Revista Mexicana de Ciencias Forestales Vol. 14 (79)
Septiembre - Octubre (2023)

DOI: 10.29298/rmcf.v14i79.1365

Research article

Especies de macrohongos en matorrales del Noreste de México

Macrofungi species from thornscrubs in Northeast Mexico

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Fecha de recepción/Reception date: 17 de marzo de 2023.
Fecha de aceptación/Acceptance date: 11 de agosto de 2023.

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Abstract

Thornscrubs cover large areas in Northeast Mexico and few species of macrofungi have been reported. The objective of this study was to know the diversity of macrofungi associated with thornscrubs. The results showed a diversity of 218 fungal taxa, belonging to 145 genera and 62 families. 186 species are distributed in both states of *Nuevo León* and *Tamaulipas*, 23 only in *Tamaulipas* and nine only in *Nuevo León*. 34 of these species are new records for Northeast Mexico. Basidiomycetes are the most diverse with 187 species, 125 genera and 50 families, followed by Ascomycetes with 23 species, 13 genera and seven families. The Myxomycetes (formerly considered as fungi) were less abundant with eight species, seven genera and five families. As for the genera with the greatest richness, *Xylaria* had fourteen taxa it was followed by *Amanita* ten, *Lactarius* and *Lentinus* six, *Ganoderma*, *Phellinus* and *Geastrum* four, *Boletus* three, and the rest less than three. Regarding the edibility of the taxa, 175 were not edible, 18 edible and 25 toxic species were recorded. In relation to growth habit, 62 are mycorrhizal, 117 are saprotrophic, 31 are parasitic and eight are phagotrophic. The altitudinal distribution showed that 94 taxa were recorded between 100 and 500 m of altitude and 104 species grow between 500-700 m. Mycorrhizal and parasitic fungi are associated with 41 plant species.

Key words: Distribution, diversity, ecology, macrofungi, thornscrubs, Northeast Mexico.

Resumen

Los matorrales ocupan grandes extensiones en el Noreste de México, pero en ellos pocas especies de macrohongos han sido citadas. El objetivo de este estudio fue conocer su diversidad asociada a matorrales. Los resultados demostraron una diversidad de 218 taxa de hongos pertenecientes a 145 géneros y 62 familias. En los estados de Nuevo León y Tamaulipas se distribuyeron 186 especies, 23 solo en Tamaulipas y nueve únicamente en Nuevo León. De ellos, 34 son nuevos registros para el Noreste de México. Los basidiomicetos son los más diversos con 187 especies, 125 géneros y 50 familias, le siguen los ascomicetos con 23 especies, 13 géneros y siete familias. Los mixomicetos (antes considerados hongos) son menos abundantes, con ocho especies, siete géneros y cinco familias. En cuanto a los géneros con mayor riqueza: *Xylaria* está representado por 14 taxones, *Amanita* con 10, *Lactarius* y *Lentinus* con seis, *Ganoderma*, *Phellinus* y *Geastrum* por cuatro, *Boletus* con tres y el resto menos de tres. Con respecto a la comestibilidad de los taxones, se registraron 175 no comestibles, 18 comestibles y 25 tóxicas. En relación al hábito de crecimiento, 62 son micorrícicos, 117

saprobios, 31 parásitos y ocho fagotróficos. La distribución altitudinal de 94 taxa se ubicó entre 100 y 500 m, 124 especies en un intervalo de 500 a 700 m. Los hongos micorrícicos y parásitos se asociaron a 41 especies de plantas.

Palabras clave: Distribución, diversidad, ecología, macrohongos, matorrales, Noreste de México.

Introduction

The Tamaulipas biogeographic province in the area of the Gulf of Mexico coast is distributed in around 200 000 km^2, from Northern Mexico to southern Texas, in the United States of America (Conabio, 2021). It is made up of scrub of several types (González, 2003). The thorny scrub has plant species that are 1-4 m tall and grow at altitudes of 100-650 m. The submontane scrub is home to sub-armless trees 4-6 m tall, located in the lower parts of the *Sierra Madre Oriental* in an east-west direction, between 650 and 700 masl. Both types of scrub include multipurpose plants that are used in rural communities (Alanís, 2006; Estrada *et al.*, 2014). People use them as round wood for the construction of houses and fences, as well as for the manufacture of domestic furniture, agricultural tools, such as charcoal or firewood, and they consume the fruits of some wild species (Alanís, 2006).

The clearing of scrubs for the introduction of grass and livestock for agricultural purposes or for the production of orange trees is a common practice that causes a dramatic loss of biodiversity (Pando *et al.*, 2014), which disappears without being scientifically known. Such is the case of many macro and micro fungi that recycle organic matter.

Some studies in which species of macrofungi have been recorded in Northern Mexican scrub, for example: *Favolus brasiliensis* (Fr.) Fr., *Polyporus alveolaris* (DC.) Bondartsev & Singer, *Montagnea arenaria* (DC.) Zeller, *Podaxis pistillaris* (L.) Fr., *Phellorinia herculeana* (Pers.) Kreisel and *Tulostoma* Pers. spp., are those of Castillo and Guzmán (1970), Esqueda-Valle *et al.* (1995) and Esqueda *et al.* (2012). Up to day, there are no reports of macromycetes associated with *sensu lato* scrub in Northeast Mexico. The objective of this study was to generate information about the species of macromycetes that grow in some scrublands of Northeast Mexico.

Materials and methods

The mushrooms were collected during the last 35 years in more than 100 locations in the states of *Nuevo León* and *Tamaulipas*. The classic protocols for the study of macrofungi were followed, which include recording their macroscopic characteristics *in situ* in fresh specimens (Largent *et al.*, 1973; Villarreal and Gómez, 1995; Lodge *et al.*, 2004; Bessette *et al.*, 2016). Likewise, the characteristics of the collection sites in the field were noted: altitude, condition of the vegetation, tree, shrub and herbaceous species. Photographs (D3300 Nikon® camera, 40mm macro lens) of the specimens were taken both at a distance of 1 m, and with macrophotography in order to have the maximum details of the sporomes.

