Thirkell *et al*., 2017). They decompose organic matter and contribute to the cycle of nutrients. Certain species form mutualist associations, like mycorrhizae, which contribute to a more efficient absorption and assimilation of nitrogen and phosphorous by the plants (Weile *et al*., 2016; Mariotte *et al*., 2017).

Mushrooms are a sustainable alternative in food production that may contribute to the food safety of the population (Vries *et al*., 2017). Quiñónez and Garza, (2003) conducted a study on macromycete diversity in the Model Forest of *Chihuahua*; they registered 102 taxa which comprised 89 specie and 13 genera, included in 29 families. By the year 2004, 450 fungal species had already been documented (Moreno *et al*., 2004). However, these values are conservative, as the state has a great ecological diversity. Díaz-Moreno *et al*. (2009) recorded 83 species of wood-decaying fungi, 37 of which were registered for the first time in *Chihuahua*.

Notably, at a regional level, the study on mycorrhizal mushroom diversity in the *Bocoyna* municipality (Quiñones *et al*., 2008) cites 15 genera and 39 species, among which *Amanita*, *Astraeus*, *Boletus*, *Inocybe*, *Laccaria*, *Lactarius*, and *Russula* were the richest and most abundant genera. In a study on Gasteroids and Secotioids in several municipalities of *Chihuahua, Geastrum saccatum* Fr., *Pisolithus arhizus* (Scop.) Rauschert and *Tulostoma melanocyclum* Bres were identified as the best represented (Moreno *et al.*, 2010).

Fifty edible macromycetes species have been cited for the *Bocoyna* and *Urique* municipalities; of these, only *Amanita cochiseana* Tulloss (Sánchez-Ramírez *et al*.,2015), *A*. *rubescens* Pers., *Hypomyces lactifluorum* (Schwein) Tul. & C. Tul*., Russula brevipes* Peck. and *Agaricus campestris* L. are eaten by the population (Quiñónez *et al*., 2010).

Studies carried out for the aim of knowing and determining the use of edible mushroom species by the inhabitants of the *Sierra Tarahumara* in *Chihuahua*, indicate the preference for *A*. *rubescens*, *A*. *campestris*, *Ustilago maydis* (DC) Corda, *Hypomyces lactifluorum* and *Amanita cochiseana*. *Mestizos* in *Bocoyna* consume *Boletus edulis* Bull and *B. pinophilus* Pilát & Dermek (Quiñones-Martínez *et al.*, 2014).

The purpose of the present research was to establish the diversity and life habits of edible and toxic macromycetes species in *Madera* municipality, *Chihuahua*.

Materials and Methods

Study area

The actual study was carried out in seven sites distributed in six *ejidos* of *Madera* municipality, *Chihuahua*, located in area No. 12 of the state (Table 1; Figure 1). *Pinus* spp. constitute 88 % of the vegetal communities (Rzedowski, 2006) and, in the portion corresponding to the municipality, they are located at various altitudes on the Western *Sierra Madre*; the mean annual precipitation is 400 to 1 200 mm, with a temperature of 8 to 22 °C (Inegi, 2017).

Table 1. Mushroom sampling sites in the *Madera* municipality, *Chihuahua*.

Site	*Ejido*	Location	UTM Coordinates		Altitude (m)
			X	Y	
1	*Cebadilla de Dolores*	*Las Cascabeles*	759474	3213114	2443
2	*Madera*	*Mesa de Parras*	773750	3233918	2481
3	*Socorro Rivera*	*Mesa de Cebadilla*	777955	3244455	2212
4	*Nicolás Bravo*	*El Pedregoso*	787872	3244140	2497
5	*Nicolás Bravo*	*Mesa del Venado*	772148	3258885	2579
6	*El Oso, La Avena and neighboring areas*	*El Serrucho*	756268	3278305	2207
7	*La Norteña*	*Mesa de los Tascates*	750256	3282986	2180

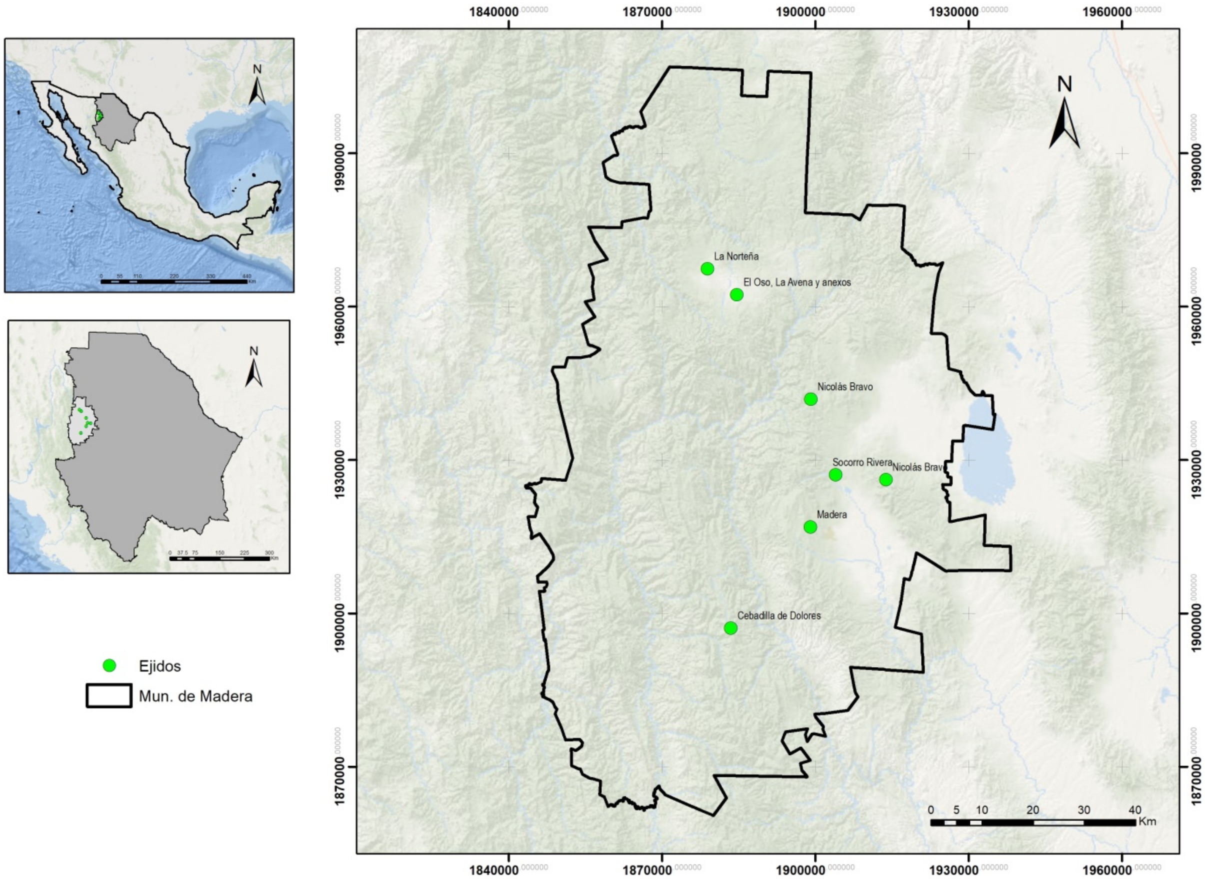

Figure 1. Location of the study area.

Collection method and taxonomic classification

The data were collected in July and August, 2016, according to the procedures of Lodge *et al.* (2004); a 100 m × 100 m plot was established for each sampling site and was georeferenced with the aid of an eTrex 10 Gramim™ satellite navigator, Furthermore, it was divided into four 50 m x 50 m quadrants; the central point of each quadrant was marked in order to establish a 20 m × 20 m square, which was in turn divided into 2 m × 2 m squares. The fungal species were counted, and the number of the square and the number of sporomes were recorded for each specimen. The macroscopic characteristics in fresh —shape, color, texture, size, diameter, and life habit— were registered in writing; a photographic support of the species was also made, using a Samsung™ ST888 camera.

Both the macroscopic and the microscopic characteristics were considered, and several specialized works (Largent *et al*., 1977; Gilbetson y Ryvarden, 1986; Singer, 1986; Phillips, 1991) were consulted for purposes of taxonomic determination. In order to corroborate the scientific names, the Index *Fungorum* (2018) and the norm NOM-059-SEMARNAT-2010 (Semarnat, 2010) were consulted in order to verify whether any of the registered species is classified in it as being at risk.

Ecological parameters

The total species richness was determined for each sampling site and according to the abundance of sporomes. The alpha diversity was estimated using *Margalef's* index (D_{MG}) and the *Shannon* index (H') with the abundance for each taxon. The sampling intensity was evaluated using the Chao 1 diversity estimator, based on the number of taxa. Jaccard's similarity index was utilized for assessing the species composition per site. The data were analyzed using PAST 3 statistical software, 1.0 version (Hammer *et al.*, 2001).