For the microscopic visualization of the different structures that characterize the species, fine cuts were manually made with a knife. These were mounted in KOH reagent (5 %) and Melzer in order to observe the contrast of the structures more clearly (Largent *et al.*, 1977).

For color terminology, the Methuen Handbook of Color (Kornerup and Wanscher, 1978) was used. At least 30 microscopic structures (basidiospores, basidia and pileipellis) were measured with an Axiostar Carl Zeiss® optical microscope (Quiñónez *et al.*, 2008). The *Q* ratio, mean length (*L*) and mean width (*W*) were obtained for basidiospores as described by Frank *et al.* (2020).

The identification of the possible hosts with which the saprobe, parasitic and mycorrhizal species were observed was carried out in the CFNL herbarium of the Graduate School of Forest Sciences of the *Universidad Autónoma de Nuevo León* in *Linares*, *Nuevo León*. The studied material was deposited in the mycological collections of the *José Castillo Tovar* (ITCV) of the Technological Institute of *Ciudad Victoria* and the CFNL herbaria. Species were ordered according to Kirk *et al.* (2008); for the classification of the species the Index Fungorum (2023) was used.

Results

In the present investigation, only a part of the diversity of macromycete species that have been determined associated with the scrublands of Northeast Mexico is documented (Figure 1). The records corresponded to 210 species of Ascomycetes and Basidiomycetes, represented in 138 genera of 57 families, in addition to eight species of Myxomycetes from seven genera belonging to five families in the states of *Nuevo León* and *Tamaulipas*. In both states, 186 were distributed, 23 only in *Tamaulipas* and nine only in *Nuevo León*. 34 species of them are new records for Northeast Mexico (Table 1).

Frequent species: A = *Ganoderma lobatum* (Cooke) G. F. Atk.; B = *Trametes versicolor* (L.) Lloyd; C = *Lysurus periphragmoides* (Klotzsch *ex* Hook.) Dring; D = *Heliocybe sulcata* (Berk.) Redhead & Ginns. Rare species: E = *Agaricus deserticola* G. Moreno, Esqueda & Lizárraga; F = *Pluteus petasatus* (Fr.) Gillet; G = *Phellodon fibulatus* K. A. Harrison.

Figura 1. Some of the macrofungi species found in the shrublands of Northeast Mexico.

Table 1. Taxonomy, growth habit, altitude, edibility and geographical distribution of the studied species.

Taxonomic groups	Species	Habit/ Altitude	Edibility	Distribution by state
EUMYCOTA				
ASCOMYCOTINA				
Sordariomycetes				

Hypocreales				
Cordycipitaceae				
	Cordyceps militaris (L.) Fr.	P	NC	NL*
Xylariales				
Graphostromataceae				
	Biscogniauxia fuscella (Rehm) F. San Martín & J. D. Rogers	P/A2	NC	NL/TAM
Hypoxylaceae				
	Daldinia concentrica (Bolton) Ces. & De Not.	P	NC	NL/TAM
Xylariaceae				
	Hypocreodendron sanguineum Henn.	S1	NC	NL/TAM
	Kretzschmaria pavimentosa (Ces.) P. M. D. Martin	P	NC	TAM
	Poronia oedipus (Mont.) Mont.	S1	NC	NL*/TAM
	Xylaria arbuscula Sacc.	S3/A2	NC	TAM
	X. corniformis (Fr.) Fr.	S3/A2	NC	TAM
	X. cubensis (Mont.) Fr.	S3	NC	TAM
	X. curta Fr.	S3	NC	TAM
	X. enterogena Mont.	S3	NC	TAM
	X. enteroleuca (J. H. Mill.) P. M. D. Martin	S3	NC	TAM
	X. feejeensis (Berk.) Fr.	S3	NC	NL/TAM
	X. multiplex (Kunze) Fr.	S3	NC	NL/TAM
	X. polymorpha (Pers.) Grev.	S3	NC	NL/TAM
	X. protea Fr.	S3	NC	NL/TAM
	Xylosphaera ianthinovelutina (Mont.) Dennis	S3	NC	TAM
Pezizomycetes				
Pezizales				
Pezizaceae				
	Hydnobolites cerebriformis Tul. & C. Tul.	M/A2	NC	NL/TAM
	Pachyphlodes citrina (Berk. & Broome) Doweld	M/A2	NC	NL/TAM
	P. virescens (Gilkey) Doweld	M/A2	NC	NL/TAM
Sarcoscyphaceae				
	Phillipsia domingensis (Berk.) Berk. *ex* Denison	S3/A2	NC	NL/TAM
	Sarcoscypha coccinea (Jacq.) Lambotte	S3/A2	NC	NL/TAM
Tuberaceae				

	Tuber nitidum Vittad.	M/A2	NC	NL/TAM
BASIDIOMYCOTINA				
Agaricomycetes				
Agaricales				
	Cyathus olla (Batsch) Pers.	S3/A2	NC	NL/TAM
	C. stercoreus (Schwein.) De Toni	S2	NC	NL/TAM
	C. striatus Willd.	S3/A2	NC	NL/TAM
Agaricaceae				
	Agaricus aridicola Geml, Geiser & Royse *ex* Mateos, J. Morales, J. A. Muñoz, Rey & C. Tovar	S1	NC	NL*/TAM
	A. campestris L.	S1	C	NL/TAM
	A. xanthodermus Genev.	S1	NC	NL/TAM
	A. placomyces Peck	S1/A2	NC	NL*/TAM
	Battarrea phalloides (Dicks.) Pers.	S1	NC	NL
	Battarreoides diguetii (Pat. & Har.) R. Heim & T. Herrera	S1	NC	NL
	Chlorophyllum molybdites (G. Mey.) Massee	S1	NC	NL/NL
	Coprinus comatus (O. F. Müll.) Pers.	S1	NC	NL/TAM
	Disciseda bovista (Klotzsch) Henn.	S1/A2	NC	NL/TAM
	Lepiota besseyi H. V. Sm. & N. S. Weber	S1	NC	TAM
	L. cristata (Bolton) P. Kumm.	S1/A2	NC	NL/TAM
	L. erythrosticta (Berk. & Broome) Sacc.	S1	NC	NL/TAM
	Leucoagaricus rubrotinctus (Peck) Singer	S1	NC	NL*/TAM
	Leucocoprinus birnbaumii (Corda) Singer	S3	NC	NL/TAM
	Leucocoprinus cepistipes var. *pseudofarinosus* Raithelh.	S1	T	NL/TAM
	L. ianthinus (Sacc.) P. Mohr	S1	T	NL/TAM
	L. sulphurellus Pegler	S1	T	TAM
	Montagnea arenaria (DC.) Zeller	S1	NC	NL/TAM
	Phellorinia herculeana (Pers.) Kreisel	S1	NC	NL
	Podaxis pistillaris (L.) Fr.	S1	NC	NL/TAM
	Tulostoma albicans V. S. White	S1	NC	NL
Amanitaceae				
	Amanita caesarea (Scop.) Pers.	M/A2	NC	NL/TAM
	A. flavorubens (Berk. & Mont.) Sacc.	M/A2	NC	NL/TAM
	A. fulva Fr.	M/A2	T	NL/TAM
	A. jacksonii Pomerl.	M/A2	C	NL*/TAM

	A. pantherina (DC.) Krombh.	M/A2	NC	NL/TAM
	A. rubescens Pers.	M/A2	T	NL/TAM
	A. vaginata (Bull.) Lam.	M/A2	NC	NL/TAM
	A. amerivirosa Tulloss, L. V. Kudzma & M. Tulloss	M/A2	NC	NL/TAM
	Limacella alachuana (Murrill) Pegler	M	NC	NL*/TAM
	Zhuliangomyces illinitus (Fr.) Redhead	M/A2	NC	NL/TAM
Bolbitiaceae				
	Bolbitius mexicanus (Murrill) Murrill	S1	NC	TAM
	Conocybe apala (Fr.) Arnolds	S1	NC	NL*/TAM
	C. deliquescens Hauskn. & Krisai	S1	NC	NL/TAM
Cortinariaceae				
	Cortinarius iodes Berk. & M. A. Curtis	M/A2	NC	NL/TAM
Cyphellaceae				
	Chondrostereum purpureum (Pers.) Pouzar	S3/A2	NC	NL/TAM
Entolomataceae				
	Clitopilus azalearum (Murrill) Noordel. & Co-David	S1	NC	TAM
	Entoloma permutatum E. Horak	S1	NC	TAM
	E. pseudopapillatum (Pegler) Courtec. & Fiard	S1	NC	TAM
Galeropsidaceae				
	Panaeolus antillarum (Fr.) Dennis	S2	NC	NL/TAM
	P. cyanescens Sacc.	S2	NC	NL*/TAM
	Panaeolina foenisecii (Pers.) Maire	S2	NC	NL*
Hygrophoraceae				
	Hygrocybe erinacea (Pat.) Singer	S1/A2	T	NL/TAM
	Hygrophorus buccinulus (Speg.) Dennis	S1	NC	NL/TAM
Lycoperdaceae				
	Calvatia cyathiformis (Bosc) Morgan	S1	C	NL/TAM
Lyophyllaceae				
	Calocybe cyanea Singer *ex* Redhead & Singer	S1/A2	T	NL*/TAM
Marasmiaceae				
	Crinipellis eggersii Pat.	S3	NC	NL*/TAM
	C. septotricha Singer	S3	NC	NL/TAM
	Tetrapyrgos nigripes (Fr.) E. Horak	S3	NC	NL*/TAM
Mycenaceae				

	Mycena pura (Pers.) P. Kumm.	S1/A2	NC	NL/TAM
	Panellus pusillus (Pers. *ex* Lév.) Burds. & O. K. Mill.	S3/A2	T	NL*/TAM
	Trogia cantharelloides (Mont.) Pat.	S1/A2	T	TAM
	T. icterina (Singer) Corner	S1/A2	T	NL*
Omphalotaceae				
	Clitocybula familia (Peck) Singer	S1	T	NL*/TAM
	Collybiopsis confluens (Pers.) R. H. Petersen	S1/A2	T	NL/TAM
	Gymnopus dryophilus (Bull.) Murrill	S1/A2	NC	NL/TAM
	Omphalotus subilludens (Murrill) H. E. Bigelow	S3/A2	T	NL*/TAM
Paxillaceae				
	Neopaxillus dominicanus Angelini & Vizzini	S1	NC	NL
Physalacriaceae				
	Dactylosporina steffenii (Rick) Dörfelt	S2	NC	NL/TAM
	Desarmillaria tabescens (Scop.) R. A. Koch & Aime	P/A2	T	NL/TAM
	Hymenopellis radicata (Relhan) R. H. Petersen	S1	T	NL/TAM
	Xerula pudens (Pers.) Singer	S3/A2	T	NL*/TAM
Pleurotaceae				
	Hohenbuehelia petaloides (Bull.) Schulzer	S1/A2	T	NL/TAM
	H. atrocaerulea (Fr.) Singer	S1/A2	T	TAM
	Lepista nuda (Bull.) Cooke	S1/A2	C	NL*/TAM
	Pleurotus djamor (Rumph. *ex* Fr.) Boedijn	S3	C	NL/TAM
	Resupinatus applicatus (Batsch) Gray	S3	NC	NL*/TAM
Pluteaceae				
	Volvariella hypopithys (Fr.) Shaffer	S3	C	NL*/TAM
	V. villosovolva (Lloyd) Singer	S3	NC	NL*/TAM
Psathyrellaceae				
	Parasola plicatilis (Curtis) Redhead, Vilgalys & Hopple	S1	NC	NL/TAM
	Candolleomyces candolleanus (Fr.) D. Wächt. & A. Melzer	S1	NC	NL/TAM
Schizophyllaceae				
	Schizophyllum commune Fr.	S3/A2	C	NL/TAM
	S. umbrinum Berk.	S3/A2	NC	NL*
Strophariaceae				