Margalef's diversity index was determined using the following equation:

$$D_{Mg} = \frac{S-1}{lnN^{\circ}}$$

Where:

D_{Mg} =Margalef's diversity index

S= Number of species present

N=Total number of sporomes

The Shannon-Wiener diversity index was determined using the following equation:

$$H' = \sum_{i=1}^{s} Piln(Pi)$$

Where:

H'=Shannon-Wiener diversity index

S = Number of species

Pi =Proportion of sporomes of species *i*

The higher the value of H', the greater the diversity of species is considered to be.

Results and Discussions

Taxonomic description and habits

A richness of 69 species of macromycetes, Basidiomycetes were represented by 68 species, and Ascomycetes, by one; these species belong to 27 families and 46 genera. The saprobic life habit had the best representation, with 37 taxa (53.62 %), mainly belonging to the families Agaricaceae, Mycenaceae, Omphalotaceae, and Polyporaceae. The *ejidos* with the largest wealth of saprobe species were *Socorro Rivera* (14), *Nicolás Bravo (El Pedregoso* site) (10), *La Norteña* (8) and *Madera* (6). The presence of these species indicates that this area has high amounts of organic matter, in whose recycling the fungi intervene. *Cebadillas de Dolores* and *El Oso, La Avena* and neighboring areas exhibited the lowest richness, with only one taxon per *ejido*.

The best represented genera were *Gymnopus* and *Lycoperdon*, with four taxa (Table 2), among which *L. perlatum* Pers., *L. echinatum* Pers. and *L. curtisii* Pers., stand out as edible species. The study by Díaz-Moreno *et al*. (2009) records 83 species of the saprobe group. The results of this research are consistent with this study in that the family Polyporaceae has the highest species richness. The record of 37 species for *Madera* municipality is significant, as it is a large figure, compared to those cited by the above authors, who provide a value that includes more than one municipality of *Chihuahua*.

Table 2. List of fungal species registered in the *ejidos* of *Madera* municipality.

Family	Genus	Species	Authors	Habit	Edibility	Site
Agaricaceae	*Coprinus*	*micaceus*	(Bull.) Vilgalys, Hopple y Jacq. Johnson	Saprobe	Edible	4
Agaricaceae	*Cyathus*	*striatus*	(Huds) Wild.	Saprobe	Inedible	2
Agaricaceae	*Cystodermella*	*granulosa*	(Batsch) Harmaja	Saprobe	Toxic	4
Agaricaceae	*Leucocoprinus*	*fragilissimus*	(Ravenek ex Berk., Curtis) Pat.	Saprobe	Toxic	3
Agaricaceae	*Lycoperdon*	*perlatum*	Pers.	Saprobe	Edible	1,7
Agaricaceae	*Lycoperdon*	*echinatum*	Pers.	Saprobe	Edible	4
Agaricaceae	*Lycoperdon*	*curtisii*	Berk.	Saprobe	Edible	7
Agaricaceae	*Lycoperdon*	*umbrinum*	Pers.	Saprobe	Toxic	2
Amanitaceae	*Amanita*	*cochiseana*	Tulloss	Mycorrhizal	Edible	6
Amanitaceae	*Amanita*	*citrina*	Pers.	Mycorrhizal	Toxic	3
Amanitaceae	*Amanita*	*muscariavar. flavivolvata*	(Cantante) DT Jenkins	Mycorrhizal	Toxic	2,6
Amanitaceae	*Amanita*	*novinupta*	Tulloss& J. Lindgr.	Mycorrhizal	Toxic	2,4,5,6
Amanitaceae	*Amanita*	*phalloides*	(Vaill. Ex Fr.) Link	Mycorrhizal	Fatally toxic	5,6
Amanitaceae	*Amanita*	*rubescens*	Pers.	Mycorrhizal	Edible*	3
Auriculariaceae	*Auricularia*	*mesenterica*	(Sw.) Birkebak, (Dicks) Pers.	Saprobe	Edible	2,4
Auriscalpiaceae	*Artomyces*	*pyxidatus*	(Pers.) Jülich	Saprobe	Inedible	7
Bankeraceae	*Phellodon*	*melaleucus*	(Sw. ex Fr.) P. Karst.	Saprobe	Toxic	7
Bankeraceae	*Sarcodon*	*squamosus*	(Schaeff.) Quél.	Saprobe	Toxic	5
Boletaceae	*Boletus*	*aff. edulis*	Bull.	Mycorrhizal	Edible	2
Boletaceae	*Boletus*	*barrowsi*	Thiers& AH Sm.	Mycorrhizal	Edible	2
Boletaceae	*Boletus*	*rubriceps*	D. Arora& J.L. Frank	Mycorrhizal	Toxic	5