	Deconica coprophila (Bull.) P. Karst.	S2	NC	NL/TAM
Tricholomataceae				
	Leucopaxillus albissimus (Peck) Singer	M/A2	T	NL*/TAM
	L. gracillimus Singer & A. H. Sm.	M	T	NL*/TAM
Auriculariales				
Auriculariaceae				
	Auricularia mesenterica (Dicks.) Pers.	S3/A2	C	NL/TAM
	A. nigricans (Sw.) Birkebak, Looney & Sánchez-García	S3/A2	C	NL/TAM
	Elmerina berkeleyi (Sacc. & Cub.) Petch	S3/A2	NC	NL/TAM
Boletales				
Boletaceae				
	Aureoboletus auriporus (Peck) Pouzar	M/A2	NC	NL/TAM
	Austroboletus gracilis (Peck) Wolfe	M/A2	NC	NL/TAM
	A. neotropicalis Singer, J. García & L. D. Gómez	M/A2	NC	NL/TAM
	Boletus luridellus (Murrill) Murrill	M/A2	NC	TAM
	B. miniato-olivaceus Frost	M/A2	NC	NL/TAM
	B. subvelutipes Peck	M/A2	NC	NL/TAM
	Boletellus coccineus (Sacc.) Singer	M/A2	C	NL/TAM
	Caloboletus inedulis (Murrill) Vizzini	M/A2	NC	NL/TAM
	Cyanoboletus pulverulentus (Opat.) Gelardi, Vizzini & Simonini	M/A2	NC	NL/TAM
	Exsudoporus floridanus (Singer) Vizzini, Simonini & Gelardi	M/A2	NC	NL/TAM
	Hortiboletus rubellus (Krombh.) Simonini, Vizzini & Gelardi	M/A2	C	NL/TAM
	Phylloboletellus chloephorus Singer	M/A2	NC	NL/TAM
	Porphyrellus cyaneotinctus (A. H. Sm. & Thiers) Singer	M/A2	NC	NL/TAM
	Suillellus luridus (Schaeff.) Murrill	M/A2	NC	NL/TAM
	Strobilomyces confusus Singer	M/A2	NC	NL/TAM
	S. strobilaceus (Scop.) Berk.	M/A2	NC	NL/TAM
	Tylopilus ferrugineus (Kuntze) Singer	M/A2	NC	NL/TAM
	T. griseocarneus Wolfe & Halling	M/A2	NC	TAM
	T. plumbeoviolaceus (Snell & E. A. Dick) Snell & E. A. Dick	M/A2	NC	NL/TAM
	Xerocomellus intermedius (A. H. Sm. & Thiers) Svetash., Simonini & Vizzini	M/A2	NC	NL*/TAM

	Xerocomus truncatus Singer, Snell & E. A. Dick	M/A2	NC	NL/TAM
Boletinellaceae				
	Boletinellus rompelii (Pat. & Rick) Watling	M	NC	NL/TAM
	Phlebopus portentosus (Berk. & Broome) Boedijn	M	NC	NL*/TAM
Diplocystidiaceae				
	Astraeus hygrometricus (Pers.) Morgan	M/A2	NC	NL/TAM
Gyroporaceae				
	Gyroporus castaneus (Bull.) Quél.	M/A2	NC	NL/TAM
	G. subalbellus Murrill	M/A2	NC	NL*/TAM
Sclerodermataceae				
	Pisolithus tinctorius (Mont.) E. Fisch.	M/A2	NC	NL/TAM
	Scleroderma areolatum Ehrenb.	M/A2	NC	NL/TAM
	S. cepa Pers.	M/A2	NC	NL/TAM
	S. verrucosum (Bull.) Pers.	M/A2	NC	NL/TAM
Cantharellales				
Hydnaceae				
	Cantharellus cibarius Fr.	M/A2	C	NL/TAM
	C. lateritius (Berk.) Singer	M/A2	C	NL/TAM
	Craterellus cornucopioides (L.) Pers.	M/A2	C	NL/TAM
	Hydnum repandum L.	M/A2	C	NL/TAM
Geastrales				
Geastraceae				
	Geastrum minimum Schwein.	S1/A2	NC	NL/TAM
	G. quadrifidum Pers.	S1/A2	NC	NL/TAM
	G. saccatum Fr.	S1/A2	NC	NL/TAM
	G. triplex Jungh.	S1/A2	NC	NL/TAM
	Myriostoma coliforme (Dicks.) Corda	S1/A2	NC	NL
	Sphaerobolus stellatus Tode	S2	NC	NL/TAM
Gloeophyllales				
Gloeophyllaceae				
	Gloeophyllum striatum (Fr.) Murrill	S3/A2	NC	NL/TAM
Hymenochaetales				
Hymenochaetaceae				
	Coltricia perennis (L.) Murrill	M	T	NL/TAM
	Fuscoporia licnoides (Mont.) Oliveira-Filho & Gibertoni	P/A2	NC	TAM
	Fomitiporia robusta (P. Karst.) Fiasson & Niemelä	P/A2	NC	NL/TAM