Boletaceae	*Butyriboletus*	*regius*	(Krombh.) D. Arora & J.L. Frank	Mycorrhizal	Toxic	5
Boletaceae	*Chroogomphus*	*vinicolor*	(Cantante) O.K. Miller	Mycorrhizal	Inedible	7
Cantharellaceae	*Cantharellus*	*cibarius*	Fr.	Mycorrhizal	Edible	6
Cortinariaceae	*Cortinarius*	*violaceus*	(L.) Gray	Mycorrhizal	Toxic	2,4
Dacrymycetaceae	*Dacrymyces*	*chrysospermus*	Berk. & MA Curtis	Saprobe	Inedible	5
Dacrymycetaceae	*Dacryopinax*	*spathularia*	(Schwein.) GW Martin	Saprobe	Inedible	4
Diplocystidiaceae	*Astraeus*	*hygrometricus*	(Pers.) Morgan	Mycorrhizal	Inedible	2,3,6
Entolomataceae	*Entocybe*	*nitida*	(Quél.) TJ Baroni, Largent& V. Hofst.	Saprobe	Toxic	7
Gomphaceae	*Ramaria*	*stricta*	(Pers.) Quél.	Mycorrhizal	Toxic	2
Hydnangiaceae	*Laccaria*	*laccata*	(Scop.) Cooke	Mycorrhizal	Edible	3
Hygrophoraceae	*Hygrocybe*	*conica*	(Schaeff.) P. Kumm.	Saprobe	Toxic	3,7
Hygrophoraceae	*Hygrophorus*	*russula*	(Schaeff. Ex Fr.) Kauffman	Saprobe	Edible	2
Hymenochaetaceae	*Coltricia*	*cinnamomea*	(Jacq.) Murrill	Mycorrhizal	Inedible	7
Hymenogastraceae	*Deconica*	*coprophila*	(Bull.) P. Kumm.	Saprobe	Toxic	3
Hymenochaetaceae	*Onnia*	*circinata*	(P.) P. Karst.	Saprobe	Forest pathogen	3
Hypocreaceae	*Hypomyces*	*lactifluorum*	(Schwein.) Tul. Y C. Tul.	Pathogenic	Edible	2,4
Inocybaceae	*Crepidotus*	*mollis*	(Schaeff.) Staude	Saprobe	Toxic	3
Inocybaceae	*Inocybe*	*calamistrata*	(Fr.) Gillet	Mycorrhizal	Toxic	3
Inocybaceae	*Inocybe*	*geophylla*	(Bull.) P. Kumm.	Mycorrhizal	Toxic	3
Inocybaceae	*Inocybe*	*lacera*	(Fr.) Kumm.	Mycorrhizal	Toxic	3
Inocybaceae	*Inocybe*	*rimosa*	(Bull.) P.Kumm.	Mycorrhizal	Toxic	3
Mycenaceae	*Mycena*	*epipterygia*	(Scop.) Gray	Saprobe	Toxic	4
Mycenaceae	*Mycena*	*galopus*	(Pers.) P. Kumm.	Saprobe	Toxic	3
Mycenaceae	*Mycena*	*pura*	(Pers.) P. Kumm	Saprobe	Toxic	3
Mycenaceae	*Phyllotopsis*	*nidulans*	(Pers.) Singer	Saprobe	Toxic	2

Mycenaceae	*Panellus*	*stipticus*	(Bull.) P. Karst.	Saprobe	Inedible	6
Omphalotaceae	*Gymnopus*	*androsaceus*	(L.) DellaMagg. Y Trassin.	Saprobe	Inedible	3
Omphalotaceae	*Gymnopus*	*butyraceus-trichopus*	Murrill	Saprobe	Toxic	3,4,5,7
Omphalotaceae	*Gymnopus*	*dryophilus*	(Bull.) Murr.	Saprobe	Edible	7
Omphalotaceae	*Gymnopus*	*erytropus*	(Pers.) Antonin, Halling&Noordel	Saprobe	Toxic	5
Phanerochaetaceae	*Byssomerulius*	*incarnatus*	(Schwein.) Gilb.	Saprobe	Medicinal	4
Physalacriaceae	*Armillaria*	*mellea*	(Vahl) P. Kumm.	Forest pathogen	Edible	2
Physalacriaceae	*Hohenbuehelia*	*petaloides*	(Bull.) Schulzer	Saprobe	Toxic	3
Polyporaceae	*Heliocybe*	*sulcata*	(Berk.) Redhead&Ginns	Saprobe	Inedible	4
Polyporaceae	*Lentinus*	*arcularius*	(Batsch) Zmitr.	Saprobe	Inedible	3
Polyporaceae	*Neofavolus*	*alveolaris*	DC.) Sotome y T. Hatt.	Saprobe	Edible	3
Psathyrellaceae	*Psathyrella*	*candolleana*	(Fr.) Maire.	Saprobe	Toxic	2
Russulaceae	*Lactarius*	*indigo*	(Schwein.) P.	Mycorrhizal	Edible	7
Russulaceae	*Lactarius*	*piperatus*	(L.) Pers.	Mycorrhizal	Toxic	2,4
Russulaceae	*Lactarius*	*volemus*	(Fr.) Fr.	Mycorrhizal	Edible	3
Russulaceae	*Russula*	*emetica*	(Schaeff.) Pers.	Mycorrhizal	Toxic	1,2
Russulaceae	*Russula*	*nigricans*	Pers.	Mycorrhizal	Toxic	1,5,6,7
Russulaceae	*Russula*	*rosea*	Pers.	Mycorrhizal	Toxic	5
Stereaceae	*Stereum*	*gausapatum*	(Fr.) P.	Saprobe	Inedible	4
Stereaceae	*Stereum*	*ostrea*	(Blume y T. Nees)	Saprobe	Inedible	3,4
Suillaceae	*Suillus*	*tomentosus*	Singer	Mycorrhizal	Edible	5
Tricholomataceae	*Leucopaxillus*	*gentianeus*	(Quél.) Kotl.	Mycorrhizal	Toxic	7
Tricholomataceae	*Clitocybe*	*gibba*	(Pers.) P. Kumm.	Mycorrhizal	Edible	2,3