	Inonotus calcitratus (Berk. & M. A. Curtis) Gomes-Silva & Gibertoni	P	NC	NL/TAM
	I. hispidus (Bull.) P. Karst.	P/A2	NC	NL/TAM
	Phellinus badius (Cooke) G. Cunn.	P	NC	NL/TAM
	P. fastuosus (Lév.) S. Ahmad	P	NC	NL/TAM
	P. gilvus (Schwein.) Pat.	P	NC	NL/TAM
	P. robiniae (Murrill) A. Ames	P/A2	NC	NL/TAM
	Phylloporia fruticum (Berk. & M. A. Curtis) Ryvarden	P/A2	NC	NL/TAM
	P. spathulata (Hook.) Ryvarden	M	NC	TAM
	Tropicoporus linteus (Berk. & M. A. Curtis) L. W. Zhou & Y. C. Dai	P	NC	NL/TAM
Nigrofomitaceae				
	Nigrofomes melanoporus (Mont.) Murrill	P/A2	NC	NL/TAM
Phallales				
Phallaceae				
	Clathrus crispus Turpin	S1	NC	NL/TAM
	Lysurus periphragmoides (Klotzsch *ex* Hook.) Dring	S1	NC	NL/TAM
	Phallus indusiatus Vent.	S1	NC	TAM
	P. ravenelii Berk. & M. A. Curtis	S1/A2	NC	NL/TAM
Polyporales				
Cerrenaceae				
	Cerrena hydnoides (Sw.) Zmitr.	S3/A2	NC	NL/TAM
Fomitopsidaceae				
	Daedalea quercina (L.) Pers.	P/A2	NC	NL/TAM
	Phaeodaedalea incerta (Curr.) Ţura, Zmitr., Wasser & Spirin	P/A2	NC	TAM
	Rhodofomes roseus (Alb. & Schwein.) Kotl. & Pouzar	P/A2	NC	NL/TAM
Ganodermataceae				
	Cristataspora coffeata (Berk.) Robledo, Costa-Rezende & de Madrignac Bonzi	S1	NC	NL/TAM
Incrustoporiaceae				
	Tyromyces lacteus (Fr.) Murrill	S3/A2	NC	NL/TAM
Irpicaceae				
	Byssomerulius incarnatus (Schwein.) Gilb.	S3/A2	NC	NL/TAM
Meripilaceae				
	Rigidoporus ulmarius (Sowerby) Imazeki	P/A2	NC	NL/TAM

Panaceae				
	Cymatoderma caperatum (Berk. & Mont.) D. A. Reid	S3/A2	NC	NL*/TAM
	Panus conchatus (Bull.) Fr.	S3/A2	T	NL/TAM
Phanerochaetaceae				
	Phlebiopsis crassa (Lév.) Floudas & Hibbett	P	NC	NL/TAM
Podoscyphaceae				
	Abortiporus biennis (Bull.) Singer	P	NC	NL*/TAM
Polyporaceae				
	Diacanthodes novoguineensis (Henn.) O. Fidalgo	P	NC	NL7TAM
	Daedaleopsis confragosa (Bolton) J. Schröt.	P/A2	NC	NL/TAM
	Fabisporus sanguineus (L.) Zmitr.	S3	NC	NL/TAM
	Favolus tenuiculus P. Beauv.	S3/A2	NC	NL*/TAM
	Funalia floccosa (Jungh.) Zmitr. & Malysheva	P/A2	NC	NL/TAM
	Ganoderma applanatum (Pers.) Pat.	P/A2	NC	NL/TAM
	G. curtisii (Berk.) Murrill	P	NC	NL/TAM
	G. lobatum (Cooke) G. F. Atk.	P	NC	NL/TAM
	G. resinaceum Boud.	P	NC	NL*/TAM
	Hexagonia cucullata (Mont.) Murrill	S3/A2	T	NL/TAM
	Lentinus arcularius (Batsch) Zmitr.	S3	NC	NL/TAM
	L. badius (Berk.) Berk.	S3	T	NL/TAM
	L. crinitus (L.) Fr.	S3/A2	T	NL/TAM
	L. levis (Berk. & M. A. Curtis) Murrill	S3/A2	C	NL/TAM
	L. tigrinus (Bull.) Fr.	S3/A2	NC	NL/TAM
	L. tricholoma Berk. & Cooke	S3	NC	NL/TAM
	Trametes elegans (Spreng.) Fr.	P/A2	NC	NL/TAM
	T. maxima (Mont.) A. David & Rajchenb.	P	NC	NL/TAM
	T. variegata (Berk.) Zmitr., Wasser & Ezhov	S3	NC	NL/TAM
	T. villosa (Sw.) Kreisel	S3	NC	NL/TAM
	Truncospora livida (Kalchbr.) Zmitr.	P/A2	NC	NL*/TAM
Russulales				
Albatrellaceae				
	Albatrellus pilosus (Petch) Ryvarden	M/A2	NC	NL*/TAM
Peniophoraceae				
	Peniophora albobadia (Schwein.) Boidin	P	NC	NL/TAM

Russulaceae				
	Lactarius subpalustris Hesler & A. H. Sm.	M/A2	NC	NL/TAM
	L. fuliginellus A. H. Sm. & Hesler	M/A2	NC	TAM
	L. indigo (Schwein.) Fr.	M/A2	C	NL/TAM
	L. romagnesii Bon	M/A2	NC	NL/TAM
	L. strigosipes Montoya & Bandala	M/A2	NC	NL/TAM
	L. volemus (Fr.) Fr.	M/A2	C	NL/TAM
	Russula cyanoxantha (Schaeff.) Fr.	M/A2	C	NL/TAM
Stereaceae				
	Stereum ostrea (Blume & T. Nees) Fr.	S3/A2	NC	NL/TAM
Sebacinales				
Sebacinaceae				
	Helvellosebacina concrescens (Schwein.) Oberw., Garnica & K. Riess	S3	NC	TAM
	Sebacina schweinitzii (Peck) Oberw.	S3	NC	NL/TAM
Thelephorales				
Thelephoraceae				
	Thelephora palmata (Scop.) Fr.	M	NC	NL/TAM
Dacrymycetes				
Dacrymycetales				
Dacrymycetaceae				
	Dacryopinax spathularia (Schwein.) G. W. Martin	S3/A2	NC	NL/TAM
Tremellomycetes				
Tremellales				
Tremellaceae				
	Tremella lutescens Lloyd	S3/A2	NC	NL/TAM
Protozoa				
Myxogastrea				
Cribrariida				
Cribrariidae				
	Cribraria violacea Rex	F/A2	NC	NL/TAM
Liceida				
Reticulariidae				
	Lycogala epidendrum (J. C. Buxb. *ex* L.) Fr.	F/A2	NC	NL/TAM
Trichiida				
Trichidae				
	Arcyria denudata (L.) Wettst.	F	NC	NL/TAM