*Edible with precautions (only cooked); Hierarchical taxonomic arrangement based on Kirk *et al*. (2008).

The state has large forested areas, which are kept balanced thanks to various interactions, including the mycorrhizal associations that participate in the conservation of forest ecosystems. 30 taxa of mycorrhizal fungi were identified; the *ejidos* with the greatest species richness were *Madera* (10) and *Socorro Rivera* (10), followed by *Nicolás Bravo* (*Mesa del Venado* site) (7), *El Oso, La Avena* and neighboring areas (7), and *La Norteña* (5). The lowest values were for *Nicolás Bravo (El Pedregoso* site) (3) and *Cebadilla de Dolores* (2). The genera with the greatest species richness were: *Amanita* (6), with *A. cochiseana*, *A. citrina* Pers., *A. muscaria* var*. flavivolvata* (Cantante) DT, *A. novinupta* Tulloss & J. Lindgr*., A. phalloides* (Vaill. ex Fr.) Link and *A. rubescens*, of which *A. cochiseana* and *A. rubescens* are edible; *A. novinupta* was collected in four of the study sites.

Boletus (4), with *Boletus aff. edulis*, *B. barrowsi* Thiers & AH Sm., *B. rubriceps* D. Arora & J. L. Frank and *B. regius* (Krombh.) D. Arora & J.L. Frank. The first two species are considered to be edible. Like *Amanita muscaria* and *Hygrophorus russula* (Schaeff. ex Fr.) Kauffan, *B. aff. edulis* is cited in the norm NOM-059-SEMARNAT-2010 as at risk or threatened (Semarnat, 2010).

Inocybe (4), with *I. calamistrata* (Fr.) Gillet, *I*. *geophylla* (Bull.) P. Kumm. *I*. *lacera* (Fr.) Kumm. and *I*. *rimosa* (Bull.) P. Kumm. are toxic. *Lactarius* (3), with *L. indigo* (Schwein.) P., *L. piperatus* (L.) Pers. and *L. volemus* (Fr.) Fr., of which the first and the last are edible. As for the genus *Russula*, the registered species were *R. emetica* (Schaeff.) Pers, *R. nigricans* Pers*.* and *R. rosea* Pers., in agreement with Quiñónez *et al.* (2009), who point out the same genera as those with the greatest species richness, except for *Inocybe*, in four *ejidos* of *Urique* municipality in the *Sierra Tarahumara*; they also cite most species of the genus *Amanita*.

The richness of mycorrhizal species for the *Madera* municipality is considered to be high, compared to other municipalities like *Bocoyna*, where Quiñónez *et al.* (2008)

document 39 species; of these, *A. muscaria* var*. flavivolvata* and *R. emetica* were the most representative. They register others, like *Astraeus hygrometricus* (Pers.) Morgan, in most of their sampling sites; a similar situation occurs in the *Madera* municipality, where four *ejidos* were registered (Table 2).