	Hemitrichia calyculata (Speg.) M. L. Farr	F/A2	NC	NL/TAM
Physarida				
Physarridae				
	Fuligo intermedia T. Macbr.	F/A2	NC	NL/TAM
	F. septica (L.) F. H. Wigg.	F	NC	NL/TAM
	Physarum pusillum (Berk. & M. A. Curtis) G. Lister	F	NC	NL/TAM
Stemonitales				
Stemonitaceae				
	Stemonitis fusca Roth	F/A2	NC	NL/TAM

S1 = Saprobe in soil; S2 = Fimicolous; S3 = Saprobe in wood; M = Mycorrhizal; P = Parasite; F = Phagotrophic; T = Toxic; C = Edible; NC = Not Edible; NL = *Nuevo León*; TAM = *Tamaulipas*; NL/TAM = Both States; A2 = Species that grow at altitudes of 500-700 m, the rest of the species grow at altitudes of 100-500 m. * New reports for the region.

Basidiomycetes were the most diverse, with 187 species from 125 genera and 50 families. The Ascomycetes followed with 23 species, 13 genera and seven families; and the Myxomycetes (previously considered fungi) are represented by five families, seven genera and eight species. The Boletaceae, Agaricaceae, Polyporaceae, and Hymenochaetaceae families presented 14, 13, 10, and eight genera, respectively; and the rest had less than ten. The families with the greatest richness were: Agaricaceae 24, Boletaceae 21, Polyporaceae 21, Xylariaceae 14, Hymenochaetaceae 12, Amanitaceae ten, the rest with less than ten. Of the genera, *Xylaria* Hill *ex* Schrank had 14 taxa, *Amanita* Dill. *ex* Boehm. ten, *Lactarius* Pers. and *Lentinus* Fr. six, *Ganoderma* P. Karst., *Phellinus* Quél. and *Geastrum* Pers. four, *Boletus* Tourn. three, and the rest less than three.

Habit, edibility, and geographical and altitudinal distribution of species

A total of 62 mycorrhizal species (28.44 %), 117 saprobes (53.66 %), 31 parasites (14.22 %) and eight fimícolas (3.66 %) were recorded. Likewise, 175 non-edible species (80.27 %), 18 edible (8.25 %) and 25 toxic (11.46 %) are recognized.

On the other hand, regarding its distribution, it was observed that 107 taxa (49.08 %) are common in the Northeast states, 71 species (32.56 %) were located only in *Tamaulipas* and 43 (19.72 %) only in *Nuevo León*. In addition, regarding its altitudinal distribution, 94 species (43.11 %) grow in intervals of 100 to 500 m and 124 (56.88 %) between 500 and 700 masl.

Main probable hosts of fungi

Forty-one probable hosts for the fungal species were identified, 33 at altitudes of 100-500 m, 18 at 500-700 m ranges and ten in the entire altitudinal spectrum, that is, from 100-700 m.

The main host plant species of parasitic fungi are: *Vachellia farnesiana* (L.) Wight & Arn., *Bumelia celastrina* Kunth, *Cordia boissieri* A. DC., *Ebenopsis ebano* (Berland.) Barneby & J. W. Grimes, *Ehretia anacua* (Terán & Berland.) I. M. Johnst., *Cylindropuntia leptocaulis* (DC.) F. M. Knuth and *Parkinsonia aculeata* L.

Regarding mycorrhizal fungi, it is probable that some species are associated with *Quercus virginiana* Mill., *Q. canbyi* Trel. or with *Carya illinoinensis* (Wangenh.) K. Koch.

Discussion

In Mexico, there are few studies on thorny scrub macrofungus species that have been published. This study is the first to attempt to show the great diversity of macromycete species that inhabit the scrublands of Northern Mexico. One of them is carried out in the Northwestern zone of the country in the states of *Sonora* and *Chihuahua*, where some species of gasteroid macromycetes (macromycetes with fruiting bodies with intermediate forms from epigeous to hypogeous) were recorded, *e. g*. that grow associated with native vegetation (Esqueda *et al.*, 2006, 2012; Moreno *et al.*, 2007, 2010).

In the present study, 218 species of macrofungus associated with the scrublands of Northeast Mexico were obtained for the first time. Of these, 34 species are new records for Northeast Mexico. Some of the taxa agree with those cited from temperate forests at the foot of the mountain by Garza *et al.* (2019). Likewise, some of the species studied here were indicated by various authors for their edibility or growth habit (Castillo and Guzmán, 1970; García *et al.*, 1986; García, 1993; Garza-Ocañas, 1993).

In regard to the medicinal potential of some of the species studied, there is a coincidence with those referred to by González *et al.* (2009) (*Ganoderma* spp.). *Hortiboletus rubellus* (Krombh.) Simonini, Vizzini & Gelardi, *Pisolithus tinctorius* (Mont.) E. Fisch. and *Scleroderma cepa* Pers. are species referred to here that have

forestry potential to inoculate oaks in nurseries to plant them in urban areas, since they quickly form abundant mycorrhizae; this agrees with what was described by Garza *et al.* (2022) for *Boletus luridellus* (Murrill) Murrill. This study considers some plants that might form ectomycorrhizae with fungal species, but there are no previous records of such associations. Therefore, it is necessary to carry out the synthesis of mycorrhizae under controlled conditions to verify it, as part of another more precise investigation in this regard. Among some fungi that are suspected to form mycorrhizae with plant species such as *Cordia boissieri* is *Phlebopus brassiliensis* Singer.

From the diversity of plant species with which parasitic fungal species or possible mycorrhizal fungi are associated, it was decided to include only the main ones. It is worth mentioning that the diversity of macromycetes is high in this region and it is intended to be published in several scientific articles. The foregoing is the large extension occupied by the scrubs, the few mycologists in the region and the uncertainty of the occurrence of rain in the region due to climate change.

Other studies on the diversity of macrofungus species from different regions and types of vegetation in the country highlight their ecological and functional importance, as well as their edibility, medicinal properties, or biotechnological potential (Quiñónez *et al.*, 2008; Pérez-López *et al.*, 2015).

The change in land use leads to disturbances and fragmentation of the scrub habitat and this is referred to as one of the main problems facing the diversity of macrofungus in Northeast Mexico (Alanís, 2006; Pando *et al.*, 2014). Esqueda-Valle *et al.* (1995) and Esqueda *et al.* (2006, 2012) refer to some species of gasteroid fungi from thorny scrub in northwestern Mexico and some of the genera that stand out -*Battarrea* Pers., *Cyathus* Haller, *Chlorophyllum* Massee, *Disciseda* Czern., *Montagnea* Fr., *Podaxis* Desv., *Phellorinia* Berk., *Tulostoma* Pers.- coincide with those of the present study. Some of the gasteroid species reported by Moreno *et al.*

(2010) and Esqueda *et al.* (2012) also grow in arid areas where there are scrublands in Northeast Mexico.

Conclusions

The results obtained demonstrated that there is a great diversity of macrofungi in the *sensu lato* scrublands of Northeast Mexico, however, although there are many more species that have been studied, only a few are listed here. Likewise, there are many more species to be studied that are associated with this ecosystem, which is why even more research is required and that in the future the areas of post-agriculture and post-livestock regeneration are included to generate more information about the pioneer species in this type of vegetation.

Acknowledgements

The authors make clear their gratitude to the authorities of their respective institutions for the support provided for the field and laboratory work for the processing of information.

Conflict of interests

The authors have no conflict of interest in relation to the publication of this article. The data presented here are original and have not been published or sent to be published by other sources.

The authors declare that there is no link with the sponsoring institutions of the research that supports the contributions, so that the published data grant them professional, labor or economic advantages.

Contribution by author

Fortunato Garza Ocañas: collection and identification of species; Jesús García Jiménez: collection and identification of species; Gonzalo Guevara Guerrero: collection and identification of species; Miroslava Quiñónez Martínez: collection of species and writing of the manuscript; María Inés Yáñez Díaz: collection of species and writing of the manuscript.

Referencias

Alanís, G. J. 2006. Los matorrales y pastizales, su valor como recurso natural. In: Martínez-Muñoz, A. (Edit.). Tratado sobre el medio ambiente y los recursos naturales de Nuevo León. Universidad Autónoma de Nuevo León y Consejo Estatal de Flora y Fauna de Nuevo León. Monterrey, NL, México. pp. 102-123.

Bessette, A. E., W. C. Roody and A. R. Bessette. 2016. Boletes of Eastern North America. Syracuse University Press. New York, NY, United States of America. 471 p.

Castillo, J. y G. Guzmán. 1970. Estudio sobre los Polyporaceos de Nuevo León, II. Observaciones sobre las especies conocidas y discusiones acerca de su distribución

en México. Boletín de la Sociedad Mexicana de Micología 31:1-47. Doi: 10.17129/botsci.1105.

Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (Conabio). 2021. *Matorrales*. *Biodiversidad Mexicana*. https://www.biodiversidad.gob.mx/ecosistemas/Matorral. (16 de marzo de 2023).

Esqueda, M., A. Gutiérrez, M. L. Coronado, M. Lizárraga, T. Raymundo y R. Valenzuela. 2012. Distribución de algunos hongos gasteroides (Agaricomycetes) en la planicie central del Desierto Sonorense. Revista Mexicana de Micología 36:1-8. https://www.redalyc.org/articulo.oa?id=88326197003. (16 de marzo de 2023)

Esqueda, M., M. Coronado, A. Sánchez, E. Pérez-Silva and T. Herrera. 2006. Macromycetes of Pinacate and Great Altar Desert Biosphere Reserve, Sonora, Mexico. Mycotaxon 95:81-90. https://www.researchgate.net/publication/290264608_Macromycetes_of_Pinacate_and_Great_Altar_Desert_biosphere_reserve_Sonora_Mexico. (16 de marzo de 2023).

Esqueda-Valle, M., E. Pérez-Silva, R. E. Villegas y V. Araujo. 1995. Macromicetos de zonas urbanas, II. Hermosillo, Sonora, México. Revista Mexicana de Micología 11:123-132. Doi: 10.33885/sf.1995.3.833.

Estrada C., E., J. Á. Villarreal Q. y M. Pando M. 2014. Diversidad de plantas y sus principales usos. In: López L., Á. y M. Pando M. (Coords). Región citrícola de Nuevo León, su complejidad territorial en el marco global. Instituto de Geografía de la Universidad Nacional Autónoma de México y Facultad de Ciencias Forestales de la Universidad Autónoma de Nuevo León. Coyoacán, D. F., México. pp. 77-89.

Frank, J. L., N. Siegel, C. F. Schwarz, B. Araki and E. C. Vellinga. 2020. *Xerocomellus* (Boletaceae) in western North America. Fungal Systematic and Evolution 6(1):265-288. Doi: 10.3114/fuse.2020.06.13.