Edible macromycetes have been scarcely studied in northern Mexico even though they have a great ethnomycological importance; 20 of these were identified (28.98 %). The *ejidos* with the largest number of species were *Madera* (8) and *Socorro Rivera, Nicolás Bravo (El Pedregoso* site) and *La Norteña*, with four taxa each. The family Agaricaceae and the genus *Lycoperdon* stand out for having most edible species; other identified edible species were *A*. *cochiseana*, *A*. *rubescens*, *H. russula*, *H. lactifluorum, L*. *indigo*, and *Laccaria laccata* (Scop.) Cooke, equally cited by Quiñónez *et al.* (2010) in the forests of *Bocoyna* and *Urique, Chihuahua*. According to Quiñones-Martínez *et al*. (2014), the most widely consumed taxa among the inhabitants of the *Sierra Tarahumara* are *A. rubescens, Agaricus campestris* L.*, Ustilago maydis* (DC) Corda*, H. lactifluorum* and *A*. *cochiseana*, *Boletus edulis* and *B. pinophilus*. *H. lactifluorum* was the only species in the Ascomycetes group registered in this study, and it has a high nutritional value for the inhabitants of the area (Table 2).

Ecological parameters

Alpha diversity

Socorro Rivera ejido had the greatest species richness, with 21 taxa, followed by *Madera, Nicolás Bravo (El Pedregoso* site) and *La Norteña*, with 17, 16 and 13 taxa, respectively. The *ejidos* with the lowest values were *Nicolás Bravo (Mesa del Venado* site), and *El Oso, La Avena* and neighboring areas, both with eight taxa. *Socorro Rivera* had the highest diversity (H'=2.44 and D_{MG}=3.58), while *Cebadilla de Dolores* (H'=1.15 and D_{MG} =0.75) had the lowest (Table 3).

Table 3. Diversity indexes of macromycetes in *Madera* municipality.

Index	Site						
	Cebadilla de Dolores	***Madera***	***Socorro Rivera***	***Nicolás Bravo***	***Nicolás Bravo***	***El Oso, La Avena* and neighbor-ing areas**	***La Norteña***
Taxa	4	17	21	16	8	8	13
Sporomes	53	339	267	625	128	31	163
Shannon_H	1.15	1.66	2.44	1.89	1.73	1.78	2.22
Margalef	0.76	2.75	3.58	2.33	1.44	2.04	2.36
Chao-1	4	17	21	19	8	8	16

A total of 1 606 sporomes were registered. *Nicolás Bravo ejido* (*El Pedregoso* site) was the most abundant (38.91 %), and *El Oso, La Avena* and neighboring areas, the least abundant, with a mere 1.93 %.

The most abundant species, with over 100 sporomes, were *Astraeus hygrometricus*, present in *Madera, Socorro Rivera, and El Oso, La Avena ejidos* and neighboring areas, amounting to 14.82 % of the total sporomes; *Stereum gausapatum* (Fr.) P., with 12.20 %; *Auricularia mesentérica* (Sw.) Birkebak, (Dicks) Pers. (with 8.96 %), collected in *Nicolás Bravo (El Pedregoso* site) and *Socorro Rivera*; *Stereum ostrea* (Blume and T. Nees), with 8.34 %, and *H. lactifluorum*, with 7.34 %. This last species was registered for *Nicolás Bravo (El Pedregoso* site) and *Madera*; the rest of the species included 1 to 69 sporomes, distributed among the various study sites.

The results of Chao 1 for *Cebadilla de Dolores, Madera, Socorro Rivera, Nicolás Bravo (Mesa del Venado* site), and *El Oso, La Avena* and neighboring areas, indicate that the record of species met the expected number of taxa; a diversity of 19 and 16 species is estimated to exist in the localities of *Nicolás Bravo (El Pedregoso* site) and *La Norteña* (Table 3). More long-term diversity studies on this group are necessary in order to achieve greater knowledge of the species distributed in the area and at a national level (Aguirre-Acosta *et al.*, 2014).

Jaccard's similarity

The highest percentage of similarity occurred in *Madera* and *Nicolás Bravo ejidos (El Pedregoso* site), with 18 %; the species identified in the two sites were *A. novinupta*, *Auricularia mesenterica*, *Cortinarius violaceus* (L.) Gray, *H. lactifluorum* and *L. piperatus*. *El Oso*, *La Avena* and neighboring areas registered a value of 14 %, like *Madera* and *Nicolás Bravo (Mesa del Venado* site). Shared taxa were *A. novinupta*, *A. hygrometricus* and *R*. *nigricans* (tables 2 and 4).

Table 4. Values for *Jaccard's* index of similarity between species per site.

	Cebadilla de Dolores	***Madera***	***Socorro Riera***	***Nicolás Bravo***	***Nicolás Bravo***	***El Oso, La Avena and neighbor-ing areas***	***La Norteña***
Cebadilla de Dolores	1.00						
Madera	0.05	1.00					
Socorro Riera	0.00	0.06	1.00				
Nicolás Bravo	0.00	0.18	0.03	1.00			
Nicolás Bravo	0.00	0.04	0.00	0.04	1.00		
El Oso, La Avena and neighboring areas	0.09	0.14	0.04	0.04	0.14	1.00	
La Norteña	0.07	0.00	0.03	0.00	0.00	0.00	1.00

Conclusions

The *Madera* municipality has a great species richness; the 69 species registered in this research are a significant contribution to the knowledge of the macromycetes of northern Mexico. The fungal resources are available and can be exploited in a sustainable and strategic manner, according to their role in the ecosystem.