García, J., G. Gaona, J. Castillo y G. Guzmán. 1986. Nuevos registros de Boletaceos en México. Revista Mexicana de Micología 2:343-366. Doi: 10.33885/sf.1986.3.675.

García, J. 1993. Una lista preliminar de los hongos del suborden Boletineae (Basidiomycetes, Agaricales) en el noreste de México. Facultad de Ciencias Forestales de la Universidad Autónoma de Nuevo León. Linares, NL, México. 131 p.

Garza O., F., M. Quiñónez M., L. Garza O., A. Carrillo P., … and M. García M. 2019. Some edible, toxic and medicinal mushrooms from temperate forests in the north of Mexico. In: Sridhar, K. R. and S. K. Deshmukh (Edits.). Advances in Macrofungi. Diversity, ecology, and biotechnology. CRC Press Taylor & Francis Group. Boca Raton, FL, United States of America. pp. 144-198.

Garza O., F., M. Quiñónez M., G. Guevara G., A. Carrillo-Parra, J. I. de la Fuente and J. García J. 2022. Growth responses of Quercus fusiformis (Fagaceae) to ectomycorrhizal inoculation with *Boletus luridellus*. Österreichische Zeitschrift für Pilzkunde 29:193–202. https://www.myk.univie.ac.at/wp-content/uploads/2022/04/OZP29_Fortunato_Boletus_luridellus.pdf. (16 de marzo de 2023).

Garza-Ocañas, F. 1993. Producción de compuestos antibióticos por dos especies de hongos ectomicorrícicos. Facultad de Ciencias Forestales de la Universidad Autónoma de Nuevo León. Linares, NL, México. 146 p.

González B., P., L. Garza O., M. C. Salinas C., L. Vera C., … y Ó. Torres A. 2009. Actividad antioxidante, antimicrobiana y citotoxicidad de dos especies mexicanas de *Suillus* spp. Ciencia UANL 12(1):62-70. https://www.redalyc.org/pdf/402/40212110.pdf. (16 de marzo de 2023).

González M., F. 2003. Las comunidades vegetales de México. Propuesta para la unificación de la clasificación y nomenclatura de la vegetación de México. Instituto Nacional de Ecología. Tlalpan, D. F., México. 77 p.

Index fungorum. 2023. Index Fungorum. The Royal Botanic Gardens Kew and Chinese Academy of Science. https://www.indexfungorum.org/names/names.asp. (16 de marzo de 2023).

Kirk, P. M., P. F. Canon, D. W. Minter and J. A. Stalpers (Edits.). 2008. Ainsworth and Bisby's Dictionary of the Fungi. CAB International. Wallingford, OX, United Kingdom. 711 p.

Kornerup, A. and J. H. Wanscher. 1978. Methuen Handbook of Colour. Eyre Methuen. London, LND, United Kingdom. 252 p.

Largent, D. L. 1973. How to identify mushrooms to genus I: Macroscopic Features. Mad River Press. Eureka, CA, United States of America. 166 p.

Largent, D. L., D. Johnson and R. Watling. 1977. How to identify mushrooms to genus III: Microscopic Features. Mad River Press. Eureka, CA, United States of America. 148 p.

Lodge, D. J., J. F. Ammirati, T. E. O´Dell, G. M. Mueller, … and D. L. Czederpiltz. 2004. Terrestrial and lignicolous macrofungi. In: Mueller, G. M., G. F. Bills and M. S. Foster (Edits). Biodiversity of Fungi: Inventory and Monitoring Methods. Academic Press. San Diego, CA, United States of America. pp. 127-172.

Moreno, G., M. Esqueda, E. Pérez-Silva, T. Herrera and A. Altés. 2007. Some interesting gasteroid and secotiod fungi from Sonora, Mexico. Persoonia 19(2):265-280. https://www.ingentaconnect.com/content/nhn/pimj/2007/00000019/00000002/art00007. (16 de marzo de 2023).

Moreno, G., M. Lizárraga, M. Esqueda and M. L. Coronado. 2010. Contribution to the study of gasteroid and secotioid fungi of Chihuahua, Mexico. Mycotaxon 112:291-315. Doi: 10.5248/112.291.

Pando M., M., J. L. Pérez D. y D. O. Mendoza A. 2014. Cambio de uso de suelo y fragmentación del paisaje. In: López L., Á. y M. Pando M. (Coords). Región citrícola de Nuevo León, su complejidad territorial en el marco global. Instituto de Geografía de la Universidad Nacional Autónoma de México y Facultad de Ciencias Forestales de la Universidad Autónoma de Nuevo León. Coyoacán, D. F., México. pp. 159-178.

Pérez-López, R. I., G. Mata, A. Aragón G., D. Jiménez G. y O. Romero-Arenas. 2015. Diversidad de hongos silvestres comestibles del cerro El Pinal, municipio de

Acajete, Puebla, México. Ecosistemas y Recursos Agropecuarios 2(6):277-289. http://www.redalyc.org/articulo.oa?id=358640694004. (21 de agosto de 2023).

Quiñónez M., M., F. Garza O., M. Sosa C., T. Lebgue K., P. Lavin M. y S. Bernal C. 2008. Índices de diversidad y similitud de hongos ectomicorrizógenos en bosques de Bocoyna, Chihuahua, México. Ciencia Forestal en México 33(103):59-78. http://cienciasforestales.inifap.gob.mx/index.php/forestales/article/view/741. (16 de marzo de 2023).

Villarreal, L. and A. Gómez. 1997. Inventory and monitoring wild edible mushrooms in México: challenge and opportunity for sustainable development. In: Palm, M. E. and I. H. Chapela (Edits.). Mycology in sustainable development: Expanding concepts, vanishing borders. Parkway Publishers Inc. Boone, NC, United States of America. 306 p.