Each site has a different species composition, and the abundance of sporomes varies contrastingly. The best represented genus is *Amanita*, with species present in most sites and the largest distribution interval in *Chihuahua*.

However, more studies are required in order to determine the diversity of fungal species in various ecosystems of the state and of northern Mexico in general.

Acknowledgments

The present study was conducted through a series of projects financed by Profos-Conafor. The first author wishes to express her gratitude to Conacyt for the scholarship granted by this Council to finance her MS studies in Agricultural Sciences and Forestry (MICAF) at the Juarez University of the State of Durango (*Universidad Juárez del Estado de Durango*, as well as to the Faculty of Forestry of the Autonomous University of Nuevo León (*Universidad Autónoma de Nuevo León*) for the support provided by its mycology research team.

Conflict of interests

The authors declare no conflict of interests.

Contribution by author

Elena Flores Cavada: research development, capture and analysis of data, drafting and structuring of the manuscript; Artemio Carrillo Parra: drafting and general review of the manuscript; Christian A. Wehenkel: financial support through inclusion in one of his projects; Fortunato Garza Ocañas: identification of the fungal species registered at the sampling sites, support in the structuring of the manuscript, selection of the variables, drafting and review of the manuscript; José Ciro Hernández Díaz: general review of the manuscript.

References

Aguirre-Acosta, E., M. Ulloa, S. Aguilar, J. Cifuentes y R. Valenzuela. 2014. Biodiversidad de hongos en México. Revista Mexicana de Biodiversidad Supl. 85:S76-S81. DOI: 10.7550/rmb.33649.

Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (Conabio). 2017. Principales tipos de vegetación. https://www.gob.mx/conabio (28 de abril de 2017).

Díaz-Moreno, R., R. Valenzuela, J. G. Marmolejo y E. Aguirre-Acosta. 2009. Hongos degradadores de la madera en el estado de Chihuahua, México. Revista Mexicana de Biodiversidad 80(1): 13-22.

Gilberson, R. L. and L. Ryvarden. 1986. North American Polypores. Vol. 1. *Abortiporus-Lindtneria*. Fungiflora A/S. Oslo, Norway. 433 p.

González-Elizondo, M. S., M. González-Elizondo, J. A. Tena-Flores, L. Ruacho-González e I. L. López-Enríquez. 2012. Vegetación de la Sierra Madre Occidental, México: Una síntesis. Acta Botánica Mexicana 100:351-403.

Hammer, Ø., D. A. T. Harper and P. D. Ryan. 2001. PAST: Palentological Statistic Software Package for Education and Data Analysis. Palaentologia Electronica 4(1): 1-9.

Heredia A. G. y M. Arias M. R. (2014). Hongos saprobios y endomicorrizógenos en suelos. https://www.researchgate.net/publication/242718990_Hongos_saprobios_y_endomicorrizogenos_en_suelos?enrichId=rgreq-44e7e98b19fd7692cf50c68142eac414-XXX&enrichSource=Y292ZXJQYWdlOzI0MjcxODk5MDtBUzoxMDg2NjAyOTg2MjA5MzBAMTQwMjkxODA0MjcyMQ%3D%3D&el=1_x_2&_esc=publicationCoverPdf (4 de enero de 2017).

Index Fungorum. 2018. Search Index Fungorum. http://www.indexfungorum.org/. (10 de enero de 2018).

Instituto Nacional de Estadística y Geografía (Inegi). 2010. Compendio de Información Geográfica Municipal de los Estados Unidos Mexicanos Madera, Chihuahua. http://www.beta.inegi.org.mx/contenidos/app/mexicocifras/datos_geograficos/08/08040.pdf (2 de julio de 2018).

Instituto Nacional de Estadística y Geografía (Inegi). 2017. Compendios de información geográfica municipal. http://www.inegi.org.mx/geo/contenidos/topografia/compendio.aspx (15 de enero de 2017).

Kirk, P. M., P. F. Cannon, D. W. Minter and J. C. Stalpers (eds.). 2008. Dictionary of the Fungi 10^{th} ed. CABI. Wallingford, UK. 784p.

Largent, D. L., D. Johnson and R. Watling. 1977. How to identify mushrooms to genus III: Microscopic features. Mad Rivers Press Inc. Eureka. California, CA, USA. 86 p.

Lodge, D. J., J. F. Ammirati, T. E. O´Dell and G. Muller. 2004. Collecting and describing macrofungi. *In*: Muller, G., G. Bills and M. Foster (eds.). Biodiversity of fungi Inventory and monitoring methods. Elsevier Academic Press. California, CA, USA. pp. 128-153.

Mariotte, P., A. Canarini and F. A. Dijkstra. 2017. Stoichiometric N: P flexibility and Micorrícico symbiosis favour plant resistance against drought. Journal of Ecology 105: 958–96.

Moreno F., Á., E. Aguirre A. y L. Pérez R. 2004. Conocimiento tradicional y científico de los hongos en el estado de Chihuahua, México. Etnobiología 4: 89-10.

Moreno, G., M. Lizárraga, M. Esqueda y M. L. Coronado. 2010. Contribution to the study of gasteroid and secotioid fungi of Chihuahua, Mexico. Micotaxon 112(1):291–315.

Phillips, R. 1991. Mushroom of North America. Little Brown and Company. Boston, MA, USA. 319 p.

Quiñónes-Martínez, F. Ruan-Soto, I. E. Agilar-Moreno, F. Garza-Ocañas, T. Lebgue-Keleng, P. A. Lavín-Murcio and I. D. Enríquez-Anchondo. 2014. Knowledge and use of Comestible mushroom in two municipalities of the Sierra Tarahumara, Chihuahua, Mexico. Journal of Ethnobiology 10:67. DOI: 10.1186/1746-4269-10-67.

Quiñónez M., M., F. Garza O., S. Anguiano F., V. Chacón R. y S. Bernal C. 2010. Diversidad de hongos comestibles en los bosques de Bocoyna y Urique del estado de Chihuahua. Ciencia en la frontera: Revista de ciencia y tecnología de la UACJ 8(1):29-34.

Quiñónez M., M., P. Lavin M., F. Garza O., A. De La Mora C., T. Lebgue K. y A. Woocay P. 2009. Riqueza y frecuencia de hongos ectomicorrizógenos en el municipio de Urique, Chihuahua, México Ciencia en la frontera: revista de ciencia y tecnología de la UACJ 7(2): 33-40.

Quiñones M., M., F. Garza O., M. Sosa C., T. Lebgue K., P. Lavín M. y S. Bernal C. 2008. Índices de diversidad y similitud de hongos ectomicorrizógenos en el bosque Bocoyna, Chihuahua, México. Ciencia Forestal en México 33(103): 59-78.

Quiñones M., M. y F. Garza O. 2003. Taxonomía, ecología y distribución de hongos macromicetos de Bosque modelo, Chihuahua. Revista de ciencia y tecnología de la UACJ 7(1):63-69.

Rzedowski, J., 2006. Vegetación de México. 1ª edición digital. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. México, D.F., México. 504 p.

Secretaría de Medio Ambiente y Recursos Naturales (Semarnat). 2010. Norma Oficial Mexicana NOM-059-SEMARNAT-2010. Segunda sección. Diario Oficial de la Federación. 30 de diciembre de 2010. México, D.F., México. 78 p. https://www.gob.mx/profepa/es/documentos/norma-oficial-mexicana-nom-059-semarnat-2010 (23 de marzo de 2018).

Sánchez-Ramírez, S., R. E. Tulloss, L. Guzmán-Dávalos, J. Cifuentes-Blanco, R. Valenzuela, A. Estrada-Torres, F. Ruán-Soto, R. Díaz-Moreno, N. Hernández-Rico, M. Torres-Gómez, H. León and J. M. Moncalvo. 2015. In and out of refugia: historical patterns of diversity and demography in the North American Caesar's mushroom species complex. Molecular Ecology 24(23):5938–5956 doi: 10.1111/mec.13413.

Singer, R. 1986.The Agaricales in Modern Taxonomy. Koeltz Scientific Books. Köenigstein, Federal Republic of Germany. 981 p.

Thirkell, T. J., M. D. Charters, J. E. Ashleigh, M. S. Steven and K. J. Field. 2017. Are mycorrhizal fungi our sustainable saviours? Considerations for achieving food security. Journal of Ecology 105: 921–92.

Vries, F. T. and M. D. Wallenstein. 2017. Below-ground connections underlying above-ground food production: a framework for optimising ecological connections in the rhizosphere. Journal of Ecology 105: 913–92.

Weile, C., R. T. Kiyde and D. M. Eissenstat. 2016. Root morphology and mycorrhizal type strongly influence root production in nutrient hot spots of mixed forests. Journal of ecology 106:148-156. DOI: 10.1111/1365-2745.128